Conservation Biology of

AMPHIBIANS OF ASIA

Status of Conservation and Decline of Amphibians: Eastern Hemisphere

Edited by

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Natural History Publications (Borneo)
Kota Kinabalu

2014

Published by

Natural History Publications (Borneo) Sdn. Bhd. (216807-X)
A913, 9th Floor, Wisma Merdeka Phase 1,
P.O. Box 15566,
88864 Kota Kinabalu, Sabah, Malaysia.
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website: www.nhpborneo.com

First published July 2014.

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This is Volume 11, Part 1, of Amphibian Biology

ISBN 978-983-812-154-5

Printed in Taiwan.

CHAPTER 17

Conservation Status of the Amphibians of Malaysia and Singapore

Indraneil Das, Norsham Yaakob, Jeet Sukumaran, and Tzi Ming Leong

Abbreviations in text and references: ACIAR = Australian Centre for International Agricultural Research; asl = above sea level; Bd = Batrachochytrium dendrobatidis; *BTNR = Bukit Timah Nature Reserve; CCNR = Central Catchment Nature Reserve; CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora; DDT =dichlorodiphenyltrichloroethane; DWNP = Department of Wildlife and National Parks; FAO = Food and Agriculture Organization (of the United Nations); GAA = Global Amphibian Assessments; ILAR= Institute for Laboratory Animal Research; IPM = Integrated Pest Management; IUCN = International Union for the Conservation of Nature and Natural Resources/The World Conservation Union; MRL = maximum residue limit; PA = protected area(s); PAC = Programme Advisory Committee; PERHILITAN = Jabatan Perlindungan Hidupan Liar dan Taman Negara.*

I. INTRODUCTION

Malaysia and Singapore are two independent countries in southeastern Asia (Fig. 1), situated north of the equator, and enjoying mostly tropical climate (with a hint of seasonality in the north). One part of the former (Peninsular Malaysia) stretches from the southern border of Thailand southward to the narrow Johor Strait that separates it from the island state of Singapore. A second, insular, part of Malaysia lies across the South China Sea on the northern coast of Borneo (see below). Malaysia has a total land area of 328,657 km^2, far exceeding the land area of Singapore (700 km^2). The term 'Malay Peninsula' here will refer to Peninsular Malaysia and Singapore, 'Malaysia' to the Malaysian Federation, comprising Peninsular Malaysia, Sabah, Sarawak, and Labuan. The geological history of the landmass has been described by Hutchison and Tan (2009); also see Wong (2011) for a recent synthesis of the biological (including palaeontological) and physical characteristics of the southeastern Asian region as a whole.

Fig. 1. Relief map of Malaysia and Singapore.

The total area of Peninsular Malaysia is 130,268 km^2, and extends in a north-northwestern to south-southeastern direction, with a maximum length of 750 km and maximum width of 330 km. Important mountain ranges (see Raj 2009 for details) include the Nakawan Range (extreme northwestern part of the Peninsula); the Kedah-Singgora Range (southern Thailand to central-western Kedah); the Bintang Range (in the north, up to southwestern Perak); the Kledang Range (offshoot of Main Range, branching off in northern Perak); the Main Range (from the north, along the central portion of the Peninsula, as far as Negri Sembilan); the Benom Range (a southern range along the borders of Negeri Sembilan, Melaka, and Johor); the Tahan Range (along the eastern part of the Peninsula); and the East Coast Range (extending from Kelantan through interior Terengganu to Sungai Pahang). The highest summit is Gunung Tahan (2187 m asl) within the state of Pahang. The dense network of rivers and streams has been attributed to the Peninsula's extended subaerial exposure as well as to its humid tropical climate. Important rivers include Sungai Pahang, Sungai Kelantan, and Sungai Perak; no single river dominates the overall drainage pattern (Raj 2009).

Malaysia's insular possessions lie on Borneo, one of four major islands of the Indo-Malayan Archipelago (along with Sumatra, Java, and Sulawesi) on the eastern edge of the Sunda Shelf. Borneo covers a land area of approximately 743,380 km^2, of which the Malaysian segments are the states of Sarawak (124,450 km^2) and Sabah (73,710 km^2) and the Federal Territory of Labuan (75 km^2). During the Pleistocene glaciation, sea levels fell between 120 and 200 m below current levels (Ollier 1985; Wang and Wang 1990), uniting the islands of the Sundas (Molengraaff and Weber 1921; Morley and Flenley 1987). Generalized reconstructions of the southeastern Asian archipelago during the Pleistocene can be found in a paper by Heaney (1991), although it does not take into account tectonic movements of these islands (partially considered by Hall 1996 and Voris 2000). The highest point on Borneo is Low's Peak (4101 m) within Gunung Kinabalu, northern Sabah, making it the highest peak

between the Himalayas on mainland Asia and Puncak Jaya (5050) of Indonesia's New Guinean, Papua Province (Indonesia). The highest mountain in Sarawak is Gunung Murud, at 2423 m. Borneo is home to several large rivers that sometimes form important biogeographic limits, including the Baram and the Rejang (in Sarawak) and the Segama and the Kinabatangan (in Sabah). Other noteworthy geological features are the extensive cave systems, including isolated limestone outcrops in coastal Sarawak and northwestern Sabah (Harrisson 1964). MacKinnon and MacKinnon (1986) identified seven regions within Borneo, based on phytogeology. Those within Malaysia are: (1) The Riau Pocket Region (in the northwest, demarcated by the Sungei Rejang to the east; the Central Highlands to the southeast; and the Sungei Kapuas to the southwest); (2) The Northwestern Lowlands (in the north, demarcated by Sungei Rejang to the west and the Central Highlands to the south); (3) The Kinabatangan and Sesayap Drainages (in the northeast, demarcated by Banjaran Bulungan to the south and the Central Highlands to the west and north); and (4) The Central Highlands (in the central and northeastern parts, north of Sungei Barito, Sungei Mahakkam, and Sungei Kapuas, and extending from central Borneo to the northeastern tip, including Banjaran Crocker and Gunung Kinabalu of Sabah, bounded by the drainages of numerous rivers that originate from these mountain ranges).

Malaysia is composed of five major geological terranes: (1) the western belt of Peninsular Malaysia (west of the Titiwangsa or main mountain range) comprising the oldest known rocks (dating to the Middle Cambrian or earliest Paleozoic) in the country; (2) the core region (a part of Sundaland), comprising the rest of Peninsular Malaysia, the associated islands on the Sunda Shelf (including Singapore), in addition to westernmost Sarawak; (3) central and northern Sarawak and western Sabah; (4) the Kinabalu zone; and (5) eastern Sabah. Exceptional phytogeographic regions based on plant endemism patterns, as described by Wong (1998), include the Riau Pocket of northwestern Borneo, the eastern coast of Sabah, an area in northern Borneo that is influenced by seasonal Asiatic and east Malesian-Australian elements, the western coast of Peninsular Malaysia that has floral similarities to that of Sumatra, and finally, a northern influence of Burmese-Thai lineages that extend up to the Kuala Lumpur region. Whether herpetofaunal distributions show similar patterns remain open to investigation.

Malaysia is a megadiverse country in terms of its biodiversity (based on an estimate of the total number of organisms) (Mittermeier *et al*. 1997), the underpinning reasons being attributed to (1) the fact that parts of the region remained unglaciated at the height of the Pleistocene glaciation and hence functioned as refuges (Heaney 1991); (2) a complex history of fluctuation in sea level that attached and detached islands to the Asian mainland; (3) heterogeneity of geology and climate, and therefore, the representation of diverse ecological conditions; and (4) large tracts of primary forests, especially tropical rainforests and montane forests (Das and Norsham 2007; Anonymous 2009; Wong 2011).

II. THE AMPHIBIAN FAUNA

A. The Malay Peninsula (West Malaysia and Singapore)

Knowledge of the amphibian fauna of Malaysia began with the arrival of early European naturalists attached to British trade and administrative centres. The earliest published works are those of Theodore Cantor (1847) and Ferdinand Stoliczka (1870a, 1870b, 1870c, 1873) who reported on collections made from Malacca and Singapore. Theodore Edward Cantor (1809–1860), a Dane, was surgeon-naturalist with the English East India Company, while Ferdinand Stoliczka (1838–1874), a Moravian, was a palaeontologist with the Geological Survey of India. Both had an intense interest in natural history and, in a sense, collections were made 'beyond the call of duty' for both men, whose official tasks were medicine and geological exploration for mineral resources, respectively. Stoliczka coined the bufonid generic name, *Ansonia*, for specimens collected on Penang's highest mountain–Great Hill or Bukit Bendera, an eponym for Lieutenant-Governor of Penang, Major General Archibald Edward Harbord Anson (1826–1925). A subsequent collector of note was Major Stanley Smyth Flower (1871–1946) of the Northumberland Fusiliers, who wrote notes on amphibians (Flower 1896, 1899) and sent specimens to the British Museum (Natural History), London, where some of them were described as new to science. As a result of these collections, the knowledge of the fauna of Peninsular Malaysia continued to expand, and the first checklists were published by Arthur Lennox Butler (1873–1939), Curator of the Selangor State Museum in the years 1902 and 1904.

Between 1899 and 1900, English biologists, especially students from Cambridge and Oxford universities, joined the Skeat Expedition, organized by Walter William Skeat (1866–1953), a British ethnographer and a member of the Malayan Civil Service (Skeat 1900). The main goal was research on ethnology, zoology, botany, and geology of the Pattani States of Siam (currently in southern Thailand), and also adjacent portions of northern Malaysian states, including Terengganu and Kelantan (sites listed by Skeat 1901). The amphibians obtained were reported by Frank Fortescue Laidlaw (1876–1963) in a paper published in 1900. The next major collection from the Malay Peninsula was made by Thomas Nelson Annandale (1876–1924), at the time a student of Balliol College, Oxford, who later joined the Indian Museum, and Herbert Christopher Robinson (1874–1929), subsequently Curator of the Selangor Museum. The expedition was held between 1901 and 1902 and the amphibians were described by Boulenger (1903) in a special volume edited by Annandale and Robinson. Karl Richard Hanitsch (1860–1940) was the Raffles Museum's first Curator (1895–1919) and a specialist of the Blattidae. Hanitsch (1898) prepared a catalogue of the herpetofauna of the Malay Peninsula and archipelago. Cecil Boden Kloss (1877–1949), Director of the Raffles Museum (between 1923–1932), and the Museum Curator, Frederick Nutter Chasen (1897–1942), made collections from the Cameron Highlands, Gunung Angsi, Pulau Aur, and Pulau Tioman, and wrote notes on significant amphibian records, and made material available to Malcolm Arthur Smith (1875–1958), physician at the Royal Court of Siam, who published descriptions and faunal lists (Smith 1922, 1924a, 1924b, 1930, 1935). Two other inventories are worth mentioning- the Gunung Benom Expedition (Grandison 1972) and the Gunung Lawit Expedition (Dring 1979).

Despite Singapore's relatively small size and low proportion of original forest cover, new species of amphibians have been described from this island nation. These include one caecilian, *Ichthyophis singaporensis*, and two frogs (*Leptobrachium nigrops* and *Limnonectes malesianus*) (Fig. 2).

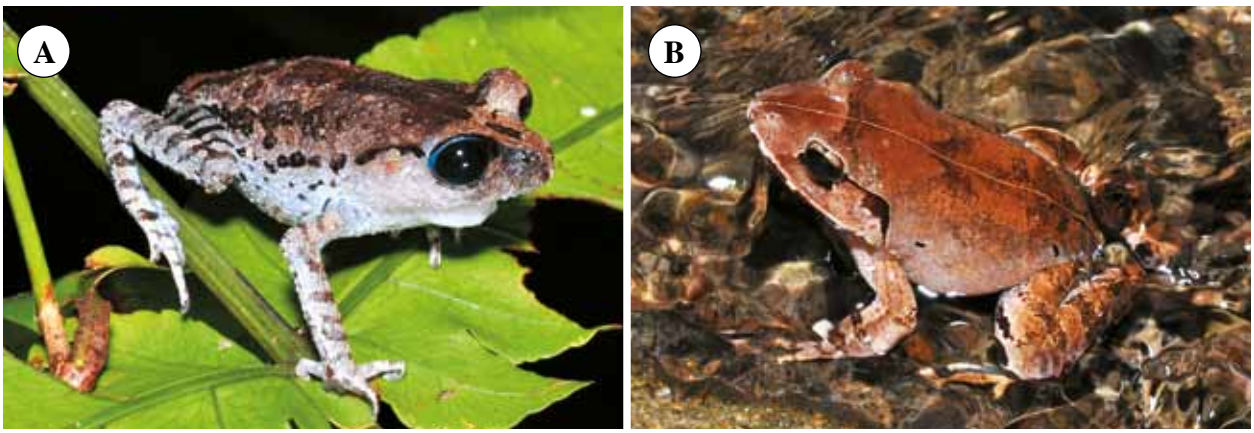

Fig. 2. Singapore is the type locality for two frogs: (**A**) *Leptobrachium nigrops* Berry and Hendrickson, 1963, and (**B**) *Limnonectes malesianus* (Kiew 1984). Photographs by Leong Tzi Ming.

B. Sarawak

The earliest scientific observer of amphibians in Borneo was probably the Scottish botanist, Hugh Low (1824–1905), who prepared the first checklist, showing three species, in a book entitled '*Sarawak. Its Inhabitants and Productions being Notes during a Residence in that Country with His Excellency Mr Brooke*' (Low 1848). Three amphibians were listed: *Rana cancrivora* (current name *Fejervarya cancrivora*), *Bufo* (referring to a member of the family Bufonidae), and *Hyla* (probably equivalent to a member of the family Rhacophoridae).

Early collections extant in western museums, but derived from Borneo, have labels indicating the specimens to have been bought or received as donations by the European, mostly English, civil servants in the pay of the Rajas of Sarawak. Important collectors include Sarawak Civil Service staff, Charles Hose (1863–1929) and Alfred Hart Everett (1849–1898), whose amphibian specimens were described by curators in the British Museum of Natural History (Günther 1872; Boulenger 1892, 1893, 1895, 1896). Foreign visitors, who were either attached to European scientific institutions or who were professional collectors, also visited Borneo for acquiring

specimens. Important collectors of the time include Alfred Russel Wallace (1823–1913) and the Italian nobleman Marquis Giacomo Doria of Genoa (1840–1913) and the Italian botanist Odoardo Beccari (1843–1920). Several curators of the Sarawak Museum made noteworthy collections of amphibians. The first was Edward Bartlett (*ca*. 1836–1908), who wrote a series of papers in *The Sarawak Gazette*, the monthly official gazette for the staff of the Sarawak Civil Service, including one on amphibians (Bartlett 1894), based on material largely extant in the Sarawak Museum. His successor was Robert Walter Campbell Shelford (1872–1912), who wrote taxonomic papers on herpetological subjects, including one (Shelford 1905) making available a frog's name (*Rana sariba*, currently *Ingerana sariba*). Eric Georg Mjöberg (1882–1938, born Hallands Ian) was Curator of the Museum briefly (1922–1924), and was perhaps the most intrepid collector of all, ascending some of the most remote parts of Sarawak, including Gunung Murud, Gunung Penrissen, and Gunung Pueh and adjacent Gunung Beremput, and made specimens available to Smith (1925a, 1925b). Nearer the present time, the next major collection was made during the Gunung Mulu Expedition (1977–1978), organized by the Sarawak Government and the Royal Geographical Society. Amphibians were collected by the British biologist, Julian Christopher Mark Dring (1951–the present), and several new species were described by him (Dring 1983a, 1983b, 1987) and by others.

C. Sabah

Historically, the highest mountain in Borneo, Gunung Kinabalu (summit at 4095 m asl), has been the most collected area in Sabah. The first expedition was led by John Whitehead (1860–1899), an ornithologist, between 1887 and 1888. The expeditions were described in his folio-format work entitled '*The exploration of Mount Kina Balu*' (Whitehead 1893), and the amphibian specimens were deposited both with the British Museum (Natural History), London, and the Muséum National d'Histoire Naturelle, Paris. This, unfortunately, led to some species being described nearly simultaneously by Boulenger (1887) at the former institution and by Mocquard (1890) at the latter. Other subsequent expeditions to Kinabalu were by Karl Richard Hanitsch (in 1899), Frederick Nutter Chasen (1897–1942) and Henry Maurice Pendlebury (1893–1945) between April and May 1929 (Pendlebury and Chasen 1932), whose large herpetological collections were studied by Smith (1931). Sabah continues to be visited (since the early 1950s) by Robert Frederick Inger (1920–the present) of the Field Museum of Natural History, Chicago, whose contributions to field guides and publications of papers on systematics, ecology, and biogeography are numerous.

D. Lineage Composition and Regional Distribution

A total of 238 species are currently known for the region; all but two (*Ichthyophis paucisulcus* and the introduced *Hylarana guentheri*) (see Leong and Lim 2011) are known from Malaysia (Table 1; Fig. 3) of which 30 are also known from Singapore (Table 2) (Lim and Chou 1990). These numbers, of course, are transient, as cryptic species are shown to exist in a multitude of lineages within amphibians, leading to descriptions of new species as well as to name changes (see Stuart *et al*. 2006). The amphibian fauna of Singapore, owing to the size of its land area and its proximity to the Asian mainland, is a subset of that of Peninsular Malaysia (except for the caecilian species mentioned above, which is shared with Sumatra). The faunas of Sabah and Sarawak, as expected from their locations and isolation, have unique lineages that are not present on the Asian mainland, but which have representatives in eastern insular Asia (especially, the Philippines). A total of 109 species are known from Peninsular Malaysia, while the collective count from Sabah and Sarawak is 173. The number of species from Peninsular Malaysia that do not occur in the eastern portion of the country is 62, although some of these co-occur in adjacent portions of the Asian mainland, especially southern Thailand, and also occur in Sumatra. On Sarawak and Sabah are 130 species that do not occur on Peninsular Malaysia; some of these are not true Bornean endemics but are shared with Sumatra and the southern islands of the Philippines, especially Palawan, due to recent land connections between the two areas. The mainland portion of Malaysia is rich in species of *Ingerophrynus*, *Hylarana,* and *Theloderma*. On the other hand, Borneo has a large number of endemic genera, each with its own radiation, including *Sabahphrynus*, *Borneophrys*, *Leptobrachella*, *Meristogenys,* and *Staurois*. For a number of taxa, there appear to be ecological analogues on sister land masses: *Ingerana tenasserimensis*

Table 1. Checklist of the amphibians of Malaysia, current as of 21 August 2013. Introduced species are indicated by an asterisk.

ORDER ANURA: Family Bufonidae
Ansonia albomaculata Inger 1960
Ansonia echinata Inger and Stuebing 2009
Ansonia endauensis Grismer 2006
Ansonia fuliginea (Mocquard 1890)
Ansonia guibei Inger 1966
Ansonia hanitschi Inger 1960
Ansonia jeetsukumarani Wood, Grismer, Ahmad and Senawi 2008
Ansonia latidisca Inger 1966
Ansonia latiffi Wood, Grismer, Ahmad and Senawi 2008
Ansonia latirostra Grismer 2006
Ansonia leptopus (Günther 1872)
Ansonia longidigita Inger 1960
Ansonia malayana Inger 1960
Ansonia minuta Inger 1960
Ansonia penangensis Stoliczka 1870
Ansonia platysoma Inger 1960
Ansonia spinulifer (Mocquard 1890)
Ansonia tiomanica Hendrickson 1966
Ansonia torrentis Dring 1984
Duttaphrynus melanostictus (Schneider 1799)
Ingerophrynus divergens (Peters 1871)
Ingerophrynus gollum Grismer 2007
Ingerophrynus kumquat (Das and Lim 2001)
Ingerophrynus macrotis (Boulenger 1887)
Ingerophrynus parvus (Boulenger 1887)
Ingerophrynus quadriporcatus (Boulenger 1887)
Leptophryne borbonica (Tschudi 1838)
Pedostibes everetti (Boulenger 1896)
Pedostibes hosii (Boulenger 1892)
Pedostibes rugosus Inger 1958
Pelophryne api Dring 1984
Pelophryne guentheri (Boulenger 1882)
Pelophryne linanitensis Das 2008
Pelophryne misera (Mocquard 1890)
Pelophryne murudensis Das 2008
Pelophryne rhopophilia Inger and Stuebing 1996
Pelophryne saravacensis Inger and Stuebing 2009
Pelophryne signata (Boulenger 1895)
Phrynoidis aspera (Gravenhorst 1829)
Phrynoidis juxtaspera (Inger 1964)
Pseudobufo subasper Tschudi 1838
Sabahphrynus maculatus (Mocquard 1890)

Family Ceratobatrachidae
"*Ingerana*" *baluensis* (Boulenger, 1896)

Family Dicroglossidae
Fejervarya cancrivora (Gravenhorst 1829)
Fejervarya limnocharis (Gravenhorst 1829)
Fejervarya pulla (Stoliczka 1870)
Fejervarya schlueteri (Werner 1893)
**Hoplobatrachus rugulosus* (Wiegmann 1834)
Ingerana sariba (Shelford 1905)
Ingerana tenasserimensis (Sclater 1892)
Limnonectes blythii (Boulenger 1920)
Limnonectes doriae (Boulenger 1887)
Limnonectes finchi (Inger 1966)
Limnonectes hascheanus (Stoliczka 1870)
Limnonectes ibanorum (Inger 1964)
Limnonectes ingeri (Kiew 1978)
Limnonectes kenepaiensis (Inger 1966)
Limnonectes kuhlii (Tschudi 1838)
Limnonectes laticeps (Boulenger 1882)
Limnonectes leporinus Andersson 1923
Limnonectes macrognathus (Boulenger 1917)
Limnonectes malesianus (Kiew 1984)
Limnonectes nitidus (Smedley 1932)
Limnonectes palavanensis (Boulenger 1894)
Limnonectes paramacrodon (Inger 1966)
Limnonectes plicatellus (Stoliczka 1873)
Limnonectes tweediei (Smith 1935)
Occidozyga baluensis (Boulenger 1896)
Occidozyga lima (Gravenhorst 1829)
Occidozyga martensii (Peters 1867)
Occidozyga sumatrana (Peters 1877)

Family Megophryidae
Borneophrys edwardinae (Inger 1989
Leptobrachella baluensis Smith 1931
Leptobrachella brevicrus Dring 1984
Leptobrachella mjobergi Smith 1925
Leptobrachella palmata Inger and Stuebing 1992
Leptobrachella parva Dring 1984
Leptobrachella serasanae Dring 1984
Leptobrachium abbotti (Cochran 1926)
Leptobrachium gunungense Malkmus 1996
Leptobrachium hendricksoni Taylor 1962
Leptobrachium ingeri Hamidy, Matsui, Nishikawa, and Belabut 2012
Leptobrachium kanowitense Hamidy, Matsui, Nishikawa, and Belabut 2012
Leptobrachium montanum Fischer 1885
Leptobrachium nigrops Berry and Hendrickson 1963
Leptolalax arayai Matsui 1997

Leptolalax dringi Dubois 1987
Leptolalax gracilis (Günther 1872)
Leptolalax hamidi Matsui 1997
Leptolalax heteropus (Boulenger 1900)
Leptolalax kajangensis Grismer, Grismer and Youmans 2004
Leptolalax kecil Matsui, Belabut, Ahmad and Yong 2009
Leptolalax maurus Inger, Lakim, Biun and Yambun 1997
Leptolalax pelodytoides (Boulenger 1893)
Leptolalax pictus Malkmus 1992
Leptolalax platycephalus Dehling 2012
Leptolalax solus Matsui 2006
Megophrys kobayashii Malkmus and Matsui 1997
Megophrys nasuta (Schlegel 1858)
Xenophrys aceras (Boulenger 1903)
Xenophrys baluensis (Boulenger 1899)
Xenophrys dringi (Inger, Stuebing and Tan 1995)
Xenophrys longipes (Boulenger 1886)

Family Microhylidae
Calluella brooksii (Boulenger 1904)
Calluella flava Kiew 1984
Calluella guttulata (Blyth 1856)
Calluella minuta Das, Yaakob and Lim 2004
Calluella smithi (Barbour and Noble 1916)
Chaperina fusca Mocquard 1892
Gastrophrynoides borneensis (Boulenger 1897)
Gastrophrynoides immaculatus Chan, Grismer, Ahmed and Daicus 2009
Kalophrynus baluensis Kiew 1984
Kalophrynus calciphilus Dehling 2011
Kalophrynus eok Das and Haas 2003
Kalophrynus heterochirus Boulenger 1900
Kalophrynus intermedius Inger 1966
Kalophrynus nubicola Dring 1984
Kalophrynus palmatissimus Kiew 1984
Kalophrynus punctatus Peters 1871
Kalophrynus robinsoni Smith 1922
Kalophrynus subterrestris Inger 1966
Kalophrynus yongi Matsui 2009
Kaloula baleata (Müller in Van Oort and Müller 1833)
Kaloula pulchra Gray 1831
Metaphrynella pollicaris (Boulenger 1890)
Metaphrynella sundana (Peters 1867)
Microhyla annectens Boulenger 1900
Microhyla berdmorei (Blyth 1856)
Microhyla borneensis Parker 1928
Microhyla butleri Boulenger 1900
Microhyla fissipes Boulenger 1884
Microhyla heymonsi Vogt 1911
Microhyla maculifera Inger 1989
Microhyla malang Matsui 2011
Microhyla mantheyi Das, Yaakob and Sukumaran 2007
Microhyla nepenthicola Das and Haas 2010
Microhyla palmipes Boulenger 1897
Microhyla perparva Inger and Frogner 1979
Microhyla petrigena Inger and Frogner 1979
Microhyla superciliaris Parker 1928
Micryletta inornata (Boulenger 1890)
Phrynella pulchra Boulenger 1887

Family Ranidae
Amolops larutensis (Boulenger 1899)
Huia cavitympanum (Boulenger 1893)
Humerana miopus (Boulenger 1918)
Hylarana banjarana (Leong and Lim 2003)
Hylarana baramica (Boettger 1900)
Hylarana erythraea (Schlegel 1837)
Hylarana glandulosa (Boulenger 1882)
**Hylarana guentheri* (Boulenger 1882)
Hylarana labialis (Boulenger 1887)
Hylarana laterimaculata (Barbour and Noble 1916)
Hylarana luctuosa (Peters 1871)
Hylarana macrodactyla Günther 1858
Hylarana megalonesa (Inger, Stuart and Iskandar 2009)
Hylarana nicobariensis (Stoliczka 1870)
Hylarana nigrovittata (Blyth 1856)
Hylarana picturata (Boulenger 1920)
Hylarana raniceps (Peters 1871)
Hylarana siberu (Dring, McCarthy and Whitten 1990)
Hylarana signata (Günther 1872)
**Lithobates catesbeianus* (Shaw 1802)
Meristogenys amoropalamus (Matsui 1986)
Meristogenys dyscritus Shimada, Matsui, Yambun and Sudin 2011
Meristogenys jerboa (Günther 1872)
Meristogenys kinabaluensis (Inger 1966)
Meristogenys macrophthalmus (Matsui 1986)
Meristogenys maryatiae Matsui, Shimada and Sudin 2010
Meristogenys orphnocnemis (Matsui 1986)
Meristogenys phaeomerus (Inger and Gritis 1983)
Meristogenys poecilus (Inger and Gritis 1983)
Meristogenys stenocephalus Shimada, Matsui, Yambun and Sudin 2011

Meristogenys stigmachilus Shimada, Matsui, Yambun and Sudin 2011
Meristogenys whiteheadi (Boulenger 1887)
Odorrana hosii (Boulenger 1891)
Odorrana monjerai (Matsui and Jaafar 2006)
Staurois guttatus Günther 1858
Staurois latopalmatus (Boulenger 1887)
Staurois parvus Inger and Haile 1959
Staurois tuberilinguis Boulenger 1918

Family Rhacophoridae
Chiromantis nongkhorensis (Cochran 1927)
Feihyla kajau (Dring 1984)
Kurixalus appendiculatus (Günther 1858)
Nyctixalus pictus (Peters 1871)
Philautus acutus Dring 1987
Philautus amoenus Smith 1931
Philautus aurantium Inger 1989
Philautus bunitus Inger, Stuebing and Tan 1995
Philautus davidlabangi Matsui 2009
Philautus disgregus Inger 1989
Philautus erythrophthalmus Stuebing and Wong 2000
Philautus gunungensis Malkmus and Riede 1996
Philautus hosii (Boulenger 1895)
Philautus ingeri Dring 1987
Philautus juliandringi Dehling 2010
Philautus kerangae Dring 1987
Philautus macroscelis (Boulenger 1896)
Philautus mjobergi Smith 1925
Philautus petersi (Boulenger 1900)
Philautus refugii Inger and Stuebing 1996
Philautus saueri Malkmus and Riede 1996
Philautus tectus Dring 1987
Philautus umbra Dring 1987
Philautus vermiculatus (Boulenger 1900)
Polypedates chlorophthalmus Das 2005
Polypedates colletti (Boulenger 1890)
Polypedates leucomystax (Gravenhorst 1829)
Polypedates macrotis (Boulenger 1891)
Polypedates otilophus (Boulenger 1893)
Rhacophorus angulirostris Ahl 1927
Rhacophorus baluensis Inger 1954
Rhacophorus bipunctatus Ahl 1927
Rhacophorus cyanopunctatus Manthey and Steiof 1998
Rhacophorus dulitensis Boulenger 1892
Rhacophorus fasciatus Boulenger 1895
Rhacophorus gadingensis Das and Haas 2005
Rhacophorus gauni (Inger 1966)
Rhacophorus harrissoni Inger and Haile 1959
Rhacophorus nigropalmatus Boulenger 1895
Rhacophorus pardalis Günther 1858
Rhacophorus penanorum Dehling 2008
Rhacophorus prominanus Smith 1924
Rhacophorus reinwardtii (Schlegel 1840)
Rhacophorus robinsonii Boulenger 1903
Rhacophorus rufipes Inger 1966
Raorchestes parvulus (Boulenger 1893)
Theloderma asperum (Boulenger 1886)
Theloderma horridum (Boulenger 1903)
Theloderma leporosum Tschudi 1838
Theloderma licin McLeod and Ahmad 2007

ORDER GYMNOPHIONA: Family Ichthyophiidae
Ichthyophis biangularis Taylor 1965
Ichthyophis dulitensis Taylor 1960
Ichthyophis lakimi Nishikawa, Matsui, and Yambun 2012
Ichthyophis larutensis Taylor 1960
Ichthyophis monochrous (Bleeker 1858)
Ichthyophis nigroflavus Taylor 1960
Ichthyophis paucisulcus Taylor 1960
Ichthyophis singaporensis Taylor 1960

on Peninsular Malaysia, a vicar of the Bornean *I. sariba*, and *Gastrophrynoides immaculatus* on the mainland replaced on Borneo by *G. borneensis*. Another species-pair is the mainland *Metaphrynella pollicaris* from the Peninsula and its replacement on Borneo, *M. sundana*.

A few exotic frog species have now become established as a result of human-mediated transport, and include extra-Asian species (the North American *Lithobates catesbeianus*), two extra-Malaysian/Singaporean species (both east Asian: *Hoplobatrachus rugulosus* and *Hylarana guentheri*), and species previously not recorded from their current ranges, including *Kaloula pulchra* and *Duttaphrynus melanostictus* from Singapore and northern Borneo (see Flower 1896; Charles 2008; Charles and Das 2008) and *Microhyla fissipes* in Singapore (see Leong and Lim 2011).

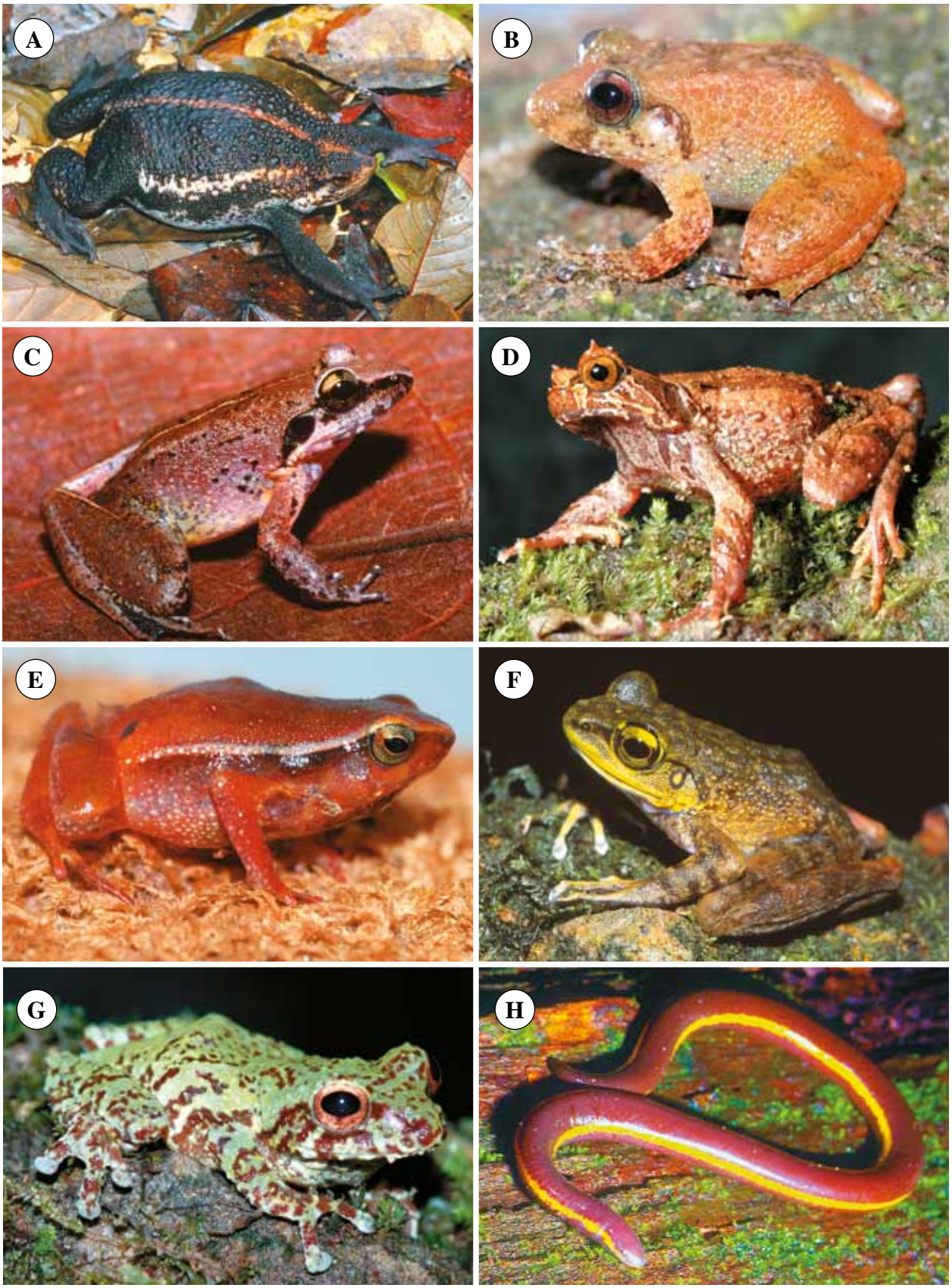

Fig. 3. Representative amphibians of Malaysia. **A.** *Pseudobufo subasper*. **B.** *Ingerana baluensis*. **C.** *Limnonectes paramacrodon*. **D.** *Xenophrys baluensis*. **E.** *Kalophrynus heterochirus*. **F.** *Meristogenys whiteheadi*. **G.** *Philautus bunitus*. **H.** *Ichthyophis asplenia*. Photographs by Indraneil Das.

Table 2. Checklist of the amphibians of Singapore. Current as of 14 December 2012. Introduced species indicated by an asterisk.

ORDER ANURA
Family Bufonidae
Duttaphrynus melanostictus (Schneider 1799)
Ingerophrynus quadriporcatus (Boulenger 1887)
Pelophryne signata (Boulenger 1895)

Family Dicroglossidae
Fejervarya cancrivora (Gravenhorst 1829)
Fejervarya limnocharis (Gravenhorst 1829)
Limnonectes blythii (Boulenger 1920)
Limnonectes kuhlii (Tschudi 1838)
Limnonectes malesianus (Kiew 1984)
Limnonectes paramacrodon (Inger 1966)
Limnonectes plicatellus (Stoliczka 1873)
Occidozyga sumatrana (Peters 1877)

Family Megophryidae
Leptobrachium nigrops (Berry and Hendrickson 1963)
Megophrys nasuta (Schlegel 1858)

Family Microhylidae
Kaloula pulchra (Gray 1831)
Microhyla butleri (Boulenger 1900)
Microhyla fissipes (Boulenger 1884)
Microhyla heymonsi (Vogt 1911)
Microhyla mantheyi (Das, Yaakob and Sukumaran 2007)

Family Ranidae
Hylarana baramica (Boettger 1900)
Hylarana erythraea (Schlegel 1837)
Hylarana glandulosa (Boulenger 1882)
**Hylarana guentheri* (Boulenger 1882)
Hylarana laterimaculata (Barbour and Noble 1916)
**Lithobates catesbeianus* (Shaw 1802)

Family Rhacophoridae
Nyctixalus pictus (Peters 1871)
Polypedates leucomystax (Gravenhorst 1829)
Rhacophorus cyanopunctatus (Manthey and Steiof 1998)
Theloderma horridum (Boulenger 1903)

ORDER GYMNOPHIONA
Family Ichthyophiidae
Ichthyophis paucisulcus (Taylor 1960)
Ichthyophis singaporensis (Taylor 1960)

III. THREATS TO AMPHIBIANS

A. Destruction and Fragmentation of Habitat

The forests of southeastern Asia reportedly show the highest relative rate of deforestation of major tropical regions, and may have lost three-quarters of its original cover and up to an estimated 42% of its biodiversity by 2010 (Sodhi *et al*. 2004). Rainforests of Malaysia and adjacent regions have been impacted for the past 600 years (Maloney 1985), although, only since the 1970s has the conversion of forests for agricultural use begun to exert stress on tropical forests (Aiken and Moss 1975). In its eastern part, the forests of Sabah and Sarawak are primarily threatened by logging and by conversion to plantations, especially of two major cash crops, rubber and oil palm (Primack and Hall 1992; Abdullah and Hezri 2008). Another anthropogenic activity that is a potential threat to local amphibians and their habitats is limestone mining (in northwestern Peninsular Malaysia, western and central Sarawak, and northeastern Sabah). Latiff and Zakri (1998) considered transformation of once pristine landscape, especially in montane regions, as one of the most worrisome issues of the time, as it has brought about associated changes in soil, water, vegetation, and atmosphere. According to the same study, land reclamation for development has also led to the drying up of a number of wetlands, aided, in part, by incentives provided for economic development.

In the city state of Singapore, proportionately more (*ca*. 95%) (Brook *et al*. 2003) of forest land has been lost as a result of urbanization, especially areas cleared for, *inter alia*, airports, buildings, harbours, ports, reclaimed sites, reservoirs, agricultural fields, and even ornamental gardens of exotic plants (Sanson 1992; Tan *et al*. 2007). The largest patch of forest — Bukit Timah, a 50–60 ha area that reaches 163 m asl, is protected as a Nature Reserve. Another significant region of importance for conservation is the Central Catchment area, comprising MacRitchie, Seletar, and the Lower and Upper Peirce Reservoirs, some 2000 ha of secondary forest, has been protected since 1910 (Sanson 1992). Within such a landscape, amphibian species richness and diversity

is related to fragment size and connectivity as well as to heterogeneity of the breeding habitat (Bickford *et al*. 2010a). Collectively, the Bukit Timah Nature Reserve (BTNR) and Central Catchment Nature Reserve (CCNR) are managed by the National Parks Board (Fig. 4).

Other drivers of loss of forest include fires as a land-conversion practice, logging, and unusually intense El Niño events. The ecological effects of vulnerability of forests to fire have been discussed by Sodhi *et al*. (2004) and include loss of seedlings, and population declines in megafaunas, besides haze and other atmospheric pollution; these partially negate economic gains. The 1997–1998 El Niño, for instance, caused material damage estimated between US$ 4.4 and 9.7 billion, affecting some 70 million people (Lohman *et al*. 2007).

Fig. 4. In the heart of Singapore lies the Central Nature Reserve, which includes the Bukit Timah Nature Reserve on the southwest and the larger, Central Catchment Nature Reserve, to the east. Approximately 70% of Singapore's native frog species are confined to these forested habitats. Map prepared by Tony O'Dempsey.

B. Pollution

Amphibians are affected by environmental contaminants that are absorbed through their skin and also via food and pulmonary routes (Smith *et al*. 2007). Chemicals linked with agriculture and industry constitute hazards for humans and, when released into the environment, may affect life histories of local amphibian species in specific ways. Tan (1998) reported that levels of certain organochlorine pesticides (including endosulfan, dieldrin, lindane, and DDT) have exceeded the critical levels for aquatic life in sample sites in Peninsular Malaysia. Organochlorines and other pesticides are used in Malaysia to control crop pests (Meier *et al*. 1983; Lee *et al*. 2009) and a variety of toxins are released as a byproduct of industrial and agricultural industries. However, there have been few published studies of their effects on local frog populations, one being Lee's and Stuebing's (1990) report of heavy metal contamination in a population of *Phrynoidis juxtaspera* near a copper mine in Sabah. The study reported by Othman *et al*. (2009), based on a Thai population of *Fejervarya limnocharis*, is relevant to Malaysia and Singapore, and shows cadmium accumulation from contaminated sites. Abdullah *et al*. (2005) reported that large quantities of pesticides used by the horticultural industry in the Cameron Highlands, a known amphibian hotspot in Peninsular Malaysia, are absorbed by the topsoil. The same study brought attention to the high amounts of fertilizers that are used locally and which have the potential to cause nitrate contamination of the groundwater in these hills.

C. Exploitation

Exploitation of amphibians for food and medicine in Malaysia is varied, depending on locality. A majority of the human population in Peninsular Malaysia is ethnically Malay and followers of Islam, which prohibits the use of amphibian flesh (Das 2012). Nonetheless, an undocumented number of large species of frogs are harvested by indigenous tribes (such as the Orang Asli). In larger towns, restaurants may serve the exotic *Lithobates catesbeianus*, which is farmed for this purpose. Farms are generally privately operated, although at least one, operated by the Department of Veterinary Services, Perak Darul Ridzuan, offers advice on frog farming (Anonymous 2008) and courses on frog farming, involving exotic frog species, are conducted by the privately owned Sepang Today Aquaculture Center. In Singapore, the Jurong Frog Farm, in Kranji, farms *L. catesbianus*

for meat, extracts of essence (for Chinese traditional medicine), and other products. In Sarawak and Sabah, large species of frogs are collected by forest-dwelling tribes such as the Ibans, Bidayuhs, and Dusun-Kadazans, and include *Limnonectes ingeri, L. leporinus,* and *L. malesianus*. Farms, both for *Lithobates catesbeianus* and *Hoplobatrachus rugulosus,* exist in Sarawak and Sabah, respectively, to supply restaurants in towns and cities, and often tadpoles are on offer in pet shops and in fishing shops for use as bait or as food for carnivorous ornamental fish (chiefly, the Arowana or the bonytongue fishes, *Scleropages* spp.). Native amphibians are not known to be farmed for food, although a study by Ho *et al*. (2008) reported lower fat content in the locally-occurring *Limnonectes leporinus* compared to the exotic *Lithobates catesbianus*. Additionally, Lee *et al*. (2008) reported heavy metal contamination as well as antibiotic resistance in bacteria extracted from farm-reared *L. catesbianus* from Malaysia, suggesting potential health hazards to their consumers.

The pet trade in the region features mostly exotic (American, African, and Chinese) amphibian species. However, several websites of retail outlets in Kuala Lumpur offer local species of amphibians to Malaysian and foreign buyers, and list forest-dwelling species of frogs and caecilians, that are, in all likelihood, harvested from the wild.

D. Other Threats

The fungal pathogen *Batrachochytrium dendrobatidis* (Bd) is known to have an impact on amphibian populations, causing the disease chytridiomycosis (Rachowicz *et al*. 2006; Berger *et al*. 2009; Heatwole 2013). A recent report by Savage *et al*. (2011) announced the discovery of Bd from four families of frogs from Peninsular Malaysia, while searches for its occurrence in East Malaysia and Singapore have, thus far, been negative. Nonetheless, the breeding and sale of African *Xenopus laevis, Hymnochirus* cf. *boettgeri,* and the Neotropical horned frog, *Ceratophrys* spp., may be a cause for concern as these species have been implicated in the spread of Bd (Weldon *et al*. 2004; Une *et al*. 2008). Additionally, exotic species that escape from frog farms, especially the carnivorous tadpoles of *Hoplobatrachus rugulosus* and adults both of this species and of *Lithobates catesbianus*, may potentially compete with local amphibian and fish species. Frog species may also be deliberately introduced, as a religious practice. Several religions, including Buddhism, preach that releasing animals brings good luck (Iliff 2002; Hughes 2007; Ng and Lim 2010) and the occurrence of *L. catesbianus* in at least one locality (Gunung Ledang, Johor, Peninsular Malaysia), reported by Chan *et al*. (2008), as well as in localities in the Kepong area (personal observations), may be the result of such practice.

Climatic change may yet pose as the most serious threat to the region's amphibians, with current trends in land-use also posing a potential problem for survival (review by Bickford *et al*. 2010b).

III. CONSERVATION

A. Identifying Threatened Species

An early attempt to identify amphibians locally threatened in Singapore was provided by Lim (1994), who listed four species in the Singapore Red Data Book: *Ichthyophis pauciculcus*, *Pelophryne brevipes* (Sunda populations currently referred to *Pelophryne signata*), *Rana paramacrodon* (current name: *Limnonectes paramacrodon*), and *Kalophrynus pleurostigma*. These are listed as under varying levels of threat, primarily from habitat destruction, and for two species, local rarity. No equivalent effort appears to have been conducted for Malaysia before the Global Amphibian Assessments, a collaborative project of the Species Survival Commission of the IUCN, The World Conservation Union, the Center for Applied Science of Conservation International, and NatureServe (Stuart *et al*. 2004), held between 2001 and 2004. These assessments identified 1856 species of amphibians as threatened worldwide, representing 32.5% of the known fauna. Of the 218 amphibian species then known from Malaysia, 47 were threatened with extinction (Critically Endangered) and 12 were considered Endangered and 34 Vulnerable. Drivers of threat include habitat loss and deforestation, since a majority of the species occurs in areas targeted for commercial logging and industrialization, as well as for residential/urban development. Primary habitats are also used for agriculture and livestock farming, and suffer pollution from industrial, military, agricultural, and forestry effluents (Stuart *et al*. 2008).

B. Protected Areas

Starting with a wildlife reserve in northern Pahang, in the central portion of the Malay Peninsula in 1924, and including, in 1938, parts of Kelantan and Terengganu, the first Malaysian national park, the King George V National Park (currently Taman Negara), was established (Marshall 1973). As elsewhere in the region, focal species were megavertebrates, although numerous amphibians are found in this and other protected areas in the country. The current area under the PA system in Malaysia is 5 million ha, comprising 15.3% of the land area of the country (Anonymous 2011). The same source estimated forest cover (including plantation forests) as 19.52 million ha, or 59.5% of the total land area. Apart from a number of PAs in the country, Malaysia has two UNESCO World Heritage Sites and six Ramsar Sites (Anonymous 2009).

C. Legislation and Enforcement

The Malaysian Constitution empowers the Federal and State governments to make laws for wildlife conservation. Eleven states in Peninsular Malaysia follow the Malaysian (Federal) Wildlife Acts, while Sabah has the Wildlife Conservation Enactment, 1997, and Sarawak, the Wildlife Protection Ordinance, 1998. Wildlife in Singapore comes under the jurisdiction of National Parks Singapore and also, the Agri-Food and Veterinary Authority of Singapore (including enforcement of the 'Animal and Birds Act'). No specific amphibian species are protected under existing legislation in Malaysia and Singapore, although as 'wildlife', these fall under the purview of agencies entrusted with enforcement of legislation concerning conservation. Implementing agencies include the (1) Department of Wildlife and National Park (DWNP, locally, Jabatan Perindungan Hidupan Liar dan Taman Negara, or Perhilitan) for Peninsular Malaysia, (2) Singapore National Parks Board for Singapore, (3) Sabah Parks and Sabah Wildlife Department for Sabah and Sarawak Forest Department, and (4) Sarawak Forestry Corporation for Sarawak. Both Malaysia and Singapore are signatories of CITES.

D. Pollution

Integrated pest management within Malaysia falls under the purview of the Pesticides Board of Malaysia, which has its roots in the 1980s, when emphasis was placed on selective use of pesticides, with removal or restriction of those of broad-spectrum and with long residual effect (Othman and Palasubramaniam 2001). Pesticides removed from use are listed in Table 3 (after Yeoh 2000). Although a user of agrochemicals associated with production of its major export crop, palm oil, the levy for cleaning up of chemical wastes in Malaysia has been attributed to the low levels of aquatic pollution from these sources (Vincent 1993). Several governmental agencies (including the Natural Resources and Environment Board of Sarawak, the Department of Environment in Sabah, and the Department of Environment, Malaysia) are active in monitoring pollution, including water pollution brought about by land clearing, sewage discharge, and industrial effluents. In Singapore, the National Environment Agency is tasked with monitoring and control of pollution. Occasionally, large-scale developments in close proximity to forested habitats have resulted in the degradation of stream quality. For example, in May 2009, extensive excavations near a major highway caused large amounts of silt and mud to overflow into a forest tributary system that meandered for many kilometers. In its path, many stream-dependant frogs were found smothered in mud that disrupted respiration across their permeable skin (Fig. 5).

Fig. 5. A Malaysian Giant Frog, *Limnonectes blythii,* smothered in fine mud along a forest stream in May 2009. The source of this pollution was traced to careless excavation works uphill and upstream of this tributary. Photograph by Vilma D'Rozario.

Table 3. Pesticides withdrawn or banned/restricted by the Pesticide Board of Malaysia. Data from Yeoh (2000).

Pesticide	**Action**
Aldrin	Withdrawn by parent company
Azinphos-ethyl	Withdrawn by parent company
Diledrin	Withdrawn by parent company
Endrin	Withdrawn by parent company
Benomyl	Withdrawn by parent company
Parathion-methyl	Banned
Captafol	Banned
Chlordane	Banned
DDT	Banned
Folpet	Banned
Heptachlor	Banned
Sodium	Banned
Penthachlorophenate	Partial ban (not for paddy)
Endosulphan	Partial ban (not for cocoa and pepper)
Lindane (gamma-BHC)	Partial ban (use only for palm oil and coconut)
Methamidophos	Partial ban (used only for palm oil and coconut)
Monocrotophos	Partial ban (used only for palm oil and coconut)

E. Guides for Identification

There are guides for identification of the amphibians of Peninsular Malaysia, including depiction of a limited number of species in black-and-white photographs, and accompanied by limited ecological and distributional information (cf. Berry 1975). Inger and Stuebing (2005) produced a guide for Sarawak and Sabah that, besides being more recent, contains coloured illustrations critical for the identification for amphibians. The amphibian fauna of Singapore is richly illustrated in the current field guides by Lim and Lim (2002) and Baker and Lim (2008). Two websites present current information on the amphibians of Malaysia: "Amphibians and Reptiles of Peninsular Malaysia" (Ahmad *et al*. 2011) and "Frogs of Borneo" (Haas and Das 2007), both updated periodically.

F. *Ex Situ* Conservation and Public Education

Few public zoological facilities target amphibians, as all existing *ex situ* programmes for threatened animals focus mainly on mammals; also treated are two species of birds and two of reptiles (Anonymous 2009). Zoo Negara, Malaysia's national zoological gardens and the Singapore Zoological Gardens, both exhibit local and exotic species of amphibians, but no *ex situ* conservation programme has been initiated. Zoo Negara, in collaboration with AmphibianArk has, in the past, conducted regional workshops on *ex situ* techniques specific for the frogs of southeastern Asia. At the Singapore Zoo, a 'Conservation Needs Assessment Workshop' was organized between 31 October and 2 November 2011, in conjunction with Amphibian Ark and the National University of Singapore, to better ascertain the updated status and current threats to native frogs. Prior to this, a poster on Singapore's frogs was produced in 2008 (the Year of the Frog) and subsequently distributed to local schools. Laboratory protocol for breeding of the indigenous *Fejervarya cancrivora*, the current mainstay of the international trade in frog legs (Kusrini and Alford 2006; Kusrini 2012), has been published recently (Kurniawan *et al*. 2009), and

knowledge of captive husbandry of amphibians, including breeding, is available with western zoos and academic institutions (see Browne and Zippel 2007; Griffiths and Pavajeau 2008), should this be required.

One of few examples of public outreach for the region's amphibians include the Frog Museum, maintained by the Institute of Tropical Biodiversity Centre at Universiti Sabah Malaysia in Kota Kinabalu, Sabah. A recent statement (Rowley *et al*. 2009) by leading researchers in the region also called for strong involvement of stakeholders, students, and professionals for undertaking activities relevant to the conservation of Malaysian and other southeastern Asian amphibians.

IV. ACKNOWLEDGEMENTS

We thank Harold Heatwole for inviting us to prepare this essay and for his editorial input. We are grateful to the following colleagues for information, publications, and ideas: David Bickford, Kelvin Kueh Boon Hee, Datuk Chan Chew Lun, Chan Kin Onn, Joseph Charles, Lord Cranbrook, T. Ulmar Grafe, L. Lee Grismer, Alexander Haas, Robert F. Inger, Alexander Haas, Maklarin Lakim, Lim Boo Liat, Kelvin K. P. Lim, Peter K. L. Ng, Ong Jia Jet, Robert B. Stuebing, Mona Octavia Sulai, Tan Heok Hui, Andrew Alek Tuen, Khoon Meng Wong, Paul Yambun, Dennis Yong, Yong Hoi Sen, and Pui Yong Min. Over the years, our researches on amphibians of Malaysia and Singapore were supported by grants administered by Universiti Malaysia Sarawak, the Forest Research Institute Malaysia, and the National University of Singapore.

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