The Diversity of Amphibians in Tarutao Island, Satun Province with The Comparative Study of *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009) between Tarutao Island and Peninsular Thailand

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ชื่อวิทยานิพนธ์ ความหลากชนิดของสัตว์สะเทินน้ำสะเทินบกบนเกาะตะรุเตา จังหวัดสตูล และการศึกษาเปรียบเทียบกบเขาหลังตอง *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009) ระหว่างเกาะตะรุเตากับภาคใต้ของประเทศไทย

ชื่อผู้เขียน Mr. Tshering Nidup (นายซีริ่ง นีดุป)

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ปี 2557

บทคัดย่อ

ในประเทศไทยมีการศึกษาความหลากชนิดของสัตว์สะเทินน้ำสะเทินบกมากมาย แต่การศึกษาตามหมู่เกาะต่างๆเช่น เกาะตะรุเตา นั้นมีอยู่น้อยมาก ในการศึกษาความหลากชนิดบนเกาะตะรุเตาครั้งนี้ได้กระทำในปี พ.ศ. 2556 โดยสำรวจ 4 สถานที่ ได้แก่ พันเตมะละกา ตะโละวาว ตะโละอุดัง และน้ำตกลูดู โดยได้สำรวจในเวลากลางคืนด้วยวิธีการพบเห็นตัวโดยตรงและการบันทึกเสียงร้อง รวมทั้งได้ศึกษาตัวอย่างจากพิพิธภัณฑสถานธรรมชาติวิทยา ๕๐ พรรษาสยามบรมราชกุมารี จากการสำรวจพบสัตว์สะเทินน้ำสะเทินบกจำนวน 12 ชนิด คือ คางคกแคระ (*Ingerophrynus parvus*) จงโคร่ง (*Phrynoidis aspera*) อึ่งอ่างมลายู (*Kaloula baleata*) อึ่งอ่างบ้าน (*Kaloula pulchra*) กบน้ำเค็ม (*Fejervarya cancrivora*) กบทูด (*Limnonectes blythii*) กบป่าไผ่ (*Limnonectes hascheanus*) เขียดจิก (*Hylarana erythraea*) กบเขาหลังตอง (*Hylarana eschatia*) ปาดบ้าน (*Polypedates leucomystax*) อึ่งกรายลายจุด (*Leptobrachium hendricksoni*) และ *Rhacophorus* sp. และยังได้พบลูกอ๊อดของคางคกแคระ (*Ingerophrynus parvus*) กบเขาหลังตอง (*Hylarana eschatia*) และปาดบ้าน (*Polypedates leucomystax*) ได้

บันทึกเสียงร้องของ คางคกแคระ (*Ingerophrynus parvus*) อึ่งกรายลายจุด (*Leptobrachium hendricksoni*) และ *Rhacophorus* sp. จากนั้นได้ทำการวิเคราะห์เสียงร้องเชิงคลื่น ชนิดที่สำรวจพบมี 3 ชนิด คือ คางคกแคระ (*Ingerophrynus parvus*) จงโคร่ง (*Phrynoidis aspera*) และกบทูด (*Limnonectes blythii*) จัดอยู่ในบัญชีสัตว์ป่าคุ้มครองของประเทศไทย และมีความเสี่ยงที่จะสูญพันธุ์ในอนาคต อย่างไรก็ตาม จำเป็นต้องมีการศึกษาความหลากชนิดบนเกาะตะรุเตาเพิ่มเติมอีกในอนาคต

การศึกษาเปรียบเทียบกบเขาหลังตอง *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009) ในภาคใต้ของประเทศไทยได้กระทำในระหว่างปี พ.ศ. 2556 - 2557 ทั้งจากการรวบรวมตัวอย่างจากภาคสนามทั้งสิ้น 7 สถานที่และตัวอย่างจากพิพิธภัณฑสถานธรรมชาติวิทยา ๕๐ พรรษาสยามบรมราชกุมารีทั้งสิ้น 8 สถานที่ นำมาวิเคราะห์ความแตกต่างด้วย t-test และ ANOVA จากนั้นจึงจำแนกด้วย Hierarchical cluster ในการศึกษาครั้งนี้พบขอบเขตการกระจายของกบเขาหลังตอง (*Hylarana eschatia*) เพิ่มเติม คือ ทางตอนเหนือจนถึงจังหวัดชุมพรและทางตอนใต้จนถึงจังหวัดนราธิวาส จากการศึกษาเปรียบเทียบลักษณะทางสัณฐานวิทยาของประชากรกบเขาหลังตอง (*Hylarana eschatia*) จากแต่ละสถานที่ พบว่า มีความแตกต่างกันระหว่างเพศอย่างชัดเจน โดยเพศเมียมีขนาดใหญ่กว่าเพศผู้ ทั้งสองเพศนั้นสามารถจำแนกด้วย 11 ลักษณะจาก 12 ลักษณะที่ศึกษา อีกทั้งยังพบว่า 10 ลักษณะที่ศึกษานั้นยังมีความแปรผันไปตามความยาวจากปลายจมูกถึงรูเปิดทวาร (SVL) จากการศึกษาเปรียบเทียบลักษณะทางสัณฐานของกบเขาหลังตอง (*Hylarana eschatia*) พบว่าสามารถแบ่งได้เป็น 3 กลุ่มลักษณะ คือ (1) กลุ่มของกบเขาหลังตอง (*Hylarana eschatia*) ที่พบทางตอนบนของภาคใต้ของประเทศไทย ซึ่ง nuptial pad ในเพศผู้มีทั้งแบบแบ่งเป็น 2 ตุ่มและแบบเป็นตุ่มยาวต่อเนื่อง และไม่พบจุดดำบนหลัง (2) กลุ่มของ

กบเขาหลังตอง (*Hylarana eschatia*) ที่พบทางตอนใต้ของภาคใต้ของประเทศไทย พบว่า nuptial pad ในเพศผู้มีทั้งแบบแบ่งเป็น 2 ตุ่มและแบบเป็นตุ่มยาวต่อเนื่อง และมีจุดดำบนหลัง ซึ่งช่วงเปลี่ยนถ่ายของการมีจุดสีดำและไม่มีจุดสีดำบนหลังอยู่บริเวณเทือกเขาบรรทัด (3) กลุ่มของกบเขาหลังตอง (*Hylarana eschatia*) ที่พบบนเกาะตะรุเตา ซึ่งไม่มีจุดสีดำบนหลัง ขาสีน้ำตาลเด่นชัด และnuptial pad ในเพศผู้มีเฉพาะแบบแบ่งเป็น 2 ตุ่ม นอกจากนี้จากการศึกษาพบว่าประชากรบนเกาะตะรุเตายังสามารถแยกออกจากประชากรทั้งสองกลุ่มบนแผ่นดินใหญ่ด้วยขนาดของลักษณะภายนอก ซึ่งประชากรที่พบบนเกาะตะรุเตานั้นมีขาสีน้ำตาลที่เด่นชัด และพังผืดของนิ้วเท้านิ้วที่ 4 แคบก่อนจะเกาะกับขอบนิ้วที่บริเวณตุ่ม distal subarticular อย่างไรก็ตาม ยังต้องมีการศึกษาเพิ่มเติมด้วยลักษณะทางพันธุกรรม เนื่องจากลักษณะทางสัณฐานภายนอกไม่เพียงพอที่จะบ่งบอกความแตกต่างได้

นอกจากนี้ยังได้มีการรวบรวมเอกสารที่เกี่ยวข้องกับการศึกษาสัตว์สะเทินน้ำสะเทินบกในประเทศไทย และได้จัดทำบัญชีรายชื่อของสัตว์สะเทินน้ำสะเทินบกที่พบในประเทศไทยอีกด้วย

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ABSTRACT

Many amphibian species diversity study have been conducted in Thailand but least was focused in the biogeographically important Archipelagos such as Tarutao Island. The diversity of amphibian species was studied in Tarutao Island in 2012. Four sites: Pante Malaka, Talo Wow, Talo Udang and Ludu Waterfall were surveyed at night using visual and acoustic sampling technique and the specimens from Princess Maha Chakri Sirindhorn Natural History Museum were included in this study. In this study twelve species of frogs: *Ingerophrynus parvus, Phrynoidis aspera, Kaloula baleata, Kaloula pulchra, Fejervarya cancrivora, Limnonectes blythii, Limnonectes hascheanus, Hylarana erythraea, Hylarana eschatia, Polypedates leucomystax, Leptobrachium hendricksoni* and *Rhacophorus* sp. were documented from Tarutao Island. The tadpoles of *Ingerophrynus parvus, Hylarana eschatia* and *Polypedates leucomystax* were documented. The calls of *Ingerophrynus parvus, Leptobrachinm hendricksoni* and *Rhacophorus* sp. were analyzed for eight temporal and spectral features. Three species, *Ingerophrynus parvus, Phrynoidis aspera* and *Limnonectes blythii* were documented in the protected list of Thailand and there is high risk of stochastic extinction. However, there is the need of more diversity exploration in Tarutao Island in future.

The comparative study of *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009) in peninsular Thailand was conducted in 2012-2013 with the field specimen from seven localities and eight localities from museum specimen of Princess Maha Chakri Sirindhorn Natural History Museum, using t-test, ANOVA and Hierarchical cluster analysis. Additional distribution range of this species were reported from northwards to Chumphon Province and southwards to Narathiwat

Province. The morphology of each population were documented. This study found that *Hylarana eschatia* has strong sexual dimorphism that is female biased. Females and males can be separated distinctly by the eleven measurements amongst twelve measured. There is the strong correlation between other ten characters and snout to vent length (SVL). Population of *Hylarana eschatia* were divided into three groups based on morphological difference: (1) *Hylarana eschatia* described from northern part of peninsular Thailand have divided or undivided nuptial pads in males and lacks black spots on the back; (2) *Hylarana eschatia* collected from southern part of peninsular Thailand have divided or undivided nuptial pads in males and black spot on the back for which the transition zone of spotted and unspotted population is proposed to be in Khao Ban Tad mountain range; (3) *Hylarana eschatia* collected from Tarutao Island were unspotted with distinct brown limbs but males have only divided nuptial pads and this population can also be separated from two mainland population by few body measurements. Tarutao Island population also has distinct brown limbs and fourth toe web narrows before reaching distal subarticular tubercles. However, this species needs further study with the genetic analysis since the morphology alone could not provide a clear separation.

The historical review of amphibian research in Thailand was done and the complete checklist of amphibians of Thailand is provided.

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Tshering Nidup

CONTENTS

Contents **Page**

CONTENTS (*continued*)

LIST OF FIGURES

LIST OF FIGURES (*continued*)

LIST OF FIGURES (*continued*)

LIST OF FIGURES (*continued*)

LIST OF FIGURES (*continued*)

LIST OF TABLES

CHAPTER I

INTRODUCTION

With the increased global effort on conservation the biodiversity was witnessed to decline questioning their services to ecosystem and economic aspect which 12% to 55% of animal and plant species are threatened with extinction. The population of the wild vertebrates decreased by 31% globally between 1970 to 2006 with the high rate in the tropical region and fresh water ecosystems. Amongst all 42% of amphibian population are declining and facing greatest risk of extinction (Secretariat of the convention on biological diversity, 2010). However, the number of recognized amphibian species has also increased drastically in the recent years (Stuart, Inger and Voris, 2006) due to increased studies in the tropical regions or re-examination of the complex species having broad geographical distribution (Onn and Grismer, 2010; Mahony, 2011; Bain *et al*., 2003; Stuart, Inger and Voris, 2006). Amphibians have gained increased conservation attention due to global population decline witnessed in early 1970s (Stuart *et al*., 2004) because of the threats like the habitat loss, commercial over exploitation, fungal disease like *Batrachochytrium dendrobatides* infection, climate change and pollutions (Kiesecker, Blaustein and Belden, 2001; Mohneke and Rodel, 2009). However, in Southeast Asia the major threats are habitat lost and the overexploitation (Stuart *et al*., 2004). Southeast Asia has the earth's land area of only 4% but harbors 20-25% of plant and animal species making biological hotspot (Woodruff, 2010).

Thailand lies in the heart of Southeast Asia of Oriental zoogeographic region and Sundiac subregion, with six zoogeographical subregions within a country (Kloss, 1915). Approximately 20% of Thailand is under protection (Tantipisanuh and Gale, 2013) with approximately 103 National Parks (Thailandbird.com, 2010). Tarutao National Park was established with 51 islands including three major archipelagos i.e Adang, Rawi and Tarutao (Royal Thai Government Gazette, 1974). It is located between 6°30'N, 99°44'E and 6°44'N, 99°9'E and covering 1500 km^2 (Congdon, 1982). Wet season is from May to October with the rainfall of 240-400 mm and average temperature of 27°C to 28°C and mean relative humidity is around 80%

(Tarutao National Park, 2013). Although it was recognized almost four decades earlier only in recent decade few animal diversity studies were carried out like ants (Watanasit, Sonthichai and Noon-anant, 2003) and marine resource diversity along Adang-Rawi archipelago and adjacent Andaman Sea areas by Nootmorn, Hoimuk and Keawkaew (2002). However, it is reported that Tarutao National Park have the record of 30 species of various mammals, 268 species of birds, and 30 species of reptiles (Watanasit *et al*., 2003). Khonsue *et al*. (2011) compiled the handbook of amphibian species of Thai Islands recording 26 species of amphibians from five islands and island groups. However, diversity in Tarutao Island is not known being the biggest island in Tarutao National Park. Therefore, gaining insights and inventorying of the diversity in such pocket archipelagos is essential since the islands are well known for their various ecosystem with unique plants and animals with unique evolutionary history contributing to conservation, educational, recreational, cultural and economic benefits (Convention on biological diversity, 2014).

Sundaic region have complex history of geological processes and floristic migration (Inger and Voris, 2001) favoring numerous species complex. The diversity of amphibian in this region is under serious underestimation (Bain and Stuart, 2005; Stuart, Inger and Voris, 2006; Inger, Stuart and Iskandar, 2009) where widespread forest-dwelling species is impossible rather common pattern of morphologically similar frogs (Bain and Stuart, 2005; Stuart, Inger and Voris, 2006). This is influenced by species recognition and mate choices that lead to conserved morphology even though they are reproductively isolated since amphibians chiefly rely on advertisement calls and pheromones to attract the mate of opposite sex of the same species (Ki, 2013).

One of the examples is *Hylarana chalconota* complex which was separated into seven species including *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009) from southern Thailand. *Hylarana eschatia* is the species with medium size of 40-57 mm snout to vent length, no dorsal spotting, relatively wide head, long leg with no dark crossbars, and males with constricted or divided nuptial pads (Inger, Stuart and Iskandar, 2009). This species was described from northern part of peninsular Thailand and no samples were collected from the southern part of peninsular Thailand.

Therefore, this study principally aimed at the study of the amphibian diversity in Tarutao Island and comparative study of *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009).

OBJECTIVES

1. To study the diversity of the amphibian species found in Tarutao Island and to provide a possible complete checklist of amphibian in Thailand.
2. To carry out a comparative study of *Hylarana eschatia* (Inger, Stuart and Iskandar, 2009) between Tarutao Island and peninsular Thailand.

CHAPTER II

LITERATURE REVIEW

The historical review of amphibian research in Thailand

Anura (Waldheim, 1831)

The first individual to collect amphibian specimens in Thailand was Henri Mouhot. The exact date of this collection is not known but is thought to be about 170 years ago (Khonsue and Thirakhupt, 2001). Dr. Albert Gunther was the first author to describe an amphibian collection from Thailand (Gunther, 1861; Khonsue and Thirakhupt, 2001). This was followed by two papers by Major Stanley Flower, "Notes on a collection of reptiles and batrachians made in the Malay Peninsula in 1895-96; with a list of the species recorded from that region" (Flower, 1896) and "Notes on a second collection of reptiles made in the Malay Peninsula and Siam, from November 1896 to September 1898, with a list of the species recorded from those countries" (Flower, 1899). However the second paper is fully on reptiles. Since this time, a variety of different herpetologists have undertaken research of Thailand's herpetofaunal diversity, publishing new records, reviews of particular taxa, and descriptions of new species.

One of the earliest and most prolific researchers of Thai amphibians was the English naturalist Malcolm Arthur Smith, who was a long term resident of Thailand and physician to his Majesty the King of Thailand. In 1912, he described the 'A vertebrate fauna of the Malay Peninsula from the Isthmus of Kra to Singapore, including the adjacent Islands' Boulenger (1912). Subsequently, according to Inger and Chan-ard (1997) and Khonsue and Thirakhupt (2001), he published extensively on the subject between 1915 and 1923, including Smith (1915; 1916a, b, c; 1917a, b, c, d; 1922a, b, c, and 1923).

In Smith (1915), he recorded three species: *Rana macrodon*, *Rhacophorus leucomystax* (locality not mentioned) and *Bufo asper*. In the same year, Smith and Kloss (1915) described a collection of specimens from the coast and islands of

Southeast Thailand. They reported the presence of eight species of batrachians viz. *Oxyglossus martensii*, *Rana limnocharis, R. tigrina, R. doriae, R. nigrovittata, R. erythrea, Microhyla berdmorii* and *Bufo melanostictus*. In Smith (1916a), he described five tadpoles that belonged to the species *Callula pulchra*, *Microhyla ornata, Rana nigrovittata, Bufo purvus* and *Microhyla achantina* and in Smith (1916b) he described 28 species of Anura and one species of Gymnophiona (*Icthyophis glutinosus*). In 1916c, Smith also included three species of the genus *Oxyglossis* (*O. laevis, O. lima* and *O. martensi*).

Further research in 1916 led to the description of a new species, *Rana pileata* (currently included in *Limnonectes glydenstolpei*) based on a series of specimens from Khao Sebab, Chantabun Province (Boulenger, 1916). Smith (1917a) described *Callula mediolineata* as new species to science from Prachuap Kirikan. Smith (1917b) listed 52 species of amphibian known to be recorded from Thailand. Smith (1917c) described 16 tadpoles of *Rana kuhlii, R. rugulosa, R. cancrivora, R. limnocharis, R. macrodactyla, R. lateralis, R. erythrea, Rhacophorus leucomystax, Microhyla ornata, M. butleri, Glyphoglossus molossus, Calluella guttulata, Megalophrys montana, M. pelodytoides, M. hasseltii* and *Bufo melanostuctus*. Smith (1917d) described *Rana cubatalis* as new species to science from Doi Nga Chang, Northern Thailand.

Smith (1917b)'s list included 22 species from the genus *Rana.* He also doubted the occurrence of *Rana esculenta* from the list of Flower (1899) since it is not found anywhere in South Asia (Smith, 1917a).

Boulenger (1918) described a new species, *Rana miopus,* based on a specimen collected from Nakon Si Thammarat, Thailand. In the same year, Barron (1918) reported the presence of *Megalophrys carinense* based on a specimen collected by Sherriff from Me Taw, a tributary of Me Wang River. Meanwhile, Smith (1918) reported the presence of *Rana cancrivora*, which was found to be common in Petriu, a little to the east of Bangkok. Smith (1922a), following the study of collections made by his local collector and colleague (names not mentioned) in early 1921, described *Rana aenea* from Doi Chang (Type locality) of Northern Thailand as new to herpetological science. Smith in the same paper also united *Rana mortensinii* with

*Rana nigrovittata*to as one species and *Microhyla butleri* with *Microhyla latastii,* also as one species (Smith, 1922a). In the same year, Smith recognized three cryptic species within the species complex *Rana dorie* (*R. macrognathus, R. pileata,* and *R. kohchangae*) and also described a race of *R. macrognathus* (Smith, 1922b). Later after the publication of the preceding paper, he included *Rana plicatella* in the *Rana dorie* group after studying a specimen collected at an altitude of above 1200 meters in the Malay Peninsula (Smith, 1922c).

Cochran (1927), after studying specimens collected by Smith from 1923 to 1927 from Thailand, presented the discovery of two new species from the genus *Philautus* (*P. nongkhorensis* and *P. hansenae*) from Nong Khor, and one species of *Microhyla* (*M. malcolmi*) form Pak Jong. He also combined the genus *Chirilaxus* (Boulenger, 1893) with *Philautus* (Gistel, 1848) (Cochran, 1927). Taylor (1934), an American scientist, recorded 11 species of amphibians based on collections made by Mr. R. M. De Schauensee, for the Academy of Natural Sciences of Philadelphia, from Chang Mai in northern Thailand and Chantaboon in southeastern Thailand. He described *Microhyla fowleri* as a new species for the country (type locality = Chiang Mai Province). In 1953 and 1954 Taylor also identified many specimens sent from Thailand to the United States but no specific publication was made. In 1955, Robert E. Elbel, who had spent the previous four years in Thailand with the United States Operations Mission, returned to the United States with a number of specimens. Subsequently this collection was published in Taylor and Elbel (1958). This paper recorded 79 species of amphibians including *Micrixalus magnapustulosus* which was new for Thailand. However, the specimens are collected by Boonsong Lekagul, Baron de Schauensee and Smith.

During the period of 1957-1960, Taylor undertook a thorough amphibian survey of Thailand (covering 71 provinces). On the basis of this and previous work, he published "The amphibian fauna of Thailand" recording about 100 species (Taylor, 1962). The paper listed 42 species of the family Ranidae and one species each for the Hylidae and Antlopodidae. The author also included species from the families Pelobatidae, Bufonidae, Rhacophoridae and Microhylidae. There were also several new species and subspecies, namely: *Leptobrachium minimum* (from Doi Suthep,

1000 m abs, Chiang Mai), *L. hendricksoni* (from Bhetong, Yala), *Rhacophorus bisacculus* (from Phu Kading, Leo Province), *Theloderma stellatum* (Doi Suthep, 4000ft abs, Chiang Mai province), *Theloderma gordoni* (Khao Sebab, 18 Km Northeast of Chanthaburi, near waterfall), and *Microhyla inornata lineate* (from 10 Km west of Nakhon Si Thammarat). He also reported *Rhacophorus dulitensis prominanus* from Benang Star, Yala Province.

Inger (1970) described a new species, *Rana fasciculispina* based on a specimen collected by Boonak from the Kao Soi Dao, Chang Wat Chantaburi, Thailand. Kiew (1984) described a new species of *Ansonia siamensis* from Isthmus of Kra and Grismer and Wood also mapped its occurrence in Thailand (Grissmer, 2006; Wood *et al*., 2008).

Chan-ard (1992: in Thai language) listed 16 species of amphibians from a study of the peat swamp forest of Toh Dang. Five of these was found exclusively in the peat swamp forest, seven species were in the tea tree forest, and four species were common to both forest types. However, no new species or new record was reported. Kongthong and Nabhitabhata (1993) prepared a checklist of Thai amphibians that included 106 species. It was followed by the checklist of Nabhitabhata *et al*. (2000) of the amphibians and the reptiles in Thailand. This comprised 132 amphibian species and 325 reptilian species.

Inger and Chan-ard (1998) discovered a new species, *Rana archotaphus* from Doi Inthanon National Park, Chiang Mai Province that is similar to *Rana livida* but differs in having a smaller size, grooves around the disk of fingers, green color dorsally, outer metatarsal tubercles, and lacking sexual dimorphism in the size of the tympanum. Matsui *et al*. (1998) also reported a new species, *Ansonia inthanon* from Doi inthanon. Later, Matsui *et al*. (1999) described a new species, *Leptobrachium smithi* from Ton Nam Plu Waterfall, Khao Chong, Trang Province. Pauwels *et al*. (1999) reported the first record of *Kaloula baleata* based on the specimens collected from Phang-Nga, Phuket and Trang Provinces. Khonsue and Thirakhupt (2001) undertook a review of the literature and prepared a checklist of the amphibians of Thailand that included about 130 species from eight families and three orders. *Rana*

catesbeiana, which is a non-native frog, is also listed as one of the amphibian species found in Thailand; it had been introduced into Thailand 10 year ago for human consumption. The new species in the checklist are *Rana archotaphus* (Inger and Chan-ard, 1998), *Ansonia inthanon* (Matsui *et al*., 1998), *Rhacophorus cyanopunctatus* (Manthey and Steiof, 1998), and *Leptobrachium smithi* (Matsui *et al*., 1999).

In October 2001 a representative of the genus *Chaperina* was collected from Khlong Sang Wildlife Sanctuary, Suratthani Province. The species was not identified with certainty but was provisionally assigned to *Chaperina fusca* (Taksintum *et al*., 2003: in Thai language). Pauwels *et al.* (2002) studied the amphibians and reptiles diversity in the Phang-nga Province, southern Thailand and found 39 amphibian species, which included 38 species of anurans and 1 species of caecilian. Leong *et al*. (2003) added 5 anuran species as new records (*Ansonia malayana*, *Microhyla heymonsi*, *Megophrys parva*, *Limnonectes macrognathus*, and *Taylorana hascheana*) from Phuket. In addition, Chuaynkern *et al*. (2009) further confirmed the presence of two species, *Rana baramica* and *R. laterimaculata*, through the study of specimens collected by Chan-ard *et al*. (2003) and Leong *et al*. (2003) respectively, from the Hala-Bala wildlife Sanctuary. Taksintum *et al*. (2003: in Thai language), based on the study of tadpoles in Songkhla and Suratthani Provinces recorded the flying frog *Rhacophorus pardalis* for the first time from Thailand.

Stuart *et al*. (2005) described one new species, *Huia melasma* from Tham Tarn National Park and Kaeng Krachan National Park, western Thailand that increased *Huia* genus to six members from five. Matsui *et al*. (2005) recorded a new species, *Ansonia kraensis* from Isthmus of Kra, Thailand. Bain and Stuart (2005) also recorded a new species of cascade frog, *Rana indeprensa,* which belongs to the *Rana livida* species complex through a collection made from the locality of Nakhon Ratchasima and Nakhon Nayok Province, eastern Thailand.

Nabhitabhata and Chan-ard (2005) contributed to the “Thailand Red Data: Mammals, reptiles and Amphibians”. They listed 137 species (138 forms) of amphibians, where

5 species are categorised as Vulnerable, 33 as Near Threatened, 64 (65 forms) as Least Concern, 35 as Data Deficient and 7 species as Endemic to Thailand.

Several specialists conducted considerable research on tadpoles. Inthara *et al*. (2005) identified the tadpoles of 44 species of frogs of Thailand through the collections made from December 1998 to March 2004 from various provinces.

Matsui (2006) discovered three new Megophryid species, *Leptolalax melanoleucus* (type locality = Khlong Saeng Wildlife Sanctuary, Surat Thani Province), *L. fuliginosus* (type locality = Pa Lao U, Prachuap Khiri Khan Province), and *L. solus* (type locality = Bala in Hala Bala Wildlife Sanctuary, Narathiwat Province), from southwestern and southern Thailand, using acoustic and morphological characteristics. Matsui and Nabhitabhata (2006) reported a new species, *Amolops panhai,* type locality = Pa Lao U, Prachuap Khiri Khan Province, from western and peninsular Thailand; this species is a torrent dweller. Stuart *et al.* (2006) added three new species of anura to the Thai checklist of amphibians, namely: *Megophrys lekaguli* from Chantaburi and Sa Kaeo Provinces; *Odorrana aureola* from Loei Province; and *Fejervarya triora* from Ubon Ratchatani Province. With the support of molecular techniques, they also studied the tadpoles that belonged to the newly described species of *Megophrys* and *Fejervarya* and the newly discovered *Rhacophorus* species of eastern Thailand. In the same year, Matsui and Panha (2006) described a new species, *Rhacophorus jarujini*, from Kalasin and Roi Et Provinces (Type locality), eastern Thailand. From May 2001 to January 2003, a study of anuran diversity in Khlong Sang Wildlife Sanctuary, Surat Thani Province was undertaken (Taksintum *et al*., 2006: in Thai language). They recorded 39 species of frogs (including their tadpoles) that belong to 18 genera and 5 families. They also gave the descriptions of *Rhacophorus pardalis* and *Chaperina fusca* that were new records for Thailand. Ohler and Delorme (2006) separated *Rhacophorus kio* as the new species from *R. reinwardtii* complex, and its distribution in Thailand was considered to be Doi Chiang Dao, Chiang Mai Province, and Me Wang in northern Thailand, and Tak Province in southern Thailand. Pauwels and Cherot (2006) translated the original Thai description of *Kaloula aurata* (Nutphand, 1989) into English with the designation of the lectotype and nominating type locality as Nakhon Si Thammarat. However, this

species is not included in the checklists of Thailand (Nabhitabha, Chan-ard and Chuaynkern, 2000; Khonsue and Thirakhupt, 2001).

McLeod and Ahmad (2007) discovered new species, *Theloderma licin* through the study of five specimens collected from southern Thailand and Peninsular Malaysia. This was the third *Theloderma* species reported at that time from Thailand (the fourth from Peninsular Malaysia). Chan-ard *et al*. (2007) confirmed the presence of *Brachytarsophrys feae* in northern Thailand through the study of a specimen deposited in Field Museum of Natural History (Chicago), collected from Doi Inthanon, and believed to be collected by C.R. Carpenter before 1940 whilst studying gibbons.

McLeod (2008) discovered a new species of fanged-bird eating frog (*Limnonectes megastomias*) from eastern Thailand; molecular analysis supported its relationship to the "*Limnonectes khulii*" complex. In 2008, Chuaynkern and colleagues re-examined specimens of *Rana baramica* from Thailand and confirmed that they were referable to *Rana laterimaculata,* which was described from Malaysia. The status of *Rana baramica* in Thailand is unknown and requires further study (Chuaynkern *et al*., 2009).

Chuaynkern *et al*. (2010) studied the morphology, morphometrics, and behaviour of the subgenus *Nidirana* and separated the taxon into three species groups: (1) the *Rana okinavana* group, which comprises *Rana chapaensis*, *Rana daunchin*a, and *Rana okinavana*; (2) the *Rana adenopleura* group of *Rana adenopleura*, *Rana caldwelli*, and *Rana lini*; and (3) the *Rana pleuraden* group. Based on external morphological characters the specimens identified as *Rana adenopleura* and *Rana chapaensis* from Thailand were re-allocated to *Rana lini*. They also extended the geographical distribution of *Rana lini* to China, Laos, and Thailand (Chuaynkern *et al*., 2010).

Danaisawat *et al*. (2010: in Thai language) through the study of specimens collected in 2008 from Khao Sip Ha Chan Proposed National Park, Chanthaburi Province, described and prepared a dichotomous key for tadpoles of 26 species, 15 genera and 6 families. They described the structure of mouthparts and the labial tooth row formula

for each of the tadpoles. A comparison of the species of anurans in different habitat types in the Kui Buri National Park was undertaken by Taksintum *et al*. (2010: in Thai language). They found that the anuran species are more common in forest edge habitats than in the agriculture land or forested areas. Ha-Ngam *et al*. (2010) reported the results of two surveys in Trat Agroforestry Research Station in Trat Province, which had been conducted in 2005 and 2006. They collected 22 species of amphibian and 38 species of reptile. However, they did not report any new species or new record for the country.

Matsui *et al*. (2010a) described two new species of *Limnonectes, L. taylori* (Ban Khun Klang, Doi Inthanon, Chiang Mai Province) and *L. jarujini* (Kaeng Krachan, Phetchaburi Province) from the "Kuhlii" complex where *L. taylori* is northern and *L. jarujini* is southern lineage. Matsui *et al*. (2010b) studied the phylogeny of the Southeast Asian genus *Ansonia* with the use of 2461 base pair sequences of the mitochondrial 12S rRNA, $tRNA^{val}$, and 16S rRNA genes. They found that there are two major clades in the genus where clade 1 includes 11 species from Malaysia and Thailand, and six from Borneo, and clade 2 includes ten species from Borneo. They also found that there are two cryptic species of *Ansonia* in Thailand, which are provisionally named as *Ansonia* sp. 1 (from Pilok, Kanchanaburi) and *Ansonia* sp. 2 (Phuket Island). Onn and Grismer (2010) treated *Rhacophorus kio* from northern Thailand as a separate species and recommended the re-evaluation of the taxon *R. reinwardtii* (Ohler and Delorme, 2006). They also described *Rhacophorus norhayatii* (previously included in *R. reinwardtii*) as a new species to science and omitted *R. reinwardtii* from the faunal list of Thailand.

Chan-ard *et al*. (2011) listed 154 species of amphibians in his work "The Amphibians of Eastern region, with a checklist of Thailand". The authors listed all three living orders of amphibian. From Order Anura they described eight families. From the family Megophryidae, they listed six genera: *Brachytarsophrys, Leptobrachium, Leptolylax, Megophrys, Ophryophryne,* and *Xenophrys*. From the family Bufonidae, they listed six genera: *Ansonia, Duttaphrynus, Ingerophrynus, Leptophryne, Pedostibes*, and *Phrynoidis*. From the family Hylidae, only one genus was recorded: *Hyla*. From the family Microhylidae eight genera were recorded: *Calleulla*,

Chaperina, Glyphoglossus, Kaloula, Kalophrynus, Microhyla, Micryletta, and *Phrynella*. From the family Dicroglossidae seven genera were listed: *Fejervarya, Haplobatrachus, Ingerana*, *Limnonectes, Nanorana, Occidozyga and Quasipaa*. The family Rhacophoridae included eight genera: *Chiromantis, Gracixalus, Kurilaxus, Nyctixalus, Philautus, Polypedates, Rhacophorus* and *Theloderma*. Finally, ten genera of the family Ranidae were listed: *Amolops, Babina, Clinotarsus, Huia, Humerana, Hydrophylax, Hylarana, Odorrana, Pelophylax* and *Rana*. In the same book, they also gave pictorial description of 42 species from eastern Thailand which includes one species from Megophryidae, three species from Bufonidae, eleven species from Microhylidae, nine species from Dicroglossidae, eight species from Rhacophoridae and nine species from Ranidae (Chan-ard *et al*., 2011). Khonsue *et al*. (2011: Thai language) also described 26 species of amphibians from the five islands of Tarutao, Kud, Yao Yai, Angthong and Similan. Twenty-four of these are anurans. Mahony (2011) described a new species, *Megophrys takensis,* currently in the zoological collections of the Natural History Museum London, which was collected in early twentieth century by Malcolm A. Smith from Ban Pa Che, Tak Province, western Thailand. They also succeeded in studying a live specimen of this new species. Chan-ard *et al*. (2011) reported the presence of *Hylarana nicobariensis* from Ban Gujam, Tak Bai District, and Narathiwat Province. This is the second record of the species and the first since Taylor (1962). Thong-aree *et al*. (2011) recorded 34 species of anurans exclusively from Bala forest amongst a 49 species of amphibian inventory prepared by Chan-ard and his colleague from 2001 August to 2002 August.

McLeod, Kelly and Barley (2012) described new species *Limnonectes isanensis* from Loei Province increasing the member of *Limnonectes kuhlii* complex to four in Thailand.

In 2013, a new species *Polypedates discanthus* was described from southern Thailand based on morphometric and molecular data (Rujirawan, Stuart and Aowphol, 2013). In the same year the new species *Leptolalax zhangyapingi* was described from Doi Saket, Chiang Mai Province in northern Thailand based on molecular and morphological data (Jiang *et al*., 2013). This increased the number of *Leptolalax* species to seven in Thailand (Jiang *et al*., 2013).

Currently, the number of anuran species recorded from Thailand is 164 (Appendix I). However the list is increasing all the time. Species that are endemic to Thailand are *Amolops archotaphus, Ansonia kraensis, A. inthanon, A. siamensis, Chiromantis hansenae, Fejervarya triora, Ingerana tasanae, Kaloula aureata, Leptolalax fuliginosus, Leptolalax melanoleucus, Leptolalax solus, Xenophrys lekaguli, Xenophrys takensis*, *Rana scutigera, Odorrana aureola, Odorrana indeprensa, Hylarana eschatia , Huia melasma, Occidozyga magnapustulosa, Limnonectes isanensis, Limnonectes jarujini, Limnonectes megastomias, Limnonectes taylori,* and *Rhacophorus jarujini* (Frost, 2014).

The scientific names have changed considerably through time and the nomenclature used below is based on current listings in the IUCN Red List (IUCN Redlist, 2012). Some existing records are vague and few supporting evidence. For example, *Ansonia malayana* is recorded from Yala Province, Thailand (IUCN, 2013). However, there would appear to be no published literature or reports to substantiate this, although it is mapped for this area by Wood *et al*. (2008).

Another confusing species is *Ingerophrynus divergens* which is included to herpetofauna of Thailand (Chan-ard *et al*., 2011) even though it is doubtful with *Ingerophrynus parvus*. The species of *Nanorana yunnanensis* is usually reported from China, Vietnam, and Myanmar (IUCN, 2013), but it was included for Thailand by some researcher without supporting data (Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011). The *Polypedates megacephalus,* which was also included in the checklist of Khonsue and Thirakhupt (2001) is excluded here as it is currently thought to be restricted to north of the Red River in Vietnam (IUCN, 2013). *Rana baramica* is also excluded here since its status is uncertain in Thailand after its relegation from the Thai herpetology list by Chuaynkern *et al*. (2008).

In addition to numerous works on species diversity, scientists are now working on the detection of amphibian diseases and especially chytrid fungi, which is threatening amphibian populations elsewhere in the world with extinction. Mcleod *et al.* (2008) is the first to work on chytrid fungi in Thailand base on histological screening. The histological screening of 123 specimen representing 28 species showed a negative

result. However, this is not a robust method for *Batrachochytrium dendrobatidis* (*Bd*) testing according to Boyle *et al*. (2004) and Kriger *et al*. (2006) (as cited by Voros *et al*., 2012). Voros *et al.* (2012), based on a study in the protected area of the Prince of Songkla University reported the presence of *Bd* from the skin swab of *Ingerophrynus parvus.* This was the first record in natural environment for Thailand. However, this disease does not seem to be a major threat in Thailand at present time.

Gymnophiona (Muller, 1832)

The study of the Caecilians in Thailand started much later than anuran groups. The first record of a caecilian from Thailand is by Cochran (1930), listed only one species of *Ichthyopis glutinosus*. Later Taylor (1934) also listed the same species based on a collection mainly from Chiang Mai, northern Thailand made by Smith. In 1958 Taylor and Elbel recorded two species of caecilians, *Ichthyophis glutinosus* and *I. monochrous*. Taylor (1960) described five new species: *I. larutensis*, *I. youngorum* (collected from Chiang Mai by Taylor in 1957), *I. acuminatus* (collected from Me Wang valley by Smith), *I. supachaii* (collected from Na khon Si Thamarat province by Taylor in 1958) and *I. kohtoensis* (collected from Koh Tao Island by Smith). Taylor (1962) reported four species and one subspecies of *Ichthyopis*, namely: *Ichthyophis acuminatus*, *I. youngarum*, *I. supachaii*, *I. kohtaoensis kohtaoensis* and unidentified subspecies of *I. kohtaoensis*. According to the checklist and journals of different Thai and foreign herpetologists (Nabhitabhata *et al*., 2000; Chan-ard, 2003; Chan-ard *et al*., 2011), Thailand has so far 6 species of Caecilians from the two genera: *Ichthyophis* (*I. acuminatus*, *I. kohtaoensis*. *I. supachaii*, *I. youngorum*) and *Caudacaecilia* (*C. asplenia* and *C. larutensis*) but there is still some doubt about the records of *C. asplenia*. Taylor (1972) reported the examination of the scale characters of the five species (*I. acuminatus*, *I. kohtaoensis*. *I. supachaii*, *I. youngarum*, *C. asplenia*) with prepared a dichotomous key to the genera and species of the caecilians of Thailand. However the author omitted *C. larutensis* with no obvious reason. In the checklist of Khonsue and Thirakhupt (2001), only five species were included, and *Caudacaecilia larutensis* is omitted. Khonsue *et al*. (2011: Thai language) reported the presence of *Ichthyophis kohtaoensis* and included one specimen of *Ichthyophis*

from Tarutao Islands as unidentified. Pauwels *et al*. (2002) also recorded *I*. aff. *supachaii* from Phang-Nga Province.

Kupfer and Muller (2004) re-examined 11 adult and juvenile specimens of *I. supachaii* collected in the 1950s and confirmed its distinct status. Amongst all of the caecilians, *Ichthyophis acuminatus* (Chiang Mai Province in northern Thailand), *Ichthyophis supachaii* (southern Peninsular Thailand), *I. kohtaoensis* (from Koh Tao Island, Thailand) and *Ichthyophis youngorum* (Doi Suthep Mountain, near Chiang Mai, Northern Thailand) are considered to be Thai endemics (IUCN, 2012), The caecilians checklist is included in appendix II.

Caudata (Waldheim, 1813)

The first to record of a salamander species from Thailand is *Tylototriton verrucosus* (Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011). Taylor (1962) researched all the Thai provinces (71 provinces) but could record only one species of Salamander (Jordan, 1878). Smith (1859), as cited in Taylor (1962) reported the presence of *Ambystoma* species but was later found as a mislabeled specimen of the American species, *A. jeffersonianum*. Wongratana (1984) also extended the territory of the species to Phu Luang Wildlife Sanctuary (Loei Province) at an altitude of about 1500 m and the author also reported that two specimens were collected from the aforementioned sanctuary. However, until date the species was considered endemic to Chiang Mai province, Thailand. Pomchote *et al*. (2008) tried to solve the problem of the sensitivity of the species to environment through self sampling. They found positive relations to enviroment demonstrating different body colour patterns and sizes in different places and environmental conditions leading them to name as type I and II. Preceding works reported the presence of *T. verrucosus* from only four provinces; Mae Hong Son, Chiang Mai, Nan and Loei but Pomchote *et al*. (2008) added two new provinces; Chiang Rai and Phitsanulok. However, in 2013 these two morphological pattern which was refferred to as type I and type II were separated as two different species by Nishikawa and coworkers through molecular and morphology. Type I is named as *Tylototriton uyenoi* found in Chiang Mai Province,

Thailand (Doi Ang Khang, Doi Chang Kien, Doi Inthanon, Doi Pui, and Doi Suthep) and the type II as *Tylototriton panhai* found in Phitsanulok Province (Phu Hin Rong Kla National Park) and Loei Province (Phu Luang Wildlife Sanctuary and Phu Suan Sai National Park), Thailand (Nishikawa *et al*., 2013) but the other clade found in Doi Lahnga, Chiang Rai Province remained undescribed due to the lack of specimen however it is grouped under subgenus *Tylototriton*. The *Tylototriton* species in Thailand however seems to be taxomically complex and the status of *Tylototriton* is still not clear since the Thai population is identified as *Tylototriton shanjing* rather than *Tylototriton verrucosus* (Nishikawa *et al*., 2013) and we cannot rule out its presence unless all three Thai populations were named. The tentative number of caudata found in Thaland is three based on the reviewed literatures and here *T. verrucosus* is also listed.

Amphibian species of Tarutao National Park

The literature on the amphibian diversity of Tarutao National Park is scarce. The only literature as far as concerned is Khonsue *et al*. (2011). This is the compilation of amphibian diversity of islands of Thailand. It includes Kud Island, Yao Yai Island, Tarutao Island group, Ang Thong Island group and Similan Island group. Nine species of Anura were recorded from Kud Island with one caecilian species that is *Ichthyophis kohtaoensis*, fourteen species of Anura from Yao Yai Island, eleven species of Anura from Tarutao Island group with one undescribed *Ichthyophis* species, eight species of Anura from Ang Thong Island group and four species of Anura from Similan Island group confirming 26 species of amphibian to be found in islands of Thailand. The anuran species recorded during the time from Tarutao group of islands are *Phrynoidis aspera*, *Ingerophrynus parvus*, *Hylarana erythraea*, *Hylarana chalconota*, *Limnonectes macrognathus*, *Limnonectes blythii*, *Fejervarya cancrivora*, *Limnonectes hascheanus*, *Polypedates leucomystax*, *Kaloula pulchra* and *Kaloula baleata*. They also found one sample of *Ichthyophis* sp. confirming 12 amphibian species in Tarutao group of islands (Khonsue *et al*., 2011).

Hylarana chalconota complex

The family Ranidae is one of the species rich groups of Anura (Che *et al*., 2007). Sundaland frog of genus *Rana* has always drawn considerable attention due to the unresolved phylogeny and a confusing taxonomy (Inger, 1996; Brown & Guttman, 2002; Bain *et al*., 2003; Chen *et al*., 2005; Matsui *et al*., 2005; Che *et al*., 2007; Cai *et al*., 2007) with the need of thorough revision (Boulenger, 1920). Though there have been attempts to resolve its chaos but always seems to be contentious with considerable difference in findings (Boulenger, 1888; Inger, 1996; Matsui *et al*., 2005) of different herpetologists.

It is remarked by several researchers that single widespread species in Southeast Asia are actually an entity of intricate species thereby undermining the species diversity in the region (Bain *et al*., 2003 and 2005). By no means is species complex of *Odorrana livida* and *Hylarana chalconota* any exception and several new forms was described in recent years (Bain *et al*., 2003 and 2005; Inger and Iskandar, 2005; Inger, Stuart and Iskandar, 2009).

Nevertheless, the two species complexes, *Odorrana livida* and *Hylarana chalconota* were always confused and separation of their members always contentious being similar in morphology (Stuart, Inger and Voris, 2006). *Odorrana livida* was originally described from Myanmar and was reported from India to Vietnam. Though this species was left as single widespread entity despite finding few morphological differences between the specimen of Thai and Vietnamese localities which were claimed to have no clear differentiation that would allow the recognition of the population as different species (Inger and Chan-ard, 1997). However, it was never as considered rather the complex of at least seven species exclusively in Vietnam. Later three were described as new species and four as its morphotypes (Bain *et al*., 2003). Bain *et al*. (2003) also found that *Rana chloronota* which was described originally from Darjeeling, eastern India and reported from many Southeast Asian countries like China, Lao PDR, Thailand, Vietnam and Myanmar including various parts of India (Lalremsanga *et al*., 2007), was the widely distributed species complex erroneously included in the *Odorrana livida* group and was later separated into seven new species.

The *Rana chalconota* was originally described from Java and is reported from peninsular Thailand, peninsular Malaysia, Borneo, Sumatra and various archipelagos (Boulenger, 1920; Bain *et al*., 2003; Leong, Grismer and Mumpuni, 2003; Stuart, Inger and Voris, 2006). However, *Odorana livida*, *Rana chloronota* and *Hylarana chalconota* complexes were first separated by Stuart, Inger and Voris (2006) through molecular phylogeny and also commented that "Frogs that have been identified on the basis of morphology as *O. livida* and *Hylarana chalconota* represent at least 14 species" (Stuart, Inger and Voris, 2006) defying this species to be the single widespread species in Sundaland. During the time eight amongst the fourteen forms observed were name either by resurrecting the old junior synonyms (*Odorrana chlororona*, *Hylarana labialis* and *Hylarana raniceps*) or by correctly applying commonly used name (*Odorrana livida*, *Odorrana hosii* and *Rana chalconota*). However, six of the species from both the complexes were left unnamed, two clades from *Odorrana livida* complex and four clades from *Rana chalconota* complex (Stuart, Inger and Voris, 2006).

Boulenger (1920) considered *Hylarana labialis* from Malay Peninsula to be the typical variety of *Rana chalconota* of Java due to difference in having short foot; slender hind limb and smaller size however mentioned that the intermediate specimen completely connects the two extreme forms though ambiguous of to which population specimen was referred. Inger and Iskandar (2005) also found two similar morphological types in West Sumatra befitting general description of *Rana chalconota* however they were morphologically dissimilar in some characters like humeral gland, body color, degree of webbing, morphology of nuptial pads and SVL of adults. Subsequently the identity of the individual species in *Rana chalconota* complex was brought to light by Inger, Stuart and Iskandar (2009) although some of the Malaysian samples were left unrevealed during the time due to insufficient data. With the robust study of the complex both genetically and morphologically, *Hylarana eschatia* was described as new species with separation of the group into seven species (Inger, Stuart and Iskandar, 2009). The three newly described species were *Hylarana megalonesa*, *Hylarana rufipes* and *Hylarana parvaccola* and other three species were assigned the previously used names viz. *Hylarana chalconota*: described for the first

time in Thailand by smith in 1916 as *Hylarana labialis* from Nakhon Si Thammarat Province, Thailand through the study of tadpoles however it was also described as *Hylarana chalconota* by Smith (1930) from the same province and also mentioned that Smith and van Kampen agrees to merge *Hylarana labialis* that was described as new species for the first time by Boulenger (1887) from Malacca, peninsular Malaysia and *Rana chalconota*.

Distribution of *Hylarana eschatia* is said to be only in southern Thailand (holotype and paratype from Ngao Waterfalls National Park, Ranong Province). The specimens from Khao Luang National Park, Nakhon Si Thammarat Province, Khao Phanom Bencha National Park, Krabi Province, Khao Sok National Park and Kaeng Krung National Park, Surat Thani Province were also studied. The species can be distinguished from its congeners by "moderate size with males up to 40 mm snout to vent length and females up to 57 mm snout to vent length, relatively having wide head and long leg, males in having constricted or divided nuptial pads, and lacking black spots on dorsum". It breeds in pulse near by the slow flowing streams, side pools along the stream, in the various types of forests from primary to secondary including swamps (Inger, Stuart and Iskandar, 2009). However the problem in this complex still perpetuates since they did not study the specimen from the complete locality where *Rana raniceps* (Chan-ard, 2003; Khonsue and Thirakhupt, 2001; Wangkulangkul, Dejtaradol and Waharak, 2008), *R. chalconota* (Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata, Chan-ard and Chuaynkern, 2000; Khonsue and Thirakhupt, 2001; Khonsue *et al*., 2011) and *Rana labialis* (Boulenger and Robinson, 1912) were reported from Thailand. Furthermore Thong-aree, Cota and Makchai (2011) reported from Bala, Narathiwat Province as *Hylarana eschatia* (the genus name was modified from *Rana* to *Hylarana* after Frost *et al*., 2006) and as *Rana chalconota* from Tarutao group by Khonsue *et al*., (2011) questioning the unstable status of *Hylarana eschatia* in Thailand and complicating the problem of *Hylarana chalconota* complex as a whole. Moreover, there seems to have some morphological variations within this species which needs further investigation.

CHAPTER III

MATERIALS AND METHODS

Part I. The diversity of amphibians in Tarutao Island

Study area

Tarutao Island is located in the west coast of Thailand about 26 km away from mainland Satun Province, stretching about 151 km^2 in the Andaman Sea and making the principle island in Tarutao National Park (Congdon, 1982). Tarutao Island mainly have ten types of vegetation according to Congdon (1982). It includes mangrove and brackish water forest constituting about 4.5% of the island area, freshwater swamp forest along the freshwater stream beds joining the sea, freshwater marsh, Pes-carae formation, Barringtonia formation, coastal health forest, limestone vegetation, scrub forest, semi-evergreen forest and secondary vegetation (Congdon, 1982; Figure 1).

Four sites were selected based on the locations and the explorative probability since most parts of the island is covered by thick tropical rainforest and surrounded by the rocky cliffs (Figure 1). The four sites were:

1) Pante Malaka (6°42′ 08.84″ N and 99°38′ 48.81″ E): The habitats surveyed were disturbed grassy beach, mangrove forest constantly flooded by sea water, limestone hills and the nature trail (Figure 2A).

2) Talo Wow (6°37′ 17.65″ N and 99°40′ 48″ E): The habitats surveyed includes the shallow stream, mangrove forest, ephemeral pools and thick lowland primary forest (Figure 2B).

3) Talo Udang (6°32′ 26.68″ N and 99°40′ 33.06″ E): The habitats surveyed includes the mangrove beach, meandering freshwater brooks that join brackish water, abandoned nature trail, the temporary pools and the swamps (Figure 2C and 2D).

4) Ludu Waterfall (6°36′ 57.21″ N and 99°36′ 51.05″ E): The survey was conducted along the banks of the freshwater streams that runs through the thick forest (Figure 2E and 2F).

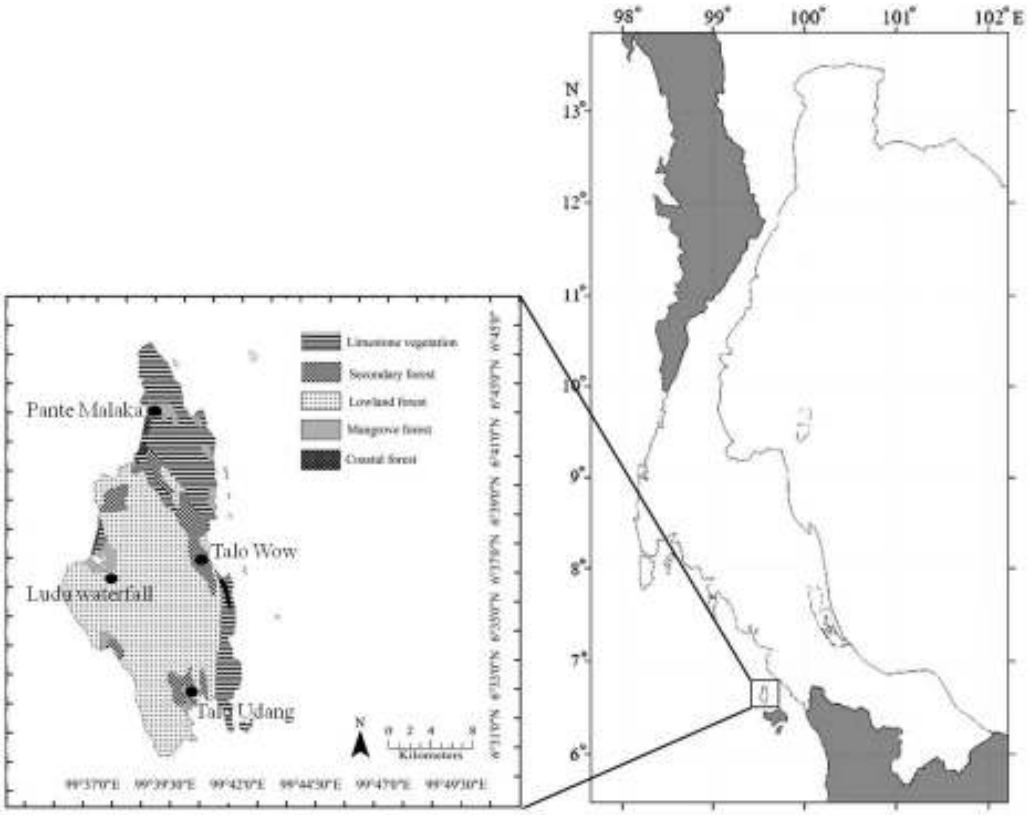

Figure 1. Major vegetation and the four sites surveyed in Tarutao Island. (Modified from Congdon, 1982).

The sites were surveyed for 340 man hours. The methods are a slight modification of Heyer *et al*. (1994), walking along both the main and the branch streams. The surveys were taken at night time during 19.00 – 23.00 hours. The live specimens were measured at the study site and only 1-3 specimens were kept at the reference collection of Princess Maha Chakri Sirindhorn Natural History Museum in Prince of Songkla University for the further study.

Figure 2. The habitats surveyed in Tarutao Island, (A)- Mangrove forest in Pante Malaka (B)- Freshwater stream in Talo Wow, (C)- Freshwater stream in Talo Udang, (D)- Mangrove beach in Talo Udang, (E) and (F)- Freshwater streams in Ludu Waterfall.

Specimen collection

The adult specimens were caught by hand and handled according to the procedure of Heyer *et al*. (1994). Caught specimens were put in the plastic bags and few leaves and small amount of water were added. Tadpoles were fished with small dipnet. It is collected in plastic bags or plastic bottles with about a liter of water. Each collected specimens were given the field number instantly in the field by the collector. The field numbers were written with the permanent ink marker which is water resistant. The localities and environmental informations were also noted in the field notebook. The collected live specimens were carried back to the University. The specimens were kept in the same plastic bags until fixed and preserved (Heyer *et al*., 1994).

Preservation and storage

Before fixing and preserving the specimen all the materials like field tags (with written field number, museum reference number, date of collection and locality), trays (tissue paper laid on it), tissue paper, alcohol (70% and 95%) and injecting syringe were set ready on the working table. Water resistant paper was used for field tags and permanent alcohol resistant pen was used. The collected specimens were euthanized by giving a cold shock in the refrigerator. Once the specimen was dead and relaxed it is taken out of the refrigerator and plastic bag. The specimens were placed on the plastic tray and limbs were placed at the lateral sides of the body. The fingers and toes were stretched to display the webs. In order to maintain the position few milliliter of 95% ethanol was injected depending on the size of the specimen. The specimen was left to fix for 2-3 hours and then transferred to 70% ethanol for storage (Heyer *et al.* 1994). If the specimen fixing were not finished in the same day they were put back to get frozen in the refrigerator and before preserving they were defrozed under the running tap water. Same process of preservation is repeated when preserving and storing in the next day. The tadpoles were usually fixed at the camp in the study site by adding few drops of 95% ethanol until the tadpole stopped moving. The specimens were placed in the plastic tray, fin and tail were set in natural position then fixed and stored the same way as adult specimen.

Laboratory identification

Laboratory identification includes the study of field specimen and museum specimen collected previously from Tarutao Island. All the specimens were examined in the laboratory for the correct identification and described their morphology with the consultation of literatures like Taylor (1962); Berry (1975); Inger and Stuebing (1997); Pauwels *et al*. (1999); Chan-ard (2003) and Inger, Stuart and Iskandar (2009). For fine observation such as the tubercles, finger webbings and nuptial pads in males were studied under stereo microscope, Model Stand SE 2200 with inbuilt LED lamp. The tadpoles were identified with Danaisawat, Pradatsundarasan and Khonsue (2010), measured with the determination of the labial tooth row formula (LTRF) according to Altig (2007) and the developmental stage according to Gosner (1960).

Measurements and definitions

1) Adult morphology

The live specimens were carefully handled following the instruction of Heyer *et al*. (1994). The measurements were made instantly in the field and released if the specimens were not collected. Specimens were measured in millimeters (mm) with sliding caliper nearest to 0.1 mm. Thirteen external measurements were made for the adult specimens following various literatures (e.g. Pauwels *et al*., 1999; Inger, Stuart and Iskandar, 2009; Inger and Stuart, 2010; Figure 3). All specimens were measured from the right position.

1. Snout to vent length (SVL) is the length measured from the tip of the snout to the vent.
2. Head length (HL) is the length measured from the tip of the snout to the rear of the jaw.
3. Head width (HW) is the length measured at the widest part of the head.
4. Tympanum diameter (TD) is the length measured in the horizontal axis of the right tympanum.
5. Internarial distance (IND) is the length measured between the two naris.
6. Eye diameter (ED) is the length measured from the left to the right end of the right eye.

7. Interorbital distance (IOD) is the length measured between the two pupils.
8. Eye to naris distance (END) is the length measured from the right nostril to the right eye.
9. Shortest finger (SF) is the length from the wrist to the tip of the shortest finger.
10. Longest finger (LF) is the length measured from the wrist to the tip of the longest finger.
11. Tibia length (TL) is the length measured from the right knee to the ankle.
12. Shortest toe (ST) is the length measured from the tibiotarsal articulation to the tip of the shortest toe.
13. Longest toe (LT) is the length measured from the tibiotarsal articulation to the tip of the longest toe.

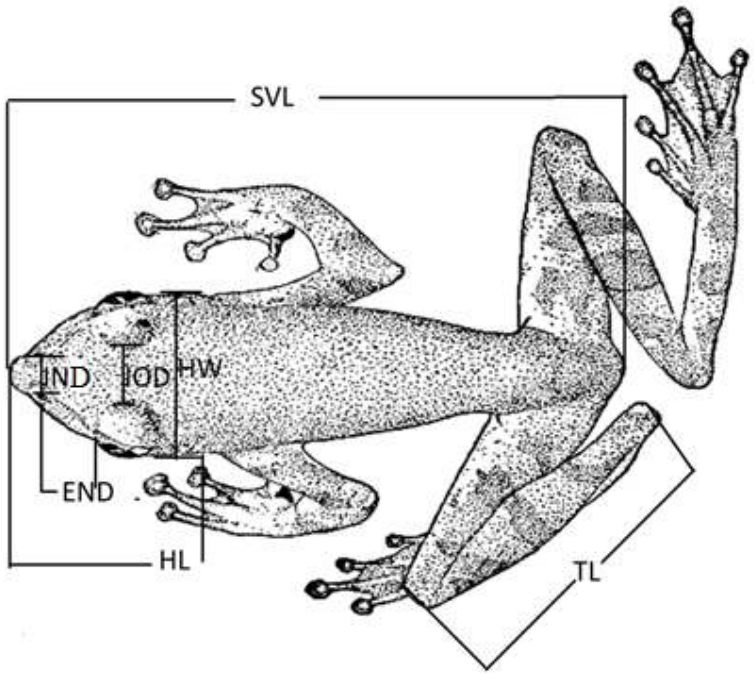

Figure 3. External measurements of the adult frog specimen (Dorsal view) (Modified from Inger, 1954)

2) Tadpole morphology

Measurements were made following Heyer (1971) and Altig (2007). All the measurements are in millimeter (mm) unless mentioned. Characters are: Body length

from tip of snout to the junction of the posterior body wall with axis of tail myotome (BL), width at midbody (MBW), interorbital distance from the center of each pupil (IOD**)**, tail length from the point where the body length measurement ends (TaL**)**, total length (TL**)** includes both head and body length. The mouth part consist of: ATR is number of anterior tooth row, PTR is number of posterior tooth row and LTRF is labial tooth row formula derrived according to Altig (2007) (Figure 4 and 5).

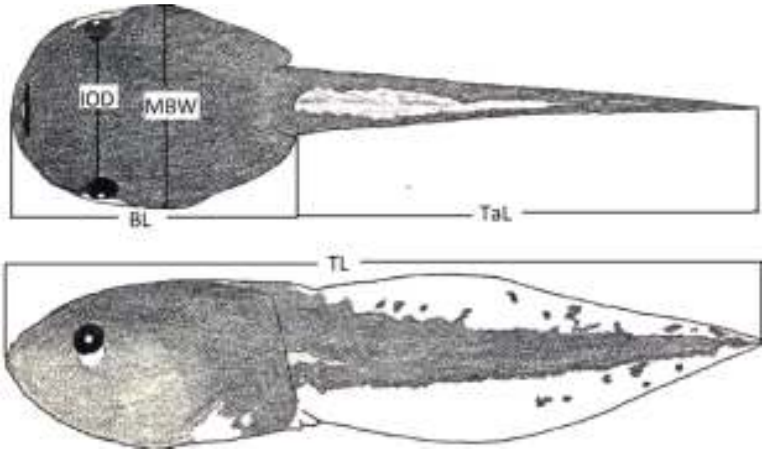

Figure 4. External measurements of tadpole (above dorsal view and below lateral view) (Modified from Heyer, 1971)

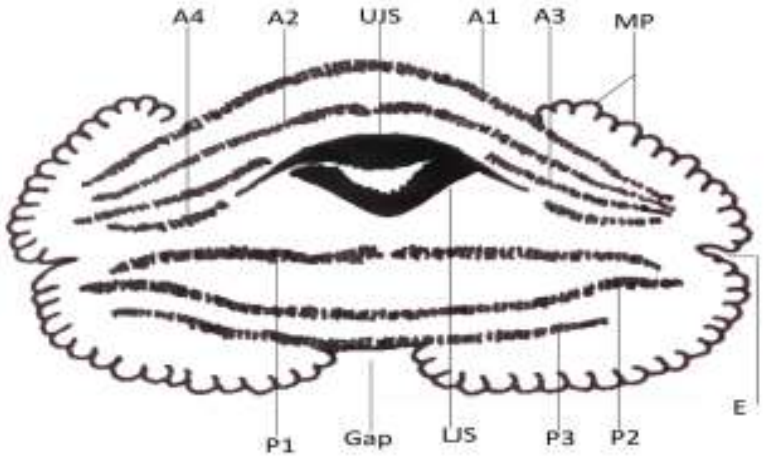

Figure 5. Face view of oral apparatus. A1-A4 is the first, second, third and fourth anterior tooth row, P1 to P3 is the first, second and third posterior tooth row, UJS is upper jaw sheath, LJS is the lower jaw sheath, E is emergination, MP is marginal papilae. (Modified from Heyer, 1971).

Data analyses

The mean and standard deviation (±SD) of the measurements were computed in Microsoft Excel 2010. The Shannon-Wiener diversity index is calculated using the formula: $\mathbf{H'=-\sum P_i \log (P_i)}$ and the index is raised to exponential value to get the effective species diversity $\mathbf{(e^{H'})}$ (Stiling, 2012).

Photography

The live photographs of the specimens were taken in the field with Nikon D5100 with normal lens of 18-55 mm with the attached external flesh. The tadpole morphology and mouth parts were photographed in the laboratory with Olympus DP-71 digital camera with calibrated scale.

Acoustic

1) **Acoustic recording**

The calls were recorded with the Samsung YP-VP2 at 44.1 KHz/16 bits from the distance of about 1 to 1.5 m from the calling individual. The ambient environmental temperature, humidity, call identification number and the species were noted instantly (Heyer, 1971). The calls were recorded for the longest duration of 5-10 minutes.

2) **Acoustic analysis**

Call analyses were performed in BatSound version 4.10 for windows with automatic Fast Fourier Transformation (FFT) (Peterson, 1983). The spectrograms, oscillograms, and power spectra were generated to quantify the temporal and spectral features of each call (Tampon *et al*., 2012). Frequency of maximum energy is measured from Power spectra. The terminologies of the calls were difficult to apply consistently to all the species (Heyer, 1971) however, for analysis and interpretation following eight terms and characters were used.

Call parameters and definitions

The call parameters follow the modified form of Duellman and Trueb (1994), Heyer (1971) and Tampon *et al*. (2012).

1) Call duration: Duration of call from beginning to its end.
2) Call period: Duration from the beginning of a call to the beginning of the next call.
3) Start frequency: Highest frequency in the call.
4) End or fundamental frequency: Lowest frequency in the call.
5) Peak Frequency: Frequency of the maximum energy in the call.
6) Note per call or group: Actual number of notes in a given call group.
7) Harmonics: Regular patterns of frequency bands on sonogram.
8) Frequency modulation: A change of frequency within a call.

Part II. Comparative study of *Hylarana eschatia*

1) **Field specimen**

Localities

In the current study seven localities were surveyed. The localities were Ban Tungka (9°52.'45.07" N, 98°41'16.26" E) in Ranong Province, Yong Waterfall National Park (8°10'N, 99°44'E) in Nakhon Si Thammarat Province, Kachong (7°32'38.42" N, 99°46'11.40" E) in Trang Province, Kho Hong Hill (7°0'5.31" N, 100°30'45.88" E) and Kaichon Stream (6°30'N, 100°26'E) in Songkhla Province, Tarutao Island (6°36'57.64" N, 99°39'3.84 " E) in Satun Province and Hala Bala Wildlife Research Station (5°47'59.3" N, 101°49'56.9" E) in Narathiwat Province (Figure 6).

Habitat surveyed

The habitats surveyed mostly includes the habitat that were most probable to be used by *Hylarana eschatia*. In this case the habitat surveyed were freshwater streams which includes both with and without torrents that runs through hills and plains but specimens were found mostly in the slow flowing streams. The survey was also

conducted in the primary and secondary forest, palm and rubber plantations if there are ponds and the streams. The surveys were also conducted along the nature trails and the abandoned roads.

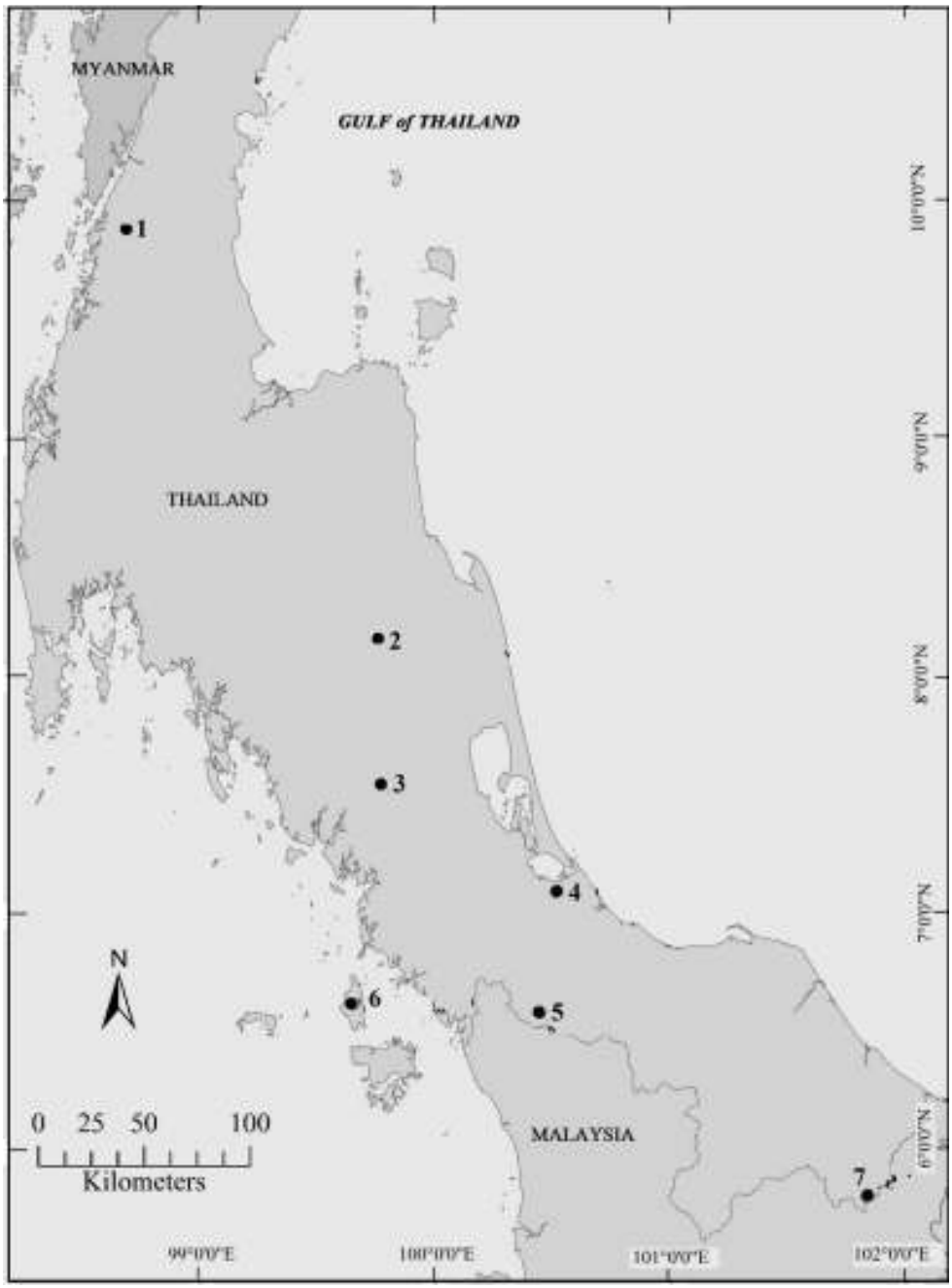

Figure 6. The localities of field specimens collected in this study. (1) Ban Tungka, (2) Yong Waterfall National Park, (3) Kachong, (4) Kho Hong Hill, (5) Kaichon Stream, (6) Tarutao Island and (7) Hala Bala Wildlife Research Station.

Specimen collection

a) Sampling

Only the adult male and female specimens were collected from the field. Snout to vent length was used to separate the sex when the size is strikingly different. In females juveniles and adults were distinguished from the snout to vent length. In males nuptial pad in the first finger was used to separate adults and juveniles. The specimens were caught by hand and handled according to the procedure of Heyer *et al*. (1994). Caught specimens were put in the plastic bags and added few leaves and small amount of water. Each collected specimens were given the field number instantly in the field by the collector. The localities and environmental information were also noted. The collected live specimens were carried back to the University. The specimens were kept in the same plastic bags until fixed and preserved (Heyer *et al*., 1994).

b) Preservation and storage

Before fixing and preserving the specimen all the materials like field tags (with written field number, museum reference number, date of collection and locality), trays (tissue paper laid on it), tissue paper, alcohol (both 70% and 95%) and injecting syringe were set ready on the working table. Water resistant paper was used for field tags and permanent alcohol resistant pen was used to write. The collected specimens were given a cold shock in the refrigerator to euthanize. Once the specimen was dead and relaxed it is taken out of the refrigerator and plastic bag. The specimens were placed on the plastic tray and limbs were placed at the lateral sides of the body. The fingers and toes were stretched to display the webs. In the maintained position few milliliter of 95% ethanol was injected depending on the size of the specimen. The specimen was left to fix for 2-3 hours and then transferred to 70% ethanol for storage (Heyer *et al*. 1994).

2) **Museum specimens**

The museum specimens studied were from Princess Maha Chakri Sirindhorn Natural History Museum at Prince of Songkla University, Thailand.

Localities

The museum specimens were deposited from eight localities that is Banna (10°48′61.23″ N, 99°07′58.87″ E) in Chumphon Province; Khao Nan National Park (8°58′N, 99°99′E) in Nakhon Si Thammarat Province, Kachong (7°32′38.42″ N, 99°46′11.40″ E) in Trang Province, Ton Nga Chang (6°56′22.07″ N, 100°14′50.59 ″ E), Kho Hong Hill (7° 0′5.31″ N, 100°30.7′ E) and Klong Hoi Khong (6°85′64.38″ N, 100°36′06.68″ E) in Songkhla Province, Tarutao Island (6°36′57.64″ N, 99°39′3.84 ″ E) in Satun Province and Hala Bala Wildlife Research Station (5°47′59.3″ N, 101°49′56.9 ″E) in Narathiwat Province (Figure 7).

Measurements and definitions

Twelve characters were measured following Inger, Stuart, and Iskandar (2009). The characters are: Snout to vent length (SVL), head length (HL), head width (HW), snout to eye length (SEL), internarial distance (IND), eye diameter (ED), upper eyelid width (UEW), interorbital distance (IOD), tympanum diameter (TD), third finger disk diameter (DF3), tibia length (TL), and femur length (FL) (Figure 8).

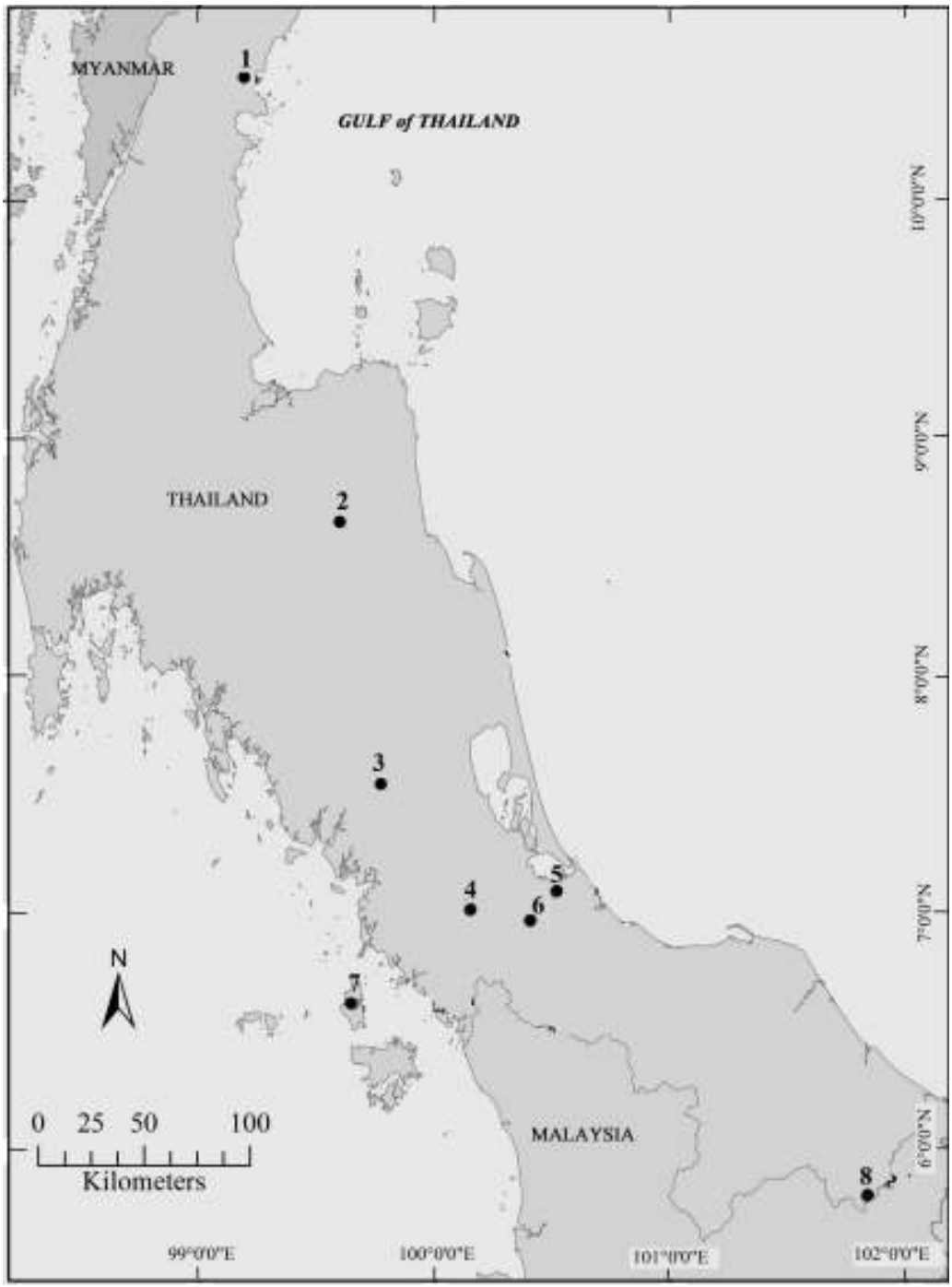

Figure 7. Localities of the museum specimen studied in current study. (1) Banna, (2) Khao Nan National Park, (3) Kachong, (4) Ton Nga Chang, (5) Kho Hong Hill, (6) Klong Hoi Khong, (7) Tarutao Island and (8) Hala Bala Wildlife Research Station.

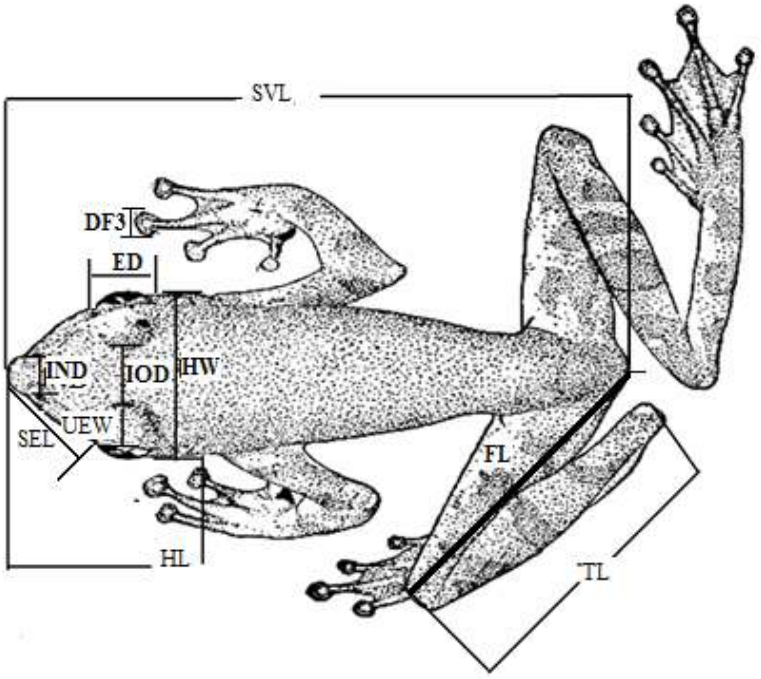

Figure 8. External measurements of the adult *Hylarana eschatia* specimen (Dorsal view) (Modified from Inger, 1954).

Data analyses

The data sets were grouped according to sex. The mean and standard deviation of the measurements were calculated. The frequency and normal distribution of the character measurements were determined and graphically represented with the histogram graph. The Sexual size dimorphism was determined with the formula of Lovich and Gibbons (1992).

The male and female characters were compared by independent sample t-test. The scatter plots of male and female characters (y-axis) against snout to vent length (SVL) (x-axis) were constructed to show the sexual dimorphism visually. The correlation of other characters with the snout to vent length is determined with the Pearson's product moment correlation (r) at 0.05 significant level (2-tailed test). Then the data is converted to ratio by dividing every characters with snout to vent length for the use in the population comparison.

To determine the between population difference analysis of variance (ANOVA) with Tukey's HSD post hoc test was run at the 2-tailed significance level of 0.05 (Ho, 2006). For the construction of the hierarchical tree diagram (dendrogram) the characters which have the significant difference in Tukey's Honestly Significant Differences (HSD) test and the ability to group the samples into the homogeneous subset were selected. The dendrogram was constructed using hierarchical cluster analysis. The distance measure used was Squared Euclidean Distance which is the most used in order to place progressively greater weight on objects that are further apart and values are standardized with the z-score. The samples were once again grouped according to the clade and compared with ANOVA. All the statistical analysis was computed in SPSS version 20 for windows (IBM Corporation, 2011).

CHAPTER IV

RESULTS

Part I. The diversity of amphibians in Tarutao Island

From the current study, six families, nine genera, and twelve species of anuran were recorded from Tarutao Island. Ten species were confirmed with the specimen but two species found at Talo Udang and Talo Wow namely *Rhacophorus* sp. and *Leptobrachium hendricksoni* were confirmed with the vocal analysis. Five species of anuran were found at Pante Malaka, six species at Talo Wow, five species at Talo Udang and four species at Ludu Waterfall (Table 1).

Table 1. Species found at the 4 localities in Tarutao Island during the present study. Species confirmed with specimen were included in the table. Number indicates the number of individuals found.

Species	Pante Malaka	Talo Wow	Talo Udang	Ludu Waterfall
Ingerophrynus parvus	-	8	7	-
Phrynoidis aspera	-	-	-	2
Kaloula baleata	3	-	-	-
Kaloula pulchra	3	-	-	-
Fejervarya cancrivora	3	-	4	-
Limnonectes blythii	-	2	3	11
Limnonectes hascheanus	-	8	-	6
Hylarana erythraea	-		5	-
Hylarana eschatia	2	5	-	4
Polypedates leucomystax	2	-	-	-

This study found that 25% of the total species found in the island is from Dicroglossidae family while Bufonidae, Microhylidae, Ranidae and Rhacophoridae makes 16.6% each and Megophryidae makes 8.33% of the total species found in Tarutao Island.

In Pante Malaka *Fejervarya cancrivora*, *Kaloula pulchra* and *Kaloula baleata* are equally found with 23% each and found less of *Hylarana eschatia* with 15%, of the whole specimen found at Pante Malaka. At Talo Wow *Limnonectes hascheanus* and *Ingerophrynus parvus* are equally found with 26% each and *Limnonectes blythii* is

least found with 6%. In Talo Udang *Ingerophrynus parvus* was found more with 33% and the least found is *Rhacophorus* sp. with 10%. In Ludu Waterfall most found species is *Limnonectes blythii* making 48% and the least found species is *Phrynoidis aspera* making only 9% (Figure 9).

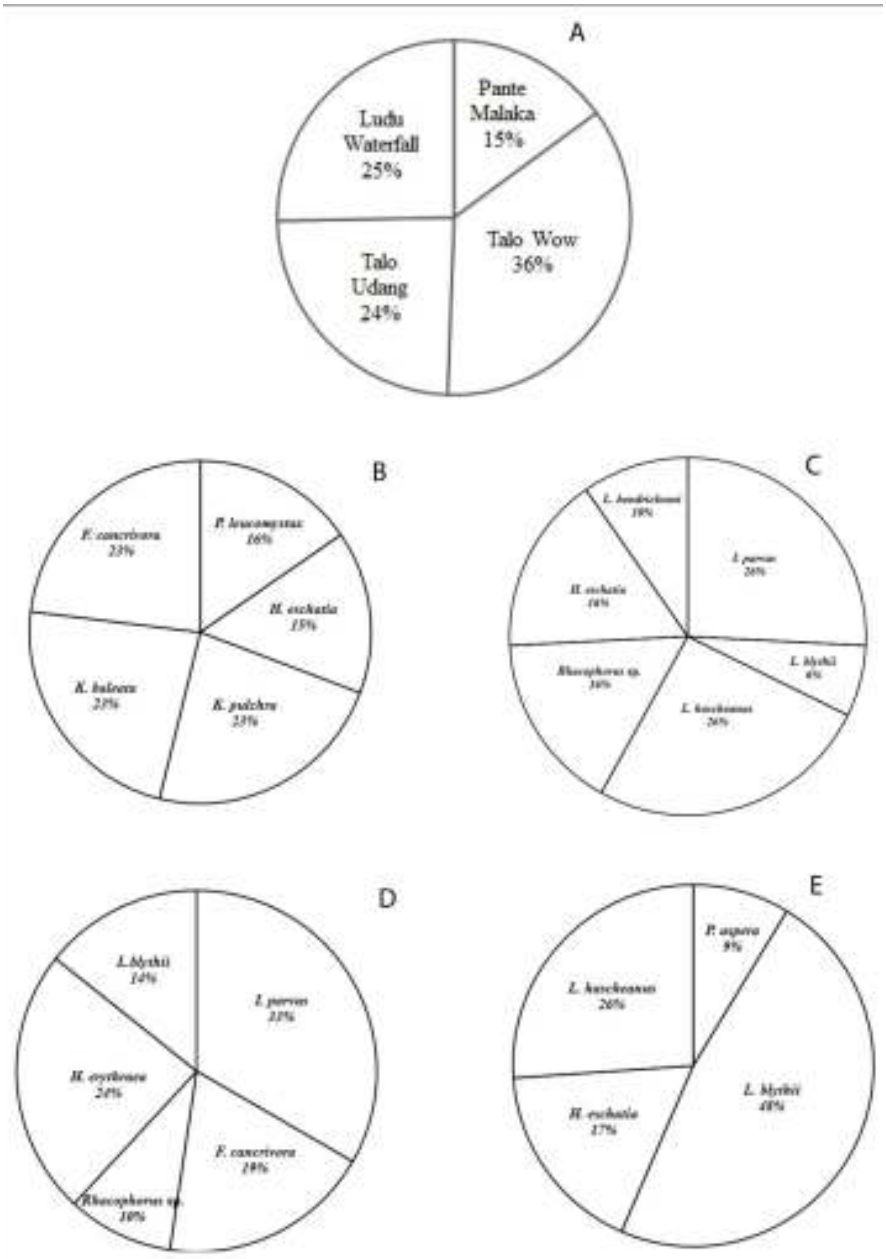

Figure 1. (A) Percentage of total species found in four study sites of Tarutao Island. Percentage abundance of each species in each sites in Tarutao Island, (B) Pante Malaka, (C) Talo Wow, (D) Talo Udang and (E) Ludu Waterfall.

Diversity index

It is evident from the Shannon-Wiener diversity index that the diversity is greater in Talo Wow with higher effective species diversity (e^H = 5.42) in comparison to all other three sites which are Pante Malaka (e^H = 4.91), Talo Udang (e^H = 4.60) and Ludu Waterfall (e^H = 3.39) respectively (Table 2).

Table 2. Shannon-Wiener diversity index and effective diversity of species.

Sites	$-\sum$Pi ln(Pi)	H'	Effective diversity (e^H)
Pante Malaka	-1.5911	1.59	4.91
Talo Wow	-1.69	1.69	5.42
Talo Udang	-1.53	1.53	4.60
Ludu Waterfall	-1.22	1.22	3.39

Species description

In total thirty two specimens from Princess Maha Chakri Sirindhorn Natural History Museum in Prince of Songkla University and seventy samples from current study were measured and studied. The external morphology of each species were studied and describe.

Family Bufonidae

This family have arciferal pectoral girdle, terminal phalanges not claw-shaped, no intercalated bones between two distal phalanges, no maxillary teeth and vomerine teeth. They are chiefly terrestrial anuran. Skin is dry with bumpy stature, this family members usually has parotid glands behind tympanum (Taylor, 1962; Chan-ard, Cota and Mekchai, 2011). In this family six genera are found in whole Thailand. In Tarutao Island only two genera that is *Ingerophrynus* and *Phrynoidis* were found. From these two genera only one species from each genus was found. The species are *Ingerophrynus parvus* and *Phrynoidis aspera.*

***Ingerophrynus parvus* (Boulenger, 1887)**

Synonym/s:

Bufo parvus Boulenger, 1887

Ingerophrynus parvus Frost *et al*. (2006)

Materials examined*: PSUZC-AMP-181, PSUZC-AMP-182, PSUZC-AMP-183, PSUZC-AMP-184, PSUZC-AM-186, PSUZC-AMP-187, PSUZC-AMP-190 and PSUZC-AMP-192*. Eight specimens were from the museum and eight samples studied were from the current study. Figure 10 and Table 3.

Description: This species is smallest toad on Tarutao Island with mean snout to vent length of 28.4 mm (n=16) and maximum snout to vent length found was 40 mm. Head is as wide as long; snout projects beyond mouth and truncate; canthus rostralis is sharp; pair of slightly curved continuous supraorbital-parietal ridge is present, supraorbital ridge is **( )**-shaped with the mean length of 4.4 ± 4.5 mm (n=16); edge of eyelid projecting slightly out; short supratympanic ridge is present; pair of oval parotid gland projects diagonally joining supratympanic ridge and has the mean length of 2.6 $\pm$ 0.5 mm (n=16); loreal region is vertical; tympanum is distinct and round; eye diameter is 1.4 times of tympanum diameter. Relatively long and slender limbs; 2nd finger is shortest and 3rd finger is longest, 3rd finger is 3.4 times longer than 2nd; two palmer tubercles present with outer larger and circular. Toes are 1/2 webbed; toe tips are similar to fingers; small subarticular tubercles are present; both inner and outer metatarsal tubercles are prominent with bigger outer; spiny rows of tubercles on inner surface of tarsus is present; tarsal fold is absent; tibiotarsal articulation reaches the front of eye; legs when folded to 90° to body heel hardly or touches. Dorsal part is covered by spiny tubercles; few dorsal tubercles are large and spotted black with pinkish tip; ventral is coarsely granular and granules unequal in size at flanks, groin and thigh is bigger; lateral warts follows parotid glands.

Live color: Light brown dorsally; one band is darker on each tibia and tarsal; ventral part black or light brown with continuous spots till tarsus; reddish pink supraorbital-parietal ridge is present; dark interorbital bar is present; on dorsal several black spots

and inverted chevrons are present; limbs have dark crossbars; ventral color is yellow to pale brown with mottling on throat and chest.

Ecological notes: This species is found in and around the ponds, primary and secondary forests, on the nature trails, freshwater streams. This species calls during the day if it showers. They call in chorus initiated by one in the beginning.

Distribution: Thailand, Malaysia, Myanmar, Indonesia, Sumatra, Java, Cambodia (Dijk and Iskandar, 2004).

Conservation status: Least Concern (IUCN, 2013).

Figure 2. (A) Dorsolateral view of a couple which are male (upper) and female (lower) *Ingerophrynus parvus* found in swamp at Talo Wow, (B) ventral view of museum submitted specimens *I. parvus* (PSUZC-AMP-182) from Tarutao Island.

Call of *Ingerophrynus parvus* (n=7)

Calls were recorded from Talo Wow at temperature of 26.1°C and humidity of 89%. Notes are highly pulsed which consists of 4-8 notes. Call duration is 0.48±0.05 seconds, and call period is 0.84±0.07 second. Start frequency is 3.66±0.05 kHz and end frequency is 1.49±0.07 kHz. Three indistinct harmonics are observed with no frequency modulation (Figure 11 and Table 4).

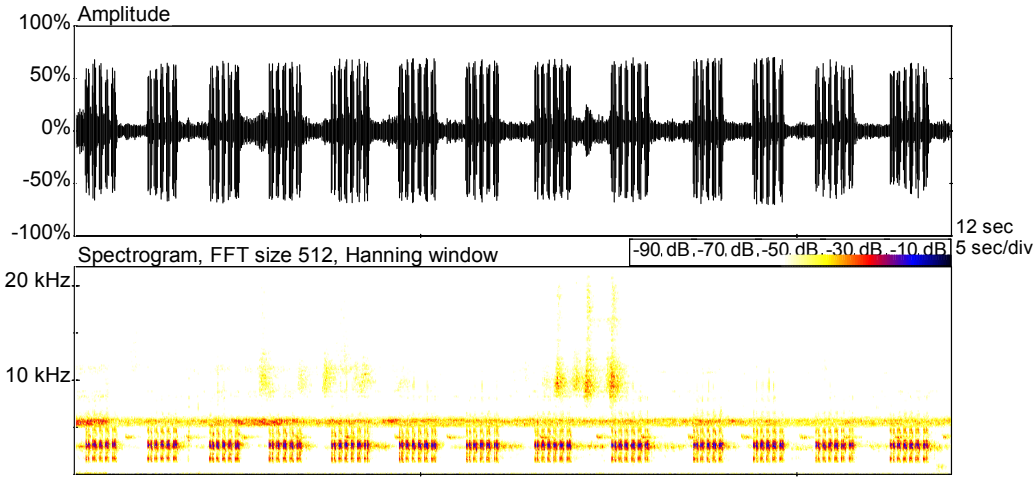

Figure 3. The oscillogram (upper) and spectrogram (lower) of male *Ingerophrynus parvus* calling at Talo Wow, Tarutao Island.

Tadpole of *Ingerophrynus parvus* (n=1)

The tadpole was caught from Talo Udang. They are in growth stage 22 which this stage is characterized by transparent fin and tail fin becomes more circular (Gosner, 1960). Total length (TL) is 18 mm; body length (BL) is 9 mm; tail length (TaL) is 9 mm; mid body length (MBL) is 4.9 mm; interorbital distance (IOD) is 2 mm. Internal organs are clearly visible from the ventral side. Mouth is ventral; emarginated from the sides; margins papillated; lower beak V-shaped; inner sides of upper and lower beak serrated. Two anterior tooth row; anterior tooth row with a gap at second anterior tooth row (A2); three posterior tooth row; 1st and 2nd posterior tooth row is equal and 1st and 2rd posterior tooth row greater than 3rd posterior tooth row (P1=P2>P3) (Figure 12). Labial tooth row formula (LTRF) is 2(2)/3.

Figure 4. Tadpole of *Ingerophrynus parvus* (growth stage 22) was caught from Talo Udang, Tarutao Island, (A) mouth part showing labial tooth row with LTRF is 2(2)/3, (B) ventral view and (C) dorsal view of the tadpole.

Phrynoidis aspera (Gravenhorst, 1829)

Synonym/s:

Bufo asper Gravenhorst, 1829

Phrynoidis asper Gravenhorst, 1829

Nectes obscurus Barbour, 1904

Phrynoidis aspera — Fei *et al*. (2005)

Materials examined. The two samples studied were from the current study. Figure 13 and Table 3.

Description: This species is largest toad on Tarutao Island with mean snout to vent length of 113±1.4 mm (n=2) and with maximum snout to vent length of 114 mm. Head width/Head length (HW/HL) is 1.1. Relatively narrow head; has distinct canthus rostralis; loreal region is vertical and nostrils is lateral; obliquely truncate snout tip; parietal crest is absent; has strong and widened supratympanic crest; supratympanic crest joins to parotid gland and upper eyelid; parotid gland is small and prominent, slightly diagonal and quite longer than wide; eye diameter to tympanum diameter ratio (ED/TD) is 2.2. Fingers are free of webbing; 3rd finger is longer than 2nd, 1.2 times longer than 2nd finger; has single well developed subarticular tubercles on the fingers; inner edge of first three fingers and outer edge of 4th finger has skin fold; two metacarpal tubercles present with outer bigger. Toes are 3/4 webbed; webs on three inner toes reaches till discs from outer side but 5th toes on inner side; 4th toes with two distal joints free of webbing; digital tips are swollen; 4th toe is longest and 1st is shortest, longest toe to shortest toe ratio (LT/ST) is 2.3; two metatarsal tubercles present with inner biggest; has strong tarsal fold surmounted by brown tubercles; tibiotarsal articulation reaches tympanum or eye; heel hardly touches when folded at 90° to body orientation. Entire skin is covered with warts of varying size; dorsum has numerous large warts; has pyramidal warts on legs; has granules on chins, breast, venter and underside of limbs with varying size but never the size of dorsum warts.
Live color: Dorsal is uniformly brown; venter brownish white with darker mottling; limbs has broad dark bands.

Ecological notes: This species is found near streams, perched on the dead woods and creepers. They calls by dipping their venter part of body under water.

Distribution: Thailand, Malaysia, Myanmar, Indonesia, Java, Sumatra, Borneo, Sulawesi and Brunei (Inger, Iskandar and van Dijk, 2004).

Conservation status: Least Concern (IUCN, 2013).

Figure 5. Dorsolateral view of *Phrynoidis aspera* from Tarutao Island.

Family Microhylidae

This family have firmisternal pectoral girdle. The maxillary teeth is absent. The phalanges terminal are T-shaped. They have plump body, short head and forelegs. The majority of species in this genus possess hidden tympana (Taylor, 1962; Chan-ard, Cota and Mekchai, 2011). In Thailand eight genera is found. In Tarutao Island only one genus and two species are found. Two species found in Tarutao Island are *Kaloula baleata* and *Kaloula pulchra*.

Kaloula baleata (Muller, 1836)

Synonym/s:

Kaloula baleata Barbour, 1909

Kaloula baleata Günther, 1859

Materials examined: *PSUZC-AMP-1044*, *PSUZC-AMP-1045* and one sample studied was from the current study. Figure 14 and Table 3.

Description: The mean snout to vent length is 26.2±4.2 mm (n=3) and maximum snout to vent length found was 31 mm. Head is wider than long; has strong ridge after naris; snout and canthus rostralis is round; tympanum is hidden; loreal region is moderately oblique; naris is on lateral tip of the snout; finger has large truncated discs; 1st finger is shortest and 3rd is longest; has two metacarpal tubercles, outer is bigger and triangular and inner is oval; Toe tips are hardly dilated; 1st toe is shortest and 4th is longest; digits has conspicuous subarticular tubercles; toes are 1/3 webbed; 5th toe distinctly longer than 2nd toe; 1st toe and 2nd toe are 1.5 free of webbing, 3rd toe

and 5th toe are with 2 free of webbing and 4th toe with 3 free of webbing; two metatarsal tubercles are present, inner is oval and compressed, outer is small and round; tibiotarsal articulation reaches shoulder when folded. Dorsal skin has pustules; ventral is smooth with minute black dots and white patches; supratympanic fold is present.

Live color: Dorsal is variegated black and has light brown patches; has light brown to grey broken patterns similar to *Kaloula pulchra*; has bright orange-yellow coloration on arms; has light yellow bands on thigh, heel and tarsus; throat is darker; belly is white patched; limbs are irregularly black patched.

Ecological notes: In Tarutao Island it was found on the tree trunk and rock, approximately 1 m high above the ground which is covered with moist leaf litters.

Distribution: Thailand, India, Indonesia, Malaysia, Philippines (Diesmos *et al*., 2004).

Conservation status: Least Concern (IUCN, 2013).

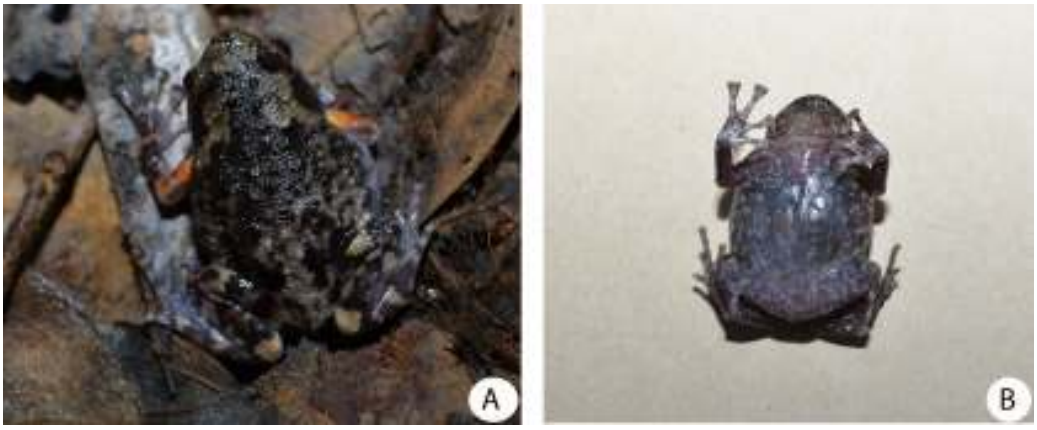

Figure 6. (A) Dorsal view of *Kaloula baleata* and (B) ventral view of *K. baleata* at Pante Malaka, Tarutao Island.

Kaloula pulchra Gray, 1831

Synonym/s:

Kaloula pulchra Barbour, 1909

Materials examined: *PSUZC-AMP-1243* and 2 samples studied were from the current study. Figure 15 and Table 3.

Description: This is stocky and large sized microhylid with the mean snout to vent length of 38.9±6.4 mm (n=3) and maximum snout to vent length found was 46 mm. Head is wider than long and head width to head length ratio (HW/HL) is 0.99; body is subtriangular; snout is broadly rounded; canthus rostralis is indistinct; loreal region is sloppy but not concave; naris is nearer to tip of snout than to eye; eye is lateral; eye to eye distance is greater than eye to naris distance; tympanum is hidden; snout is extended little beyond the mouth**.** Finger tips are expanded to truncate disc; 1st finger is shortest and 3rd finger is longest, shortest finger to longest finger ratio (SF/LF) is 0.47; finger gradually widens at tips and has no circummarginal grooves; has moderate sized subarticular tubercles; has three metacarpal tubercles, two outer metacarpal tubercles are tightly close, middle one is smallest, outer is longest; supernumerary tubercle is absent. Hind limbs are short and thick; toes are slender than fingers; toe tips are swollen; toes webbed at base; subarticular tubercles are distinct; has two distinct metatarsal tubercles; inner is shovel shaped, elevated, compressed and large; outer is rounded and small; 1st toe is shortest and 4th toe is longest, shortest toe to longest toe ratio (ST/LT) is 0.35; tibiotarsal articulation reaches to the point above arm insertion; heels do not touch when folded at 90° to body axis. Skin is finely granular or rugose above; has angulate granules on skin of chin, flank, and venter and beneath the thigh.

Live color: Ground color is dark brown; dark region narrow towards anterior ending abruptly at the line connecting eyes; has irregularly edged yellow or orange stripe from tip of snout to groin laterally; has interrupted light brown or dark band joining two legs through vent; limbs are patched with white flecks; ventral is mottled dirty yellowish brown and throat is smoky, abdomen is patched with purple-black coloration.

Ecological note: This species is found in the disturbed area. In Tarutao Island one specimen was found from the rocky secondary forest along foot path (Toe Boo cliff area).

Distribution: Thailand, Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Lao PDR, Macao, Malaysia, Myanmar, Singapore, Vietnam, Taiwan (Kuangyang *et al*., 2009).

Conservation status: Least Concern (IUCN, 2013).

Figure 7. (A) Dorsolateral view of *Kaloula pulchra* and (B) ventral view of *K. pulchra* at Pante Malaka, Tarutao Island.

Family Dicroglossidae

This family has firmisternal pectoral girdle. The maxillary and vomerine teeth are present. They does not have intercalated bones between two distal phalanges, finger tips are pointed or rounded but not swollen and without disc. Species are with or without odontoid on the lower jaw. Their tongue is not notched behind. The dorsolateral fold do not occur; the sexual dimorphism is weak. Larval stage are free living or has direct development (Taylor, 1962; Frost *et al*., 2006; Inger and Stuart, 2010; Chan-ard, Cota and Mekchai, 2011). In Thailand seven genera are found and in Tarutao Island two genera were found. The genera found in Tarutao Island are *Limnonectes* and *Fejervarya* and species found are *Limnonectes blythii*, *Limnonectes hascheanus* and *Fejervarya cancrivora*.

Limnonectes blythii (Boulenger, 1920)

Synonym/s:

Rana macrodon variety blythii Boulenger, 1920

Materials examined: *PSUZC-AMP-199*, *PSUZC-AMP-402* and *PSUZC-AMP-403*. Moreover, the twenty samples studied were from the current study. Figure 16 and Table 3.

Description: This species is large frog with mean snout to vent length of 104±23.9 mm (n=23) and maximum snout to vent length found was 151 mm. Head is longer than broad, head width to head length ratio (HW/HL) is 0.82; odontoid process is prominent; snout is rounded; tympanum is distinct, tympanum diameter is larger than eye diameter, eye diameter to tympanum diameter ratio (TD/ED) is 0.6; canthus rostralis is indistinct; loreal region is oblique and feebly concave; nostrils is near to tip of snout than to eye; eye to eye distance is greater than eye to naris distance; supratympanic fold is curve running from behind eye to above arm; transverse white lines on the mandible is present; entire chin is smoky**.** Finger tips are swollen and feebly dilated; 2nd finger is the shortest and 3rd finger is the longest, shortest finger to longest finger ratio (SF/LF) is 0.77; finger subarticular tubercles are moderately large; has three metacarpal tubercles, outer two are flat and nearly fused. Toe tips are dilated into disc, circummarginal grooves are absent; 1st toe is the shortest and 4th is the longest, shortest toe to longest toe ratio (ST/LT) is 0.47; subarticular tubercles are distinct; foots are completely webbed; outer metatarsal tubercle is absent; inner metatarsal tubercle is compressed and elongate; outer edges of first and fifth toes has skin flaps; tibiotarsal articulation reaches the nostril. Skin is smooth and minutely corrugated; dorsal surface has scattered brown tipped spots; has small pearl tipped tubercles scattered on legs; ventral skin is creamy white; yellowish to brown flank changing to creamy white ventrally; eyelids are tuberculated, two tubercles are distinctly larger than others; scapular region can be with or without ʌ-shaped or W-shaped marking.

Live color: Dorsal is reddish brown to dark brown and with or without yellow vertebral strip; flanks are mixture of creamy white and yellow color; ventral is creamy

white; limbs are with faint transverse bands; back of thigh is mottled with dark brown and yellow; back of femur has pale yellow patches.

Ecological note: This species is freshwater dwelling frog commonly found along streams or few meters away from streams in Tarutao Island.

Distribution*:* Thailand, Vietnam, Lao PDR, Malaysia, Singapore, Indonesia (van Dijk and Iskandar, 2004).

Conservation status: Near Threatened (IUCN, 2013).

Figure 8. (A) Dorsal view of *Limnonectes blythii* and (B) ventral view of *L. blythii* from Tarutao Island.

Limnonectes hascheanus (Stoliczka, 1870)

Synonym/s:

Rana limborgii Sclater, 1892

Materials examined: *PSUZC-AMP-196*, *PSUZC-AMP-197*, *PSUZC-AMP-198*, *PSUZC-AMP-201*, *PSUZC-AMP-202*, *PSUZC-AMP-203*, *PSUZC-AMP-204*, *PSUZC-AMP-205*, *PSUZC-AMP-206*, *PSUZC-AMP-207*, *PSUZC-AMP-208*, *PSUZC-AMP-209* and *PSUZC-AMP-210*. Moreover, the fourteen samples studied were from the current study. Figure 17 and Table 3.

Description: This species is small sized frog with mean snout to vent length of 21.2±1.4 mm (n=27) and maximum snout to vent length found was 24.3 mm. Their snout is rounded. The odontoid possesses do not occur on lower jaw. Distinct tympanum; head is longer than wide, head width to head length ratio (HW/HL) is 0.89; canthus rostralis is distinct; nostril is closer to snout than to eye; eye to eye distance is 2.4 times the internarial distance; occiput is slightly swollen; supratympanic fold is strong and runs from eye to shoulder; snout projects over mouth; tympanum is smaller than eye diameter, eye diameter is 3.2 times bigger than tympanum diameter. Arms and fingers are short; 2nd finger is shortest and 3rd is longest, 3rd finger is 1.4 times longer than 2nd finger; finger discs are distinct; subarticular tubercles are moderate. Toe tips are dilated to discs; inner metatarsal tubercles are distinct; lacks outer metatarsal tubercle; toes are less than 1/3 webbed; 1st toe is shortest and 4th is longest, 4th toe 3 times longer than 1st toe; toe discs are smaller than finger discs; tibiotarsal articulation reach snout tip or above eye; a pair of tubercles at occiput is present; flanks are with smooth flat granules; lacks dorsolateral fold; front and beneath the thigh is smooth; have few large black spot tubercles scattered on tibia, thigh and tarsus; venter is white; rim of mandibles has zebra lines. Skin is granular and soft.

Live color: Pale brown, dark brown to faint black; interorbital has dark crossbar; between the shoulder has dark **W**-shaped marking; lips are with dark brown vertical lines; has faded black vertebral stripes; limbs has dark crossbars.

Ecological notes*:* This species is one of the human commensals and found in disturbed area. In Tarutao Island it was found along the nature trails and along the streams sides.

Distribution: Thailand, Myanmar, Vietnam, Lao PDR, Indonesia, Malaysia (van Dijk, Stuart and Das, 2004).

Conservation status: Least Concern (IUCN, 2013).

Figure 9. (A) Dorsal view of *Limnonectes hascheanus* and (B) ventral view of *L. hascheanus* from Tarutao Island.

Fejervarya cancrivora (Gravenhorst, 1829)

Synonym/s:

Rana cancrivora Gravenhorst, 1829

Fejervarya cancrivora Iskandar, 1998

Materials examined: *PSUZC-AMP-313*, *PSUZC-AMP-395*, *PSUZC-AMP-396*, *PSUZC-AMP-397, PSUZC-AMP-398*, *PSUZC-AMP-399, PSUZC-AMP-400* and four specimen from the current study. Figure 18 and Table 3.

Description: This is medium sized salt tolerant species. The mean snout to vent length is 71.5±7.96 mm (n=11) and maximum snout to vent length found was 78.7 mm. Head is longer than broad; snout is obtusely pointed; nostrils is closer to tip of snout than to eye; canthus rostralis is indistinct; loreal region is concave and depressed; eye to eye distance is greater than eye to naris distance; tympanic ridge runs from eye arching at tympanum and ending near arm insertion; eye diameter is greater than tympanum diameter and 1.5 times greater than tympanum diameter. Digits are pointed; limbs are with alternative white and brown bars; 2nd finger is shortest and 3rd is longest, 3rd finger 1.3 times longer than 2nd finger; has distinct subarticular tubercles on digits; two metacarpal tubercles are present, outer is flat and inner is oval. Toes are 3/4 webbed; 1st toe is shortest and 4th is longest, 4th toe is 2.9 times longer than 1st toe; has oval inner metatarsal tubercle and is prominently raised, outer metatarsal tubercle is absent; tibiotarsal articulation reaches the front edge of

eye; heels touches to one another when folded at 90° to body axis. Dorsal skin has numerous glandular warts; has irregular longitudinal ridges on the back; has irregular **W**-shaped on back; skin on venter, chin and beneath the thigh is smooth; vocal sac is visible from outside.

Live color: Gray or brown dorsally with irregular dark markings; limbs are with dark crossbars; throat is smoky brown; dorsum is covered with gray-brown spots; lips are with alternating brown and white bands; has dark bar between eyes; abdomen is creamy white.

Ecological notes: This species is the only salt tolerant species found in Thailand. It is found in the stream joining sea water and mangrove forest.

Distribution: Thailand, Brunei Darussalam, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Vietnam (Zhigang *et al*., 2004).

Conservation status: Least Concern (IUCN, 2013).

Figure 10. (A) Dorsal view of *Fejervarya cancrivora* and (B) ventral view of *F. cancrivora* from Pante Malaka, Tarutao Island.

Family Ranidae

The Pectoral girdle is firmisternal in this family. The maxillary and vomerine teeth are present but no intercalated bones between two distal phalanges, the digital tips of phalanges possess discs. The tympanum is large and distinct (Taylor, 1962; Chan-ard, Cota and Mekchai, 2011). In Thailand ten genera of Ranidae are found and in Tarutao

Island only one genus and two species were found. The species found in Tarutao Island are *Hylarana erythraea* and *Hylarana eschatia*.

Hylarana erythraea (Schlegel, 1837)

Synonym/s:

Hyla erythraea Schlegel, 1837

Rana erythraea (Schlegel, 1837)

Hylarana erythraea Chen *et al*. (2005)

Hylarana erythraea Tschudi, 1838

Materials examined: *PSUZC-AMP-1063* and 3 samples were from the current study. Figure 19 and Table 3.

Description: This is medium sized ranid species. The mean snout to vent length is 41.9±1.04 mm (n=4) and maximum snout to vent length found was 43 mm. Head is longer than broad, head length is 1.3 times longer than broad; body is elongated and slender; canthus rostralis is obtuse; nostrils is close to snout tip than to eye; snout is pointed; tympanum is distinct; eye diameter is 1.2 times the tympanum diameter; loreal region is slightly concave; interorbital distance is greater than eye to naris distance. Limbs are moderately slender; digital tips are dilated into disc with circummarginal grooves. 2nd finger is shortest and 3rd finger is longest, third finger is 1.4 times longer than 2nd; 1st finger is shorter than 2nd finger; subarticular tubercles are distinct; outer finger has fringe of skin; three metacarpal tubercles is present, middle is smallest and inner is longest; has supernumerary tubercles on finger. Toe discs is smaller than finger disc; webs reaches to base of discs on 1st, 2nd and 3rd toe and on inner edge of 5th and 4th toe; two phalanges are free of web; has two metatarsal tubercles, inner is oval and outer is rounded; tibiotarsal articulation reaches nostril when folded; heels overlaps when it is folded at 90° angle to body. Skin is minutely corrugated; skin is smooth with broad dorsolateral fold from eye to rump; tympanic fold is weak; smooth venter, chin and thigh.

Live color: It is true green at the head region and fades towards the posterior end changing to faded brown; dorsolateral fold is yellow to brown; ventral surface is

creamy white; limbs yellow to brown; limbs are without crossbars; tympanum is brown.

Ecological note: This species is human commensals and was found perch on reeds in ponds around the human disturbed area.

Distribution: Thailand, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Singapore, Vietnam, Philippines (Diesmos *et al*., 2009).

Conservation status: Least Concern (IUCN, 2013).

Figure 11. (A) Dorsal view of two *Hylarana erythraea* on leaf in pond and (B) ventral view of *H. erythraea* from Talo Udang, Tarutao Island.

Hylarana eschatia (Inger, Stuart and Iskandar, 2009)

Synonym/s:

Hylarana eschatia Frost, 2009

Materials examined: *PSUZC-AMP-185*, *PSUZC-AMP-752, PSUZC-AMP-753 PSUZC-AMP-1021*, *PSUZC-AMP-1113*, *PSUZC-AMP-1114* and 4 samples studied were from the current study. Figure 20 and Table 3.

Description: This is medium sized ranid species found only in southern Thailand. The mean snout to vent length is 39.3±8.5 mm (n=10) and maximum snout to vent length found was 60 mm. Body is slender and tapering towards the vent; head is triangular; head is longer than broad and wider than trunk; snout is rounded in profile;

snout projects beyond lower jaw; eye diameter is 3/4 of its distance from snout; upper eyelid is 3/4 of inter orbital distance; interorbital wider than internarial distance and upper eyelid width; canthus rostralis is quite angular; lores are concave; tympanum is distinct and depressed; tympanum diameter is 3/4 the diameter of eye; humeral gland is absent; pineal body is visible; vomerine is oblique and lies between the chonae; distance between chonae and vomerine group length is less than intervomerine and intervomerine is greater than vomerine group; vocal sacs is invisible. Fingers are long and slender; relative finger length is 3>4>2>1; third finger length is subequal to eye to snout distance; fingers are without webbing; tips of all finger are expanded into disc with horizontal circummarginal grooves; 3rd finger disc is 1/2 the diameter of tympanum in females, in males 1/4 of tympanum diameter; disc of 1st finger is smaller than 2nd finger; subarticular tubercles are conspicuous; one supernumerary tubercle is present on each finger; one enlarged tubercles is present at the base of 1st finger despite the supernumerary tubercles; has two palmar tubercle like structure; nuptial pad in male is divided. Hind limb is slender; tips of toes are enlarged to disc with horizontal circummarginal grooves but discs are subequal to first finger disc; webbing are till disc from the outer side of first three toes; fourth toe is webbed till distal subarticular tubercles with narrow translucent skin flap connecting the disc; inner side of 2nd and 3rd toe is webbed till distal subarticular tubercles and narrows towards disc base with narrow skin flaps, inner side of fifth toe is webbed till base of the disc; has narrow dermal flaps on inner side of first and outer side of fifth toe; inner metatarsal tubercles is oval; outer metatarsal tubercles are round and conical; tibiotarsal articulation reaches the snout but never go beyond. Dorsal is spinose to smooth with low tubercle like structure; dorsolateral fold is very weak; ventral is smooth and abdomen is rugose; rictal gland is present and post rictal gland is absent; dorsolateral fold continue as supratympanic fold.

Live color: It is brown, olive or green skin; hind limb and forelimbs are distinct brown; no bands on limbs; tympanum is chest nut brown; no black spots on the back.

Ecological notes: This species is semiarboreal and found along the slow flowing streams, side pools, ephemeral pools and damp area.

Distribution: Southern Thailand (Inger, Stuart and Iskandar, 2009).

Conservation status: Not assessed for IUCN Red List and also is not in the Catalogue of life (IUCN, 2013).

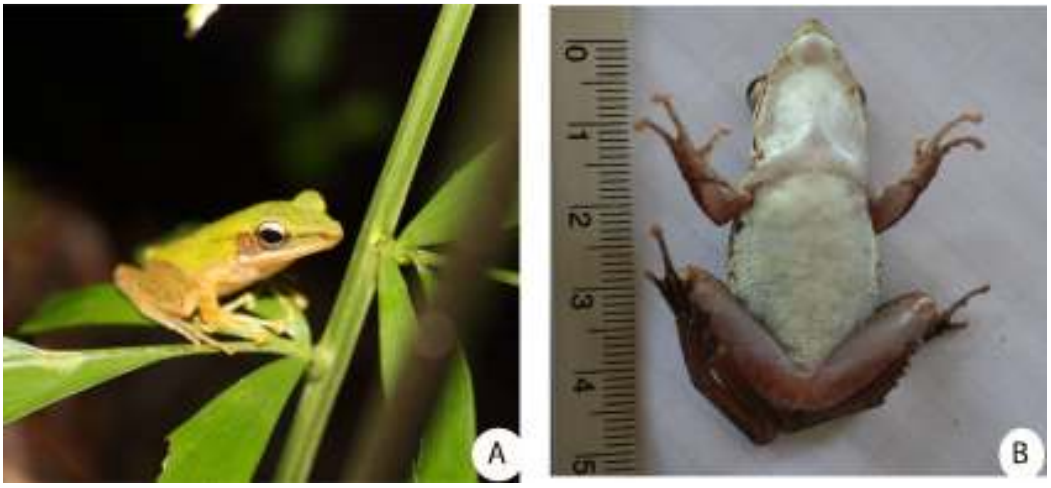

Figure 12. (A) Dorsolateral view of *Hylarana eschatia* and (B) ventral view of *H. eschatia* from Tarutao Island.

Tadpole of *Hylarana eschatia* (n=6)

Tadpoles were collected from the ephemeral ponds from Talo Wow. Tadpole growth stage is 40 (Gosner, 1960). This stage is characterized by the appearance of metatarsal tubercles and actual subarticular tubercles on the toes. Total length (TL) is 32-37 mm; body length (BL) is 11-14 mm; mid body width (MBW) is 6-7 mm; tail length (TaL) is 20-25 mm; interorbital distance (IOD) is 4-6 mm. Mouth is on ventral position; emarginated from the sides; papillae present and the papilla at the posterior base is longer; inner parts of upper and lower beaks are serrated; posterior jaw sheath is V-shaped; anterior jaw sheath is curved; marginal and submarginal papillae present; marginal papillae longer than submarginal papillae; tips of papillae with black spots; base of the posterior jaw sheath is gelatinous and anterior is dark brown; dorsal gap and inner angle of emergination is nearly at same axis. Four anterior tooth row; gap at 2nd anterior tooth row (A2), 3rd anterior tooth row (A3) and fourth anterior tooth row (A4); three posterior tooth row; gap at 1st posterior tooth row (P1) but length of 2nd posterior tooth row (P2) is greater than third posterior tooth row (P3). Labial tooth row formula (LTRF) is 4(2-4)/3(1). Figure 21.

Figure 13. Tadpole of *Hylarana eschatia* (growth stage 40) from Tarutao Island, (A) mouth part showing labial tooth row with LTRF of 4(2-4)/3(1), (B) dorsal view and (C) ventral view of the tadpole.

Family Rhacophoridae

This family has firmisternal pectoral girdle and maxillary teeth, intercalated bone is present between two distal phalanges, disc is present at digit tips and webbing are present between digits. This family is chiefly arboreal (Taylor, 1962; Chan-ard, Cota and Mekchai, 2011). In Thailand eight genera of this family is found and in Tarutao Island two genera and two species are found. The genera found in Tarutao Island are *Polypedates* and *Rhacophorus* and the species found are *Polypedates leucomystax* and *Rhacophorus* sp.

***Polypedates leucomystax* (Gravenhorst, 1829)**

Synonym/s:

Polypedates leucomystax Tschudi, 1838

Polypedates rugosus Duméril and Bibron, 1841

Polypedates teraiensis (Dubois, 1987 "1986")

Polypedates leucomystax Dutta, 1997

Materials examined: *PSUZC-AMP-184*, *PSUZC-AMP-1040* and *PSUZC-AMP-1242*. Figure 22 and Table 3.

Description: This species is medium sized tree frog with the mean snout to vent length of 46.2±9.7 mm (n=3) and maximum snout to vent length found was 57.3 mm. Head is triangular; head is longer than broad, head width to head length ratio is (HW/HL) is 0.91; loreal region is slightly concave; snout is rounded and projecting beyond lower jaw; tympanum is distinct brown with curved supratympanic fold running from eye to point above an arm insertion; diameter of eye is greater than tympanum diameter, tympanum diameter to eye diameter ratio (TD/ED) is 0.67; canthus rostralis is sharp; nostrils is laterally opened. Fingers are expanded to large rounded disc; fingers are without webbing; discs are with circummarginal grooves; 3rd finger is longer than 2nd finger, shortest finger to longest finger ratio (SF/LF) is 0.68; supernumerary tubercles are present; subarticular tubercle are distinct; three metacarpal tubercles are present, inner is flat, middle is beadlike and outer is small. Disc of toes are smaller than disc of fingers; foot is 2/3 webbed; fourth toe is one phalange free of web; 4th toe is longest and 1st toe is shortest, shortest to longest toe ratio (ST/LT) is 0.33; two metatarsal tubercles are present; tibiotarsal articulation reaches nostril. Skin is generally smooth but under microscope appears slightly granular; ventral is creamy white; breast is smooth; most of ventral and posterior surface of thigh has minute granules; no lines on the dorsum but scattered brown spot; sides of chin is vaguely granular.

Live color: This species has inconsistent coloration; background color of body is brown, yellow to brown or grey; dorsum is mottled with brown or black spots; most individuals have four narrow longitudinal dorsal lines; back of thigh has numerous

white dots; indistinct dark band is present below canthus rostralis; limbs are with darker bands.

Ecological notes: This species is arboreal and found in every forest type, farm lands, more common in human habitations and cultivated farmlands.

Distribution: Thailand, India, Bangladesh, Nepal, Bhutan, China, Singapore, Philippines, Borneo, Sumatra, Java, Sulawesi, Bali, Lombok, Natuna Islands, Anambas Islands, Sumbawa, Sumba, Flores, Timor, Japan, Papua, China (Diesmos *et al*., 2004).

Conservation status: Least Concern (IUCN, 2013).

Figure 14. (A) Dorsolateral view of *Polypedates leucomystax* and (B) ventral view of *P. leucomystax* from Pante Malaka, Tarutao Island.

Tadpole of *Polypedates leucomystax* (n=1)

The tadpole was caught from Panta Malaka. The Growth stage was identified to stage 22. This stage is characterized by transparent fin and tail fin becomes more circular (Gosner, 1960). Found in the artificial pond. Total length (TL) is 30 mm; body length (BL) is 12 mm; interorbital distance (IOD) is 5 mm; mid body width (MBW) is 6.5 mm; tail length (TaL) is 18 mm. Mouth is on the ventral side; no emergination; mouth is with papillae; inner side of both the anterior and posterior beaks are serrated. Labial tooth rows are arranged in racks; lower jaw sheath is V-shaped; anterior part of the lower jaw sheath is dark brown but the base is light brown to yellow; have 5 anterior

tooth rows; gap present at 2nd, 3rd, 4th and 5th anterior tooth rows (A2, A3, A4 and A5); three posterior tooth row; all the posterior tooth rows are equal in length (P_1=P_2=P_3). Labial tooth row formula (LTRF) is 5(2-5)/3). Figure 23.

Figure 15. Tadpole of *Polypedates leucomystax* (growth stage 22) at Pante Malaka, Tarutao Island, (A) mouth part shows labial tooth row with LTRF of 5(2-5)/3), (B) dorsal view and (C) ventral view of the tadpole.

***Rhacophorus* sp.**

This species, only the vocal were recorded from Talo Wow, former prison camp and one individual is heard calling in Talo Udang from high tree canopy near the freshwater brook.

Call of *Rhacophorus* sp. (n=6)

The calls were recored at temperature of 26.1˚C and humidity of 89 %. Call duration is 0.63±0.20 seconds. Call period 1.88±0.21 seconds. Start frequency 3.67±0.10 kHz and end frequency 2.85±0.16 kHz. Peak frequency of 3.42±0.13 kHz. Lacks frequency modulation and harmonics. Call starts with single note and keeps adding (4 notes maximum observed). Figure 24 and Table 4.

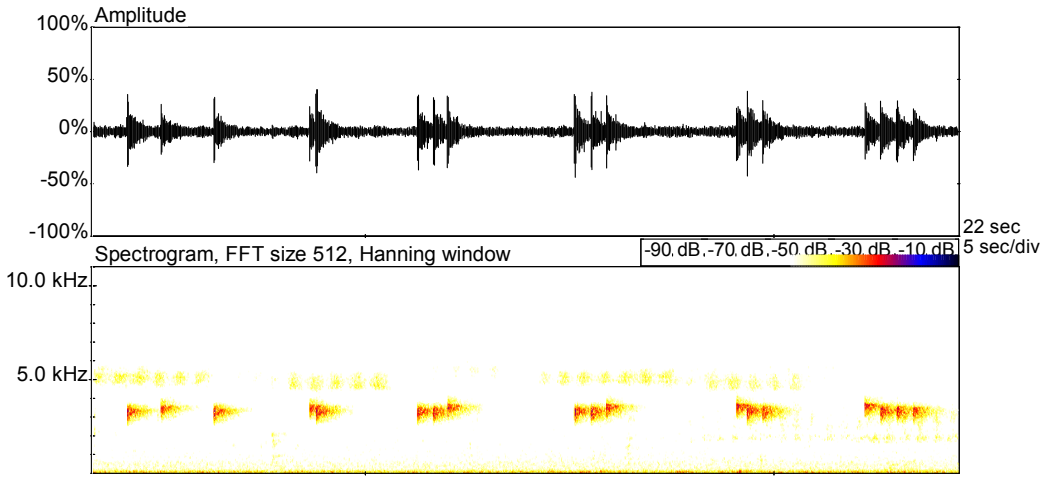

Figure 16. The oscillogram (upper) and spectrogram (lower) of *Rhacophorus* sp. recorded at Talo Wow, Tarutao Island.

Family Megophryidae

This family can be identified by the soft pointed eyelids, distinctly colored iris, short hind limbs and tubercles on torso (Chan-ard, Cota and mekchai, 2011). In Thailand six genera of the family Megophryidae are found. In Tarutao Island only one genus and one species i.e. *Leptobrachium hendricksoni* is reported with the call from this study.

Leptobrachium hendricksoni

This species only the vocals were recorded. The call was recorded at Talo Udang from the bush covered nearby high trees next to the natural trail.

Call of *Leptobrachium hendricksoni* (n=1)

Call comprise of series of 12 notes each lasting for 0.076-0.087 seconds. The call is highly pulsed. Call duration is 2.46 seconds. Start frequency 3.7 kHz and end frequency 1.5 kHz. Peak frequency of 1.88 kHz. Lacks frequency modulation and harmonics. Temperature and humidity at recording was 27.4°C and 80% respectively. Figure 25 and Table 4.

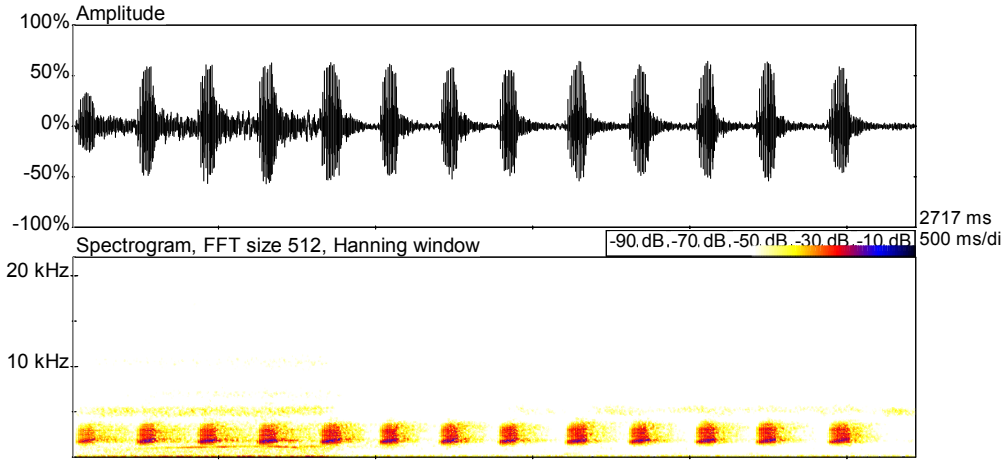

Figure 17. The oscillogram (upper) and spectrogram (lower) of *Leptobrachium hendricksoni* recorded at Talo Wow, Tarutao Island.

Table 3. Morphological measurements of eight characters of the species found in Tarutao Island (mean ± SD).

Species	N	SVL	HL	HW	TD	IND	IOD	END	TL
Ingerophrynus parvus	16	28.4±4.5	9.3±1.4	9.3±1.4	2.3±0.4	2.4±0.5	8.2±0.9	5.7±0.6	12.0±1.6
Phrynoidis aspera	2	113±1.4	36±0	40.8±2.5	5.5±2.1	8.2±0.3	30.5±0.7	21.8±1.1	52.4±3.3
Kaloula baleata	3	26.2±4.2	9.3±0.8	9.0±0	*	2.3±0.6	7.6±0.4	6±0.4	10.2±0.7
Kaloula pulchra	3	38.9±6.4	15±2.3	15.2±2.2	*	3.3±0.9	12.1±1.97	8.3±0.6	13.3±1.3
Limnonectes blythii	23	104±23.9	47.5±12.8	39.2±11.4	6.9±1.1	7.0±1.9	27.4±5.5	22±4.2	57.9±9.8
Limnonectes hascheanus	27	21.2±1.4	8.9±1.3	7.9±0.5	1.98±2.2	2.7±0.9	6.4±0.47	4.8±0.4	11.9±2.6
Fejervarya cancrivora	11	71.5±7.96	28.8±2.2	25±2.5	5.1±0.8	4.9±2.8	17.91±1.7	14.6±1.2	33.9±2.5
Hylarana erythraea	4	41.9±1.04	16.9±0.6	12.8±0.4	4.8±0.5	3.7±0.3	12.1±1	10.6±0.6	22.4±0.8
Hylarana eschatia	10	39.3±8.5	15.8±2.8	12.2±2.9	4.1±0.6	3.5±0.6	10.3±3.6	9.4±2.1	22.7±4.5
Polypedates leucomystax	3	46.2±9.7	15.8±3.6	14.4±2.7	3.7±0.3	3.7±0.46	14.1±1.96	5.5±0.5	26.8±4.9

SVL = Snout to vent length; HL = Head length; HW = Head width; TD = Tympanum diameter; IND = Internarial distance; IOD = Interorbital distance; END = Eye to naris distance; TL = Tibia length; * No exposed tympanum.

Table 4. Range of the call characters measured of 3 species: *Ingerophrynus parvus*, *Rhacophorus* sp. and *Leptobrachium hendricksoni* from Tarutao Island (mean ± SD).

Call characters	***Ingerophrynus parvus*** (n=7)	***Rhacophorus* sp.** (n=6)	***Leptobrachium hendricksoni*** (n=1)
Call duration (s)	0.42-0.54 (0.48±0.05)	0.37-0.87 (0.63±0.20)	2.46
Call period (s)	0.77-0.95 (0.84±0.07)	1.99-2.22 (1.88±0.21)	-
Start frequency (kHz)	3.6-3.7 (3.66±0.05)	3.53-3.77 (3.67±0.10)	3.7
End frequency (kHz)	1.4-1.6 (1.49±0.07)	2.63-3.03 (2.85±0.16)	1.5
Peak frequency (kHz)	3.10-3.26 (3.16±0.06)	3.30-3.65 (3.42±0.13)	1.88
Notes per call	4-8	1-4	12

Part II. Comparative study of *Hylarana eschatia*

Distribution of *Hylarana eschatia* in southern Thailand

From the study of Inger, Stuart and Iskandar (2009), *Hylarana eschatia* was recorded from five localities of four provinces in northern peninsular Thailand that is Ngao Waterfall National Park in Ranong, Kaeng Krung National Park and Khao Sok National Park in Surat Thani, Khao Luang National Park in Nakhon Si Thammarat and Khao Phanom Bencha National Park in Krabi. From the current study the distribution of *Hylarana eschatia* is extended to Chumphon Province in the north and from Trang to Narathiwat Province to the extreme south of peninsular Thailand. The new localities added are: Banna in Chumphon Province, Ban Tungka in Ranong Province, Khao Nan National Park and Yong Waterfall National Park in Nakhon Si Thammarat Province, Kachong in Trang Province, Ton Nga Chang, Kho Hong Hill, Klong Hoi Khong and Kaichon Stream in Songkhla Province, Tarutao Island in Satun Province and Hala Bala Wildlife Research Station in Narathiwat Province (Figure 26). In total sixteen localities were confirmed to find *Hylarana eschatia* in peninsular Thailand.

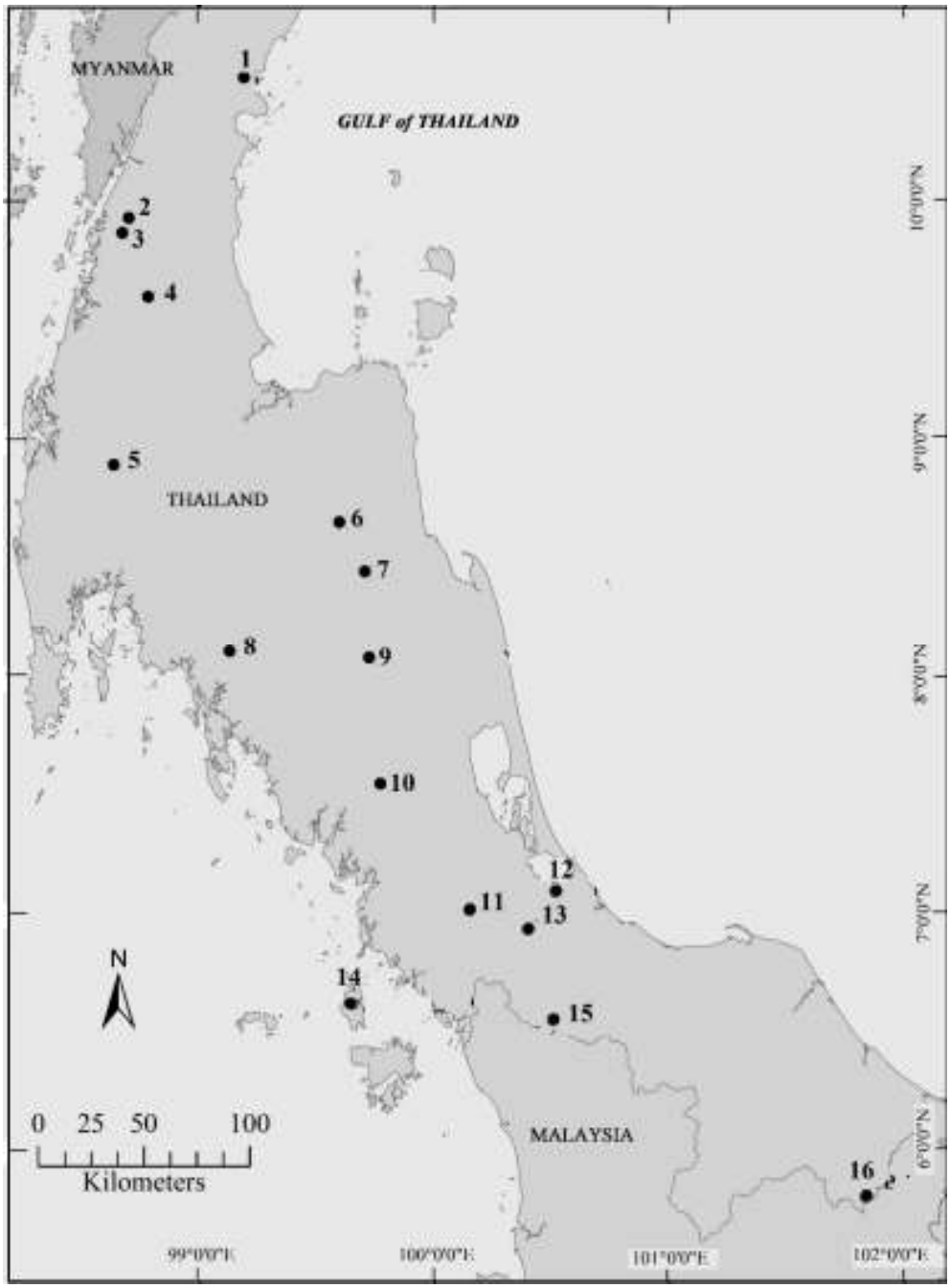

Figure 18. Distribution of *Hylarana eschatia* in peninsular Thailand, (1) Banna, (2) Ngao Waterfall National Park, (3) Ban Tungka, (4) Kaeng Krung National Park, (5) Khao Sok National Park, (6) Khao Nan National Park, (7) Khao Luang National Park, (8) Khao Phanom Bencha National Park, (9) Yong Waterfall National Park, (10) Kachong, (11) Ton Nga Chang, (12) Kho Hong Hill, (13) Klong Hoi Khong, (14) Tarutao Island, (15) Kaichon Stream and (16) Hala Bala Wildlife Research Station.

Frequency distribution of characters

The frequency distribution of 12 characters of adult female and male population of *Hylarana eschatia* from southern Thailand shows the 3 characters normal distribution in both sexes: head length (HL), femur length (FL) and tibia length (TL). The six characters: snout to vent length (SVL), head width (HW), internarial distance (IND) snout to eye length (SEL), interorbital distance (IOD) and third finger disc diameter (DF3) are symmetric only in males whereas tympanum diameter (TD) is asymmetric only in female. The eye diameter (ED) and upper eyelid width (UEW) are asymmetric in both the sexes.

Snout to vent length (SVL)

The frequency distribution of snout to vent length (SVL) for 51 females and 68 males of *Hylarana eschatia* are shown in figure 27. Females have mean snout to vent length of 44.61±3.19 mm (median=44.6, variance=10.19) ranging from 39.4 mm to 52.4 mm. Male have mean snout to vent length of 32.66±2.06 mm (median=33.2, variance=4.26) and ranges from 27 mm to 35.8 mm.

A Shapiro-Wilk's and a visual inspection of histogram, normal Q-Q plot and box plot showed that the snout to vent length are normally distributed for females with skewness of 0.362 with standard error (SE) of 0.33 and kurtosis of -0.481 with standard error (SE) of 0.656. SVL is asymmetric in males with the skewness of -0.595 (SE=0.219) and kurtosis of -0.064 with standard error (SE) of 0.574. In male SVL differs significantly from normality (Shapiro-Wilk's=0.024, $p<0.05$) but not in female (Shapiro-Wilk's=0.301, $p<0.05$). This shows that the SVL measurements in females are concentrated around the mean but not in males.

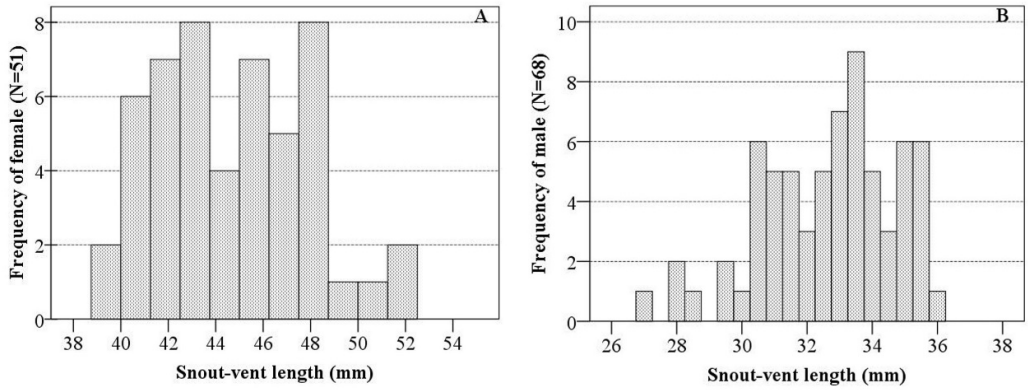

Figure 19. The frequency distribution of snout to vent length of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Head width (HW)

The frequency distribution of head width of 51 females and 68 males of *Hylarana eschatia* are shown in figure 28. The mean head width of female is 11.98±0.94 mm (median=11.9, variance=0.88) and ranges from 10.1 mm to 14.2 mm. The mean head width of male is 9.30±0.66 mm (median=9.4; variance=0.431) and ranges from 7.7 mm to 10.5 mm.

A Shapiro-Wilk's and a visual inspection of histogram, normal Q-Q plot and box plot showed that the head width is normally distributed in female with a skewness value of 0.23 (SE=0.333) and kurtosis value of -0.638 (SE=0.656) but male have asymmetric distribution with skewness value of -0.694 (SE=0.291) and kurtosis value of -0.17 (SE=0.574). The data do not differ significantly from normality (Shapiro-Wilk's=0.28, $p<0.05$) but the male head width differ significantly from the normality (Shapiro-Wilk's=0.004, $p<0.05$). This shows that the HW measurements in females are concentrated around the mean but not in males.

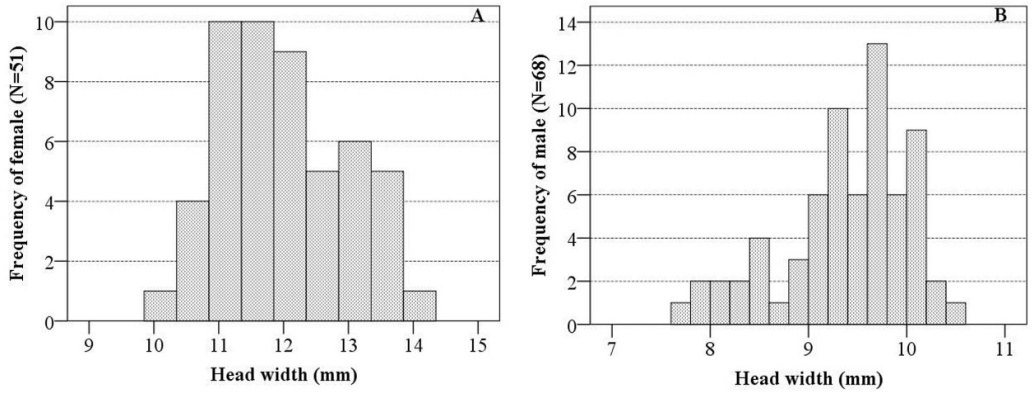

Figure 20. The frequency distribution of head width of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Head length (HL)

The frequency distribution of head length of 51 females and 68 males of *Hylarana eschatia* are shown in figure 29. The mean head width of female is 17.29±1.37 mm (median=17.4, variance=1.89) and ranges from 14.7 mm to 21 mm. Male have mean head length of 12.97±0.83 mm (median=13.5, variance=0.686) and ranges from 11 mm to 14.7 mm.

A Shapiro-Wilk's and a visual inspection of histogram, normal Q-Q plot and box plot showed that the head length are normally distributed for both the sexes with a skewness value of 0.316 (SE=0.333) and a kurtosis value of -0.247 (SE=0.656) for females, and a skewness value of -0.264 (SE=0.291) and kurtosis value of -0.308 (SE=0.574) for males. The data are little skewed but do not differ significantly from normality in both the sexes (female: Shapiro-Wilk's=0.240; male: Shapiro-Wilk's=0.439; $p<0.05$). This shows that the HL measurements are concentrated around the mean in both the sexes.

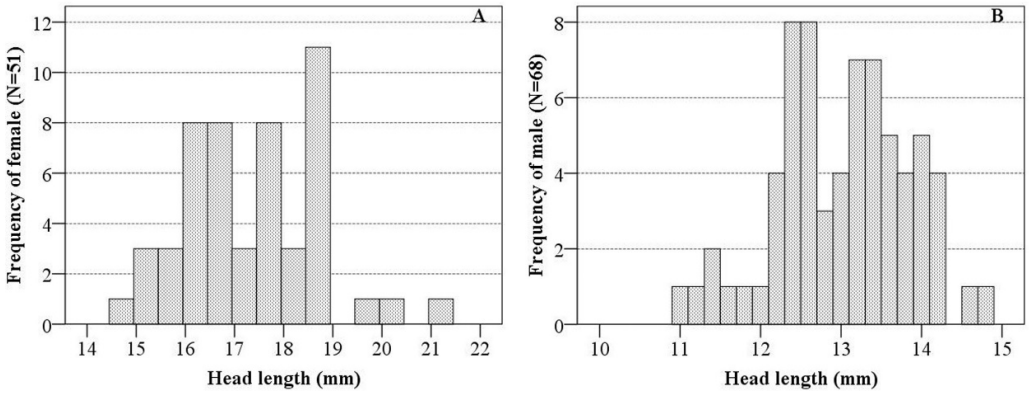

Figure 21. The frequency distribution of head length of a *Hylarana eschatia* from southern Thailand, (A) female, (B) male.

Internarial distance (IND)

The frequency distribution of internarial distance of 51 females and 68 males of *Hylarana eschatia* are shown in figure 30. The mean internarial distance in female is 3.38±0.26 mm (median=3.4, variance=0.066) and ranges from 2.8 mm to 3.9 mm. The mean internarial distance in male is 2.74±0.28 mm (median=2.8, variance=0.079) and ranges from 2 mm to 3.2 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that the internarial distance is symmetric in female with skewness value of -0.124 (SE=0.333) and kurtosis value of -0.316 (SE=0.656) and internarial distance is asymmetric in male with skewness value of -0.549 (SE=0.219) and kurtosis value of -0.426 (SE=0.574). The internarial distance is skewed but do not differ significantly from normality in female (Shapiro-Wilk's=0.062, $p<0.05$) and internarial distance differs significantly from normality in male (Shapiro-Wilk's=0.004, $p<0.05$). This indicates that the IND measurements are concentrated around the mean in females but not in males.

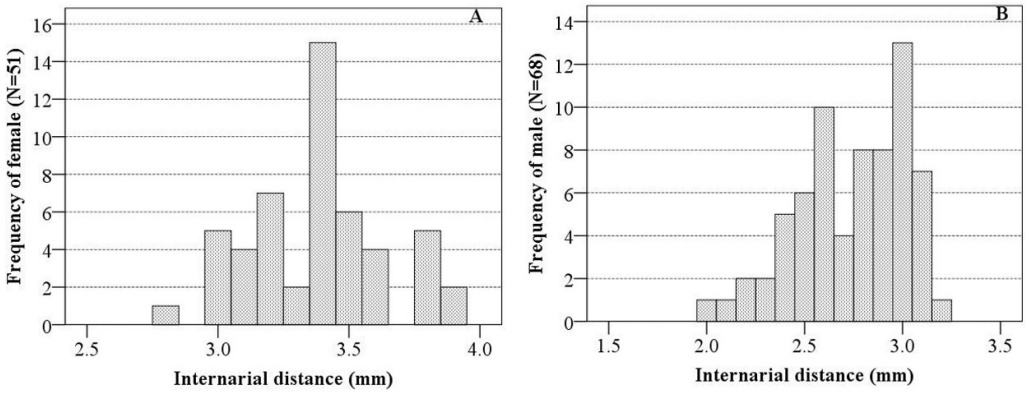

Figure 22. The frequency distribution of internarial distance of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Snout to eye length (SEL)

The frequency distribution of snout to eye length of 51 females and 68 males of *Hylarana eschatia* are shown in figure 31. The mean snout to eye length in female is 7.36±0.52 mm (median=7.4, variance=0.275) and ranges from 6.4 mm to 8.60 mm. The mean snout to eye length in male is 5.54±0.45 mm (median=5.5, variance=0.206) and ranges from 4.5 mm to 6.6 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that the upper eyelid width is symmetric in females with skewness value of 0.185 (SE=0.333) and kurtosis value of -0.680 (SE=0.656), and asymmetric in males with skewness value of 0.448 (SE=0.291) and kurtosis value of -0.150 (SE=0.574). The snout to eye length is skewed but do not differ significantly from normality in females (Shapiro-Wilk's=0.446, $p<0.05$) but differs significantly in male (Shapiro-Wilk's=0.035, $p<0.05$). This shows that the SEL value in females are concentrated around the mean but not in males.

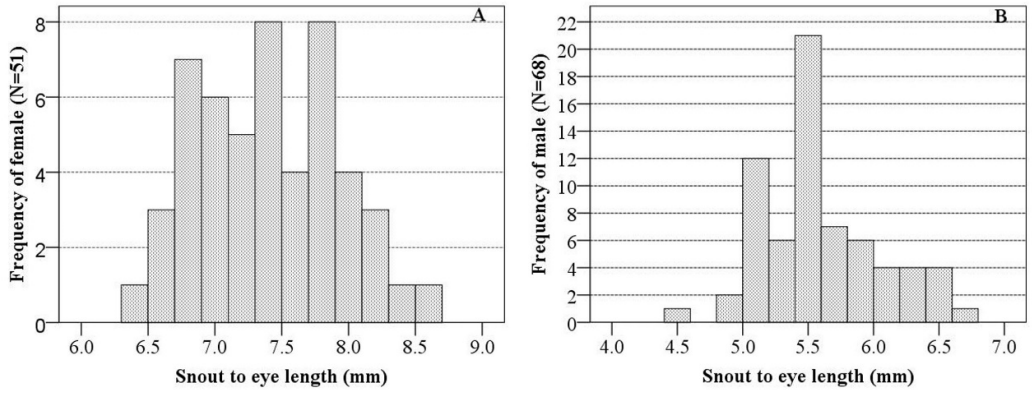

Figure 23. The frequency distribution of snout to eye length of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Eye diameter (ED)

The frequency distribution of eye diameter of 51 females and 68 males of *Hylarana eschatia* are shown in figure 32. The mean eye diameter in female is 5.51±0.57 mm (median=5.4, variance=0.331) and ranges from 4.5 mm to 7.5 mm. The mean eye diameter in male is 4.51±0.36 mm (median=4.5, variance=0.133) and ranges from 3.6 mm to 5.6 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that the eye diameter is asymmetric in both females and males with skewness value of 0.986 (SE=0.333) and kurtosis value of 1.693 (SE=0.656) in females and with skewness value of 0.451 (SE=0.291) and kurtosis value of 0.683 (SE=0.574) in males. The eye diameter differ significantly from normality in both the sexes (Female: Shapiro-Wilk's=0.007, $p<0.05$; male: Shapiro-Wilk's=0.039, $p<0.05$) which indicates that the ED measurements are scattered away from the mean in both the sexes.

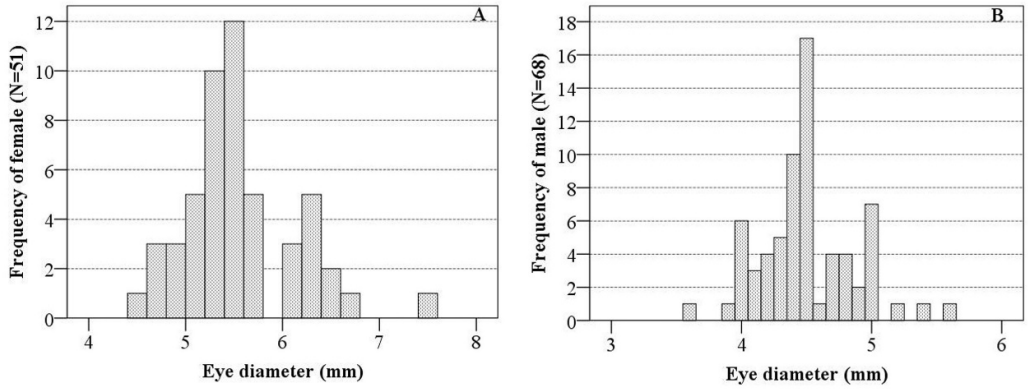

Figure 24. The frequency distribution of eye diameter of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Upper eyelid width (UEW)

The frequency distribution of upper eyelid width of 51 females and 68 males of *Hylarana eschatia* are shown in figure 33. The mean upper eyelid width in female is 3.65±0.36 mm (median=3.5, variance=0.132) and ranges from 2.9 mm to 4.4 mm. The mean upper eyelid width in male is 2.91±0.35 mm (median=3, variance=0.120) and ranges from 2.1 mm to 3.5 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that the upper eyelid width is asymmetric in both the sexes with skewness value of 0.306 (SE=0.333) and kurtosis value of -0.874 (SE=0.656) in females, and skewness value of -0.459 (SE=0.291) and kurtosis value of -0.685 (SE=0.574) in males. The upper eyelid width differs significantly from normality in both the sexes (female: Shapiro-Wilk's=0.004; male: Shapiro-Wilk's=0.005; $p<0.05$) indicating that the UEW are scattered away from the mean in both the sexes.

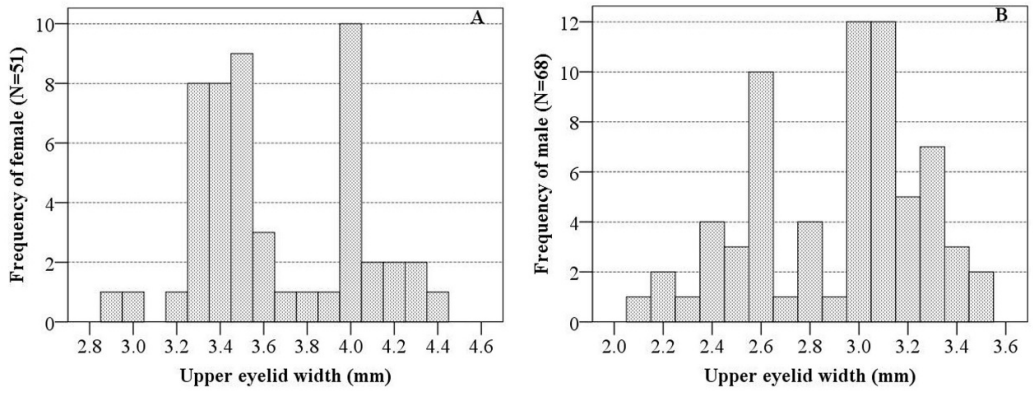

Figure 25. The frequency distribution of upper eyelid width of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Interorbital distance (IOD)

The frequency distribution of interorbital distance of 51 females and 68 males of *Hylarana eschatia* are shown in figure 34. The mean interorbital distance in female is 3.99±0.34 mm (median=4.00, variance=0.114) and ranges from 3.4 mm to 4.7 mm. The mean interorbital distance in male is 3.15±0.23 mm (median=3.20, variance=0.051) and ranges from 2.4 mm to 3.5 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that interorbital distance is symmetric in females with the skewness value of 0.082 (SE=0.333) and kurtosis value of -0.855 (SE=0.656), and asymmetric in males with skewness value of -0.892 (SE=0.291) and kurtosis value of 1.210 (SE=0.574). The interorbital distance do not differ significantly from normality in females (Shapiro-Wilk's=0.080, $p<0.05$) but differs in males (Shapiro-Wilk's=0.001, $p<0.05$) indicating that the IOD values in females are concentrated around the mean but not in males.

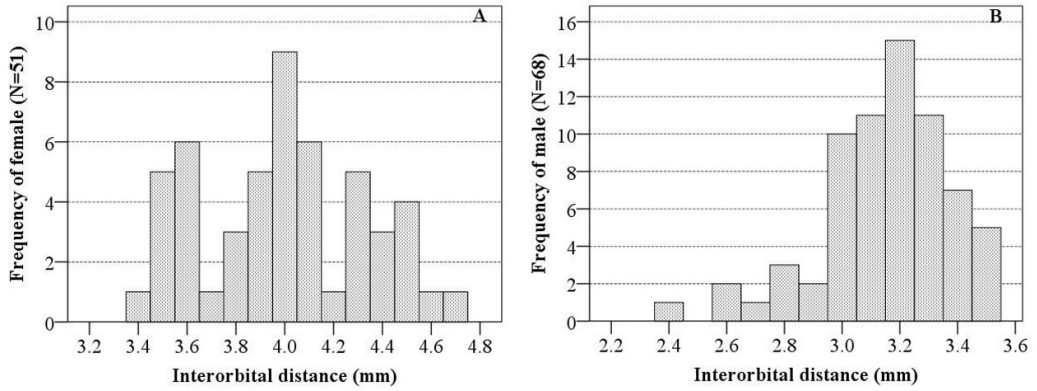

Figure 26. The frequency distribution of interorbital distance of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Tympanum diameter (TD)

The frequency distribution of tympanum diameter of 51 females and 68 males of *Hylarana eschatia* are shown in figure 35. The mean tympanum diameter of female is 3.83±0.52 mm (median=3.6, variance=0.276) and ranges from 3.1 mm to 5.4 mm. The mean tympanum diameter of male is 3.79 ± 0.46 mm (median=3.85, variance=0.215) and ranges from 2.5 mm to 5.2 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that the tympanum diameter is asymmetric in female with skewness value of 1.09 (SE=0.333) and kurtosis value of 1.07 (SE=0.656) but symmetric in male with skewness value of 0.005 (SE=0.291) and kurtosis value of 0.628 (SE=0.574). The tympanum diameter differ significantly from normality in female (Shapiro-Wilk's=0.000, $p<0.05$) and the tympanum diameter is skewed but do not differ significantly from normality in male (Shapiro-Wilk's=0.321, $p<0.05$). This indicates that the TD in males are concentrated around the mean but not in females.

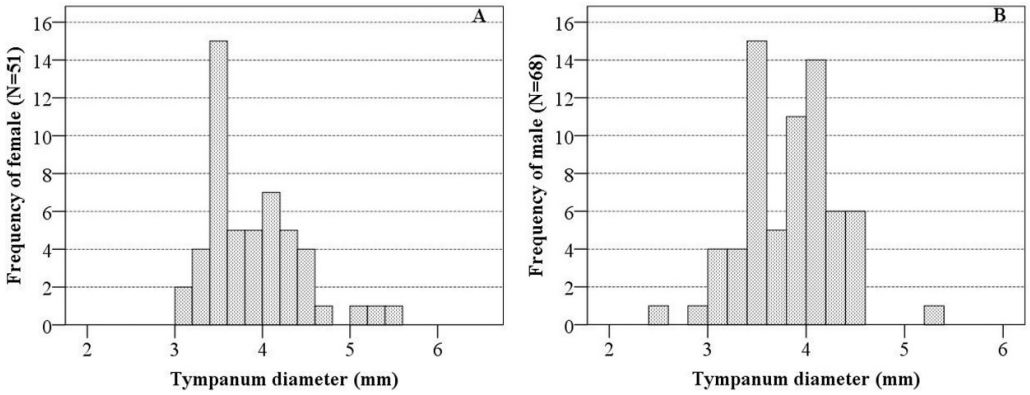

Figure 27. The frequency distribution of tympanum diameter of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Femur length (FL)

The frequency distribution of femur length of 51 females and 68 males of *Hylarana eschatia* are shown in figure 36. The mean femur length of female is 21.71± 1.9 mm (median=21.6, variance=3.622) and ranges from 18.3 mm to 27.6 mm. The mean femur length of male is 16.17 ± 1.26 mm (median=16.35, variance=1.579) and ranges from 13 mm to 19.4 mm.

A Shapiro-Wilk's and a visual inspection of histogram, Q-Q plot and box plot showed that the femur length is symmetric in both the sexes with the skewness value of 0.624 (SE=0.333) and kurtosis value of 0.669 (SE=0.656) in females, and with skewness value of -0.251 (SE=0.291) and kurtosis value of 0.304 (SE=0.574) in males. The femur length do not differ significantly from normality in both the sexes (Females: Shapiro-Wilk's=0.218, $p<0.05$; Males: Shapiro-Wilk's=0.402, $p<0.05$) indicating that the FL values are concentrated around the mean in both the sexes.

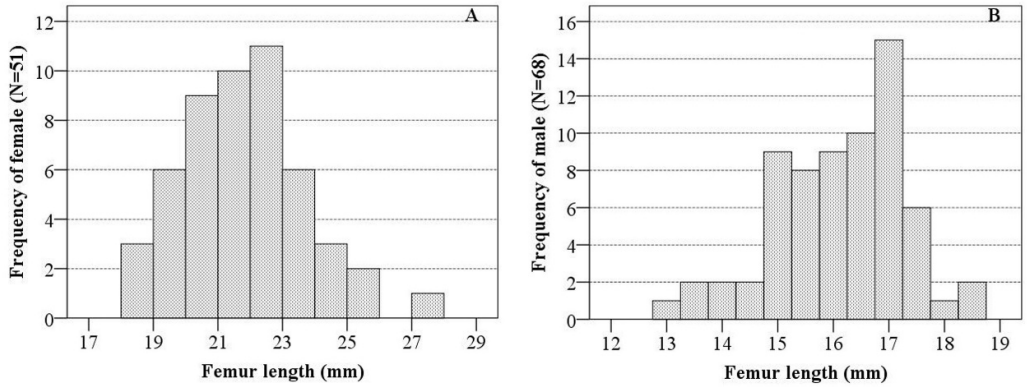

Figure 28. The frequency distribution of femur length of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Third finger disc diameter (DF3)

The frequency distribution of third finger disc of 51 females and 68 males of *Hylarana eschatia* are shown in figure 37. The mean third finger disc diameter in female is 2.15±0.33 mm (median=2.1, variance=0.113) and ranges from 1.5 mm to 2.8 mm. The mean DF3 in male is 1.48±0.25 mm (median=1.5, variance=0.065) and ranges from 1 mm to 2.2 mm.

A Shapiro-Wilk's and a visual inspection of histogram, normal Q-Q plot and box plot showed that the third finger disc is symmetric for females with a skewness value of -0.023 (SE=0.333) and kurtosis value of -0.604 (SE=0.656), but asymmetric in males with skewness value of 0.555 (SE=0.291) and kurtosis value of 0.432 (SE=0.574). The third finger disc is skewed but do not differ significantly from normality in female (Shapiro-Wilk's=0.391, $p<0.05$) but differs significantly from normality in males (Shapiro-Wilk's=0.016, $p<0.05$). This implies that the DF3 in females are concentrated around the mean but not in males.

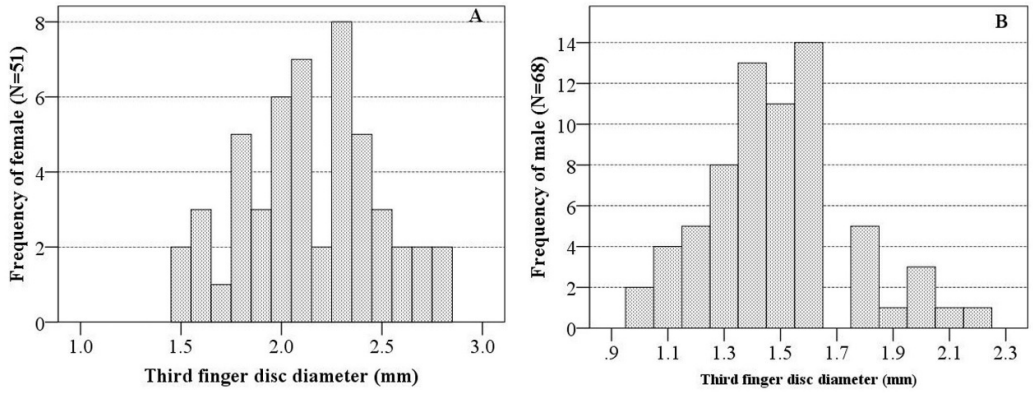

Figure 29. The frequency distribution of third finger disc of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Tibia length (TL)

The frequency distribution of tibia length for 51 females and 68 males of *Hylarana eschatia* are shown in figure 38. Females have mean tibia length of 25.45±2.22 mm (median=25.1, variance=4.19) ranging from 21 mm to 31.2 mm. Males have mean tibia length of 18.80±1.48 mm (median=19, variance=2.18) and ranges from 15.5 mm to 22.1 mm.

A Shapiro-Wilk's and a visual inspection of histogram, normal Q-Q plot and box plot showed that the snout vent length are normally distributed for both the sexes with a skewness value of 0.390 (SE=0.333) and a kurtosis value of -0.109 (SE=0.656) for females, and a skewness value of -0.279 (SE=0.291) and kurtosis value of -0.458 (SE=0.574) for males. The data are little skewed but do not differ significantly from normality in both the sexes (female: Shapiro-Wilk's=0.778; male: Shapiro-Wilk's=0.429; $p<0.05$). This indicates that all the TL measurements are concentrated around the mean in both the sexes.

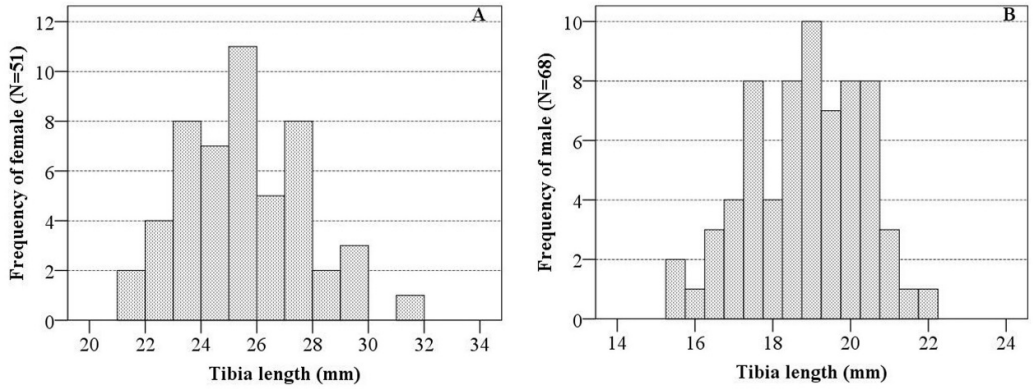

Figure 30. The frequency distribution of tibia length of a *Hylarana eschatia* from southern Thailand, (A) female and (B) male.

Sexual size dimorphism

This species, *Hylarana eschatia* show strong sexual dimorphism. The male and female can be separated into two groups with the characters measured from the adult samples. Amongst 12 characters compared between the males and females 11 characters are significantly different between the sexes except tympanum diameter (t_{117}=0.507, $p<0.05$). Table 5 shows the result of the independent sample t-test of 12 characters compared between males and females.

Eleven characters which are significantly different between adult males and females are snout to vent length, head width, head length, internarial distance, snout to eye length, eye diameter, upper eyelid width, interorbital distance, femur length, third finger disc diameter, and tibia length. Tympanum diameter is not different between males and females (Table 5).

Table 5. The morphological measurement of *Hylarana eschatia* comparison between adult male and female samples with the independent sample t-test at 0.05 significant levels.

Morphological characters	Mean measurements (mm)		*P* value
	Female	Male	
Sample size	51	68	
Snout-vent length (mm)	44.61±3.19	32.66±2.1	0.000
Head width (mm)	11.98±0.94	9.3±0.66	0.000
Head length (mm)	17.29±1.38	12.98±0.83	0.000
Internarial distance (mm)	3.38±0.26	2.74±0.28	0.000
Snout to eye length (mm)	7.36±0.52	5.4±0.45	0.000
Eye diameter (mm)	5.50±0.57	4.5±0.46	0.000
Upper eyelid width (mm)	3.65±0.36	2.91±0.35	0.000
Interorbital distance(mm)	3.99±0.34	3.15±0.23	0.000
Tympanum diameter (mm)	3.83±0.53	3.79±0.46	0.613
Femur length (mm)	21.71±1.9	16.17±1.26	0.000
Third finger disc diameter (mm)	2.15±0.34	1.49±0.26	0.00
Tibia length (mm)	25.42±2.22	18.84±1.48	0.00

To find sexual dimorphism in this species, the sexual size dimorphism index (SDI) proposed by Lovich and Gibbons (1992) was used where the ratio of female to male is subtracted by 1 if the female measurements are larger than male. Measurement used here is SVL. If the SDI value is positive the females were larger and if the SDI value is negative males are larger.

$$\text{Sexual size dimorphism Index (SDI)} = \frac{[\text{Mean adult SVL of larger sex}]}{[\text{Mean adult SVL of smaller sex}]} - 1$$

$$\text{SDI} = \frac{[\text{Mean adult SVL of female}]}{[\text{Mean adult SVL of male}]} - 1$$

$$\text{SDI} = [44.61/32.66]-1$$

$$\text{SDI} = 0.3658$$

The SDI value is 0.3658. Thus sexual size dimorphism of *Hylarana eschatia* is biased towards female with females larger than males.

To visually inspect the size dimorphism between sexes the scatter plot of the 10 significantly different characters (HW, HL, IND, SEL, ED, UEW, IOD, FL, DF3 and TL) were constructed against the SVL. All the scatter plots showed positive correlation to SVL, and also shows the explicit classification of data between male and female (figure 39-43).

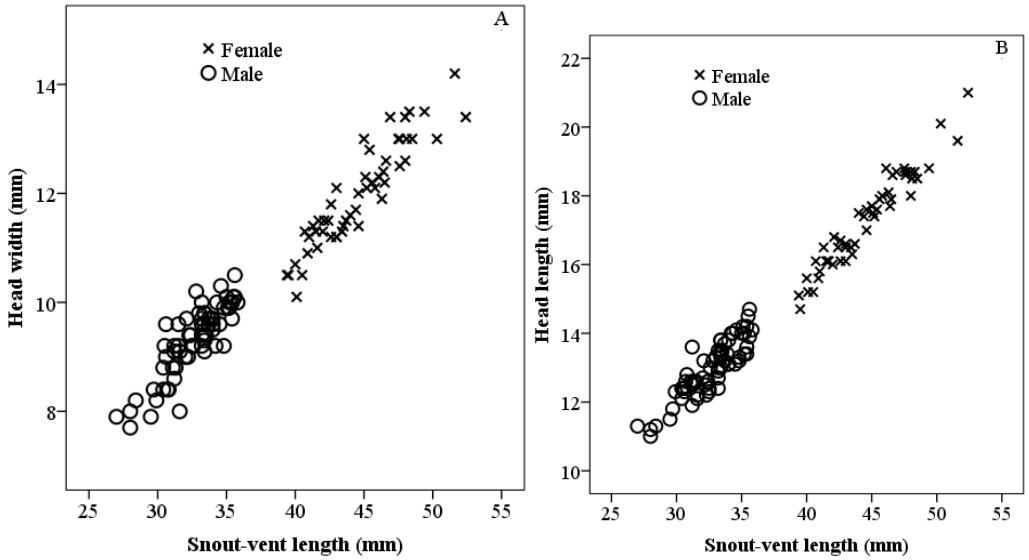

Figure 31. Scatter plots of snout to vent length against (A) head width and (B) head length of male and female *Hylarana eschatia* from southern Thailand.

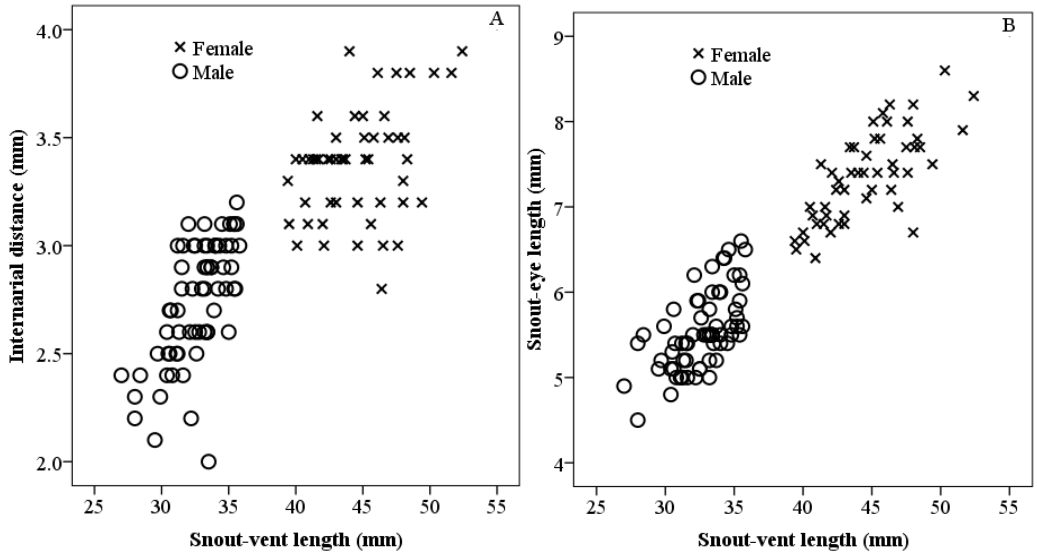

Figure 32. The scatter plots of snout to vent length against (A) internarial distance (B) snout to eye length of male and female *Hylarana eschatia* from southern Thailand.

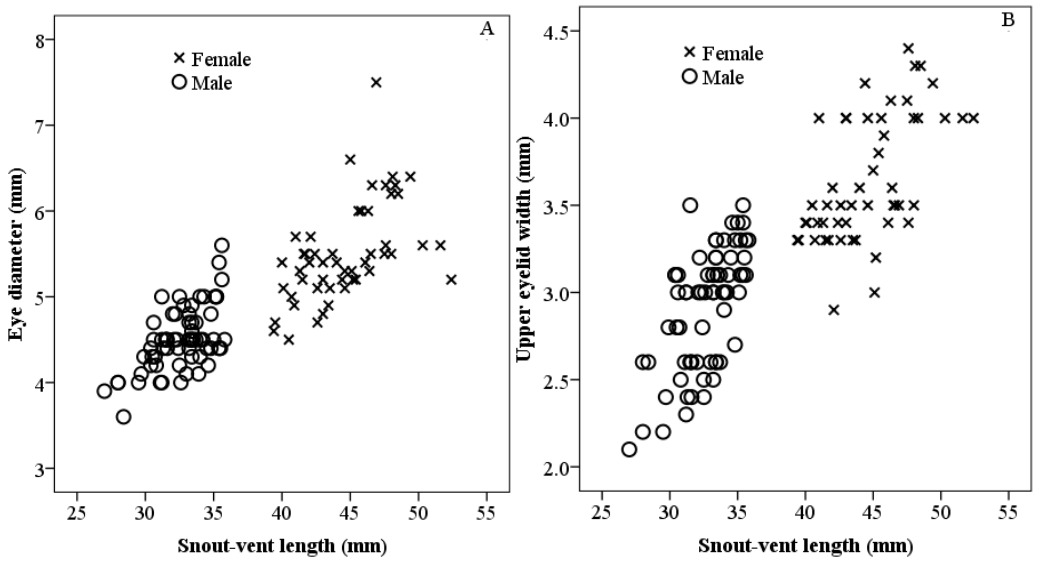

Figure 33. The scatter plots of snout to vent length against (A) eye diameter and (B) upper eyelid width of male and female *Hylarana eschatia* from southern Thailand.

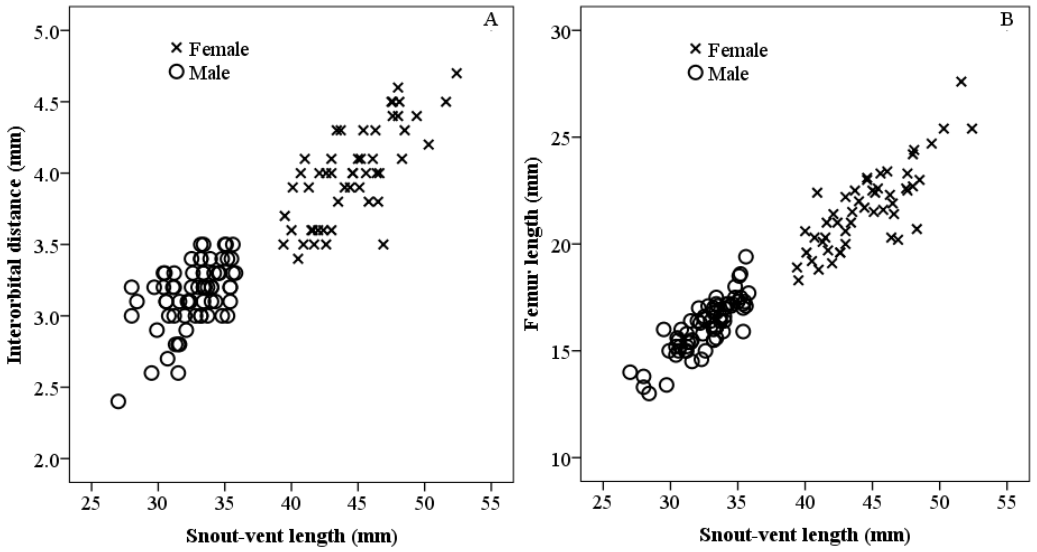

Figure 34. The scatter plots of snout to vent length against (A) interorbital distance (B) femur length of male and female *Hylarana eschatia* from southern Thailand.

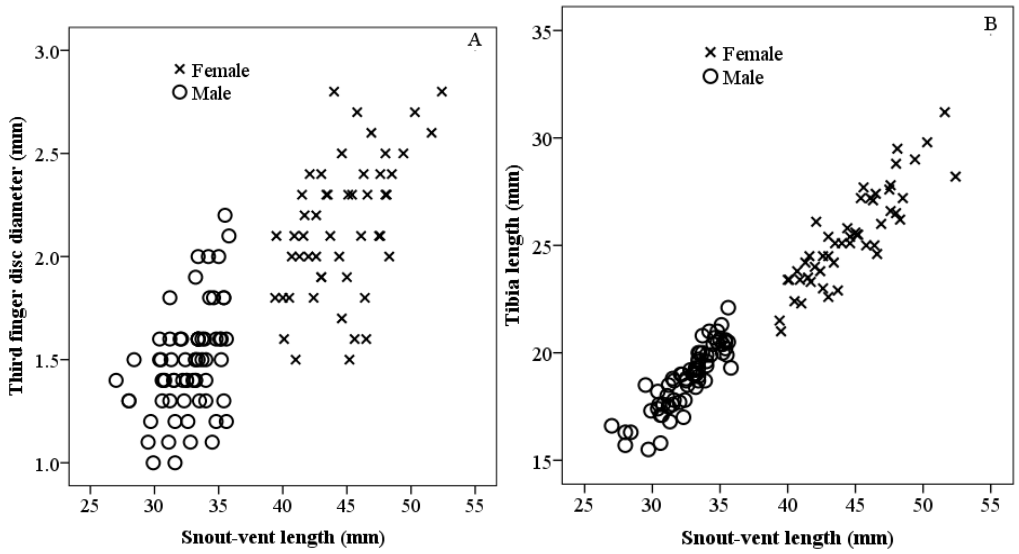

Figure 35. Scatter plots of snout to vent length against (A) third finger disc diameter and (B) tibia length of male and female *Hylarana eschatia* from southern Thailand.

Correlation of the snout to vent length with the characters

There is a significant positive correlation between the snout vent length and the other eleven characters of *Hylarana eschatia* in both the sexes. This means the other characters covary with the snout to vent length (Table 6).

Hierarchy of population classification

The 11 characters were divided with snout to vent length (SVL) to avoid the bias. Therefore, the character ratio which are significantly different in the ANOVA test (Table 7) among 8 locations including Ban Tungka (female: n=3, male: n=27) Yong Waterfall National Park (female: n=2, male: n=1), Kachong (female: n=15, male: n=11), Ton Nga Chang (female: n=0, male: n=5), Kho Hong Hill (female: n=21, male: n=7), Kaichon Stream (female: n=6, male: n=12), Tarutao Island (female: n=3, male: n=3) and Hala Bala Wildlife Research Station (female: n=1, male: n=4) were select. However, no female specimens was available from Banna and Ton Nga Chang. Only one female specimen each was available from Khao Nan, Klong Hoi Khong and Hala Bala Wildlife Research Station, and only one male spcecimen from Banna, Yong Waterfall National Park, which leads to exclusion from the comparison either in male or female data set. Along with the data of Tukey's HSD Post Hoc Test and the

characters ratio which have the capability to give clear homogeneous subsets were selected for group classification in the dendrogram from cluster analysis (For the detail of Tukey's HSD Post Hoc Test and Homogeneous subset refer appendix V and appendix VI). The Hierarchical cluster analysis with squared Euclidean distance between the group linkages of 8 locality was used to construct the cluster dendrogram for both the adult female and male *Hylarana eschatia* from southern Thailand.

Table 6. The Pearson correlation (r) of female and male *Hylarana eschatia* characters matrix with the snout to vent length at 0.05 significant level (2-tailed test).

	SVL (Female)		**SVL (Male)**	
Characters	**r**	***P* value**	**r**	***P* value**
Head width (HW)	0.924	0.000	0.863	0.000
Head length (HL)	0.967	0.000	0.886	0.000
Internarial distance (IND)	0.373	0.007	0.662	0.000
Snout to eye length (SEL)	0.737	0.000	0.623	0.000
Eye diameter (ED)	0.546	0.000	0.586	0.000
Upper eyelid width (UEW)	0.577	0.000	0.640	0.000
Interorbital distance (IOD)	0.736	0.000	0.529	0.000
Tympanum diameter (TD)	0.816	0.000	0.614	0.000
Femur length (FL)	0.814	0.000	0.837	0.000
Third finger disc diameter (DF3)	0.508	0.000	0.432	0.000
Tibia length (TL)	0.882	0.000	0.880	0.000

Table 7. The ANOVA test of adult female and male *Hylarana eschatia* characters from 8 locations: Ban Tungka, Yong Waterfall National Park, Kachong, Ton Nga Chang, Kho Hong Hill, Kaichon Stream, Tarutao Island, Hala Bala Wildlife Research Station showing P value significant at 0.05 level.

	Female		**Male**	
Characters	**Mean**	***P* value**	**Mean**	***P* value**
HW/SVL	0.2685	0.437	.2851	.000
HL/SVL	0.3876	0.009	.3975	.007
IND/SVL	0.0759	0.006	.0839	.000
SEL/SVL	0.1652	0.514	.1697	.000
ED/SVL	0.1235	0.070	.1380	.005
UEW/SVL	0.0818	0.067	.0892	.017
IOD/SVL	0.0919	0.730	.0966	.147
TD/SVL	0.0857	0.001	.1158	.000
FL/SVL	0.4867	0.112	.4951	.004
DF3/SVL	0.0484	0.000	.0455	.000
TL/SVL	0.5589	0.150	.5651	.000

The characters that fulfill above criteria are DF3/SVL and IND/SVL in both female and male populations. These two characters are used in the hierarchical cluster analysis to construct a dendrogram later.

The hierarchical cluster analysis shows the dendrogram separating the peninsular Thailand samples (clade 1) and the Tarutao Island samples (clade 2) of *Hylarana eschatia*.

In females the clade “peninsular Thailand clade” includes all the samples of *Hylarana eschatia* from peninsular Thailand and the clade “Tarutao Island clade” includes all the samples from Tarutao Island (Figure 44). The inspection of the coefficients standardized by the z-scores show the sudden shift in the coefficient value from the peninsular Thailand samples (clade 1) to Tarutao Island samples (clade 2) in female data (for coefficient values refer appendix V and VI). The mean of the measurements

were compared between the peninsular Thailand samples (clade 1) and Tarutao Island samples (clade 2) with ANOVA ($p<0.05$). The mean of DF3/SVL ($F_{1, 47}=19.523$, $p<0.05$), and IND/SVL ($F_{1, 47}=8.469$, $p<0.05$) are significantly different between the peninsular Thailand samples (clade 1) and Tarutao Island samples (clade 2) in females (Table 8).

Table 8. Significance of the mean difference of the DF3/SVL and IND/SVL between the two clades separating peninsular Thailand samples (clade 1) and Tarutao Island samples (clade 2). Mean difference significant at 0.05 levels.

	Female (N=49)			**Male (N=67)**		
Characters and clades	**Mean**	**F**	***P* value**	**Mean**	**F**	***P* value**
DF3/SVL						
Clade 1	0.0498	19.523	0.000	0.0460	6.754	0.012
Clade 2	0.0355			0.0359		
IND/SVL						
Clade 1	0.0766	8.469	0.006	0.0846	21.619	0.000
Clade 2	0.0666			0.0689		

The mean of the characters that separates the two clades are significantly different between the two clades (Table 8). The two clades can be separated at the fusion value (linkage value) of 20 in both male and female samples (Figure 44 and Figure 45).

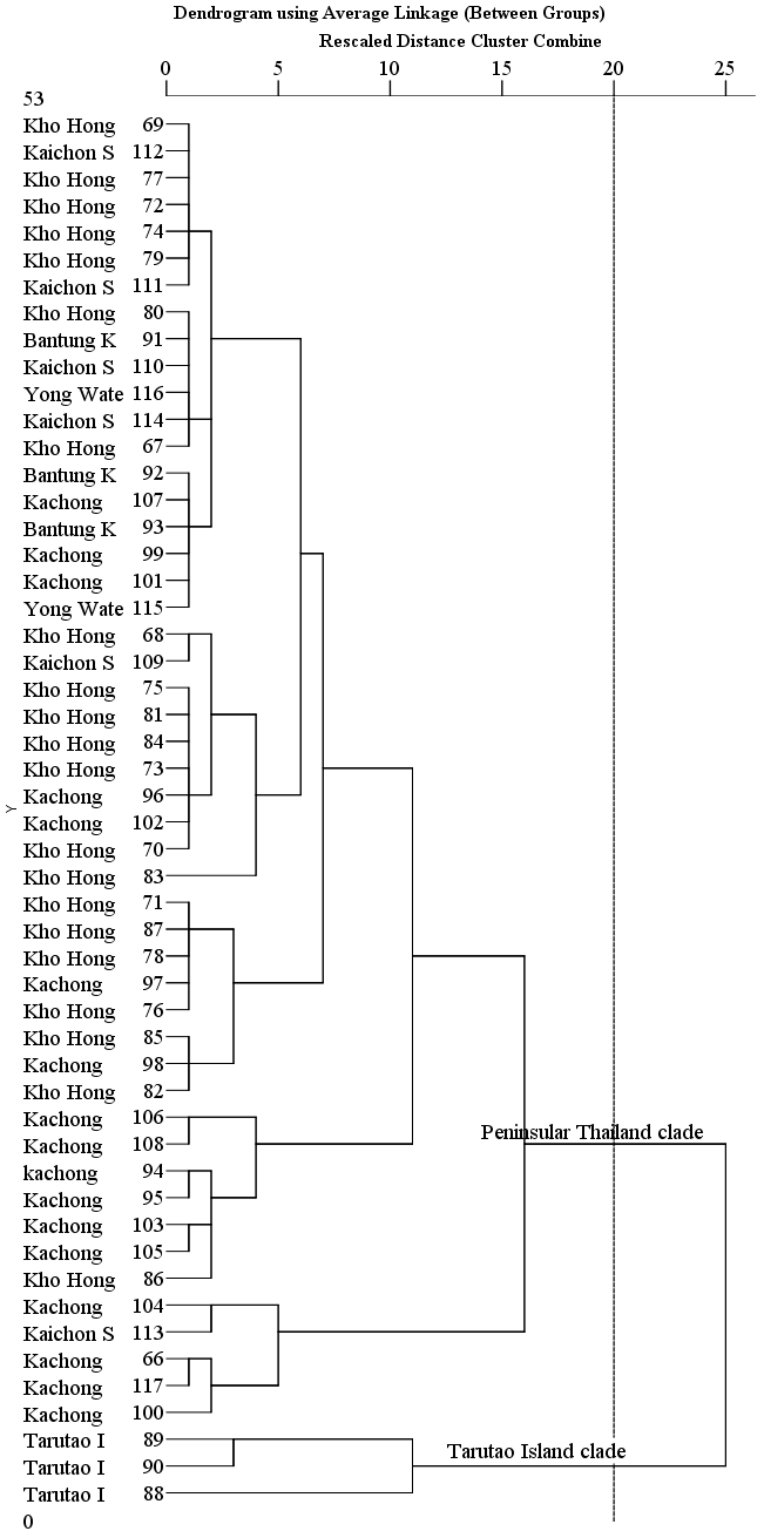

Figure 36. Dendrogram separating female samples of peninsular Thailand and Tarutao Island by DF3/SVL and IND/SVL.

In males the clade “peninsular Thailand clade” includes all the samples of *Hylarana eschatia* from peninsular Thailand and the clade “Tarutao Island clade” includes all the samples from Tarutao Island (Figure 45). The inspection of the coefficients standardized by the z-scores show the sudden shift in the coefficient value from the peninsular Thailand samples (clade 1) to Tarutao Island samples (clade 2) in male data (for coefficient values refer appendix V and VI). The mean of the measurements were compared between the peninsular Thailand samples (clade 1) and Tarutao Island samples (clade 2) with ANOVA ($p<0.05$). In males DF3/ SVL ($F_{1, 65}=6.754$, $p<0.05$) and IND/SVL ($F_{1, 65}=21.619$, $p<0.05$) are significantly different between the peninsular Thailand samples (clade 1) and Tarutao Island samples (clade 2) (Table 8).

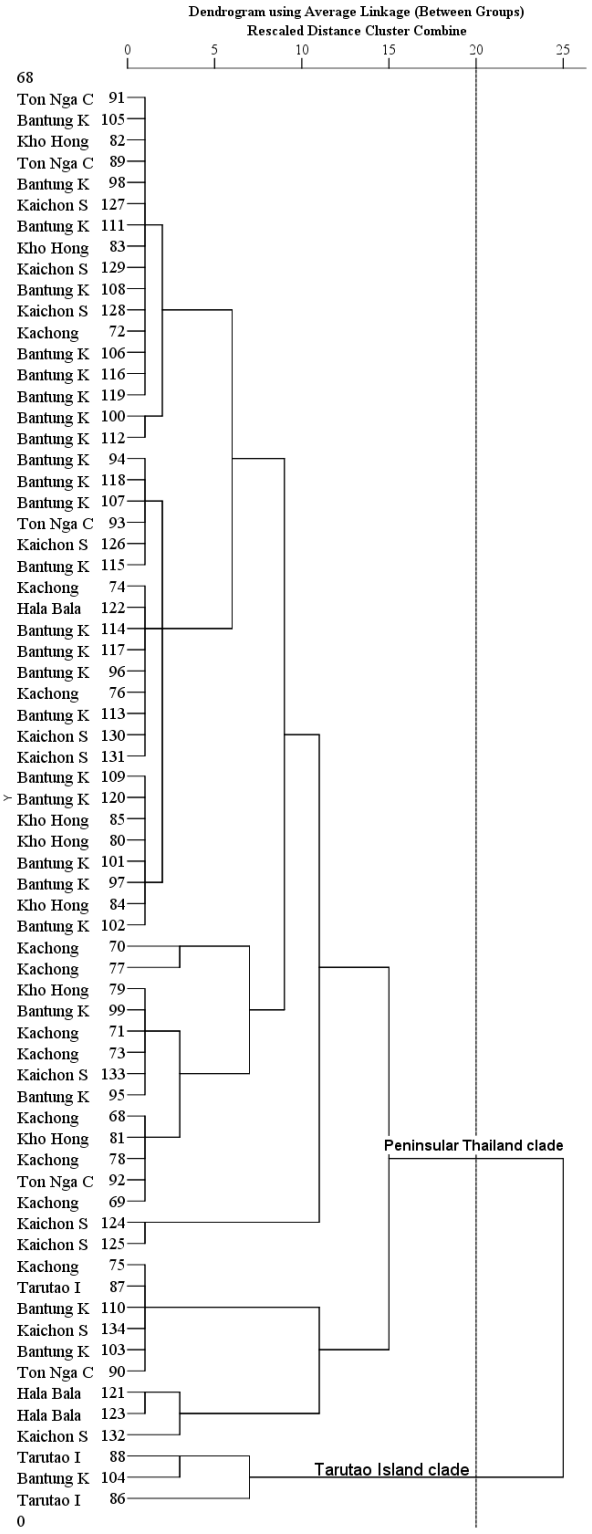

Figure 37. Dendrogram separating male samples of peninsular Thailand and Tarutao Island by DF3/SVL and IND/SVL.

Taxonomic account

The specimens from 11 localities were studied on the external morphology. The result showed a number of black spotted individual varies greatly between the populations. Banna (black spot present/total) 0/1, Ban Tungka 0/30, Khao Nan 0/1, Yong Waterfall National Park 0/3, Kachong 0/26, Ton Nga Chang 3/5, Kho Hong Hill 26/31 (3 specimens have damaged body parts), Klong Hoi Khong 0/1, Kaichon Stream 8/18, Tarutao Island 0/6 and Hala Bala 3/5. However, the dorsolateral folds are very distinct in all the live specimens but it is visible only as dark linings in preserved specimens. In addition, the specimens from 8 populations have one enlarged tubercle at the base of the first finger, foot web with dusting of melanophores, pigmented eggs and pineal body is visible.

All the male specimens have constricted or divided nuptial pad. The condition of nuptial pads also varies complicatedly between populations. Divided or undivided nuptial pad in the populations are: Banna (divided/undivided) 1/0, Ban Tungka 0/27, Yong Waterfall National Park 0/1, Kachong 6/2 (3 specimens have damaged nuptial pad), Ton Nga Chang 1/1 (3 specimens have damaged nuptial pad), Kho Hong Hill 5/2, Kaichon Stream 8/2 (1 specimen has damaged nuptial pad), Tarutao Island 2/0 (nuptial pad is not clear in 1 specimen) and Hala Bala 3/1. Another characters were describe as follow:

Ban Tungka, Banna, Khao Nan and Yong Waterfall National Park population

The specimens from Ban Tungka were collected from the pond of palm orchard (9°52ˈ45.07" N, 98°41ˈ16.26" E) nearby the type locality of *Hylarana eschatia* (9°56′N, 98°43′E; in reference of Inger, Stuart and Iskandar, 2009). Measurements from the collections are males with snout to vent length (SVL) of 30.4-35.6 mm (n=27) and females 48.5-51.6 mm (n=3) (Figure 46). The body is tapered towards the vent. Back has indistinct small round spines and the nuptial pads in males are all undivided and constricted. No black spot on the back. No crossbars on forelimbs. All fingers have narrow fold of skin from side. Third finger has one supernumerary tubercles. Dorsolateral fold distinct in live specimen but indistinct in preserved specimen. Spines on the back are prominent in males.

A male from Banna and a juvenile female from Khao Nan with SVL of 34.2 mm (n=1) and 31.5 mm (n=1) respectively, their generally characters were similar to Ban Tungka population, also without black spot on the back and divided nuptial pad in male.

The specimens from Yong Waterfall National Park, female with SVL of 45.3±2.26 mm (n=2) and male with SVL of 32.6 mm (n=1) also resemble Ban Tungka population in most of the characters and measurements however, have divided nuptial pad in males and one supernumerary tubercle on each finger. For measurements refer table 9 and table 10.

Figure 38. Representative photographs of specimens of *Hylarana eschatia* Ban Tungka (A) male and (B) female.

Kachong population

Snout to vent length (SVL) range from 44.4 mm to 49.4 mm in females (n=15) and 29.9 mm to 35.8 mm in males (n=11) (Figure 47). Black spot is absent; no crossbars on hind limbs but have indistinct lines on forelimbs; tympanum diameter is 2/3 of eye diameter; have two palmar tubercle; have one supernumerary tubercle on each finger; all fingers are with narrow skin fold; third finger disc is 1/4 the tympanum diameter; intervomerine group is subequal to vomerine length and distance between the chonae and vomerine is shorter than intervomerine. Fourth toe web reaches distal subarticular

tubercles and narrows towards disc base prominently. Nuptial pad in males is divided or undivided. For the mean measurements refer table 9 and table 10.

Figure 39. Representative photographs of specimens of *Hylarana eschatia* from Kachong (A) male and (B) female.

Ton Nga Chang population

Snout to vent length (SVL) in male ranges from 32.4 mm to 33.9 mm (n=5), no female was caught (Figure 48). Have black spot on the back; have crossbars on limbs; palmar tubercle is absent; vocal sacs are visible; tibiotarsal articulation is either equal or lower to snout; have one supernumerary tubercles on each finger; third finger disc is 1/2 the tympanum diameter; tympanum diameter is subequal to eye diameter; intervomerine group is subequal to vomerine length and distance between chonae and vomerine is shorter than intervomerine. Fourth toe web reaches distal subarticular tubercles broadly and narrows towards disc. Nuptial pad is divided or undivided. For the mean measurements refer table 10.

Figure 40. Representative photographs of specimens of *Hylarana eschatia* (male) from Ton Nga Chang.

Kho Hong Hill and Klong Hoi Khong population

Snout to vent length (SVL) ranges between 35.9-48 mm (n=21) in females and 28-32.3 mm (n=7) in males (Figure 49). Black spots are present on the back; limbs have dark crossbars; eye diameter is 2/3 of its distance from eye; third finger has two small supernumerary tubercles; third finger disc is 1/2 the diameter of tympanum; two palmar tubercles are present; tympanum diameter is subequal to eye diameter; intervomerine group is wider than vomerine group length and wider than distance from chonae. Fourth toes are webbed till distal subarticular tubercle and narrows to the base of disc. Nuptial pads are broader than other population described in here. Nuptial pad is divided or undivided. One female collected from Klong Hoi Khong is similar to Kho Hong Hill population with SVL of 37.1 mm however lack black spot on the back. For the mean measurements refer table 9 and table 10.

Figure 41. Representative photographs of specimens of *Hylarana eschatia* from Kho Hong Hill (A) male and (B) female.

Kaichon Stream population

Specimens were collected from the bank of primary forest stream at around 75 meters above sea level. SVL ranges from 41.5 mm to 47.5 mm in females (n=6) and 27 mm to 34 mm in males (n=11) (Figure 50). Black spot present on the back; has crossbars on limbs; have one supernumerary tubercles on each finger; tympanum diameter is 3/4 of eye diameter; all fingers have narrow skin fold; third finger disc is 1/2 the

tympanum diameter; no palmar tubercles; intervomerine group is subequal to vomerine length and distance between chonae and vomerine is shorter than vomerine group length. Furth toe is webbed till distal subarticular tubercles and narrows towards the disc base. Nuptial pad is divided or undivided. For the mean measurements refer table 9 and table 10.

Figure 42. Representative photographs of specimens of *Hylarana eschatia* from Kaichon Stream (A) male and (B) female.

Tarutao Island population

Snout to vent length (SVL) ranges from 45.2 mm to 46.5 mm in females (n=3) and 29.5 mm to 33.5 mm in males (n=3) (Figure 51, A). Lack black spot on the back; Lack crossbars on the limbs; two palmar tubercles present; have one supernumerary tubercle on each finger; tibiotarsal articulation reaches the snout or not but never go beyond; live specimen have very distinct brown hind limbs and fore limbs; upper eyelid is 3/4 of interorbital distance; third finger disc is 1/2 the diameter of tympanum in females, in males 1/4; tympanum diameter is 3/4 of eye diameter; intervomerine is greater than vomerine group length but less than distance between chonae and vomerine group; all fingers with narrow skin fold. Nuptial pad is divided. Fourth toe web narrows before reaching distal subarticular tubercles. For the mean measurements refer table 9 and table 10.

Hala Bala Wildlife Research Station population

Specimens were collected from the primary forest stream. Snout to vent length (SVL) is 50.3 mm (n=1) in female and ranges from 33.7 mm to 35.5 mm in males (n=4) (Figure 51, B). Black spot is present on the back; crossbars are present on limb; diameter of eye is 3/4 the distance from the eye; upper eyelid is subequal to interorbital distance; third finger disc is 1/4 the tympanum diameter in males, in females 1/2; male tympanum diameter is 3/4 the eye diameter, in female 1/2; supernumerary tubercles are absent on all fingers; internal vocal sacs is visible in males; two palmar tubercles present; all fingers are with narrow skin fold. Fourth toe broadly webbed till distal subarticular tubercles and narrows towards disc base from both sides. Nuptial pad is divided or undivided. For the mean measurements refer table 9 and table 10.

Figure 43. Representative photographs of specimens of *Hylarana eschatia* from (A) Tarutao Island (female) and (B) Hala Bala Wildlife Research Station (female).

Figure 44. Representative structures of palm, feet and the nuptial pad in *Hylarana eschatia* (A) palm with supernumerary tubercles, (B) palm without supernumerary tubercle, (C) undivided nuptial pad, (D) divided nuptial pad, (E) web ending on mainland population and (F) web ending on Tarutao Island population.

Table 9. Measurements of female *Hylarana eschatia* characters (mean ± SD). Units in millimeter (mm).

Population	N	SVL	HW	HL	IND	SEL	ED	UEW	IOD	TD	FL	DF3	TL
Ban Tungka	3	47.0	12.7	17.9	3.57	7.33	5.57	3.90	4.10	4.3	24.33	2.4	27.3
		±3.1	±0.96	±1.19	±0.40	±0.81	±0.65	±0.46	±0.53	±0.49	±2.84	±0.14	±2.2
Young Waterfall National Park	2	45.3	12.45	17.65	3.45	7.35	6.50	3.40	3.90	4.1	21.35	2.35	24.45
		±2.26	±1.34	±1.48	±0.07	±0.49	±1.41	±0.14	±0.57	±0.14	±1.63	±0.35	±2.19
Kachong	15	46.72	12.53	18.37	3.43	7.83	5.71	3.89	4.17	4.23	23.08	2.37	27.21
		±2.69	±0.73	±1.08	±0.32	±0.39	±0.44	±0.36	±0.25	±0.54	±1.49	±0.34	±1.59
Kho Hong Hill	21	41.9	11.2	16.2	3.32	6.99	5.20	3.5	3.86	3.4	20.41	1.97	23.7
		±0.54	±0.14	±0.2	±0.15	±0.38	±0.42	±0.23	±0.34	±0.04	±1.41	±0.05	±0.3
Kaichon Stream	6	44.9	12.3	17.5	3.55	7.42	5.67	3.48	3.98	3.8	21.63	2.4	25.3
		±0.9	±0.3	±0.5	±0.15	±0.41	±0.63	±0.38	±0.31	±0.2	±0.84	±0.1	±0.6
Tarutao Island	3	46.0	12.2	17.6	3.07	7.50	5.33	3.43	3.97	3.8	21.53	1.6	25.9
		±0.4	±0.08	±0.14	±0.31	±0.30	±0.15	±0.21	±0.15	±0.3	±1.09	±0.08	±0.7
Hala Bala	1	50.3	13.4	20.2	3.50	8.40	7.0	3.0	4.40	4.3	24.0	2.2	29.8

Table 10. Measurements of male *Hylarana eschatia* characters (mean ± SD). Units in millimeter (mm).

Populations	N	SVL	HW	HL	IND	SEL	ED	UEW	IOD	TD	FL	DF3	TL
Banna	1	34.2	9.4	13	2.9	6.1	4.5	3	3.4	3.7	17.1	1.6	20.5
Ban Tungka	27	33.3 ±0.3	9.6 ±0.09	13.1 ±0.1	2.80 ±0.25	5.38 ±0.27	4.57 ±0.32	2.97 ±0.30	3.21 ±0.18	3.9 ±4.5	16.70 ±1.10	1.5 ±0.03	19.4 ±0.2
Young Waterfall National Park	1	32.6	9.2	13.2	2.60	5.70	3.50	2.90	2.0	3.8	16.70	1.5	19.4
Ton Nga Chang	5	33.1 ±0.3	9.3 ±0.09	13 ±0.1	2.72 ±0.19	5.78 ±0.19	4.3 ±0.23	2.9 ±0.26	3.36 ±0.17	3.9 ±0.1	15.66 ±0.39	1.6 ±0.1	18.7 ±0.3
Kachong	11	33.54 ±1.91	9.54 ±0.72	13.65 ±0.68	2.77 ±0.21	6.19 ±0.38	4.47 ±0.22	3.15 ±0.22	3.15 ±0.24	3.93 ±0.60	16.83 ±0.88	1.77 ±0.35	19.49 ±1.28
Kho Hong Hill	7	29.7 ±2.2	8.6 ±0.3	11.9 ±0.3	2.51 ±0.23	5.39 ±0.46	4.2 ±0.38	2.69 ±0.32	3.13 ±0.08	3.5 ±0.2	14.11 ±0.99	1.4 ±0.07	16.5 ±0.3
Kaichon Stream	12	31.3 ±0.5	8.9 ±0.2	12.6 ±0.2	2.75 ±0.28	5.25 ±0.32	4.51 ±0.37	2.68 ±0.42	2.96 ±0.27	3.7 ±0.9	15.55 ±0.78	1.4 ±0.05	17.75 ±0.3
Tarutao Island	3	31.5 ±1.2	8.4 ±0.5	12.4 ±0.6	2.17 ±0.21	5.17 ±0.21	4.3 ±0.26	2.63 ±0.45	2.87 ±0.31	3.2 ±0.1	15.87 ±1.31	1.1 ±0.08	19 ±0.5
Hala Bala	4	34.8 ±0.4	9.9 ±0.1	13.9 ±0.3	3.08 ±0.13	5.83 ±0.39	5.03 ±0.57	3.18 ±0.096	3.23 ±0.096	3.9 ±0.5	16.95 ±0.24	1.3 ±0.1	20.5 ±0.08

CHAPTER V

DISCUSSION

Part I. The diversity of amphibians in Tarutao Island

The mainland Thailand is divided into six biogeographical subregions that is Northern Siam, Central Siam, Western Siam, Peninsular Siam, Eastern Siam and South-eastern Siam (Kloss, 1915). Peninsular Thailand is in the peninsular subregion. The topography of the peninsula includes hills and mountains ranges along the length with a narrow flat lowlands. It also has extensive mangrove forest along the coast and includes many islands (Rattanarithikul *et al*., 2005). Tarutao Island is located in the west coast of the peninsula, it is about 26 km away from the mainland at Satun Province. The island is dominated by the mountain ranges that runs from north to south with the highest peak reaching 708 m above sea level. Between the mountain ranges are low valleys with the perennial streams. West coast is marked by long sandy beach, mangrove swamps and thick forest hills connecting to the sea. East coast have limestone rocks, small islands and mangrove pockets (Congdon, 1982).

Distribution of the amphibians might be the sequel of the dispersal even and the complex geological events in the region (Inger and Voris, 2001; Sathiamurthy and Voris, 2006). The amphibians reached into Sundaland within last few millennia and even recently but other widely distributed species may have been able to disperse until 10,000 to 17,000 years before present (BP). The distribution of the amphibians to Tarutao Island must be contemporary and distributed to the island at least 9200 years BP (Voris, 2000). Amphibians may not have distributed by nature after 6000 BP since the sea level reached because the amphibians are extremely sensitive to saline water which acts as a barrier to the dispersal (Inger and Voris, 2001). The most probable source of the species to the Tarutao Island must be Sundaland since there was the similar exchange of the fauna between the land masses like Greater Sundas, Lesser Sundas and Malay Peninsula through the land bridges at least when the sea level is 116 m below present level (Sathiamurthy and Voris, 2006). Many of the anuran species found in Tarutao Island from the current study have the larval phase developing in the rain pools, ponds, tree holes and some are having direct

development which has a resource thereby making the species more widely distributed geographically (Inger and Voris, 2001). However, the ecological requirements of the adult anurans in determining the extent of geographical range is still not clear in Sunda shelf (Inger and Voris, 2001).

In the mainland of Thailand at least 160 species of amphibians were found and approximately 62 species are found above Isthmus of Kra, about 50 species are found below Isthmus of Kra (i.e. peninsular Thailand) and about 44 species are overlapping distribution (Chan-ard, 2003). However, in Tarutao Island only 12 species of anurans were found and it is 7.5% of species reported in Thailand. Khonsue *et al*. (2011) recorded one unidentified *Ichthyophis* species from Tarutao group of Islands but they did not specify the island hence not ruling out Gymnophiona from the island.

Andaman Islands have similar geography and climate with Thai and Indo-Burmese region (Congdon, 1982). Tarutao Island (151 km^2) has the similar habitats to the islands nearby with two types of rocks and ten types of vegetation, such as Langkawi (328 km^2) which has the mountains as high as 881 m, dipterocarp forest, and broad flat low lands around the fringe of mountains, coastal vegetation and mangrove forest (Grismer *et al*., 2006). Pulau Singa Baser Island (11.3 km^2) which is nearest to Langkawi Island, there has the similar vegetation including the habitats which are mangrove forest, sandy beach, primary and secondary forest with the topography of steep and hilly terrain (Lim *et al*., 2010). Jerek Island also has the dipterocarp forest covering much of the island area with mangrove forest, coastal and weedy vegetation (Evans, *et al*., 2011). However, species diversity in Tarutao Island (12 species) is very less when compared to the nearby small archipelagos. Langkawi Island have 23 species of amphibians (Grismer *et al*., 2006), with only 8 species sharing with Tarutao Island and Pulau Singa Besar Island where 14 species were reported (Lim *et al*., 2010), with 9 species common to Tarutao Island. Jerek Island have 8 reported species of amphibians with 4 species sharing with Tarutao Island. The similarity of Tarutao Island species is much more with the Sumatran, which has 10 species sharing of 12 species of Tarutao Island and 91 species reported from Sumatra (IUCN, 2012). It is also more similar than any archipelagos like Borneo with 7 species sharing to Tarutao from 148 species were found (Inger and Voris, 2001). According to the theories of

island biogeography like species-area (Lomolino, Riddle and Brown, 2006), Tarutao Island should have less species than Langkawi Island by smaller size but should have more species than Pulau Singa baser Island and Jerek Island by bigger size, however the amphibians species found on Tarutao Island (12 species) is less than Pulau Singa Baser Island (14 species). Therefore island biogeographic rule might be valid in the case of Tarutao Island, thus, the future study on Tarutao Island possibly have more amphibians species report.

Species diversity is determined by the pattern of rainfall vegetation characteristics or environmental structures (Rattanarithikul *et al*., 2005; Inger, 1999) however, anurans are found to be influenced mostly by habitat type similar to the case of reptiles, birds, lepidopterans (Atauri and Lucio, 2001), butterflies (Willott *et al*. 2000), ants (Watanasit, 2003) and beetles (Wananasit *et al*. 2004). For example the *Fejervarya cancrivora* was found in the brackish mangrove forest and the *Kaloula baleata* was found in the limestone mountain of Pante Malaka. The *Limnonectes blythii*, *Phrynoidis aspera* and *Hylarana eschatia* were usually found near freshwater stream with thick undisturbed jungle. However, *Polypedates leucomystax* and *Kaloula pulchra* are found in the human community and most of the anuran species seems to be habitat associated (Rickleffs and Lovette, 1999).

Advertisement calls in anuran plays vital role in taxonomic identification, it is compatible with the morphology and genetic data. It is useful in the species with the conservative morphology where the morphological variation is poor indicator (Roy and Elepfandt, 1993; Sheridan, Bickford and Su, 2010). The data from the calls recorded were also important tool for the study of distribution and ecology of frogs without interrupting their activity (Roy and Elepfandt, 1993). From Tarutao Island, calls of three species were recorded and two species i.e. *Rhacophorus* sp. and *Leptobrachium hendricksoni* were recorded only through call thereby detecting the species which are difficult to see and reach due to difficult geography. However, the calls of *Leptobrachium hendricksoni* recorded from Tarutao Island has high pitch than mainland and possible to have more than one morphologically similar species, for instance, various morphology of *Fejervarya limnocharis* were report in India and Nepal (Roy and Elepfandt, 1993). The species were usually found to call in the

evening or in the light limited canopy suggesting the darkness to be one of the stimulating factors to calling activity (Kanamadi *et al*. 1993).

Since the study of tadpole plays vital role in gaining the knowledge of amphibian diversity (Danaisawat, Pradatsundarasan and Khonsue, 2010), the tadpoles of only three species i.e. *Ingerophrynus parvus*, *Hylarana eschatia* and *Polypedates leucomystax* from Tarutao Island were collected from the current study. They shows no difference in the morphology between mainland and island tadpoles.

Most of the species found in Tarutao Island are morphologically not different from the mainland population but some are interesting to note. First, *Limnonectes blythii* in the Tarutao Island (mean SVL: 104±27.9 mm, n=23) are larger than the mainland population collected from Ranong, Nakhon Si Thammarat, Phuket, Trang, Pattalung, Songkhla, Satun and Narathiwat provinces (mean SVL=92.6±27.8 mm, n=19). The second species is *Fejervarya cancrivora*, which is widely distributed in Sundaland. According to the study of morphological variation of *Fejervarya cancrivora* by Kurniawan *et al*. (2010), the specimens from Thailand, Bangladesh and Philippines were grouped as mangrove type, the specimens from Malaysia and Indonesia were described as large type, then the specimens from Indonesia were described as Palabuhan ratu or Sulawesi type, however, no specimens were collected from nearby Islands like Tarutao. Therefore, current study suggests that *Fejervarya cancrivora* from Tarutao Island might group into mangrove type by the SVL (mean SVL: 71.5±7.96 mm, n=11) and the glandular warts, although, it still need more information.

Since Tarutao Island is least explored in herpetological diversity, this study suggests further focus on the amphibian diversity study in Tarutao Island and Tarutao National Park as a whole before we can fully understand the amphibian diversity of Tarutao Island and their relationship to other species or within species on the mainland.

Part II. Comparative study of *Hylarana eschatia*

The morphological comparative study of *Hylarana eschatia* was studied from 11 localities of peninsular Thailand and Tarutao Island. Formerly *Hylarana eschatia* was

reported from Ngao Waterfall National Park, Kaeng Krung National Park, Khao Sok National Park, Khao Luang National Park and Khao Phanom Bencha National Park (Inger, Staurt and Iskandar, 2009) but this study extended the distribution to northward until Banna, Chumphon Province. Moreover, the extreme southern distribution to Khao Nan National Park, Yong Waterfall National Park, Kachong, Ton Nga Chang, Kho Hong Hill, Klong Hoi Khong, Kaichon Stream, Tarutao Island and Hala Bala Wildlife Research Station. Pauwels *et al*. (2003) and Inger *et al*. (2009) suggested that the distribution limiting factors of *Hylarana eschatia* reach to the northern part of peninsular Thailand which below the Kra isthmus is possibly by the extent of humid condition from the south and dry season of 3-4 months during a year.

Sexual dimorphism is prominent in many anuran species, mostly 90% of the species are reported to have females' larger size than males, as in the group of Ranidae species (Shine, 1979; Monnet and Cherry, 2002; Han and Fu, 2013). The sexual dimorphism index (SDI) of *Hylarana eschatia* calculated using Lovich and Gibbons (1992) is biased towards female, 11 of the 12 charactersstudied showed the significant difference between the sexes indeed, the sexual size dimorphism (SSD) is evident in *Hylarana eschatia*.

This sexual size bias is correlated with the size of the female than does the male. It must have favored the female fecundity, clutch size and egg size which increase the advantage of reproductive strategies (Woolbright, 1983; Han and Fu, 2013). Moreover the males usually have higher mortality than females thereby males could not reach the size of female because of early death (Shine, 1979; Monnet and Cherry, 2002; Han and Fu, 2013). However, the SSD can be male biased, if male engages in physical combats during mate selection and epigamic selection (Woolbright, 1983; Lovich and Gibbons, 1992). In addition, the evolution of the small size of the males can take advantage of greater mobility and hence has greater chances to locate females. They also allows the differential use of niches without confronting the others. Another convincing factor to small size male is the energy constrains whereby energy can be utilized in territorial defense, agonistic behaviors and advertising behaviors (Shine, 1979; Woolbright, 1983).

Based on the morphology and morphometric *Hylarana eschatia* specimens from the different localities of peninsular Thailand implies occurrence of two morphologically distinct forms. The southern populations have black spots on dorsal side while the northern population lacks, however, the measurements did not separate these two populations. The hierarchal cluster analysis can group the morphometric data of the different localities of peninsular Thailand into the same clade meanwhile the samples from Tarutao Island were grouped into another clade (Figure 44 and 45). The separation of Tarutao Island samples was supported by little morphological difference where the conservative morphological evolution and the morphologically cryptic species are common pattern (Stuart, Inger and Voris, 2006), thereby showing that the Tarutao Island samples are different from the peninsular samples.

Generally the biogeographic boundary at the Isthmus of Kra were reported in many animal groups such as bird (Hughes, Round and Woodruff, 2003), mammals (Woodruff and Turner, 2009), bats (Hughes *et al*., 2011) and reptiles (Pauwels *et al*., 2003) but the detection of two forms of anurans as the *Hylarana eschatia* below Isthmus of Kra is unique. The present disclosure of the unspotted form of *Hylarana eschatia* from northern part of peninsular Thailand is biogeographically significant since it suggests the transition of spotted southern lineage, whereas another spotted members of *Rana chalconota* complex were distributed through Malaysia to Borneo, Sumatra and Java (Inger, Stuart and Iskandar, 2009). The unspotted forms were found from Kra Isthmus to Kachong, Trang Province in Peninsular Thailand including Tarutao Island, meanwhile the spotted forms are found in and below Ton Nga Chang, Songkhla Province. The intermixing zone of these two forms seems to be in Khao Bantad Mountain Range, Trang Province.

Along Thai-Malay Peninsula there are two major phytogeographical transition zone at northern part and southern part. The northern part of transition is at Isthmus of Kra, there separates the seasonal evergreen rainforest and the mixed moist deciduous forest. In this region there are 2-3 dry months in a year. The southern transition is near Thai-Malay border that lies between Pattani, Thailand and Kangar, Malaysia. This transition is also called as Kangar-Pattani line. The Kangar-Pattani line separates the perhumid rain forest and the wet seasonal evergreen dipterocarp rain forest. This

region have high humidity throughout a year (Hughes, Round and Woodruff, 2003). Whereas, between these two phytogeographical transition zones is the true intermediate vegetation and climate (Congdon, 1982). Therefore it might have influenced to the appearance of two different morphological type of *Hylarana eschatia* along the peninsula Thailand however intensive study needs to be conducted to confirm this hypothesis.

CHAPTER VI

CONCLUSION

Part I. The diversity of amphibians in Tarutao Island

The amphibian diversity of Tarutao Island was studied with the aim of inventorying species diversity in the island. Four sites, Pante Malaka, Ludu Waterfall, Talo Wow and Talo Udang were surveyed. Total of 102 field and museum specimen were studied. Specimens were measured for 13 external characters and described morphologically with the comparison to authentic literatures. From this study six families, nine genera and twelve species were recorded from Tarutao Island. Six families recorded were Bufonidae, Microhylidae, Megophryidae, Dicroglossidae, Ranidae and Rhacophoridae. Nine genera recorded were *Ingerophrynus*, *Phrynoidis*, *Kaloula*, *Limnonectes*, *Fejervarya*, *Hylarana*, *Polypedates*, *Leptobrachium* and *Rhacophorus*. Ten species were recorded with specimen and two species were recorded only with the evidence of calls. Ten species confirmed with specimens are *Ingerophrynus parvus*, *Phrynoidis aspera*, *Kaloula baleata, Kaloula pulchra*, *Limnonectes blythii*, *Limnonectes hascheanus*, *Fejervarya cancrivora*, *Hylarana erythraea, Hylarana eschatia* and *Polypedates leucomystax*. Two species recorded with calls are *Leptobrachium hendricksoni* and *Rhacophorus* sp. The specimens were well represented with the photographs from the field and museum. The largest family found in the island was Dicroglossidae and followed by Bufonidae, Microhylidae, Ranidae, Rhacophoridae and Megophryidae. The species diversity was high at Talo Wow and very low at Ludu Waterfall with Pante Malaka and Talo Udang with intermediate diversity.

The calls of *Ingerophrynus parvus* (n=7), *Leptobrachium hendricksoni* (n=1) and *Rhacophorus* sp. (n=6) were recorded and analyzed and found useful for the detection of the species which are difficult to spot and catch. Eight call characters (call duration, call period, start frequency, end frequency, peak frequency, note per call, harmonics and frequency modulations) were measured for each call and found that each species has different spectral and temporal value range making valuable for biology and

ecology. The measurements were tabulated (Table 4) and temporal and spectral diagrams were well represented in the figures.

The tadpoles of *Ingerophrynus parvus*, *Hylarana eschatia* and *Polypedates leucomystax* were studied. Tadpoles were measured for five external characters (BL, MBL, TL, TaL and IOD) and two mouth part structures (upper tooth row and lower tooth row). Labial tooth row formulae (LTRF) for the tadpoles were determined which is useful for the diversity study when the adult specimen are not available. *Ingerophrynus parvus* has the LTRF of 2(2)/3, *Hylarana eschatia* has LTRF of 4(2-4)/3(1) and *Polypedates leucomystax* has the LTRF of 5(2-5)/3) which are unique for each species. The photographs of body and mouth parts were well represented in the figures.

Potential subject of amphibian study in Thailand.

1. *Limnonectes blythii* between the mainland Thailand and Tarutao Island seems to have size difference and this will make suitable subject for island biogeography.
2. *Fejervarya cancrivora* as stated in the discussion section will make good subject of future population study since no one has collected specimen and studied from Tarutao Island.
3. *Hylarana eschatia* is interesting species and more morphological and genetic data is required to fully understand its status in Thailand.

Part II. Comparative study of *Hylarana eschatia*

Comparative study of *Hylarana eschatia* from eleven localities of field and museum specimen were studied. Twelve characters were measured from adult specimens. The measurements were compared for sexual size dimorphism between males and females by t-test. All the characters measured are bigger in females than males and are significantly different except tympanum diameter but mean measurements showed that tympanum diameter is also larger in females. The sexual dimorphism index (SDI) was calculated and found that females are larger than males with SDI of 0.3658. Scatter plots of ten characters (y-axis) with SVL (x-axis) were constructed and t-test

analysis found that females and males can be separated distinctly with all the ten characters. Thereby indicating that *H. eschatia* has sexual dimorphism biased towards females. Therefore female and male data were treated separately for all statistical comparisons.

The characters were tested for correlation to SVL and found that all the characters are positively correlated with significant Pearson's product moment correlation in both the female and male data. All the characters were converted to ratio by dividing characters with SVL. The characters ratio among the populations were compared by ANOVA with Tukey's Post Hoc Test and homogeneous subset, the result shows that Tarutao Island samples and mainland samples can be separated with only two characters (i.e. DF3/SVL and IND/SVL). The constructed dendrogram separated mainland and Tarutao Island samples into different crade, nevertheless, the mainland samples do not show any pattern of division.

The morphology of all samples were studied and two forms in peninsular mainland were recorded by the dorsal spot. The samples from northern part of peninsular Thailand which lacks spots on the back meanwhile the samples from southern part were spotted. The spotted and unspotted samples were proposed to have transition zone in Khao Bantad mountain range that runs from Nakhon Si Thammarat to Songkhla Province which experience the combination of vegetation and climate from north and south of peninsula. The Tarutao Island samples were also different from mainland samples in having small males, fourth toe web narrowing before distal subarticular tubercles, distinct brown hind limbs and forelimbs, only divided nuptial pads in males and in lacking black spot on the back. Thus there are at least three forms of *Hylarana eschatia* in Thailand according to the morphological data. However, extensive study of *Hylarana eschatia* with focus on genetic is needed in Thailand to resolve this complexity and know its taxonomic status within Thailand.

Recommendations for future study:

1. More collection of specimen is required to get the concrete idea of different forms and the distribution of different forms within peninsular Thailand and Tarutao Island.

2. Genetic study is required since morphology alone is not a sufficient tool for the morphologically conserved species.

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Appendix I

Table 1. Recorded anuran species of Thailand with supporting references and conservation status.

Order: Anura Fischer von Waldheim, 1813

Scientific name	Status	References
Family Bufonidae		
Ansonia inthanon Matsui, Nabhitabhata and Panha, 1998	DD	Matsui, Nabhitabhata and Panha, 1998; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Ansonia kraensis Matsui, Khonsue and Nabhitabhata, 2005	DD	Matsui, Khonsue and Nabhitabhata, 2005; Chan-ard *et al*., 2011
Ansonia malayana Inger, 1960	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Ansonia penangensis Stoliczka, 1870	NE	Taylor and Elbel, 1958; Taylor,1962; Khonsue and Thirakhupt, 2001;
Ansonia siamensis Kiew, 1984	VU	Kiew, 1984; Nabhitabhata *et al*., 2000;Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Duttaphrynus melanostictus (Schneider, 1799)	LC	Smith and Kloss, 1915; Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962;Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Ingerophrynus parvus (Boulenger, 1887)	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Ingerophrynus macrotis (Boulenger,1887)	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Leptophryne borbonica (Tschudi, 1838)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Pedostibes hosii (Boulenger, 1892)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Phrynoidis aspera (Gravenhorst, 1829)	LC	Smith, 1915; Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Family Hylidae		
Hyla annectens (Jerdon, 1870)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata, *et al*., 2000; Chan-ard, 2003; Chan-ard *et al*., 2011
Family Megophryidae		
Brachytarsophrys carinensis (Boulenger, 1889)	LC	Taylor, 1962; Barron, 1918; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Brachytarsophrys feae (Boulenger,1887)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chand-ard, 2003; Chan-ard *et al*., 2011
Leptobrachium chapaense (Bourret, 1937)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Leptobrachium hendricksoni Taylor,1962	LC	Taylor,1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011;
Leptobrachium smithi Matsui, Nabhitabhata & Panha,1999	LC	Matsui, Nabhitabhata & Panha,1999; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Leptolalax fuliginosus Matsui, 2006	DD	Matsui, 2006; Chan-ard *et al*., 2011
Leptolalax gracilis (Günther, 1872)	NT	Nabhitabhata *et al*., 2000
Leptolalax heteropus (Boulenger,1900)	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Leptolalax melanolecus Matsui, 2006	LC	Matsui, 2006; Chan-ard *et al*., 2011
Leptolalax minimu (Taylor, 1962)		Taylor, 1962
Leptolalax solus Matsui, 2006	DD	Matsui, 2006; Chan-ard *et al*., 2011
Leptolalax lateralis (Anderson, 1871)	NA	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Khnosue and Thirakhupt, 2001

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Leptolalax zhangyapingi (Jiang, *et al*., 2013)	NE	Jiang, *et al*., 2013
Megophrys montana Kuhland and Van Hasselt,1822	LC	Smith, 1917a; Taylor and Elbel, 1958; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Megophrys nasuta (Schlegel, 1858)	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylar, 1962; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Megophrys takensis (Mahony, 2011)	NA	Chan-ard, 2003; Mahony, 2011; Chan-ard *et al*., 2011
Ophryophryne microstoma Boulenger, 1903	LC	Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011;
Xenophrys aceras (Boulenger, 1903)	LC	Taylor and Elbel, 1958; Taylar, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, *et al*., 2011
Xenophrys lekaguli (Stuart *et al*, 2006)	DD	Stuart, Chuaynkern, Chan-ard and Inger, 2006; Chan-ard *et al*., 2011
Xenophrys longipes (Boulenger, 1886)	NT	Taylor and Elbel, 1958; Taylar, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Xenophrys major (Boulenger, 1908)	LC	Chan-ard, 2003; Taylar, 1962; Chan-ard *et al*., 2011
Xenophrys minor Stejneger, 1926	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Xenophrys parva (Boulenger, 1893)	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Family Microhylidae		
Chaperina .cf. fusca (Mocquard, 1892)	LC	Chan-ard *et al*., 2011
Calluella guttulata (Blyth, 1856)	LC	Smith, 1917a; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Glyphoglossus molossus Gunther, 1869	NT	Smith, 1917a; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Kalophrynus interlineatus (Blyth, 1855)	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Kalophrynus pleurostigma Tschudi, 1838	LC	Smith, 1917a; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Kaloula aureauta Nutphand, 1989	DD	Pauwels and Cherot, 2006
Kaloula baleata (Muller, 1836)	LC	Pauwels *et al*., 1999; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Kaloula mediolineata Smith, 1917	NT	Smith, 1917a; Smith, 1917d; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chand-ard *et al*., 2011
Kaloula pulchra Gray, 1831	LC	Smith, 1917; Taylor and Elbel, 1958; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Microhyla annamensis Smith, 1923	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Microhyla annectens Boulenger, 1900	DD	Smith, 1917a; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001
Microhyla berdmorei (Blyth, 1856)	LC	Smith and Kloss, 1915; Smith, 1917a; Taylor and Elbel,1958; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Microhyla butleri Boulenger, 1900	LC	Smith, 1917a; Smith, 1922a; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Microhyla fissipes Boulenger,1884	LC	Chan-ard *et al*., 2011
Microhyla fowleri Taylor, 1934	NE	Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Microhyla heymonsi Vogt, 1911	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Microhyla mantheyi Das, Yakoop and Sukumaran, 2007	LC	Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Microhyla ornata (Dumeril and Bibron, 1841)	LC	Smith, 1917a; Taylor and Elbel, 1958; Chan-ard, 2003; Khonsue and Thirakhupt, 2001; Nabhitabhata, 2000; Chan-ard *et al*., 2011
Microhyla pulchra (Hallowell, 1861)	LC	Smith, 1917a; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Micryletta inornata (Boulenger, 1890)	LC	Smith, 1917a; Taylor and Elbel,1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Phrynella pulchra Boulenger, 1887	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Family Dicroglossidae		
Fejervarya cancrivora (Gravenhorst, 1829)	LC	Smith, 1917a; Smith, 1917b; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Fejervarya limnocharis (Gravenhorst, 1829)	LC	Smith, 1916c; Smith and Kloss, 1915; Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Fejervarya triora Stuart, Chuaynkern, Chan-ard, and Inger, 2006)	DD	Stuart *et al*., 2006; Chan-ard *et al*., 2011
Hoplobatrachus rugulosus (Weigmann, 1834)	LC	Taylor and Elbel, 1958; Chan-ard, 2003; Taylor, 1962; Chan-ard *et al*., 2011
Ingerana tasanae (Smith,1921)	VU	Taylor and Elbel., 1958; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Taylor, 1962; Chan-ard *et al*., 2011
Ingerana tenasserimensis (Sclater, 1892)	LC	Taylor and Elbel, 1958; Chan-ard, 2003; Nabhitabhata *et al*, 2000; Taylor, 1962; Chan-ard *et al*., 2011
Limnonectes doriae (Boulenger, 1887)	DD	Smith, 1916c; Smith and Kloss, 1915; Smith, 1917; Smith, 1922b; Taylor and Elbel, 1958; Taylor, 1962; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Limnonectes glydenstolpei (Boulenger, 1916)	LC	Boulenger, 1916; Smith, 1917a; Chan-ard, 2003; Taylor and Elbel, 1958; Taylor, 1962; Chan-ard *et al*., 2011
Limnonectes kohchangae (Smith, 1922)	LC	Smith, 1922b; Nabhitabhata *et al*., 2000; Taylor, 1962; Taylor and Elbel, 1958; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Limnonectes macrognathus (Boulenger, 1917)	DD	Taylor and Elbel, 1958; Smith, 1922b; Nabhitabhata *et al*., 2000; Taylor, 1962; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Limnonectes plicatellus (Stoliczka, 1873)	LC	Smith, 1922c; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Limnonectes blythii (Boulenger, 1920)	NT	Smith, 1916c; Taylor and Elbel, 1958; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Taylor, 1962; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Limnonectes malesianus (Kiew, 1984)	NT	Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Limnonectes paramacrodon (Inger, 1966)	NT	Smith, 1915; Smith, 1917a; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011; Nabhitabhata *et al*., 2000
Limnonectes jarujini Matsui, Panha, Khonsue and Kuraishi, 2010	NE	Matsui *et al*, 2010; Chan-ard *et al*., 2011
Limnonectes kuhlii (Tschudi, 1838)	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhat *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Limnonectes laticeps (Boulenger, 1882)	LC	Taylor and Elbel, 1958; Taylor, 1962; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Limnonectes megastomias McLeod, 2008	NA	McLeod, 2008; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Limnonectes taylori Matsui, Panha, Khonsue and Kuraishi, 2010	NA	Matsui, Panha, Khonsue and Kuraishi, 2010; Chan-ard *et al*., 2011
Limnonectes hascheanus (Stoliczka, 1870)	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Taylor, 1962; Chan-ard *et al*., 2011
Limnonectes limborgi (Sclater, 1892)	DD	Smith, 1916c; Smith, 1917a; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Nanorana aenea (Smith, 1922)	DD	Smith, 1922a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Chan-ard, 2003; Chan-ard *et al*., 2011
Occidozyga laevis (Gunther, 1859)	LC	Smith, 1917a; Chan-ard, 2003; Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Occidozyga lima (Gravenhorst, 1829)	LC	Smith, 1916c; Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Occidozyga magnapustulosa (Taylor and Elbel, 1958)	LC	Taylor and Elbel, 1958; Chan-ard, 2003; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Occidozyga martensii (Peters, 1867)	LC	Smith and Kloss, 1915; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, *et al*., 2011
Quasipaa fasciculispina (Inger, 1970)	VU	Inger, 1970; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Family Ranidae		
Amolops archotaphus (Inger and Chan-ard, 1997)	LC	Inger and Chan-ard, 1997; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Amolops larutensis (Boulenger, 1899)	LC	Smith, 1917a; Taylor, 1962; Chan-ard, 2003; Chan-ard *et al*., 2011; Khonsue and Thirakhupt, 2001

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Amolops panhai Matsui and Nabhitabhata, 2006	LC	Matsui and Nabhitabhata, 2006; Chan-ard *et al*., 2011
Babina chapaensis (Bourret, 1937)	LC	Chan-ard, 2003; Chan-ard *et al*., 2011
Clinotarsus alticola (Boulenger, 1882)	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Humerana miopus (Boulenger, 1918)	LC	Boulenger, 1918; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana eschatia (Inger, stuart and Iskandar, 2009)	LC	Chan-ard, 2003; Inger, stuart and Iskandar, 2009; Chan-ard *et al*., 2011
Hylarana banjarana (Leong and Lim, 2003)	NT	Chan-ard *et al*., 2011
Hylarana cubitalis (Smith, 1917)	LC	Smith, 1917c; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana erythraea (Schlegel, 1837)	LC	Smith and Kloss, 1915; Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 200; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana faber (Ohler, Swan and Daltry, 2002)	LC	Chan-ard *et al*., 2011
Hylarana glandulosa (Boulenger, 1882)	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana laterimaculata (Barbour and Noble, 1916)	LC	Nabhitabhata *et al*., 2000; Chan-ard, 2003; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Hylarana lateralis (Boulenger, 1887)	LC	Smith, 1917a; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana leptoglossa (Cope, 1868)	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana luctuosa (Peters, 1871)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana macrodactyla Gunther, 1858	LC	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana milleti (Smith, 1921)	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Hylarana mortenseni (Boulenger, 1903)	NT	Smith, 1917a; Taylor and Elbel, 1958; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana nicobariensis (Stoliczka, 1870)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana nigrovittata (Blyth, 1856)	LC	Smith and Kloss, 1915; Smith, 1917a; Smith, 1922a; Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana signata (Gunther, 1872)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Hylarana taipehensis (van Denburgh, 1909)	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Hylarana montivaga (Smith, 1921)	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Hylarana scutigera (Andersson, 1916)	DD	Smith, 1917a; Taylor and Elbel, 1958; Taylor, 1962; Khonsue and Thirakhupt, 2001
Rana johnsi Smith, 1921	LC	Nabhitabhata *et al*., 2000; Chan-ard, 2003; Chan-ard *et al*., 2011
Odorrana andersonii (Boulenger, 1882)	LC	Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Odorrana aureola Stuart, Chuaynkern, Chan-ard, and Inger, 2006	DD	Stuart *et al*., 2006; Chan-ard *et al*., 2011
Odorrana melasma (Stuart and Chan-ard, 2005)	DD	Stuart and Chan-ard, 2005; Chan-ard *et al*., 2011
Odorrana nasica (Boulenger, 1903)	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Odorrana chloronota (Gunther, 1876)	LC	Chan-ard *et al*., 2011
Odorrana indeprensa (Bain and Stuart, 2005)	DD	Bain and Stuart, 2005; Chan-ard *et al*., 2011
Odorrana hosii (Boulenger, 1891)	LC	Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Odorrana livida (Blyth, 1856)	DD	Smith, 1917a; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard., 2003; Chan-ard *et al*., 2011
Odorrana schmackeri (Boettger, 1892)	LC	Nabhitabhata, *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011;
Odorrana andersonii (Boulenger, 1882)	LC	Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Odorrana aureola Stuart, Chuaynkern, Chan-ard, and Inger, 2006	DD	Stuart *et al*., 2006; Chan-ard *et al*., 2011
Odorrana melasma (Stuart and Chan-ard, 2005)	DD	Stuart and Chan-ard, 2005; Chan-ard *et al*., 2011
Odorrana nasica (Boulenger, 1903)	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Odorrana chloronota (Gunther, 1876)	LC	Chan-ard *et al*., 2011
Odorrana indeprensa (Bain and Stuart, 2005)	DD	Bain and Stuart, 2005; Chan-ard *et al*., 2011
Odorrana hosii (Boulenger, 1891)	LC	Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Odorrana livida (Blyth, 1856)	DD	Smith, 1917a; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard., 2003; Chan-ard *et al*., 2011
Odorrana schmackeri (Boettger, 1892)	LC	Nabhitabhata, *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011;
Family Rhacophoridae		
Chiromantis doriae (Boulenger, 1893)	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Chiromantis hansenae (Cochran, 1927)	DD	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Chiromantis nongkhorensis (Cochran, 1927)	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Chiromantis vittatus (Boulenger, 1887)	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Gracixalus gracilipes (Bourret, 1937)	LC	Chan-ard., 2003; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Kurixalus bisacculus (Taylor, 1962)	LC	Taylor, 1962; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*, 2011
Kurixalus carinensis (Boulenger, 1893)	DD	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Kurixalus verrucosus (Boulenger, 1893)	LC	Chan-ard, 2003; Chan-ard *et al*., 2011
Nyctixalus pictus (Peters, 1871)	NT	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Raorchestes parvulus (Boulenger, 1893)	LC	Chan-ard *et al*., 2011; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001
Philautus petersi (Boulenger, 1900)	LC	Taylor and Elbel, 1958; Chan-ard, 2003; Chan-ard *et al*., 2011
Philautus vermiculatus (Boulenger, 1900)	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Polypedates colletti (Boulenger, 1890)	LC	Taylor and Elbel, 1958; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Polypedates macrotis (Boulenger, 1891)	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Polypedates leucomystax (Gravenhorst, 1829)	LC	Smith, 1915; Smith, 1917a; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Taylor, 1962; Chan-ard *et al*., 2011
Polypedates discanthus (Rujirawan, Stuart and Aowphol, 2013	NE	Rujirawan, Stuart and Aowphol, 2013
Polypedates mutus (Smith, 1940)	LC	Chan-ard, 2003; Chan-ard *et al*., 2011; Nabhitabhata *et al*., 2000
Rhacophorus appendiculatus (Gunther, 1858)	LC	Chan-ard, 2003; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Rhacophorus bipunctatus Ahl, 1927	LC	Taylor and Elbel, 1958; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Rhacophorus cyanopunctatus Manthey and Steiof, 1998	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Rhacophorus feae Boulenger, 1893	LC	Chan-ard, 2003; Chan-ard *et al*., 2011; Nabhitabhata *et al*., 2000
Rhacophorus jarujini Matsui and Panha, 2006	DD	Matsui and Panha, 2006; Chan-ard *et al*., 2011
Rhacophorus kio Ohler and Delorme, 2005	VU	Chan-ard *et al*., 2011
Rhacophorus maximus Gunther, 1858	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011

Table 1. Recorded anuran species of Thailand with supporting references and conservation status *continued*.

Scientific name	Status	References
Rhacophorus nigropalmatus Boulenger, 1895	LC	Smith, 1917a; Taylor and Elbel, 195; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Rhacophorus norhayatii Onn and Grismer, 2010	NE	Onn and Grismer, 2010; Chan-ard *et al*., 2011
Rhacophorus orlovi Ziegler and Köhler, 2001	LC	Nabhitabhata *et al*., 2000
Rhacophorus prominanus Smith, 1924	LC	Taylor and Elbel, 1958; Khonsue and Thirakhupt, 2001
Rhacophorus robinsonii Boulenger, 1903	DD	Taylor, 1962; Khonsue and Thirakhupt, 2001
Theloderma asperum (Boulenger, 1886)	LC	Taylor, 1962; Khonsue and Thirakhupt, 2001
Theloderma licin McLeod and Ahmad, 2007	LC	McLeod and Ahmad, 2007; Chan-ard *et al*., 2011
Theloderma stellatum Taylor, 1962	NT	Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Theloderma gordoni Taylor, 1962	LC	Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011
Theloderma horridum (Boulenger, 1903)	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011; Chan-ard, 2003

Status is the conservation status according to IUCN red list of threatened species; DD= data deficient; LC= least concern; NT=near threatened; EN=endangered; CR=critically endangered; VU=vulnerable; NE= not evaluated.

Appendix II

Table 2. Recorded gymnophiona species of Thailand with supporting references and conservation status.

Order: Gymnophiona Müller, 1832

Scientific name	Status	References
Caudacaecilia asplenius (Taylor, 1965)	DD	Taylor, 1965; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Caudacaecilia larutensis Taylor, 1960	DD	Taylor, 1960; Nabhitabhata *et al*., 2000; Chan-ard *et al*., 2011
Ichthyophis acuminatus Taylor, 1960	DD	Taylor, 1960; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Ichthyophis kohtaoensis Taylor, 1960	LC	Taylor, 1960; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011; Khonsue *et al*., 2011
Ichthyophis supachaii Taylor, 1960	DD	Taylor, 1960; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011
Ichthyophis youngorum Taylor, 1960	DD	Taylor, 1960; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard *et al*., 2011

Status is the conservation status according to IUCN red list of threatened species; DD= data deficient; LC= least concern; NT=near threatened; EN=endangered; CR=critically endangered; VU=vulnerable; NE= not evaluated.

Appendix III

Table 3. Recorded caudata species of Thailand with supporting references and conservation status.

Order: Caudata Fischer von Waldheim, 1813

Scientific name	Status	References
Tylototriton panhai Nishikawa *et al*. 2013	NE	Nishikawa, Khonsue, Pomchote and Matsui, 2013
Tylototriton uyenoi Nishikawa *et al*. 2013	NE	Nishikawa, Khonsue, Pomchote and Matsui, 2013
Tylototriton verrucosus Anderson, 1871	LC	Taylor and Elbel, 1958; Taylor, 1962; Nabhitabhata *et al*., 2000; Khonsue and Thirakhupt, 2001; Chan-ard, 2003; Chan-ard *et al*., 2011

Status is the conservation status according to IUCN red list of threatened species; DD= data deficient; LC= least concern; NT=near threatened; EN=endangered; CR=critically endangered; VU=vulnerable; NE= not evaluated.

Appendix IV

Table 4. The measurement of *Hylarana eschatia* from peninsular Thailand

Locality	Sex	Museum No.	SVL	HL	HW	SEL	IND	ED	UEW	IOD	TD	DF3	FL	TL
Banna	M	*PSUZC.AMP*.1096	34.2	13.0	9.4	6.1	2.9	4.5	3	3.4	3.7	1.6	17.1	20.50
Ban Tungka	F	*PSUZC.AMP*.982	40.9	15.6	10.9	6.4	3.1	4.9	3.4	3.5	3.4	2.1	22.4	23.4
Ban Tungka	F	*PSUZC.AMP*.995	48.5	18.5	13	7.7	3.8	6.2	4.3	4.3	4.5	2.4	23	27.2
Ban Tungka	F	*PSUZC.AMP*.1005	51.6	19.6	14.2	7.9	3.8	5.6	4	4.5	5.1	2.6	27.6	31.2
Ban Tungka	M	*PSUZC.AMP*.1002	35.1	14.2	9.9	5.8	3.1	5	3	3.5	4.5	1.6	18.5	21.3
Ban Tungka	M	*PSUZC.AMP*.0991	34.8	13.3	9.9	5.6	2.8	4.4	2.7	3.4	3.8	1.2	17.5	21
Ban Tungka	M	*PSUZC.AMP*.976	34	13.1	9.6	5.4	3	4.3	2.9	3.2	3.8	1.4	16.6	19.6
Ban Tungka	M	*PSUZC.AMP*.977	33.4	13	9.6	5.5	2.6	4.6	3.2	3.3	3.6	1.6	16.1	18.9
Ban Tungka	M	*PSUZC.AMP*.978	33.2	12.7	9.6	5.2	2.9	4.4	3	3.4	4.2	1.4	17	19.2
Ban Tungka	M	*PSUZC.AMP*.979	33.4	13.8	9.8	5.5	2.6	4.9	2.6	3.2	4	1.5	17.5	19.7
Ban Tungka	M	*PSUZC.AMP*.990	34	13.1	9.7	5.5	3	4.5	3.3	3.2	4.2	1.3	16.4	19.4
Ban Tungka	M	*PSUZC.AMP*.980	30.4	12.4	8.8	5.1	2.6	4.4	3.1	3.3	3.5	1.6	15.2	18.2
Ban Tungka	M	*PSUZC.AMP*.981	32.2	12.5	9	5	2.2	4.8	3.2	3.1	4.3	1.4	16.3	19
Ban Tungka	M	*PSUZC.AMP*.983	33	13.3	9.8	5.5	2.8	4.1	2.6	3.2	4.1	1.4	16.4	19
Ban Tungka	M	*PSUZC.AMP*.984	35.2	14	9.9	5.7	2.9	5	3.1	3.4	3.9	1.6	17.5	20
Ban Tungka	M	*PSUZC.AMP*.985	33.2	12.4	9.7	5	2.6	4.7	3.1	3	3.8	1.5	15.5	18.4
Ban Tungka	M	*PSUZC.AMP*.986	31.2	11.9	9.1	5	2.5	4	3	3	3.5	1.3	15	17.5
Ban Tungka	M	*PSUZC.AMP*.987	33.2	13.5	10	5.5	3.1	4.5	3.1	3.4	4	1.4	16.8	19.3
Ban Tungka	M	*PSUZC.AMP*.988	30.5	12.4	9.2	5.3	2.5	4.3	2.8	3.3	3.3	1.5	15.6	17.6
Ban Tungka	M	*PSUZC.AMP*.989	35.4	13.4	9.7	5.5	3.1	4.4	3.5	3.2	3.5	1.8	17.2	20.2
Ban Tungka	M	*PSUZC.AMP*.992	32.5	12.3	9.2	5.1	3	4.2	2.5	3.4	3.5	1.4	16.6	18.8
Ban Tungka	M	*PSUZC.AMP*.993	33.4	13.3	9.3	5.5	3	4.5	2.6	3.3	3.9	1.6	16.1	18.7

Table 4. The measurement of *Hylarana eschatia* from peninsular Thailand *continued*.

Locality	Sex	Museum No.	SVL	HL	HW	SEL	IND	ED	UEW	IOD	TD	DF3	FL	TL
Ban Tungka	M	*PSUZC.AMP.*994	30.4	12.1	8.4	4.8	2.4	4.2	3.1	3.2	3.5	1.5	14.8	17.4
Ban Tungka	M	*PSUZC.AMP.*996	35.4	13.6	10	5.9	2.8	4.4	3.4	3.2	4.3	1.8	15.9	20.6
Ban Tungka	M	*PSUZC.AMP.*997	32.8	13.2	10.2	5.5	2.6	4.9	3.1	3	4.3	1.1	17.1	19.2
Ban Tungka	M	*PSUZC.AMP.*998	35.2	13.4	10	5.6	3	5	3.3	3	3.5	1.5	18.6	20.4
Ban Tungka	M	*PSUZC.AMP.*999	32.5	12.4	9.2	5.1	2.6	5	2.4	3.2	4	1.4	16.5	18.7
Ban Tungka	M	*PSUZC.AMP.*1004	33.7	13.2	9.6	5.2	2.9	4.5	2.6	3	4	1.5	16.4	20
Ban Tungka	M	*PSUZC.AMP.*1003	31.5	12.6	9.2	5.4	2.9	4.5	2.6	2.8	3.5	1.4	16.4	18.8
Ban Tungka	M	*PSUZC.AMP.*1000	35.6	13.9	10.5	5.6	3.1	5.2	3.1	3.5	4.3	1.6	19.4	22.1
Ban Tungka	M	*PSUZC.AMP.*10010	34.8	13.2	9.2	5.5	3	4.8	3.3	3	3.8	1.6	18	20.5
Yong Waterfall	F	*PSUZC.AMP.*1116	43.7	16.6	11.5	7.7	3.4	5.5	3.3	4.3	4	2.1	22.5	22.9
Yong Waterfall	F	*PSUZC.AMP.*1117	46.9	18.7	13.4	7	3.5	7.5	3.5	3.5	4.2	2.6	20.2	26
Yong Waterfall	M	*PSUZC.AMP.*1115	32.6	13.2	9.2	5.7	2.6	3.5	2.9	2	3.8	1.5	16.7	19.4
Khao Nan	F	*PSUZC.AMP.*1109	31.5	12.7	8.6	5.4	2.4	4.5	2.6	3	2.4	1.6	15.1	17.8
Kachong	F	*PSUZC.AMP.*502	45.6	17.9	12.2	7.8	3.1	6	4	4	3.4	1.6	23.3	27.7
Kachong	F	*PSUZC.AMP.*756	48.1	18.5	13	7.7	3.5	6.4	4.3	4.5	3.9	2.3	24.4	29.5
Kachong	F	*PSUZC.AMP.*757	44.4	17.4	11.7	7.4	3.6	5.2	4.2	3.9	3.5	2	21.7	25.8
Kachong	F	*PSUZC.AMP.*758	48.3	18.7	13.5	7.8	3.4	6.3	4	4.1	4	2	20.7	26.2
Kachong	F	*PSUZC.AMP.*1244	44.6	17.6	12	7.6	3	5.3	4	4	4.2	2.5	23.1	25.4
Kachong	F	*PSUZC.AMP.*1258	46.3	18.1	11.9	8.2	3.2	6	4.1	4.3	4	2.4	22.3	27.1
Kachong	F	*PSUZC.AMP.*1259	48	18.7	13.4	8.2	3.2	5.5	4	4.4	4.4	2.5	24.2	28.8
Kachong	F	*PSUZC.AMP.*1260	46.1	18.8	12.3	8	3.8	5.4	3.4	4.1	4.4	2.1	23.4	27.2
Kachong	F	*PSUZC.AMP.*1261	45.4	17.6	12.8	7.4	3.4	5.2	3.8	4.3	4.2	2.3	22.6	27.2
Kachong	F	*PSUZC.AMP.*1262	50.3	20.1	13	8.6	3.8	5.6	4	4.2	5.2	2.7	25.4	29.8
Kachong	F	*PSUZC.AMP.*1263	52.4	21	13.4	8.3	3.9	5.2	4	4.7	5.4	2.8	25.4	28.2

Table 4. The measurement of *Hylarana eschatia* from peninsular Thailand *continued*.

Locality	Sex	Museum No.	SVL	HL	HW	SEL	IND	ED	UEW	IOD	TD	DF3	FL	TL
Kachong	F	*PSUZC.AMP*.1264	42.1	16.8	11.5	7.4	3	5.7	2.9	4	4.1	2.4	21.4	26.1
Kachong	F	*PSUZC.AMP*.1265	45.8	18	12.1	8.1	3.5	6	3.9	3.8	4.2	2.7	21.6	25
Kachong	F	*PSUZC.AMP*.1266	44	17.5	11.6	7.4	3.9	5.4	3.6	3.9	3.9	2.8	22	25.1
Kachong	F	*PSUZC.AMP*.1053	49.4	18.8	13.5	7.5	3.2	6.4	4.2	4.4	4.6	2.5	24.7	29
Kachong	F	*PSUZC.AMP*.1054	47.6	18.7	13	7.4	3	6.3	4.4	4.4	3.9	2.4	22.5	26.6
Kachong	M	*PSUZC.AMP*.1246	30.7	12.6	8.4	5.4	2.7	4.3	2.8	2.7	4	1.4	15.2	17.1
Kachong	M	*PSUZC.AMP*.1247	32.1	13.2	9.7	6.2	2.6	4.5	3	2.9	3.5	1.6	17	19
Kachong	M	*PSUZC.AMP*.1248	35.8	14.1	10	6.5	3	4.5	3.3	3.3	4.5	2.1	17.7	19.3
Kachong	M	*PSUZC.AMP*.1249	35.5	14.5	10.1	6.6	2.8	4.4	3.2	3.4	4.4	2.2	17.3	19.9
Kachong	M	*PSUZC.AMP*.1250	35	14	10.1	6.2	2.6	4.5	3.4	3.5	4.1	2	17.3	20.6
Kachong	M	*PSUZC.AMP*.1251	34.2	14	9.2	6.4	2.8	4.5	3	3.3	3.4	2	17.2	21
Kachong	M	*PSUZC.AMP*.1252	33.4	13.5	9.1	6.3	2.9	4.7	3.3	3.1	4	1.6	17.2	19.6
Kachong	M	*PSUZC.AMP*.1253	29.9	12.3	8.2	5.6	2.3	4.3	2.8	2.9	2.5	1	15	17.3
Kachong	M	*PSUZC.AMP*.1254	33.4	13.8	9.8	6	2.9	4.3	3.3	3.2	3.9	2	16.8	20
Kachong	M	*PSUZC.AMP*.1256	34.6	14.1	10.3	6.5	2.9	4.2	3.4	3.3	4.4	1.8	17.2	20.7
Kachong	M	*PSUZC.AMP*.1257	34.3	14	10	6.4	3	5	3.1	3.1	4.5	1.8	17.2	19.9
Ton Nga Chang	M	*PSUZC.AMP*.110	33.2	13	9.2	5.8	2.8	4.5	2.5	3.5	3.6	1.9	16	19
Ton Nga Chang	M	*PSUZC.AMP*.114	33.4	13.4	9.4	5.5	2.6	4.5	3.2	3.5	4	1.6	15.6	19.3
Ton Nga Chang	M	*PSUZC.AMP*.121	33.9	13.4	9.7	6	2.7	4.1	3	3.4	4.1	1.6	15.9	18.7
Ton Nga Chang	M	*PSUZC.AMP*.122	32.6	13	9.2	5.7	2.5	4	3	3.3	4	1.2	15	18.5
Ton Nga Chang	M	*PSUZC.AMP*.250	32.4	12.6	9.4	5.9	3	4.4	2.8	3.1	3.6	1.5	15.8	17.8
Kho Hong Hill	F	*PSUZC.AMP*.25	43	16.1	11.2	6.8	3.5	5.2	3.4	3.6	3.4	1.9	22.2	25.40
Kho Hong Hill	F	*PSUZC.AMP*.233	40.5	15.2	10.5	7	3.4	4.5	3.5	3.4	3.4	1.8	19.2	22.40
Kho Hong Hill	F	*PSUZC.AMP*.251	47.6	18.6	12.5	8	3.5	5.6	3.4	4.5	3.8	2.1	23.3	27.80

Table 4. The measurement of *Hylarana eschatia* from peninsular Thailand *continued*.

Locality	Sex	Museum No.	SVL	HL	HW	SEL	IND	ED	UEW	IOD	TD	DF3	FL	TL
Kho Hong Hill	F	*PSUZC.AMP*.255	40.1	15.2	10.1	6.6	3	5.1	3.4	3.9	3.4	1.6	19.6	23.40
Kho Hong Hill	F	*PSUZC.AMP*.261	40	15.6	10.7	6.7	3.4	5.4	3.4	3.6	3.5	1.8	20.6	23.40
Kho Hong Hill	F	*PSUZC.AMP*.342	42.6	16.1	11.8	6.8	3.2	4.7	3.3	4	3.6	2	19.6	23.00
Kho Hong Hill	F	*PSUZC.AMP*.343	41.7	16.1	11.5	6.9	3.4	5.5	3.3	3.5	3.6	2.2	19.7	23.30
Kho Hong Hill	F	*PSUZC.AMP*.339	43	16.6	12.1	6.9	3.4	5.4	4	4.1	3.6	2.4	20	22.60
Kho Hong Hill	F	*PSUZC.AMP*.356	40.7	16.1	11.3	6.9	3.2	5	3.3	4	3.4	2	20.3	23.80
Kho Hong Hill	F	*PSUZC.AMP*.360	42	16.0	11.3	6.7	3.1	5.4	3.6	3.6	3.3	2	19.1	24.00
Kho Hong Hill	F	*PSUZC.AMP*.455	39.4	15.1	10.5	6.6	3.3	4.6	3.3	3.5	3.1	1.8	18.9	21.50
Kho Hong Hill	F	*PSUZC.AMP*.516	48	18.0	12.6	6.7	3.3	6.2	3.5	4.6	4.0	2.3	22.7	26.50
Kho Hong Hill	F	*PSUZC.AMP*.754	44.6	17.0	11.4	7.1	3.2	5.1	3.5	4	3.5	1.7	23	25.10
Kho Hong Hill	F	*PSUZC.AMP*.755	41	15.8	11.2	6.8	3.4	5.7	4	4.1	3.8	1.5	18.8	22.30
Kho Hong Hill	F	*PSUZC.AMP*.1100	41.3	16.5	11.4	7.5	3.4	5.3	3.4	3.9	3.6	2	20.1	24.20
Kho Hong Hill	F	*PSUZC.AMP*.1101	43	16.5	11.2	7.2	3.2	4.8	4	4	3.3	1.9	20.6	24.50
Kho Hong Hill	F	*PSUZC.AMP*.1102	39.5	14.7	10.5	6.5	3.1	4.7	3.3	3.7	3.3	2.1	18.3	21.00
Kho Hong Hill	F	*PSUZC.AMP*.1103	43.4	16.5	11.3	7.7	3.4	4.9	3.5	4.3	3.5	2.3	21	24.20
Kho Hong Hill	F	*PSUZC.AMP*.1104	42.6	16.7	11.2	7.3	3.4	5.1	3.5	3.5	3.4	2.2	19.6	24.50
Kho Hong Hill	F	*PSUZC.AMP*.1105	41.6	16.1	11.0	7	3.6	5.5	3.5	3.6	3.1	2.1	21	24.50
Kho Hong Hill	F	*PSUZC.AMP*.1106	42.4	16.5	11.5	7.2	3.4	5.5	3.4	3.6	3.4	1.8	21	23.80
Kho Hong Hill	M	*PSUZC.AMP*.216	28	11.0	8.0	5.4	2.3	4	2.6	3.2	3.1	1.3	13.8	15.70
Kho Hong Hill	M	*PSUZC.AMP*.218	28	11.2	7.7	4.5	2.2	4	2.2	3	3.0	1.3	13.3	16.30
Kho Hong Hill	M	*PSUZC.AMP*.355	31.2	13.6	9.2	5.4	2.7	4.5	3	3.2	4.0	1.8	15.2	17.50
Kho Hong Hill	M	*PSUZC.AMP*.1095	32.3	12.2	9.4	5.9	2.8	4.5	3	3.1	3.4	1.3	14.6	17.00
Kho Hong Hill	M	*PSUZC.AMP*.1098	28.4	11.3	8.2	5.5	2.4	3.6	2.6	3.1	3.4	1.5	13	16.30
Kho Hong Hill	M	*PSUZC.AMP*.1099	29.7	11.8	8.4	5.2	2.5	4.1	2.4	3.2	3.2	1.2	13.4	15.50

Table 4. The measurement of *Hylarana eschatia* from peninsular Thailand *continued*.

Locality	Sex	Museum No.	SVL	HL	HW	SEL	IND	ED	UEW	IOD	TD	DF3	FL	TL
Kho Hong Hill	M	*PSUZC.AMP*.1108	30.6	12.3	9.6	5.8	2.7	4.7	3	3.1	4.1	1.3	15.5	17.10
Klong Hoi Khong	F	*PSUZC.AMP*.134	37.1	13.6	11	5.4	2.7	4.6	2.5	3.5	3	1.3	19	20.4
Kaichon Stream	F	*PSUZC.AMP*.1077	45	17.7	13	7.2	3.6	6.6	3.7	4.1	3.5	1.9	22.5	25.6
Kaichon Stream	F	*PSUZC.AMP*.1083	47.5	18.8	13	7.7	3.8	5.5	4.1	4.5	4.2	2.1	22.6	27.6
Kaichon Stream	F	*PSUZC.AMP*.1084	41.5	16.1	11.3	6.8	3.4	5.2	3.3	3.6	3.4	2.3	20.3	23.5
Kaichon Stream	F	*PSUZC.AMP*.1090	43.5	16.3	11.4	7.4	3.4	5.1	3.3	3.8	3.3	2.3	21.5	25.1
Kaichon Stream	F	*PSUZC.AMP*.1091	46.6	18.6	12.6	7.4	3.6	6.3	3.5	4	4	2.3	21.4	24.6
Kaichon Stream	F	*PSUZC.AMP*.1094	45.1	17.5	12.3	8	3.5	5.3	3	3.9	4.1	2.3	21.5	25.5
Kaichon Stream	M	*PSUZC.AMP*.1078	30.8	12.8	8.4	5	2.4	4.2	2.5	3	3.5	1.4	16	17.6
Kaichon Stream	M	*PSUZC.AMP*.1080	31.6	12.2	9.1	5.4	3	4.5	2.4	3.1	3.9	1.2	15.5	17.8
Kaichon Stream	M	*PSUZC.AMP*.1081	33.2	12.9	9.4	5.5	3	4.8	3	3	3.9	1.5	15.5	19
Kaichon Stream	M	*PSUZC.AMP*.1082	31.5	12.6	9.6	5.2	2.8	4.5	3.5	2.6	3.9	1.4	15.4	17.6
Kaichon Stream	M	*PSUZC.AMP*.1085	27	11.3	7.9	4.9	2.4	3.9	2.1	2.4	3	1.4	14	16.6
Kaichon Stream	M	*PSUZC.AMP*.1086	32	12.7	9	5.5	3.1	4.8	2.6	3	3.5	1.6	16.4	17.7
Kaichon Stream	M	*PSUZC.AMP*.1087	31.3	12.6	8.8	5.2	2.6	4.4	2.4	2.8	3.7	1.5	15.4	16.8
Kaichon Stream	M	*PSUZC.AMP*.1088	31.2	12.5	8.6	5	3	5	2.3	3.3	3.6	1.6	15.8	18.5
Kaichon Stream	M	*PSUZC.AMP*.1089	34	13.8	9.5	6	3	5	3	3.1	3.9	1.5	17	19.9
Kaichon Stream	M	*PSUZC.AMP*.1092	30.6	12.4	9	5.1	2.5	4.5	3.1	3.1	3.5	1.4	15	15.8
Kaichon Stream	M	*PSUZC.AMP*.1093	31.1	12.6	8.8	5	2.5	4	2.6	3.2	4.1	1.1	15	18
Tarutao Island	F	*PSUZC.AMP*.752	46.5	17.9	12.2	7.5	3	5.5	3.5	3.8	4.4	1.6	21.9	27.4
Tarutao Island	F	*PSUZC.AMP*.753	46.4	17.7	12.4	7.2	2.8	5.3	3.6	4	3.4	1.8	20.3	25
Tarutao Island	F	*PSUZC.AMP*.1021	45.2	17.4	12.1	7.8	3.4	5.2	3.2	4.1	3.6	1.5	22.4	25.5
Tarutao Island	M	*PSUZC.AMP*.185	31.6	12.1	8	5	2.4	4.4	2.6	2.8	3.1	1	14.5	18.7
Tarutao Island	M	*PSUZC.AMP*.1113	33.5	13.5	9.4	5.4	2	4.5	3.1	3.2	3.5	1.3	17.1	20

Table 4. The measurement of *Hylarana eschatia* from peninsular Thailand *continued*.

Locality	Sex	Museum No.	SVL	HL	HW	SEL	IND	ED	UEW	IOD	TD	DF3	FL	TL
Tarutao Island	M	*PSUZC.AMP*.1114	29.5	11.5	7.9	5.1	2.1	4	2.2	2.6	3.2	1.1	16	18.5
Hala Bala	F	*PSUZC.AMP*.1110	50.3	20.2	13.4	8.4	3.5	7	3	4.4	4.3	2.2	24	29.8
Hala Bala	M	*PSUZC.AMP*.751	33.7	13.7	9.7	5.6	2.9	4.7	3.1	3.2	3.3	1.6	16.6	20.8
Hala Bala	M	*PSUZC.AMP*.759	34.5	13.1	9.6	5.4	3.1	4.4	3.2	3.3	2.9	1.1	17.1	20.4
Hala Bala	M	*PSUZC.AMP*.1111	35.6	14.7	10.1	6.1	3.2	5.6	3.3	3.3	5.2	1.2	17.1	20.5
Hala Bala	M	*PSUZC.AMP*.1112	35.4	14.2	10	6.2	3.1	5.4	3.1	3.1	4.4	1.3	17	20.5

The characters are: Snout to vent length (SVL), head length (HL), head width (HW), snout to eye length (SEL), internarial distance (IND), eye diameter (ED), upper eyelid width (UEW), interorbital distance (IOD), tympanum diameter (TD), third finger disk diameter (DF3), tibia length (TL), and femur length (FL).

Appendix V

Table 5. Tukey's HSD Post Hoc Test of female *Hylarana eschatia* from peninsular Thailand.

Population		TL/ SVL	HW/ SVL	HL/ SVL	TD/ SVL	DF3/ SVL	ED/ SVL	IN/ SVL	UEW/ SVL	FL/ SVL	SEL/ SVL	IO/ SVL
Kho Hong Hill	Tarutao Island	1.00	1.00	1.00	1.00	.008	.899	.012	.331	.881	.996	.915
	Ban Tungka	.965	.982	.982	.117	.921	.992	.969	1.00	.167	.471	.943
	Kachong	.216	.970	.007	.001	.115	1.00	.066	.980	.917	.999	.841
	Kaichon Stream	1.00	.459	.526	.990	.298	.949	1.00	.570	1.00	1.00	.915
	Yong	.795	.767	.920	.385	.847	.073	.991	.600	.987	.997	.964
Tarutao Island	Kho Hong Hill	1.00	1.00	1.00	1.00	.008	.899	.012	.331	.881	.996	.915
	Ban Tungka	.984	.989	.996	.460	.012	.999	.311	.516	.101	.916	1.00
	Kachong	.850	.994	.340	.277	.000	.895	.406	.182	.598	.983	.999
	Kaichon Stream	1.00	.774	.850	1.00	.000	.669	.025	.980	.949	.999	1.00
	Yong	.920	.849	.961	.697	.015	.048	.401	1.00	1.00	1.00	1.00
Ban Tungka	Kho Hong Hill	.965	.982	.982	.117	.921	.992	.969	1.00	.167	.471	.943
	Tarutao Island	.984	.989	.996	.460	.012	.999	.311	.516	.101	.916	1.00
	Kachong	.341	1.00	.102	1.00	.997	.991	.969	1.00	.448	.374	1.00
	Kaichon Stream	.973	.991	.517	.423	.995	.885	.958	.785	.255	.639	1.00
	Yong	.612	.990	.801	1.000	1.00	.100	1.00	.687	.273	.955	1.00
Kachong	Kho Hong Hill	.216	.970	.007	.001	.115	1.00	.066	.980	.917	.999	.841
	Tarutao Island	.850	.994	.340	.277	.000	.895	.406	.182	.598	.983	.999
	Ban Tungka	.341	1.00	.102	1.00	.997	.991	.969	1.00	.448	.374	1.00
	Kaichon Stream	.631	.829	.928	.145	1.00	.965	.233	.310	.963	.999	1.00
	Yong	1.00	.929	.980	1.000	1.00	.086	.978	.415	.887	.989	1.00

Table 5. Tukey's HSD Post Hoc Test of female *Hylarana eschatia* from peninsular Thailand *continued*.

Population		TL/ SVL	HW/ SVL	HL/ SVL	TD/ SVL	DF3/ SVL	ED/ SVL	IN/ SVL	UEW/ SVL	FL/ SVL	SEL/ SVL	IO/ SVL
Kaichon Stream	Kho Hong Hill	1.00	.459	.526	.990	.298	.949	1.00	.570	1.00	1.00	.915
	Tarutao Island	1.00	.774	.850	1.00	.000	.669	.025	.980	.949	.999	1.00
	Ban Tungka	.973	.991	.517	.423	.995	.885	.958	.785	.255	.639	1.00
	Kachong Stream	.631	.829	.928	.145	1.00	.965	.233	.310	.963	.999	1.00
	Yong	.871	1.00	1.00	.709	1.00	.327	.984	.995	.995	.999	1.00
Yong	Kho Hong	.795	.767	.920	.385	.847	.073	.991	.600	.987	.997	.964
	Tarutao Island	.920	.849	.961	.697	.015	.048	.401	1.00	1.00	1.00	1.00
	Ban Tungka	.612	.990	.801	1.00	1.00	.100	1.00	.687	.273	.955	1.00
	Kachong	1.00	.929	.980	1.00	1.00	.086	.978	.415	.887	.989	1.00
	Kaichon Stream	.871	1.00	1.00	.709	1.000	.327	.984	.995	.995	.999	1.00

Table 6. Homogeneous subset of female *Hylarana eschatia* from peninsular Thailand.

TL/SVL		
Locality	N	Subset for alpha = 0.05
		1
Yong	2	.539200
Kachong	15	.543653
Tarutao	3	.564067
Kaichon	6	.564433
Kho Hong Hill	20	.565385
Ban Tungka	3	.579200
P value		.316

HW/SVL		
Locality	N	Subset for alpha = 0.05
		1
Tarutao	3	.265767
Kho Hong Hill	20	.266420
Kachong	15	.268587
Ban Tungka	3	.269900
Kaichon	6	.273350
Yong	2	.274450
P value		.645

HL/SVL		
Locality	N	Subset for alpha = 0.05
		1
Ban Tungka	3	.380867
Tarutao	3	.383800
Kho Hong Hill	20	.383970
Yong	2	.389300
Kaichon	6	.389817
Kachong	15	.393193
P value		.169

TD/SVL		
Locality	N	Subset for alpha = 0.05
		1
Kho Hong Hill	20	.081740
Tarutao	3	.082500
Kaichon	6	.083450
Yong	2	.090550
Kachong	15	.090807
Ban Tungka	3	.091567
P value		.207

DF3/SVL			
Locality	N	Subset for alpha = 0.05	
		1	2
Tarutao	3	.035467	
Kho Hong Hill	20		.047245
Ban Tungka	3		.050400
Yong	2		.051750
Kachong	15		.051880
Kaichon	6		.052350
P value		1.000	.717

ED/SVL			
Locality	N	Subset for alpha = 0.05	
		1	2
Tarutao	3	.115849	
Ban Tungka	3	.118722	
Kho Hong Hill	20	.122243	
Kachong	15	.122448	.122448
Kaichon	6	.126285	.126285
Yong	2		.142886
P value		.653	.050

Table 6. Homogeneous subset of female *Hylarana eschatia* from peninsular Thailand *continued*.

IN/SVL			
Locality	N	Subset for alpha = 0.05	
		1	2
Tarutao	3	.066667	
Kachong	15	.073247	.073247
Ban Tungka	3	.075933	.075933
Yong	2	.076200	.076200
Kho Hong Hill	20		.078555
Kaichon	6		.079167
P value		.139	.622

FL/SVL			
Locality	N	Subset for alpha = 0.05	
		1	2
Tarutao	3	.468033	
Yong	2	.472800	.472800
Kaichon	6	.482533	.482533
Kho Hong Hill	20	.483820	.483820
Kachong	15	.491733	.491733
Ban Tungka	3		.518933
P value		.689	.069

SEL/SVL		
Locality	N	Subset for alpha = 0.05
		1
Ban Tungka	3	.156133
Yong	2	.162750
Tarutao	3	.163033
Kaichon	6	.165383
Kho Hong Hill	20	.165625
Kachong	15	.166713
P value		.480

UEW/SVL		
Locality	N	Subset for alpha = 0.05
		1
Tarutao	3	.074567
Yong	2	.075050
Kaichon	6	.077583
Kho Hong Hill	20	.082210
Ban Tungka	3	.083100
Kachong	15	.083667
P value		.270

IO/SVL		
Locality	N	Subset for alpha = 0.05
		1
Tarutao	3	.086200
Yong	2	.086500
Ban Tungka	3	.087167
Kaichon	6	.088700
Kachong	15	.089700
Kho Hong Hill	20	.096290
P value		.946

Table 7. Agglomeration schedule of female *Hylarana eschatia* from peninsular Thailand.

	Cluster Combined			Stage Cluster First Appears		
Stage	Cluster 1	Cluster 2	Coefficients	Cluster 1	Cluster 2	Next Stage
1	2	45	.001	0	0	3
2	1	42	.003	0	0	33
3	2	10	.003	1	0	18
4	13	24	.005	0	0	11
5	6	29	.018	0	0	14
6	4	20	.021	0	0	25
7	11	30	.027	0	0	19
8	25	40	.030	0	0	17
9	32	34	.034	0	0	16
10	8	14	.035	0	0	12
11	13	43	.039	4	0	13
12	8	17	.046	10	0	23
13	13	49	.049	11	0	20
14	6	35	.063	5	0	23
15	27	28	.086	0	0	35
16	32	48	.095	9	0	27
17	25	26	.097	8	0	27
18	2	5	.107	3	0	24
19	9	11	.107	0	7	25
20	13	47	.114	13	0	34
21	36	38	.153	0	0	32
22	12	44	.168	0	0	28
23	6	8	.212	14	12	29
24	2	7	.262	18	0	28
25	4	9	.294	6	19	39
26	18	31	.309	0	0	31
27	25	32	.325	17	16	34
28	2	12	.336	24	22	36
29	3	6	.355	0	23	33
30	39	41	.439	0	0	40
31	15	18	.446	0	26	39
32	19	36	.458	0	21	35
33	1	3	.524	2	29	41
34	13	25	.607	20	27	36
35	19	27	.625	32	15	40
34	13	25	.607	20	27	36
35	19	27	.625	32	15	40

Table 7. Agglomeration schedule of female *Hylarana eschatia* from peninsular Thailand *continued*.

	Cluster Combined			Stage Cluster First Appears		
Stage	Cluster 1	Cluster 2	Coefficients	Cluster 1	Cluster 2	Next Stage
36	2	13	.729	28	34	42
37	37	46	.768	0	0	44
38	22	23	.932	0	0	46
39	4	15	1.253	25	31	43
40	19	39	1.385	35	30	45
41	1	16	1.413	33	0	42
42	1	2	2.275	41	36	43
43	1	4	2.812	42	39	45
44	33	37	3.179	0	37	47
45	1	19	4.694	43	40	47
46	21	22	4.808	0	38	48
47	1	33	6.907	45	44	48
48	1	21	10.321	47	46	0

Appendix VI

Table 8. Tukey's HSD Post Hoc Test of male *Hylarana eschatia* from peninsular Thailand.

Population		TL/ SVL	HW/ SVL	HL/ SVL	TD/ SVL	DF3/ SVL	ED/ SVL	IN/ SVL	UEW/ SVL	FL/ SVL	SEL/ SVL	IO/ SVL
Kho Hong Hill	Tarutao Island	.012	.021	.916	.688	.137	.984	.003	.887	.317	.011	.007
	Ban Tungka	.049	.985	.472	1.00	.971	.940	1.00	1.00	.034	.000	.008
	Kachong	.000	.867	.881	1.00	.397	.550	.995	.970	.069	.938	.002
	Kaichon Stream	.859	.930	1.000	1.00	1.00	.991	.838	.917	.219	.004	.005
	Ton Nga Chang	.990	.896	.981	1.00	1.00	.289	.993	.999	1.00	.680	.896
	Hala Bala	.088	.946	1.000	.976	.320	1.00	.924	1.00	.921	.016	.095
Tarutao Island	Kho Hong Hill	.012	.021	.916	.688	.137	.984	.003	.887	.317	.011	.007
	Ban Tungka	.483	.027	1.000	.534	.240	1.00	.001	.896	1.00	.996	.647
	Kachong	.000	.132	.360	.572	.001	.999	.006	.453	1.00	.000	.974
	Kaichon	.087	.098	.776	.497	.191	.810	.000	.999	.998	.976	.935
	Ton Nga Chang	.096	.291	1.000	.706	.150	.943	.028	.990	.326	.361	.152
	Hala Bala	.996	.432	.976	.996	1.00	.990	.001	.815	.970	1.00	.984
Ban Tungka	Kho Hong Hill	.049	.985	.472	1.00	.971	.940	1.00	1.00	.034	.000	.008
	Tarutao Island	.483	.027	1.000	.534	.240	1.00	.001	.896	1.00	.996	.647
	Kachong	.000	.988	.004	1.00	.005	.893	.995	.720	1.00	.000	.885
	Kaichon stream	.487	.998	.109	1.00	.999	.307	.415	.888	.998	.134	.975
	Ton Nga Chang	.562	.990	.993	1.00	.964	.565	.995	1.00	.065	.004	.559
	Hala Bala	.936	.996	.884	.951	.523	.984	.807	.995	.959	.988	.997

Table 8. Tukey's HSD Post Hoc Test of male *Hylarana eschatia* from peninsular Thailand *continued.*

Population		TL/ SVL	HW/ SVL	HL/ SVL	TD/ SVL	DF3/ SVL	ED/ SVL	IN/ SVL	UEW/ SVL	FL/ SVL	SEL/ SVL	IO/ SVL
Kachong	Kho Hong Hill	.000	.867	.881	1.00	.397	.550	.995	.970	.069	.938	.002
	Tarutao Island	.000	.132	.360	.572	.001	.999	.006	.453	1.00	.000	.974
	Ban Tungka	.000	.988	.004	1.00	.005	.893	.995	.720	1.00	.000	.885
	Kaichon Stream	.000	1.00	.948	1.00	.092	.081	.299	.258	.997	.000	1.000
	Ton Nga Chang	.000	1.00	.425	1.00	.623	.982	1.00	.814	.102	.118	.207
	Hala Bala	.000	1.00	.946	.952	.005	.799	.655	1.00	.955	.001	1.00
Kaichon Stream	Kho Hong Hill	.859	.930	1.00	1.00	1.00	.991	.838	.917	.219	.004	.005
	Tarutao Island	.087	.098	.776	.497	.191	.810	.000	.999	.998	.976	.935
	Ban Tungka	.487	.998	.109	1.00	.999	.307	.415	.888	.998	.134	.975
	Kachong	.000	1.00	.948	1.00	.092	.081	.299	.258	.997	.000	1.00
	Ton Nga Chang	1.00	1.00	.893	1.00	.998	.047	.474	.999	.267	.549	.313
	Hala Bala	.403	1.00	1.00	.921	.427	.999	1.00	.862	.997	.989	1.00
Ton Nga Chang	Kho Hong Hill	.990	.896	.981	1.00	1.00	.289	.993	.999	1.00	.680	.896
	Tarutao Island	.096	.291	1.00	.706	.150	.943	.028	.990	.326	.361	.152
	Ban Tungka	.562	.990	.993	1.00	.964	.565	.995	1.00	.065	.004	.559
	Kachong	.000	1.00	.425	1.00	.623	.982	1.00	.814	.102	.118	.207
	Kaichon Stream	1.00	1.00	.893	1.00	.998	.047	.474	.999	.267	.549	.313
	Hala Bala	.380	1.00	.998	.975	.328	.519	.691	.984	.907	.428	.631

Table 8. Tukey's HSD Post Hoc Test of male *Hylarana eschatia* from peninsular Thailand *continued.*

Population		TL/ SVL	HW/ SVL	HL/ SVL	TD/ SVL	DF3/ SVL	ED/ SVL	IN/ SVL	UEW/ SVL	FL/ SVL	SEL/ SVL	IO/ SVL
Hala Bala	Kho Hong Hill	.088	.946	1.00	.976	.320	1.00	.924	1.00	.921	.016	.095
	Tarutao Island	.996	.432	.976	.996	1.00	.990	.001	.815	.970	1.00	.984
	Ban Tungka	.936	.996	.884	.951	.523	.984	.807	.995	.959	.988	.997
	Kachong	.000	1.00	.946	.952	.005	.799	.655	1.00	.955	.001	1.00
	Kaichon Stream	.403	1.00	1.00	.921	.427	.999	1.00	.862	.997	.989	1.00
	Ton Nga Chang	.380	1.00	.998	.975	.328	.519	.691	.984	.907	.428	.631

Table 9. Homogeneous subset of male *Hylarana eschatia* from peninsular Thailand.

TL/SVL					
Locality	N	Subset for alpha = 0.05			
		1	2	3	4
Kachong	11	.509645			
Kho Hong Hill	7		.554943		
Ton Nga Chang	5		.563720	.563720	
Kaichon Stream	11		.567600	.567600	
Ban Tungka	27		.581530	.581530	.581530
Hala Bala	3			.594767	.594767
Tarutao Island	3				.605300
P value		1.000	.315	.157	.450

HL/SVL		
Locality	N	Subset for alpha = 0.05
		1
Ban Tungka	27	.391504
Tarutao Island	3	.391900
Ton Nga Chang	5	.395160
Hala Bala	3	.399700
Kho Hong Hill	7	.400529
Kaichon Stream	11	.402282
Kachong	11	.407082
P value		.225

TD/SVL		
Locality	N	Subset for alpha = 0.05
		1
Tarutao Island	3	.103700
Hala Bala	3	.109367
Kho Hong Hill	7	.116100
Ban Tungka	27	.116267
Ton Nga Chang	5	.116580
Kachong	11	.116727
Kaichon Stream	11	.117573
P value		.381

DF3/SVL				
Locality	N	Subset for alpha = 0.05		
		1	2	3
Tarutao Island	3	.035900		
Hala Bala	3	.037700	.037700	
Ban Tungka	27	.044359	.044359	.044359
Kaichon Stream	11	.045409	.045409	.045409
Kho Hong Hill	7		.046629	.046629
Ton Nga Chang	5		.047080	.047080
Kachong	11			.052491
P value		.114	.123	.253

Table 9. Homogeneous subset of male *Hylarana eschatia* from peninsular Thailand *continued*.

ED/SVL		
Locality	N	Subset for alpha = 0.05
		1
Ton Nga Chang	5	.129944
Kachong	11	.133682
Tarutao Island	3	.136387
Ban Tungka	27	.137312
Kho Hong Hill	7	.141095
Hala Bala	3	.141435
Kaichon Stream	11	.144020
P value		.093

IN/SVL			
Locality	N	Subset for alpha = 0.05	
		1	2
Tarutao Island	3	.068933	
Ton Nga Chang	5		.082200
Kachong	11		.082691
Bantungka	27		.083948
Kho Hong Hill	7		.084400
Kaichon	11		.087955
Hala Bala	3		.088633
P value		1.000	.453

UEW/SVL		
Locality	N	Subset for alpha = 0.05
		1
Tarutao Island	3	.083133
Kaichon stream	11	.085564
Ton Nga Chang	5	.087600
Ban Tungka	27	.089181
Kho Hong Hill	7	.090129
Hala Bala	3	.092500
Kachong	11	.093791
P value		.338

FL/SVL		
Locality	N	Subset for alpha = 0.05
		1
Ton Nga Chang	5	.473160
Kho Hong Hill	7	.474643
Hala Bala	3	.489533
Kaichon Stream	11	.497064
Ban Tungka	27	.500948
Kachong	11	.501991
Tarutao Island	3	.503900
P value		.122

Table 9. Homogeneous subset of male *Hylarana eschatia* from peninsular Thailand *continued*.

SEL/SVL				
Locality	N	Subset for alpha = 0.05		
		1	2	3
Ban Tungka	27	.161522		
Tarutao Island	3	.164100	.164100	
Hala Bala	3	.164667	.164667	
Kaichon stream	11	.167982	.167982	
Ton Nga Chang	5		.174660	.174660
Kho Hong Hill	7			.181100
Kachong	11			.184609
P value		.689	.144	.197

IO/SVL				
Locality	N	Subset for alpha = 0.05		
		1	2	3
Tarutao Island	3	.090733		
Kachong	11	.094009	.094009	
Hala Bala	3	.094467	.094467	
Kaichon	11	.094709	.094709	
Ban Tungka	27	.096496	.096496	.096496
Ton Nga Chang	5		.101480	.101480
Kho Hong Hill	7			.105457
P value		.617	.308	.131

HW/SVL			
Locality	N	Subset for alpha = 0.05	
		1	2
Tarutao Island	3	.267200	
Hala Bala	3	.283267	.283267
Ton Nga Chang	5	.283380	.283380
Kachong	11	.284227	.284227
Kaichon Stream	11	.285073	.285073
Ban Tungka	27		.286930
Kho Hong Hill	7		.290257
P value		.050	.894

Table 10. Agglomeration schedule of male *Hylarana eschatia* from peninsular Thailand.

Agglomeration Schedule						
	Cluster Combined			Stage Cluster First Appears		Next
Stage	Cluster 1	Cluster 2	Coefficients	Cluster 1	Cluster 2	Stage
1	91	105	0.000	0	0	28
2	76	113	.004	0	0	21
3	109	120	.005	0	0	34
4	98	127	.006	0	0	5
5	98	111	.008	4	0	37
6	83	129	.011	0	0	9
7	130	131	.013	0	0	21
8	74	122	.015	0	0	42
9	83	108	.016	6	0	36
10	110	134	.017	0	0	29
11	80	101	.021	0	0	17
12	79	99	.024	0	0	23
13	114	117	.027	0	0	19
14	72	106	.031	0	0	40
15	94	118	.036	0	0	31
16	82	89	.037	0	0	28
17	80	97	.038	11	0	35
18	100	112	.041	0	0	53
19	96	114	.046	0	13	33
20	124	125	.047	0	0	64
21	76	130	.047	2	7	33
22	116	119	.048	0	0	40
23	71	79	.050	0	12	44
24	78	92	.053	0	0	38
25	73	133	.054	0	0	26
26	73	95	.063	25	0	44
27	121	123	.068	0	0	58
28	82	91	.074	16	1	37
29	103	110	.079	0	10	48
30	75	87	.091	0	0	51
31	94	107	.093	15	0	46
32	68	81	.103	0	0	45
33	76	96	.108	21	19	42
34	85	109	.108	0	3	43
35	80	84	.110	17	0	43
36	83	128	.114	9	0	49
37	82	98	.125	28	5	50
38	69	78	.128	0	24	45

Table 10. Agglomeration schedule of male *Hylarana eschatia* from peninsular Thailand *continued*.

	Cluster Combined			Stage Cluster First Appears		Next
Stage	Cluster 1	Cluster 2	Coefficients	Cluster 1	Cluster 2	Stage
39	93	126	.139	0	0	41
40	72	116	.173	14	22	49
41	93	115	.200	39	0	46
42	74	76	.215	8	33	52
43	80	85	.246	35	34	47
44	71	73	.317	23	26	57
45	68	69	.329	32	38	57
46	93	94	.368	41	31	54
47	80	102	.400	43	0	52
48	90	103	.400	0	29	51
49	72	83	.412	40	36	50
50	72	82	.433	49	37	53
51	75	90	.433	30	48	63
52	74	80	.573	42	47	54
53	72	100	.666	50	18	59
54	74	93	.873	52	46	59
55	70	77	1.000	0	0	61
56	88	104	1.001	0	0	60
57	68	71	1.076	45	44	61
58	121	132	1.171	27	0	63
59	72	74	2.263	53	54	62
60	86	88	2.683	0	56	66
61	68	70	2.891	57	55	62
62	68	72	3.626	61	59	64
63	75	121	4.564	51	58	65
64	68	124	4.678	62	20	65
65	68	75	6.207	64	63	66
66	68	86	10.977	65	60	0