

## **A Biogeographic Synthesis of the Amphibians and Reptiles of Indochina**

Authors: Bain, Raoul H., and Hurley, Martha M.

Source: Bulletin of the American Museum of Natural History, 2011(360)  
: 1-138

Published By: American Museum of Natural History

URL: <https://doi.org/10.1206/360.1>

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# A BIOGEOGRAPHIC SYNTHESIS OF THE AMPHIBIANS AND REPTILES OF INDOCHINA

RAOUL H. BAIN

*Division of Vertebrate Zoology (Herpetology)  
and Center for Biodiversity and Conservation,  
American Museum of Natural History*

*Life Sciences Section  
Canadian Museum of Nature, Ottawa,  
ON Canada*

MARTHA M. HURLEY

*Center for Biodiversity and Conservation,  
American Museum of Natural History  
Global Wildlife Conservation, Austin, TX*

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTORY

Number 360, 138 pp., 9 figures, 13 tables

Issued November 23, 2011

## CONTENTS

Abstract . . . . .	4
Introduction . . . . .	4
Quality of the Data. . . . .	6
Geological History of Indochina . . . . .	7
Current Geography of Indochina . . . . .	9
Northern Uplands and Lowlands . . . . .	9
Annamite Uplands and Lowlands. . . . .	10
Lower Mekong Watershed. . . . .	11
Cardamom Uplands and Lowlands. . . . .	11
Coasts and Islands . . . . .	11
Current Climate and Vegetation of Indochina . . . . .	12
Northern Uplands and Lowlands . . . . .	12
Annamite Uplands and Lowlands. . . . .	13
Lower Mekong Watershed. . . . .	14
Cardamom Uplands and Lowlands. . . . .	14
Coasts and Islands . . . . .	14
Paleoclimate and Paleovegetation of Indochina . . . . .	15
Review of Regional Herpetofaunal Biogeography . . . . .	16
Materials and Methods. . . . .	19
Species Included in the Analysis. . . . .	19
Subregions of Indochina . . . . .	20
Endemism and Biogeographic Affinities to Areas Outside Indochina . . . . .	21
Ecological Characteristics . . . . .	21
Analytical Methods. . . . .	24
Results . . . . .	24
(1) Relationship of Subregional Area to Species Richness, Endemism, and Survey Effort . . . . .	24
(1a) Relationship of Species Richness and Endemism to Subregional Area . . . . .	24
(1b) Relationship of Survey Effort to Subregional Area . . . . .	25
(2) Taxonomic Distribution of Species Richness and Endemism . . . . .	25
(3) Geographic Distribution of Richness and Endemism. . . . .	26
(3a) Species Richness. . . . .	26
(3b) Endemism . . . . .	27
(4) The Occurrence of Nonendemic Faunas. . . . .	27
(4a) South China. . . . .	30
(4b) Mainland Southeast Asia . . . . .	30
(4c) Malaya . . . . .	30
(4d) Pan-Asia Fauna . . . . .	30
(5) Ecological Characteristics of Indochina's Herpetofauna. . . . .	31
(5a) All Herpetofaunas . . . . .	31
(5b) Endemism . . . . .	33
(5c) Ecological Correlates of the Fauna. . . . .	35
(6) Affinities Among Subregions . . . . .	35
(6a) All Herpetofaunas . . . . .	35
(6b) Amphibians . . . . .	35
(6c) Snakes . . . . .	35
(6d) Lizards . . . . .	36
(6e) Turtles . . . . .	36
(6f) Endemics . . . . .	37
Discussion . . . . .	37
Regional Patterns of Diversity . . . . .	37
Northern Uplands and Lowlands . . . . .	37

The Annamites, Southern Lao Uplands, and Central–South Vietnam Lowlands . . .	44
The Lower Mekong Watershed and Cardamom Uplands and Lowlands . . . . .	48
Coasts and Islands . . . . .	50
General Patterns of Distribution . . . . .	51
Endemic Species . . . . .	51
Nonendemic Fauna . . . . .	53
Characterization of Indochina’s Herpetofauna . . . . .	54
Directions for Further Research . . . . .	55
Conclusions . . . . .	59
Acknowledgments . . . . .	60
References . . . . .	61
Appendix 1. Definitions of Subregions of Indochina . . . . .	89
Appendix 2A. Diversity and Distribution of Indochinese Herpetofauna . . . . .	90
Appendix 2B. References and Comments: Diversity and Distribution of Indochinese Herpetofauna . . . . .	118
Appendix 3. Species with Unconfirmed Occurrence in Indochina . . . . .	138

## ABSTRACT

Indochina (Laos, Cambodia, and Vietnam) houses over 600 species of amphibians and reptiles, roughly a quarter of which has been described within the last 15 years. Herein, we undertake the first biogeographic synthesis of the regional herpetofauna since the first half of the 20th century. We review the literature to measure and map species richness and endemism, the contributions of regional faunas, and ecological characteristics of Indochina's amphibians (Anura, Caudata), and reptiles (Serpentes, Sauria, Testudines, Crocodylia). Dividing Indochina into 19 subregions defined by topography and geology, we estimate the similarity among the regional faunas and appraise the effects of area and survey effort on these comparative analyses.

Variation in species composition is broadly correlated with topography, habitat complexity, and proximity to regions outside Indochina. Indochina's herpetofauna is dominated (in decreasing order) by endemic species, widely distributed species, a South China fauna, and a biota centered in Thailand and Myanmar. Species richness is highest in amphibians and snakes, and peaks in upland forests. Endemism, highest among amphibians and lizards, also peaks in forests of the region's northern uplands and Annamite Range. Endemic species occupy a narrower range of habitats than nonendemics. Patterns of richness and endemism are partially explained by ecological constraints: amphibians and lizards are more restricted to forests than snakes, turtles, and crocodiles; amphibians are more restricted to uplands, turtles to lowlands.

We also assess biogeography in the context of Indochina's geology, climate, and land cover. In northern Indochina, the Red River either acts as or coincides with an apparent dispersal barrier. Herpetofauna in northeastern upland areas are closely allied with fauna of southeastern China. In southern Indochina there is little evidence that the Mekong River represents a biogeographic barrier to the regional herpetofauna. The Annamite Range is composed of at least three distinct units and its elevated species richness and endemism are also noted in adjacent lowlands. Contribution of subtropical biota to Indochina's fauna is significantly greater than that of tropical biota and there is little other evidence for intermixing at intermediate latitudes.

Our results have implications for biogeography and conservation efforts, although they must be viewed in the context of rapidly evolving systematic knowledge of the region's amphibians and reptiles. Future survey efforts, and the phylogenetic analyses that come from them, are essential for supporting regional conservation efforts, as they will better resolve the known patterns of amphibian and reptile richness and endemism.

## INTRODUCTION

Indochina, which includes the modern Southeast Asian nations of Cambodia, Laos, and Vietnam, has long been recognized as a region with globally important levels of biodiversity (fig. 1) (Myers et al., 2000). Indochina is a geologically and topographically complex region, with intricate current and historical climatic patterns that contribute to its rich biotic diversity (e.g., Fontaine and Workman, 1997; Hall, 1998; An, 2000; Morley, 2000; Hall, 2001; Sterling et al., 2006). A significant portion of this biodiversity is its terrestrial and aquatic herpetofauna, with 605 recorded species of amphibians and reptiles (Frost, 2010; Uetz, 2010). There is a long history of exploration of the region (e.g., White, 1824; Mouhot, 1864;

Morice, 1875; Tirant, 1885), but the first major herpetological field investigations were carried out by Smith, starting in the 1920s (e.g., Smith, 1920). There remains a large gap in our knowledge of Indochina's herpetofaunal diversity and distribution, particularly in comparison with most of the region's other vertebrate faunas (e.g., Inger, 1999; Ohler and Delorme, 2006; Stuart et al., 2006b; Bain et al., 2007a; Grismer et al., 2007a; Stuart et al., 2010b). The most recent regional syntheses date to the first half of the 20th century, when Bourret treated each major herpetofaunal group in a separate monograph (snakes, 1936; turtles, 1941a; amphibians, 1942; lizards, 2009). Biogeographic theories addressing the diversity and distribution of Indochina's amphibians and reptiles are relatively simple, based on dated systematic

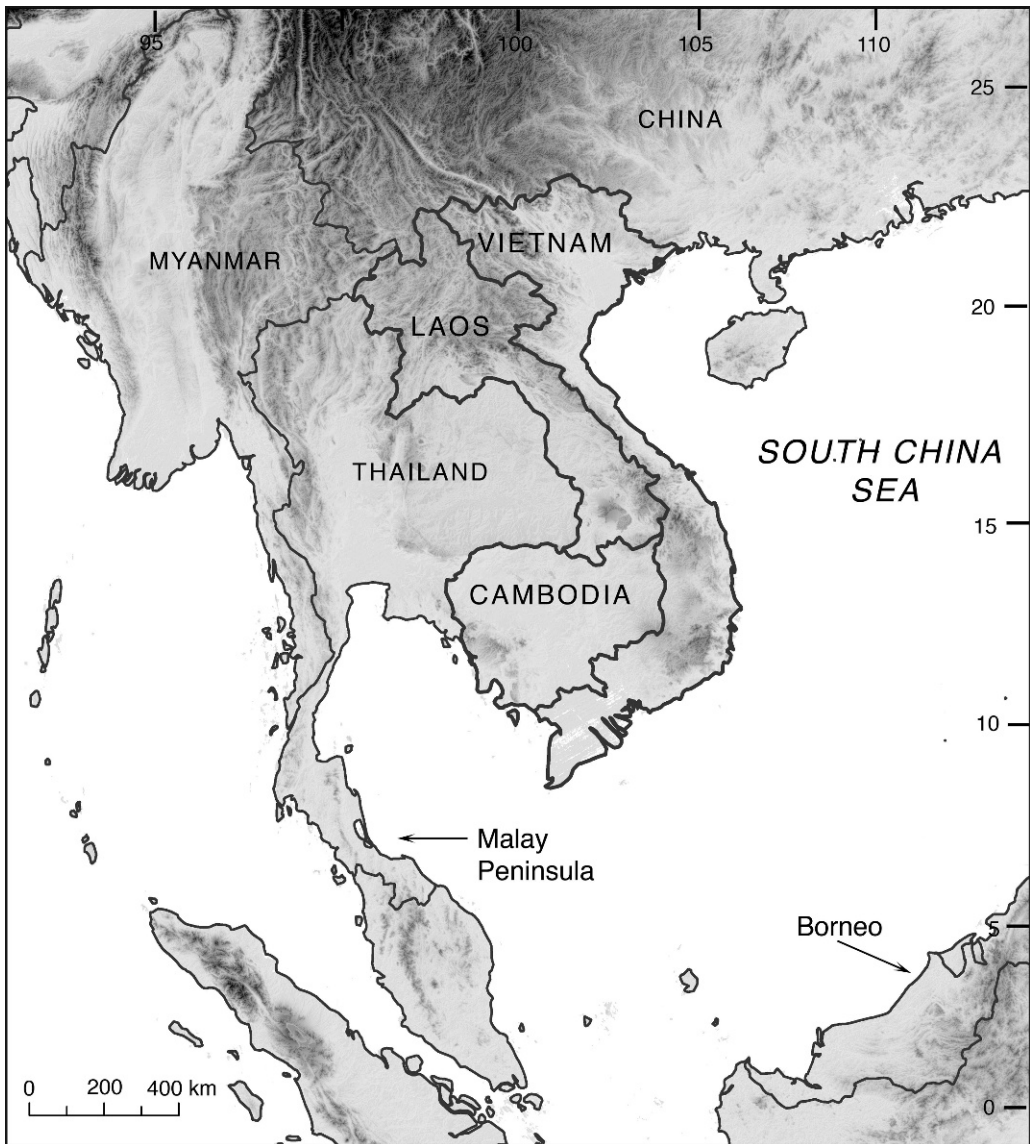


Fig. 1. Indochina (Laos, Cambodia, and Vietnam) and region in Southeast Asia.

and anecdotal evidence, and have been poorly, if ever, tested (e.g., Smith, 1931; Bobrov, 1997).

The need to synthesize information on Indochina's herpetofauna is pressing, given severe threats from human-induced pressures (Mittermeier et al., 1999, 2004). Land use has dramatically lowered the amount of forested area, which is increasingly being converted to settled agricultural areas (Fox et al., 2000; Baltzer et al., 2001). Remaining forests are

threatened by sophisticated hunting and trading practices, which have decimated local amphibian and reptile populations and extirpated species from large areas of Indochina (Li and Wang, 1999; Mateus, 2001; Stuart et al., 2000a; Stuart et al., 2002; Platt et al., 2004). These two primary threats have increased over the past 15 years with the expansion of urban markets and increasing representation of the region in the global economy (Yiming and Dianmo, 1998; Cohen,

2002; Nguyen, 2003; D'haeze et al., 2005; Seto and Fragkias, 2007). Reptiles comprise the largest portion of animals found in trade in Vietnam (TRAFFIC, 2000), and the regional trade in turtles has reached alarming rates (Hendrie, 2000; Stuart and Timmins, 2000; Stuart et al., 2000a; Tana et al., 2000). This is highly relevant to global biodiversity conservation since Indochina's freshwater turtle species richness is second only to China's in Asia (Stuart and Thorbjarnarson, 2003). To date, amphibians and reptiles have largely been left out of regional conservation decision-making processes in favor of better-known and more charismatic vertebrate taxa (e.g., Duckworth and Hedges, 1988; Geissmann et al., 2000; Nadler et al., 2003; Birdlife International in Indochina, 2004). When herpetofaunas have been included, it is most often in the context of their abundance in the wildlife trade and not their geographic distribution, species richness, and ecology (e.g., Le and Broad, 1995; Stuart et al., 2000a).

Herein, we present a modern synthesis of amphibian and reptile species richness and distribution patterns in Indochina and its surrounding areas. We quantify the relative contributions of endemic species, regional faunas, and ecology to the biogeography of amphibians and reptiles in Vietnam, Laos, and Cambodia and address the major, nonexclusive biogeographic hypotheses that have been proposed to explain Indochina's floral and faunal diversity. Proposed explanations include the following:

- (a) Indochinese species composition results from the intersection of a subtropical and temperate biota whose major repositories are in the north with a tropical biota whose major repositories are in the south (e.g., Smith, 1931; Bourret, 1936a, b, 1941a, 1942; Bobrov, 1997; MacKinnon, 1997; Averyanov et al., 2003; Orlov, 2005; Sterling et al., 2006);
- (b) the Red River, which bisects northern Vietnam, forms a biogeographic barrier to both flora and fauna (e.g., Delacour et al., 1928; MacKinnon, 1997; Geissman et al., 2000; Orlov et al., 2001a; Averyanov et al., 2003);
- (c) the Mekong River, the longest in Southeast Asia, forms a biogeographic barrier to fauna (Yongcheng et al., 1994; Fooden, 1996; Meijaard and Groves, 2006);
- (d) The Annamite Range, the region's dominant upland formation, represents an area (or areas) of elevated endemism (Stattersfield et al., 1998; Baltzer et al., 2001; Sterling et al., 2006).

We hope that this analysis will focus future regional efforts in systematics, ecology, biogeography, and conservation. To place our present efforts in context, we include a description of current data constraints, an account of the region's current and historical geology, climate, and vegetation, and a review of the regional herpetofaunal biogeography.

#### QUALITY OF THE DATA

Any analysis of the Indochinese herpetofauna must include a discussion of the factors that affect data quality. One influential factor is a history of disparate sampling, both in scale of effort and scope of localities (e.g., see comments in Inger, 1999; Inger et al., 1999; Daltry and Chheang, 2000; Ohler et al., 2000, 2002; Bain and Nguyen, 2004b; Teynie et al., 2004; Stuart, 2005b). Political unrest and extensive military activity in all three countries put a virtual stop to survey efforts by foreigners from the early 1940s to the early 1980s. Researchers from Soviet bloc countries were allowed to work within the borders of Vietnam and Laos starting in the early 1980s. Foreign scientists from "Western" nations were only granted access in the 1990s, and to this day, many border areas remain tightly controlled or completely out-of-bounds to foreign researchers. Foreign presence is significant, since it has markedly increased the capacity for Vietnamese, Lao, and Cambodians to study their own fauna. Currently, there are over 25 trained Vietnamese herpetologists, but there is only one Lao herpetologist and one Cambodian herpetologist. As a result, Indochina's reported herpetofaunal species richness and distribution are incompletely understood and potentially biased to reflect survey effort rather than true species composition and range. The true ranges even of well-known species remain imperfectly known and continue to be modified (e.g., Ohler and Delorme, 2006; Stuart, 2006; Bain et al., 2007b; Grismer et al., 2007a; Nguyen et al., 2007a, b, c;

Ohler, 2007; Teynie and David, 2007; Grismer et al., 2008b; Rowley et al., 2010; Stuart et al., 2010b).

As a result of this, much of the Indochinese amphibian and reptile diversity has been described only in the past decade and a half, owing to a recent resurgence of sampling effort concomitant with regional political stability (e.g., Duckworth et al., 1999; Inger et al., 1999; Daltry and Chheang, 2000; Ohler et al., 2000; Orlov et al., 2001a; Teynie et al., 2004; Stuart et al., 2006c; Bain et al., 2007b). The reported distributions of these newly described species may be misleading since many are currently known only from their type localities. Thus, reference to species that are endemic or have restricted ranges must be tempered by the knowledge that these reported ranges may be smaller than their true ranges, pending further survey effort. This current state of incomplete knowledge has also constrained distributional analyses, since the ranges of many species cannot be analyzed via range limits, or grid occurrences (Williams et al., 1999; Elith et al., 2006).

There are also multiple taxonomic challenges to an analysis of Indochina's herpetofauna. Identification remains difficult for many species (e.g., Malhotra and Thorpe, 2004a, b; Matsui et al., 2005; Bain et al., 2006a, b; Ohler and Delorme, 2006; Ohler, 2007; Stuart et al., 2006b; Vogel and David, 2006; Bain et al., 2009c). These alpha taxonomic problems have been compounded by poor integration of taxonomy between China and the countries of Mainland Southeast Asia, resulting in many species' ranges terminating abruptly at political borders. As a result, the currently reported distributions of the Indochinese herpetofauna likely exclude species that are present in China, and concurrently inflate the number of endemic species restricted to only one side of the border. This cross-border communication gap also biases the ranges of species found outside Indochina.

The recent discovery of regional species complexes, or cryptic species—groups of similar-looking species that have historically been believed to represent a single, wide-ranging species—have added to these alpha taxonomic challenges (e.g., Ohler and Delorme, 2006; Stuart et al., 2006b, and

references therein). The use of molecular data to assist in the delimitation of cryptic species boundaries within Indochinese species formerly considered widespread has greatly increased the known species richness of all of Mainland Southeast Asia, mirroring a global trend (e.g., Toda et al., 1998a; Chan et al., 2001; Evans et al., 2003; Köhler et al., 2006; Stuart and Bain, 2008).

Ecological reports of amphibians and reptiles of the region also suffer from uneven quality, as they are based primarily on field observations from inventory studies. Ecological studies of herpetofaunas in Mainland Southeast Asia are largely limited to tadpole community analyses in Thailand (Heyer, 1971, 1973, 1974; Wassersug et al., 1981), accounts of stomach contents from adult amphibians and reptiles from Vietnam (Kuzmin and Tarkhshnivili, 1997; Ziegler and Weitkus, 1999a, b; Ziegler, 2002), and some disparate studies or observations for individual species (e.g., Pope, 1935; Taylor, 1962; Dring, 1979; Tarkhshnivili, 1995; Orlov, 1997). This is problematic because, in addition to the sampling limitations outlined above, species may only be encountered when they are out of the water, aboveground, or down from the trees, and this observational bias may hide their essential ecology. Inadequate study can also hide a species' complex ecology, such as that of the Vietnamese salamander, *Paramesotriton deloustali*, which was long assumed to be an obligate aquatic, but instead has a bimodal life history as an aquatic adult and a terrestrial juvenile (Darvsky and Salomatina, 1989).

#### GEOLOGICAL HISTORY OF INDOCHINA

Indochina is a geological collage of basaltic, granitic, and sedimentary formations, which has evolved through volcanic activity, alluvial deposition, and the imperfectly understood interactions of known lithosphere plates (Hutchinson, 1989; Hall, 1998). Today the Indochinese Peninsula lies along Mainland Southeast Asia's eastern rim where it is united along its southern half with the shallow Sunda Shelf, whose emergent sections form the Malay Peninsula (including parts of Myanmar, Thailand, and Malaysia) and the Greater Sunda Islands (including



Sumatra, Java, and Borneo) (Hutchinson, 1989).

Until 400 Mya, the continental blocks that would eventually amalgamate to form Indochina were attached to the northern and eastern margins of greater Gondwanaland. In the early Carboniferous (ca. 350 Mya) a series of terranes, including the South China, Indochina, and East Malaya blocks, separated from Gondwanaland and migrated northwards, coalescing again at higher latitudes to form the equatorial continental body of Cathaysialand (Gatinsky and Hutchinson, 1986; Metcalfe, 2001; Nagy et al., 2001). Around 300 Mya a second set of continental slivers, including the Sibumasu block, began rifting from Gondwanaland, eventually separating around 270 Mya (Metcalfe, 2001). These two sets of northward-drifting terranes reoriented, accreted, and consolidated during the Late Paleozoic and the Mesozoic eras (400–65 Mya) (Hutchinson, 1989; Metcalfe, 2001). The Cathaysian-affinity Indochina block comprises modern-day Vietnam (except the northeastern portion), Laos, Cambodia, eastern Thailand, and eastern Peninsular Malaysia; the Gondwanian-affinity Sibumasu block includes part of western Yunnan Province, Myanmar's Shan states, northwestern Thailand, Tenasserim, and western Peninsular Malaysia (Gatinsky and Hutchinson, 1986; Metcalfe, 2001). Northeastern Vietnam is part of the South China Platform, which includes portions of western Guangxi Autonomous Region, southern Guizhou, and eastern Yunnan provinces of China (Averyanov et al., 2003). It is bounded by the Song Ma suture zone, which lies parallel to and south of the Red River's course in northern Vietnam, although sections of the South China plate extend in beyond it into northeastern Indochina in places (Findlay, 1999; Lepvrier et al., 2004). A final group of continental blocks, including modern-day southwestern Sumatra, southeastern Borneo, and West Sulawesi, separated from Gondwanaland between 230 and 140 Mya, moving northward and eventually joined the growing Southeast Asian composite (Hutchinson, 1989; Metcalfe, 2001).

Associated with these plate movements were a series of folding events (the Indosinian Orogeny) which largely shaped the topography of Indochina. The initial period of deforma-

tion and folding took place 400–350 Mya, establishing mountains that would later become parts of the Hoang Lien Son and the northern Annamite ranges (Fontaine and Workman, 1978) (see fig. 2). This was followed at 350–300 Mya by the general uplifting of modern-day Indochina and the formation of uplands in Vietnam's central and Southern Annamites (Workman, 1975; Averyanov et al., 2003). The final and most violent period of mountain building (250–240 Mya) was caused by the collisions of Indochina with South China to the northeast and Sibumasu to the west (Workman, 1975; Nagy et al., 2001; Lepvrier et al., 2004), evidenced in the uplands of northern Laos and those along the Vietnamese border with Cambodia and Laos.

By the beginning of the Cenozoic (65 Mya), Mainland Southeast Asia had largely achieved its current configuration, although major tectonic activity continued to have profound effects on its geology and topography and sea level fluctuations controlled the extent of the Sunda Shelf exposed (Workman, 1977; Hall, 1998, 2001). The continental plates of both India and Australia began to separate from Gondwanaland and move northward in the Cretaceous (ca. 140 Mya), although the latter remained connected to Antarctica until ca. 45 Mya (Hall, 1998; Metcalfe, 2001). The Indian plate collided with the Eurasian continent around 50 Mya, and the energy of this on-going event caused the southeastward extrusion and clockwise rotation of the Indochinese peninsula along with internal deformations (Tapponier et al., 1982, 1986; Peltzer and Tapponier, 1988). These deformations are most evident in extensive faulting and folding in northwestern Vietnam and adjacent northern Laos, creating a series of parallel northwest-southeast oriented ridges and valleys (Tapponier et al., 1990; Findlay, 1999; Lepvrier et al., 2004). India's collision with Eurasia also resulted in the rise of the Tibetan Plateau (45–50 Mya to 5–10 Mya) (Harrison et al., 1992; Molnar et al., 1993; Spicer et al., 2003). The slower-moving Australian plate collided with the southern margin of Sundaland around 25 Mya and, combined with other arc and plate movements, resulted in significant reorganization of plate boundaries (Hall, 1998).

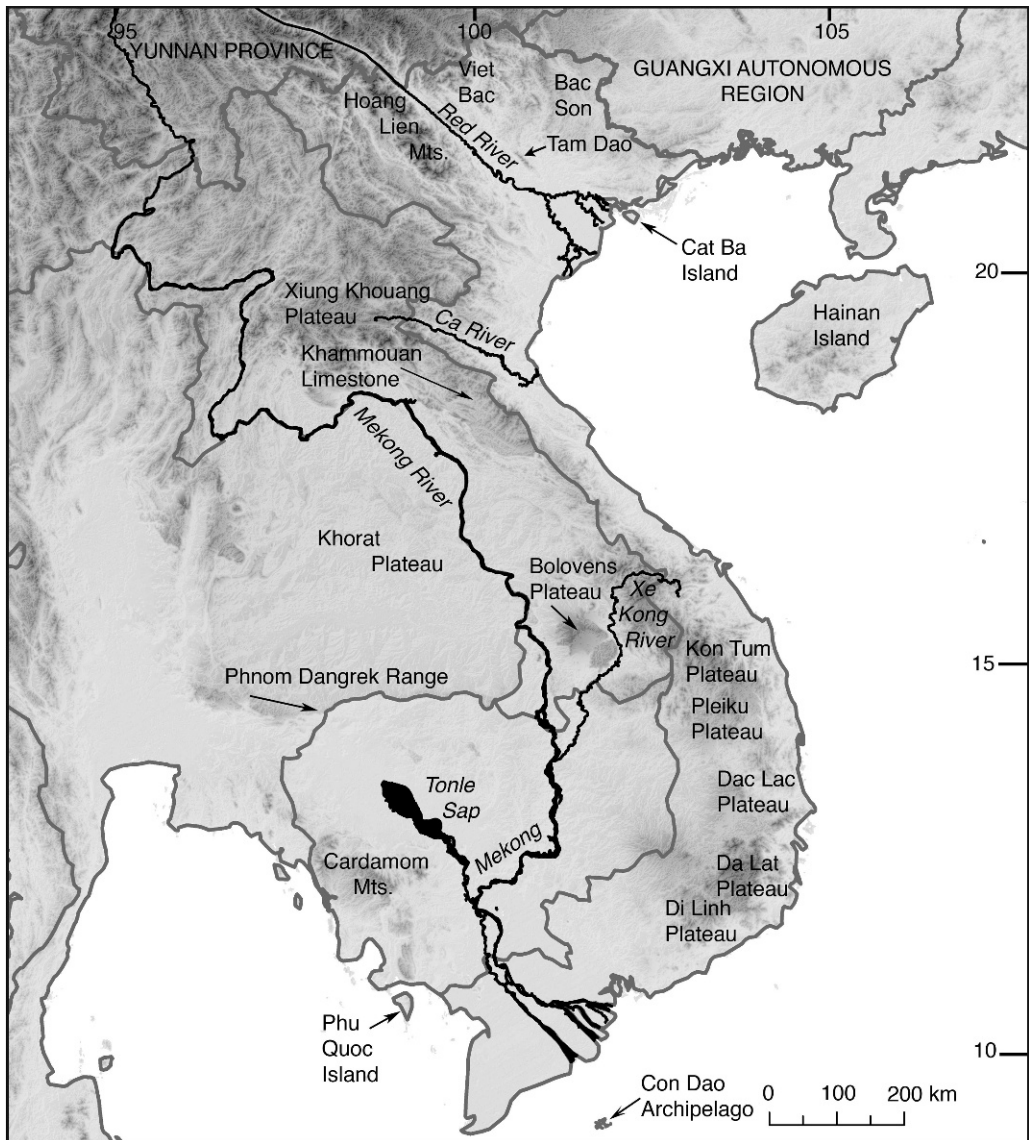


Fig. 2. Major geographic features of Indochina.

These two collisions and subsequent geological events 30–20 Mya led to changes in climate as well as both increased and decreased dispersal opportunities between Asia and Australia (Holloway and Hall, 1998; Hall, 2001).

#### CURRENT GEOGRAPHY OF INDOCHINA

**NORTHERN UPLANDS AND LOWLANDS:** Indochina's complex geological past is ech-

oed in its present-day topography and geomorphology (fig. 2). Northeastern Vietnam, the only section of Indochina formed from the South China block, is bounded to the west by the Red River on a northwest-southeast axis (Fontaine and Workman, 1997; Findlay, 1999). The geology of this region is a combination of metamorphic rocks and marine sediments with granitic extrusions, the largest of which is the Viet Bac Massif directly east of the Red River

at the Chinese border (Hutchinson, 1989; Fontaine, 2002). Many of the limestone sediments here form eroded karst topography, particularly in the Bac Son Massif (Glazek, 1968). Also in the northeast is the Tam Dao Massif, an isolated uplands rising abruptly out of the Red River Delta from 100 m to a peak of 1542 m. Directly west of and parallel to the Red River lies the Hoang Lien Son Range, a granitic extension of the Ailao Shan Mountains of central Yunnan and the Hengduan and southern Himalayan ranges (Harrison et al., 1996; Rundel, 2000). This area is mountainous, with many peaks reaching 2500–3000 m, and contains Indochina's highest point, Fan Si Pan (3143 m). Southwest of this range in northern Vietnam lie regions of complex folding and plateaus (up to 1800 m) divided by deep valleys.

The topography of northern Laos is dominated by northwest-to-southeast trending uplands at 1200–1500 m (with a few peaks over 2000 m) dissected by narrow valleys at 500–700 m (Duckworth et al., 1999). The highest peaks in Laos rise above the 800–1500 m Xiang Khouang Plateau of central northern Laos, with its highest, Phou Bia, reaching 2820 m (Rundel, 2000). This plateau is largely folded sedimentary rock reaching 1000–1500 m along the Vietnam-Laos border, with some granitic intrusives in areas southwest of the Hoang Lien Son (Bridges, 1990).

All of northern Vietnam's uplands lie within the Red River's watershed (Revengea et al., 1998). The Red River flows swiftly southeast through deep, narrow gorges and then into an alluvial valley among low, wide terraces, to form the 10,300 km<sup>2</sup> Red River Delta (Le and Rambo, 1993; Tanabe et al., 2006). Most of northern Laos is also continuous with the uplands of northwestern Vietnam, the Yunnan Plateau, and extreme northeastern Myanmar, but (except for the extreme eastern portion) its waterways drain westward to the Mekong River (Revengea et al., 1998).

**ANNAMITE UPLANDS AND LOWLANDS:** The mountains of the Annamite Range are Indochina's major upland formations, running from northwest to southeast through Laos, Vietnam, and northeastern Cambodia for roughly 1200 km. Delineation of the Annamites (*Saiphou Louang* in Lao and

*Truong Son* in Vietnamese) varies depending on whether geological, geomorphic, or biogeographic criteria are used (e.g., Hutchinson, 1989; MacKinnon, 1997; Rundel, 2000). In general, its eastern, largely Vietnamese, slopes drain into central and southern Vietnam's lowlands and coasts whereas the western, largely Lao slopes form part of the lower Mekong watershed of southern Laos and eastern Cambodia, eventually draining into the Mekong Delta (Yap, 2002). The range's complex geological makeup is the consequence of a history of sedimentation followed by folding, uplift, and volcanic events (Workman, 1975; Hutchinson, 1989; Lepvrier et al., 1997; Findlay, 1999; Lepvrier et al., 2004). In the northern reaches of the Annamites, folded formations in central Laos can reach maximum heights of 2200 m whereas in north-central Vietnam they rarely reach 1300 m (Rundel, 2000). Significant folded limestone formations are exposed across the Northern Annamites in both countries from southwest of the Hoang Lien Son Range to central Vietnam. These include the extensive Khammouan limestone, a semiconnected series of large karst outcroppings and hills, cutting across central Laos and Vietnam for 150 km (Do, 1998; Fontaine, 2002).

South and southeast of these limestone formations, central Indochina's large Kon Tum Massif extends over 250 km north to south and 200 km inland. Separated from the Khammouan limestone by a 600–1000 m lower erosional surface of basaltic plateaus and folded sedimentary rocks, this plateau contains metamorphosed rocks of possible Gondwana origin (Rundel, 2000; Nagy et al., 2001; Osanai et al., 2004). Kon Tum's uplands, the Central Annamites' dominant formation, reach elevations of 1500–2000 m and above, with foothills extending southwest into Cambodia's Rattanakiri Province. West of the Kon Tum Massif is the isolated Boloven Plateau, a saucer-shaped volcanic basalt upland formed during the Quaternary, which reaches 900 m and 1550 m at its southern and northern rims, respectively, with a mean elevation of ca. 1050 m (Rainboth, 1996; Rundel, 2000). Its easternmost slopes are separated from the western foothills of the Annamite Range by the Xe Kong

River valley, which lies at an elevation of ca. 120 m and is 20 km wide at its narrowest point. It is partially surrounded by the Mekong lowlands, which separate it from the Khorat Plateau to the west and the low (maximum 550 m), south-facing Phnom Dangrek escarpment to the southwest that forms the Thai-Cambodian border. The Khorat Plateau, a broad, low (90–200 m) surface of Triassic sandstone sloping gently to the southeast, is centered in northeastern Thailand and extends into southern Laos west of the Mekong (LaMoreaux et al., 1958).

South of the Kon Tum Massif, folded formations continue as a patchwork of volcanic plateaus and younger intrusive granites that as a group comprise the Southern Annamites (Workman, 1975). Directly south, the Pleiku and Dac Lac plateaus (referred to together, along with the Kon Tum Plateau, as the Tay Nguyen Plateau or the Central Highlands) of Vietnam sit at lower elevations (400–800 m), their waterways largely draining west toward the Mekong (Rundel, 2000; Eames and Eames, 2001; Averyanov et al., 2003). Farther south and isolated from these more northern plateaus is the high Da Lat Plateau (800–2400 m; also called the Lam Vien or Lang Bian Plateau) formed from basaltic, quartzite, and granite composites (Stattersfield et al., 1998; Rundel, 2000). This formation extends southwestward to form the Di Linh Plateau in Vietnam's Lam Dong Province, and westward into Cambodia's Monduliri Province. The terraced southern margins of the Annamite Range gradually give way to the Mekong Delta to the south.

**THE LOWER MEKONG WATERSHED:** The Lower Mekong Watershed stretches from northern Laos to the southern tip of Vietnam's Ca Mau Peninsula. The Mekong River flows into Laos in a rock-cut channel ca. 500 m above sea level; it slowly drops and broadens as it flows through Laos, eventually reaching over 14 km in width before plummeting ca. 20 m over the steep cascades of the Khone Falls at the Cambodian border (Rundel, 2000; Gupta et al., 2002). The Mekong lowlands in Laos are composed of Quaternary alluvia and begin at the eastern perimeter of the Khorat Plateau around

Vientiane, extending southward to Champasak Province on the country's southeastern border. To the south, sandstone plains cover much of Cambodia's northern and north-eastern lowlands (Rundel, 2000). Eastern Cambodia is dominated by basaltic areas that gradually merge with the Annamite foothills, whereas central Cambodia's lowlands are largely covered by the alluvial plains of the Tonle Sap basin and the Mekong River Delta (Fontaine and Workman, 1997). The Tonle Sap, connected to the Mekong via the Tonle Sap River, serves as a Mekong reservoir, mitigating flooding and seasonal changes in the river's flow. During the wet season, its tributary reverses flow and the Tonle Sap expands its area from ca. 3000 km<sup>2</sup> to over 15,000 km<sup>2</sup> in surface area (Kite, 2001). This backwashing is responsible for rich alluvial sediment deposition in the fertile Mekong Delta (ca. 50,000 km<sup>2</sup>), including the majority of Vietnam south of 12°N. Flooding can last 4–5 months in the Mekong Delta and reach depths of 3 m depending on topography and the intensity of the monsoon circulation pattern (Buckton et al., 1999). When the Mekong's flow ebbs during the dry season, saltwater intrusion can affect roughly one-third of the delta in Vietnam (Le, 1994).

**CARDAMOM UPLANDS AND CARADAMOM LOWLANDS:** In southwestern Indochina, Cambodia's interior lowlands gently rise to broad slopes that connect with the Cardamom Mountains, an upland formation that includes the Elephant Mountains. These uplands, with rolling peaks reaching 1600 m in several areas and a maximum of 1813 m on Phnom Aural, extend southward to the coast where they fall abruptly to a narrow coastal plain along the Gulf of Thailand. Geologically, the massif is part of Cambodian and Vietnamese islands in Rach Gia Bay and rocky hills on the associated mainland.

**COASTS AND ISLANDS:** Coastal plains of varying, but generally narrow, widths ring the eastern and southern perimeters of Indochina. Vietnam's coastline is an irregular alluvial plain interrupted by outcroppings of the Annamites, most notably from ca. 17°N to the Hai Van Pass at 16°N. Dozens of islands lie offshore of Indochina and were last

connected to the mainland ca. 10,000–15,000 years ago when they were cut off by rising sea levels. Islands in the north are groups of closely associated karst formations with steep precipices rising 300–600 m above a flat sea bottom lying ca. 25 m below sea level (Glazek, 1968; Darevsky, 1999; Fenart et al., 1999). The southern islands include the volcanic Con Dao Archipelago, 100 km southeast of Vietnam's Ca Mau Peninsula, and Phu Quoc (geologically part of the Cardamom Mountains), which sits 11 km south of Cambodia's coastline. The Indochinese peninsula is contiguous with the southern Chinese continental shelf to the north and the Sunda Shelf to the south; shallow marine basins (<120 m) lie under the Gulf of Tonkin and southern offshore areas. However, a steep, fault-controlled shelf characterizes the continental margin along Vietnam's coast between 11°N and 16°N (Rangin et al., 1995).

#### CURRENT CLIMATE AND VEGETATION OF INDOCHINA

Indochina's climate is dominated by monsoon circulation patterns that determine the seasonality of temperature and rainfall throughout southern and Southeast Asia. In the winter, cold, dry northwestern monsoon winds out of central Asia dominate much of Indochina's climate, whereas in the summer, warm, wet southwestern monsoon winds flow from the Indian Ocean and the Gulf of Thailand (An, 2000). These dynamic circulation patterns interact with regional land and ocean configurations, exposing Indochina, particularly Vietnam, to a wide variety of rainfall and temperature regimes (Nguyen et al., 2000). At a regional level, uplands can produce strong orographic effects, which are evident in the rainfall patterns in and around the Cardamom Mountains. At a local level, landscape and elevation changes can be so dramatic that climatic regimes can differ widely among areas that are geographically close (Rundel, 2000).

**NORTHERN UPLANDS AND LOWLANDS:** The climate of much of northern Indochina is subtropical. Short, dry winters (< 50 mm precipitation per month) lasting three to four months (September–March) correspond to the northeastern monsoon winds; summers

are generally the wettest and hottest months, peaking in July and August (Nguyen et al., 2000). There is significant climatic variation in this region of Vietnam and Laos due to topography and distance inland. Annual rainfall in Vietnam's interior lowlands is ca. 1500–2000 mm (1800 mm in Ha Noi) with a dry season of three to four months whereas west in Laos rainfall is generally lower with a dry season of four to five months. Annual monthly temperatures in northern Vietnam's lowlands are highly seasonal, with winter lows of 4°C and summer highs reaching over 40°C; the northern Lao lowlands, sheltered somewhat from the northeast monsoon winds by mountains, experience less variation in temperature (Rundel, 2000). Here the natural vegetation is mixed deciduous forests (including Teak *Tectona grandis*) and semievergreen forests, much of which has been heavily logged and degraded by human activities (Duckworth et al., 1999). Vietnam's northern lowlands were once dominated by broad-leaved evergreen forests but have been largely converted to agricultural use, most extensively in the Red River Delta (Pedersen and Nguyen, 1996; Le, 1997; Wege et al., 1999).

The mountainous areas of northern Vietnam and Laos are cooler and wetter, reaching an extreme in the Hoang Lien Son Range. Mt. Fan Si Pan's climate is almost temperate, with frequent freezing in the two coldest months, two to three snow days per year, and summer highs of 29°C; annual rainfall is 3500 mm and there are no dry months (Nguyen and Harder, 1996; Nguyen et al., 2000). Northern Laos's upland climatic regime is similar to that of northern Vietnam, although its position further inland and more limited topographic variation generally result in lower rainfall (< 3000 mm) and increased temperature variability (Rundel, 2000). Forest composition changes dramatically at 800–1000 m across this region, losing most of its deciduous components as well as evergreen members of the tropical family Dipterocarpaceae. Forests up to 1500 m are largely broad-leaved evergreen formations dominated by Fagaceae and Lauraceae, a forest type widespread throughout Mainland Southeast Asia. Also occurring here are open coniferous forests dominated by a few species of pine (e.g., *Pinus merkusii*, *P. kesiya*). In more

humid conditions above 2000 m, mixed hardwood and coniferous (including *Fokienia hodginsii* and *Podocarpus neriifolius*) forests occur supporting rich epiphytic communities (Rundel, 2000; Averyanov et al., 2003). Forests on the upper slopes of the Hoang Lien Son (> 2000 m) include many relict species (e.g., *Taiwania cryptomeriodes*) and have a strong affinity with Yunnan Province's older, subtropical flora (Nguyen and Harder, 1996; Nguyen, 1998; Farjon et al., 2004; Nguyen et al., 2004). Also found here at 2000–2800 m is a distinctive hemlock (*Tsuga dumosa*) and fir (*Abies delavayi fansipanensis*) forest (Rundel, 2000). Northern Indochina's limestone hills and ridges, including karst formations, generally host wet evergreen forests near their bases, open semievergreen forests at intermediate elevations, and open coniferous forests at the highest altitudes (ca. 1200 m and above) (Rundel, 2000; Whitten et al., 2001; Averyanov, et al., 2003).

**ANNAMITE UPLANDS AND LOWLANDS:** South of the Ca River, central Indochina experiences a wetter monsoon climate, although the timing and degree of seasonality, especially rainfall, can vary widely depending on elevation and exposure to humid winds. In Laos the western foothills and submontane portions (< 800 m) of the northern and central Annamite Range experience a semihumid climate with annual rainfall of 1500–2000 mm and a four-month dry season, whereas along the eastern foothills in Vietnam and extreme northeastern Cambodia, precipitation is generally higher (up to 2500 mm) and the dry season shorter (Rundel, 2000). The lowlands of central and southern Laos receive 2000–3000 mm rainfall per year, except for the western edge along the Khorat Plateau with less than 1500 mm annually (Nguyen et al., 2000; Rundel, 2000). Lowland evergreen forests are extensive along the wetter eastern slopes of the Annamites; on the western side they are found only in those few areas where the annual rainfall exceeds 2500 mm and the dry season lasts three months or less. Semievergreen forests occupy the lowland alluvial plains and foothills up to 900 m in central and southern Laos. Deciduous dipterocarp forests and woodlands with open canopies

and a grassy understory replace them where rainfall is lower (< 1500 m) and the dry periods longer (up to six months) although semievergreen and deciduous dipterocarp forests often co-occur in mosaics depending on local conditions. During the wet season these formations are dotted with temporary pools and inundated areas. In arid regions experiencing repeated anthropogenic burnings, deciduous forest cover is reduced and a savannah-like formation dominates. In these lowland regions of central Indochina, there is often no clear transition between evergreen, semievergreen, and deciduous lowland forest types (Rundel, 2000).

Transitions in forest composition from lowland to montane are sharp in the northern and Central Annamites. Between 800 and 1200 m, climatic conditions vary between semihumid and humid (> 2500 mm annual rainfall) depending on exposure to moisture-bearing winds with the eastern upland slopes of the Central Annamites generally receiving higher rainfall than the western ones (Duckworth et al., 1999; Rundel, 2000). Above these elevations temperatures drop and precipitation is generally higher. The isolated Boloven Plateau, for example, catches the southwestern and northeastern monsoon rains, receiving 4000–5000 mm of rain per year, one of the highest amounts in Laos. Mixed hardwood and coniferous forests replace Fagaceae and Lauraceae forests at higher elevations than in the north, beginning at 1100–1200 m in Vietnam and 1500 m in more humid parts of southern Laos and upland areas in central Indochina receiving sufficient rainfall (> 3000 mm). These areas support broad-leaved evergreen formations with some coniferous elements. In montane habitats at 1600–1800 m that experience frequent fogs and mists, a distinctive, shrubby cloud forest occurs with extensive epiphytes and mosses (Averyanov et al., 2003). Central Indochina's exposed limestone deposits are covered with forests similar to those occurring in the north.

Indochina's climate south of the Kon Tum Massif is similar to the central section's but with less seasonal temperatures. Below 800 m in northern Cambodia and adjacent Vietnam south to approximately 11°N, the climate is generally semihumid with moderate rainfall

(1500–2300 mm) and three to four months of dry season (Nguyen et al., 2000; Rundel, 2000). These regions support evergreen, semievergreen, and deciduous dipterocarp forests, woodlands, and savannah-like habitats depending largely on soil moisture and other local conditions and human activity. The lowland areas surrounding the Da Lat Plateau receive elevated annual rainfall (1500–3000 mm), and are dominated by evergreen forests.

The Da Lat Plateau's upland climate is wettest along its eastern edges where rainfall exceeds 3800 mm and there are no dry months (Rundel, 2000). The climate passes through the same elevational transitions as the Kon Tum Plateau and forest types are also similar, although floristic composition diverges and both uplands harbor significant floral endemism (e.g., orchids). Broad-leaved evergreen and mixed hardwood-coniferous forests dominate the Da Lat Plateau with cloud forests harboring members of the genus *Rhododendron* along the highest, wettest ridges (Rundel, 2000; Averyanov et al., 2003; BirdLife International in Indochina and MARD, 2004). The western extension of the Da Lat Plateau into Mondulhiri Province is also relatively humid because these slopes are exposed to moist southwestern monsoon winds. By contrast, the dry Di Linh Plateau to the southwest lies in the partial rain shadow of Cambodia's southwestern uplands (Rundel, 2000).

**LOWER MEKONG WATERSHED:** From the Tonle Sap basin east to the foothills of the Annamites and southward across the Mekong Delta (excepting western Ca Mau Peninsula) the climate is drier, annual rainfall averages < 1500 mm with extended dry seasons (five to six months), and annual temperature variation is only 2–3°C (Rundel, 2000).

The floodplain of the Tonle Sap basin is dominated by seasonally inundated short tree shrub lands where flooding lasts six to eight months but the soils are not permanently saturated. Peat swamp forests occur in patches along the lake's dry season shoreline where the soils remain saturated year-round. The woody species in these forests are largely deciduous, losing their leaves when they become submerged (Rundel, 2000). The Mekong Delta within Vietnam has been

almost entirely converted to rice cultivation though a few small patches of seasonally inundated grasslands remain (Le, 1994; Buckton et al., 1999). Jutting into the Gulf of Thailand, the Ca Mau Peninsula's western edge receives higher annual rainfall than other areas of the delta (ca. 2300 mm) (Nguyen et al., 2000). Isolated from the Mekong's waterways, Ca Mau is inundated by salt water during both the dry and wet seasons (Le, 1994). This region supports the largest area of peat swamp forest in Indochina, dominated by the paperbark tree *Melaleuca cajuputi* (Safford et al., 1998; Tran et al., 2000).

**CARDAMOM UPLANDS AND LOWLANDS:** The climate of the Cardamom Mountains and adjacent lowlands is also subject to orographic effects. The southwestern slopes of these mountains rise precipitously from the Gulf of Thailand, intercepting the summer monsoons and experiencing high annual rainfalls of 3700–4400 mm with peaks over 5300 mm. These coastal slopes are dominated by wet evergreen forest, whereas the rain-shadowed northern slopes receive only 1500–2000 mm and support semievergreen forests, including significant stands of *Pinus merkusii*. As elsewhere in Indochina, a sharp transition in composition and structure from lowland to montane forests is observed here at 800 m (Rundel, 2000).

**COASTS AND ISLANDS:** Indochina's coasts and islands generally experience the same climatic regime as adjacent inland areas with a few exceptions. Northeastern Vietnam's coastline, from the Chinese border south to the Red River Delta, experiences higher annual rainfall (2000–2500 mm) than the adjacent northern Vietnamese lowlands (Nguyen et al., 2000). In contrast, southern Vietnam's wide coastal plain from Nha Trang south to Phan Thiet lies in the rain shadow of the Southern Annamites; it includes the driest point in Vietnam at Cape Padaran, which receives ca. 750 mm of rainfall annually. The dunes, slopes, and brackish inland pools of this region support unique arid-adapted coastal forests and thickets, including endemic dipterocarp and cycad species (Truong, 1997; Rundel, 2000; Hill et al., 2004). Indochina's mangrove forests are found along Vietnam's northern

and southern delta regions but are largely absent from the exposed central coastline and Cambodia's rocky southern coasts (Phan and Hoang, 1993). The Red River's once extensive mangrove forests have now almost disappeared and Indochina's largest mangrove stands are found on the tip of the Ca Mau Peninsula (Pedersen and Nguyen, 1996; Buckton et al., 1999). Islands directly south of Indochina have higher rainfalls than the nearby mainland (Phu Quoc > 3000 mm; Con Dao > 2000 mm), whereas those off Vietnam's southeastern coast receive ca. 1200 mm (Nguyen et al., 2000). Both Phu Quoc and Con Dao are largely covered with moist lowland evergreen forests and fringed with small mangrove stands (Birdlife International in Indochina and MARD, 2004). Islands off the northeastern coast of Vietnam are predominantly limestone and are covered with limestone vegetation typical of the rest of Indochina (Fenart et al., 1999).

#### PALEOCLIMATE AND PALEOVEGETATION OF INDOCHINA

Southeast Asia's paleoclimate and paleovegetation were strongly influenced by global fluctuations in climate and the appearance and intensification of regional monsoon circulation patterns that mediate seasonality, vegetative communities, and fluctuations in sea level (Hope et al., 2004). Starting in the Tertiary (65 Mya), the earth's climate experienced increasingly dramatic temperature oscillations that reached their apogee in the Quaternary ice ages (2.6–0.01 Mya) (Hewitt, 2000).

Following the relatively cool and dry periods of the Oligocene and earliest Miocene (34–20 Mya), the climate grew warmer and wetter in the early and middle Miocene (20–15 Mya) and tropical Asian forests attained their greatest distributions, reaching as far north as Japan (Morley, 1998, 2000). During much of this period, global sea levels were typically 25 m or more above their present-day level as polar ice caps and glaciers melted (Woodruff, 2010). These warm and moist climates were followed in the late Miocene (12–6 Mya) by a period of cooling and drying; sea levels dropped to a maximum of ca. 30–60 m below present-day levels as water was locked up in the expanding ice caps (Morley,

2000; Miller et al., 2005). During this period of lowered sea levels, the formerly widespread humid forests contracted and seasonally dry forest types expanded (Morley, 1998). During the early Pliocene (5.5–4.2 Mya) a second warming period occurred and sea levels rose again to ca. 50 m above present-day levels (Miller et al., 2005). During periods of lowered sea level, the increase in exposed land area led to decreasing moisture content of the monsoon winds, resulting in cooler and drier conditions. Likewise, moisture content increased and seasonality decreased during warmer periods of marine transgression (Heaney, 1991; Verstappen, 1997). Despite these periodic marine transgressions associated with warming events, much of the Sunda Shelf was emergent throughout the Neogene (23–2.6 Mya) (Hall, 2001).

The uplift of the Tibetan Plateau increased seasonality in eastern and Southeast Asia by shifting patterns of wind and rainfall (Hall, 1998; An, 2000; An et al., 2001; Clift et al., 2002). A significant increase in the elevation of the Tibetan plateau 10–8 Mya is associated with the onset of the Indian and Asian monsoons and later uplifts are linked to the intensification and increased variability of these circulation systems (An et al., 2001). Around 2.8–2.5 Mya the east Asian winter monsoons strengthened. This event, and the possible weakening of the summer monsoons, resulted in a seasonal climate (An et al., 2001; Gupta and Thomas, 2003) that was associated with an overall reduction in the extent of humid forest (Gathorne-Hardy et al., 2002).

In the late Pliocene (ca. 2.5 Mya) the earth began experiencing more rapid and dramatic shifts in climate associated with fluctuations in the extent of polar ice sheets and overall climates became drier and more seasonal than during the Neogene (Verstappen, 1997; Hewitt, 2000; Hope et al., 2004). At the Last Glacial Maximum (LGM; 18,000 years ago) the winter monsoon strengthened and the summer monsoon weakened; as a result rainfall over the Sunda Shelf may have been 30%–50% lower than present levels. Temperatures were reduced by as much as 6–7°C, and sea levels withdrew to a maximum of 120 m below current levels (Wang et al., 1999; Kershaw et al., 2001; Gingele et al.,



2002; Bird et al., 2005); however, there is evidence that despite being cooler the climate was not significantly less humid (Wang et al., 2009).

These Quaternary climate fluctuations had strong effects on the distribution of vegetation in Southeast Asia. Humid montane forest zones and their associated fauna moved downward approximately 700 m during the LGM, and grasslands and pine woodlands replaced evergreen forests in lowland areas with seasonal climates (Heaney, 1991; Hall, 1998; Morley, 2000; Kershaw et al., 2001). Vegetation on the now-exposed Sunda Shelf included savannahs and drier forest types; however, much lowland and submontane evergreen forest remained in less seasonal areas, near the sea, at higher elevations, and along the many rivers covering the shelf (Sathiamurthy and Voris, 2006; Wang et al. 2009). During warming events these shifts in vegetation coverage were reversed. The amount and distribution of wet and dry vegetation types and the extent of forest cover remain uncertain throughout the Quaternary (e.g., Hope et al., 2004; Bird et al., 2005 and references therein). Because of the large amount of exposed land on the Sunda Shelf (>200 million km<sup>2</sup>) during the LGM and the expansion of humid forest zones, rain forests covered a larger area than they do currently; however, due to aridity, these evergreen forests may have been fragmented (Kershaw et al., 2001). It is clear, though, that major forest types expanded in Southeast Asia during the Quaternary's hypothermal phases and that at present evergreen forests cover a substantially smaller area than during the LGM (Cannon et al., 2009; Woodruff, 2010).

Fluctuations in sea level during both the Neogene and the cyclical glacial events of the Plio-Pleistocene provided potential dispersal routes and opportunities for isolation between Mainland Southeast Asia, Hainan Island via the southern Chinese continental shelf, and the islands of the Sunda Shelf. Recent reconstructions of Pleistocene sea levels suggest that, although maximum lows were brief, they remained at 40 m below present levels or lower for more than half of the glacial period (Voris, 2000). Opportunities for successful movement across exposed

land bridges were mediated by the length of time they were emergent, species-specific habitat requirements, and the distribution of moist and dry vegetation covering the bridges (Bird et al., 2005). During warming events these land bridges were flooded, isolating the previously connected land masses. Evidence suggests that isolation by physical or habitat barriers for periods exceeding 1 million years may be associated with speciation events and increased regional diversity (Avice, 2000; Woodruff, 2003). In Southeast Asia, speciation would most likely be associated with events of the Neogene, as there is currently little support for the hypothesis that cyclical Pleistocene environmental changes are responsible for extensive speciation events (Klicka and Zink, 1999; Hewitt, 2000).

#### REVIEW OF REGIONAL HERPETOFAUNAL BIOGEOGRAPHY

The biogeography of Indochina has been classified multiple times using different, and sometimes contrasting, units. Udvardy (1975) placed Indochina within the Indo-Malayan Realm, a widespread region extending from Pakistan to the Greater Sunda Islands, including Hainan Island and portions of southern China. MacKinnon and MacKinnon (1986) and MacKinnon (1997) refined this classification of the Indo-Malayan Realm, splitting Indochina into four units based on biotic distinctiveness: (1) Coastal Indochina, consisting of the coastal regions from the Red River Delta in northeastern Vietnam to the coast of southern Myanmar on the Indian Ocean and including the Cardamom Mountains of Cambodia; (2) South China, consisting of a narrow fringe of land along the south coast of mainland China and Hainan Island that broadens westward as far as the Red River in Vietnam; (3) Annamese Mountains, consisting of two mountain blocks, one centered on Ngoc Linh Mountain in the Central Annamites and one on the Da Lat Plateau in the Southern Annamites; and (4) Indochina, consisting of the extensive inland plains and valleys of the Mekong River, the upper catchments of the Chao Phraya River and the Salween River, and extending to the Himalayan foothills of

southern China. Based on amphibian distributions, Inger (1999) divided Indochina into three biogeographic regions, each of which extends beyond Indochina's boundaries: the Northeast Montane Region extends from northeastern India (Meghalaya, Manipur, and Nagaland) across northern portions of Myanmar and Thailand, as well as the central and northern portions of Vietnam, northeastern Cambodia, and almost all of Laos; the Thai-Lao Dry Plateau includes northwestern Thailand and the remaining western portion of Laos; and the Southeast Asian lowlands include all coastal regions as well as the eastern and southern lowlands of Vietnam, the remaining areas of Cambodia, and southern Thailand and Myanmar above the Isthmus of Kra. Inger's (1999) arrangement is in partial disagreement with the other two classification systems. Aside from recognition of the Annamite uplands, none of these classifications has a fine enough resolution to address most biogeographic questions within Indochina's borders.

The current hypotheses explaining Indochina's herpetofaunal biogeography include various combinations of dispersal (colonization and recolonization), vicariance, and in situ differentiation. Results of several phylogenetic analyses suggest that major amphibian radiations including Ichthyophidae, Dicroglossidae, Ranidae, and Rhacophoridae, as well as lineages of the reptile family Agamidae, dispersed from the Indian subcontinent after its collision with Eurasia in the Tertiary, and from there throughout the Southeast Asian mainland and its accompanying island archipelagoes (e.g., Richards and Moore, 1998; Honda et al., 1999; Richards et al., 2000; Bossuyt and Milinkovitch, 2001; Gower et al., 2002; Roelants et al., 2004; Che et al., 2010).

Sea level fluctuations throughout the Cenozoic created alternating periods of connectivity and isolation between the Asian mainland and nearby shallow-shelf islands, allowing for multiple colonization and recolonization events (e.g., Hall, 1998; Lazell, 1999; Voris, 2000). This has been proposed to explain the herpetofaunal overlap among Hainan Island, mainland southeastern China, and northeastern Vietnam (e.g., Lazell, 1999; Chou et al., 2001; Honda et al., 2000a,

2001; Ota et al., 2002; see also Stuart and Parham, 2004; Yu et al., 2007a). These cycles of isolation and reconnection have also been invoked to explain the disjunct island and mainland distributions of several lineages: aquatic homalopsine and natricinae snakes (Malnate, 1960; Inger and Voris, 2001); the pitvipers *Daboia russelli siamensis* and *Calloselasma rhodostoma* (Wüster et al., 1992, 1995; Thorpe et al., 2007); wormsnakes of the genus *Calamaria* (Inger and Voris, 2001); green grass lizards of the genus *Takydromus* (Chou et al., 2001); torrent frogs of the genera *Amolops* and *Meristogenys* (Inger and Voris, 2001); and tree frogs of the genus *Philautus* (Inger and Voris, 2001).

The nested phylogenetic position of mainland lizard species *Physignathus cocincinus* among Australian agamids is also explained by an ancestral dispersal from Southeast Asia into Australia via Sundaic land bridges, and subsequent recolonization of Southeast Asia (Honda et al., 2000b). Similarly, within the Asian grass lizard genus *Takydromus*, nested phylogenetic positions of mainland species among island species have been explained by dispersal from Southeast Asia and southern China to east Asian islands with a subsequent recolonization of the continent (Ota et al., 2002), or by a bifurcated dispersal from southeast China, west to Mainland Southeast Asia, and east to east Asian islands (after Lin et al., 2002). Flying lizards of the genus *Draco* and fanged frogs of the genus *Limnonectes* also have mainland species nested among Sunda island clades, suggesting ancestral dispersal between the mainland and islands (Honda et al., 1999; Emerson et al., 2000; Evans et al., 2003). Isolation due to fluctuating sea levels has also been used to explain the endemism of Vietnam's offshore islands (the geckoes *Cyrtodactylus condorensis* and *C. paradoxus* and the blind lizard *Dibamus kondaoensis*; Darevsky and Szczerbak, 1997; Darevsky, 1999; Honda et al., 2001), and the restriction of some reptiles to Indochina's islands and the immediately adjacent mainland (e.g., *Leiolepis guntherpetersi*; Darevsky, 1999).

Dispersal to and from Mainland Southeast Asia to North America via Beringia has also been used to explain disjunct Asian and American distributions of lineages, such as

those of natricine snakes (Malnate, 1960). The same dispersal route has been proposed for those lineages that have American species embedded within Asian clades, such as the tortoise genus *Gopherus* (Spinks et al., 2004; Le et al., 2006), and the skink genera *Scincella* and *Sphenomorphous* (Honda et al., 2003; Macey et al., 2006). Similar explanations have been given for Asian species embedded within clades of American species, such as the treefrog genus *Hyla* (thought possibly to have dispersed via Beringia; after Faivovich et al., 2005, and Macey et al., 2006), elapid snakes (Slowinski and Keogh, 2000; Slowinski et al., 2001), and ranid frogs (e.g., Macey et al., 2006).

The uplift of the Tibetan Plateau has also been postulated as a major vicariance event, in association with dispersal scenarios, to explain patterns of current richness and distribution of *Ophisaurus*, a genus of glass lizards (Macey et al., 1999). Macey et al. (1999) posited that the nested position of Old World anguids within New World lineages was due to a complex dispersal route, which started from North America first to western and then to eastern Asia. These east Asian populations were subsequently isolated by the Tibetan Plateau, and they diversified and crossed Beringia to reinvade North America. Ancestors of dicroglossid frogs closely linked to montane streams diversified in the mountains and valleys throughout the Himalayas, and split into the genera *Paa* and *Nanorana* (Che et al., 2010). Estimates of genetic divergence suggest that the split into the lineages *Paa* and *Nanorana* occurred ca. 19 Mya due to vicariant events driven by the continuous uplift of the Himalayas and Tibetan Plateau system (Che et al., 2010). Che et al. (2010) also infer that another taxonomic split of this dicroglossid group is associated with an as yet undescribed major tectonic event along the Truong Son Mountain Range ca. 24 Mya. This orogenic event served to divide the western highlands and eastern lowlands along the Ailao Shan–Red River shear zone, which runs from southwestern China along the coast of Vietnam south to the Hai Van Pass.

Genetic divergence among mainland and island species has also been used to estimate timing of colonizing and recolonizing events.

Ancestors of the dicroglossid frog genus *Limnonectes* are hypothesized to have begun multiple dispersal events between the mainland and the Greater Sundas over 50 Mya (Emerson et al., 2000; Evans et al., 2003). Ancestral skinks of the genus *Tropidophorus* dispersed from Mainland Southeast Asia to the Sundas ca. 23 Mya; following 9 Mya of isolation by fluctuating sea levels, these populations speciated allopatrically and reinvaded Indochina (Honda et al., 2006). Alfaro et al. (2008) estimated a similar time frame (22 Mya) for the invasion of the Sundas by Mainland Southeast Asian ancestors of homalopsine water snakes. However, because of data limitations, they were not able to estimate when this lineage reinvaded the mainland.

Cenozoic temperature fluctuations also could have affected herpetofaunal biogeography by causing changes in the distribution of vegetation types (Inger, 1999). During cooling periods, montane amphibians and reptiles are thought to have dispersed to lower elevations along with the upland flora. This allowed these previously montane-restricted faunas to migrate across lowland areas to other montane regions. Subsequent warming events caused montane floras to recede to higher elevations, again restricting the movement of species between highlands. These processes have been used to explain both the occurrence of disjunct montane populations of widespread species found throughout Indochina, e.g., the frogs *Ophryophryne microstoma*, *Quasipaa boulengeri*, and *Babina chapaensis* (Inger, 1999), as well as the diversity and sympatric distributions of widespread species complexes, e.g., *Odorrana livida*, *Limnonectes "kuhlii,"* and *Leptotalax pelodytoides* (Inger, 1999; Emerson et al., 2000).

Only recently have phylogenetic analyses employed rich-enough sampling to understand complicated evolutionary scenarios of regional herpetofauna. Zhang et al. (2009) recovered deep genetic structure within *L. ailaonicum* (known from southwestern China and northeastern Vietnam) that coincides with the major river valley systems in this region. They present further evidence to suggest that these clades diverged in allopatry. Zhang et al. (2009) also noted that tight

mtDNA haplotype clustering suggests historical population isolation, possibly due to specific habitat requirements. *Leptobrachium ailaonicum* breeds in cold, slow-flowing water found at midelevation montane streams. This habitat requirement limits the rate of dispersal and possible migration routes of *L. ailaonicum* through intervening lowland areas. If lowland river valleys (including the Red River valley) are considered natural barriers to dispersal, a past vicariance hypothesis would be consistent with the geological history and topography within the range of *L. ailaonicum*. Statistical dating methods placed the divergence times in late Miocene to mid-Pliocene, roughly congruent with the most significant uplift of Mount Ailao in southwestern China.

Zhang et al. (2009) further suggest that pairs of divergent lineages coexist at two sampled localities, which implies secondary contact after initial divergence. They suggest that this secondary contact was caused by dispersing downslope and across the historical lowland barriers during Pleistocene glacial cooling. In the following interglacial periods until the present, populations of *L. ailaonicum* would again have been isolated in the virtual islands of fragmented mountain habitats.

There are also lineages whose distributional and phylogeographic patterns of diversity remain unexplained by dispersal and vicariance scenarios. Phylogenetic analyses of the widespread turtle genus *Mauremys* (family Geoemydidae) are equivocal in explaining the disjunct distribution of the genera's Southeast Asian species and its Middle Eastern, North African, and Eastern European members (e.g., Feldman and Parham, 2004).

## MATERIALS AND METHODS

### SPECIES INCLUDED IN THE ANALYSIS

The basic taxonomic units for analysis were species and lineages of species. As with any classification scheme of Southeast Asian herpetofauna, the paucity of phylogenetic estimates, contemporary taxonomic identification keys, and other species-boundary data, compelled us to make some taxonomic

decisions. We followed current literature to determine species boundaries, and justify our choices regarding ambiguous taxa. The cutoff date for our literature search was August 31, 2010. Our higher-level classification of the amphibians followed Frost (2010). Our higher-level classification of the reptiles followed Uetz (2010), supplemented by Zaher (1999), Tu et al. (2000), Helfenberger (2001), Utiger et al. (2002, 2005), Grossman and Tillack (2003), Malhotra and Thorpe (2004a, b), Schmitz et al. (2004), Schultz et al. (2000), Guo et al. (2007), Vidal et al. (2007), and Murphy et al. (2008).

We derived estimates of the richness and distribution of Indochina's terrestrial and aquatic amphibian and reptile species from published literature that refer to museum-deposited voucher specimens, with some exceptions for severely under-sampled regions. Due to the paucity of information from these areas, we also collected data from the following reports that included some records lacking associated voucher specimens: a survey of reptiles from the Cardamom Uplands (Daltry and Chheang, 2000), a series of reptile surveys from Laos (Stuart, 1999), a series of surveys of the Mekong River in Cambodia (Bezuijen et al., 2009), and reports on lizards of Vietnam (Bobrov, 1993a, b, 1998, 2003a, b). To address the lack of verification from these publications, we only included species whose identification is unambiguous and whose locality data were conservative; in addition, the species have to have been examined by the authors themselves. Finally, we included 16 referred specimens from the collection of the American Museum of Natural History (AMNH), and seven specimens from the collection of the Institute of Ecology and Biological Resources (IEBR), each of which fill in distribution gaps, but did not extend geographic ranges (see appendix 2A, 2B).

Species recorded from Indochina are included in overall species count, but otherwise excluded from the analysis if locality data were too vague to place them into a subregion (species shaded gray in appendix 2A, 2B). Species whose occurrence in Indochina could not be confirmed were also excluded from the analysis (appendix 3). We also made the following decisions for those

taxa with seriously unresolved taxonomic issues. Indochinese records of the order Gymnophonia were excluded owing to the exceedingly poor state of knowledge of taxa in this group (e.g., Wilkinson et al., 2002; Kupfer and Mueller, 2004; Teynie et al., 2004). Although it seems likely that historical records of *Tylotriton verrucosus* in Indochina refer to other species of *Tylotriton*, we treated it as present in Indochina until otherwise demonstrated (see Nussbaum et al., 1995). There is conflicting evidence as to whether *Leptobrachium echinatum* is a valid species or synonym of *L. ailaonicum* (Dubois and Ohler, 1998; Ho et al., 1999; Grosjean, 2001; Ohler et al., 2000; Rao and Wilkinson, 2008; Zheng et al., 2008; Zhang et al., 2009; Matsui et al., 2010). The phylogenetic evidence of Matsui et al. (2010), and Rao and Wilkinson (2008) conflicts with that of Zheng et al. (2008), as the former studies found the two to be distinct lineages, but the latter study found that recognizing *L. echinatum* renders *L. ailaonicum* nonmonophyletic. Furthermore, although Zhang et al. (2009) found four distinct clades of *L. ailaonicum*, including one that reaches the type locality of *L. echinatum*, they refrained from making any taxonomic resolution, owing to absence of enough data. Although these divergent outcomes need to be addressed, we followed the conservative estimate and recognize that *L. echinatum* is a synonym of *L. ailaonicum*. Although it has been demonstrated that *Leptobrachium chapaense* is a species complex (Zheng et al., 2008; Matsui et al., 2010), we referred to the range of the complex as that of *L. chapaense* sensu stricto because species boundaries have not yet been properly established. McLeod (2010) established that there are five distinct species of *Limnonectes* currently found in Indochina, only one of which, *L. bannaensis*, is currently named. For the purpose of this analysis, we recognized *L. bannaensis* (as per McLeod, 2010) and included the localities of the other four species together under one name, *L. "kuhlii"* 4 spp., but we did not include them in the analysis. We referred to *Odorrana hmongorum* as a valid species, and not a synonym of *O. jingdongensis*, owing to the insufficient evidence for synonymy suggested by Ohler (2007). We refer all Indochinese specimens of

the *Rhacophorus rhodopus* group as *Rh. rhodopus*, owing to the proximity of its type locality (Mengyang, Yunnan Province, China) to Indochina, but recognize that the complexity of this group's species boundaries likely indicates that more than one species is present in Indochina (after Yu et al., 2007a; Li et al., 2008). We recognized *Liopeltis* cf. *tricolor* from Indochina (sensu Orlov et al., 2003b) as *L. stoliczkae* owing to the similarity of their descriptions (see also Stuart et al., 2006c; Stuart and Heatwole, 2008). We recognized *O. fasciolatus*, *O. ocellatus*, and *O. saintgiroisi* of the *Oligodon cyclurus* group from Indochina (Campden-Main, 1970c; Saint Girons, 1972a; Teynie et al., 2004; David et al., 2008b, c). We recognized *Xenochrophis piscator* occurring in uplands and lowlands of northwestern Laos (after Vogel and David, 2006). We referred to a wider Indochinese distribution of *Leiolepis belliana* than did Ananjeva et al. (2007a), who suggested that its distribution in Vietnam be restricted to Phu Quoc (= Fukuok) Island and Kien Giang Province. *Leiolepis belliana* and *L. reevesii* have been shown to be polytypic (Schmitz et al., 2001), but no other species have been formally described, so we recognized these as only two species. We recognized the following species of *Draco* in Indochina: *D. indochinensis*, *D. maculatus*, and *D. taeniopterus* (after Musters, 1983; McGuire and Heang, 2001; Stuart and Emmett, 2006; Stuart et al., 2006c). We included distributional data for species whose populations have likely been extirpated locally or even regionally by human activities owing to the lack of negative data (e.g., *Ophiophagus hannah*, *Varanus* spp., *Crocodylus* spp., and *Cuora* spp.).

#### SUBREGIONS OF INDOCHINA

To estimate current herpetofaunal richness and distribution patterns within Indochina, we mapped the recorded localities for each species onto a subregional classification (table 1, fig. 3A, B; refer to appendix 1 for definitions of subregions). These subregions also serve as hypotheses, since the current level of regional knowledge does not allow us to conduct the fine scale analyses (e.g., species distribution modeling) needed to infer biogeographic

TABLE 1  
Subregions of Indochina and their associated area (km<sup>2</sup>)

Subregion	Abbreviation	Area
Northwest Uplands	NWU	132,140
Northeast Uplands	NEU	18,084
Northern Annamites	NAN	46,951
Northeast Lowlands	NEL	94,798
Upper Mekong Lowlands	UML	52,094
Central Annamites	CAN	41,774
Southern Annamites	SAN	26,612
Central-South Vietnam Lowlands	CSL	56,305
Southern Lao Uplands	SLU	4,752
Southern Lao Lowlands	SLL	26,895
Mekong Delta	MEK	69,896
Interior Cambodian Lowlands	CMB	140,361
Cardamom Uplands	CDU	7,630
Cardamom Lowlands	CDL	10,054
Northern Coast	NC	n/a
Central Coast	CC	n/a
Southern Coast	SC	n/a
Northern Islands	NIS	990
Southern Islands	SIS	1,149
INDOCHINA		730,485

subregions from the species distributions themselves. Also, because there is no agreement among existing biogeographic classifications of Indochina, and those that do exist are too coarse in resolution to resolve distributional questions, we divided Indochina into 19 subregions using topographic and geographic criteria, including: major river systems and their deltas, island groups, mountain ranges and associated lowland regions, and location on the coast. We used national boundaries to define Indochina's limits, as well as some internal divisions, recognizing that they are an important component of conservation decision-making. We scored each taxon for presence within each subregion, and defined lowlands as areas below 450 m, and uplands as areas above 450 m (but see Ecological Characteristics below).

We refer to **northern Indochina** as including all northern upland subregions, both northern lowland regions, and the northern coast and islands. **Southern Indochina** includes the Central Annamites and Southern Annamites, Cardamom Uplands and Lowlands, the Mekong Delta and interior lowlands, Central and Southern Coasts, and the Southern Islands.

#### ENDEMISM AND BIOGEOGRAPHIC AFFINITIES TO AREAS OUTSIDE INDOCHINA

Endemic species are those known only from Indochina. To examine the relationship of Indochina's herpetofauna to the surrounding regions, we used the published literature to generate global distributions for all Indochinese amphibian and reptile species. Biogeographic distribution was scored for each species using the units defined below. We referred to fauna known both in Indochina and outside its political areas by the outside area name (e.g., South China fauna) as a point of reference, not as a biogeographic term indicating attributes such as point of origin or center of diversity. Although we referred to endemic Indochinese fauna and those with affinities with other regions throughout the study, we recognize that these designations will change for many of these species as systematic research continues.

We defined the biogeographic regions outside Indochina as follows: **South China**: southeastern Yunnan Province, southern Guangxi Autonomous Region, Guangdong Province coast, and Hainan Island, which corresponds to biogeographic subregions S-B and S-C of Zhao and Adler (1993: 291, fig. 37); **Mainland Southeast Asia**: Thailand and central Myanmar south to the Isthmus of Kra at 12°N; **East Asia**: Korean peninsula, Japan, the central, northern, and eastern provinces of China, and adjacent islands including Taiwan; **Southern Himalayas**: Himalayas of Nepal, northeastern India, northern Myanmar, and western China (the latter defined as southern and eastern Xizang [Tibet], southwestern Sichuan, western portions of Yunnan; corresponding to subregions SW-A, SW-B, and S-B of Zhao and Adler [1993: 291, fig. 37]); **Malaya**: Malay Peninsula below 12° latitude and the Greater Sunda Islands (including Borneo, Java, Sumatra). **Pan-Asia**: species found outside both Mainland Southeast Asia and South China.

#### ECOLOGICAL CHARACTERISTICS

To examine the ecological attributes of Indochina's herpetofauna, we scored all species for elevation, adult macrohabitat, adult habitat preference, and breeding attributes

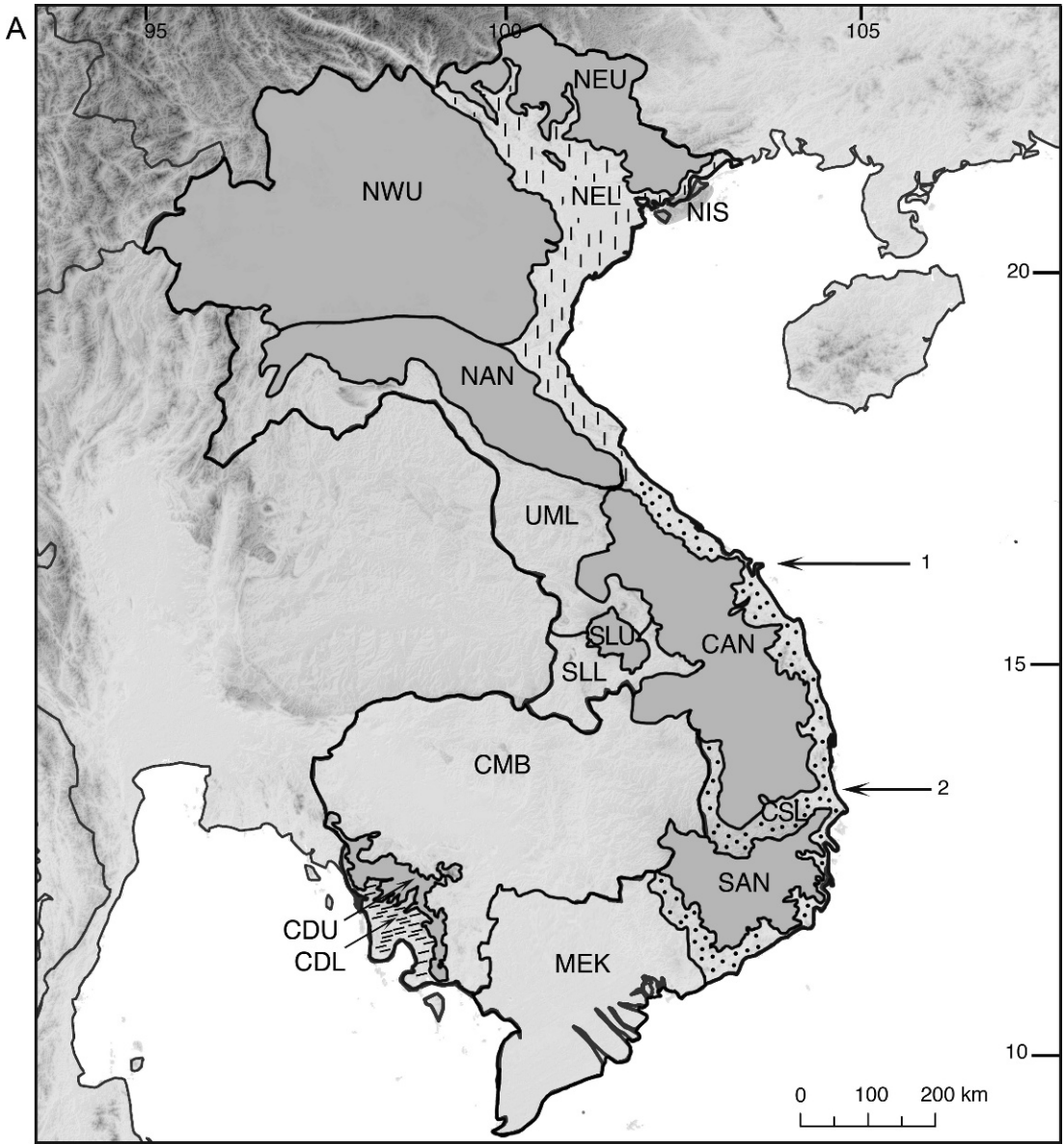


Fig. 3. Subregions of Indochina. A. Northern Coast extends above arrow 1; Central Coast extends between arrows 1 and 2; Southern Coast extends below arrow 2. The Southern Islands include all islands below arrow 2. Note that the enclosed area within Northeast Lowlands is Tam Dao, part of the Northeast Uplands. Refer to table 1 for abbreviations. B. (opposite page) Subregions of Indochina, with elevation levels.

(appendix 2A). Elevation was divided into three levels: highland (montane) for species found above 800 m, upland (submontane) for those found between 310 and 800 m, and lowland for those found below 300 m. The 300 m and 800 m boundaries reflect significant

vegetation changes that occur at these elevations throughout Indochina (see Introduction). Adult macrohabitats were divided into three states: forested, open, or forested and open. Habitat preferences, defined as habitats that active adults used most often, are scored

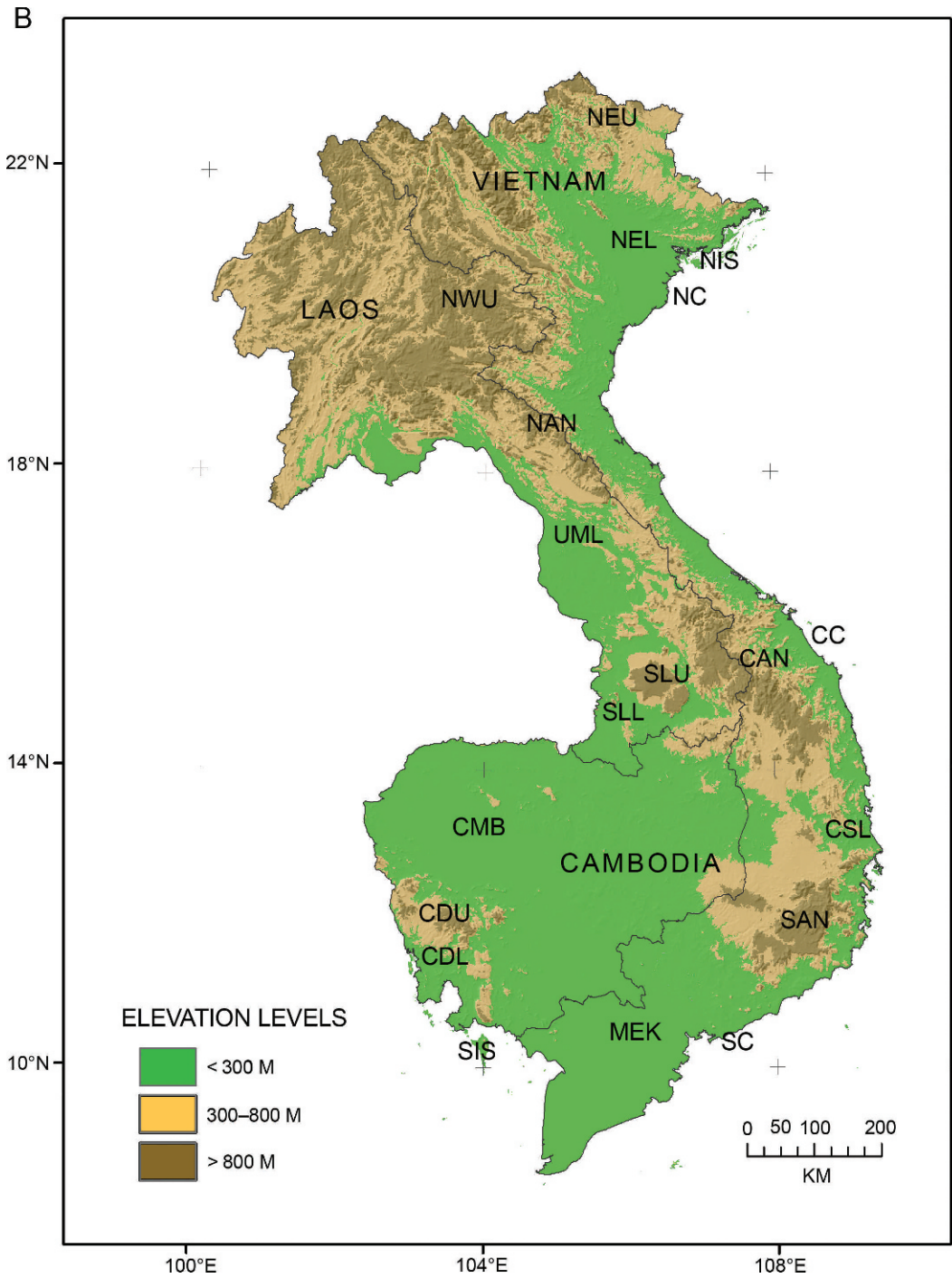


Fig. 3. Continued



for one or a combination of the following states: fossorial, rupicolous, terrestrial, aquatic, and arboreal. Activity under leaf litter was considered terrestrial, rather than fossorial. Rupicolous activity included that on rocks or walls. Activity atop grass was considered arboreal. Because most amphibian species go to a water source to breed, we coded habitat preferences for nonbreeding adults in an effort to standardize the data with reptiles. Breeding attributes were categorized separately for amphibians and reptiles: amphibians were scored for egg deposition (forest, open), and larval microhabitat (fast-moving water, slow-moving water, still water, terrestrial, arboreal holes, terrestrial holes, aerial over water); reptiles were scored for mode of reproduction (oviparous, ovoviviparous, parthenogenetic).

#### ANALYTICAL METHODS

We estimated species richness, endemism, and biotic affinity of each subregion and for Indochina as a whole. Estimates were made separately for each taxonomic group: amphibians (Amphibia), snakes (Serpentes), lizards (Sauria), crocodylians (Crocodylia), and turtles (Testudines). All variables used in species-area analyses were log-transformed (after Rosenzweig, 1995). Subregions were ranked using the residuals from a regression of log (area) on log (species richness) for both total species richness and endemic species richness.

We calculated survey effort in each subregion in order to examine its possible effects on richness and endemism estimates. Survey effort was inferred by counting the number of times each area was visited, as recorded in the literature. All surveys were treated as equal survey events because reports of survey effort are not standardized. Surveys that could not be assigned to subregions were not included in the analysis.

To examine the degree of biotic affinity between different subregions based on species composition, we employed Ward's method for cluster analysis and squared Euclidean distance to measure the distance between binary pairs (SPSS 16.0.1 for Macintosh, 2007). Subregions that held less than 15% of the Indochinese fauna for each group (e.g., lizards, snakes) were omitted from the cluster analysis at the group-level to prevent biasing the results. Ward's method utilizes both shared presences and

absences in constructing estimates of similarity. In subregions with depauperate faunas, shared absences are likely to swamp out the signal of shared species, biasing the results. All other statistical tests are after Zar (2004).

#### RESULTS

A total of 606 amphibian and reptile species (211 amphibians, 198 snakes, 166 lizards, 2 crocodiles, 29 turtles) occur in Indochina (appendix 2A, 2B). Of these, we included 578 (96%) species in the analysis; locality data for those species excluded due to ambiguous specimen records are shaded gray in appendices 2A, 2B. Indochina's herpetofauna makes up 6.4% of total global herpetofaunal species richness: 2.9% of all amphibians, 6.2% of snakes, 3.2% of lizards, 8.7% of crocodylians, and 9.0% of turtles (after Frost, 2010; Uetz, 2010). The distribution of this species richness across taxonomic groups differs significantly from that of the global herpetofauna. Compared to global figures, Indochina is relatively rich in snake, crocodile, and turtle species, and relatively poor in amphibian and lizard species ( $\chi^2 = 83.424$ ,  $df = 4$ ,  $p < 0.0001$ ).

#### (1) RELATIONSHIP OF SUBREGIONAL AREA TO SPECIES RICHNESS, ENDEMISM, AND SURVEY EFFORT

(1a) RELATIONSHIP OF SPECIES RICHNESS and ENDEMISM TO SUBREGIONAL AREA: Species richness within subregions was not significantly correlated with subregional area for the herpetofauna as a whole ( $R^2 = 0.6$ ,  $df = 11$ ,  $p = 0.06$ ; both variables log-transformed; coastal subregions of unknown area and subregions containing less than 15% of Indochinese fauna for each group excluded) and for all of the major taxonomic groups (amphibians:  $R^2 = 0.22$ ,  $df = 10$ ,  $p = 0.14$ ; snakes:  $R^2 = 0.27$ ,  $df = 12$ ,  $p = 0.07$ ; lizards:  $R^2 = 0.14$ ,  $df = 12$ ,  $p = 0.22$ ; turtles:  $R^2 = 0.01$ ,  $df = 9$ ,  $p = 0.75$ ). There is also no significant correlation between the number of endemic species and subregional area for the herpetofauna as a whole ( $R^2 = 0.10$ ,  $df = 11$ ,  $p = 0.78$ ) and for the individual taxonomic groups (amphibians,  $R^2 = 0.11$ ,  $df = 10$ ,  $p = 0.32$ ; snakes  $R^2 = 0.25$ ,  $df = 12$ ,  $p = 0.08$ ; lizards  $R^2 = 0.01$ ,  $df = 12$ ,  $p = 0.85$ ;

subregions with no recorded endemic species excluded). To control for any effect of area on richness and endemism we used standardized residuals from the linear regressions for all subsequent analyses, including rankings.

(1b) RELATIONSHIP OF SURVEY EFFORT TO SUBREGIONAL AREA: The number of surveys per subregion varied widely (table 2). Controlling for subregional area, there was a significant difference between the subregions in survey effort ( $\chi^2 = 513$ ,  $df = 14$ ,  $p < 0.0001$ ). Subregions surveyed more than average per  $\text{km}^2$  are the Northeast Uplands, Northern Annamites, Northeast Lowlands, Central Annamites, Southern Lao Uplands, and the Northern Islands and Southern Islands. Subregions surveyed less than average per  $\text{km}^2$  are the Northwest Uplands, Upper Mekong Lowlands, Southern Annamites, Central-South Vietnam Lowlands, Southern Lao Lowlands, Mekong Delta, Interior Cambodia Lowlands, and the Cardamom Uplands and Cardamom Lowlands.

## (2) TAXONOMIC DISTRIBUTION OF SPECIES RICHNESS AND ENDEMISM

There are significant differences in species richness between taxonomic groups: snakes are the most species-rich group in Indochina, followed by amphibians, lizards, turtles, and crocodiles in descending order ( $\chi^2 = 299.336$ ,  $df = 4$ ,  $p < 0.0001$ ) (table 3; appendix 2). A total of 203 (35.1%) species are endemic to Indochina, with higher levels of endemism recorded for lizards (53%) and amphibians (43%) than for snakes (17%), and turtles (11%), ( $\chi^2 = 129.873$ ,  $df = 3$ ,  $p < 0.0001$ ). Crocodylians, with no endemic species, were excluded from the analysis.

The most speciose amphibian families are Rhacophoridae (25% of the Indochinese amphibian fauna), Ranidae (23%), Megophryidae (15%), and Dicoglossidae (11%). The most speciose families also have the highest proportions of endemic species with the exception of the Salamandridae: Megophryidae (16; 52% of familial fauna), Ranidae (24; 50%), Salamandridae (3; 50%), Rhacophoridae (25; 47%), Microhylidae (6; 32%), and Dicoglossidae (6; 26%). Bombinatoridae, Bufonidae, and Hylidae have no species endemic to Indochina.

TABLE 2

### Number of survey events per subregion and summary statistics within Indochina

The Cardamom Uplands and Cardamom Lowlands subregions were combined for this analysis due to insufficient data. “?” refers to survey events that could not be allocated to a subregion. See table 1 for subregions spelled out.

NWU	65
NEU	70
NAN	49
NEL	94
UML	19
CAN	68
SAN	23
CSL	13
SLU	7
SLL	14
MEK	43
CMB	43
CDU/CDL	15
NC	2
CC	12
SC	23
NIS	10
SIS	13
?	31
Total	614
Range	2–94
Mean	32
Median	21
CV	0.83

The most species-rich snake lineages were Colubrinae (36% of Indochinese snake fauna), Natricidae (19%), and Viperidae (11%). Unlike amphibians, the most speciose snake families generally did not have the highest proportions of endemic species: Calamarinae (4; 50% of familial fauna), Xenodermatidae (2; 40%), Viperidae (4; 21%), Natricidae (6; 18%), Typhlopidae (1; 20%), Pseudoxenodontidae (1; 17%), Homolopsidae (2; 15%), Colubrinae (6; 8%), and Elapidae (1; 7%). No other snake lineages contain species endemic to Indochina.

The most species-rich lizard families are Gekkondidae (40% of Indochinese lizard fauna), Scincidae (31%), and Agamidae (19%). All remaining families contain fewer than 10 species and make up less than 5% of the total lizard fauna. With one exception, the Dibamidae, the most speciose lizard families also have the highest proportions of endemic species: Dibamidae (5 species; 83% of the

TABLE 3

**Species richness and number of endemic species for the Indochinese herpetofauna**

Shaded areas indicate a subregion that holds less than 15% of the total Indochinese species richness for the individual taxonomic groups. Refer to Table 1 for subregion abbreviations.

	All Fauna		Amphibians		Snakes		Lizards		Turtles	
	Total spp.	End. spp.	Total spp.	End. spp.	Total spp.	End. spp.	Total spp.	End. spp.	Total spp.	End. spp.
<b>Indochina</b>	605	203	210	81	198	32	166	87	29	3
NWU	259	36	101	24	102	3	48	9	8	0
NEU	217	30	69	16	97	4	42	10	8	0
NAN	179	32	63	19	71	6	38	7	7	0
NEL	180	22	44	5	77	3	47	13	12	1
UML	75	4	27	2	32	2	13	0	3	0
CAN	211	70	77	36	80	9	44	24	9	1
SAN	142	36	46	17	58	4	35	14	2	1
CSL	172	27	48	12	67	4	44	9	11	2
SLU	36	12	12	6	13	2	10	4	1	0
SLL	148	9	31	1	70	2	35	6	9	0
MEK	145	22	21	2	71	4	44	16	11	0
CMB	145	11	31	4	67	3	36	4	10	0
CDU	100	9	33	4	38	1	26	4	2	0
CDL	118	4	39	1	44	2	27	1	7	0
NC	63	0	9	0	43	0	10	0	1	0
CC	50	4	4	0	31	2	13	2	1	0
SC	71	10	3	0	40	2	24	8	3	0
NIS	44	2	0	0	23	0	21	2	0	0
SIS	61	15	8	1	16	1	36	13	0	0
<b>Subregional Summary Statistics</b>										
Range	36–259	0–70	0–101	0–36	13–102	0–9	10–48	0–24	0–12	0–2
Mean	127.16	18.68	35.05	7.89	54.74	2.84	31.00	7.68	5.53	0.26
Median	142	12	31	4	58	2	35	7	7	0
CV	0.52	0.92	0.80	1.28	0.47	0.67	0.42	0.85	0.77	2.14

familial fauna), Gekkonidae (42; 64%), Agamidae (15; 47%), Scincidae (22; 43%), and Lacertidae and Anguillidae (each with 1; 33%).

The Bataguridae is the most species-rich turtle family (69% of Indochinese turtle fauna) and contains all three turtle species endemic to Indochina. All other families contribute less than 20% to the total turtle fauna.

### (3) GEOGRAPHIC DISTRIBUTION OF RICHNESS AND ENDEMISM

(3a) SPECIES RICHNESS: Species richness per subregion varies by more than a factor of 8 (table 3). The subregions with the highest species richness (controlled for area) are the Northeast Uplands, Southern Islands, Central Annamites, Southern Lao Lowlands, and Northwest Uplands in descending order (table 4). The subregion ranked lowest in species richness is the Southern Lao Uplands,

followed in ascending order by the Upper Mekong Lowlands, Interior Cambodia Lowlands, Caradomom Lowlands, and Mekong Delta. These geographic patterns of species richness were generally mirrored within each taxonomic group; the Northeast Uplands, Northern Annamites and Central Annamites, and Southern Lao Lowlands subregions were in the top half of species richness rankings for each taxonomic group.

Amphibian species richness is strongly skewed toward upland subregions. Six of the seven upland subregions are ranked highest for amphibian richness. Snake (CV = 0.47) and lizard (CV = 0.42) species richness are more evenly distributed across the subregions than is amphibian richness (CV = 0.80); both have high levels of species richness in the Central Annamites, Northwest Uplands and Northeast Uplands, as well as the Northeast Lowlands and Central-South Vietnam Low-

TABLE 4  
**Subregions of Indochina ranked by species richness**

Both crocodile species were excluded from this analysis. Subregions that hold less than 15% of the total Indochinese species richness for the individual taxonomic groups were excluded from the analysis.

Subregion	All Fauna	Amphibians	Snakes	Lizards	Turtles
NEU	1	1	1	6	7
NWU	2	2	4	2	8
CAN	3	3	3	5	6
CSL	4	5	5	4	2
SLL	5	10	2	8	5
NAN	6	4	7	9	10
NEL	7	8	6	1	1
SAN	8	6	9	10	-
CDU	9	7	11	12	-
MEK	10	-	8	7	3
CMB	11	11	10	11	4
CDL	12	9	12	13	9
UML	-	-	13	3	-

lands. Snakes and lizards are also the only herpetofaunal groups recorded in every subregion. Unlike all other groups, turtle species richness is concentrated in the lowlands, with the Northeast Uplands the only upland area to rank in the top five most turtle-rich subregions. Turtles are also less evenly distributed across the subregions than the other three reptile groups ( $CV = 0.77$ ). Both crocodile species were historically widespread throughout Indochina, predominantly in lowland areas.

(3b) ENDEMISM: Endemism is less evenly distributed across Indochina than species richness (tables 3, 5). Upland subregions make up four of the top five subregions ranked for endemic species richness (controlled for area): Central Annamites, Southern Islands, Southern Annamites, Northeast Uplands, and Northern Annamites. Among the 12 lowland, coastal, and island subregions, the Southern Islands, Central–South Vietnam Lowlands, Mekong Delta, and Northeast Lowlands have the highest rankings for endemic species richness.

The distribution of endemic species across Indochina mirrored the distribution of species richness. Endemic amphibian species ( $CV=1.28$ ) are concentrated in the uplands, with six of the seven upland subregions being the highest ranked for amphibian endemism. Endemic lizard ( $CV=0.74$ ) and snake ( $CV=0.82$ ) species are more evenly distributed across the region. Indochina's three endemic turtle species ( $CV=2.14$ ) are con-

centrated in a total of four localities in the Northern Annamites and Central Annamites and the Central–South Vietnam Lowlands.

#### (4) THE OCCURRENCE OF NONENDEMIC FAUNAS

Of the 578 amphibian and reptile species included in the analysis, 382 (65%) are also found outside Indochina (table 6;

TABLE 5  
**Subregions of Indochina ranked by endemic species richness**

Turtles were excluded from the analysis as only three species are known to be endemic to Indochina.

Subregions that hold less than 15% of the total Indochinese species richness for the individual taxonomic groups were excluded from the analysis.

Subregion	All Fauna	Amphibians	Snakes	Lizards
CAN	1	1	1	1
SAN	2	3	4	3
NEU	3	2	3	6
NAN	4	4	2	9
CSL	5	5	5	8
NWU	6	6	12	7
MEK	7	-	6	2
NEL	8	8	8	4
CDH	9	7	13	12
SLL	10	10	7	10
CMB	11	9	10	11
CDL	12	11	11	13
UML	-	-	9	5

TABLE 6  
**Non-endemic faunas of Indochina's herpetofauna**

Number of species (with proportion of subregional fauna in parentheses). Shaded areas indicate a subregion that holds less than 15% of the total Indochinese species richness for the individual taxonomic groups. Refer to Table 1 for subregion abbreviations; refer to Materials and Methods for definition of Mainland Southeast Asia, South China, Malaya, and Pan-Asia.

SOUTH CHINA					
	All Fauna	Amphibians	Snakes	Lizards	Turtles
<b>Indochina</b>	94 (0.16)	34 (0.18)	36 (0.19)	16 (0.10)	8 (0.29)
NWU	63 (0.24)	28 (0.28)	26 (0.25)	6 (0.13)	3 (0.38)
NEU	68 (0.31)	21 (0.30)	31 (0.32)	12 (0.28)	4 (0.50)
NAN	25 (0.14)	9 (0.14)	10 (0.14)	3 (0.08)	3 (0.43)
NEL	37 (0.21)	6 (0.14)	17 (0.22)	9 (0.19)	5 (0.42)
UML	1 (0.01)	0	1 (0.03)	0	0
CAN	18 (0.09)	6 (0.08)	9 (0.11)	0	3 (0.33)
SAN	7 (0.05)	4 (0.09)	3 (0.05)	0	0
CSL	8 (0.05)	2 (0.04)	2 (0.03)	1 (0.02)	3 (0.27)
SLU	0	0	0	0	0
SLL	3 (0.02)	1 (0.03)	2 (0.03)	0	0
MEK	2 (0.01)	1 (0.05)	1 (0.01)	0	0
CMB	3 (0.02)	1 (0.03)	2 (0.03)	0	0
CDU	1 (0.01)	1 (0.03)	0	0	0
CDL	1 (0.01)	1 (0.03)	0	0	0
NC	12 (0.19)	2 (0.22)	9 (0.21)	2 (0.20)	0
CC	2 (0.04)	0	2 (0.06)	0	0
SC	0	0	0	0	0
NIS	11 (0.25)	0	6 (0.26)	5 (0.24)	0
SIS	0	0	0	0	0
MAINLAND SOUTHEAST ASIA					
	All Fauna	Amphibians	Snakes	Lizards	Turtles
<b>Indochina</b>	54 (0.09)	19 (0.10)	13 (0.07)	20 (0.12)	2 (0.07)
NWU	14 (0.05)	8 (0.08)	1 (0.01)	4 (0.08)	1 (0.13)
NEU	5 (0.02)	3 (0.04)	1 (0.01)	1 (0.02)	0
NAN	10 (0.06)	3 (0.05)	2 (0.03)	4 (0.11)	1 (0.14)
NEL	6 (0.03)	3 (0.07)	0	2 (0.04)	1 (0.08)
UML	9 (0.12)	3 (0.11)	2 (0.06)	3 (0.23)	1 (0.33)
CAN	14 (0.07)	8 (0.10)	3 (0.04)	2 (0.05)	1 (0.11)
SAN	14 (0.10)	5 (0.11)	5 (0.09)	4 (0.11)	0
CSL	19 (0.11)	8 (0.17)	4 (0.06)	7 (0.16)	0
SLU	1 (0.03)	0	1 (0.08)	0	0
SLL	18 (0.12)	4 (0.13)	7 (0.10)	5 (0.14)	2 (0.22)
MEK	10 (0.07)	1 (0.05)	6 (0.08)	3 (0.08)	0
CMB	16 (0.11)	2 (0.06)	7 (0.10)	6 (0.17)	1 (0.10)
CDU	19 (0.19)	8 (0.24)	3 (0.08)	7 (0.27)	1 (0.50)
CDL	19 (0.16)	9 (0.23)	5 (0.11)	4 (0.15)	1 (0.14)
NC	1 (0.02)	0	0	0	1 (1.00)
CC	0	0	0	0	0
SC	3 (0.04)	0	3 (0.08)	0	0
NIS	1 (0.02)	0	0	1 (0.05)	0
SIS	2 (0.03)	1 (0.13)	0	1 (0.03)	0

TABLE 6  
(Continued)

MALAYA					
	All Fauna	Amphibians	Snakes	Lizards	Turtles
<b>Indochina</b>	5 (0.01)	0	4 (0.02)	1 (0.01)	0
NWU	0	0	0	0	0
NEU	0	0	0	0	0
NAN	0	0	0	0	0
NEL	0	0	0	0	0
UML			0	0	0
CAN	2 (0.01)	0	2 (0.03)	0	0
SAN	1 (0.01)	0	1 (0.02)	0	0
CSL	1 (0.01)	0	1 (0.01)	0	0
SLU	0	0	0	1 (0.03)	0
SLL	1 (0.01)	0	0	0	0
MEK	1 (0.01)	0	1 (0.01)	0	0
CMB	1 (0.01)	0	1 (0.01)	0	0
CDU	0	0	0	0	0
CDL	0	0	0	0	0
NC	0	0	0	0	0
CC	0	0	0	0	0
SC	1 (0.01)	0	1 (0.03)	0	0
NIS	0	0	0	0	0
SIS	0	0	0	0	0
PAN-ASIA					
	All Fauna	Amphibians	Snakes	Lizards	Turtles
<b>Indochina</b>	179 (0.31)	33 (0.17)	96 (0.49)	34 (0.21)	14 (0.50)
NWU	113 (0.44)	21 (0.21)	66 (0.65)	23 (0.48)	3 (0.38)
NEU	92 (0.42)	18 (0.26)	54 (0.56)	17 (0.40)	3 (0.38)
NAN	93 (0.52)	22 (0.35)	47 (0.66)	21 (0.55)	3 (0.43)
NEL	98 (0.54)	21 (0.48)	52 (0.68)	20 (0.43)	5 (0.42)
UML	54 (0.73)	17 (0.63)	25 (0.78)	10 (0.77)	2 (0.67)
CAN	90 (0.43)	19 (0.25)	53 (0.66)	14 (0.32)	3 (0.33)
SAN	73 (0.51)	15 (0.33)	42 (0.72)	14 (0.40)	1 (0.50)
CSL	104 (0.60)	20 (0.42)	52 (0.78)	24 (0.55)	6 (0.55)
SLU	20 (0.56)	4 (0.33)	9 (0.69)	6 (0.60)	1 (1.00)
SLL	105 (0.71)	20 (0.65)	54 (0.77)	22 (0.61)	7 (0.78)
MEK	100 (0.69)	14 (0.67)	54 (0.76)	19 (0.48)	11 (1.00)
CMB	100 (0.69)	18 (0.58)	50 (0.75)	21 (0.60)	9 (0.90)
CDU	61 (0.61)	13 (0.39)	31 (0.82)	15 (0.58)	1 (0.50)
CDL	83 (0.70)	20 (0.51)	35 (0.80)	21 (0.78)	6 (0.86)
NC	47 (0.75)	6 (0.67)	32 (0.74)	8 (0.80)	0
CC	41 (0.82)	4 (1.00)	24 (0.77)	11 (0.85)	1 (1.00)
SC	53 (0.75)	3 (1.00)	31 (0.78)	15 (0.63)	3 (1.00)
NIS	27 (0.61)	0	17 (0.74)	10 (0.48)	0
SIS	41 (0.67)	5 (0.63)	14 (0.88)	21 (0.58)	0

appendix 2A). Both crocodiles are Pan-Asia species.

(4a) SOUTH CHINA: Sixteen percent of Indochina's nonendemic herpetofaunal species are otherwise restricted to South China. This South China fauna is present in all herpetofaunal taxonomic groups although they differ significantly in the proportion ( $\chi^2 = 9.307$ ,  $df = 3$ ,  $p < 0.05$ ). The highest proportion of this fauna is in turtles (29%), with intermediate values in snakes (19%) and amphibians (18%), and the lowest proportion in lizards (10%). The proportion of the South China fauna in Indochina's subregions declines with elevation from uplands to lowlands and with latitude from north to south. With the exception of the faunally depauperate Upper Mekong Lowlands, there is a distinct dropoff in the presence of South China fauna between northern and southern Indochina with an intermediate value (9%) recorded in the Central Annamites. It is entirely absent from the Southern Lao Uplands, Southern Coast, and Southern Islands, and only one South China amphibian species (*Ingerophrynus galeatus*) is present in the Cardamoms, both uplands and lowlands. The Northeast Uplands have a higher proportion of South China fauna than do the Northwest Uplands. There is a weak trend for this difference to be significant for the herpetofauna as a whole ( $\chi^2 = 2.824$ ,  $df = 1$ ,  $p = 0.09$ ), but not for the individual groups (amphibians:  $\chi^2 = 0.118$ ,  $df = 1$ ,  $p = 0.73$ ; snakes:  $\chi^2 = 1.018$ ,  $df = 1$ ,  $p = 0.39$ ; lizards:  $\chi^2 = 2.362$ ,  $df = 1$ ,  $p = 0.12$ ; turtles: Fisher's exact test,  $p = 1.00$ ).

(4b) MAINLAND SOUTHEAST ASIA: Nine percent of Indochina's nonendemic amphibian and reptile species are otherwise restricted to Mainland Southeast Asia (i.e., Thailand and Myanmar south to the Isthmus of Kra). There is no difference in the overall proportion of Mainland Southeast Asia species among taxonomic groups ( $\chi^2 = 3.419$ ,  $df = 3$ ,  $p = 0.33$ ). The distribution of this fauna decreases from west to east but its occurrence does not vary between upland and lowland subregions. The Mainland Southeast Asia fauna is highest in the subregions that border the region, making up at least 10% of the Cardamom Uplands

and Caradomom Lowlands, Cambodia Interior Lowlands, the Southern Lao Lowlands, and Upper Mekong faunas. However, except for the Upper Mekong Lowlands, it makes up less than 10% of all northern subregional Indochinese faunas, and is rare in the Northeast Uplands and Northeast Lowlands. Mainland Southeast Asia species constitute a significantly lower proportion of the overall Indochinese herpetofauna than do South China species ( $\chi^2 = 12.398$ ,  $df = 1$ ,  $p < 0.0005$ ).

(4c) MALAYA: There are very few strictly Malaya herpetofaunal species in Indochina: four snakes and one lizard, making up less than 1% of total species richness. They occur in only seven subregions and only the Central Annamites harbor more than one species (two). The South China ( $\chi^2 = 87.504$ ,  $df = 1$ ,  $p < 0.0001$ ) and Mainland Southeast Asian ( $\chi^2 = 42.884$ ,  $df = 1$ ,  $p < 0.0001$ ) faunas both contribute more species to Indochina's herpetofauna than does the Malaya fauna.

(4d) PAN-ASIA FAUNA: Pan-Asia herpetofaunal species make up the largest proportion of the Indochinese herpetofauna (31%). They are a significantly greater contributor to it than fauna from South China ( $\chi^2 = 34.648$ ,  $df = 1$ ,  $p < 0.0001$ ), Mainland Southeast Asia ( $\chi^2 = 83.989$ ,  $df = 1$ ,  $p < 0.0001$ ), and Malaya ( $\chi^2 = 195.596$ ,  $df = 1$ ,  $p < 0.0001$ ). Pan-Asia species dominate the subregional fauna in lowland subregions and comprise over half of species richness in all areas except for three upland subregions: Northeast Uplands, Northwest Uplands, and Central Annamites.

Although there is no significant difference in the proportion of Pan-Asia and endemic species in Indochina's herpetofauna ( $\chi^2 = 2.252$ ,  $df = 1$ ,  $p = 0.13$ ), this is not true for the individual taxonomic groups. When compared to the contribution of endemic species, Pan-Asia species form a significantly larger proportion of the snake ( $\chi^2 = 47.754$ ,  $df = 1$ ,  $p < 0.0001$ ) and turtle ( $\chi^2 = 10.220$ ,  $df = 1$ ,  $p < 0.0025$ ) faunas, but a significantly smaller proportion of the amphibian ( $\chi^2 = 28.872$ ,  $df = 1$ ,  $p < 0.0005$ ) and lizard ( $\chi^2 = 35.533$ ,  $df = 1$ ,  $p < 0.0001$ ) faunas than do endemic species.

TABLE 7

**Adult macrohabitat and elevation of the Indochinese herpetofauna**

Abbreviations: Op: Open; Fo: Forest; Unk.: Unknown; Lo: Lowlands; Up: Uplands; Hi: Highlands. See Materials and Methods for definitions.

	Adult Macrohabitat				Elevation						
	Fo	Op	Op-Fo	Unk.	Lo	Up	Hi	Lo-Up	Up-Hi	Lo-Up-Hi	Unk
<b>Amphibians</b>											
All	138	20	28	4	8	14	56	13	34	63	3
Endemics	71	4	4	2	3	11	31	4	19	12	1
South China	28	1	5	0	0	1	15	0	9	9	0
Mainland SEA	12	1	5	1	2	1	3	1	2	10	0
Malaya	0	0	0	0	0	0	0	0	0	0	0
Pan-Asian	15	12	6	0	3	0	2	5	2	21	0
<b>Snakes</b>											
All	91	23	66	14	22	14	15	18	14	105	6
Endemics	18	2	4	8	8	10	5	2	3	1	3
South China	21	3	9	3	0	0	6	3	2	23	2
Mainland SEA	2	4	6	1	5	2	0	3	0	3	0
Malaya	3	1	0	0	1	2	1	0	0	0	0
Pan-Asian	39	12	43	2	8	0	3	8	5	71	1
<b>Lizards</b>											
All	104	16	26	18	46	16	14	34	6	42	6
Endemics	60	7	8	12	32	14	11	9	2	15	4
South China	9	2	2	3	3	0	1	4	2	5	1
Mainland SEA	14	0	5	1	5	2	1	5	2	5	0
Malaya	1	0	0	0	1	0	0	0	0	0	0
Pan-Asian	15	7	11	1	5	0	1	15	0	13	0
<b>Turtles</b>											
All	13	2	13	0	14	0	1	5	1	7	0
Endemics	2	0	1	0	1	0	0	1	0	1	0
South China	5	1	2	0	3	0	1	1	0	3	0
Mainland SEA	2	0	0	0	1	0	0	0	0	1	0
Malaya	0	0	0	0	0	0	0	0	0	0	0
Pan-Asian	3	1	10	0	9	0	0	3	0	2	0

#### (5) ECOLOGICAL CHARACTERISTICS OF INDOCHINA'S HERPETOFAUNA

(5a) ALL HERPETOFAUNAS: The ecological information currently available for Indochina's herpetofauna is included in appendix 2A. Although all of the major herpetofaunal taxonomic groups of Indochina are dominated by forest-dwelling species (table 7), there are significant differences among them in the extent of this dependence ( $\chi^2 = 37.150$ ,  $df = 6$ ,  $p < 0.0001$ ). The majority of the amphibians (73%) and lizards (63%) and just under half of the snakes (47%) and turtles (46%) are restricted to forested habitat, while a larger proportion of snakes (34%)

and turtles (46%) are found in both forested and open environments compared to amphibians (15%) and lizards (16%). A small percentage (less than 12%) from each taxonomic group is found only in open areas. Both crocodile species live in forested and open environments.

Various primary microhabitats are occupied by each herpetofaunal group (table 8): the majority of turtles are aquatic (71%); the bulk of snake species are terrestrial (41%); the amphibians include large numbers of terrestrial (31%), arboreal (26%), and terrestrial-aquatic (21%) species; and lizards are found in terrestrial (23%), rupicolous (21%), and arboreal (15%) niches. Currently available



TABLE 8  
**Adult microhabitat related to biotic affinity of the Indochinese herpetofauna**

Abbreviations: TE: Terrestrial; AQ: Aquatic; AR: Arboreal; FS: fossorial; RU: rupicolous; Multi: at least three different adult microhabitats. See Materials and Methods for definitions.

	Adult Microhabitat												
	TE	AQ	AR	FS	RU	TE-AQ	TE-AR	TE-FS	TE-RU	AR-RU	AQ-AR	Multi	Unk.
<b>Amphibians</b>													
All	59	17	50	0	1	39	7	0	1	0	1	11	4
Endemics	21	6	23	0	1	18	3	0	0	0	1	7	2
South China	8	6	8	0	0	8	1	0	1	0	1	1	0
Mainland	6	2	6	0	0	3	1	0	0	0	0	0	1
SEA													
Malaya	0	0	0	0	0	0	0	0	0	0	0	0	0
Pan-Asian	15	1	7	0	0	8	1	0	0	0	0	1	0
<b>Snakes</b>													
All	80	24	31	18	3	13	10	3	0	1	0	2	9
Endemics	11	3	1	6	1	2	1	0	0	1	0	1	5
South China	14	7	2	4	2	1	2	1	0	0	0	1	2
Mainland	6	3	2	1	0	0	1	0	0	0	0	0	0
SEA													
Malaya	1	1	1	1	0	0	0	0	0	0	0	0	0
Pan-Asian	44	8	22	5	0	7	6	2	0	0	0	0	2
<b>Lizards</b>													
All	38	0	25	10	35	4	16	2	1	8	2	4	19
Endemics	16	0	14	6	27	0	5	0	1	2	1	2	13
South China	6	0	1	1	2	2	1	0	0	0	0	0	3
Mainland	4	0	3	2	2	2	3	1	0	1	0	0	2
SEA													
Malaya	0	0	1	0	0	0	0	0	0	0	0	0	0
Pan-Asian	10	0	5	1	4	0	6	1	0	5	0	2	0
<b>Turtles</b>													
All	6	20	0	0	0	2	0	0	0	0	0	0	0
Endemics	1	2	0	0	0	0	0	0	0	0	0	0	0
South China	2	6	0	0	0	0	0	0	0	0	0	0	0
Mainland	0	1	0	0	0	1	0	0	0	0	0	0	0
SEA													
Malaya	0	0	0	0	0	0	0	0	0	0	0	0	0
Pan-Asian	3	10	0	0	0	1	0	0	0	0	0	0	0

data show that most species in each taxonomic group occupy a single adult microhabitat. The two crocodile species inhabit both terrestrial and aquatic habitats.

Elevational zonation varies significantly among Indochina's herpetofauna ( $\chi^2 = 100.83$ ,  $df = 6$ ,  $p < 0.0001$ ) (table 7): over half of the amphibians (55%) are restricted to uplands (above 300 m), just as half of the turtles (50%) are restricted to lowlands (300 m and below). The majority of snakes (65%) and almost half the lizards (48%) occupy both

upland and lowland areas. Amphibians (31%) are also significantly more likely to be restricted to highland areas above 800 m than are snakes (8%), lizards (9%), or turtles (4%) ( $\chi^2 = 48.961$ ,  $df = 3$ ,  $p < 0.0001$ ). Elevation distribution is correlated with phylogeny in some lineages. Most species in the amphibian families Bombinatoridae, Megophyiidae, Hylidae, Ranidae, Rhacophoridae, and Salamandridae, as well as the snake family Xenodermatidae, are upland species. The majority of snakes in the family Homalopsidae and turtles of the family

TABLE 9  
**Number and proportion of amphibian larval habitat**  
 See materials and methods for definitions.

	Number	Proportion of Amphibian Fauna
Arboreal Hole	5	0.03
Terrestrial Hole	1	0.01
Terrestrial	1	0.01
Fast Moving Water	7	0.04
Slow Moving Water	22	0.12
Still Water	34	0.18
Arial Over Water	17	0.09
Arial-Terrestrial Holes	2	0.01
Fast-Slow Moving Water	1	0.01
Slow-Still Moving Water	11	0.06
Unknown	89	0.47

Trionychidae are found only in the lowlands. One species of crocodile, *C. porosus*, is restricted to lowlands, whereas *C. siamensis* is known from lowland and upland habitats.

Data on breeding ecology and reproductive mode remain unknown for a large proportion of Indochina's amphibian, snake, and lizard species. All Indochinese amphibians are oviparous and breeding ecology (egg deposition habitat and microhabitat) has been recorded for 101 (53%) of the species (table 9). The majority (69%) of amphibians whose breeding ecology remains unknown are Indochinese endemics. Of the known species, 67% require forest habitats for breeding, 19% require open habitats, and 14% can breed in either area. The majority of amphibians (66% of those species whose behavior is known) deposit their eggs in or around still or slow water. Fast-water deposition is limited to three megophryid species

and ranids of the genera *Amolops* and *Odorrana* as well as one bufonid, *Phrynooidis asper*. Only two species, the salamander *Tylostotriton asperrimus* and the dicroglossid *Limnonectes hascheanus*, are known to deposit eggs within the ground. The dicroglossid *Kaloula baleata*, and six rhacophorids (*Nyctixalis pictus*, and the five species of *Theloderma* for which the information is known) are known to deposit eggs within tree holes.

Most Indochinese reptiles for which reproductive mode is known (137 snakes, 101 lizards, all turtles) are oviparous. Vivipary has been recorded for 26 snake species in the following families: Cylirodophiidae (1 species), Typhlopidae (1), Acrochordidea (2), Colubrinae (2), Homalopsidae (11), Natricnidae (1), and Viperidae (8). Ten lizard species are viviparous: the monotypic Xenosauridae, and seven scincids. Parthenogenesis is extremely uncommon among Indochina's reptiles. It is restricted to a single snake species in the Typhlopidae and six lizards (two agamids and four gekkonids).

(5b) ENDEMISM: Indochinese endemic amphibians, snakes, and lizards are dominated by forest-dwelling species. There is no difference among these three groups in the proportion of endemic species found in forested, open, or both forested and open habitats (Fisher's exact test,  $p = 0.24$ ). The majority of endemic species are found in a single microhabitat, however amphibians are significantly more likely to occupy more than one microhabitat than are snakes and lizards ( $\chi^2 = 9.365$ ,  $df = 2$ ,  $p < 0.01$ ). Similarly, the majority of endemic amphibians, snakes, and lizards occupy a single elevational zone,

TABLE 10  
**Ecological correlates of Indochinese endemic herpetofauna**

Chi-squared values for pair-wise tests for significance. Crocodiles ( $n=0$ ) and Turtles ( $n=3$ ) excluded due to small sample size. Code for level of significance: no asterisk  $p>0.05$ ; \*  $p<0.05$ ; \*\* $p<0.01$ ; \*\*\*  $p<0.001$ ; \*\*\*\*  $p<0.0001$ .

	Amphibians	Snakes	Lizards
Restricted to Forested Macrohabitats	17.634****	6.620*	5.785*
Number of Microhabitats Occupied	0.879	0.193	9.023**
Number of Elevations Occupied	10.573**	47.232****	29.647****
Restricted to Lowlands (<300 m)	0.022	6.654**	7.551***
Restricted to Highlands (>800 m)	4.861*	4.322*	4.177*

TABLE 11  
**Ecological correlates of non-endemic Indochinese herpetofauna**

Results of pair-wise Chi-squared tests for significance. Chi-squared value is presented above the line; p-value presented below the line; df=1 for all tests. Malaya fauna excluded due to small sample size (n=5). Refer to Table 10 for level of significance code.

Restriction to forested macrohabitats				
	South China	Mainland SE Asia	Pan-Asia	Endemic
South China	X	2.377	22.102	5.098
Mainland SE Asia	NS	X	5.129	14.042
Pan-Asia	***	*	x	68.796
Endemic	*	***	****	x
Number of microhabitats occupied				
South China	x	0.010	0.032	0.015
Mainland SE Asia	NS	X	0.067	0.045
Pan-Asia	NS	NS	x	0.005
Endemic	NS	NS	NS	x
Number of elevations occupied				
South China	X	0.981	7.340	25.810
Mainland SE Asia	NS	x	12.021	9.998
Pan-Asia	**	***	x	82.898
Endemic	****	**	****	x
Restriction to lowland areas (<300 m)				
South China	X	10.092	4.330	12.245
Mainland SE Asia	***	x	2.655	0.055
Pan-Asia	*	NS	x	3.865
Endemic	***	NS	*	x
Restriction to upland areas (>800 m)				
South China	x	7.140	30.036	0.046
Mainland SE Asia	**	x	1.637	7.237
Pan-Asia	****	NS	x	32.810
Endemic	NS	**	****	x

although there is a marginally significant tendency for snakes to be more restricted to a single elevation zone than amphibians or lizards ( $\chi^2 = 5.803$ ,  $df = 2$ ,  $p = 0.05$ ).

There are significant differences among amphibian and reptile groups in the distribution of endemic species across elevations ( $\chi^2 = 59.114$ ,  $df = 10$ ,  $p < 0.0001$ ). In general, endemic amphibians and snakes are associated with higher elevations than endemic lizard species. Both endemic snakes (28%) and lizards (39%) are more restricted to lowland areas below 300 m than are endemic amphibians (4%) ( $\chi^2 = 28.921$ ,  $df = 2$ ,  $p < 0.0001$ ), which are more restricted to highland areas above 800 m (39%) than are endemic snakes (17%) and lizards (13%) ( $\chi^2 = 15.293$ ,  $df = 2$ ,  $p < 0.0005$ ).

Endemic species are more ecologically restricted than their nonendemic counterparts (results from  $\chi^2$  tests for significance are summarized in table 10). The proportion of endemic species restricted to forested habitats is significantly higher than that of nonendemic species for amphibians, snakes, and lizards. Endemic lizards are more restricted to a single microhabitat than either amphibians or snakes. Endemics tend to be more restricted to a single elevation zone than nonendemics. Endemic snakes and lizards, but not amphibians, are more restricted to regions below 300 m, whereas in all three groups endemics are more restricted to areas above 800 m than their nonendemic counterparts.

There are no crocodiles endemic to Indochina and endemic turtle species were excluded.

ed from the analysis due to small sample size (three).

(5c) ECOLOGICAL CORRELATES OF THE FAUNA: There are significant broad ecological differences among Indochina's four non-endemic faunas (tables 7, 8; results from  $\chi^2$  tests for significance are summarized in table 11). Both South China and Mainland Southeast Asia species are more restricted to forested habitats than Pan-Asia species; however, there is no difference in forest dependence between the South China and Mainland Southeast Asia faunas. There were no significant differences in the number of microhabitats occupied by South China, Mainland Southeast Asia, and Pan-Asia species. South China species and Mainland Southeast Asia species are significantly more restricted to a single elevation than Pan-Asia species, but there is no difference between these two faunas in the extent of altitude zoning. South China species are more common at elevations above 800 m than both Mainland Southeast Asia and Pan-Asia species. Conversely, the South China fauna is less common than both the other faunas at elevations below 300 m. There is no difference between the Pan-Asia and Mainland Southeast Asia faunas in their restriction to lowland or highland elevations.

Comparing the endemic and nonendemic herpetofaunas, South China, Mainland Southeast Asia, and Pan-Asia species are all significantly less restricted to forested habitats than their Indochina-endemic counterparts. However, there is no difference between endemic species and these three faunas in the number of microhabitats occupied. Endemic species are significantly more likely to occupy a single elevation than South China, Mainland Southeast Asia, and Pan-Asia species. Indochina's endemic fauna is significantly more restricted to elevations below 300 m than the South China and Pan-Asia faunas but not the Mainland Southeast Asia fauna. The region's endemic species are also significantly more restricted to elevations above 800 m than Mainland Southeast Asia and Pan-Asia faunas but not South China fauna.

There were not enough Malaya species to include them in these analyses (tables 7, 8).

## (6) AFFINITIES AMONG SUBREGIONS

Cluster analyses indicate that subregional faunal similarity is tightly linked to geographic proximity and elevation when all herpetofaunal groups are analyzed together. However, these patterns differ slightly when each herpetofaunal group is considered separately.

(6a) ALL HERPETOFAUNAS (fig. 4): Two major groups are recovered in the analysis: northern subregions (group A), and southern subregions (group B). Group A included two clusters; the Northern Annamites and Northeast Lowlands are most similar to each other, and these two cluster with the Northwest Uplands and Northeast Uplands, which are most similar to each other. Within group B, the Cardamom Uplands and Cardamom Lowlands are most similar to each other, and then to the Southern Annamites (Biii). These three subregions are most similar to Bii: (((Southern Lao Lowlands + Interior Cambodia Lowlands) + Mekong Delta) + Central-South Vietnam Lowlands))). The Central Annamites are distinct from all other southern subregions.

(6b) AMPHIBIANS (fig. 5): The Northwest Uplands and Northeast Uplands (group C) are the most similar to each other and most unique from all other subregions. The remaining subregions (group D) cluster in two groups: the remaining northern subregions with the Central Annamites (Di); and the southern subregions (Dii). In Di, the Northern Annamites and Northeast Lowlands are most similar to each other, and they cluster with the Central Annamites. In Group Dii, the Southern Annamites are unique from all other group members, clustering with: ((Cardamom Uplands + Cardamom Lowlands) + ((Southern Lao Lowlands + Interior Cambodia Lowlands) + Central-South Vietnam Lowlands))).

(6c) SNAKES (fig. 6): There are two major groupings in the snake phenogram. Group E is unique from the remaining subregions and contains all northern subregions except the Northern Annamites. Within Group E, the Northwest Uplands and Northeast Uplands are most similar. Together, they cluster with the Northeast Lowlands + Northern Coast. Group F contains three clusters. Fi (unique from Fii + Fiii) is an Annamite group with

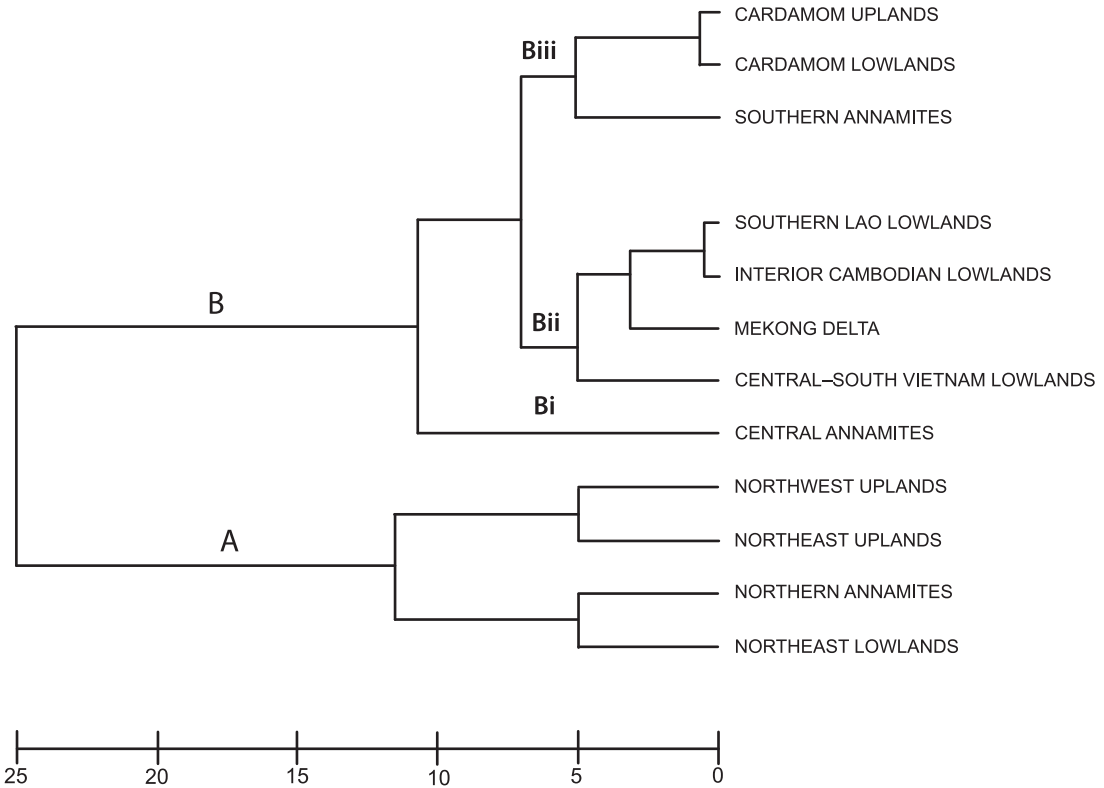


Fig. 4. Cluster analysis phenogram for the herpetofauna of Indochina.

the following cluster: ((Central Annamites + Southern Annamites) + Northern Annamites)). Fii consists of the southern lowlands: Mekong Delta + Interior Cambodia Lowlands clustering with Southern Lao Lowlands + Central-South Vietnam Lowlands. In Fiii, the Cardamom Uplands and Caradamom Lowlands are most similar to each other. Together they cluster with the following subregions: ((Upper Mekong Lowlands + Central Coast) + Southern Coast).

(6d) LIZARDS (fig. 7): There are two major groupings in the lizard phenogram. Group G is a strictly northern cluster, unique from all other subregions: (((Northwest Uplands + Northeast Lowlands) + Northern Annamites) + Northeast Uplands))). This is unique from the south-central group (H). Hi contains only the Central Annamites, which is most distinct from the rest of the south-central group. In Hii, the Mekong Delta exhibits the closest affinity with the Southern

Islands. Together they cluster with Hiii, which includes the remaining six southern subregions: the Southern Annamites is the most distinct and clusters with the following: (((Cardamom Uplands + Caradamom Lowlands) + (Interior Cambodia Lowlands + Southern Lao Lowlands)) + Central-South Vietnam Lowlands))).

(6e) TURTLES (fig. 8): There are two major groupings in the turtle phenogram. Group I, which consists of only southern lowlands, was distinct from the remaining subregions (group J). In group I, the Southern Lao Lowlands clusters with the Caradamom Lowlands, whereas the Mekong Delta clusters with the Interior Cambodia Lowlands. Ji is composed of the Northeast Lowlands and Central-South Vietnam Lowlands. It clusters most closely with Jii: ((Northwest Uplands + Northern Annamites) + (Northeast Uplands + Central Annamites)).

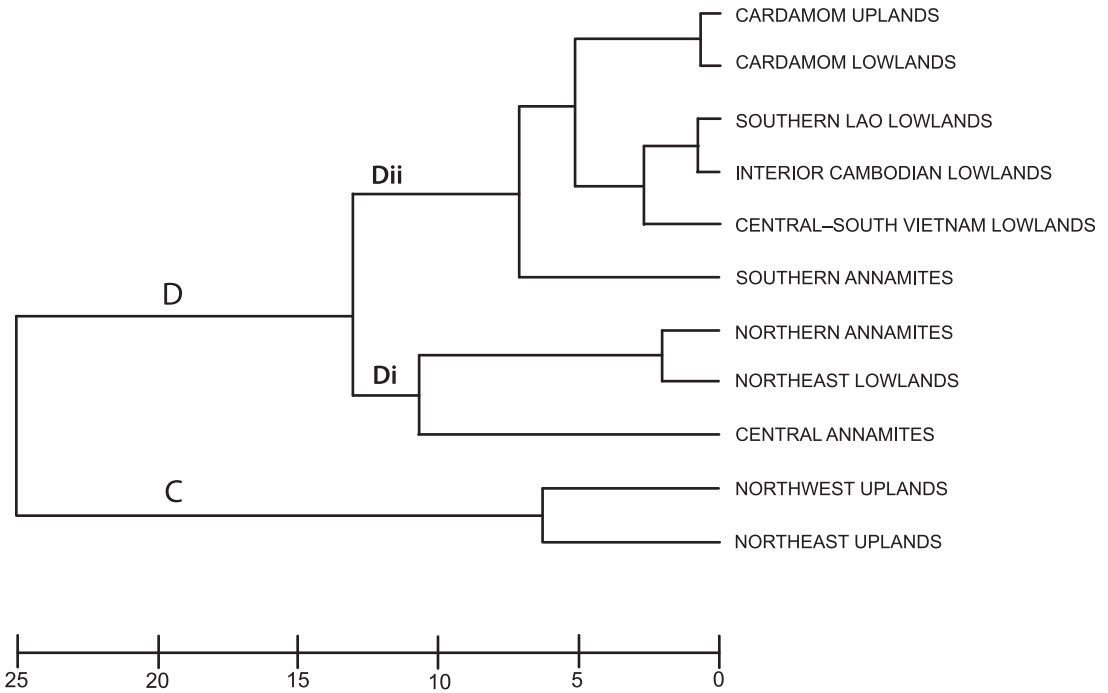


Fig. 5. Cluster analysis phenogram for the amphibians of Indochina.

(6f) ENDEMIC (fig. 9): The most unique subregion for endemic species is the Central Annamites, group K. The Northwest Uplands and Northeast Uplands cluster (Li) is most dissimilar to the remaining subregions. The rest of the subregions fall into two major subgroups (Lii and Liii). In Lii, the Northern Annamites, Central-South Vietnam Lowlands, and Northeast Lowlands all cluster together. Together, they cluster with five subregions: (((Cardamom Uplands + Cardamom Lowlands) + (Southern Lao Lowlands + Interior Cambodia Lowlands) + Mekong Delta) + Southern Annamites).

## DISCUSSION

### REGIONAL PATTERNS OF DIVERSITY

**NORTHERN UPLANDS AND LOWLANDS:** Northern Indochina represents a transitional zone between subtropical and temperate regions lying to the north and a mixture of drier and warmer habitats with a strong

endemic Annamite component lying to the south. Northern Indochina's two lowland subregions differ markedly from each other in richness, endemism, and species composition.

*Northeast Lowlands:* The Northeast Lowlands is geographically central to northern Indochina and has the greatest latitudinal range of any subregion, penetrating deeply into the northern uplands along the Red and Black rivers to the Chinese border. It has relatively high species richness (including over half of Indochina's known freshwater turtle species), and an intermediate level of endemism. Approximately one-fifth of its herpetofauna is also known from South China. There is extensive faunal overlap of certain species groups between these lowlands and the three adjacent northern subregions. The Northeast Lowlands share the most amphibian and turtle species with the Northern Annamites, the most snake species with Northern Coast, and the most lizard species with Northwest Uplands. Its high turtle richness is a combination of South China species restricted to

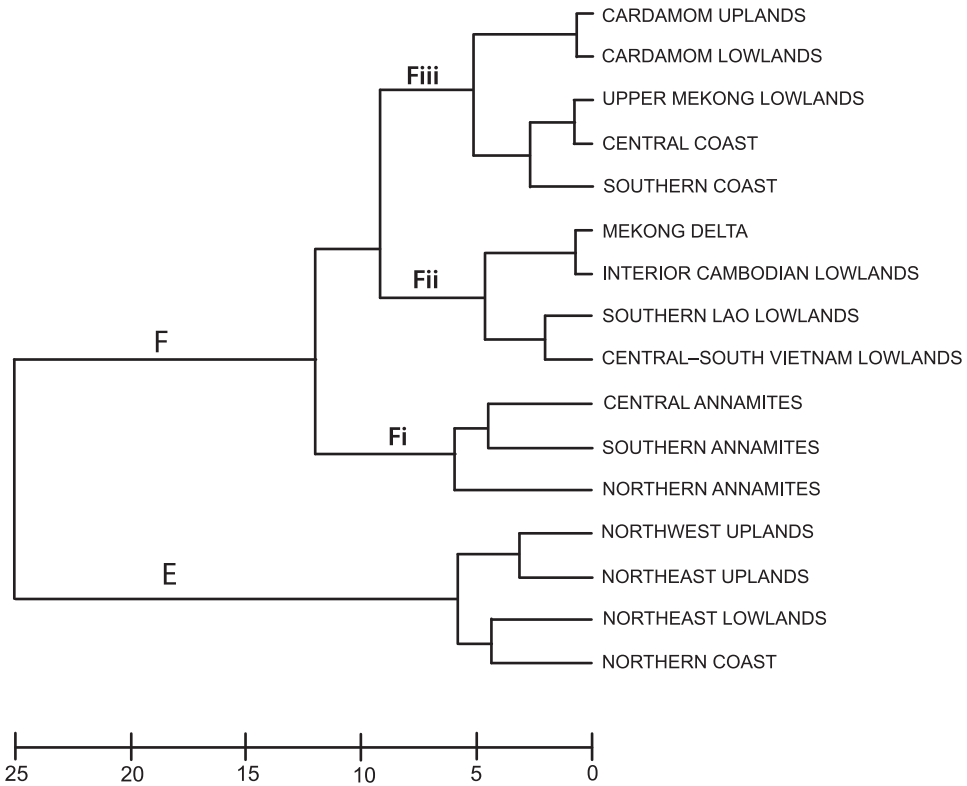


Fig. 6. Cluster analysis phenogram for the snakes of Indochina.

this region of Indochina (e.g., *Mauremys sinensis*, *Rafetus swinhoiei*), widely distributed Pan-Asia species (e.g., *Pelochelys cantorii*, *Indotestudo elongata*), and a single endemic (*Cuora bourreti*).

Many endemic species recorded from the Northeast Lowlands are also found in adjacent upland subregions, with the largest number (seven) shared with the Northern Annamites. The Northeast Lowlands also harbor a set of seven endemics unique to the subregion: *Cuora bourreti*, *Cyrtodactylus chauquangensis*, *C. phonghakebangensis*, *C. roesleri*, *Fimbrios smithi*, *Gekko scientiaventura*, and *Leptoseps tetradactylus*. The majority of these unique endemic species have been described from the lowland regions adjacent to the Northern Annamites that, along with the shared endemics, suggests a strong affinity between these two regions. The large number of freshwater-dependent species (i.e., turtles and amphibians) shared between

them also suggests a relatively high level of communication between them. Additionally, the Northeast Lowlands clusters with the Northern Annamites. Taken together, these observations suggest that extensive dispersal between the Northeast Lowlands and the Northern Annamites is an important factor structuring both the species richness and the level of endemism of these two subregions. In addition, the Northeast Lowlands shares five endemic species with the Central-South Vietnam Lowlands (with which they communicate), and the Central Annamites. Although largely altered by agricultural practices, this area would likely have been a historically important corridor connecting the surrounding subregions. This hypothesis can be tested by measuring intraspecific genetic divergence of species both within the Northeast Lowlands and between it and their surrounding subregions. Similar levels of divergence within and between these

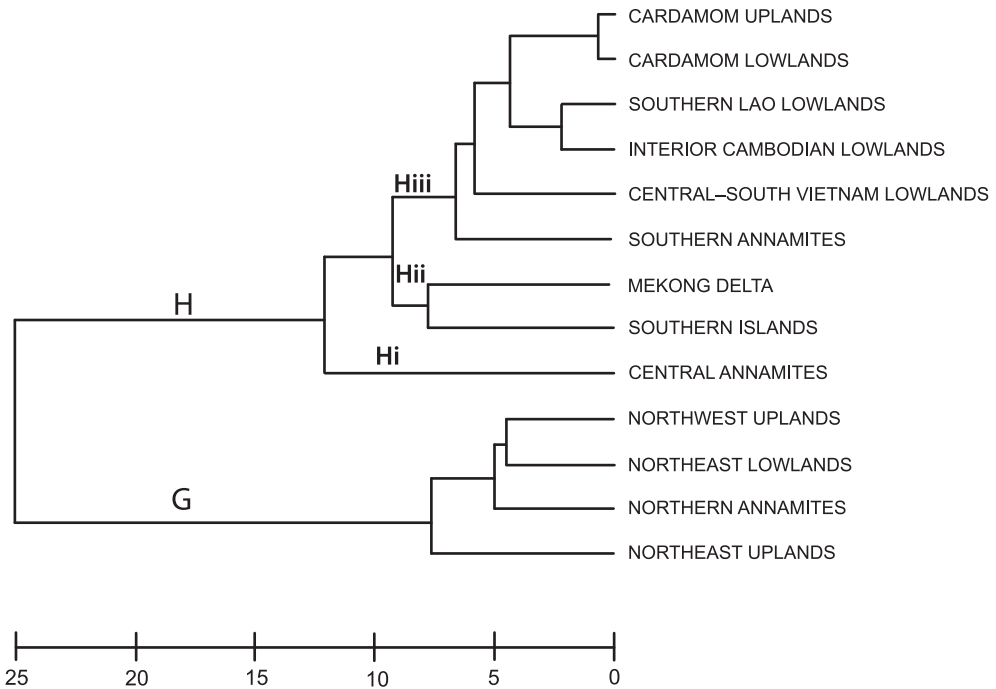


Fig. 7. Cluster analysis phenogram for the lizards of Indochina.

subregions would support the hypothesis of high levels of dispersal between the subregions. These estimates can also be used to look at the relative importance of a northeastern lowland corridor to these subregions.

*Upper Mekong Lowlands:* In contrast, the herpetofauna of the Upper Mekong Lowlands is depauperate, holding less than half of the species richness of the adjacent Southern Lao Lowlands. It is formed almost exclusively of Pan-Asia species; despite its location adjacent to the Khorat Plateau, Mainland Southeast Asia species constitute less of the Upper Mekong Lowlands herpetofauna than ones from the more distant Southern Annamites. Two possible factors could account for this: under sampling and habitat type. Despite its large area (> 52,000 km<sup>2</sup>; 93% more area than the Southern Lao Lowlands) and its accessibility, the Upper Mekong Lowlands has been surveyed only 12 times outside of the capital of Vientiane. The current state of knowledge of the subregion is based almost exclusively on

four publications (Deuve, 1970; Stuart, 1999, 2005b; Bezuijen et al., 2009). Additionally, the subregion itself and the surrounding areas are dominated by dry habitats, which have now been largely altered for agriculture. Across the Mekong to the west lies the dry Khorat Plateau and to the east the abutting uplands host semievergreen forests on their lower slopes in contrast to the wetter eastern slopes of the Annamites. For these reasons, one would not expect this region to have high species richness, especially among freshwater-dependent species. Only four endemic species are currently known from the entire Upper Mekong Lowlands, suggesting a relatively low level of endemism independent of survey effort. In contrast to the Northeast Lowlands, geographic distribution of these endemics suggests dispersal of restricted-range species primarily from lowlands to the south as opposed to adjacent uplands: *Amolops cremnobatus* (Northern Annamites), *Homalopsis nigroventralis* (Southern Lao Lowlands, Interior Cambodia Lowlands), and *Oligodon deuvi* (Mekong Delta,



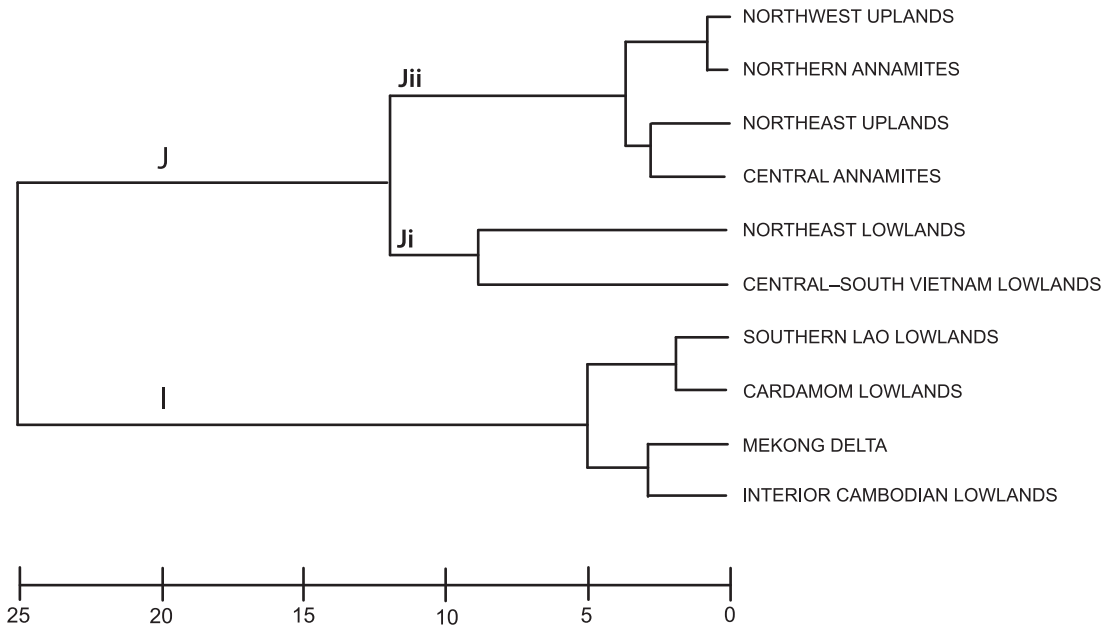


Fig. 8. Cluster analysis phenogram for the turtles of Indochina.

Cardamom Lowlands). *Rhacophorus speleus* was recently described (Orlov et al., 2009) and is not known from outside the subregion.

**Northwest Uplands and Northeast Uplands:** The Northwest and Northeast Uplands share high levels of species richness and endemism. A substantial proportion (24–31%) of this richness is made up of South China species whose southernmost range limits are in the subregions (e.g., *Bombina maxima*, *Dinodon meridionale*, *Japalura fasciata*) (table 6). Of the South China herpetofauna occurring across Indochina's northern uplands, over half (54%) of it is recorded from both the Northeast Uplands and Northwest Uplands. This high proportion of shared South China fauna, along with the shared presence of widespread Pan-Asia species, is largely responsible for their close clustering in similarity analyses. The contribution of South China fauna to northern Indochina's species richness is also observed in the region's other taxa, including mammals (gibbons of the genus *Nomascus*, and the squirrels *Callosciurus inornatus* and *Dremomys gularis*) (Corbet and Hill, 1992; Brandon-Jones et al.,

2004); birds (*Hemixos castanonotus*, *Garrulax milnei*, *Actinodura ramsayi*) (MacKinnon et al., 2000; Robson, 2000); conifers (*Pinus kwangtungensis*, *Pseudotsuga sinensis*, *Amentotaxus yunnanensis*; and orchids (Averyanov et al., 2003; Nguyen et al., 2004; Thomas et al., 2007). High levels of endemism have also been recorded for the subregions: the Northeast Uplands ranks third and the Northwest Uplands sixth in overall endemic species richness.

However, there is also significant divergence in the species composition of these two upland subregions, with differences in the geographic occurrence of both endemic and nonendemic herpetofauna. Of the 53 endemic species found in the northern uplands, only 25% have been recorded from both sides of the Red River. Among the South China fauna recorded from the northern uplands, a group of eight species is restricted to northeast Vietnam and areas of South China lying east of the Red River, including Guangdong Province, Guangxi Autonomous Region, and Hainan Island: *Paramesotriton guanxiensis*, *Tylosotriton asperrimus*, *Achalinus rufescens*, *Opisthotropis*

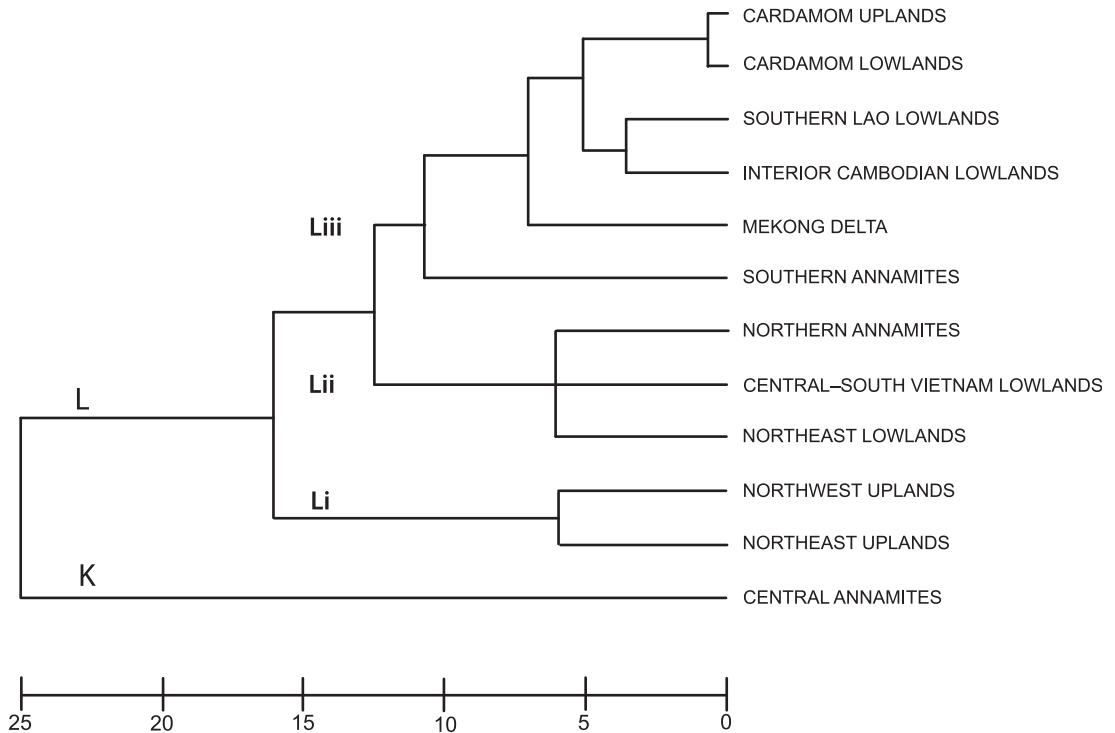


Fig. 9. Cluster analysis phenogram for the endemic herpetofauna of Indochina.

*andersonii*, *Rhynchophis boulengeri*, *Goniurosaurus lichtenfelderi*, *Tropidophorus sinicus*, and *Shinisaurus crocodilurus* (Zhao, 1990, 1999, 2005; Lazell, 1999; Le and Ziegler, 2003; Böhme et al., 2005; Fei et al., 2005; Lü et al., 2005; Zhao et al., 2005; David et al., 2008a; Yang and Rao, 2008; Ziegler et al., 2008 c, d; Fei et al., 2009). High levels of affinity between northeastern Indochina and southeastern China have been observed in other taxonomic groups as well, e.g., southeastern Yunnan's limestone flora has greater affinity with that of northeastern Vietnam than it does with the rest of China (Zhu et al., 2003). Furthermore, of the 14 Mainland Southeast Asia species recorded from the northern uplands, five are found in both subregions while the remaining nine are restricted to the Northwest Uplands: *Caluella guttulata*, *Limnnectes gyldenstolpei*, *Occidozyga magnapustulosa*, *Kurixalus carinensis*, *Rhacophorus orlovi*, *Tropidophorus*

*laotus*, *Scincella melanosticta*, *Tropidophorus microlepis*, and *Cyclemys oldhamii*.

These patterns of faunal overlap and divergence among northern Indochina's upland and highland herpetofauna might be explained by three major nonexclusive hypotheses.

1. *Variation in dispersal opportunities between northern Indochina and adjacent regions.* Due to topographic differences, northwest Indochina has more limited opportunities for faunal exchange with the rest of Asia than does the northeast. Most regions adjacent to the Northwest Uplands (southern Himalayas, northeastern Myanmar and Thailand, southwestern Yunnan Province) lie at much higher elevations than northern Indochina. This may limit the dispersal of organisms both into and out of northwestern Indochina that are intolerant of altitudes exceeding ca. 3500 m. In addition, these uplands lying west of Indochina largely run

north to south, which might further impede eastward dispersal into Indochina. Since the uplift of the Himalayas, and the Tibetan Plateau in particular, the dispersal corridor connecting south Asia to northwest Indochina has been restricted to a narrow band of habitat lying between the lowlands of Bangladesh and the upland areas of eastern India (An et al., 2001).

In contrast, the Northeast Uplands and mainland southeast China are connected via montane regions lying at ca. 1000–2000 m as well as lower elevation corridors along the coast. Furthermore, during periods of lower sea level, eastern Indochina was contiguous with large areas of southeastern China (including Hainan Island) via emergent land bridges extending as far south as central Vietnam's Hai Van pass (e.g., Lazell, 1999; Chou et al., 2001; Honda et al., 2000; Honda et al., 2001; Ota et al., 2002; see also Stuart and Parham, 2004; Yu et al., 2007a). It is unclear what role dispersal across historical land bridges with southeastern China has in structuring diversity outside the Northeast Uplands. If this were an important dispersal route for herpetofaunal lineages from Hainan Island and southeast China to eastern Indochina, then we would predict that northern Annamite populations would be genetically less divergent from those of the Northeast Uplands (and possibly southeast China to Hainan Island) than from those of the Northwest Uplands.

These geographic and paleoclimatic factors favor a greater number and frequency of dispersal events between the Northeast Uplands and southeastern China than between the Northwest Uplands and its surrounding regions, including southwestern China. The high incidence of Mainland Southeast Asian species in the Northwest Uplands may reflect limited dispersal with other adjacent regions to the north and west, while the higher biogeographic affinity between the Northeast Uplands and South China may reflect a more frequent interchange of fauna. Additionally, these factors may explain the higher species richness observed in the Northeast Uplands when compared to the Northwest Uplands.

2. *Variation in climate.* A second hypothesis explaining the observed patterns of

species richness, divergence, and similarity in northern Indochina's uplands is climatic variation across the region. Although the complex topography in the north makes local climates extraordinarily variable, northeastern Indochina and adjacent South China are generally both wetter and warmer than northwestern Indochina and its adjacent regions. In general, warmer and wetter climates favor many herpetofaunal lineages (including freshwater turtles, aquatic or semiaquatic snakes and lizards, and almost all amphibian species), and this hypothesis is consistent with observed greater species richness in the Northeast than the Northwest Uplands for all herpetofaunal groups except for the lizards, which are the least environmentally sensitive group. Similarly, the high variability in rainfall due to topography would result in significant geographic species restrictions for rainfall-dependent taxa. Comparative ecological analyses of the climatic and habitat requirements of potentially informative species groups can be used to further test this hypothesis. However, the detailed ecological data required is not available for the vast majority of Indochinese amphibians and reptiles. Alternatively, ecological niche modeling could be applied to determine range delimitations of species suites currently restricted to either side of the Red River in northern Vietnam (e.g., Graham et al., 2006; Raxworthy et al., 2007).

3. *Red River as a dispersal barrier.* A third hypothesis explaining patterns of divergence across northern Indochina's montane uplands is that the Red River either acts as, or is coincident with, a barrier to dispersal. The Red River has a swift-flowing course through steep, narrow gorges in northern Vietnam, which has remained largely unchanged for at least the past 5 million years (Allen et al., 1984; Replumaz et al., 2001), making it a plausible long-term barrier to dispersal movement. This theory has been advanced previously to explain the distribution patterns of a wide variety of both flora and fauna (e.g., Delacour et al., 1928; MacKinnon, 1997; Geissman et al., 2000; Orlov et al., 2001; Averyanov et al., 2003; Ziegler et al., 2008c; Zhang et al., 2009). Our results are consistent with the role of the Red

River as a partial biogeographic barrier to herpetofauna.

A number of predictions can be developed to test whether the Red River is a biogeographic barrier. If the Red River does not act as a barrier to movement, one would predict an even cline in the distribution of southeast China species from east to west and southwest China/northeast Myanmar–Thailand species in the opposite direction. Our results show that 81% (42/52) of the southeast China species found in Indochina are present in northwestern Indochina. They further show that 54% (47/87) of the southwest Yunnan/northeast Thailand and Myanmar species found in Indochina are present in northeastern Indochina. This suggests that if there is a barrier between the two subregions, it is relatively weak with respect to adjacent faunas.

However, recent phylogenetic evidence suggests that it may play a stronger role than suggested by the above results. Genetic analyses of lineages present on both sides of the river can be used to test its effectiveness as a dispersal barrier. If the Red River is a barrier, then there should be greater genetic divergence across it than within northern Indochina's uplands on each side of the river. If it is not a barrier (or a relatively weak one), then genetic divergence among northern Indochina's upland populations will be strongly correlated with distance regardless of their location relative to the river's course. The former hypothesis is supported by several phylogenetic analyses that show deep maternal lineage divergence between taxa from either side of the Red River: *Paramesotriton* (Chan et al., 2001; Lü et al., 2004), *Leptobranchium* (Rao and Wilkinson, 2008; Zheng et al., 2008), *Odorrana* (Bain et al., 2009c), and *Acanthosaura* (Kalyabina-Hauf et al., 2004).

A number of additional recent phylogenetic analyses also indicate greater affinity of northeastern Indochinese lineages to South China than to the more proximal northwestern Indochina lineages, supporting the hypothesis that dispersal across the Red River is limited. The megophryid frog *Leptobranchium* “*chapaense*” from the Northeast Uplands is sister to *L. hainanense* from Hainan and more distant from *L. chapaensis*,

sensu stricto, from the Northwest Uplands (Zheng et al., 2008). Similarly, lineages of the tree vipers *Viridovipera stejnegeri* and *Cryptelytrops albolabris* from the Northeast Uplands are more closely related to those from eastern China than to the rest of Indochina's populations (Malhotra and Thorpe, 2004a, b). This pattern of divergence between a northeastern Indochinese–southern Chinese fauna and northwestern Indochinese one is also observed in the three northernmost species of the crested gibbon genus *Nomascus*. The two northeastern species, *N. hainanus*, restricted to Hainan Island, and *N. nasutus*, found in northeastern Vietnam and small regions of southeast China, form a clade and are distantly related to the species found directly west of the Red River, *N. concolor*, a pattern that has been attributed in part to the Red River acting as a dispersal barrier (Geissmann et al., 2000, Thinh et al., 2010).

If the Red River is a barrier to dispersal it could shape distribution patterns through a number of processes. Ancestral populations may have been split by the Red River in a vicariant event and subsequently diverged from each other. Under this mechanism, divergence times should cluster around 5 Mya or earlier. Alternatively, ancestral populations may have dispersed across the Red River after its formation and diverged in allopatry. Under these circumstances, we expect divergence times to be younger than the formation of the Red River's current course. Finally, it is possible that these populations shared common ancestors at the river's headwaters in Yunnan Province, China. This origin would be supported by the presence of a zone of hybridization. As with the second scenario, divergence times should be more recent than 5 Mya. All three of these processes may have occurred; relative divergence times will indicate which scenarios have shaped the observed patterns.

It is also possible that the Red River is not itself a dispersal barrier but rather coincides with a separate feature driving divergence between northwestern and northeastern Indochina. Northeastern Vietnam is part of the South China Platform whereas the remaining areas of Indochina are formed from the Indochina plate. The suture zone between

these two plates lies parallel to and slightly south of the Red River. If the divergence observed between the northern Indochinese uplands were due to differences in faunal inputs between the two plates, then the suture zone itself would form a barrier coincident with the Red River. We believe this to be an unlikely explanation for subregional divergence because the collision between the plates occurred at least 65 Mya and was followed by ample opportunities for the dispersal and divergence of fauna carried on the two platforms. This hypothesis can be tested by sampling herpetofauna from the thin upland strip of the South China plate currently lying southwest of the Red River. If the hypothesis is true, this fauna should have greater faunal and genetic affinities with the Northeast Uplands than with the rest of the Northwest Uplands.

**THE ANNAMITES, SOUTHERN LAO UPLANDS, AND CENTRAL–SOUTH VIETNAM LOWLANDS:** The Annamite Range, a series of adjacent uplands and plateaus with intervening lower-lying regions, lies entirely within Indochina. At its northern limit it is adjacent to the Northwest Uplands, Northeast Lowlands, and Upper Mekong Lowlands. In the south it terminates among the lowlands of eastern Cambodia and southern Vietnam. Overall, both the region and its associated lowlands have high levels of herpetofaunal species richness and endemism (tables 4, 5). The relatively depauperate nature of the Southern Annamites and Southern Lao Uplands may be attributable to the fact that they are under-surveyed per unit area compared to the rest of Indochina's subregions.

Elevated numbers of endemic species have also been recorded from the Annamites for a wide range of other taxa (MacKinnon, 1997; Stattersfield et al., 1998; Baltzer et al., 2001; Sterling et al., 2006): at least two of the recently described ungulates (*Pseudoryx nghetinhensis*, *Muntiacus vuquangensis*); the recently described rabbit *Nesolagus timminsi*; the doucs (*Pygathrix* spp.), a group of three leaf monkey species; and two of the three recently described babblers (*Garrulax konkakhensis*, *G. ngoclinhensis*) are currently understood to be endemic to the Annamites.. Two conifers are endemic to the mountain

range as well: *Pinus krempfi* is restricted to the Southern Annamites and the conifer *P. dalatensis* is restricted to the Central Annamites and Southern Annamites with the exception of a single population in the Northern Annamites in Laos (Nguyen et al., 2004; Thomas et al., 2007). Orchid endemism is also high in the Annamites, with 8%–10% of species in the Vietnamese sections of the central and southern sections of the range endemic to the country (Averyanov and Averyanov, 2003; Averyanov et al., 2003).

The mechanisms responsible for high levels of Annamite endemism remain unclear and have only recently become the subject of phylogenetic work. Phylogenetic analyses of the rabbit *N. timminsi* and its only known congener, *N. netscheri*, which is restricted to the uplands of Sumatra, suggest that the species diverged ca. 8 Mya, when lowered sea levels allowed the Greater Sundas to communicate directly with southern Indochina via emergent landbridges (SurrIDGE et al., 1999). Presumably, the ancestral *Nesolagus* was distributed over parts of this region during periods of lower sea levels, which allowed it to disperse between Mainland Southeast Asia and the Sundas. The occurrence of disjunct Annamite-Sundaic distributions of the snakes, *Sibynophis melanocephalus* and *Calamaria loyii* (the latter a small, burrowing species), suggests similar scenarios associated with dispersal across land bridges and subsequent isolation resulting in relict populations of these evergreen forest-dependent species. Complete regional samplings of a variety of herpetofaunal lineages will be necessary before the potential role of dispersal and isolation between mainland and insular Southeast Asia underlying the Annamites's high proportion of endemic species can be addressed.

**Annamite substructuring:** The recognition of three distinct subregions (northern, central, and southern) within the range is supported by their strong divergence in faunal composition: of all the Annamite herpetofaunas, only the snake faunas cluster all three subregions together in the biotic affinity analyses (figs. 4–8). This contrasts with the northeast and northwest upland subregional faunas, which co-occur in the same cluster. Difference in

endemic species composition is one of the main factors underlying this divergence: 76% of the 106 Indochinese endemic species recorded from the Annamites are found within only one of the Annamite subregions. This is reflected in the cluster analyses of endemic species as all three upland subregions are placed in separate clusters (fig. 9). Given the relatively small size of the Annamite uplands (115,000 km<sup>2</sup> total; northern: 47,000 km<sup>2</sup>; central: 42,000 km<sup>2</sup>; southern: 26,500 km<sup>2</sup>), both the overall rate of endemism and the extent of substructuring within the range are notable.

Evidence for substructuring of the endemic Annamite fauna has also been recorded for other taxa. Among avifauna there is notable divergence between restricted-range species composition of the adjacent Kon Tum (Central Annamites) and Da Lat (Southern Annamites) Endemic Bird Areas (EBAs; regions covering the global ranges of two or more restricted-range bird species) (Stattersfield et al., 1998; Tordoff, 2002). The former contains nine restricted-range bird species and the latter 11, only five of which are found in both subregions (*Rheinardia ocellata*, *Garulax milleti*, *G. vassali*, *Jabouilleia danjoui*, and *Sitta solangiae*) (Tordoff, 2002; Ounekham and Inthapatha, 2003; Collar, 2006). Among primates, the red-shanked douc (*Pygathrix nemaeus nemaeus*) occupies the Northern Annamites and Central Annamites whereas the black-shanked douc (*P. nigripes*) is concentrated largely in the Southern Annamites and associated lowlands; the intermediate gray-shanked (*P. n. cinerea*) form lives in the southern section of the Central Annamites, overlapping both of the other taxa. The Saola (*Pseudoryx nghentinhensis*) is restricted to the northern and Central Annamites. The distribution of the additional recently described large mammals in the Annamites remains unclear due to a long history of exploitation and open phylogenetic questions (Amato et al., 2000; Groves and Schaller, 2000).

The presence of at least three distinct biogeographic units in the Annamite Range is also concordant with the patterns described in some recent phylogenetic studies. The freshwater turtle *Cuora galbinifrons* species group was found to have three distinct lineages, with a southern Annamite clade sister to a central

plus northern Annamite clade (although the provenance of the southern Annamite clade was inferred from trade data) (Stuart and Parham, 2004, and references therein). Phylogenetic analyses of primates are concurrent with this pattern. A phylogeny of the douc complex indicates a sister relationship between *P. n. nemaeus* (northern and Central Annamites) and *P. n. cinerea* (Central Annamites), with *P. n. nigripes* (Southern Annamites) sister to this clade (Roos and Nadler, 2001).

*Northern Annamites*: Indochina's Northern Annamites is contiguous with both the Northwest Uplands to the north and the Central Annamites to the south. Its geographic location between the northern uplands and the remaining Annamite uplands subregions is reflected in their faunal composition and biotic affinity. The Northern Annamites ranks fourth in overall species richness and the cluster analyses suggest greater faunal overlap with adjacent northern subregions than southern ones: of all groups, only the snakes cluster tightly with a southern subregion, the Central Annamites (figs. 4–8). The subregion's endemic species cluster with both the Northeast Lowlands and the Central–South Vietnam Lowlands in the biotic affinity analyses of endemic species (fig. 9). Of the 32 species of endemic Indochinese fauna recorded from the Northern Annamites, half are strictly northern Indochinese endemics and half are known from both northern and southern Indochina. This contrasts with the Northeast Uplands and Northwest Uplands, which are dominated by strictly northern Indochinese endemics, and the Central and Southern Annamites, which are dominated by strictly southern endemics. Biogeographically, the Northern Annamites also appear to be transitional between northern and southern Indochina. The proportion of South China fauna present in the Northern Annamites (14%) is intermediate between the high values recorded in the northern uplands (24–31%) and the much lower ones in the Annamite uplands to the south (5–9%). Given the above results we hypothesize (1) that northern Annamite populations of a given species should be less divergent from populations in other upland subregions than are populations between other upland subregions, and (2) that, given their clustering with

northern subregions, Northern Annamite populations should have lower levels of genetic divergence from the Northern uplands than from the Central and Southern Annamites.

*Central Annamites:* The central Annamite uplands form a contiguous montane block with the Northern Annamites; however, it is separated from the Southern Annamites by low-lying areas covered by a mixture of evergreen, semievergreen, and dry forest types. The Central Annamites ranks third among Indochinese subregions in total species richness. Central Annamite herpetofauna as a whole forms a unique group within a southern cluster of subregions (fig. 4), a pattern that is also true for the lizard fauna (fig. 7). The other three taxonomic groups exhibit greater variation in their affinity with other subregions and cluster with at least one northern subregion: the Central Annamites amphibian fauna clusters with the adjacent Northern Annamites + Northeast Lowlands (fig. 5); the Central Annamites snake fauna is part of a strictly Annamitic cluster (fig. 6); and turtles are the only Central Annamites fauna clustering most closely with a nonadjacent subregion, the Northeast Uplands (fig. 8). The Central Annamites has the highest level of herpetofaunal endemism in Indochina, forming a unique cluster in the affinity analysis; this indicates that its composition is highly divergent from the rest of Indochina (fig. 9).

Because of its intermediate position between the northern and southern upland regions of Indochina, previous researchers have proposed that the Central Annamites serves as a refuge for northern upland herpetofauna whose ecological niches require cooler, humid, upland habitats (e.g., de Laubenfels, 1975; Brandon-Jones, 1996; Inger, 1999; SurrIDGE et al., 1999; Orlov, 2005). We detected 113 species from the central Annamite fauna that were also found in the Northwest Uplands and/or the Northeast Uplands (the Northern Annamites were excluded from this analysis due to their physical continuity with the Central Annamites). Eight of these species (7%) are restricted to regions above 300 m, and only one is restricted to areas above 800 m (*Geomyda spengleri*). A similar pattern of faunal overlap is observed for the Central Annamites and southern uplands (Southern Annamites, Southern Lao Uplands, and Cardamom

Uplands). Of the 120 species shared between these regions, 9 (8%) are restricted to regions above 300 m and only one is restricted to areas above 800 m (*Leptobrachium pullum*).

Although the numbers are relatively low, these two suites of species are notable for being entirely exclusive of each other. This suggests that the Central Annamites may capture upland-restricted species dependent on evergreen forests at both the southernmost and northernmost extent of their ranges in Indochina. The ranges of the upland Central Annamite species that are also known from the Northwest Uplands and Northeast Uplands (i.e., the frogs *Leptolalax bourreti*, *Babina chapaensis*, *Rhacophorus feae*, *Theloderma gordonii*; the tree viper *Viridovipera gumprechtii*; the elapid *Bungarus slowinskii*; and the turtles *Platysternon megacephalum*, and *Geoemyda splengeri*) extend to South China and/or Mainland Southeast Asia. The ranges of Central Annamites fauna also known from the southern uplands are dominated by Indochinese endemics. Three of these species are frogs endemic to the Annamites: *Brachytarsophrys intermedius*, *Leptobrachium mouhoti*, and *Chiromantis laevis*; three are Indochinese endemics: the snake *Fimbrios klossi*, the frog *Ophryophryne gerti*, and the lizard *Acanthosaura capra*; two are frogs found across South China and/or Mainland Southeast Asia: the frogs *L. pullum* and *Feihyla palpebralis*; and one snake extends to the Southern Himalayas: *Calliophis intestinalis*.

Biogeographical analyses mirror this pattern. There is a significantly higher proportion of South China and/or Mainland Southeast Asia species in the shared northern uplands–Central Annamites fauna (34%) than in the shared southern uplands–central Annamite fauna (21%) ( $\chi^2 = 7.018$ ,  $df = 1$ ,  $p < 0.01$ ). Similarly, the proportion of endemic Indochinese fauna shared between the southern uplands and the Central Annamites (17%) is higher than that shared between the northern uplands and the Central Annamites (4%) ( $\chi^2 = 10.854$ ,  $df = 1$ ,  $p < 0.001$ ). Both the northern and southern upland herpetofauna share an equal proportion of Pan-Asia species (63%) with the Central Annamites.

*Southern Annamites:* The Southern Annamites consists of a suite of plateaus that are isolated geographically from the Central Annamites. It is also a younger formation created by different orogenies than those that uplifted the Central Annamites. Affinity analyses indicate that the combined herpetofauna of the Southern Annamites cluster most closely with the Cardamom Uplands and Caradamom Lowlands (fig. 4) despite their geological uniqueness and separation from these two subregions by a large expanse of lowland delta (fig. 1). This clustering likely results in large part from the relatively low number of surveys conducted in these three subregions and the underlying assumptions of the clustering algorithm that weights shared presences and absences equally (see Methods). Although all three subregions harbor more than 15% of Indochina's total herpetofauna, their overall species richness ranks are low (table 4). Despite this, the Southern Annamites ranked second overall in regional endemism per unit area (table 5). Further surveys of the Southern Annamites will be necessary before its species richness, endemic composition, biogeographic affinities, and relationship to the rest of Indochina's subregions can be accurately assessed.

*Southern Lao Uplands:* Given its relatively large size (47,500 km<sup>2</sup>, similar to both the Northern Annamites and Central Annamites), the presence of evergreen forests, as well as its geographic complexity and close proximity to the species-rich Central Annamites, we predict that this region should be relatively species-rich. However it remains under-surveyed per unit area when compared to other subregions of Indochina, having been rigorously surveyed for herpetofauna only twice (Teynie et al., 2004; Stuart, 2005b). We excluded the Southern Lao Uplands from the cluster analysis for both richness and endemism because of its low overall species numbers.

A relatively high proportion of the Southern Lao Uplands herpetofauna is endemic (33%), a level that is similar to that recorded for the Central (33%) and Southern Annamites (25%) and the Southern Islands (25%). A roughly equal proportion of this endemic fauna is made up of species restricted to southern Indochina and those found in both northern and southern

Indochina. A similar ratio is observed in the Central–South Vietnam Lowlands, Southern Lao Lowlands, and Interior Cambodia Lowlands; the remaining southern subregions' endemic faunas are dominated by southern Indochinese species.

Evidence from other research suggests that the Southern Lao Uplands might be an extension of the Central Annamites rather than a separate biogeographic unit. A pattern of shared fauna between the two subregions has been suggested for butterflies (Monastyrskii, 2007) and plants (Averyanov et al., 2003), and at least two bird species endemic to the Annamites have also been recorded from the Southern Lao Uplands (*Garrulax vassali*, *Macronous kelleyi*) (Tordoff, 2002; Ounekham and Inthapatha, 2003). Given the lack of data on species composition of the Southern Lao Uplands, it is unclear whether this affinity is also true for the herpetofauna. A species comparison of the Southern Lao Uplands and nearby uplands shows that there is extensive faunal overlap with the Central Annamites (81%) and the Southern Annamites (70%) and a lower level of exchange with the Cardamom Uplands (42%). However, only 57% of the Southern Lao Uplands fauna is also found on the Khorat Plateau of neighboring Thailand. These findings are congruent with those of Teynie et al. (2004), who suggested that the Bolovens Plateau of the Southern Lao Uplands might act as a refuge for herpetofauna associated with upland and highland humid areas.

The high similarity between the herpetofauna of the Bolovens Plateau and adjacent upland subregions may be attributable to its relatively recent age; a basaltic formation created ca. 800,000 years ago (Fontaine and Workman, 1997; Attwood and Johnston, 2001). It is therefore likely that the plateau was colonized recently by fauna from neighboring upland areas unaffected by the giant lava flows that created it. This hypothesized recent colonization is congruent with at least one phylogenetic analysis, which found that a central Annamite population of *Viridovipera vogeli* was more closely related to populations on the Dongreak Mountains (Thailand), than those of the intervening Bolovens Plateau (Malhotra and Thorpe, 2004a).



*Central–South Vietnam Lowlands:* The Central–South Vietnam Lowlands has high levels of both species richness and endemism. In general, the subregion has the greatest faunal overlap with Indochina's other lowland subregions (figs. 4–9). This is likely due to the high number of Pan-Asia species distributed across Indochina's lowlands, although they cluster with the northern subregions and Central Annamites in our affinity analysis.

The Central–South Vietnam Lowlands stands out as the only non-island lowland subregion with a notable number of endemic species (27); it ranks fifth in endemic species richness for all major groups except lizards (table 5). This is largely due to its proximity with the adjacent Central and Southern Annamite uplands with which it shares 67% of their endemic species. A finer-scale mapping of this subregion than is currently possible would allow us to define those areas that are most faunally similar in composition to the Central Annamites and Southern Annamites, respectively, and identify possible dispersal corridors between these upland formations as well as with the adjacent Northeast Lowlands.

It is also possible that this lowland region contains more than one biogeographic unit. The Central–South Vietnam Lowlands is a diverse area composed of three largely noncontiguous blocks covering almost five degrees of latitude and including three major forest habitat types (evergreen, semievergreen, and deciduous dipterocarp). Although portions of the Central–South Vietnam Lowlands are adjacent to the Northeast Lowlands, they do not share as many species as do the Central–South Vietnam Lowlands and the partly adjacent Southern Lao Lowlands. This can be attributed to habitat differences and as yet unrecognized structuring of diversity within the lowland units.

**THE LOWER MEKONG WATERSHED AND CARDAMOM UPLANDS AND LOWLANDS:** The southernmost third of Indochina is dominated by the large, ecologically and biotically uniform lower Mekong watershed, which encompasses three lowland subregions: the Southern Lao Lowlands, Mekong Delta, and Interior Cambodia Lowlands. The species richness of these lowlands is high, though its herpetofauna is dominated by widespread, Pan-Asia species. There is little evidence of

substructure in the distribution of amphibians and reptiles within the region. In contrast to Indochina's other lowland areas, the lower Mekong watershed has few adjacent upland regions and a low, uniform elevation except for a series of low parallel rocky hills separated by agricultural plains in its southern regions.

The only portion of Cambodia lying outside the Mekong watershed is the Cardamom Massif. The Cardamom Uplands and its associated Lowlands share over half of their nonendemic species (61%), although of the 11 endemic species found in the two subregions, only two occupy both the uplands and lowlands. Because of their proximity to Thailand, both subregions are dominated by species also found in Thailand. A large number of these are species restricted to Mainland Southeast Asia, a fauna that makes up 19% of upland and 16% of its lowland species richness. Overall, the Cardamoms are relatively depauperate of herpetofauna: the uplands rank fourth from last and the lowlands last in species richness and endemism. Recent bird surveys in the Cardamoms also indicate a relatively depauperate avifauna compared to other Indochinese uplands, although three restricted-range species are found there, including one endemic to the area (*Garrulax ferrarius*) (Eames et al., 2002; Collar, 2006). This depauperate fauna may be partly attributable to low survey efforts. The Cardamoms are relatively under-surveyed per unit area compared to the other subregions in Indochina; and to date there have been only four major surveys specifically targeting the Cardamoms (Daltry and Chheang, 2000; Daltry and Wüster, 2002; Ohler et al., 2002; Stuart and Emmett, 2006; Grismer et al., 2007a, 2008a, b) supplemented by short site-specific visits and patchy survey efforts (e.g., Mouhot, 1864; Smith, 1928; Bauer and Das, 1998; Platt et al., 2003, 2006; Holloway and Sovannara, 2004).

Studies of mammalian distribution patterns, and of primates in particular, have supported the hypothesis that the Mekong River presents a geographic barrier to dispersal (Fooden, 1996; Nadler et al., 2005; Meijaard and Groves, 2006). We found little evidence of this for amphibians and reptiles. The three southern subregions through which

the Mekong River flows (Mekong Delta, Interior Cambodia Lowlands, Southern Lao Lowlands) clustered closely together both for total and endemic species richness. Furthermore, over half of Indochina's total herpetofauna (256 species) are also found in Thailand, which is largely separated from Indochina by the Mekong River. The weak role of the Mekong as a biogeographic barrier is congruent with phylogenetic analyses of *Viridovipera vogeli*, whose populations from the Central Annamites (west of the Mekong) are more closely related to Thai populations from the Dongraek Mountains (east of the Mekong) than they are to Boloven populations (west of the Mekong) (Malhotra and Thorpe, 2004a). Furthermore, the monotypic *Mantheuys phuwuanensis*, known from the Upper Mekong Lowlands and adjacent Thailand is found on either side of the Mekong River.

Historically, there has been little opportunity for populations on either side of the Mekong to diverge. The river has undergone a complex series of captures and course shifts over the past 7 million years (Rainboth, 1996). Until the late Pleistocene its upper section flowed westward around the Khorat Plateau and into the Gulf of Thailand via the Chao Phraya River, whereas the lower Mekong south of Khong Island (located just north of the Lao-Cambodian border) flowed westward, entering the gulf near Kampot on Cambodia's southern coast, until ca. 5000 years ago (Attwood and Johnston, 2001). Today it flows to the east of the Khorat Plateau and enters the gulf in southern Vietnam. Given these recent shifts and captures, the lower Mekong Basin of Indochina may have formed a contiguous region until quite recently, allowing little time for divergence of either genetic or faunal composition. This is in contrast to the Red River, which has followed its current course for a minimum of 5 million years.

Taken together, the analyses and history of the Mekong River's course shifting suggest that the Mekong Delta, Interior Cambodia Lowlands, and Southern Lao Lowlands should be considered a single biogeographic unit instead of three subregions divided by political boundaries. Considering the lower Mekong watershed as a single unit would create an enormous subregion, the largest in

Indochina, covering approximately one-quarter of Indochina's total land area with an overall species richness of 213 (ranked 8 out of 10, controlled for area), 34 of which are endemic species (ranked 7 out of 10, controlled for area). Although this extensive area's fauna is composed primarily of Pan-Asia species (62%), it holds 14 freshwater turtles, representing over half of Indochina's overall freshwater turtle biodiversity. The same number of turtles occurs in the Northeast Lowlands, but only four species are common to both areas (*Cuora mouhotii*, *Cyclemys oldhami*, *Indotestudo elongata*, and *Pelochelys cantorii*).

Recent survey results suggest that there are still undiscovered species in the isolated hills and outcroppings in the lower Mekong watershed as well as nearshore islands that would have been connected to the mainland during glaciation events. Isolated rocky outcrops within the lower Mekong Delta have been shown to house endemics of the gekkonid genus *Cnemaspis* (a genus known from the Sundas, Malay Peninsula, Mainland Southeast Asia, and southern regions of Cambodia and Vietnam). Until very recently, there was a large gap in the distribution of *Cnemaspis* between southeast Thailand (*C. chanthaburiensis*) and the Con Dao Islands in the South China Sea (*C. boulengeri*). *Cnemaspis chanthaburiensis* has since been recorded from the Cardamoms and six more endemic congeners described from the Cardamoms and southern Vietnam, including small rocky hills of the Mekong Delta and offshore islands of Rach Gia Bay, which represent partly submerged areas of the Cardamom Massif (Grismer et al., 2010a, b). The endemic rupicolous pitviper, *Cryptelytrops honsonensis*, has also been described from Rach Gia Bay (Grismer et al., 2008c). Grismer and Ngo (2007) further point out that these lower Mekong outcroppings would have existed as islands during sea level highstands, greatly reducing any opportunity for genetic exchange. They postulate that if Indochinese *Cnemaspis* species form a monophyletic group, it is likely that upland isolation due to sea level highstands drove speciation, although the timing of these highstands has yet to be calibrated. These processes may also explain the geographic distribution of *C. honsonensis*.

**COASTS AND ISLANDS:** The unique attributes of Indochina's coastal and island subregions strongly structure their faunal composition. Indochina's narrow coastal subregions span almost its entire latitudinal extent and present relatively harsh conditions, particularly to amphibians: the deltas are brackish near the coasts and elsewhere conditions are largely arid. Only nine of the region's 120 coastal species are amphibians, representing less than 5% of Indochina's total amphibian fauna. The coasts are also Indochina's most faunally depauperate subregions; snakes are the only major taxonomic group with a sizable presence in all three coastal areas where they make up over half of the herpetofauna. Although historically present in the Central Coast and Southern Coast, *Crocodylus porosus*, one of two species of crocodiles known from Indochina, has now become virtually unknown in these areas. Two-thirds of the coastal herpetofauna are Pan-Asia species (67%) and, as a whole, the fauna has broad ecological tolerances: 58% of all species are found in open habitats (including those also found in forests) and 57% can be found at all elevations. However, these coastal regions are also home to some unique endemic species not found elsewhere in Indochina. This includes a suite of reptiles known only from the southern coasts: two colubrid snakes, *Oligodon macrurus* and *O. moricei*; two gekkoes, *Dixonius aaronbaueri* and *Gekko grossmanni*; and one agamid lizard, *Leiolepis ngovantri*.

The island subregions, as defined in this analysis, remain somewhat artificial units because they combine survey data from individual islands, which may be poorly comparable. We would have preferred to group islands by geological and geographic relatedness and treat each group as a separate subregion. Regardless, there are some general comments that we can make about the richness and distribution of Indochina's island fauna.

As with the coasts, the species composition of Indochina's island amphibian and reptile communities appear to be strongly affected by local climate and habitat. Arid-tolerant snakes and lizards are the only groups to have significant levels of richness on the offshore islands and of the 17

Indochinese endemic species found on islands, 15 are lizards. The remaining two endemics are the viper *Cryptelytrops honsonensis* and the frog *Limnonectes dabanus*. In contrast, no turtles have been recorded from the offshore islands and among the eight amphibians present, six are widespread, ecologically tolerant Pan-Asia species. All islands lack the permanent and diverse freshwater habitats found on the mainland, with the single exception of the Rach Cua Can River on Phu Quoc. This distribution pattern is similar to that recorded in the generally dry coastal areas where snakes and lizards also have higher species richness than the more freshwater-dependent amphibians and turtles. However, only two Indochinese endemics known from the coasts are also found on the islands: the parthenogenetic lizard *Leiolepis guentherpetersi* known from the Central Coast and Southern Islands, and *L. guttata* from the Southern Coast and Northern Islands (the unusual distribution pattern of the latter species suggests that identification of this taxa from the Northern Islands needs to be revisited).

Indochina's island faunas largely resemble relict mainland faunas, reflecting their likely origins as remnant communities of the Sunda Shelf, which were last connected to the mainland approximately 15,000 years ago. This is supported by the suite of Indochinese endemic species known from the Southern Islands and interior mainland, but not from the intervening coasts: the skink *Sphenomorphus rufocaudatus* and the gekko *Hemidactylus vietnamensis* (both widespread throughout Indochina across elevations); the fossorial lizard *Dibamus montanus* and the frog *Limnonectes dabanus* (both known only from southern Indochina); and the gekko *Cyrtodactylus paradoxus* (also known from the Mekong Delta). Most of the islands lie close to the mainland, the major exception being Con Dao, a small granitic and ruggedly mountainous island archipelago 80 km southeast of the Mekong Delta (Le, 1989; BirdLife International in Indochina and MARD, 2004). Its greater isolation during periods of sea level fluctuation likely explains the presence of three lizard species endemic to the archipelago (*Cnemaspis boulengeri*, *Cyrtodactylus condorensis*, and *Dibamus kon-*

*daoensis*) (Darevsky and Szczerbak, 1997; Darevsky, 1999; Honda et al., 2001). The remaining seven island endemics (i.e., not known from the mainland) are known from geological extensions of the Cardamom Massif: the rupicolous viper *Cryptelytrops honsonensis*, and a suite of gekkoes scattered among Phu Quoc and small islands of Rach Gia Bay (see lower Mekong watershed section above). Nonherpetofaunal taxa endemic to this archipelago include two squirrels (*Ratufa bicolor condorensis*, *Callosciurus finlaysonii germani*) (Dao, 1967; van Peenen et al., 1969; Kuznetsov, 2000) and a primate (*Macaca fascicularis condorensis*) (Brandon-Jones et al., 2004).

Only a single Malaya species has been recorded from Indochina's coasts and islands: the aquatic snake *Acrochordus javanicus*, which has been recorded from the Southern Coast. Widespread in southern Indochina's lowland regions, it is the only Malaya species not restricted to forested habitats. This is consistent with the previous observation from the Annamite region that the few strictly Malaya species found in Indochina represent apparently relict populations of evergreen-forest-dependent species, which were more widely distributed during historical periods when this forest type was more widespread.

#### GENERAL PATTERNS OF DISTRIBUTION

Indochina's major herpetofaunal groups share some broad habitat associations: species in all five groups occur in higher numbers in forested environments; are more likely to occupy a single habitat than multiple ones; and, with the exceptions of turtles, are more likely to be found at elevations above 300 m. However, there is also significant variation among the major taxonomic groups and between suites of species with different geographic distributions and biogeographic affinities. It should be noted that, given the active state of herpetofaunal work in Indochina, any conclusions concerning the distribution of its amphibians and reptiles are contingent on the results of further research. This is particularly true for species currently considered regional endemics, 69% of which have been described since 1997. This strongly suggests that knowl-

edge of their distribution and ecology will change over time.

The four major taxonomic groups differ with respect to microhabitat associations, the number of microhabitats used, and elevation zone. Turtles are the only major group with a large proportion of species (50%) restricted to areas below 300 m. Amphibians are more likely than reptiles to be restricted to forests and uplands, and are the only group with a sizable suite of species (30%) limited to areas above 800 m. Snake and lizard species occur more frequently in open areas, across wider elevation gradients, and in greater variety of microhabitats (i.e., rupicolous, fossorial) than do amphibians or turtles. Some of these patterns correlate with the broad habitat requirements of each taxonomic group. Indochina's turtles are dependent on water resources, but a subset of species (four; 14% of the fauna) is able to tolerate brackish, estuarine environments. Given low overall turtle species richness (28), the occurrence of these species in the region's slow lowland deltas may contribute to the group's overall association with lowland habitats. Although the breeding ecology of Indochina's freshwater turtles is imperfectly known, it is also possible that lowland areas are more conducive to their egg-laying habits than the often-rocky banks of upland and highland waterways. Amphibians are dependent on freshwater resources and the vast majority requires bodies of water associated with forests. Today, this combination is found most commonly in Indochina's extensive upland and highland areas. However, historically lowland regions would also have hosted suitable large areas of forest that could be utilized by species dependent on slower or still freshwater environments. Snakes and lizards are less freshwater-dependent and therefore capable of occupying a wider variety of habitats, such as open, rocky, or dry areas, which amphibians and turtles cannot tolerate.

**ENDEMIC SPECIES:** The habitats occupied by endemic species are significantly more restricted than those of nonendemic species. In general, endemic species occupy a narrower range of elevations and a subset of the microhabitats used by their nonendemic counterparts, two ecological variables that are frequently correlated (e.g., fast-flowing streams

in upland environments, rupicolous niches on low-lying rocky outcrops). This negative correlation between ecological niche width and geographic range is shared by the three lineages in which it could be analyzed (amphibians, snakes, and lizards). However, within each group, the distribution (geographic and taxonomic) of endemic species is often strongly correlated with lineage-level habitat requirements. As a result, there is significant variation between the groups in the distribution of endemic species across Indochina's landscape.

Among amphibians, the occurrence of endemic species is correlated with upland and highland forested regions. Within the group, lineages with restricted breeding requirements contain a higher proportion of restricted range or endemic species. Of the 34 Indochinese species in the ranid genera *Amolops* and *Odorrana*, both of which require cold, fast-flowing water for egg deposition, 59% are endemic to the region. Only one species from this group, *O. chloronota*, has a Pan-Asia distribution; however, it appears that this species is, in fact, a complex of multiple species with possible smaller ranges (Stuart et al., 2006b). Similarly, Indochinese species in the rhacophorid genera *Kurixalus* and *Rhacophorus*, both of which require vegetation overhanging slow or still water within forests, have an elevated number of endemics (52%). Two nonexclusive hypotheses likely explain the correlation between restrictive breeding requirements and endemism. First, restricted breeding requirements limit the number of microhabitats a species can exploit. In a region such as Indochina, with its wide variety of elevations and habitats, this will inherently decrease geographic range as compared to species with more permissive breeding requirements. Second, restricted breeding requirements limit effective dispersal opportunities. This increases the likelihood for lineages to become isolated and subsequently diverge, events that may subsequently produce new, possibly restricted-range species.

In contrast, those amphibian families whose members breed in open, slow, or stagnant waters, including temporary sources such as ditches, tire tracks, or the wet rice paddies that are ubiquitous through the region, have the lowest rates of amphibian endemism in Indochina: Bufonidae (0%),

Dicroglossidae (21%), and Microhylidae (27%). These lineages also have high numbers of Pan-Asia species compared to the rest of the amphibian fauna: Bufonidae (50%), Dicroglossidae (28%), and Microhylidae (36%). The correlation between slow and/or still water open-habitat breeding requirements and broad geographic distributions is also observed for individual species within other lineages (e.g., *Hylarana erythraea*, *H. taipehensis*, *Kurixalus verrucosus*, *Polypedates leucomystax*, and *P. megacephalus*). For these families and species, the ability to occupy widespread lowland, open habitats increases potential geographic range and reduces the likelihood of isolation and subsequent lineage divergence. If these species are truly widespread and panmictic, then genetic analyses should reveal high levels of gene flow within species across their wide range.

Like amphibians, endemic snakes are significantly more likely to be found in forested environments and within a single altitude zone than their nonendemic counterparts. Unlike amphibians, there is no bias towards an upland distribution; they are more likely to be restricted to either upland or lowland environments. The relationship between microhabitat use and the occurrence of endemic snake species is less clear. Among snakes restricted to a single microhabitat, there is a significant difference between endemics and nonendemics in the type of microhabitat occupied (Fisher's exact test,  $p < 0.05$ ; 19% of endemics and 15% of nonendemics use multiple microhabitats). The major differences are seen in three groups: more endemics are fossorial (19% of the endemic fauna vs. 7% of the nonendemic one) and fewer are terrestrial (34% vs. 43%) or arboreal (3% vs. 19%) than nonendemic snakes. These results are consistent with recent work in Sundaland suggesting that, at the time scale of Pleistocene climatic fluctuations, terrestrial and arboreal snake species have higher dispersal potential than fossorial ones (Inger and Voris, 2001). In Indochina, snake lineages with the highest rates of endemism in the region are the largely fossorial families Xenodermatidae and Typhlopidae and subfamily Calamariinae. In the Viperidae, which also has a high number of endemic species, three endemics

are fossorial (*Protobothrops sieversorum*, *Protobothrops trungkhanhensis*, *Viridovipera truongsongensis*) and the remaining one is rupicolous (*Cryptelytrops honsonensis*). Fossorial behavior limits mobility and reduces dispersal opportunities, as individuals may have to go above ground to move substantial distances (Goodenough et al., 2009). The negative relationship between arboreality and endemism is less clearly related to lineage-level ecological constraints. Only one strictly arboreal snake, *Boiga burreti*, is endemic to Indochina, and the 11 strictly terrestrial endemics are distributed across seven families or colubrid subfamilies.

Endemism among lizards is similar to that of snakes: it is correlated with forested environments at all elevations with individual species generally occupying only a single altitude zone. However, endemic lizards are more strongly associated with lowland environments than are amphibians and the other reptile groups: a relatively large proportion (37%) are found only in the lowlands and an equal number of endemic species can be found above and below 300 m. As with snakes, fossorial behavior is correlated with restricted range with high rates of endemism observed among the limbless, burrowing family Dibamidae. Endemic lizards are also significantly more restricted than non-endemics to a single microhabitat and the number and type of microhabitats used by endemic species vary with both elevation and lineage. Lowland-restricted endemic lizards are significantly more likely to occupy a single microhabitat than the rest of Indochina's endemic lizards ( $\chi^2 = 10.325$ ,  $df = 1$ ,  $p < 0.005$ ). This suite of lowland endemics is dominated by 17 strictly rupicolous species (61% of all lowland endemic lizard fauna) all of which are gekkonids with the single exception of the scincid *Leptoseps tetradactylus*. The high number of lowland endemics within this group is likely related to their habitat use. Recent intensive surveys of Indochina's granitic and limestone karst forests have yielded large numbers of previously undescribed gekkonids of the genera *Cnemaspis* and *Cyrtodactylus* occupying remarkably small geographic ranges (e.g., Grismer, 2010; Grismer et al., 2010b; Ziegler et al., 2010). Many of these species have been discovered in the low-lying South-

ern Islands and the low rocky outcrops of the lower Mekong watershed (which act as virtual islands). Although this pattern of highly-localized, rupicolous endemism has only been recently been recognized, the large numbers of these species occupying small ranges suggest that increased survey effort will have little effect on the reported distributions. The high occurrence of endemism among this group may be related to the isolating nature of such habitats.

Among Indochina's herpetofauna, traits associated with greater dispersal potential are correlated with reduced endemism and larger geographic ranges and vice versa. In addition to the lineage-specific ecological and behavioral attributes discussed above, it is worth noting a few other factors that may underlie the distribution of Indochina's endemic species. In general, body size is positively correlated with dispersal distance for actively dispersing organisms (Sutherland et al., 2000; Jenkins et al., 2007). This may contribute to the observation of lower overall endemism rates among snakes, turtles, and crocodiles compared to the smaller, inherently less vagile amphibians and lizards. Additionally, the ability to exploit interconnected and widespread habitats within a given region can also increase an organism's inherent capacity for movement. In Indochina, reduced rates of endemism are observed among a suite of larger-bodied aquatic or semiaquatic lineages adapted for rapid movement within the region's widespread network of lowland waterways and wetlands: varanid lizards, freshwater turtles (Geoemydidae, Tryonichidae), the agamid lizard *Phrynosignathus cocincinus*, pythons, the aquatic homalopsine and natricine snakes, and both crocodile species.

**NONENDEMIC FAUNA:** Indochina's major nonendemic faunal components (South China, Mainland Southeast Asia, Pan-Asia) occupy wider ecological niches than the endemic fauna. However, there are significant differences in ecological characteristics among these faunal components that correlate with the geographic ranges they occupy outside Indochina. Regions of South China adjacent to northern Indochina are dominated by forested uplands and highlands and of the South China species known from Indochina,

72% are forest-restricted and 25% are found only at elevations above 800 m. Mainland Southeast Asia species restricted to a single elevation are equally likely to be found above and below 300 m (24%), mirroring the combination of upland and lowland habitats found in adjacent regions of Thailand and Myanmar. Although the distribution of these two faunas (as well as the poorly represented strictly Malaya fauna) across Indochina is largely correlated with geographic proximity, ecological characteristics also contribute to their Indochinese distributions, e.g., South China species in the Central Annamites; Malaya species in the central and Southern Annamites.

The Indochinese fauna found outside these two regions are dominated by species capable of widespread dispersal: for example, the majority of species in the Pan-Asia fauna tolerate open environments (59%) and are found at all elevations (60%). These characteristics allow species to move across relatively large regions, which historically would have included the river-crossed lowlands of the Sunda Shelf exposed during periods of lower sea level as well as higher elevations leading to east Asia and the foothills of the Himalayas.

#### CHARACTERIZATION OF INDOCHINA'S HERPETOFAUNA

Our observations are in general agreement with previous research suggesting that Indochina's floral and faunal diversity is driven in part by the intersection of a northerly subtropical and temperate biota with a southerly tropical one (e.g., Smith, 1931; Bourret, 1936a, b, 1941a, 1942; Bobrov, 1997; MacKinnon, 1997; Averyanov et al., 2003; Orlov, 2005; Sterling et al., 2006). There is a larger presence of species restricted to areas north of Mainland Southeast Asia (South China, Southern Himalayas, East Asia) to Indochina's herpetofauna is significantly stronger than there is of those restricted to regions to the south (Malaya).

Although there is strong latitudinal variation in the distribution of these two subtropical/temperate and tropical faunas, the transition between the two more closely resembles a threshold than a gradient, with

little evidence of true mixing at intermediate latitudes, regardless of elevation. At a finer scale, there is evidence that the Central Annamites harbors small, roughly equivalent numbers of highland-restricted species from the Northeast and/or Northwest Uplands and southern Indochina's combined upland regions (Southern Annamites, Southern Lao Uplands, Cardamom Uplands). In addition, the substantial endemic Indochinese herpetofauna cannot be easily characterized as temperate, subtropical, or tropical given the region's complex topography and climate.

Indochina's geographic location south of China and along the eastern coastal edge of Mainland Southeast Asia likely drives the distribution of nonendemic faunas within the region. The majority of South China species are concentrated in the northern Indochinese uplands adjacent to floristically and climatically similar habitats in China and extreme northern Myanmar, which provide corridors for movement (Nguyen and Harder, 1996; Zhu, 1997; Zhu et al., 2003). Mainland Southeast Asia species are concentrated along Indochina's western edge. These occur in lower numbers than South China species despite the fact that Indochina shares a longer border with Thailand and Myanmar (2812 km) than with China (1704 km). This may be due to lower species richness and lower dispersal rates across Thailand's Khorat Plateau, a largely dry, homogeneous plain stretching 900 km along Indochina's western border. Recent surveys that have filled in distributional gaps for two Pan-Asia lineages, the lizard genus *Cnemaspis* and pitviper genus *Cryptelytrops*, suggest that the lower number of Mainland Southeast Asia species in Indochina may also be an artifact of survey effort along Indochina's southernmost limits (Grismer and Ngo, 2007; Grismer et al., 2008c).

Historically, the repeated cycles of connectivity and isolation between Mainland Southeast Asia and the Sunda Islands have affected the distribution of Indochina's nonendemic fauna. Beginning in the mid-Miocene through the present, periods of lower sea level allowed movement across the exposed continental shelf, a lowland region covered with a mosaic of rivers, gallery and evergreen forests, and

drier vegetation types. Dispersal across these land bridges is consistent with the observation that the vast majority of Indochina's lowland-restricted Pan-Asia species (93%) also occur in the Sunda Islands. This ecologically tolerant group would have been able to move through the exposed continental shelf fairly easily. The hypothesis that Pan-Asia species have moved frequently and easily between mainland and insular Southeast Asia can be tested by examining the extent of genetic divergence between lineages from the two regions.

The existence of periods of connectivity between Mainland Southeast Asia and the Sunda Islands is also consistent with the presence of apparently relict upland Sundaic species in the Annamites. Of the five strictly Malaya species known from Indochina, three are restricted to forested uplands and known from single locations in the Central Annamites (*Sibynophis melanocephalus*, *Calamaria lovii*) and Southern Annamites (*Boiga jaspidea*). If the Indochinese populations of these three species are actually distinct species from the Sunda populations, then a sister relationship between island and mainland species would support the hypothesis of allopatric speciation via dispersal across the exposed continental shelf and subsequent isolation during periods of higher sea level. If they are not sister species, further examination of genetic divergence between lineages could be used to infer the dispersal patterns of the Indochinese species.

Within Indochina, the distribution of a subset of the herpetofauna has been positively affected by people. Much of Indochina, particularly the deltas and other lowland subregions, have been vastly altered by human activities for millennia and such activities have contributed to the wide distribution of amphibian and reptile species whose broad ecological tolerances enable them to colonize and persist in human-modified habitats. This group includes species with feeding requirements that are favored in human-dominated environments (e.g., *Gekko gecko*, *Hemidactylus frenatus*, *Chrysopelea ornata*, *Coelognathus radiata*, *Orthriophis taeniura*, *Ptyas korros*, *Rhabdophis* spp., *Rhamphotyphlops braminus*); species that are insensitive to perturbation of forested areas (e.g., species of *Calotes*, *Lygosoma*, *Mabuya*, *Scincella*, as

well as *Theloderma asperum*, *Bungarus fasciatus*, *Naja kaouthia*, *Ophiophagus hannah*, *Python reticulatus*); and species that are native to open grass and scrublands (e.g., *Takydromus sexlineatus*, *Ahaetulla prasina*, *Xenopeltis unicolor*). These species are currently widespread across Indochina and elsewhere in Asia; it is unclear if their ranges were more restricted before human colonization. Estimates of genetic diversification between populations could be used to detect the recent rapid population increases expected if their geographic ranges expanded rapidly following human disturbance (Knowles, 2009).

#### DIRECTIONS FOR FURTHER RESEARCH

Future research will continue to refine and elaborate our understanding of Indochina's herpetofaunal biogeography and its origins in the region's complex history. Results from recent efforts clearly indicate that Indochina's amphibian and reptile richness remains imperfectly known. Between 1997 and August of 2010, increased survey effort and closer examination of natural history collections resulted in the description of 65 new species of amphibians and 77 new species of reptiles from Indochina, as well as new records for 40 amphibian and 36 reptile species previously not known from Indochina. This productivity is consistent with a recent analysis indicating high levels of unknown biodiversity, and suggests that survey efforts are still inadequate (Stuart and Bain, 2008; Giam et al., 2010). Combining current knowledge with trends in survey work and taxonomic and systematic research allows us to postulate what some of the effects of an increased effort would be.

Surveys of greater Southeast Asia, combined with taxonomic work (see below) will likely increase the known relative contributions of the adjacent South China and Mainland Southeast Asia faunas to Indochina's fauna. It is unlikely that large numbers of widespread species have yet to be identified from Indochina. However, our knowledge of their true ranges within the region will benefit greatly from future surveying; this is particularly true for widespread species whose conservation is of concern, including varanids, crocodylians, pythonids, and freshwater turtles.



Within this context, our analyses of survey efforts indicate that some regions are particularly poorly known: the islands and coasts, as well as the western portions of Indochina, including the Cardamoms, Southern Lao Uplands, and Upper Mekong Lowlands. Efforts in the Cardamoms to date have been weak (15 total visits) and surveys continue to increase their known diversity. The productivity of this work is potentially quite high, for example, the discovery of the last remaining population of *Crocodylus siamensis* likely reflects a relatively intact herpetofaunal assemblage in the Cardamoms (e.g., Platt and Ngo, 2000; Stuart and Platt, 2000). In addition to increasing estimates of the subregion's species richness and endemism, future work will clarify the relationship between the Cardamom fauna and that of adjacent Thailand.

Both the flora and fauna of the Southern Lao Uplands, including the Boloven Plateau, remain poorly known. The region has been rigorously surveyed for herpetofauna seven times and remains poorly surveyed for plants (Vidal, 1956–1960), mammals (Delacour, 1940), birds (Delacour, 1942, Duckworth et al., 1999), fish (Roberts, 1997, 1998; Kottelat, 2000), and invertebrates (Gressitt, 1970). This overall lack of knowledge makes it difficult to predict the nature of the subregion's herpetofauna. We anticipate that current species richness for this upland area is greatly underestimated, especially given its complex topography and high annual rainfall. Increased survey efforts will also define the relationship of the Southern Lao Uplands fauna to the Annamites and to the northern uplands.

Although Indochina's Northern and Southern Islands have been visited more than average per km<sup>2</sup> when compared to the rest of the region, their insular nature suggests that further surveying is required. Only 13 of the more than 70 islands have been visited to date and multiple surveys have only been conducted on the largest formations: Con Dao, Phu Quoc, and Cat Ba (Smith, 1920; Darevsky, 1999; Grismer and Ngo, 2007; Ziegler et al., 2008c; Grismer et al., 2008c, 2010b; Ngo et al., 2010). Recent descriptions of a gekko in the Northern Islands, as well as gekkonids and a viperid in Rach Gia Bay off southern Vietnam suggest that these areas are not only under-

surveyed, but potentially harbor endemic species (Grismer and Ngo, 2007; Ziegler et al., 2008c; Grismer et al., 2008c, 2010b; Ngo et al., 2010). Given the lack of permanent and diverse freshwater sources, it is unlikely that future surveys will record many more amphibian or freshwater turtle species from these areas.

Relative survey effort could not be estimated for Indochina's coastal regions; however, it is certain that these areas have been surveyed infrequently (table 2), particularly in the north, and only a few locations have been visited more than once (Smith, 1920; Ziegler and Wetkus, 1999a, b; Das, 2004). There is evidence from both cycads and Dipterocarpaceae that the south-central and southern coast of Vietnam may be areas of elevated endemism associated with extreme aridity (Nguyen and Phan, 1999; Rundel, 2000). A small suite of endemic reptiles restricted to the coasts is known, so increased efforts may further add to the overall number of reptile species, as well as endemic species.

Survey effort is unevenly distributed within subregions as well as among them. To date, 51 out of the 65 surveys conducted in the Northwest Uplands have been restricted to Vietnam, which makes up less than half of this subregion and has much smaller borders with regions outside Indochina than does northern Laos. As more surveys are undertaken in northern Laos, we expect recorded species richness to increase, including endemic species and those currently known from southwestern Yunnan, northern Thailand, and northern Myanmar. For some subregions, only a few localities account for a large proportion of the overall survey effort: Nha Trang, 37% of all South Coast surveys; Da Nang, 58% of all Central Coast surveys; Ho Chi Minh City, 25% of all Mekong Delta surveys; Vientiane, 36% of all Upper Mekong lowlands surveys; Tam Dao, 45% of all Northeast Uplands surveys; and Fan Si Pan, 37% of all Northwest Uplands surveys (appendix 2A). More locality-balanced survey work will have a great impact on determining species richness within these subregions in particular.

Future survey work will also refine Indochina's biogeographic subunits as defined by its herpetofauna and answer questions that currently cannot be resolved. The strong

amphibian and reptile faunal overlap between South China and the upland subregions of northern Indochina suggests that future research, and especially increased international collaborations, will help to resolve the borders of this region as a single biogeographic unit. Strong current similarities between the Cardamoms and Mainland Southeast Asia faunas suggest that additional surveys are needed to clarify how closely this region is allied with the rest of Mainland Southeast Asia. Vietnam's northeast and Central–South Vietnam Lowlands may contain more substructure than our subregional classification was able to capture, given the limited data available. Similarly, the Annamites may have more substructuring than we outline in our a priori boundaries of its three focal subregions. In particular, the faunal relationship between the Annamites and the Southern Lao Uplands remains to be clarified. Finally, characterizing the relationships between the Central–South Vietnam Lowlands and its associated uplands (Central and Southern Annamites) and lowlands (lower Mekong watershed) may help us to understand the factors affecting the distribution of endemic species in southern Indochina. More detailed distribution data will also allow us to map distributions for a sufficient number of species to test biogeographic hypotheses and refine the boundaries of our largely a priori subregions.

Future taxonomic work is also greatly needed in the region. Cross-border taxonomic issues (primarily with China) clearly bias our estimates of species richness and endemic species numbers. There are 78 species of amphibians and reptiles whose distributions terminate at the international border between Indochina and South China: 38 species distributed through China up to the Vietnam and/or Lao border, but not within Indochina (table 12) and 40 species that are distributed through Indochina up to the Chinese border, but not within China (table 13) (after Daming, 2002; Zhou and Yu, 2002; Ye et al., 2007; Fei et al., 2008, 2009; see appendix 2A). These ranges are the result of the parallel systematic work historically undertaken on each side of the border, with little communication or cooperation. This is significant because these international borders are not concomitant

with any geographic feature and represent a taxonomic artifact that biases biogeographic analyses. It is likely that a number of these species belong to the large group restricted to South China and northern Indochina; only nine species are known from outside these regions, eight from Mainland Southeast Asia and one from Pan-Asia, a pattern that mirrors the large faunal sharing between northern Indochina and South China. Furthermore, species not yet recorded from border areas have also been shown to exist across these international borders (e.g., Bain and Stuart, 2006a), suggesting that the extent of the cross-border taxonomic problem as presented above is an underestimation. Increased cross-border communication, will result in a decrease of the known regional richness, concomitant with an increase in synonymy, and a decrease in known Indochinese endemism.

At the same time, increased taxonomic and systematic work will likely increase estimates of Indochina's species richness and endemism. Certain taxonomic groups are underrepresented in the region's current species list. These include fossorial species that often evade detection in surveys, such as ichthyophiids, anguids, dibamids, and calamarines; strictly arboreal species that can also evade detection; species that are part of poorly defined taxonomic groups such as those of the genera *Dinodon* (see Orlov and Ryabov, 2004), *Oligodon* (see David et al., 2008b, c), *Amphiesma* (see David et al., 2007), and *Draco* (see McGuire and Heang, 2001). Combined survey efforts and morphological and molecular analyses will likely resolve some of the wide-ranging cryptic species complexes such as those of the genera *Paramesotriton* (see Chan et al., 2001), *Fejervarya* (see Toda et al., 1998a, b; Veith et al., 2001), *Limnodynastes* (see Emerson et al., 2000; Evans et al., 2003; McLeod, 2010), *Odorrana* (see Fei et al., 2001; Li et al., 2001; Bain et al., 2003, 2009c; Orlov et al., 2006c), *Hylarana* (see Murphy et al., 1997; Matsui et al., 2002), *Polypedates* (see He, 1999; Orlov et al., 2002b; Bain and Nguyen, 2004b), *Rhacophorus* (see Ohler and Delorme, 2006), *Calotes* (see Zug et al., 2006), *Leiolepis* (see Schmitz et al., 2001), *Takydromus* (see Lin et al., 2002), *Dixonius* (see Ota

TABLE 12  
**Herpetofauna of China with ranges ending at the northern border of Indochina**  
 See Materials and Methods for definition of ranges.

Species	Current Range
<b>Amphibia</b>	
<i>Bufo gargarizans</i>	South China/East Asia
<i>Bufo luchunnicus</i>	South China
<i>Bufo menglianus</i>	South China
<i>Brachytarsophrys carinense</i>	South China/Mainland SEA
<i>Leptolalax ventripunctatus</i>	South China
<i>Kaloula verrucosa</i>	South, Central China
<i>Microhyla fowleri</i>	South China/Mainland SEA
<i>Fejervarya multistriata</i>	South China
<i>Nanorana unculuanus</i>	South China
<i>Amolops caelumnoctis</i>	South China
<i>Amolops mengyangensis</i>	South China
<i>Babina lini</i>	South China
<i>Hylarana hekouensis</i>	South China
<i>Hylarana menglaensis</i>	South China
<i>Odorrana jingdongensis</i>	South China
<i>Odorrana rotodora</i>	South China
<i>Rana chaochiaoensis</i>	South China
<i>Sanguirana varians</i>	South China
<i>Ingerana liui</i>	South China
<i>Polypedates spinus</i>	South China
<i>Pseudophilautus menglaensis</i>	South China
<i>Rhacophorus nigropunctatus</i>	South, Central China
<i>Rhacophorus omeimontis</i>	South China
<b>Serpentes</b>	
<i>Pareas boulengeri</i>	South, Central China
<i>Pareas chinensis</i>	South China
<i>Cyclophiops doriae</i>	South China/Mainland SEA
<i>Macropisthodon rudis</i>	South China
<i>Sinonatrix annularis</i>	South China/East Asia
<i>Opisthotropis kuatunensis</i>	South China
<i>Opisthotropis latouchii</i>	South China
<i>Opisthotropis maxwelli</i>	South China
<i>Protobothrops xiangchengensis</i>	South, Central China
<b>Sauria</b>	
<i>Japalura flaviceps</i>	South, Central China
<i>Japalura splendida</i>	South, Central China
<i>Gekko chinensis</i>	South China
<i>Sphenomorphus incognitus</i>	South China
<i>Takydromus intermedius</i>	South China
<b>Testudines</b>	
<i>Mauremys guangxiensis</i>	South China

et al., 2001), *Emoia* (see Emilio et al., 1996), *Naja* (see Wüster and Thorpe, 1992), possibly *Sacalia* (Shi et al., 2008), and several genera of green tree vipers (see Malhotra and Thorpe, 2004a, b). This will result in an increase in the number of endemic species

and a concomitant decrease in the number of widespread species. Resolution of these complexes will also provide phylogenetically based insights into ecological, geographic, and historical barriers structuring regional diversity.

TABLE 13  
**Herpetofauna of Indochina with ranges ending at the northern border with China**  
 See Materials and Methods for definition of ranges.

Species	Current Range
<b>Amphibia</b>	
<i>Paramesotriton deloustali</i>	Northern Indochina
<i>Tylototriton vietnamensis</i>	Northern Indochina
<i>Leptotalax bourreti</i>	Northern Indochina
<i>Leptotalax pluvialis</i>	Northern Indochina
<i>Nanorana delacouri</i>	Northern Indochina
<i>Occidozyga magnapustulosa</i>	Northern Indochina/Mainland SEA
<i>Babina chapaensis</i>	Northern Indochina
<i>Amolops cucae</i>	Northern Indochina
<i>Amolops daorum</i>	Northern Indochina
<i>Amolops iriodes</i>	Northern Indochina
<i>Amolops minutus</i>	Northern Indochina
<i>Amolops splendissimus</i>	Northern Indochina
<i>Amolops vitrea</i>	Northern Indochina
<i>Odorrana bacboensis</i>	Northern Indochina
<i>Odorrana heatwolei</i>	Northern Indochina
<i>Odorrana hmongorum</i>	Northern Indochina
<i>Kurixalus carinensis</i>	Northern Indochina/Mainland SEA
<i>Philautus maosonensis</i>	Northern Indochina
<i>Philautus petilus</i>	Northern Indochina
<i>Pseudophilautus gryllus</i>	Indochina
<i>Pseudophilautus parvulus</i>	Indochina/Mainland SEA
<i>Rhacophorus dorsovirens</i>	Northern Indochina
<i>Rhacophorus duboisi</i>	Northern Indochina
<i>Rhacophorus hoanglienensis</i>	Northern Indochina
<i>Rhacophorus kio</i>	Indochina/Mainland SEA
<i>Rhacophorus orlovi</i>	Indochina
<i>Theلودerma bicolor</i>	Northern Indochina
<i>Theلودerma corticale</i>	Northern Indochina
<i>Theلودerma gordoni</i>	Indochina/Mainland SEA
<b>Serpentes</b>	
<i>Pararhabdophis chapaensis</i>	Northern Indochina
<i>Rhabdophis angeli</i>	Northern Indochina
<i>Asthenodipsas laevis</i>	Mainland SEA/Malaya
<i>Plagiopholis delacouri</i>	Northern Indochina
<i>Bungarus slowinskii</i>	Northern Indochina
<b>Sauria</b>	
<i>Hemidactylus vietnamensis</i>	Indochina
<i>Japalura chapaensis</i>	Northern Indochina
<i>Eutropis chapaense</i>	Indochina
<i>Eutropis darevskii</i>	Northern Indochina
<i>Sphenomorphus cryptotis</i>	Northern Indochina
<i>Ropidophorus murphyi</i>	Northern Indochina

## CONCLUSIONS

Our analysis provides the first modern synthesis of Indochina's biogeography. Research to date clearly indicates that amphib-

ian and reptile species of Indochina represent a globally significant fauna, given its high levels of endemism, significant presence of species found outside Mainland Southeast Asia, and strong differentiation among

internal subregions. The composition of this herpetofauna reflects an intricate evolutionary history that has been strongly influenced by the region's complex geological and climatic history. Despite these high levels of species richness and endemism, Indochina is still insufficiently surveyed.

We have made some preliminary assessments of the structure of regional diversity. We have also outlined areas in need of refinement and further testing, including: (1) assessments of the degree of substructure in the Annamites, lowlands of central-south Vietnam, and the lower Mekong watershed; (2) the relationship of the Southern Lao Uplands herpetofauna to the rest of Indochina's uplands; (3) the divergence of disjunct Indochina-Sunda populations; (4) the presence and structure of a restricted-range northern Indochina/South China herpetofauna; and (5) clarification of the biogeographic barrier separating northeastern Vietnam from northwestern Vietnam and northern Laos. Finer resolution mapping (resulting in part from increased survey efforts), alpha-level taxonomic work, and phylogenetic analyses at a regional level will assist in elucidating both distributional patterns and the evolutionary histories contributing to current patterns of diversity.

The unique character of the region and its herpetofauna makes it a vital focus for conservation efforts, given the current intensity of threats to Indochina's natural resources. Currently, 41 amphibian and 23 reptile species included in this review are classified as globally threatened, of which 29 (17 amphibians, 12 reptiles) are endemic to the region of Indochina and South China (IUCN, 2010). This survey provides data on amphibian and reptile species richness and distribution that are necessary for the development of regional and global conservation priorities. Effective conservation efforts require that this material be integrated with data on threat levels to the herpetofauna; consequently, the development of a database of threatened amphibian and reptile species is now a major priority in the region. Synthesizing data on conservation status with the above biogeographic analyses will help elucidate the patterns of threat

to the Indochinese herpetofauna and enable this fauna to be incorporated into regional conservation planning.

#### ACKNOWLEDGMENTS

We acknowledge the generous support of the John D. and Catherine T. MacArthur Foundation, National Science Foundation under grant no. 98-70232 (to J.M. Carpenter and E.J. Sterling), and NASA grant no. NAG5-12333, 2002-2005 (to D. Frost) for making the development of this manuscript possible. We also acknowledge the partial financial support to Martha M. Hurley from National Science Foundation while she was a NYCEP postdoctoral associate at AMNH under the NYCEP IGERT grant no. DGE 03-33415. Global Wildlife Conservation generously provided support for publication costs.

We are grateful to countless colleagues who provided assistance and encouragement with the project, and we benefited from those who provided formal and informal reviews. Several colleagues at AMNH also provided invaluable assistance: Kevin Koy, Peter Ersts, and Jeff Silverman assisted with map generation and informatics discussions; Mary DeJong greatly assisted with general research; Ho Ling Poon provided timely and accurate translations of Chinese material; David Kizirian, Darrin Lunde, and Paul Sweet all engaged in valuable discussions on the Indochinese fauna; Prosanta Chakrabarty and Richard Pearson engaged in valuable discussions of modeling and biogeography; and Darrel Frost and Chris Raxworthy engaged in valuable discussions regarding the nature of the data in general.

Several colleagues closely edited the data matrix for taxonomic, ecological, and distributional data. We are grateful for their efforts and the enlightening discussions that resulted from them: Patrick David and Gernot Vogel (snakes); James Parham and Minh Le (turtles); Lee Grismer (lizards). Bryan Stuart, Thomas Ziegler, and Nguyen Quang Truong carefully reviewed the entire data matrix.

In addition to providing material support, Eleanor Sterling provided a valuable review of the manuscript in its early stage of development. Bob Inger, Simon Stuart, and

Richard Pearson also reviewed an earlier version of the manuscript. Bryan Stuart and Robert Inger formally reviewed the manuscript, with extensive comments and suggestions for all aspects. Altering the advice of any of our reviewers was done so at our risk, and any errors within the manuscript are those of the authors.

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## APPENDIX 1

## DEFINITIONS OF SUBREGIONS OF INDOCHINA

*Upland subregions (above 450 m)*

**Northwest Uplands (NWU):** upland areas west of the Red River, east of the Mekong River, and north of the Ca River in Nghe An Province, Vietnam, and adjacent Xiang Khouang Province, Laos.

**Northeast Uplands (NEU):** upland areas east of the Red River in Vietnam.

**Northern Annamites (NAN):** upland areas of Vietnam lying between the Ca River in Nghe An Province and the Quang Tri River in Quang Tri Province; and upland areas of the Lao provinces of Xieng Khouang (south of the Ca River), Vientiane, Bolikhamxay, Khammouan, and Savannakhet (north of the Quang Tri River).

**Central Annamites (CAN):** upland areas between the Quang Tri River (Quang Tri Province) and Da Rang River (near the southern border of Gia Lai Province) in Vietnam and in adjacent provinces of Laos (Xe Kong [east of the Kong River], Attapu, Saravan, and Savannakhet) and Cambodia (Rattanakiri). This subregion includes the Kon Tum Plateau in Vietnam and Laos, the Pleiku Plateau in Vietnam, the Ratanakiri Plateau and Virachey Mountains in Cambodia, and the Dong Phu Vieng Mountains in Laos.

**Southern Annamites (SAN):** upland areas south of Da Rang River to the last hills before the Mekong lowlands in Binh Phuoc and Dong Nai provinces, Vietnam, and Mondulakiri Province, Cambodia. This includes the Dac Lac, Da Lat, and Chhlong plateaus.

**Southern Lao Uplands (SLU):** upland areas in Champasak, Xe Kong (west of the Kong River), Saravan, and Attapu provinces, Laos, including the Boloven Plateau.

**Cardamom Uplands (CDU):** upland areas of Battambang, Pursat, Koh Kong, Kompog Speu, Kampot, and Kompong Som provinces, Cambodia.

*Lowland subregions (below 450 m)*

**Northeast Lowlands (NEL):** lowlands of Vietnam north of the Quang Tri River (Quang Tri Province) and lowlands of Laos that lie within the Red River watershed.

**Upper Mekong Lowlands (UML):** lowlands of northern Laos from the Vientiane plain to the Southern Lao Uplands that lie within the Mekong River watershed.

**Central-South Vietnam Lowlands (CSL):** adjacent to the Kon Tum, Pleiku, Dac Lac, Da Lat, and Di Linh plateaus south to the lowlands of Binh Phuoc and Binh Thuan provinces.

**Southern Lao Lowlands (SLL):** south of the Southern Lao Uplands.

**Mekong Delta (MEK):** includes the delta region downstream of Phnom Penh in Cambodia and southern Interior Cambodia Lowlands.

**Interior Cambodia Lowlands (CMB):** Cambodian lowlands south of the Phnom Dangrek Mountain range, east of the Cardamom Mountains, west of the southern Annamite foothills, and north of Phnom Penh; this subregion includes the Tonle Sap basin.

**Caradomom Lowlands (CDL):** southern and western foothills of the Cardamom Mountains.

*Coastal and island groups*

**Northern Coast (NC):** all coastal lowland areas north of the Hai Van Pass (ca. 16°N) that lie just north of Da Nang City, Quang Nam Province, Vietnam.

**Central Coast (CC):** all coastal lowland area south from Hai Van pass to latitude ca. 13°N where the southern Truong Son extends to the coast in Phu Yen Province.

**Southern Coast (SC):** all coastal areas from south of 13°N to the Cambodia-Thai border on the Gulf of Thailand.

**Northern Islands (NIS):** islands off the coast of Vietnam in the Gulf of Bac Bo (Tonkin), including Hon Nor Way, Cu Lao Ba Mun, Cu Lao Phon Vong, and Cat Ba.

**Southern Islands (SIS):** islands along the coast of southern Vietnam and Cambodia to the Gulf of Thailand, including Cu Lao Cham, Con Dao (also known as Pulo Condore), Hon Bay Canh, Tho Chu (also known as Lao Panjang or Phan Rang), Phu Quoc, and Hon Thom.





APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
2,4	<i>Nanorana yunnanensis</i>	x									
2,4,6,7	<i>Occidozyga lima</i>	x	x	x	x	x	x		x		x
4	<i>Occidozyga magnapustulosa</i>	x									
2,4	<i>Occidozyga martensii</i>			x	x	x			x		x
3	<i>Occidozyga vittata</i>							x			
1*	<i>Quasipaa acanthophora</i>		x								
2	<i>Quasipaa boulengeri</i>	x	x								
4	<i>Quasipaa fasciculispina</i>										
2	<i>Quasipaa spinosa</i>	x		x							
2	<i>Quasipaa verrucospinosa</i>	x	x				x		x		
	<b>Anura: Hylidae</b>										
2,4,6	<i>Hyla annectans</i>	x	x	x							
2	<i>Hyla chinensis</i>	x	x	x							
2	<i>Hyla simplex</i>	x	x	x			x	x			
	<b>Anura: Megophryidae</b>										
2,4	<i>Brachytarsophrys feae</i>	x	x								
3	<i>Brachytarsophrys intermedia</i>			x			x	x			
1*	<i>Leptobrachium ailaonicum</i>	x									
3*	<i>Leptobrachium banae</i>						x				
3*	<i>Leptobrachium buchari</i>									x	
2,4	<i>Leptobrachium chapaense</i>	x	x	x	x						
3*	<i>Leptobrachium mouhoti</i>						x	x			
3*	<i>Leptobrachium ngoelinhense</i>						x				
2	<i>Leptobrachium promustache</i>	x									
4	<i>Leptobrachium pullum</i>						x	x			
4,6	<i>Leptobrachium smithi</i>					x					
3*	<i>Leptobrachium xanthospilum</i>						x				
3*	<i>Leptolalax applebyi</i>						x				
1,3	<i>Leptolalax bourveti</i>	x	x				x				
1*	<i>Leptolalax nahangensis</i>		x								
2,4	<i>Leptolalax oshanensis</i>	x	x	x	x		x				
1*	<i>Leptolalax pluvialis</i>	x	x								
2*	<i>Leptolalax sungi</i>	x	x								
3*	<i>Leptolalax tuberosus</i>						x				
1,3*	<i>Ophryophryne gerti</i>						x	x	x	x	
1,3*	<i>Ophryophryne hansii</i>			x	x		x		x		
2,4	<i>Ophryophryne microstoma</i>	x	x				x		x		
2	<i>Ophryophryne pachyproctus</i>	x		x	x						
3	<i>Ophryophryne poilani</i>						x				
3*	<i>Ophryophryne synoria</i>							x			
3*	<i>Xenophrys auralensis</i>										
2	<i>Xenophrys brachykolos</i>		x								
2	<i>Xenophrys jingdongensis</i>	x									
2	<i>Xenophrys kuatunensis</i>	x	x	x							
2,4,6	<i>Xenophrys major</i>	x	x	x	x		x		x	x	
2	<i>Xenophrys minor</i>	x									
2	<i>Xenophrys pachyproctus</i>	x									
2	<i>Xenophrys palpebralespinosa</i>	x	x								
2,4,6	<i>Xenophrys parva</i>	x	x								

APPENDIX 2A  
(Extended Continued)

											ECOLOGICAL CHARACTERS				
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS	Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode	
									FO	AQ	HI	FO	SL		
x	x		x	x					FO-OP	TE-AQ	LO-UP	FO-OP	ST		
										AQ	UP				
	x		x					x	FO-OP	TE-AQ	LO-UP	FO-OP	ST		
									FO-OP	TE-AQ	UP				
									FO	AQ	HI				
									FO	AQ	HI	FO	SL		
		x	x						FO	AQ	LO-UP-HI				
									FO	AQ	UP-HI	FO	SL-ST		
									FO	AQ	LO-UP-HI	FO	SL-ST		
									FO-OP	AR	UP-HI	FO-OP	ST		
									FO-OP	AR	LO-UP-HI	FO-OP	SL-ST		
								x	FO-OP	AR	LO-UP-HI	OP	ST		
									FO	TE	HI	FO	SL		
									FO	TE	UP-HI	FO	SL		
									FO	TE	HI	FO	SL		
									FO	TE	UP-HI	FO	ST		
									FO	TE	HI				
									FO	TE	UP-HI				
									FO	TE	UP-HI				
									FO	TE	LO-UP-HI	FO	SL-ST		
									FO	TE	UP-HI				
									FO	TE	HI	FO	ST		
									FO	TE	HI				
									FO	TE	UP-HI				
									FO	TE	LO-UP-HI	FO	SL-ST		
									FO	TE	UP				
									FO	TE	UP				
									FO	TE	LO-UP-HI	FO	FA		
		x	x						FO	TE	LO-UP	FO	ST		
									FO-OP	TE	HI	FO	SL		
									FO	TE	UP-HI	FO	ST		
									FO	TE	LO-UP-HI	FO	FA-SL		
									FO	TE	HI	FO	SL		
									FO	AR	HI	FO	SL		
									FO	TE	UP-HI	FO	SL		
									FO	TE	UP-HI	FO	SL		

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
	<b>Anura: Microhylidae</b>										
4	<i>Calluella guttulata</i>	x			x		x		x		x
2	<i>Calluella yunnanensis</i>	x									
4	<i>Glyphoglossus molossus</i>								x		x
2,4	<i>Kalophrynus interlineatus</i>	x	x	x	x	x		x	x		x
2	<i>Kalophrynus menglienicus</i>										
4,7	<i>Kaloula baleata</i>						x	x	x		x
4	<i>Kaloula mediolineata</i>								x		
2,4,6,7	<i>Kaloula pulchra</i>	x	x	x	x	x	x	x	x		x
4	<i>Microhyla annamensis</i>								x		
2,4,6,7	<i>Microhyla berdmorei</i>	x		x	x	x	x	x	x		x
2,4,7	<i>Microhyla butleri</i>	x	x	x	x	x	x	x	x		x
3*	<i>Microhyla erythropoda</i>								x		
2,4,5,6,7	<i>Microhyla fissipes</i>	x	x	x	x	x	x	x	x		x
3	<i>Microhyla fusca</i>								x		
2,4,7	<i>Microhyla heymonsi</i>	x	x	x	x	x	x		x	x	x
1,3*	<i>Microhyla marmorata</i>			x			x				
3*	<i>Microhyla nanapollexa</i>						x				
3	<i>Microhyla picta</i>								x		
2,4,6	<i>Microhyla pulchra</i>		x	x	x	x			x		x
3*	<i>Microhyla pulverata</i>						x				
2,4,7	<i>Micryletta inornata</i>			x	x	x			x		x
	<b>Anura: Ranidae</b>										
1*	<i>Amolops akhaorum</i>	x									
1,3*	<i>Amolops compotrix</i>			x			x				
1*	<i>Amolops crennobatus</i>			x		x					
1*	<i>Amolops cucae</i>	x									
1*	<i>Amolops daorum</i>	x									
1*	<i>Amolops iriodes</i>		x								
1*	<i>Amolops minutus</i>	x									
2	<i>Amolops ricketti</i>	x	x								
3*	<i>Amolops spinapectoralis</i>						x				
2	<i>Amolops splendidissimus</i>	x									
2,4,6	<i>Amolops viridimaculatus</i>	x	x								
1*	<i>Amolops vitreus</i>	x									
2,4,5	<i>Babina adenopleura</i>										
1,3	<i>Babina chapaensis</i>	x	x	x			x				
1,3*	<i>Hylarana attigua</i>			x			x	x	x	x	
4,7	<i>Hylarana erythraea</i>			x	x	x	x		x		x
4,3*	<i>Hylarana faber</i>										
2,4	<i>Hylarana cubitalis</i>	x									
4,7	<i>Hylarana glandulosa</i>										
2	<i>Hylarana guentheri</i>		x	x	x		x				
2,4	<i>Hylarana macrodactyla</i>	x	x	x	x	x		x	x		x
1	<i>Hylarana maosonensis</i>		x	x							
4	<i>Hylarana montivaga</i>							x			
4	<i>Hylarana mortenseni</i>										
2,4	<i>Hylarana milleti</i>	x					x	x			
2,4,6,7	<i>Hylarana nigrovittata</i>			x	x		x	x	x		x
2,4,5,6	<i>Hylarana taipehensis</i>	x	x	x	x	x	x	x			x

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
	x		x							OP	TE	LO-UP	OP	ST	
										FO-OP	TE	UP	OP	ST	
x	x									FO	TE	LO	FO	ST	
x	x	x	x							FO-OP	TE	LO-UP	FO-OP	ST	
x										FO-OP	TE-AR	LO-UP-HI	FO	AH	
										FO-OP	TE	LO	FO	ST	
x	x	x	x	x	x	x				OP	TE	LO-UP	OP	ST	
			x							FO	TE-AQ**	UP-HI			
x	x	x	x					x		FO	TE	LO-UP-HI	FO-OP	ST	
x	x		x							OP	TE-AQ**	LO-UP-HI	OP	ST	
										OP	TE	LO			
x	x	x	x	x	x					OP	TE	LO-UP-HI	OP	ST	
										FO	TE	UP-HI			
										FO	TE	HI			
x										OP	TE	LO			
x	x		x							OP	TE-AQ**	LO-UP-HI	OP	ST	
										FO	TE	UP			
x	x	x	x							OP	TE	LO-UP	OP	ST	
										FO	TE-AR	HI			
										FO	TE-AQ**	HI			
										FO	TE-AQ**	LO-UP	FO	FA	
										FO	TE-AQ-AR**	UP			
										FO	TE-AQ	HI			
										FO	TE-AQ-AR	HI			
										FO	TE-AQ**	HI			
										FO	TE-AQ**	UP-HI	FO	FA	
										FO	TE-AQ**	HI			
										FO	AQ-AR**	HI			
										FO	TE-AQ**	HI	FO	FA	
										FO	TE-AQ**	UP-HI			
										OP	AQ	UP	OP	ST-SL	
										FO	TE-AQ**	UP-HI	FO	ST-SL	
										FO	TE-AQ-AR**	LO-UP-HI	OP	SL	
x	x	x	x					x		FO-OP	TE-AQ	LO-UP-HI	OP	ST	
			x	x						FO	TE	LO-UP-HI			
										FO	TE	UP			
										FO-OP	TE-AQ	LO		ST	
x	x	x	x	x						OP	TE-AQ	LO-UP-HI	OP	ST	
										OP	TE	LO-UP-HI	OP	ST	
										FO-OP	TE-AQ**	UP-HI	FO-OP	ST-SL	
										FO	TE-AQ**	HI	FO	SL	
			x	x						FO-OP	TE-AQ**	LO-UP-HI			
		x	x	x						FO	TE-AQ**	LO-UP-HI			
		x								FO	TE-AQ**	LO-UP-HI	FO	SL	
	x	x	x							OP	TE	LO-UP-HI	OP	ST	



APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
1,3*	<i>Odorrana absita</i>			x			x				
2,4	<i>Odorrana andersonii</i>	x									
1*	<i>Odorrana bachoensis</i>	x	x	x	x						
1,3*	<i>Odorrana banaorum</i>				x		x	x			
3*	<i>Odorrana bolavensis</i>										x
2	<i>Odorrana chapaensis</i>	x									
2,4,6	<i>Odorrana chloronota</i>	x	x	x	x		x	x			
2*	<i>Odorrana geminata</i>		x								
3*	<i>Odorrana gigatympana</i>						x				
2	<i>Odorrana grahami</i>	x									
2	<i>Odorrana graminea</i>		x								
1*	<i>Odorrana heatwolei</i>	x									
1*	<i>Odorrana hmongorum</i>	x									
2	<i>Odorrana junlianensis</i>	x									
3*	<i>Odorrana khalam</i>						x				
2	<i>Odorrana margaretae</i>	x?									
1,3*	<i>Odorrana morafkai</i>			x			x	x	x	x	
2,4	<i>Odorrana nasica</i>	x	x	x							
1,3*	<i>Odorrana orba</i>			x			x		x		
2	<i>Odorrana schmackeri</i>	x	x								
2	<i>Odorrana tiannanensis</i>	x	x	x	x						
1*	<i>Odorrana trankieni</i>	x									
1*	<i>Odorrana yentuensis</i>		x								
2,4	<i>Pelophylax lateralis</i>						x	x	x		x
2	<i>Rana johnsi</i>	x	x	x	x		x	x			
<b>Anura: Rhacophoridae</b>											
2,4	<i>Chiromantis doriae</i>	x				x	x				x
3	<i>Chiromantis laevis</i>						x	x			
4	<i>Chiromantis nongkhorensis</i>					x	x	x	x		x
3*	<i>Chiromantis samkosensis</i>										
2,4	<i>Chiromantis vittatus</i>	x		x	x	x	x		x		
2	<i>Feihyla palpebralis</i>						x	x			
2,4	<i>Gracixalus gracilipes</i>	x	x								
2	<i>Gracixalus jinxiuensis</i>	x									
1*	<i>Gracixalus quyeti</i>			x							
3*	<i>Gracixalus supercornutus</i>						x		x		
1*	<i>Kurixalus ananjevae</i>			x							
3*	<i>Kurixalus baliogaster</i>						x				
1,3	<i>Kurixalus banaensis</i>			x			x		x		
4	<i>Kurixalus carinensis</i>	x									
2	<i>Kurixalus odontotarsus</i>	x	x								
2,4	<i>Kurixalus verrucosus</i>	x	x	x	x		x	x		x	x
4,7	<i>Nyctixalus pictus</i>						x				
3*	<i>Philautus abditus</i>						x				
2	<i>Philautus albopunctatus</i>	x	x								
3*	<i>Philautus cardamonus</i>										
1	<i>Philautus maosonensis</i>	x	x								
1*	<i>Philautus petilus</i>	x									
3*	<i>Philautus truongsoneensis</i>						x				
2,4,6	<i>Polypedates colletti</i>										

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
										FO	TE-AQ**	UP-HI			
										FO	TE-AQ-AR**	LO-UP-HI	FO	SL	
										FO	TE-AQ-AR**	LO-UP			
	x									FO	TE-AQ-AR**	LO-UP-HI			
										FO	TE-AQ**	HI			
										FO	TE-AQ**	HI			
										FO	TE-AQ-AR**	LO-UP-HI			
										FO	TE-RU	HI			
												HI			
										FO	TE-AQ**	HI	FO	ST	
										FO	TE-AQ**	UP-HI			
										FO	TE-AQ**	UP-HI			
										FO	TE-AQ-AR**	HI			
										FO	TE-AQ**	UP-HI	FO	FA	
										FO	TE-AQ**	HI			
										FO	TE-AQ**	UP	FO	FA	
	x									FO	TE-AQ-AR**	LO-UP-HI			
										FO	TE-AQ-AR**	UP-HI	FO	FA	
										FO	TE-AQ**	LO-UP			
										FO	TE-AQ	LO-UP-HI			
										FO	TE-AQ-AR**	LO-UP-HI			
										FO	TE-AQ**	UP			
										FO	TE-AQ**	UP			
	x	x	x							FO-OP	TE	LO-UP	FO	ST-SL	
										FO	TE	LO-UP-HI	FO	SL	
										FO-OP	TE-AR	LO-UP-HI	FO-OP	OV	
										FO	AR	UP-HI			
										FO-OP	TE-AR	LO-UP-HI	FO-OP		
										FO	AR	UP			
	x	x	x	x						OP	AR	LO-UP-HI	FO-OP	OV	
										FO	AR	UP-HI	FO	OV	
										FO	AR	HI	FO	OV	
										FO-OP	AR	HI		ST	
										FO	AR	UP-HI			
										FO	AR	LO-UP-HI	FO	OV	
										FO	AR	HI	FO	OV	
										FO	AR	UP-HI	FO		
										FO	AR	LO-UP-HI			
										FO-OP	AR	HI	OP	ST	
										FO-OP	AR	LO-UP-HI	OP	ST	
										FO	AR	LO-UP-HI	FO	AH	
										FO	AR	UP-HI			
										FO	AR	UP	FO	ST	
										FO	AR	HI			
										FO	AR	UP-HI			
										FO	AR	UP			
										FO	AR	LO-UP-HI	FO	OV	
	x									FO	AR	LO			

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
2,4,5,6,7	<i>Polypedates leucomystax</i>	x	x	x	x		x	x	x	x	x
2,4,5	<i>Polypedates megacephalus</i>	x		x	x				x		x
2,4	<i>Polypedates mutus</i>	x	x	x	x						
1,3	<i>Pseudophilautus gryllus</i>	x	x					x		x	
2	<i>Pseudophilautus longchuanensis</i>	x									
4	<i>Pseudophilautus parvulus</i>	x	x				x				
1,3	<i>Rhacophorus annamensis</i>			x			x	x	x		
1,3	<i>Rhacophorus calcaneus</i>				x		x	x	x		
3*	<i>Rhacophorus chuyangsinensis</i>							x			
2,4	<i>Rhacophorus dennysi</i>		x	x	x						
1	<i>Rhacophorus dorsoviridis</i>	x									
1*	<i>Rhacophorus duboisi</i>	x									
2	<i>Rhacophorus dugritei</i>	x	x								
1,3*	<i>Rhacophorus exechopygus</i>			x			x				
2,4	<i>Rhacophorus feae</i>	x					x				
1*	<i>Rhacophorus hoanglienensis</i>	x	x								
?	<i>Rhacophorus cf. hungfuensis</i>	x									
4	<i>Rhacophorus kio</i>	x	x	x	x	x	x		x		
3*	<i>Rhacophorus marmoridorsum</i>						x				
2,4,6	<i>Rhacophorus maximus</i>				x						
4	<i>Rhacophorus orlovi</i>	x		x	x		x		x		
2,4,6,7	<i>Rhacophorus rhodopus</i>	x	x	x	x		x		x		
3*	<i>Rhacophorus spelaeus</i>					x					
2,4,6,7	<i>Theloderma asperum</i>	x	x	x		x		x	x		x
1	<i>Theloderma bicolor</i>	x									
1	<i>Theloderma corticale</i>		x								
4	<i>Theloderma gordonii</i>	x	x				x		x		
1*	<i>Theloderma lateriticum</i>	x									
2	<i>Theloderma rhododiscus</i>		x								
3*	<i>Theloderma ryabovi</i>						x				
4	<i>Theloderma stellatum</i>						x	x	x		
<b>SERPENTES</b>											
<b>Achrochordidae</b>											
2,4,6,7,	<i>Acrochordus granulatus</i>								x		x
7	<i>Acrochordus javanicus</i>								x		
<b>Colubridae</b>											
3*	<i>Colubroelaps nguyenvansangi</i>							x			
<b>Calamariinae</b>											
3*	<i>Calamaria abramovi</i>						x				
3	<i>Calamaria buchi</i>							x			
3*	<i>Calamaria gialaiensis</i>						x				
7	<i>Calamaria lovii</i>						x				
2,4,5,6,7	<i>Calamaria pavimentata</i>	x	x		x		x	x	x	x	x
2	<i>Calamaria septentrionalis</i>	x	x	x							
3*	<i>Calamaria sangi</i>						x				
1*	<i>Calamaria thanhi</i>			x							
2	<i>Calamaria yunnanensis</i>	x									



APPENDIX 2A  
(Continued)

Global Range	SUBREGIONS									
	NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
	<b>Colubrinae</b>									
4,6						X		X		X
4,6,7	X	X	X	X	X	X	X	X		X
1*			X							
2,4,6			X		X	X	X	X		X
4,6,7						X				
4,7						X				
2	X	X	X	X		X				
7							X			
2,5	X	X		X		X		X		
2,4,6,7	X	X	X	X	X	X	X	X		X
4,6,7							X	X		X
2,4,6	X	X	X	X	X	X	X	X		X
4,6,7						X		X		
2,4,6,7	X	X	X	X	X	X	X	X	X	X
2,5	X	X	X							
2	X	X	X			X	X	X		
4,6				X		X			X	
2	X	X	X	X		X				
2,4,5,6,7	X	X	X		X	X		X		X
2,4							X			X
2,4		X		X						
2	X	X		X						
5	X	X	X							X
2			X	X						
2,4,6	X	X	X			X	X	X		
2,4			X		X	X		X		X
2,4	X	X		X						
2,5	X									
2,4,5,6	X	X	X							X
2,6	X			X						
2,4,6,7	X	X	X	X		X		X	X	X
4,6,7			X				X			X
2,4,6	X		X			X				X
4,6			X				X			
2,4,5,6,7						X	X	X		X
4										
2,4,6	X	X	X	X						
2,5	X	X	X	X		X	X	X		
2,4,6	X			X	X	X	X			X
3						X				
2,5	?	X	X	X						
2,4,5,6,7	X	X	X	X		X	X	X		X
2,4,5,6,7	X	X	X	X					X	X
3							X			
4	X	X					X	X		X
2,4,6	X	X		X						
2	X	X				X				
2,4,6,7	X	X	X	X		X	X	X		X
1,3*					X					
2	X	X	X	X						X

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS				Larval	Rep.
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS	Macro-hab.	Microhab.	Elev.	Egg Dep.	Hab.	Mode	
x	x		x			x		x	FO-OP	AR	LO-UP			VI	
x	x	x	x	x	x	x	x	x	FO-OP	AR	LO-UP-HI			VI	
									FO	AR	UP				
x	x	x	x					x	FO	AR	LO-UP-HI			OV	
x			x						FO-OP	AR	LO-UP			OV	
									FO	AR	HI				
									FO	TE	LO-UP-HI			OV	
									FO	AR	HI				
									FO	AR	LO-UP-HI			OV	
x	x	x		x	x	x			FO-OP	AR	LO-UP-HI			OV	
			x						FO	AR	LO-UP-HI			OV	
x	x	x	x		x	x		x	FO-OP	AR	LO-UP-HI			OV	
									FO-OP	TE	LO-UP-HI			OV	
x	x	x	x	x	x	x	x	x	OP	TE	LO-UP-HI			OV	
				x					FO	TE	LO-UP-HI			OV	
				x	x				FO	AR	LO-UP-HI			OV	
									FO	AR	LO-UP-HI			OV	
									FO	AR	LO-UP-HI			OV	
x	x	x	x	x	x	x	x		FO-OP	TE	LO-UP-HI			OV	
x	x	x			x	x			FO-OP	AR	LO-UP			OV	
				x					FO	TE	LO-UP-HI			OV	
									FO-OP	TE	LO-UP-HI			OV	
									FO-OP	TE	LO-UP-HI			OV	
									FO	TE	LO-UP-HI			OV	
									FO	AR	LO-UP-HI			OV	
									FO	AR	LO-UP-HI			OV	
x	x	x	x						FO	AR	LO-UP-HI			OV	
									FO-OP	TE-AR	LO-UP				
									FO	AR	UP-HI				
x	x				x	x		x	FO-OP	TE	LO-UP-HI			OV	
			x						FO	TE	UP				
x									FO	TE-AR	LO-UP-HI			OV	
									FO	TE	LO-UP			OV	
x	x								FO	TE	LO-UP-HI			OV	
									FO	TE	LO-UP			OV	
									FO	TE	LO-UP-HI			OV	
x	x								FO-OP	TE	LO-UP-HI			OV	
				x					FO-OP	TE	LO-UP-HI			OV	
										TE				OV	
x			x				x		OP	TE	LO-UP-HI			OV	
		x							FO	TE	LO-UP-HI			OV	
								x	FO-OP	TE	LO-UP-HI			OV	
x	x			x	x	x		x	FO-OP	TE	LO-UP-HI			OV	
x			x						FO-OP	TE	LO				
		x							FO	TE	LO-UP-HI			OV	

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
2,4,6	<i>Oligodon fasciolatus</i>	x	x		x	x	x	x	x		x
2,5	<i>Oligodon formosanus</i>		x		x						
4	<i>Oligodon inornatus</i>										x
4	<i>Oligodon joynsoni</i>										
2	<i>Oligodon lacroixi</i>	x									
3	<i>Oligodon macrurus</i>										
3*	<i>Oligodon moricei</i>										
4	<i>Oligodon mouhoti</i>										
3	<i>Oligodon ocellatus</i>								x		x
3*	<i>Oligodon saintgironi</i>										
2,4	<i>Oligodon taeniatus</i>		x	x	x			x	x		x
2	<i>Orthriophis moellendorffi</i>		x		x						
2,4,5,6,7	<i>Orthriophis taeniurus</i>	x	x		x		x		x		x
2,4,6,7	<i>Ptyas carinata</i>				x		x	x	x		x
2,6	<i>Ptyas dhumnades</i>	x	x								
2,4,6,7	<i>Ptyas korros</i>	x	x	x	x	x			x		x
2,4,5,6,7	<i>Ptyas mucosa</i>	x	x						x		x
2,4,6	<i>Ptyas nigromarginata</i>	x									
2	<i>Rhynchophis boulengeri</i>	x	x								
2,5	<i>Sibynophis chinensis</i>	x	x	x	x		x				
2,4,5,6,7	<i>Sibynophis collaris</i>	x			x		x	x			x
7	<i>Sibynophis melanocephalus</i>						x				
4	<i>Sibynophis triangularis</i>							x			
4,7	<i>Xenelaphis hexagonotus</i>										
<b>Cylindrophiidae</b>											
2,4	<i>Cylindrophis ruffus</i> Laurenti 1768				x	x			x		x
<b>Elapidae</b>											
4,7	<i>Bungarus candidus</i>	x			x		x	x	x		x
2,4,6,7	<i>Bungarus fasciatus</i>	x	x	x	x	x	x	x	x		x
4,7	<i>Bungarus flaviceps</i>							x	x		
2,4,6	<i>Bungarus multicinctus</i>	x	x		x	x					x
1,3*	<i>Bungarus slowinskii</i>	x					x				
4,6	<i>Calliophis bivirgatus</i>										
4,6	<i>Calliophis intestinalis</i>						x	x			
4,7	<i>Calliophis maculiceps</i>					x			x		x
2	<i>Naja atra</i>	x	x	x	x	x	x				
2,4,6,7	<i>Naja kaouthia</i>	x		x			x	x	x		x
4	<i>Naja siamensis</i>			x		x	x	x	x		x
2,4,6,7	<i>Ophiophagus hannah</i>	x	x	x	x	x	x	x	x		x
2	<i>Sinomicrurus kelloggi</i>	x	x		x						
2,4,5,6	<i>Sinomicrurus macclellandi</i>	x	x	x	x		x	x	x		
<b>Homalopsidae</b>											
4,6,7	<i>Cerberus rynchops</i>										
2, 7	<i>Enhydris bennetti</i>										
4,7,	<i>Enhydris bocourti</i>					x					
2	<i>Enhydris chinensis</i>		x		x			x			
2,4,6,7	<i>Enhydris enhydris</i>				x				x		x
4	<i>Enhydris innominata</i>										
4	<i>Enhydris jagorii</i>					x	x				x

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
x	x	x	x		x	x		x		FO-OP	TE	LO-UP-HI			OV
				x						OP	TE	LO-UP-HI			OV
	x	x	x								TE	LO-UP			OV
											TE	HI			OV
										FO	TE	LO			OV
	x									FO-OP	TE	LO			OV
x	x		x		x					FO	TE-AR	LO			OV
x												LO			
x	x				x	x				FO	TE	LO-UP-HI			OV
										OP	RU	LO-UP			OV
x	x	x	x	x						FO-OP	TE	LO-UP-HI			OV
		x	x							FO-OP	TE	LO-UP-HI			OV
										OP	TE	UP-HI			OV
x	x	x	x	x	x	x	x			FO-OP	TE-AR	LO-UP-HI			OV
x	x	x	x	x		x				FO-OP	TE-AR	LO-UP-HI			OV
								x		FO	TE-AR	LO-UP-HI			
										FO	TE	LO-UP-HI			OV
x		x	x		x					FO-OP	TE	LO-UP-HI			OV
										FO	TE	UP			
										FO-OP	TE	UP			
x										FO-OP	TE	LO			OV
x	x				x					OP	FS	LO-UP			VI
x	x	x	x		x	x				FO	TE	LO-UP-HI			OV
x	x	x	x	x	x	x				FO-OP	TE	LO-UP-HI			OV
x										FO	TE	LO-UP-HI			OV
x										FO	TE	UP			OV
x										FO	TE	LO-UP			OV
										FO-OP	TE	UP-HI			OV
x	x							x		FO	TE-FS	LO-UP-HI			OV
				x			x			FO-OP	TE	LO-UP-HI			OV
x	x	x	x			x	x			OP	TE	LO-UP			OV
x	x		x			x				OP	TE	LO-UP			OV
x	x	x	x	x		x	x	x		FO-OP	TE	LO-UP-HI			OV
										FO	TE	LO-UP-HI			OV
										FO-OP	TE	LO-UP-HI			OV
x	x					x				FO-OP	AQ	LO			VI
				x			x			OP	AQ	LO			VI
x	x		x			x				OP	AQ	LO			VI
				x						FO-OP	AQ	LO-UP			VI
x	x					x		x		OP	AQ	LO			VI
x										FO-OP	AQ	LO			VI
x	x									FO-OP	AQ	LO-UP			VI



APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
3	<i>Enhydris longicauda</i>										
2,4,5,7	<i>Enhydris plumbea</i>	x	x	x	x	x	x	x	x		x
4	<i>Erpeton tentaculatum</i>										
4,6,7	<i>Fordonia leucobalia</i>										
4,6,7	<i>Homalopsis buccata</i>				x		x		x		x
1,3	<i>Homalopsis nigroventralis</i>					x					x
	<b>Lamprophiidae</b>										
4	<i>Psammophis indochinensis</i>										x
	<b>Natricidae</b>										
1*	<i>Amphiesma andreae</i>			x							
2	<i>Amphiesma atemporale</i>		x								
2,4	<i>Amphiesma bitaeniatum</i>	x	x								
2	<i>Amphiesma boulengeri</i>	x	x		x		x	x			
2.4	<i>Amphiesma craspedogaster</i>		x								
2	<i>Amphiesma deschauenseei</i>		x								
2,4,6	<i>Amphiesma khasiense</i>	x	x		x		x	x			x
1,3*	<i>Amphiesma leucomystax</i>			x	x		x		x	x	
2,4,6	<i>Amphiesma modestum</i>	x	x	x	x			x	x		
2	<i>Amphiesma optatum</i>		x								
2	<i>Amphiesma popei</i>		x								
2	<i>Amphiesma sauteri</i>	x	x		x						
2,4,5,6	<i>Amphiesma stolatum</i>	x	x	x	x	x	x		x		x
2	<i>Amphiesmoides ornateiceps</i>			x	x						
2	<i>Opisthotropis andersonii</i>										
3	<i>Opisthotropis annamensis</i>						x				
2	<i>Opisthotropis balteatus</i>										
3*	<i>Opisthotropis daovantieni</i>						x				
2	<i>Opisthotropis jacobi</i>	x	x								
2	<i>Opisthotropis lateralis</i>	x	x		x		x				
1*	<i>Opisthotropis tamdaoensis</i>		x								
1	<i>Pararhabdophis chapaensis</i>	x									
2,4	<i>Paratapinophis praemaxillaris</i>	x		x							
2,4,6,7	<i>Psammodynastes pulverulentus</i>	x	x	x	x		x	x	x		x
1	<i>Rhabdophis angelii</i>		x								
2	<i>Rhabdophis callichroma</i>	x	x								
2,4,7	<i>Rhabdophis chrysargos</i>	x		x	x		x	x			x
2,4	<i>Rhabdophis nigrocinctus</i>	x	x	x			x				
2	<i>Rhabdophis nuchalis</i>	x	x								
2,4,6,7	<i>Rhabdophis subminiatus</i>	x	x	x	x	x	x	x	x	x	x
2,4	<i>Rhabdophis tigrinus</i>										
2	<i>Sinonatrix aequifasciata</i>	x	x	x	x						
2,4,6	<i>Sinonatrix percarinata</i>	x	x	x	x		x		x		x
4,6	<i>Xenochrophis piscator</i>	x			x	x					
2,4,5,6,7	<i>Xenochrophis flavipunctatus</i>	x	x	x	x	x	x	x	x		x
4,6,7	<i>Xenochrophis trianguligerus</i>		x								
	<b>Pareatidae</b>										
4,7	<i>Asthenodipsas laevis</i>	x									
2,4,5,6,7	<i>Pareas carinatus</i>	x	x	x			x	x	x		x

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS				Larval	Rep.
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Hab.	Mode
x	x									OP	AQ	LO			VI
x	x	x	x	x	x	x	x			FO-OP	AQ	LO-UP-HI			VI
x	x									OP	AQ	LO			VI
x	x									OP	AQ	LO			VI
x	x	x	x							FO-OP	TE-AQ	LO-UP			VI
	x									FO-OP	AQ	LO			
									x	FO-OP	TE-AR	LO			OV
										FO	TE	UP			
										FO		HI			OV
										FO	AQ	LO-UP-HI			
										OP	TE	LO-UP-HI			
										FO	TE-AQ	UP-HI			OV
										FO-OP	TE-AQ	LO-UP-HI			
										FO-OP	TE-AQ-AR	LO-UP-HI			
										FO	TE	LO-UP-HI			
										OP	AQ	LO-UP-HI			OV
										FO	AQ				
										FO-OP	AQ	LO-UP-HI			OV
x	x	x								FO-OP	TE	LO-UP-HI			OV
										FO	TE-AR	LO-UP			
										FO	AQ	LO-UP-HI			
										FO	AQ	LO-UP-HI			
										FO-OP	AQ	LO-UP-HI			OV
										FO	TE-AQ	LO-UP-HI			
										FO	AQ	LO-UP-HI			
										FO-OP	AQ	LO-UP-HI			OV
										FO-OP	AQ	LO-UP-HI			OV
										FO-OP	AQ	LO-UP-HI			OV
										FO-OP	TE-AQ	LO-UP-HI			OV
										FO-OP	TE-AQ	LO-UP-HI			OV
										FO-OP	TE-AQ	LO-UP-HI			OV
										FO	AR	UP-HI			OV
										FO	AR	LO-UP-HI			OV

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
2,4	<i>Pareas hamptoni</i>	x	x	x	x		x	x	x	x	x
2,4,6,7	<i>Pareas macularius</i>	x	x	x	x				x		
2,4,7	<i>Pareas margaritophorus</i>	x	x	x	x	x	x	x	x	x	x
4,6	<i>Pareas monticola</i>	x	x								
	<b>Pseudoxenodontidae</b>										
1	<i>Plagiopholis delacouri</i>	x	x								
2,4,6	<i>Plagiopholis nuchalis</i>	x		x	x						
2	<i>Plagiopholis styani</i>	x	x								
2	<i>Pseudoxenodon bambusicola</i>	x	x	x	x		x				
2	<i>Pseudoxenodon karlschmidtii</i>	x	x								
2,4,6,7	<i>Pseudoxenodon macrops</i>	x	x	x	x		x	x		x	x
	<b>Pythonidae</b>										
4,7	<i>Python brogersmai</i>								x		
2,4,6,7	<i>Python molurus</i>	x	x	x	x	x	x	x	x		x
4,5,6,7	<i>Python reticulatus</i>	x	x	x	x	x	x	x	x		x
	<b>Typhlopidae</b>										
2,4,5,6,7	<i>Ramphotylops braminus</i>	x	x	x	x	x	x	x	x		x
2,4,5,6,7	<i>Typhlops diardii</i>	x							x		x
3	<i>Typhlops giadhensis</i>								x		
4,7	<i>Typhlops muelleri</i>										
4	<i>Typhlops siamensis</i>										
	<b>Viperidae</b>										
2,4,6	<i>Azemiops feae</i>		x								
4,7	<i>Calloselasma rhodostoma</i>					x	x	x	x		x
2,4,6,7	<i>Cryptelytrops albolabris</i>	x	x	x	x		x	x	x		x
3*	<i>Cryptelytrops honsonensis</i>										
4	<i>Cryptelytrops macrops</i>							x	x		x
2,4,6,7	<i>Daboia siamensis</i>										
2	<i>Deinagkistrodon acutus</i>	x	x								x
2,4,6,7	<i>Ovophis monticola</i>	x	x	x			x	x	x	x	x
2	<i>Ovophis tonkinensis</i>	x	x		x						
4,6	<i>Popeia popeiorum</i>	x									
2	<i>Protobothrops cornutus</i>	x			x		x		x		
2,4,6	<i>Protobothrops jerdonii</i>	x									
2,4,5,6	<i>Protobothrops mucrosquamatus</i>	x	x	x	x		x		x		x
1*,3	<i>Protobothrops sieversorum</i>			x	x				x		
1*	<i>Protobothrops trungkhanhensis</i>		x								
4,7	<i>Tropidolaemus wagleri</i>										
2,4	<i>Viridovipera gumprechtii</i>	x		x			x				
2,4,6,7	<i>Viridovipera stejnegeri</i>	x	x		x						
1*	<i>Viridovipera truongsongensis</i>			x							
4	<i>Viridovipera vogeli</i>			x			x	x	x	x	x
	<b>Xenodermatidae</b>										
2	<i>Achalinus ater</i>		x								
2	<i>Achalinus rufescens</i>		x		x						
2,5	<i>Achalinus spinalis</i>	x	x		x						
3	<i>Fimbrios klossi</i>						x	x		x	
1*	<i>Fimbrios smithi</i>				x						

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
				x						FO	AR	LO-UP-HI			OV
x	x			x						FO	AR	LO-UP-HI			OV
x	x	x	x	x						FO	TE-AR	LO-UP-HI			OV
										FO	AR	UP-HI			OV
											TE	UP-HI			
												LO-UP-HI			
				x						FO	TE	HI			OV
										FO	TE	LO-UP-HI			
x	x									FO	TE	UP-HI			
x	x			x	x	x				FO-OP	TE	LO-UP-HI			OV
x	x				x	x		x		FO-OP	TE	LO-UP-HI			OV
x	x	x	x	x			x			OP	FS	LO-UP-HI			PA
x	x		x				x	x		FO	FS	LO-UP-HI			VI
										FO	FS	LO			OV
		x	x							OP	FS	LO-UP			OV
	x									OP	FS	LO			
x	x		x				x			FO	TE	HI			OV
x	x		x							FO-OP	TE	LO-UP-HI			OV
x	x	x	x	x	x	x	x			FO-OP	AR	LO-UP-HI			VI
									x	FO-OP	RU	LO			
x	x	x	x							FO-OP	AR	LO-UP-HI			VI
	x									OP	TE	LO-UP-HI			VI
x	x									FO	TE	LO-UP-HI			OV
	x	x								FO-OP	TE	LO-UP-HI			OV
										FO-OP	TE	LO-UP-HI			OV
										FO	AR	LO-UP-HI			VI
										FO-OP	RU	LO-UP-HI			OV
										FO	AR	HI			VI
				x				x		FO	TE	LO-UP-HI			OV
										FO	TE	LO-UP			
										FO		UP			
x										FO	AR	LO			VI
										FO-OP	AR	UP-HI			VI
				x	x					FO	AR	LO-UP-HI			VI
										FO	AR-RU	UP			
		x								FO	AR	LO-UP-HI			VI
										FO	FS	UP-HI			OV
										FO	FS	LO-UP-HI			OV
										FO-OP	FS	LO-UP-HI			OV
		x									TE	UP-HI			OV
										FO	TE	UP			

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
	<b>Xenopeltidae</b>										
2	<i>Xenopeltis hainanensis</i>	x	x	x							
2,4,6,7	<i>Xenopeltis unicolor</i>	x	x	x	x	x	x	x	x		x
	<b>SAURIA</b>										
	<b>Agamidae</b>										
1,3	<i>Acanthosaura capra</i>							x			
4*	<i>Acanthosaura cardamomensis</i>										
3	<i>Acanthosaura coronata</i>						x	x			
4,7	<i>Acanthosaura crucigera</i>	x	x				x		x		
2,4	<i>Acanthosaura lepidogaster</i>	x	x	x	x		x	x	x		x
3*	<i>Acanthosaura nataliae</i>						x		x		x
3*	<i>Bronchocela orlovi</i>						x				
3	<i>Bronchocela smaragdina</i>						x	x			x
3*	<i>Bronchocela vietnamensis</i>						x				
2,4,6,7	<i>Calotes emma</i>	x	x	x	x		x		x		x
2,4,6	<i>Calotes mystaceus</i>	x	x	x			x	x	x		x
2,4,5,6,7	<i>Calotes versicolor</i>	x	x	x	x	x	x	x	x	x	x
3	<i>Draco indochinensis</i>						x	x	x		
2,4,7	<i>Draco maculatus</i>	x	x	x	x		x		x		x
4,7	<i>Draco sumatranus</i>										
4	<i>Draco taeniopterus</i>										
7	<i>Gonocephalus grandis</i>										x
1	<i>Japalura chapaensis</i>	x									
2	<i>Japalura fasciata</i>		x								
4,7	<i>Leiolepis belliana</i>	x			x				x		x
3*	<i>Leiolepis guentherpetersi</i>										
1,3	<i>Leiolepis guttata</i>								x		
3*	<i>Leiolepis ngovantri</i>										
2	<i>Leiolepis reevesii</i>								x		
4*	<i>Mantheyus phuwanensis</i>					x					
2,4	<i>Physignathus cocincinus</i>	x	x	x	x		x	x	x		x
1	<i>Pseudocalotes brevipes</i>	x	x								
4	<i>Pseudocalotes floweri</i>										
2,4	<i>Pseudocalotes microlepis</i>	x					x	x			
1,3	<i>Pseudocalotes poilani</i>						x			x	x
3*	<i>Pseudocophotis kontumensis</i>						x				
3*	<i>Pseudocophotis ziegleri</i>						x				
	<b>Anguidae</b>										
2,4,6	<i>Ophisaurus gracilis</i>	x	x	x				x			
2	<i>Ophisaurus harti</i>	x	x								
3	<i>Ophisaurus sokolovi</i>						x		x		
	<b>Dibamidae</b>										
2	<i>Dibamus bourreti</i>	x	x		x						
3*	<i>Dibamus deharvengi</i>										
3*	<i>Dibamus greeri</i>						x				
3*	<i>Dibamus kondaoensis</i>										
3	<i>Dibamus montanus</i>							x			
3	<i>Dibamus smithi</i>							x			

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
										FO-OP	TE-FS	LO-UP-HI			OV
x	x		x	x	x					FO-OP	TE-FS	LO-UP-HI			OV
	x									FO	AR	LO-UP			OV
		x								FO	TE-AR	UP-HI			OV
	x									FO	TE-AR	UP			
	x	x	x				x			FO	TE-AR	LO-UP-HI			OV
x	x						x			FO	AR	LO-UP-HI			OV
										FO	AR	LO-UP-HI			OV
										FO		UP			
x	x									FO	AR	LO-UP			OV
x										FO	AR	LO-UP-HI			
x	x		x	x	x	x		x		FO	AR	LO-UP			OV
x	x	x	x				x			FO	TE-AR	LO-UP			OV
x	x	x	x		x	x		x		FO-OP	AR	LO-UP			OV
		x	x							FO	AR	LO-UP			OV
x	x	x	x				x	x		FO	AR	LO-UP			OV
	x	x	x					x		FO	AR	LO-UP			OV
										FO	AR	LO-UP-HI			OV
										FO	AR	LO			OV
												HI			OV
x	x		x	x	x	x				OP	FS	LO-UP			OV
								x		OP	TE	LO			PA
x							x			OP	TE	LO			OV
										OP	FS	LO			PA
										OP	TE	LO			OV
										FO-OP	RU	LO			OV
x	x		x			x		x		FO	AQ-AR	LO-UP			OV
		x								AR	HI				OV
										FO	TE-AR	HI			OV
							x			FO	TE-AR	LO-UP-HI			OV
											AR	LO-UP-HI			OV
										FO	AR	HI			OV
										FO	AR	HI			OV
										FO	TE	HI			OV
										FO-OP	TE	UP-HI			OV
										FO	TE	LO-UP-HI			
								x		FO	FS	LO-UP-HI			OV
x										FO	FS	LO			OV
										FO	FS	UP-HI			OV
								x		FO	FS	LO			OV
		x						x		FO	FS	LO-UP			OV
						x				FO	FS	LO-UP-HI			OV

APPENDIX 2A  
(Continued)

Global Range	SUBREGIONS									
	NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
<b>Gekkonidae</b>										
3*	<i>Cnemaspis auranticopes</i>									
3	<i>Cnemaspis boulengerii</i>									
3*	<i>Cnemaspis caudanivea</i>									
4	<i>Cnemaspis chanthaburiensis</i>									
3*	<i>Cnemaspis laoensis</i>									
3*	<i>Cnemaspis neangthyi</i>									
3*	<i>Cnemaspis nuicamensis</i>									
3*	<i>Cnemaspis psychedalia</i>									
3*	<i>Cnemaspis tucludupensis</i>									
3*	<i>Cyrtodactylus badenensis</i>									
3*	<i>Cyrtodactylus buchardi</i>									
3*	<i>Cyrtodactylus caovansungi</i>									
3*	<i>Cyrtodactylus cattienensis</i>									
1*	<i>Cyrtodactylus chauquangensis</i>									
3	<i>Cyrtodactylus condorensis</i>									
1*	<i>Cyrtodactylus cryptus</i>									
3*	<i>Cyrtodactylus eisenmani</i>									
3*	<i>Cyrtodactylus grismeri</i>									
3*	<i>Cyrtodactylus hontreensis</i>									
3*	<i>Cyrtodactylus huynhi</i>									
4	<i>Cyrtodactylus interdigitalis</i>									
4	<i>Cyrtodactylus intermedius</i>									
3	<i>Cyrtodactylus irregularis</i>									
4	<i>Cyrtodactylus jarunjini</i>									
3*	<i>Cyrtodactylus nigriocularis</i>									
3*	<i>Cyrtodactylus paradoxus</i>									
1*	<i>Cyrtodactylus</i>									
	<i>  phongnhakebangensis</i>									
3*	<i>Cyrtodactylus phuquocensis</i>									
3*	<i>Cyrtodactylus</i>									
	<i>  pseudoquadrivirgatus</i>									
1*	<i>Cyrtodactylus roesleri</i>									
3*	<i>Cyrtodactylus takouensis</i>									
3*	<i>Cyrtodactylus yangbayensis</i>									
3*	<i>Cyrtodactylus zieglerei</i>									
3*	<i>Dixonius aaronbaueri</i>									
4	<i>Dixonius melanostictus</i>									
4	<i>Dixonius siamensis</i>									
3*	<i>Dixonius vietnamensis</i>									
4	<i>Gehyra fehlmanni</i>									
4	<i>Gehyra lacerata</i>									
2,4,5	<i>Gehyra mutilata</i>									
3*	<i>Gekko badenii</i>									
1*	<i>Gekko canhi</i>									
2,4,5,6	<i>Gekko gecko</i>									
3*	<i>Gekko grossmanni</i>									
2	<i>Gekko palmatus</i>									
4	<i>Gekko petricolus</i>									
1*	<i>Gekko scientiadventura</i>									
3*	<i>Gekko russelltraini</i>									

APPENDIX 2A  
(Extended Continued)

											ECOLOGICAL CHARACTERS				
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS	Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode	
x									FO-OP	RU	LO				
								x			LO			OV	
								x	FO-OP	RU	LO			OV	
	x										UP-HI				
										RU					
	x								OP	RU					
x									FO-OP	RU	LO				
								x	FO	RU	LO			OV	
x									OP	RU	LO			OV	
x									FO	RU	HI				
								x	FO	RU	LO				
									FO	AR	LO-UP				
x									FO	TE-AR	LO				
									FO	RU	LO				
								x			LO			OV	
									FO	TE-AR-RU	LO-UP			OV	
								x	FO-OP	RU	LO				
x									FO	RU	LO				
								x		RU	LO				
									FO	RU	LO				
									FO	RU	LO				
									FO	AR	UP			OV	
x		x	x						FO-OP	AR-RU	LO-UP-HI			OV	
									FO	TE-AR	LO-UP-HI			OV	
									FO	TE	UP			OV	
x									FO	RU	HI				
x								x	FO	RU	LO			OV	
									FO	RU	LO			OV	
								x	FO	RU	LO				
									FO	RU	LO				
									FO	TE-AR	UP-HI			OV	
									FO	RU	LO				
									FO	RU	UP				
									FO	RU	UP			OV	
								x	FO		HI				
									FO		LO				
									FO-OP	FS	LO-UP				
x	x	x	x						FO	TE-FS	LO-UP			OV	
x	x							x	FO-OP	FS-AR-RU	LO-UP-HI				
									FO-OP	TE-AR	LO			OV	
									FO	FS	LO			OV	
x								x	FO-OP	AR-RU	LO-UP-HI			OV	
x									FO-OP	RU	LO-UP			OV	
									FO		LO-UP-HI				
x	x	x	x	x				x	FO-OP	AR-RU	LO-UP-HI			OV	
								x	FO		LO				
									FO	AR	LO-UP-HI			OV	
								x	FO	RU	LO-UP			OV	
									FO	AR-RU	LO				
									FO	AR	LO			OV	



APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
3*	<i>Gekko takouensis</i>							x			
3*	<i>Gekko vietnamensis</i>										
1*	<i>Goniurosaurus araneus</i>		x								
1*	<i>Goniurosaurus catbaensis</i>										
1*	<i>Goniurosaurus huulienensis</i>		x								
2	<i>Goniurosaurus lichtenfelderi</i>		x		x						
2	<i>Goniurosaurus luii</i>		x								
5	<i>Hemidactylus bowringii</i>	x	x		x						
2,4,5,6,7	<i>Hemidactylus frenatus</i>	x	x	x	x	x	x	x	x		x
2,4,5,6	<i>Hemidactylus garnotii</i>	x	x	x	x	x					x
4,6	<i>Hemidactylus karenorum</i>			x							
2,4,5,6,7	<i>Hemidactylus platyurus</i>	x			x	x			x		x
2,5,7	<i>Hemidactylus stejnegeri</i>										
1,3	<i>Hemidactylus vietnamensis</i>	x	x		x				x		
2,4,5,6,7+	<i>Hemiphyllodactylus typus</i>	x		x	x						
2,4	<i>Hemiphyllodactylus yunnanensis</i>	x									
2,4,5,6,7+	<i>Lepidodactylus lugubris</i>										
4,6	<i>Ptychozoon lionotum</i>								x		
4*	<i>Ptychozoon trinitaterra</i>						x	x	x		
	<b>Lacertidae</b>										
1,3*	<i>Takydromus hani</i>				x		x				
2	<i>Takydromus kuehnei</i>	x		x	x						
2,4,6,7	<i>Takydromus sexlineatus</i>	x	x	x	x	x	x	x	x		x
	<b>Scincidae</b>										
2	<i>Ateuchosaurus chinensis</i>		x		x						
4,5,6,7	<i>Dasia olivacea</i>								x		
2,5,7	<i>Emoia atrocostata</i>										
3	<i>Emoia laobaoensis</i>						x				
1, 3	<i>Eutropis chapaense</i>	x	x		x						
1	<i>Eutropis darevskii</i>	x									
2,4,5,7	<i>Eutropis longicaudata</i>	x	x	x	x	x		x	x		x
4,6,7	<i>Eutropis macularia</i>	x		x	x		x	x	x	x	x
2,4,5,6,7	<i>Eutropis multifasciata</i>	x	x	x	x	x	x	x	x	x	x
3	<i>Leptoseps poilani</i>						x				
1*	<i>Leptoseps tetradactylus</i>				x						
4,7	<i>Lipinia vittigera</i>			x			x	x	x		x
6,7	<i>Lygosoma albopunctatum</i>										
3	<i>Lygosoma angeli</i>								x		x
1*	<i>Lygosoma boehmei</i>			x							
2,4,5,7	<i>Lygosoma bowringii</i>	x	x	x	x	x	x	x	x	x	x
3*	<i>Lygosoma carinatum</i>						x				
3	<i>Lygosoma corpulentum</i>							x		x	
4	<i>Lygosoma haroldyoungi</i>					x					
2,4,7	<i>Lygosoma quadrupes</i>				x			x	x	x	x
3*	<i>Paralipinia rara</i>						x				
2	<i>Plestiodon chinensis</i>										
2	<i>Plestiodon elegans</i>				x						
2,4	<i>Plestiodon quadrilineatus</i>	x	x	x	x						
2	<i>Plestiodon tamdaoensis</i>	x	x		x						
1*	<i>Scincella apraefrontalis</i>			x							

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
										OP	RU	UP			OV
x										OP	RU	LO			
										FO	RU	UP			OV
								x		FO	TE-RU	LO			
										FO	RU	UP			
								x		FO	RU	LO-UP			OV
										FO	RU	LO-UP			
x				x				x		OP	RU	LO-UP			OV
x	x	x	x	x	x	x	x	x		OP	RU	LO-UP-HI			OV
										FO-OP	RU	LO-UP			PA
										FO-OP	TE				OV
x	x		x					x		FO-OP	AR-RU	LO-UP			OV
								x		OP	RU	LO			PA
x								x		FO-OP	AR-RU	LO-UP			PA
										FO	AR-RU	LO-UP-HI			OV
		x								OP	TE	LO			PA
								x		FO-OP	AR-RU	LO-UP			OV
										FO	AR	LO-UP-HI			OV
								x		FO-OP	TE-AR	LO-UP			OV
x	x	x	x			x	x			OP	TE-AR	LO-UP-HI			OV
											TE	LO-UP			OV
x	x		x					x		FO	AR	LO			OV
						x	x			FO	TE-AR-RU	LO			OV
										FO		UP			OV
						x				FO	TE	LO-UP-HI			VI
										FO	TE				VI
x	x		x	x				x		FO-OP	TE	LO-UP			OV
x	x	x	x		x	x		x		FO-OP	TE	LO-UP			OV
x	x	x	x	x	x	x	x	x		FO-OP	TE-FS	LO-UP			VI
											HI				
		x	x	x		x		x		FO-OP	RU	LO			
x	x									FO	TE-AR	LO-UP			OV
											TE	LO			
											TE	LO			
										FO	TE	UP			
x	x	x	x	x	x	x		x		FO	TE	LO-UP-HI			OV
										FO	TE	UP			
										FO	TE	LO-UP-HI			
										FO	TE	LO			
			x		x	x		x		FO	TE	LO-UP			OV
										FO	AR	UP			
								x		OP	TE	LO			
										FO	TE	LO			OV
		x						x		FO	TE	LO-UP-HI			
												LO-UP-HI			
										FO	TE	LO			OV

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
2,4	<i>Scincella doriae</i>	x					x		x		
4	<i>Scincella melanosticta</i>	x		x	x			x	x		x
2	<i>Scincella monticola</i>		x								
1	<i>Scincella ochracea</i>		x								
2,4,7	<i>Scincella reevesii</i>	x	x	x	x				x		x
3	<i>Sphenomorphus buenloicus</i>						x				
1*	<i>Sphenomorphus cryptotis</i>	x		x	x						
1*	<i>Sphenomorphus devorator</i>		x								
2,4,5	<i>Sphenomorphus indicus</i>	x		x	x		x		x		x
4	<i>Sphenomorphus lineopunctulatus</i>										x
2,4,5,6,7	<i>Sphenomorphus maculatus</i>		x	x			x	x	x		x
1,3	<i>Sphenomorphus rufocaudatus</i>		x	x			x	x		x	x
4,7,	<i>Sphenomorphus stellatus</i>							x		x	x
3	<i>Sphenomorphus tridigitus</i>						x			x	
1	<i>Sphenomorphus tritaeniatus</i>		x		x						
1	<i>Tropidophorus baviensis</i>	x		x	x						
1*	<i>Tropidophorus boehmei</i>	x									
4	<i>Tropidophorus cocincinensis</i>			x			x		x		
2	<i>Tropidophorus hainanus</i>	x	x	x	x						
4	<i>Tropidophorus laotus</i>	x				x					
4	<i>Tropidophorus microlepis</i>	x						x			x
1*	<i>Tropidophorus murphyi</i>		x								
1*	<i>Tropidophorus noggei</i>			x							
2	<i>Tropidophorus sinicus</i>		x		x						
3*	<i>Vietnascincus rugosus</i>						x				
<b>Varanidae</b>											
2,4,5,6,7	<i>Varanus nebulosus</i>	x		x					x		x
2,4,5,6,7	<i>Varanus salvator</i>	x	x	x	x				x		x
<b>Xenosauridae</b>											
2	<i>Shinisaurus crocodilurus</i>		x								
<b>CROCODYLIA</b>											
4,7	<i>Crocodylus siamensis</i>							x	x		x
2,4,5,7	<i>Crocodylus porosus</i>						x		x		x
<b>TESTUDINES</b>											
<b>Bataguridae</b>											
4,6,7	<i>Batagur baska</i>										
4,6,7	<i>Cuora amboinensis</i>								x		x
1	<i>Cuora bourreti</i>				x						
2	<i>Cuora galbinifrons</i>	x	x	x			x				
2,4,6	<i>Cuora mouhotii</i>	x	x	x	x		x				
3	<i>Cuora picturata</i>										
2	<i>Cuora trifasciata</i>		x	x	x		x		x		
4	<i>Cyclemys atripons</i>										x
3	<i>Cyclemys pulchistriata</i>							x	x		
4	<i>Cyclemys oldhamii</i>	x		x	x	x	x				x
2	<i>Geoemyda spengleri</i>		x				x				
4,7	<i>Heosemys annandalii</i>										x
4,7	<i>Heosemys grandis</i>										x

APPENDIX 2A  
(Extended Continued)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro-hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
										FO	TE	LO-UP-HI			
	x	x	x				x	x		FO	TE	LO-UP-HI			
										FO	TE	HI			
												UP			
x	x	x		x	x	x	x	x		FO	TE	LO-UP-HI			
												HI			
										FO	AQ-AR	LO-UP-HI			
										FO	AR	UP			
		x	x		x					FO-OP	TE	LO-UP-HI			VI
	x									FO-OP	TE	LO			
	x	x	x						x	FO	TE	LO-UP-HI			OV
		x							x	FO	TE	LO-UP-HI			
			x							FO	TE-AR	LO-UP-HI			
										FO	TE	LO-UP-HI			
										FO	TE	LO-UP			OV
										FO	TE	HI			
x	x									FO	TE-AQ	LO-UP-HI			OV
										FO	TE-AQ	LO-UP-HI			OV
										FO		LO-UP			
		x								FO	TE-AQ	LO-UP			VI
										FO	TE	HI			VI
										FO	TE				
										FO		UP-HI			VI
										FO	TE-AR	UP			
	x					x		x		FO-OP	TE-AR	LO-UP-HI			OV
x	x		x				x	x		OP	TE-AQ-AR	LO-UP-HI			OV
										FO	TE-AQ	LO-UP-HI			VI
x	x	x	x					x		FO-OP	TE-AQ	LO-UP			OV
x	x				x	x				FO-OP	TE-AQ	LO			OV
x	x					x				OP	AQ	LO			OV
x	x		x							FO-OP	TE-AQ	LO			OV
										FO	TE	LO			OV
										FO	TE	LO-UP-HI			OV
x										FO	TE	LO-UP			OV
										FO	TE	UP			
										FO	AQ	LO-UP			OV
			x							FO	AQ	LO			OV
										FO	AQ	LO-UP			OV
	x	x		x						FO	TE-AQ	LO-UP-HI			OV
										FO	TE	HI			OV
x	x		x							FO-OP	AQ	LO			OV
x	x									FO-OP	AQ	LO-UP			OV

APPENDIX 2A  
(Continued)

Global Range		SUBREGIONS									
		NWU	NEU	NAN	NEL	UML	CAN	SAN	CSL	SLU	SLL
4,7	<i>Malayemys subtrijuga</i>					x					x
3	<i>Mauremys annamensis</i>						x		x		
2,5	<i>Mauremys mutica</i>				x						
2	<i>Mauremys nigricans</i>				x						
2	<i>Mauremys sinensis</i>				x				x		
4,7	<i>Notochelys platynota</i>										
2	<i>Sacalia quadriocellata</i>	x		x	x						
4,7	<i>Siebenrockiella crassicollis</i>								x		
	<b>Platysternidae</b>										
2,4	<i>Platysternon megacephalum</i>	x	x				x				
	<b>Testudinidae</b>										
2,4,6,7	<i>Indotestudo elongata</i>		x		x				x		x
2,4,7	<i>Manouria impressa</i>	x		x			x	x		x	
	<b>Trionychidae</b>										
2,4,6,7	<i>Amyda cartilaginea</i>						x		x		x
2	<i>Palea steindachneri</i>	x	x						x		
2,4,5,6,7	<i>Pelochelys cantorii</i>				x	x			x		x
2,5,7	<i>Pelodiscus sinensis</i>	x	x	x	x				x		
2	<i>Rafetus swinhoei</i>				x						

APPENDIX 2A  
(*Extended Continued*)

										ECOLOGICAL CHARACTERS					
MEK	CMB	CDU	CDL	NC	CC	SC	NIS	SIS		Macro- hab.	Microhab.	Elev.	Egg Dep.	Larval Hab.	Rep. Mode
x	x									FO-OP	AQ	LO			OV
										FO-OP	AQ	LO-UP-HI			OV
										FO-OP	AQ	LO			OV
										FO-OP	AQ	LO			OV
										FO-OP	AQ	LO			OV
x										FO	AQ	LO-UP-HI			OV
x	x					x				FO-OP	AQ	LO			OV
										FO	AQ	UP-HI			OV
x	x	x	x							FO	TE	LO-UP-HI			OV
										FO	TE	LO-UP-HI			OV
x	x		x			x				FO-OP	AQ	LO			OV
										FO	AQ	LO-UP-HI			OV
x			x		x					FO-OP	AQ	LO			OV
										FO-OP	AQ	LO-UP			OV
										OP	AQ	LO			OV

## APPENDIX 2B

## REFERENCES AND COMMENTS: DIVERSITY AND DISTRIBUTION OF INDOCHINESE HERPETOFAUNA

Range codes are as follows: (1) northern Indochina, (2) South China, (3) southern Indochina, (4) Mainland Southeast Asia, (5) East Asia, (6) Southern Himalayas, (7) Malaya.

Taxa shaded gray were not included in the analysis (see Materials and Methods and relevant comments under References column).

## References

## AMPHIBIA

## Gymnophonia: Ichthyophidae

<i>Ichthyophis banmanicus</i>	Gower et al., 2002; referred specimen IEBR 1518
<i>Ichthyophis kohtaoensis</i>	Stuart et al., 2006c—ichthyophis identification too ambiguous to include in analysis
<i>Ichthyophis laosensis</i>	Taylor, 1969—ichthyophis identification too ambiguous to include in analysis

## Caudata: Salamandridae

<i>Paramesotriton deloustali</i>	Bourret, 1942; Darevsky and Salomatina, 1989; Lu et al., 2004; Rehak, 1984
<i>Paramesotriton guanxiensis</i>	Ho et al., 2005; Orlov et al., 2002b
<i>Paramesotriton laoensis</i>	Stuart and Pappenfus, 2002
<i>Tylostrotion asperrimus</i>	Bourret, 1942; Bain and Nguyen, 2004b; Ho et al., 2005; referred specimen AMNH R-168656
<i>Tylostrotion verrucosus</i>	Orlov et al., 2002b; Pope, 1931; Smith, 1924c
<i>Tylostrotion vietnamensis</i>	Böhme et al., 2005

## Anura: Bombinatoridae

<i>Bombina maxima</i>	Bain and Nguyen, 2004b; Ohler et al., 2000; Orlov et al., 2001a; Yu et al., 2007b
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## Anura: Bufonidae

<i>Bufo cryptotypanicus</i>	Liu et al., 2000
<i>Bufo pageoti</i>	Bourret, 1942; Ohler et al., 2000; Fei et al., 2009
<i>Duttaphrynus melanostictus</i>	Angel, 1927; Bain and Nguyen, 2004b; Bain et al., 2007b; Bourret, 1942; Chou and Lin, 1997; Grismer et al., 2008c; Heyer, 1973; Ohler et al., 2000; Parker, 1925; Pope, 1931; Smith, 1917, 1920; Stuart, 2005b; Stuart et al., 2006c; Tarkhishvili, 1995; Vassilyev, 2003; Ziegler et al., 2004a; Ziegler and Weitkus, 1999a
<i>Ingerophrynus galeatus</i>	Bourret, 1942; Inger et al., 1999; Ohler et al., 2002; Smith, 1921a; Stuart, 2005b; Stuart et al., 2006c; Vassilyev, 2003; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Ingerophrynus macrotis</i>	Bain et al., 2007b; Grismer et al., 2007a; Inger et al., 1999; Ohler et al., 2002; Stuart, 2005b
<i>Ingerophrynus parvus</i>	Ohler et al., 2002
<i>Phrynooidis asper</i>	Berry, 1975; Wogan et al., 2008; reported by Orlov et al., 2002b, without vouchers

## Anura: Dicroglossidae

<i>Annandia delacouri</i>	Angel, 1928; Bain and Nguyen, 2004b; Bourret, 1942, 1944; Dubois, 1975
<i>Euphlyctis cyanophlyctis</i>	reported by Orlov et al., 2002b, without vouchers
<i>Fejervarya cancrivora</i>	Bourret, 1942; Grismer et al., 2007a; Ohler et al., 2002; Smith, 1917
<i>Fejervarya limnocharis</i>	Anderson, 1942; Bain and Nguyen, 2004b; Bourret, 1942; Chen et al., 2005; Chou and Lin, 1997; Ohler and Delorme, 2006; Ohler et al., 2000; Parker, 1925; Pope, 1931; Smith, 1917; Stuart et al., 2006c; Tarkhishvili, 1995; Teynie et al., 2004; Vassilyev, 2003; Wogan, 2004; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999a; referred specimen AMNH A-169293
<i>Hoplobatrachus rugulosus</i>	Bain and Nguyen, 2004b; Bourret, 1942; Chen et al., 2006; Chou and Lin, 1997; Grosjean et al., 2004; Ohler and Delorme, 2006; Ohler et al., 2002; Pope, 1931; Schmidt, 1928; Smith, 1917; Stuart, 2005b; Tarkhishvili, 1995; Ziegler and Herrmann, 2000
<i>Limnometes bannaensis</i>	McLeod, 2010
<i>Limnometes dabanus</i>	Chen et al., 2006; Orlov et al., 2002b; Smith, 1922b; Stuart et al., 2006c
<i>Limnometes gyldenstolpei</i>	Bourret, 1942; Ohler and Dubois, 1999; Ohler et al., 2002; Stuart, 2005b
<i>Limnometes hascheanus</i>	Bain et al., 2007b; Bourret, 1942; Ohler et al., 1999; Ohler et al., 2002; Ziegler et al., 2004a; referred specimens IEBR 1579, 1580

APPENDIX 2B  
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	References
<i>Limnonectes khammonensis</i>	Bourret, 1942; Smith, 1929
<i>Limnonectes kohchangae</i>	Ohler et al., 2002; Grismer et al., 2007a; Stuart and Emmett, 2006
<i>Limnonectes "kuhlii" 4 spp</i>	Bain and Nguyen, 2004b; Bourret, 1942; Chen et al., 2006; Chou and Lin, 1997; Inger et al., 1999; ; McLeod, 2010; Ohler et al., 2000; Ohler and Delorme, 2006; Pope, 1931; Smith, 1917; Stuart et al., 2006c; Tsuji and Lue, 2000; Vassilyev, 2003; Ziegler and Herrmann, 2000
<i>Limnonectes macrognathus</i>	Bourret, 1942
<i>Limnonectes poilani</i>	Anderrson, 1942; Bain et al., 2007b; Bourret, 1942; Emerson, 1998; Inger et al., 1999; Ngo et al., 2006; Ohler et al., 2002; Orlov, 1997; Stuart et al., 2006c; Ziegler et al., 2006b
<i>Nanorana aenea</i>	Bourret, 1942; Dubois and Ohler, 2005; Ohler et al., 2000
<i>Nanorana bourreti</i>	Bain and Nguyen, 2004b; Dubois, 1987; Ohler et al., 2000; Huang et al., 2009
<i>Nanorana yunnanensis</i>	Bourret, 1942; Ngo et al., 2006; Pope, 1931
<i>Occidozyga lima</i>	Annandale and Rao, 1917; Bourret, 1942; Chen et al., 2006; Grismer et al., 2007a; Heyer, 1973; Inger et al., 1999; Pope, 1931; Semenov, 2001; Stuart, 2005b; Tarkhishvili, 1995; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999a
<i>Occidozyga magnapustulosa</i>	Ohler and Delorme, 2006
<i>Occidozyga martensii</i>	Bain et al., 2007b; Grismer et al., 2007a; Stuart, 2005b; Ngo et al., 2006; Pope, 1931; Smith, 1920; Tarkhishvili, 1995; Teynie et al., 2004; Ziegler and Herrmann, 2000; referred specimen AMNH-161171
<i>Occidozyga vittata</i>	Anderson, 1942
<i>Quasipaa acanthophora</i>	Dubois and Ohler, 2009
<i>Quasipaa boulengeri</i>	Bain and Nguyen, 2004b; Bourret, 1942
<i>Quasipaa fasciculispina</i>	Grismer et al., 2007a; Inger, 1970; Ohler et al., 2002; Ohler and Dubois, 2006; Stuart and Emmett, 2006
<i>Quasipaa spinosa</i>	Bourret, 1939c, 1942; Chen et al., 2006; Pope, 1931; Smith, 1924b; Dubois and Ohler, 2009
<i>Quasipaa verrucospinosa</i>	Bourret, 1942, 1944; Inger et al., 1999; Ohler et al., 2000; referred specimen AMNH A-169299
<b>Anura: Hylidae</b>	
<i>Hyla annectans</i>	Anderrson, 1942; Bourret, 1942; Liu, 1950; Ohler et al., 2000; Orlov et al., 2002b; Parker, 1925; Pope, 1931; Zhao and Adler, 1993
<i>Hyla chinensis</i>	Chou and Lin, 1997; Orlov et al., 2002b; Pope, 1931
<i>Hyla simplex</i>	Bourret, 1942; Pope, 1931; Ziegler and Herrmann, 2000; Ziegler et al., 2004a; Ziegler and Weitkus, 1999a
<b>Anura: Megophryidae</b>	
<i>Brachytarsophrys feae</i>	Bain et al., 2007b; Boulenger 1890, 1908, Bourret, 1942; Ho et al., 2005; Inger et al., 1999
<i>Brachytarsophrys intermedia</i>	Bourret, 1942; Inger et al., 1999; Orlov et al., 2002b; Smith, 1921a; Stuart, 2005b; Ziegler et al., 2006
<i>Leptobrachium ailaonicum</i>	Dubois and Ohler, 1998; Grosjean, 2001; Ohler et al., 2000; Zhang et al., 2009
<i>Leptobrachium banae</i>	Bain et al., 2007b; Lathrop et al., 1998b; Stuart, 2005b
<i>Leptobrachium buchari</i>	Ohler et al., 2004
<i>Leptobrachium chapaense</i>	Bain and Nguyen, 2004b; Bourret, 1942; Dubois and Ohler, 1998; Ho et al., 2005; Lathrop et al., 1998b; Ohler et al., 2000; Semenov, 2001; Stuart, 2005b; Ziegler et al., 2004a
<i>Leptobrachium mouhoti</i>	Bain and Nguyen, 2006; Stuart et al., 2006c
<i>Leptobrachium ngoclinhense</i>	Orlov, 2005
<i>Leptobrachium promustache</i>	Rao et al., 2006; Bain et al., 2009a
<i>Leptobrachium pullum</i>	Bourret, 1942; Inger et al., 1999; Smith, 1921a
<i>Leptobrachium smithi</i>	Stuart, 2005b
<i>Leptobrachium xanthospilum</i>	Lathrop et al., 1998b



APPENDIX 2B  
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	References
<i>Leptolalax applebyi</i>	Rowley and Cao, 2009
<i>Leptolalax bourreti</i>	Bain and Nguyen, 2004b; Dubois, 1983; Ohler et al., 2000; Stuart, 2005b
<i>Leptolalax nahangensis</i>	Lathrop et al., 1998a
<i>Leptolalax oshanensis</i>	Ho et al., 2005; Inger et al., 1999; Pope, 1931; Stuart, 2005b; Ziegler and Herrmann, 2000
<i>Leptolalax pluvialis</i>	Bain et al., 2007b; Ohler et al., 2000
<i>Leptolalax sungi</i>	Bain et al., 2007b; Lathrop et al., 1998a; Fei et al., 2009
<i>Leptolalax tuberosus</i>	Bain and Nguyen, 2002a; Bain et al., 2007b; Inger et al., 1999
<i>Ophryophryne gerti</i>	Bain et al., 2007b; Ohler, 2003; Stuart, 2005b
<i>Ophryophryne hansii</i>	Bain et al., 2007b; Ohler, 2003; Stuart, 2005b; Stuart et al., 2006c; Ziegler et al., 2006; AMNH A-161353
<i>Ophryophryne microstoma</i>	Bain and Nguyen, 2004b; Bain et al. 2007b; Bourret, 1942; Inger et al., 1999; Grosjean, 2003; Ohler, 2003
<i>Ophryophryne pachyproctus</i>	Bain et al., 2007b; Inger et al., 1999; Ohler, 2003; Orlov, et al 2002b
<i>Ophryophryne poilani</i>	Stuart et al., 2010b
<i>Ophryophryne synoria</i>	Stuart et al., 2006c
<i>Xenophrys auralensis</i>	Grismer et al., 2007a; Ohler, 2003; Stuart and Emmett, 2006
<i>Xenophrys brachykolos</i>	reported by Orlov et al., 2002b without vouchers
<i>Xenophrys jingdongensis</i>	Ohler et al., 2000
<i>Xenophrys kuatunensis</i>	reported by Orlov et al., 2002b without vouchers
<i>Xenophrys major</i>	Bain and Nguyen, 2004b; Bourret, 1944; Ho et al., 2005; Inger et al., 1999; Ohler et al., 2000; Semenov, 2001; Stuart, 2005b; Ziegler et al., 2004a; Stuart et al., 2010b; referred specimen AMNH A-169288
<i>Xenophrys minor</i>	Ohler et al., 2000
<i>Xenophrys pachyproctus</i>	Ohler et al., 2000
<i>Xenophrys palpebralespinosa</i>	Bain and Nguyen, 2004b; Bourret, 1942; Ho et al., 2005; Inger et al., 1999; Stuart, 2005b
<i>Xenophrys parva</i>	Ohler et al., 2000; Stuart, 2005b; Bain and Nguyen, 2004b; Boulenger, 1890
<b>Anura: Microhylidae</b>	
<i>Calluella guttulata</i>	Bourret, 1942; Inger et al., 1999; Orlov et al., 2002b; Smith, 1917; Stuart and Emmett, 2006; Bezuijen et al., 2009
<i>Calluella yunnanensis</i>	reported by Orlov et al., 2002b without vouchers
<i>Glyphoglossus molossus</i>	Bourret, 1942; Heyer, 1973; Smith, 1917
<i>Kalophrynus interlineatus</i>	Bourret, 1942; Grismer et al., 2008b; Ohler and Grosjean, 2005; Orlov et al., 2002b; Stuart, 2005b; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Ziegler et al., 2004a
<i>Kalophrynus menglienicus</i>	reported by Ohler and Grosjean, 2005 without vouchers
<i>Kaloula baleata</i>	Orlov et al., 2002b; Teynie et al., 2004; referred specimen IEBR VC081
<i>Kaloula mediolineata</i>	Heyer, 1971; Orlov et al., 2002b
<i>Kaloula pulchra</i>	Bourret, 1942; Grismer et al., 2007a; Heyer, 1971; Orlov et al., 2002b; Ohler and Delorme, 2006; Parker, 1925; Semenov, 2001; Stuart, 2005b; Teynie et al., 2004; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Microhyla annamensis</i>	Bain and Nguyen, 2004a; Bourret, 1942; Ohler et al., 2002; Semenov, 2001; Smith, 1923
<i>Microhyla berdmorei</i>	Bourret, 1942; Grismer et al., 2008a; Inger et al., 1999; Leong, 2004; Smith, 1924b; Stuart, 2005b; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Vassilyev, 2003; Ziegler and Herrmann, 2000; Ziegler et al., 2004a; referred specimen AMNH A-169289
<i>Microhyla butleri</i>	Bourret, 1942; Chou and Lin, 1997; Grismer et al., 2007a; Heyer, 1973; Ohler et al., 2000; Parker 1934; Pope, 1931; Smith, 1917, 1922a; Stuart, 2005b; Tarkhnishvili, 1995; Teynie et al., 2004; Ziegler et al., 2004a
<i>Microhyla erythropoda</i>	Tarkhnishvili, 1994, 1995

APPENDIX 2B  
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	References
<i>Microhyla fissipes</i>	Bourret, 1942; Heyer, 1973; Matsui et al., 2005; Parker, 1925, 1934; Pope, 1931; Smith, 1917; Stuart, 2005b; Tarkhnishvili, 1995; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999a
<i>Microhyla fusca</i>	Anderrson, 1942
<i>Microhyla heymonsi</i>	Bain and Nguyen, 2004b; Chou and Lin, 1997; Goldberg and Bursey, 2005c; Grismer et al., 2007a; Heyer, 1973; Ohler et al., 2000; Pope, 1931; Semenov, 2001; Stuart, 2005b; Tarkhnishvili, 1995; Vassilyev, 2003; Ziegler and Herrmann, 2000
<i>Microhyla marmorata</i>	Bain and Nguyen, 2004a; Bain et al., 2007b
<i>Microhyla nanapollexa</i>	Bain and Nguyen, 2004a
<i>Microhyla picta</i>	Bourret, 1942; Schenkel, 1901; Smith, 1921a
<i>Microhyla pulchra</i>	Bourret, 1942; Bain and Nguyen, 2004b; Grismer et al., 2007a; Liu, 1950; Semenov, 2001; Stuart, 2005b; Orlov et al., 2002b; Parker, 1925; Pope, 1931; Tarkhnishvili, 1995; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Microhyla pulverata</i>	Bain and Nguyen, 2004a
<i>Micryletta inornata</i>	Bourret, 1942; Grismer et al., 2008a; Heyer, 1971; Smith, 1924b; Stuart, 2005b; Stuart and Emmett, 2006; Ziegler and Herrmann, 2000
<b>Anura: Ranidae</b>	
<i>Amolops akhaorum</i>	Stuart et al., 2010a
<i>Amolops compotrix</i>	Bain et al., 2006; Stuart, 2008
<i>Amolops crenmobatus</i>	Bain and Nguyen, 2001a; Bain et al., 2007b; Goldberg and Bursey, 2005a; Inger and Kottelatt, 1998; Ngo et al., 2006; Stuart, 2005b
<i>Amolops cucae</i>	Bain et al., 2006; Stuart, 2008
<i>Amolops daorum</i>	Bain et al., 2003, 2006; Stuart, 2005b; Stuart et al., 2010a
<i>Amolops iriodes</i>	Bain and Nguyen, 2004b; Stuart, 2008
<i>Amolops minutus</i>	Orlov and Ho, 2007
<i>Amolops ricketti</i>	Bain and Nguyen, 2004b; Inger et al., 1999; Ngo et al., 2006; Noble, 1929; Pope, 1931
<i>Amolops spinapectoralis</i>	Bain and Nguyen, 2002e; Inger et al., 1999; Ngo et al., 2006
<i>Amolops splendidissimus</i>	Orlov and Ho, 2007; Rao and Wilkinson, 2007
<i>Amolops viridimaculatus</i>	Ho et al., 2005; Ohler et al., 2000; Wogan et al., 2004; Ao et al., 2003
<i>Amolops vitreus</i>	Bain et al., 2006; Stuart, 2008
<i>Babina adenopleura</i>	reported by Orlov et al., 2002b, from "northern Vietnam" without vouchers
<i>Babina chapaensis</i>	Bourret, 1942; Bain and Nguyen, 2001b; Orlov et al., 2002b; Stuart, 2005b; referred specimen, IEBR 3673
<i>Hylarana attigua</i>	Bain and Nguyen, 2002d; Bain et al., 2007b; Gawor et al., 2009; Hendrix et al., 2008; Inger et al., 1999; Stuart, 2005b; Stuart et al., 2006c
<i>Hylarana erythraea</i>	Bourret, 1942; Darevsky, 1999; Ngo et al., 2006; Parker, 1925; Smith, 1917, 1920; Teynie et al., 2004; Ziegler and Herrmann, 2000
<i>Hylarana faber</i>	Ohler et al., 2002; Stuart, 2005c; Stuart and Emmett, 2006
<i>Hylarana cubitalis</i>	Ohler, 2007; Stuart et al., 2006a; Wogan et al., 2008
<i>Hylarana glandulosa</i>	reported by Orlov et al., 2002b from southern Vietnam without vouchers
<i>Hylarana guentheri</i>	Anderrson, 1942; Bain and Nguyen, 2004b; Bourret, 1942; Chen et al., 2006; Chou and Lin, 1997; Gawor et al., 2009; Parker, 1925; Pope, 1931; Ziegler, 2002; Ziegler and Weitkus, 1999a
<i>Hylarana macrodactyla</i>	Anderrson, 1942; Bourret, 1942; Chen et al., 2006; Pope, 1931; Semenov, 2001; Smith, 1917; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Vassilyev, 2003; Ziegler and Weitkus, 1999a; referred specimen AMNH 88672
<i>Hylarana maosonensis</i>	Bain and Nguyen, 2004b; Gawor et al., 2009; Hendrix et al., 2008; Inger et al., 1999; Ohler, 2007; Orlov et al., 2002b; Semenov, 2001; Stuart, 2005b; Ziegler, 2002
<i>Hylarana montivaga</i>	Smith, 1921a
<i>Hylarana mortenseni</i>	Ohler et al., 2002; Stuart and Emmett, 2006
<i>Hylarana milleti</i>	Inger et al., 1999; Smith, 1921a; Stuart and Emmett, 2006; Ohler, 2007

APPENDIX 2B  
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	References
<i>Hylarana nigrovittata</i>	Gawor et al, 2009; Grosjean, 2005; Heyer, 1973; Inger et al., 1999; Semenov, 2001; Smith, 1921a; Stuart et al., 2006c; Teynie et al., 2004; Vassilyev, 2003; Ziegler and Herrmann, 2000; referred specimens AMNH 161277, 161281
<i>Hylarana taipehensis</i>	Bain and Nguyen, 2004b; Chen et al., 2006; Chou and Lin, 1997; Inger et al., 1999; Orlov et al., 2002b; Pope, 1931; Stuart, 2005b; Stuart et al., 2006c; Teynie et al., 2004; Ziegler and Herrmann, 2000
<i>Odorrana absita</i>	Bain and Nguyen, 2005; Bain et al., 2007b; Stuart, 2008; Stuart and Charn-ard, 2005
<i>Odorrana andersonii</i>	Bourret, 1942; Cai et al., 2007; Ziegler and Herrmann, 2000
<i>Odorrana bacboensis</i>	Bain et al., 2003, 2007b; Chen et al., 2006
<i>Odorrana banaorum</i>	Bain et al., 2003; Bain et al., 2007b; Chen et al., 2006; Stuart et al., 2006c
<i>Odorrana bolavensis</i>	Stuart and Bain, 2005
<i>Odorrana chapaensis</i>	Bain and Nguyen, 2004b; Chen et al., 2006; Ohler et al., 2000
<i>Odorrana chloronota</i>	Bain et al., 2003; Bain and Nguyen, 2004b; Chen et al., 2006; Ohler et al., 2000
<i>Odorrana geminata</i>	Bain et al., 2009c
<i>Odorrana gigatympana</i>	Orlov et al., 2006c
<i>Odorrana grahami</i>	Ohler et al., 2000; Cai et al., 2007
<i>Odorrana graminea</i>	Bain et al., 2003
<i>Odorrana heatwolei</i>	Stuart and Bain, 2005
<i>Odorrana hmongorum</i>	Bain et al., 2003
<i>Odorrana julianensis</i>	Bain and Stuart, 2006a
<i>Odorrana khalam</i>	Bain et al., 2007b; Stuart, 2008; Stuart et al., 2005
<i>Odorrana margaretae</i>	reported by Orlov et al., 2002b without vouchers
<i>Odorrana morafkai</i>	Bain et al., 2003, 2007b; Bain and Stuart, 2006b "2005"; Chen et al., 2006; Stuart et al., 2006c; Teynie et al., 2004
<i>Odorrana nasica</i>	Chen et al., 2006; Inger et al., 1999; Ngo et al., 2006; Orlov et al., 2002b; Stuart, 2005b; Stuart and Chan-ard, 2005
<i>Odorrana orba</i>	Bain et al., 2007b; Stuart and Bain, 2005
<i>Odorrana schmackeri</i>	reported by Orlov et al., 2002b without vouchers
<i>Odorrana tiannanensis</i>	Bain et al., 2003; Bain and Nguyen, 2004b; Ngo et al., 2006; Chen et al., 2006; Ohler, 2007; Stuart and Bain, 2005
<i>Odorrana trunkieni</i>	Orlov et al., 2003a
<i>Odorrana yentuensis</i>	Tran et al., 2008
<i>Pelophylax lateralis</i>	Bourret, 1942; Chen et al., 2006; Orlov et al., 2002b; Smith, 1917; Stuart, 2005b
<i>Rana johnsi</i>	Inger et al., 1999; Ngo et al., 2006; Smith, 1921a, 1924b; Stuart, 2005b; Stuart et al., 2006c; Ziegler et al., 2006b; Ziegler and Herrmann, 2000; referred specimens AMNH A-168732, 169307, IEBR 3661
<b>Anura: Rhacophoridae</b>	
<i>Chiromantis doriae</i>	Inger et al., 1999; Ohler and Delorme, 2006; Pope, 1931; Stuart, 2005b; Teynie et al., 2004
<i>Chiromantis laevis</i>	Orlov et al., 2004a; Smith, 1924a
<i>Chiromantis nongkhorensis</i>	Bourret, 1942; Grismer et al., 2007a, 2008b; Heyer, 1971, 1973; Inger et al., 1999; Ohler et al., 2000; Stuart, 2005b; Stuart and Emmett, 2006; Stuart et al., 2006c; Tarkhnishvili, 1995; Teynie et al., 2004
<i>Chiromantis samkosensis</i>	Grismer et al., 2007b
<i>Chiromantis vittatus</i>	Bain et al., 2007b; Bourret, 1942; Grismer et al., 2007b; Inger et al., 1999; Pope, 1931; Smith, 1924a,b; Stuart, 2005b; Stuart and Emmett, 2006; Ziegler et al., 2004a
<i>Feihyla palpebralis</i>	Bourret, 1942; Inger et al., 1999; Smith, 1924a
<i>Gracixalus gracilipes</i>	Bain and Nguyen, 2004b; Ohler et al., 2000
<i>Gracixalus jinxiuensis</i>	Ohler et al., 2000; Orlov et al., 2004a; Li et al., 2009
<i>Gracixalus quyeti</i>	Nguyen et al., 2008c; Li et al., 2009
<i>Gracixalus supercornutus</i>	Orlov et al., 2004a; referred specimen AMNH A-169318
<i>Kurixalus ananjevae</i>	Matsui and Orlov, 2004
<i>Kurixalus baliogaster</i>	Inger et al., 1999

APPENDIX 2B  
(Continued)

	References
<i>Kurixalus banaensis</i>	Bain et al., 2007b; Bourret, 1942; Hendrix et al., 2008; Orlov et al., 2002b; Li et al., 2009
<i>Kurixalus carinensis</i>	Ohler et al., 2000; Orlov et al., 2004a
<i>Kurixalus odontotarsus</i>	Bain and Nguyen, 2004b; Ohler et al., 2000
<i>Kurixalus verrucosus</i>	Bain and Nguyen, 2004b; Bourret, 1942; Inger et al., 1999; Ohler and Delorme, 2006; Ohler et al., 2002; Orlov et al., 2002b
<i>Nyctixalus pictus</i>	Das et al., 2004; Orlov et al., 2002b
<i>Philautus abditus</i>	Inger et al., 1999; Orlov et al., 2006; Stuart et al., 2010
<i>Philautus albopunctatus</i>	reported by Orlov et al., 2002b without vouchers; Yu et al., 2007a suggested this is a synonym of <i>Theلودerma asperum</i>
<i>Philautus cardamonis</i>	Ohler et al., 2002
<i>Philautus maosonensis</i>	Bain and Nguyen, 2004b; Inger et al., 1999; Orlov et al., 2002b
<i>Philautus petilus</i>	Stuart and Heatwole, 2004
<i>Philautus truongsongensis</i>	Orlov and Ho, 2005
<i>Polypedates colleti</i>	reported by Orlov et al., 2002b without vouchers
<i>Polypedates leucomystax</i>	Goldberg and Bursley, 2005b; Grismer et al., 2007a, 2008b, c; Heyer, 1973; Inger et al., 1999; Ohler and Delorme, 2006; Parker, 1925; Pope, 1931; Smith, 1917; Tarkhnishvili, 1995; Teynie et al., 2004; Vassilyev, 2003; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999a; referred specimen AMNH A-169321
<i>Polypedates megacephalus</i>	Chou and Lin, 1997; Orlov et al., 2001a
<i>Polypedates mutus</i>	Ohler and Delorme, 2006; Orlov et al., 2001a; Ziegler, 2002; Ziegler et al., 2006b
<i>Pseudophilautus gryllus</i>	Bourret, 1942; Orlov et al., 2002b; Smith, 1924a; Teynie et al., 2004; Li et al., 2009
<i>Pseudophilautus longchuanensis</i>	reported by Orlov et al., 2002b without vouchers
<i>Pseudophilautus parvulus</i>	Bain and Nguyen, 2004b; Grismer et al., 2007a; Inger et al., 1999; Orlov et al., 2002b; Stuart, 2005b; Stuart and Emmett, 2006; Li et al., 2009
<i>Rhacophorus annamensis</i>	Bourret, 1942; Bain et al., 2007b; Inger et al., 1999; Orlov et al., 2002b; Smith, 1924a; Stuart et al., 2006c; Ziegler et al., 2006b
<i>Rhacophorus calcaneus</i>	Bain et al., 2007b; Bourret, 1942; Inger et al., 1999; Smith, 1924a; Stuart, 2005b; referred specimen AMNH A-169328
<i>Rhacophorus chuyangsinensis</i>	Orlov et al., 2008a
<i>Rhacophorus dennysi</i>	Liu and Hu, 1961; Orlov et al., 2002b; Pope, 1931; Stuart, 2005b; Ziegler and Herrmann, 2000
<i>Rhacophorus dorsoviridis</i>	Bourret, 1942; Ohler et al., 2000; Orlov et al., 2001a
<i>Rhacophorus duboisi</i>	Ohler et al., 2000; Orlov et al., 2002b
<i>Rhacophorus dugritei</i>	Bain and Nguyen, 2004b; Ohler et al., 2000
<i>Rhacophorus exechopygus</i>	Bain et al., 2007b; Bain and Nguyen, 2002c; Hendrix et al., 2008; Inger et al., 1999
<i>Rhacophorus feae</i>	Bourret, 1942; Orlov et al., 2002b; Stuart, 2005b
<i>Rhacophorus hoanglienensis</i>	Bain and Nguyen, 2004b; Orlov et al., 2001a
<i>Rhacophorus cf. hungfuensis</i>	Orlov et al., 2001a
<i>Rhacophorus kio</i>	Bain et al., 2007b; Ho et al., 2005; Inger et al., 1999; Ohler and Delorme, 2006; Orlov et al., 2001a, Stuart, 2005b; Ziegler and Herrmann, 2000
<i>Rhacophorus marmoridorsum</i>	Orlov, 2008
<i>Rhacophorus maximus</i>	Nguyen et al., 2008a
<i>Rhacophorus orlovi</i>	Bain et al., 2007b; Stuart, 2005a,b; Ziegler et al., 2002a, 2004a; Ziegler and Koehler, 2001
<i>Rhacophorus rhodopus</i>	Bain et al., 2007b; Grismer et al., 2007a, 2008b; Inger et al., 1999; Nguyen et al., 2008b; Ohler and Delorme, 2006; Ohler et al., 2002; Stuart, 2005b; Stuart and Emmett, 2006; Ziegler et al., 2004a; Yu et al., 2007
<i>Rhacophorus spelaeus</i>	Orlov et al., 2009a
<i>Theلودerma asperum</i>	Bain and Nguyen, 2004b; Bourret, 1942; Leong and Lim, 2003; Ohler et al., 2002; Orlov et al., 2002b; Stuart, 2005b; Stuart et al., 2006c; Ziegler and Herrmann, 2000; Ziegler et al., 2004a; referred specimen AMNH A-168772, 168773
<i>Theلودerma bicolor</i>	Ohler et al., 2000

APPENDIX 2B  
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	References
<i>Theلودerma corticale</i>	Bourret, 1942; Inger et al., 1999; Orlov and Rybaltovskiy, 1999; Ziegler et al., 2006a
<i>Theلودerma gordonii</i>	Nguyen and Ho, 2002; Orlov et al., 2002b; Inger et al., 1999
<i>Theلودerma lateriticum</i>	Bain et al., 2009b
<i>Theلودerma rhododiscus</i>	Bain and Nguyen, 2004b; Yu et al., 2007a
<i>Theلودerma ryabovi</i>	Orlov et al., 2006a
<i>Theلودerma stellatum</i>	Inger et al., 1999; Nguyen and Nguyen, 2008; Orlov et al., 2002b; Stuart and Emmett, 2006; Stuart et al., 2006c; Tarkhnishvili, 1995; Wassersug et al., 1981
<b>SERPENTES</b>	
<b>Achrochordidae</b>	
<i>Acrochordus granulatus</i>	Bourret, 1934b, 1939b; Saint Girons, 1972a; Smith, 1943; Campden-Main, 1970c; Zhao and Adler, 1993
<i>Acrochordus javanicus</i>	Campden-Main, 1970c; Saint Girons, 1972a; Smith, 1943
<b>Colubridae</b>	
<i>Colubroelaps nguyenfansangi</i>	Orlov et al., 2009b
<b>Calamariinae</b>	
<i>Calamaria abramovi</i>	Orlov, 2009
<i>Calamaria buchi</i>	Inger and Marx, 1965; Orlov et al., 2003b
<i>Calamaria gialaiensis</i>	Ziegler et al., 2008b
<i>Calamaria lovii</i>	Darevsky and Orlov, 1992
<i>Calamaria pavementata</i>	Angel, 1929; Bourret, 1937b, 1939b,d; Darevsky, 1999; Deuve, 1970; Orlov et al., 2000; Saint Girons, 1972a; Smith, 1943; Teynie et al., 2004; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Calamaria septentrionalis</i>	Bain and Nguyen, 2004b; Bourret, 1936, 1939b; Orlov et al., 2000; Szyndlar and Nguyen, 1996; Ziegler and Herrmann, 2000; Zhou and Yu, 2002
<i>Calamaria sangi</i>	Nguyen et al., 2010g
<i>Calamaria thanhi</i>	Ziegler and Le, 2005; Ziegler et al., 2007a
<i>Calamaria yunnanensis</i>	Stuart and Heatwole, 2008
<b>Colubrinae</b>	
<i>Ahaetulla nasuta</i>	Campden-Main, 1970c; Grismer et al., 2007a; Henderson and Binder, 1980; Saint Girons, 1972b; Stuart, 1999; Szyndlar and Nguyen, 1996
<i>Ahaetulla prasina</i>	Bain and Nguyen, 2004b; Bourret, 1937b, 1939c; Campden-Main, 1970c; Daltry and Chheang, 2000; Darevsky, 1999; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a,b; Smith, 1920; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Boiga bourreti</i>	Tillack et al., 2004; Ziegler et al., 2006a
<i>Boiga cyanea</i>	Campden-Main, 1970c; Deuve, 1970; Greene, 1989; Grismer et al., 2008b; Saint Girons, 1972a,b; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993
<i>Boiga dendrophila</i>	Campden-Main, 1970c; Greene, 1989; Orlov et al., 2003b; Smith, 2005; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996
<i>Boiga drapiezii</i>	Chuaynkern and Makchai, 2006; Greene, 1989; Orlov et al., 2003b
<i>Boiga guangxiensis</i>	Orlov et al., 2003b; Zhou and Yu, 2002; Ziegler et al., 2006a; Ziegler et al., 2007a
<i>Boiga jaspidea</i>	Greene, 1989; Orlov et al., 2003b
<i>Boiga kraepelini</i>	Bourret, 1935, 1939c; Chu et al., 2005; Greene, 1989; Nguyen Doan and Nguyen, 2007a; Orlov et al., 2002b, 2003b; Ziegler, 2002
<i>Boiga multomaculata</i>	Angel, 1929; Bourret, 1937b, 1939b,d; Campden-Main, 1970c; Deuve, 1970; Farkas and Fritz, 1999c; Greene, 1989; Orlov et al., 2000; Saint Girons, 1972b; Stuart, 1999; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler and Herrmann, 2000

APPENDIX 2B  
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	References
<i>Boiga siamensis</i>	Daltry and Chheang, 2000; Grismer et al., 2008a; Orlov et al., 2002b, 2003b; Stuart, 1999; Stuart and Emmett, 2006; Pauwels et al (2005) report that <i>B. ocellatus</i> is a synonym of <i>B. siamensis</i>
<i>Chrysopelea ornata</i>	Campden-Main, 1970c; Daltry and Chheang, 2000; Darevesky, 1999; Deuve, 1970; Grismer et al., 2007a; Orlov et al., 2000; Saint Girons, 1972a,b; Smith, 1920, 1943; Stuart, 1999; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhao and Adler, 1993; Ziegler and Herrmann, 2000
<i>Coelognathus flavolineatus</i>	Orlov et al., 2003b; Grismer et al., 2008a; Szyndlar and Nguyen, 1996
<i>Coelognathus radiatus</i>	Bourret, 1934b, 1937b; Campden-Main, 1970c; Daltry and Chheang, 2000; Darevesky, 1999; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a; Stuart, 1999; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Cyclophiops major</i>	Bourret, 1937b, 1939c; Deuve, 1970; Orlov et al., 2000; Smith, 1930, 1943; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler et al., 2006b
<i>Cyclophiops multicinctus</i>	Angel, 1929; Bourret, 1937b, 1939b,d; Campden-Main, 1970c; Orlov et al., 2000; Parker, 1925; Smith, 1921a, 1943; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler, 2002
<i>Dendrelaphis cyanochloris</i>	Stuart, 1999; Teynie et al., 2004; Vogel and Rooijen, 2007
<i>Dendrelaphis ngansonensis</i>	Bain et al., 2007b; Bourret, 1937b; Deuve, 1970; Nicodemo and Bain, 2007; Orlov et al., 2000; Ziegler, 2002; Ziegler et al., 2004a; Ziegler and Vogel, 1999
<i>Dendrelaphis pictus</i>	Campden-Main, 1970c; Deuve, 1970; Parker, 1925; Saint Girons, 1972a,b; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Dendrelaphis subocularis</i>	Campden-Main, 1970c; Deuve, 1970; Grismer et al., 2007a; Smith, 1921a; Zhao and Adler, 1993
<i>Dinodon flavozonatum</i>	Orlov et al., 2000; Zhao and Adler, 1993; Zhou and Yu, 2002
<i>Dinodon meridionale</i>	Bourret, 1939c; Orlov and Ryabov, 2004
<i>Dinodon rufozonatum</i>	Deuve, 1970; Norval and Mao, 2004; Orlov et al., 2000; Orlov and Ryabov, 2004; Zhao and Adler, 1993; Ziegler et al., 2006, 2007a
<i>Dinodon rosozonatum</i>	Orlov and Ryabov, 2004
<i>Dinodon septentrionale</i>	Angel, 1929; Bourret, 1939c; Bain et al., 2007b; Orlov and Ryabov, 2004; Orlov et al., 2003b; Parker, 1925; Stuart et al., 2006c; Vassilyev, 2003
<i>Dryocalamus davisonii</i>	Campden-Main, 1970c; Deuve, 1970; Grismer et al., 2008a; Nguyen, 2007; Saint Girons, 1972a,b; Stuart, 1999; Stuart and Emmett, 2006; Ziegler and Herrmann, 2000, Ziegler et al., 2006b
<i>Elaphe bella</i>	Bourret, 1944 ; Deuve, 1970; Orlov et al., 2003b; Smith, 1943
<i>Elaphe carinata</i>	Bourret, 1939c; Orlov et al., 2003b; Smith, 1943
<i>Euprepiophis mandarinus</i>	Bain et al., 2007b; Bourret, 1939c; Smith, 1943; Orlov et al., 2000; Le and Ziegler, 2004; Zhao and Adler, 1993; Zhou and Yu, 2002
<i>Gonyosoma frenatum</i>	Bourret, 1939b; Orlov et al., 2003b; Smith, 1943; Zhou and Yu, 2002
<i>Gonyosoma prasinum</i>	Bourret, 1937b, 1939c; Orlov et al., 2003b; Parker, 1925; Smith, 1943; Stuart and Heatwole, 2008; Zhao and Adler, 1993; Ziegler et al., 2007a
<i>Gonyosoma oxycephalum</i>	Campden-Main, 1970c; Daltry and Emmett, 2000; Deuve, 1970; Saint Girons, 1972a; Smith, 1921a, 1943; Stuart, 1999; Stuart and Emmett, 2006; Ziegler and Herrmann, 2000
<i>Liopeltis frenata</i>	Angel, 1929; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2003b; Smith, 1940; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993; Ziegler et al., 2007a
<i>Liopeltis stoliczkae</i>	Stuart and Heatwole, 2008; Stuart et al., 2006c; L. cf. tricolor sensu Orlov et al. (2003b) included as this species in Indochina (B.L. Stuart, personal commun.)
<i>Lycodon capucinus</i>	Bourret, 1934a, 1939b; Campden-Main, 1970c; Darevesky, 1999; Saint Girons, 1972a,b; Smith, 1943
<i>Lycodon cardamomensis</i>	Daltry and Wüster, 2002; Pauwels et al., 2005

APPENDIX 2B  
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	References
<i>Lycodon fasciatus</i>	Deuve, 1970; Orlov et al., 2000; Smith, 1943; Zhou and Yu, 2002; Ziegler et al., 2004a, 2007a
<i>Lycodon futsingensis</i>	Vogel et al., 2009
<i>Lycodon laoensis</i>	Bain et al., 2007c; Campden-Main, 1970c; Deuve, 1970; Grismer et al., 2008a; Saint Girons, 1972a,b; Stuart, 1999; Zhao and Adler, 1993; Zhou and Yu, 2002
<i>Lycodon paucifasciatus</i>	Campden-Main, 1970c; Orlov et al., 2003b; Smith, 1943; Vogel et al., 2009
<i>Lycodon ruhstrati</i>	Bourret, 1939b,d; Orlov et al., 2000; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Vogel et al., 2009
<i>Lycodon subcinctus</i>	Bourret, 1937b; Deuve, 1970; Orlov et al., 2000; Smith, 1943; Zhao and Adler, 1993; Zhou and Yu, 2002
<i>Oreocryptophis porphyraceus</i>	Bourret, 1939c; Deuve, 1970; Stuart, 1999; Orlov et al., 2003b; Teynie et al., 2004; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler et al., 2004a
<i>Oligodon annamensis</i>	Campden-Main, 1970c; Leviton, 1953
<i>Oligodon barroni</i>	Bourret, 1939b; Campden-Main, 1970c; Daltry and Chheang, 2000; David et al., 2008c; Ho et al., 2005; Pauwels et al., 2002; Saint Girons, 1972a; Smith, 1943; Teynie et al., 2004
<i>Oligodon catenatus</i>	Bourret, 1937b, 1939c; Deuve, 1970; Pauwels et al., 2002; Smith, 1943; Zhou and Yu, 2002
<i>Oligodon chinensis</i>	Bourret, 1936, 1939b,d; Orlov et al., 2000; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Oligodon cinereus</i>	Bourret, 1939d; Campden-Main, 1970c; Deuve, 1970; Pauwels et al., 2002; Saint Girons, 1972a,b; Smith, 1943; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Stuart et al., 2006c; Teynie et al., 2004
<i>Oligodon deuvei</i>	David et al., 2008c
<i>Oligodon eberhardti</i>	Angel, 1929; Bourret, 1939b,d; Deuve, 1970; Orlov et al., 2000, 2003b; Zhao and Adler, 1993
<i>Oligodon fasciolatus</i>	Campden-Main, 1970c; Daltry and Chheang, 2000; Darevsky, 1999; Deuve, 1970; Grismer et al., 2008a; Orlov et al., 2000; Pauwels et al., 2002; Saint Girons, 1972a,b; Stuart, 1999; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhao and Adler, 1993
<i>Oligodon formosanus</i>	Orlov et al., 2000; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; David et al., 2008b
<i>Oligodon inornatus</i>	Daltry and Chheang, 2000; Saint Girons, 1972a; Stuart and Emmett, 2006; Teynie et al., 2004
<i>Oligodon joynsoni</i>	Cox et al. (1998) report this from Laos but without reference to vouchers; there is a Laos specimen in the MNHN (P. David, personal commun.), but the authors did not study it
<i>Oligodon lacroixi</i>	Bourret, 1939c; Pauwels et al., 2002; Smith, 1943
<i>Oligodon macrurus</i>	Angel, 1927; Campden-Main, 1970c; Smith, 1943
<i>Oligodon moricei</i>	David et al., 2008c
<i>Oligodon mouhoti</i>	Campden-Main, 1969, 1970c; David et al., 2008c; Saint Girons, 1972a; Szyndlar and Nguyen, 1996
<i>Oligodon ocellatus</i>	Campden-Main, 1970a; Saint Girons, 1972a; Stuart et al., 2006c; Teynie et al., 2004; may be present in uplands, but only confirmed in lowlands
<i>Oligodon saintgironsi</i>	David et al., 2008b
<i>Oligodon taeniatus</i>	Angel, 1920; Bain and Nguyen, 2004b; Bourret, 1939b; Campden-Main, 1969, 1970c; David et al., 2008c; Orlov et al., 2000; Pauwels et al., 2002; Saint Girons, 1972a,b; Teynie and David, 2007; Vassilyev, 2003
<i>Orthriophis moellendorffi</i>	Angel, 1929; Bourret, 1939c; Orlov et al., 2000; Zhou and Yu, 2002
<i>Orthriophis taeniurus</i>	Angel, 1929; Bourret, 1937b, 1944; Daltry and Chheang, 2000; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Ptyas carinata</i>	Campden-Main, 1970c; Smith, 1943; Stuart and Emmett, 2006; Stuart et al., 2006c; Zhao and Adler, 1993
<i>Ptyas dhumnades</i>	Orlov et al., 2000

APPENDIX 2B  
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	References
<i>Ptyas korros</i>	Bain and Nguyen, 2004b; Bourret, 1934b, 1939b, 1944; Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a,b; Schmidt, 1928; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Ptyas mucosa</i>	Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Orlov et al., 2000; Saint Girons, 1972a,b; Smith, 1943; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Ptyas nigromarginata</i>	Bourret, 1936; Smith, 1943
<i>Rhynchophis boulengeri</i>	Bourret, 1939b; Darevsky, 1999; Smith, 1935; Szyndlar and Nguyen, 1996
<i>Sibynophis chinensis</i>	Bain et al., 2007b; Bourret, 1939b,d; Campden-Main, 1970; Orlov et al., 2000; Smith, 1930; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Sibynophis collaris</i>	Angel, 1929; Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993
<i>Sibynophis melanocephalus</i>	Orlov et al., 2003b
<i>Sibynophis triangularis</i>	Stuart et al., 2006c
<i>Xenelaphis hexagonotus</i>	Campden-Main, 1970c; Smith, 1943
<b>Cylindrophiiidae</b>	
<i>Cylindrophis ruffus</i> Laurenti 1768	Bourret, 1936, 1939c; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Saint Girons, 1972a, Schmidt, 1928; Smith, 1921b, 1943; Stuart, 1999; Teynie et al., 2004; Zhao and Adler, 1993; Ziegler and Vo, 2005
<b>Elapidae</b>	
<i>Bungarus candidus</i>	Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Kuch and Zug, 2004; Saint Girons, 1972a; Slowinski, 1994; Stuart, 1999; Stuart et al., 2006c; Szyndlar and Nguyen, 1996
<i>Bungarus fasciatus</i>	Angel, 1929; Bourret, 1937b, 1939c; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a,b; Slowinski, 1994; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2007a
<i>Bungarus flaviceps</i>	Orlov et al., 2003b; Slowinski, 1994
<i>Bungarus multicinctus</i>	Bourret, 1939b; Deuve, 1970; Orlov et al., 2000; Slowinski, 1994; Stuart, 1999; Zhou and Yu, 2002
<i>Bungarus slowinskii</i>	Kizirian et al. 2002; Kuch et al., 2005; Orlov et al., 2003b; referred specimen IEBR 2978
<i>Calliophis bivirgatus</i>	Bourret, 1936; Slowinski et al., 2001
<i>Calliophis intestinalis</i>	Orlov et al., 2003b
<i>Calliophis maculiceps</i>	Campden-Main, 1970c; Deuve, 1970; Saint Girons, 1972a,b; Slowinski et al., 2001; Szyndlar and Nguyen, 1996
<i>Naja atra</i>	Darevsky, 1999; Deuve, 1970; Orlov et al., 2000; Slowinski and Wüster, 2000; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Naja kaouthia</i>	Chan-ard et al., 2001; Daltry and Chheang, 2000; Kyi and Zug, 2003; Saint Girons, 1972a; Slowinski and Wüster, 2000; Stuart, 1999; Szyndlar and Nguyen, 1996; Wüster and Thorpe, 1992, Wüster et al., 1995; Ziegler and Herrmann, 2000
<i>Naja siamensis</i>	Chan-ard, et al., 2001; Grismer et al., 2008a; Slowinski and Wüster, 2000; Stuart, 1999; Teynie and David, 2007; Wüster and Thorpe, 1992, Wüster et al., 1995, 1997
<i>Ophiophagus hamah</i>	Bourret, 1939c; Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Orlov et al., 2000; Saint Girons, 1972a; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Sinomicrurus kelloggi</i>	Bourret, 1939c; Orlov et al., 2003b; Slowinski et al., 2001
<i>Sinomicrurus maccllellandi</i>	Angel, 1929; Bourret, 1937b, 1939b, 1944; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Slowinski et al., 2001; Szyndlar and Nguyen, 1996; Vassilyev, 2003; Zhou and Yu, 2002



APPENDIX 2B  
(Continued)

References	
<b>Homalopsidae</b>	
<i>Cerberus rynchops</i>	Campden-Main, 1970c; Saint Girons, 1972a,b; Szyndlar and Nguyen, 1996; Voris and Murphy, 2002
<i>Enhydris bennetti</i>	Smith, 1943; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Enhydris bocourti</i>	Deuve, 1970; Campden-Main, 1970c; Saint Girons, 1972a,b; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Voris and Murphy, 2002
<i>Enhydris chinensis</i>	Orlov et al., 2000; Szyndlar and Nguyen, 1996; Voris and Murphy, 2002; Zhou and Yu, 2002
<i>Enhydris enhydris</i>	Angel, 1927; Bourret, 1939b; Campden-Main, 1970c; Deuve, 1970; Karns et al., 2000; Saint Girons, 1972a,b; Szyndlar and Nguyen, 1996; Voris and Murphy, 2002
<i>Enhydris innominata</i>	Campden-Main, 1970c; Saint Girons, 1972b; Voris and Murphy, 2002
<i>Enhydris jagorii</i>	Campden-Main, 1970c; Saint Girons, 1972a,b; Stuart, 1999; Teynie et al., 2004
<i>Enhydris longicauda</i>	Saint Girons, 1972a; Smith, 1943; Stuart et al., 2000b; Voris and Murphy, 2002
<i>Enhydris plumbea</i>	Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Farkas and Fritz, 1999b; Grismer et al., 2008b; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a,b; Smith, 1943; Stuart, 1999; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Voris and Murphy, 2002; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999b
<i>Erpeton tentaculatum</i>	Campden-Main, 1970c; Saint Girons, 1972a,b; Voris and Murphy, 2002
<i>Fordonia leucobalia</i>	Campden-Main, 1970c; Smith, 1943; Szyndlar and Nguyen, 1996; Voris and Murphy, 2002
<i>Homalopsis buccata</i>	Bourret, 1934b; Campden-Main, 1970c; Deuve, 1970; Szyndlar and Nguyen, 1996; Stuart, 1999; Saint Girons, 1972a,b; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Voris and Murphy, 2002
<i>Homalopsis nigroventralis</i>	Deuve, 1970; Stuart et al., 2006c
<b>Lamprophiidae</b>	
<i>Psammophis indochinensis</i>	Campden-Main, 1970c; Stuart and Heatwole, 2008
<b>Natricidae</b>	
<i>Amphiesma andreae</i>	Ziegler and Le, 2006
<i>Amphiesma atemporale</i>	Bourret, 1936; Orlov et al., 2000
<i>Amphiesma bitaeniatum</i>	David et al., 2005; Orlov et al., 2000; Smith, 1943
<i>Amphiesma boulengeri</i>	David et al., 2007; Orlov et al., 2000; Zhou and Yu, 2002
<i>Amphiesma craspedogaster</i>	Orlov et al., 2000
<i>Amphiesma deschauenseei</i>	David et al., 2007
<i>Amphiesma khasiense</i>	Bourret, 1939b,d, 1944; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993
<i>Amphiesma leucomystax</i>	David et al., 2007; Stuart and Heatwole, 2008; Stuart et al., 2010b
<i>Amphiesma modestum</i>	Angel, 1929; Bain and Nguyen, 2004b; Bourret, 1937b; Deuve, 1970; Orlov et al., 2000; Smith, 1921a, 1943; Saint Girons, 1972a
<i>Amphiesma optatum</i>	David et al., 1998; Orlov et al., 2000
<i>Amphiesma popei</i>	David et al., 2007
<i>Amphiesma sauteri</i>	Bourret, 1936, 1939c; Orlov et al., 2000; Zhou and Yu, 2002
<i>Amphiesma stolatum</i>	Bourret, 1936, 1939b,d; Campden-Main, 1970c; Deuve, 1970; Norval et al., 2005; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a,b; Smith, 1943; Stuart, 1999; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler et al., 2004a
<i>Amphiesmoides ornaticeps</i>	Nguyen et al., 2010c
<i>Opisthotropis andersonii</i>	Darevsky, 1999
<i>Opisthotropis annamensis</i>	Campden-Main, 1970c; Stuart, 2006; Stuart and Chuaynkern, 2007
<i>Opisthotropis balteatus</i>	Smith, 1943; recorded from "Cambodia" and "Tonking" (= northern Vietnam) but without being more specific
<i>Opisthotropis daovantieni</i>	Orlov et al., 1998

APPENDIX 2B  
(Continued)

	References
<i>Opisthotropis jacobii</i>	Bourret, 1936, 1939c; Orlov et al., 2000
<i>Opisthotropis lateralis</i>	Bourret, 1936; Szyndlar and Nguyen, 1996; Orlov et al., 2000; Ziegler et al., 2008e
<i>Opisthotropis tamdaoensis</i>	Ziegler et al., 2008e
<i>Pararhabdophis chapaensis</i>	Bourret, 1936
<i>Paratapinophis praemaxillaris</i>	Angel, 1929; Deuve, 1970; Smith, 1943
<i>Psammodynastes pulverulentus</i>	Angel, 1929; Bourret, 1937b; Campden-Main, 1970c; Deuve, 1970; Grismer et al., 2007a, 2008a; Orlov et al., 2000; Saint Girons, 1972a; Stuart, 1999; Stuart and Emmett, 2006; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Ziegler et al., 2004a
<i>Rhabdophis angelii</i>	Bourret, 1936; Orlov et al., 2000
<i>Rhabdophis callichroma</i>	Bourret, 1936; Orlov et al., 2000
<i>Rhabdophis chrysargos</i>	Angel, 1929; Bourret, 1936; Campden-Main, 1970c; Daltry and Chheang, 2000; Deuve, 1970; Grismer et al., 2007a; Saint Girons, 1972a; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Szyndlar and Nguyen, 1996; Ziegler, 2002; Ziegler et al., 2004a
<i>Rhabdophis nigrocinctus</i>	Bourret, 1936; Daltry and Chheang, 2000; Stuart and Heatwole, 2008; Stuart and Emmett, 2006
<i>Rhabdophis nuchalis</i>	Orlov et al., 2000; Parker, 1925; Smith, 1930
<i>Rhabdophis subminiatus</i>	Angel, 1929; Campden-Main, 1970c; Deuve, 1970; Bourret, 1944; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a,b; Schmidt, 1928; Smith, 1930; Stuart, 1999; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Rhabdophis tigrinus</i>	Bourret, 1936
<i>Sinonatrix aequifasciata</i>	Bain and Nguyen, 2004b; Bain et al., 2007b; Nguyen et al., 2007b; Orlov et al., 2000; Stuart and Heatwole, 2008; Vogel et al., 2004b; Zhou and Yu, 2002; Ziegler and Hoang, 2005
<i>Sinonatrix percarinata</i>	Bain and Nguyen, 2004b; Bain et al., 2007b; Bourret, 1936, 1937b, 1944; Campden-Main, 1970c; Orlov et al., 2000; Parker, 1925; Stuart and Heatwole, 2008; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler et al., 2004a
<i>Xenochrophis piscator</i>	Bourret, 1934b,c; Vogel and David, 2006
<i>Xenochrophis flavipunctatus</i>	Angel, 1927; Bourret, 1939b,d; Campden-Main, 1970c; Darevsky, 1999; Deuve, 1970; Orlov et al., 2000; Saint Girons, 1972b; Schmidt, 1928; Smith, 1920, 1921b, 1943; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Weitkus, 1999b
<i>Xenochrophis trianguligerus</i>	Bourret, 1936, 1939c; Orlov et al., 2000; Stuart and Emmett, 2006
<b>Pareatidae</b>	
<i>Asthenodipsas laevis</i>	Deuve, 1970
<i>Pareas carinatus</i>	Bain et al., 2007b; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Smith, 1943; Saint Girons, 1972a,b; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhao and Adler, 1993; Ziegler et al., 2006b
<i>Pareas hamptoni</i>	Angel, 1929; Bain and Nguyen, 2004b; Bourret, 1937b, 1939b; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Smith, 1930, 1943; Stuart, 1999; Teynie et al., 2004; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler, 2002; Ziegler et al., 2007a
<i>Pareas macularius</i>	Bourret, 1937b; Deuve, 1970; Orlov et al., 2000; Smith, 1943; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler et al., 2007a
<i>Pareas margaritophorus</i>	Bourret, 1936; Campden-Main, 1970c; Deuve, 1970; Grismer et al., 2007a, 2008b; Orlov et al., 2000; Smith, 1943; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhao and Adler, 1993; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000
<i>Pareas monticola</i>	Bourret, 1939c; Orlov et al., 2003b; Wogan et al., 2008

APPENDIX 2B  
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**Pseudoxenodontidae**

- Plagiopholis delacouri* Angel, 1929 ; Bourret, 1936; Orlov et al., 2000  
*Plagiopholis nuchalis* Orlov et al., 2003b; Szyndlar and Nguyen, 1996  
*Plagiopholis styani* Bourret, 1939b; Orlov et al., 2003b  
*Pseudoxenodon bambusicola* Bourret, 1937b; Orlov et al., 2000; Stuart and Heatwole, 2008; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler et al., 2006a  
*Pseudoxenodon karlschmidtii* Bain and Nguyen, 2004b; Bourret, 1939b, d; Orlov et al., 2000  
*Pseudoxenodon macrops* Bain et al., 2007b; Campden-Main, 1970c; Farkas and Fritz, 1999a; Orlov et al., 2000; Parker, 1925; Stuart and Heatwole, 2008; Zhou and Yu, 2002; Ziegler et al., 2007a

**Pythonidae**

- Python brogersmai* Bourret, 1936; Campden-Main, 1970c; Keogh et al., 2001; Orlov et al., 2003b  
*Python molurus* Bourret, 1936; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2000; Parker, 1925; Saint Girons, 1972a; Stuart, 1999; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002  
*Python reticulatus* Campden-Main, 1970c; Darevsky, 1999; Deuve, 1970; Saint Girons, 1972a, b; Smith, 1943; Stuart, 1999; Szyndlar and Nguyen, 1996; Ziegler and Herrmann, 2000

**Typhlopidae**

- Ramphotylops braminus* Angel, 1929; Bourret, 1939c, 1944; Daltry and Chheang, 2000; Darevsky, 1999; Deuve, 1970; Saint Girons, 1972a, b; Schmidt, 1928; Smith, 1943; Stuart, 1999; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhou and Yu, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2006b; Zhou and Yu, 2002  
*Typhlops diardii* Bourret, 1936, 1937; Darevsky, 1999; Deuve, 1970; Grismer et al., 2008b; Smith, 1923, 1943; Szyndlar and Nguyen, 1996; Ziegler and Herrmann, 2000; data includes that of *T. giadhensis*, a junior synonym (P. David, personal commun.)  
*Typhlops giadhensis* Bourret, 1937; Smith, 1943  
*Typhlops muelleri* Daltry and Chheang, 2000; Stuart and Emmett, 2006  
*Typhlops siamensis* Saint Girons, 1972a

**Viperidae**

- Azemiops feae* Bourret, 1936; Orlov et al., 2002a; Orlov et al., 2003b; Smith, 1943; Zhou and Yu, 2002  
*Calloselasma rhodostoma* Bain et al., 2007a; Campden-Main, 1970c; Deuve, 1970; Orlov et al., 2002a,c; Saint Girons, 1972a; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c  
*Cryptelytrops albolabris* Bourret, 1939b; Campden-Main, 1970c; Darevsky, 1999; Deuve, 1970; Grismer et al., 2007a; Malhotra and Thorpe, 2004b; Orlov et al., 2002a,c; Orlov et al., 2000; Saint Girons, 1972a,b; Stuart, 1999; Stuart et al., 2006c; Szyndlar and Nguyen, 1996; Wogan et al., 2005; Zhou and Yu, 2002; Ziegler, 2002; Ziegler and Herrmann, 2000  
*Cryptelytrops honsonensis* Grismer et al., 2008c  
*Cryptelytrops macrops* Orlov et al., 2003b; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004  
*Daboia siamensis* Saint Girons, 1972a; Thorpe et al., 2007; Wüster et al., 1992  
*Deinagkistrodon acutus* Bourret, 1936; Deuve, 1970; Orlov et al., 2002a, 2003b  
*Ovophis monticola* Bourret, 1939b,d, 1944; Campden-Main, 1970c; Orlov et al., 2002a; 2004b; Saint Girons, 1972a; Smith, 1921a, 1930; Stuart and Heatwole, 2008  
*Ovophis tonkinensis* Bourret, 1937b; Orlov et al., 2002a  
*Popeia popeiorum* Vogel et al., 2004a  
*Protobothrops cornutus* Bourret, 1939c; Campden-Main, 1970c; David et al., 2008a; Herrmann et al., 2004; Orlov et al., 2002c, 2003b; Smith, 1930; Ziegler et al., 2004a, 2007a  
*Protobothrops jerdonii* Burger, 2005; Orlov et al., 2002a, 2001b, 2003b

APPENDIX 2B  
(Continued)

	References
<i>Protobothrops mucrosquamatus</i>	Bain et al., 2007b; Bourret, 1944; Darevsky, 1999; Malhotra and Thorpe, 2004b; Nguyen et al., 2007c; Orlov et al., 2002a; Orlov et al., 2000; Orlov et al., 2001b; Smith, 1943; Stuart and Heatwole, 2008; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002; Ziegler, 2002; Ziegler et al., 2006a, 2008a; referred specimen AMNH R-154631
<i>Protobothrops sieversorum</i>	Herrmann et al., 2002; Orlov et al., 2002b, 2003b, 2004; Ziegler et al., 2000, 2007a, 2004a
<i>Protobothrops trungkhanhensis</i>	Orlov et al., 2009c
<i>Tropidolaemus wagleri</i>	Orlov et al., 2002a; and Orlov et al., 2003b report this with reference to market-purchased vouchers
<i>Viridovipera gumprechtii</i>	Bourret, 1939c; David et al., 2002; Malhotra and Thorpe, 2004a
<i>Viridovipera stejnegeri</i>	Bain and Nguyen, 2004b; Campden-Main, 1970c; Orlov et al., 2002a, 2000; Szyndlar and Nguyen, 1996; Zhou and Yu, 2002
<i>Viridovipera truongsongensis</i>	Orlov et al., 2004b; Ziegler et al., 2007a; Dawson et al., 2008
<i>Viridovipera vogeli</i>	Bain et al., 2007b; Campden-Main, 1970c; Grismer et al., 2007a; Malhotra and Thorpe, 2004a,b; Orlov et al., 2003b; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Vogel et al., 2004a
<b>Xenodermatidae</b>	
<i>Achalinus ater</i>	Bourret, 1936
<i>Achalinus rufescens</i>	Bourret, 1936; Orlov et al., 2003b; Smith, 1935; Zhou and Yu, 2002; Ziegler, 2002
<i>Achalinus spinalis</i>	Bourret, 1936, 1939c; Orlov et al., 2000
<i>Fimbrios klossi</i>	Campden-Main, 1970c; Smith, 1921a, 1943; Stuart and Heatwole, 2008
<i>Fimbrios smithi</i>	Ziegler et al., 2008a
<b>Xenopeltidae</b>	
<i>Xenopeltis hainanensis</i>	Kizirian et al., 2003; ; Orlov, 2000; Orlov et al., 2000, 2003b; Ziegler et al., 2007a
<i>Xenopeltis unicolor</i>	Bourret, 1939b, 1944; Campden-Main, 1970c; Deuve, 1970; Orlov, 2000; Orlov et al., 2000; Saint Girons, 1972a,b; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Szyndlar and Nguyen, 1996; Teynie et al., 2004; Zhao and Adler, 1993; Ziegler and Herrmann, 2000; Ziegler and Weikus, 1999b
<b>SAURIA</b>	
<b>Agamidae</b>	
<i>Acanthosaura capra</i>	Bobrov, 1993a; Bourret, 1937a; Orlov et al., 2006b; Smith, 1935; Stuart et al., 2006c; Ananjeva et al., 2008
<i>Acanthosaura cardamomensis</i>	Wood et al., 2010
<i>Acanthosaura coronata</i>	Stuart et al., 2006c; Stuart et al., 2010b; Ananjeva et al., 2008
<i>Acanthosaura crucigera</i>	Bobrov, 1992a; Grismer et al., 2007a; Smith, 1935; Stuart, 1999; Stuart and Emmett, 2006
<i>Acanthosaura lepidogaster</i>	Bain and Nguyen, 2004b; Bobrov, 1993b; Bourret, 1937a; Darevsky, 1999; Parker, 1925; Semenov, 2001; Smith, 1935; Teynie et al., 2004; Vassilyev, 2003; Ziegler and Herrmann, 2000; Ziegler et al., 2004a; referred specimen AMNH R-154612
<i>Acanthosaura nataliae</i>	Orlov et al., 2006b; Stuart et al., 2010b
<i>Bronchocela orlovi</i>	Hallermann, 2004
<i>Bronchocela smaragdina</i>	Bobrov, 1992a; Bourret, 1939b; Hallermann, 2004; Smith, 1935; Stuart et al., 2006c
<i>Bronchocela vietnamensis</i>	Hallermann, 2005; Nguyen and Böhme, 2008
<i>Calotes emma</i>	Bain et al., 2007b; Bobrov, 1993a, 2003a; Bourret, 1937a; Darevsky, 1999; Parker, 1925; Smith, 1921a, 1935; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Calotes mystaceus</i>	Bobrov, 1992a, 1993a; Bourret, 1944; Daltry and Chheang, 2000; Hallermann and Böhme, 2000; Ngo and Ziegler, 2009; Smith, 1921a, 1935; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c

APPENDIX 2B  
(Continued)

	References
<i>Calotes versicolor</i>	Angel, 1927, 1929; Bobrov, 1992a, 1993a,b, 2003a,b; Bourret, 1937a, 1939d, 1944; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a, 2008c; Hallermann and Böhme, 2000; Schmidt, 1928; Smith, 1920, 1935; Stuart, 1999; Teynie et al., 2004; Vassilyev, 2003; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Draco indochinensis</i>	Bobrov, 1992a, 1993a; Musters, 1983; Smith, 1928; Grismer et al., 2008a; Stuart and Emmett, 2006; Stuart et al., 2006c
<i>Draco maculatus</i>	Angel, 1929; Bobrov, 1993a,b, 2003a,b; Bourret, 1939d, 1944; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a; Musters, 1983; Ngo et al., 2010; Smith, 1935; Stuart, 1999; Stuart and Emmett, 2006; Teynie et al., 2004; Ziegler, 2002
<i>Draco sumatranus</i>	Grismer et al., 2008c
<i>Draco taeniopterus</i>	Daltry and Chheang, 2000; Grismer et al., 2007a; Smith, 1935; Stuart and Emmett, 2006
<i>Gonocephalus grandis</i>	Teynie et al., 2004; reported from Vietnam (Ananjeva et al., 2007a) but without voucher specimens
<i>Japalura chapaensis</i>	Bourret, 1939c; Ota, 1989
<i>Japalura fasciata</i>	Ota, 2000
<i>Leiolepis belliana</i>	Ananjeva et al., 2007a; Angel, 1920; Bobrov, 1993a; Bourret, 1937a, 1944; Grismer et al., 2008b; Schmidt, 1928; Smith, 1921a
<i>Leiolepis guentherpetersi</i>	Bobrov, 1993a; Darevsky, 1999; Darevsky and Kupriyanova, 1993
<i>Leiolepis guttata</i>	Bobrov, 1993a; Bourret, 1937a; Ngo and Ziegler, 2009; Schmitz et al., 2001; Smith, 1935
<i>Leiolepis ngovantri</i>	Grismer and Grismer, 2010
<i>Leiolepis reevesii</i>	Darevsky and Nguyen, 2004; Ziegler and Weitkus, 1999b
<i>Mantheyus phuvuanensis</i>	Ananjeva and Stuart, 2001
<i>Physignathus cocincinus</i>	Angel, 1920; Bain and Nguyen, 2004b; Bobrov, 1993a, 2003b; Bourret, 1944; Daltry and Chheang, 2000; Grismer et al., 2007a; Ngo and Ziegler, 2009; Schmidt, 1928; Smith, 1923; Stuart, 1999; Ngo et al., 2010; Stuart and Emmett, 2006; Stuart et al., 2006c; Parker, 1925; Vassilyev, 2003; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Pseudocalotes brevipes</i>	Hallermann, 2000; Hallermann and Böhme, 2000; Hallermann and McGuire, 2001; Smith, 1935
<i>Pseudocalotes floweri</i>	Bain et al., 2007b; Hallermann and Böhme, 2000; Hallermann and McGuire, 2001; Hallermann et al., 2010
<i>Pseudocalotes microlepis</i>	Bain et al., 2007b; Bobrov, 1993a; Hallermann and McGuire, 2001; Smith, 1921a, 1935; Stuart, 1999; Ziegler et al., 2006a
<i>Pseudocalotes poilani</i>	Bourret, 1939d; Hallermann and Böhme, 2000; Hallermann and McGuire, 2001; Teynie et al., 2004
<i>Pseudocophotis kontumensis</i>	Ananjeva et al., 2007b
<i>Pseudocophotis ziegleri</i>	Hallerman et al., 2010
<b>Anguidae</b>	
<i>Ophisaurus gracilis</i>	Angel, 1929; Bobrov, 1993a; Campden-Main, 1970b; Darevsky and Nguyen, 1983
<i>Ophisaurus harti</i>	Bain and Nguyen, 2004b; Bobrov, 1998; Bobrov and Ho, 1993; Bourret, 1937a; Smith, 1930
<i>Ophisaurus sokolovi</i>	Bain and Nguyen, 2002b; Bobrov, 1993a; Darevsky, 1992; Darevsky and Nguyen, 1983
<b>Dibamidae</b>	
<i>Dibamus bourreti</i>	Bobrov, 1993a; Bourret, 1939c; Darevsky, 1992, 1999; Greer, 1985
<i>Dibamus deharvengi</i>	Ineich, 1999
<i>Dibamus greeri</i>	Bain et al., 2007b; Darevsky, 1992
<i>Dibamus kondaoensis</i>	Darevsky, 1999

APPENDIX 2B  
(Continued)

	References
<i>Dibamus montanus</i>	Bobrov, 1993a; Darevsky, 1992, 1999; Ineich, 1999; Smith, 1921a
<i>Dibamus smithi</i>	Darevsky, 1992; Greer, 1985
<b>Gekkonidae</b>	
<i>Cnemaspis auranticopes</i>	Grismer and Ngo, 2007
<i>Cnemaspis boulengerii</i>	Bobrov, 1993a; Darevsky, 1999; Dring, 1979; Grismer and Ngo, 2007; Smith, 1920
<i>Cnemaspis caudanivea</i>	Grismer and Ngo, 2007
<i>Cnemaspis chanthaburiensis</i>	Grismer et al., 2008b
<i>Cnemaspis laoensis</i>	Grismer, 2010
<i>Cnemaspis neangthyi</i>	Grismer et al., 2010a
<i>Cnemaspis nuicamensis</i>	Grismer and Ngo, 2007
<i>Cnemaspis psychedalia</i>	Grismer et al., 2010
<i>Cnemaspis tucludupensis</i>	Grismer and Ngo, 2007
<i>Cyrtodactylus badenensis</i>	Nguyen et al., 2006
<i>Cyrtodactylus buchari</i>	David et al., 2004
<i>Cyrtodactylus caovansungi</i>	Orlov et al., 2007; Ngo and Ziegler, 2009
<i>Cyrtodactylus cattienensis</i>	Geissler et al., 2009
<i>Cyrtodactylus chauquangensis</i>	Hoang et al., 2007
<i>Cyrtodactylus condorensis</i>	Bobrov, 1993a; Darevsky, 1999; Smith, 1920
<i>Cyrtodactylus cryptus</i>	Heidrich et al., 2007
<i>Cyrtodactylus eisenmani</i>	Ngo, 2008
<i>Cyrtodactylus grismeri</i>	Ngo, 2008
<i>Cyrtodactylus hontreensis</i>	Ngo et al., 2008
<i>Cyrtodactylus huynhi</i>	Ngo and Bauer, 2008
<i>Cyrtodactylus interdigitalis</i>	Stuart, 1999
<i>Cyrtodactylus intermedius</i>	Daltry and Cheang, 2000; Grismer et al., 2007a; Ngo and Grismer, 2006; Stuart and Emmett, 2006
<i>Cyrtodactylus irregularis</i>	Bobrov, 2003b; Smith, 1921a, 1935; Ziegler et al., 2004b
<i>Cyrtodactylus jarunjini</i>	Stuart, 1999
<i>Cyrtodactylus nigriocularis</i>	Nguyen et al., 2006b
<i>Cyrtodactylus paradoxus</i>	Darevsky, 1999; Darevsky and Szczerbak, 1997; Orlov et al., 2007
<i>Cyrtodactylus phonghakebangensis</i>	Ziegler et al., 2004a, 2002b
<i>Cyrtodactylus phuquocensis</i>	Ngo et al., 2010
<i>Cyrtodactylus pseudoquadrivirgatus</i>	Rösler et al., 2008; Stuart et al., 2010b
<i>Cyrtodactylus roesleri</i>	Ziegler et al., 2010
<i>Cyrtodactylus takouensis</i>	Ngo and Bauer, 2008
<i>Cyrtodactylus yangbayensis</i>	Ngo and Onn, 2010
<i>Cyrtodactylus zieglerei</i>	Nazarov et al., 2008
<i>Dixonius aaronbaueri</i>	Ngo and Ziegler, 2009
<i>Dixonius melanostictus</i>	Bobrov, 1992a
<i>Dixonius siamensis</i>	Daltry and Chheang, 2000; Grismer et al., 2007a; Parker, 1925; Smith, 1935; Stuart, 1999; Teynie et al., 2004; Szczerbak and Nekrasova, 1994; Bezuijen et al., 2009
<i>Dixonius vietnamensis</i>	Das, 2004; Nguyen et al., 2006a; Stuart et al., 2006c
<i>Gehyra fehlmanni</i>	Szczerbak and Nekrasova, 1994
<i>Gehyra lacerata</i>	Szczerbak and Nekrasova, 1994
<i>Gehyra mutilata</i>	Bobrov, 1993a, 2003b; Bourret, 1937a, 1944; Darevsky, 1999; Schmidt, 1928; Semenov, 2001; Stuart, 1999; Szczerbak and Nekrasova, 1994; Ziegler et al., 2004a
<i>Gekko badenii</i>	Szczerbak and Nekrasova, 1994; Darevsky and Orlov, 1994b; Nguyen et al., 2010f
<i>Gekko canhi</i>	Rösler et al., 2010
<i>Gekko gekko</i>	Angel, 1927; Bobrov, 1992a, 1993b, 2003b; Bourret, 1939b; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a, 2008c; Ineich, 1999; Smith, 1920; Stuart, 1999; Teynie et al., 2004; Vassilyev, 2003; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2004a
<i>Gekko grossmanni</i>	Ngo and Ziegler, 2009; Gunther, 1994 does not give a precise locality data

APPENDIX 2B  
(Continued)

	References
<i>Gekko palmatus</i>	Bobrov, 1993a,b; Bourret, 1937a; Darevsky, 1999; Ota et al., 1995; Ziegler et al., 2006b
<i>Gekko petricolus</i>	Stuart, 1999
<i>Gekko scientiadventura</i>	Rösler et al., 2005
<i>Gekko russelltrainsi</i>	Ngo et al., 2009
<i>Gekko takouensis</i>	Ngo and Gamble, 2010
<i>Gekko vietnamensis</i>	Nguyen, 2010
<i>Goniurosaurus araneus</i>	Grismer et al., 1999
<i>Goniurosaurus catbaensis</i>	Ziegler et al., 2008d
<i>Goniurosaurus huilienensis</i>	Orlov et al., 2008b
<i>Goniurosaurus lichtenfelderi</i>	Bobrov, 1993a; Darevsky, 1999; Grismer, 2000; Orlov and Darevsky 1999; Orlov et al., 2008b
<i>Goniurosaurus luii</i>	Grismer et al., 1999; Vu et al., 2006
<i>Hemidactylus bowringii</i>	Bobrov, 1992a, 1993a; Bourret, 1939b; Darevsky, 1999; Parker, 1925; Ziegler and Weitkus, 1999b
<i>Hemidactylus frenatus</i>	Bobrov, 1992a, 1993a,b, 2003b; Bobrov and Ho, 1993; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a, 2008c; Schmidt, 1928; Semenov, 2001; Smith, 1935; Stuart, 1999; Szczerbak and Nekrasova, 1994; Teynie et al., 2004; Vassilyev, 2003; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler et al., 2004a; Ziegler and Weitkus, 1999b
<i>Hemidactylus garnottii</i>	Smith, 1935; Stuart, 1999; Ziegler and Herrmann, 2000
<i>Hemidactylus karenorum</i>	Ziegler and Herrmann, 2000; Ziegler et al., 2006b, indicate that the record from Vietnam is questionable
<i>Hemidactylus platyurus</i>	Bobrov, 1992a, 1993a, 2003b; Bourret, 1944; Darevsky, 1999; Grismer et al., 2007a, 2008b, c; Stuart, 1999; Szczerbak and Nekrasova, 1994; Teynie et al., 2004; Bezuijen et al., 2009
<i>Hemidactylus stejnegeri</i>	Darevsky, 1999; Bobrov, 1993a
<i>Hemidactylus vietnamensis</i>	Bobrov, 1993a; Darevsky et al., 1984
<i>Hemiphyllodactylus typus</i>	Bobrov, 1993a, 1998; Bobrov and Ho, 1993; Bourret, 1944; Vassilyev, 2003
<i>Hemiphyllodactylus yunnanensis</i>	Smith, 1935; Bezuijen et al., 2009
<i>Lepidodactylus lugubris</i>	Darevsky, 1999
<i>Ptychozoon lionotum</i>	Bobrov, 1993a, 2003b; Stuart and Emmett, 2006
<i>Ptychozoon trinitoterra</i>	Brown, 1999
<b>Lacertidae</b>	
<i>Takydromus hani</i>	Chou et al., 2001; Kizirian, 2004; Ziegler et al., 2006b
<i>Takydromus kuehnei</i>	Bobrov, 1993a, 2003a; Ziegler, 2002; Ziegler and Bischoff, 1999; Ziegler et al., 1999; Ziegler and Herrmann, 2000
<i>Takydromus sexlineatus</i>	Angel, 1929; Bobrov, 1992a, 1993a,b, 2003a; Bourret, 1937a, 1939c; Darevsky, 1999; Grismer et al., 2008b; Smith, 1935; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Ziegler, 2002; Ziegler et al., 1999; Ziegler and Herrmann, 2000
<b>Scincidae</b>	
<i>Ateuchosaurus chinensis</i>	Smith, 1935
<i>Dasia olivacea</i>	Bobrov, 1993a; Darevsky, 1999; Smith, 1920, 1935; Stuart and Emmett, 2006
<i>Emoia atrocostata</i>	Bobrov, 1993a; Bourret, 1937a; Brown, 1991
<i>Emoia laobaensis</i>	Bourret, 1937a; Brown, 1991
<i>Eutropis chapaense</i>	Bourret, 1937a; Bobrov, 1993a, 1998
<i>Eutropis darevskii</i>	Bobrov, 1992b

APPENDIX 2B  
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	References
<i>Eutropis longicaudata</i>	Bobrov, 1993a, 2003a,b; Bourret, 1937a; Darevsky, 1999; Darevsky and Orlov, 2005; Norval et al., 2004; Gonzalez and Vindum, 2005; Grismer et al., 2008a; Schmidt, 1928; Bezuijen et al., 2009 Smith, 1935; Stuart, 1999; Teynie et al., 2004; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999
<i>Eutropis macularia</i>	Bobrov, 1992a, 2003b, 2003a; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a; Ngo and Ziegler, 2009; Schmidt, 1928; Smith, 1935; Stuart, 1999; Teynie et al., 2004; Vassilyev, 2003; Ziegler and Herrmann, 2000
<i>Eutropis multifasciata</i>	Bobrov, 1992a, 1993a, 2003a,b; Bourret, 1937a, 1939b, 1944; Daltry and Chheang, 2000; Darevsky, 1999; Darevsky and Orlov, 2005; Grismer et al., 2007a, 2008b; Ngo and Ziegler, 2009; Semenov, 2001; Parker, 1925; Schmidt, 1928; Smith, 1935; Stuart, 1999; Teynie et al., 2004; Vassilyev, 2003; Ziegler, 2002; Ziegler and Herrmann, 2000; Ziegler and Weitkus, 1999b
<i>Leptoseps poilani</i>	Bourret, 1941b
<i>Leptoseps tetradactylus</i>	Darevsky and Orlov, 2005
<i>Lipinia vittigera</i>	Bobrov, 1992a, 2003b; Daltry and Chheang, 2000; Grismer et al., 2007a; Mahony, 2008; Ngo and Ziegler, 2009; Schmidt, 1928; Semenov, 2001; Smith, 1922a, 1935; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Ngo et al., 2010
<i>Lygosoma albopunctatum</i>	Tirant, 1885
<i>Lygosoma angeli</i>	Bobrov, 1992a; Smith, 1937; Teynie et al., 2004
<i>Lygosoma boehmei</i>	Ziegler et al., 2007b
<i>Lygosoma bowringii</i>	Bobrov, 1992a, 1993a; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a; Smith, 1935; Stuart and Emmett, 2006; Teynie et al., 2004; Bezuijen et al., 2009
<i>Lygosoma carinatum</i>	Darevsky and Orlova, 1996
<i>Lygosoma corpulentum</i>	Smith, 1921a; Teynie et al., 2004
<i>Lygosoma haroldyoungi</i>	Moravic and Böhme, 2008
<i>Lygosoma quadrupes</i>	Bobrov, 1992a, 1993a; Bourret, 1937a, 1941b; Daltry and Chheang, 2000; Darevsky and Orlov, 2005; Ngo and Ziegler, 2009; Schmidt, 1928; Stuart et al., 2006c; Teynie et al., 2004; Ziegler et al., 2006a
<i>Paralipinia rara</i>	Darevsky and Orlov, 1997
<i>Plestiodon chinensis</i>	Bobrov, 1993a; Darevsky, 1999; Smith, 1935
<i>Plestiodon elegans</i>	Bobrov, 1993a; Darevsky and Orlov, 2005; Norval, 2004
<i>Plestiodon quadrilineatus</i>	Bain et al., 2007b; Bobrov, 1993a,b, 2003a; Darevsky and Orlov, 2005; Smith, 1935
<i>Plestiodon tamdaoensis</i>	Bobrov, 1993a, 2003a; Bourret, 1941b; Hikida and Darevsky, 1987; Ziegler et al., 2006a
<i>Scincella apraefrontalis</i>	Nguyen et al., 2010e
<i>Scincella doriae</i>	Bourret, 1939b; Bobrov, 1992a; Ziegler et al., 2006a
<i>Scincella melanosticta</i>	Bobrov, 1993a; Daltry and Chheang, 2000; Darevsky, 1999; Grismer et al., 2007a; Ouboter, 1986; Smith, 1935; Stuart and Emmett, 2006; Teynie et al., 2004; Ziegler and Herrmann, 2000; Nguyen et al., 2010e
<i>Scincella monticola</i>	Nguyen et al., 2010b
<i>Scincella ochracea</i>	Eremchenko, 2003; Nguyen et al., 2010c
<i>Scincella reevesii</i>	Bain and Nguyen, 2004b; Bobrov, 1993a,b, 1998; Daltry and Chheang, 2000; Darevsky, 1999; Darevsky and Orlov, 2005; Ouboter, 1986; Smith, 1935; Stuart, 1999; Vassilyev, 2003
<i>Sphenomorphus buenloicus</i>	Darevsky and Nguyen, 1983
<i>Sphenomorphus cryptotis</i>	Bain et al., 2007b; Darevsky et al., 2004
<i>Sphenomorphus devorator</i>	Darevsky et al., 2004
<i>Sphenomorphus indicus</i>	Bobrov, 1993a; Daltry and Chheang, 2000; Darevsky and Orlov, 2005; Grismer et al., 2007a; Schmidt, 1928; Stuart, 1999; Ziegler, 2002; Ziegler et al., 2004a; Hartmann et al., 2010b



APPENDIX 2B  
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	References
<i>Sphenomorphus lineopunctulatus</i>	Hartmann et al., 2010b
<i>Sphenomorphus maculatus</i>	Bobrov, 1993a; Darevsky, 1999; Daltry and Chheang, 2000; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004; Hartmann et al., 2010b
<i>Sphenomorphus rufocaudatus</i>	Bobrov, 1993a; Darevsky and Nguyen, 1983; Schmitz and Ziegler, 2003; Stuart, 1999; Stuart and Emmett, 2006; Stuart et al., 2006c; Teynie et al., 2004
<i>Sphenomorphus stellatus</i>	Smith, 1921a; Stuart and Emmett, 2006
<i>Sphenomorphus tridigitus</i>	Bain et al., 2007b; Bourret, 1939d; Heatwole and Stuart, 2008; Teynie et al., 2004
<i>Sphenomorphus tritaeniatus</i>	Bobrov, 1993b, 2003a; Bourret, 1937a
<i>Tropidophorus baviensis</i>	Bobrov, 1993b, 2003a; Nguyen et al., 2010a
<i>Tropidophorus boehmei</i>	Nguyen et al., 2010d
<i>Tropidophorus cocincinensis</i>	Bain et al., 2007b; Bobrov, 1993a; Bourret, 1941b; Darevsky and Orlov, 2005; Smith, 1935; Ziegler and Herrmann, 2000; Nguyen et al., 2010a; Stuart et al., 2010b; Hartmann et al., 2010a
<i>Tropidophorus hainamus</i>	Bain et al., 2007b; Bobrov, 1993b, 2003a; Bourret, 1937a; Semenov, 2001; Stuart, 1999; Ziegler et al., 2006a, 2008a
<i>Tropidophorus laotus</i>	Smith, 1935; Stuart, 1999
<i>Tropidophorus microlepis</i>	Bobrov, 1993a; Smith, 1935; Stuart et al., 2006c; Teynie et al., 2004
<i>Tropidophorus murphyi</i>	Hikida et al., 2002
<i>Tropidophorus noggei</i>	Ziegler et al., 2005, 2006b
<i>Tropidophorus sinicus</i>	Bourret, 1939b; Smith, 1935; Nguyen et al., 2010a
<i>Vietnascincus rugosus</i>	Darevsky and Orlov, 1994a
<b>Varanidae</b>	
<i>Varanus nebulosus</i>	Bobrov, 1993a; Böhme and Ziegler, 1997; Bourret, 1941b; Darevsky, 1999; Stuart, 1999; Bezuijen et al., 2009
<i>Varanus salvator</i>	Angel, 1929; Bobrov, 1993a,b, 2003a,b; Bourret, 1937a; Daltry and Chheang, 2000; Darevsky, 1999; Stuart, 1999; Ziegler and Herrmann, 2000; Bezuijen et al., 2009
<b>Xenosauridae</b>	
<i>Shinisaurus crocodilurus</i>	Le and Ziegler, 2003; Ziegler et al., 2008c
<b>CROCODYLIA</b>	
<i>Crocodylus siamensis</i>	Daltry and Chheang, 2000; Platt and Ngo, 2000; Platt et al., 2004, 2006; Polet, 2004; Saint Girons, 1972a; Smith, 1935; Stuart, 1999, 2004; Stuart et al., 2002; Stuart and Platt, 2000
<i>Crocodylus porosus</i>	Stuart, 2004; Stuart et al., 2002; Stuart and Platt, 2000
<b>TESTUDINES</b>	
<b>Bataguridae</b>	
<i>Batagur baska</i>	Bourret, 1941a; Ernst and Barbour, 1989; Holloway and Sovannarra, 2004; Iverson, 1992; Platt et al., 2003; Smith, 1931; Stuart et al., 2001; Stuart and Platt, 2004
<i>Cuora amboinensis</i>	Bourret, 1937a, 1941a; Daltry and Chheang, 2000; Ernst and Barbour, 1989; Iverson, 1992; Smith, 1931; Stuart, 1999; Stuart et al., 2001; Stuart and Platt, 2004
<i>Cuora bourreti</i>	Lehr et al., 1998; Obst and Reimann, 1994; Stuart and Parham, 2004
<i>Cuora galbinifrons</i>	Bourret, 1941a; Iverson, 1992; Lehr et al., 1998; Nguyen et al., 2005; Stuart and Parham, 2004; Stuart and Platt, 2004
<i>Cuora mouhotii</i>	Bourret, 1939a, 1941a; Iverson, 1992; Smith, 1931; Stuart et al., 2001; Stuart and Platt, 2004
<i>Cuora picturata</i>	Lehr et al., 1998, described this species from market specimens
<i>Cuora trifasciata</i>	Blanck et al., 2006; Bourret, 1941a; Ernst and Barbour, 1989; Iverson, 1992; Spinks and Shaffer, 2007
<i>Cyclemys atripons</i>	Fritz et al., 2008; Grismer et al., 2008a; Stuart and Platt, 2004; Stuart et al., 2001
<i>Cyclemys pulchistriata</i>	Fritz et al., 2008; Stuart et al., 2006c, 2001
<i>Cyclemys oldhamii</i>	Bourret, 1939d, 1941a; Fritz et al., 2008, 2001; Iverson, 1992; Iverson and McCord, 1997; Stuart and Fritz, 2008; Stuart and Platt, 2004; Stuart et al., 2010b

APPENDIX 2B  
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	References
<i>Geoemyda spengleri</i>	Bourret, 1941a; Iverson, 1992
<i>Heosemys annandalii</i>	Bourret, 1941a; Iverson, 1992; Le, 2007; Smith, 1931; Stuart et al., 2001; Stuart and Platt, 2004
<i>Heosemys grandis</i>	Bourret, 1941a; Iverson, 1992; Le, 2007; Smith, 1931; Stuart and Platt, 2004
<i>Malayemys subtrijuga</i>	Bourret, 1941a; Le, 2007; Smith, 1931; Stuart and Platt, 2004
<i>Mauremys annamensis</i>	Bourret, 1941a; Le et al., 2004; Parham et al., 2006
<i>Mauremys mutica</i>	Bourret, 1941a
<i>Mauremys nigricans</i>	Bourret, 1941a; Iverson, 1992
<i>Mauremys sinensis</i>	Bourret, 1941a; Iverson, 1992
<i>Notochelys platynota</i>	Bourret, 1941a; Smith, 1931
<i>Sacalia quadriocellata</i>	Bourret, 1939a; Stuart et al., 2001; Stuart and Platt, 2004; Ziegler, 2002
<i>Siebenrockiella crassicolis</i>	Bourret, 1941a; Le, 2007; Smith, 1931; Stuart et al., 2001; Stuart and Platt, 2004
<b>Platysternidae</b>	
<i>Platysternon megacephalum</i>	Bourret, 1937a, 1941a; Iverson, 1992; Stuart and Platt, 2004
<b>Testudinidae</b>	
<i>Indotestudo elongata</i>	Bourret, 1941a; Daltry and Chheang, 2000; Grismer et al., 2007a; Iverson, 1992; Pham et al., 2004; Smith, 1931
<i>Manouria impressa</i>	Bourret, 1939c, 1941a; Daltry and Chheang, 2000; Lehr and Holloway, 2000; Smith, 1931; Stuart and Platt, 2004; Ziegler et al., 2006b
<b>Trionychidae</b>	
<i>Amyda cartilaginea</i>	Bourret, 1937a, 1941a; Daltry and Chheang, 2000; Farkas and Ziegler, 2002; Iverson, 1992; Smith, 1931; Stuart and Platt, 2004; Teynie et al., 2004
<i>Palea steindachneri</i>	Bourret, 1941a; Smith, 1931
<i>Pelochelys cantorii</i>	Bourret, 1941a; Daltry and Chheang, 2000; Smith, 1931; Stuart et al., 2001; Stuart and Platt, 2004
<i>Pelodiscus sinensis</i>	Bourret, 1939a, 1941a; Smith, 1931
<i>Rafetus swinhoei</i>	Farkas and Webb, 2003

APPENDIX 3  
SPECIES WITH UNCONFIRMED OCCURRENCE IN INDOCHINA

Species	Comment
<i>Amolops archotaphus</i>	Bain et al (2006) showed that the known range does not yet include Indochina
<i>Amolops chunganensis</i>	Bain et al (2006) showed that the known range does not yet include Indochina
<i>Kalophrynus pleurostigma</i>	Ohler and Grosjean (2005) restrict the name to Philippine populations
<i>Microhyla palmipes</i>	Bain and Nguyen (2004) considered the wide range extension into Vietnam unjustified due to lack of voucher
<i>Limnonectes doriae</i>	Reported by Swann and Daltry (2000), but not by Ohler et al (2002), who restudied the series
<i>Sylvirana leptoglossa</i>	Orlov et al (2002b) treated the Vietnam records as <i>Sylvirana nigrovittata</i>
<i>Polypedates omeimontis</i>	Orlov et al (2002b) treated Vietnam records as <i>P. duboisi</i>
<i>Rhacophorus bimaculatus</i>	Stuart 2005a reports that records in Vietnam are of <i>R. orlovi</i>
<i>Xenophrys longipes</i>	Inger et al., (1999) suggest that more evidence is required before reporting this species from Vietnam
<i>Ramphotyphlops lineatus</i>	Uetz (2010) reports this from Indochina, but this has long been shown to be incorrect; e.g. Pope (1935), Taylor (1965)
<i>Boiga cynodon</i>	Orlov et al. (2003b) and Ziegler et al. (2006a) suggest that Indochinese records are confused with <i>B. siamensis</i> and <i>B. guangxiensis</i> ; identification of historical records must be confirmed
<i>Rhabdophis himalayanus</i>	Uetz and Hallermann (2007) report this species from Laos, but this is based on a subspecies ( <i>laobaoensis</i> ), that Smith (1943) showed to be a synonym of <i>R. subminiata</i>
<i>Bronchocela cristatella</i>	Hallermann (2005) suggested that this species is widespread throughout southeast Asia, but not in Indochina
<i>Lygosoma punctata</i>	Smith (1935) states that "There is a specimen in the British Museum said to have been collected in the Man-son Mountain, Tonking, by Fruhstorfer", but does not report on the voucher; it is otherwise known from South Asia
<i>Sphenomorphus malayanum</i>	Bobrov 1995 reports from Vietnam, but neither of his sources refer to voucher material to support such a large range extension from Sumatra and the Malay Peninsula
<i>Tomistoma schlegelii</i>	Stuebing et al 2006 report a sighting by US Soldier in southern Vietnam in 1967 but there is no voucher