Fall/Winter 2006
VOLUME 4 www.herpetofauna.org DECEMBER

AMPHIBIAN & REPTILE CONSERVATION

THE INTERNATIONAL JOURNAL DEVOTED TO THE WORLDWIDE PRESERVATION AND MANAGEMENT OF AMPHIBIAN AND REPTILIAN DIVERSITY

Discovery of Chytrid fungus in the Brazilian Atlantic forest

Conservation of Indonesian amphibians and reptiles

Herpetofaunal diversity in the Togo Hills of West Africa

Land use and anuran biodiversity in southeast Kansas, USA

Borneo's montane herpetofauna

PRINT
ISSN: 1083-446X

http://www.doaj.org/
OPEN ACCESS JOURNAL
http://www.doaj.org/doaj?func=openurl&issn=1083446X&genre=journal

ONLINE
ISSN: 1525-9153

Amphibian and Reptile Conservation 4(1):3-11.
DOI: 10.1514/journal.arc.0040015 (1504KB PDF)

Crocker Range National Park, Sabah, as a refuge for Borneo's montane herpetofauna

INDRANEIL DAS[1]

Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, MALAYSIA

***Abstract.*—Crocker Range National Park in Sabah (East Malaysia), northern Borneo, is an exceptional area for herpetological diversity. Inventories of the Park are incomplete, but show high diversity, as well as regional endemicity shared with the adjacent and more well-known Gunung Kinabalu National Park. The montane ecosystem of the Range offers refuge for a number of rare herpetofaunal taxa, including *Stoliczkia borneensis, Rhabdophis murudensis, Oligodon everetti, Philautus bunitus, Ansonia anotis, Sphenomorphus aesculeticola,* and undescribed species of squamates of the genera *Sphenomorphus* and *Gongylosoma*. The 59 species of amphibians and 45 species of reptiles now recorded from the Range represent 39 and 16.2 per cent of the total Bornean amphibian and reptile fauna, respectively. The high levels of deforestation of the surrounding regions of Borneo, particularly lowland rainforests, highten the importance of protection of primary forests of northern Borneo's Crocker Range.**

Key words. *Crocker Range National Park, Sabah, Malaysia, herpetofauna, conservation*

Citation: Das, Indraneil. 2006. Crocker Range National Park, Sabah, as a refuge for Borneo's montane herpetofauna. Amphib. Reptile Conserv. 4(1):3-11(e15).

Introduction

Borneo, one of four major islands of the great Indo-Malayan Archipelago (along with Sumatra, Java and Sulawesi), is situated on the eastern edge of the Sunda Shelf between coordinates 04° S to 07° N and from 109–119° E. It is the second largest tropical island in the world (after New Guinea), covering a land area of approximately 743,380 sq km. During the Pleistocene glaciation, sea levels fell between 120–200 m below current levels, uniting the islands of the Sundas (Morley and Flenley 1987). Palynological evidence reveals that during the last glacial maxima, upland plant species moved down, in response to temperature changes (Flenley 1997; Newsome and Flenley 1988).

Vegetational zonation for Borneo is arguably best known from Gunung Kinabalu (Kitayama 1991), the northern edge of Crocker Range, which has a largely intact vegetation. At about 1,200 m is the upper boundary of lowland rainforest, where the majority of emergent trees, comprises primarily the dipterocarps, disappear from the canopy (Beaman and Beaman 1998). The lower montane forest is five-layered, lacking emergents. The upper limit of the lower montane forest is 2,000–2,350 m, that of the upper montane forest, between 2,800–3,000 m. The upper montane forest has a dense herbaceous layer. The upper limit of the lower subalpine coniferous forests is 3,400 m, which is sparse in undergrowth and lower in height. Unfortunately, not much is known of the ecological distribution of the montane fauna within these altitudinal ranges and even less so of their conservation status. Montane regions, particularly ranges at 1,200 m above sea level, because of their Paleohistory, have been centers for speciation and endemism. Because of the inaccessible nature of montane regions in terms of logistics, these have also remained one of the least known, and most generalizations stem from studies conducted in Gunung Kinabalu, the highest mountain in Borneo (see MacKinnon et al. 1996).

Adjacent to the Gunung Kinabalu National Park is the Crocker Range National Park, although the Kinabalu region is geologically and floristically part of the same range. Situated in northwestern Sabah, this is the largest protected area in East Malaysia, covering an area of 1,399 sq km. The Park is named for William Maunder Crocker (?–1899), a British administrator with the Rajah Brooke's Sarawak Civil Service, who introduced British administrative practice in what was then British North Borneo (now the Malaysian State of Sabah). The altitudinal variation of this Park is remarkable, in rising from near sea level to 1,670 m and extending from the base of Gunung Alab to the town of Tenom. The higher slopes are dominated by moss forests and by a profusion of rhododendrons and orchids. A general description of the site is in Briggs (1997:68). Preliminary studies on the herpetofauna of the Crocker Range National

Correspondence. [1]*Email: idas@ibec.unimas.my*

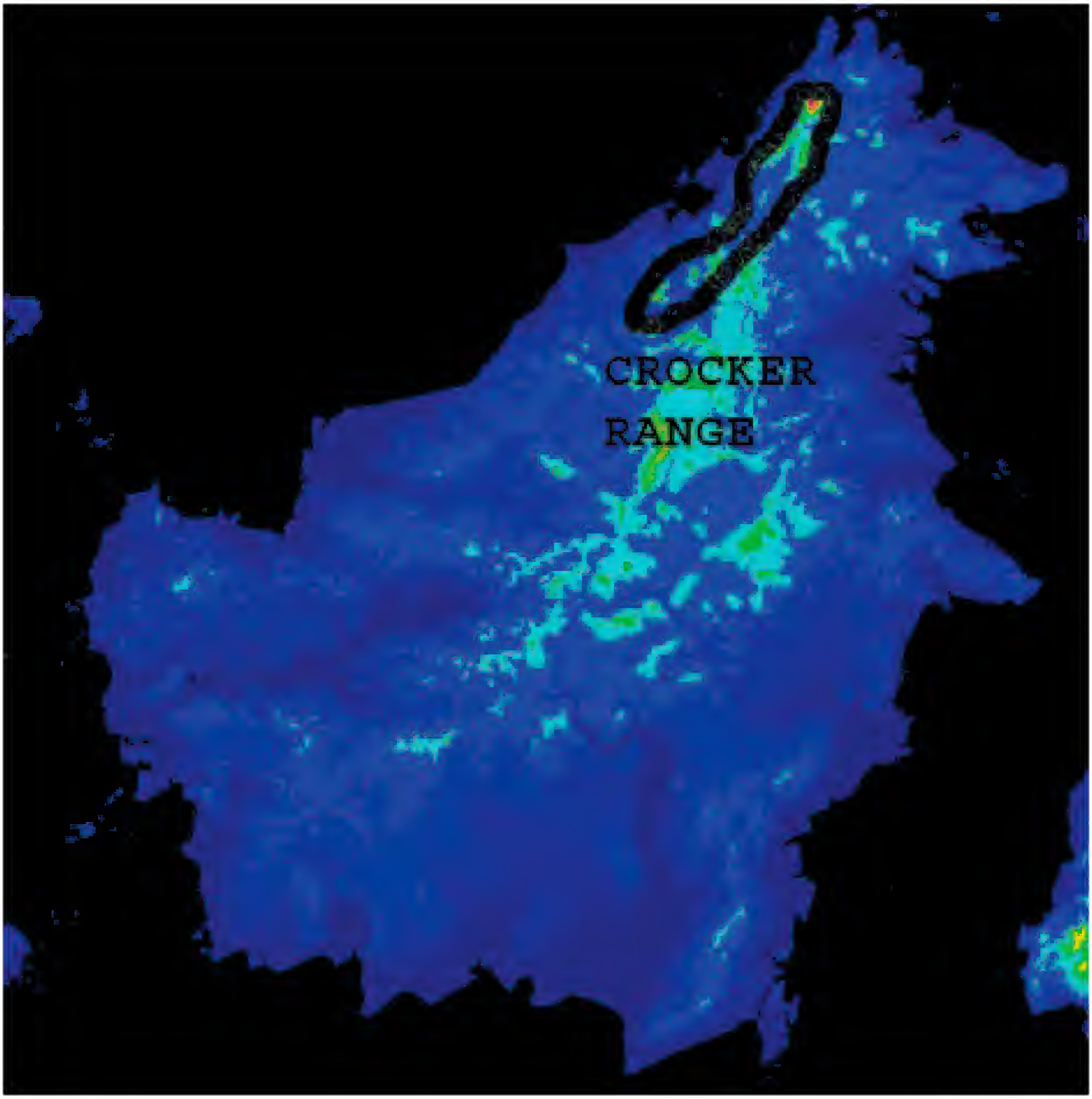

Figure 1. Map of Borneo, showing the location of Crocker Range National Park, Sabah. Map generated with the MICRODEM mapping program written by Peter Guth of the U.S. Naval Academy, using the GTOPO30 data set and edited by the author using Photoshop version 6.0.
DOI: 10.1514/journal.arc.0040015g001

Park, at low elevations (290–410 m) have been conducted by Tan (1992), resulting in the discovery of new species by Inger (1989) and in general ecological studies of amphibians by Inger and Stuebing (1992). As predicted by Inger (1966) and Inger and Stuebing (1989), the fauna of both Sabah and of Borneo had continued to grow through new collections and better laboratory and field techniques. An assessment of the herpetological biodiversity of Crocker Range, Sabah, was conducted 2000–2001, in order to gather baseline data on species occurrence and habitat use. The present manuscript, written in 2001, was delayed in press, and two subsequent field collections from the Crocker Range have now been published– Ramlah et al. (2001) and Hee et al. (2004) both reported anuran amphibians collected from the Range. Their lists have been included in the present inventory.

Methodology

Field work was conducted between the years 1999–2001, during both the dry and wet months. Collecting techniques included netting for aquatic amphibians (adults as well as the larval stages), and "cruising" collection, including walking along forest trails or streams at all times of the day, and particularly after dusk, following evening showers. Potential microhabitats (e.g., under fallen trunks and branches and but-

Table 1. Checklist of the herpetofauna of Crocker Range (the National Park and associated lowlands).

Amphibians
Bufonidae
Ansonia anotis Inger, Tan & Yambun, 2001
Ansonia hanitschi Inger, 1960
Ansonia leptopus (Günther, 1872)
Ansonia longidigita Inger, 1960
Ansonia spinulifer (Mocquard, 1890)
Bufo asper Gravenhorst, 1829
Bufo juxtasper Inger, 1964
Leptophryne borbonica (Kuhl & van Hasselt, 1827)
Pedostibes maculatus (Mocquard, 1890)
Pedostibes rugosus Inger, 1958
Megophryidae
Leptobrachella baluensis Smith,1931
Leptobrachella parva Dring, 1983
Leptobrachium montanum Fischer, 1885
Leptolalax cf. *gracilis* (Günther, 1872)
Leptolalax cf. *pictus* Malkmus, 1992
Megophrys nasuta (Schlegel,1858)
Megophrys cf. *kobayashii* Malkmus & Matsui, 1997
Microhylidae
Chaperina fusca Mocquard, 1892
Kalophrynus heterochirus (Boulenger, 1900)
Kalophrynus pleurostigma Tschudi, 1838
Kalophrynus subterrestris Inger, 1966
Kaloula pulchra Gray, 1831
Metaphrynella sundana (Peters, 1867)
Microhyla borneensis Parker, 1926
Ranidae
Fejervarya limnocharis (Wiegmann, 1835)
Huia cavitympanum (Boulenger, 1893)
Ingerana baluensis (Boulenger, 1896)
Limnonectes finchi (Inger, 1966)
Limnonectes ingeri (Kiew, 1978)
Limnonectes kuhlii (Tschudi,1838)
Limnonectes leporinus (Andersson, 1923)
Limnonectes palavanensis (Boulenger, 1894)
Meristogenys kinabaluensis (Inger, 1966)
Meristogenys orphnocnemis (Matsui, 1986)
Meristogenys poecilus (Inger & Gritis, 1983)
Meristogenys whiteheadi (Boulenger, 1887)
Occidozyga baluensis (Boulenger, 1896)
Rana erythraea (Schlegel, 1837)
Rana hosii Boulenger, 1891
Rana luctuosa (Peters, 1871)
Rana raniceps (Peters, 1871)
Rana signata (Günther, 1872)
Staurois latopalmatus (Boulenger, 1887)
Staurois natator (Günther, 1858)
Staurois tuberilinguis Boulenger, 1918
Rhacophoridae
Nyctixalus pictus (Peters, 1871)
Philautus aurantium Inger, 1989
Philautus bunitus Inger, Stuebing & Tan, 1995
Philautus hosii (Boulenger, 1895)
Philautus mjobergi Smith, 1925

Continued on page 007.

Plate 1. A view of forests of the Crocker Range National Park at 16th Mile, on the Papar-Keningau Pass.
DOI: 10.1514/journal.arc.0040015g002

Plate 2. *Megophrys nasuta.*
DOI: 10.1514/journal.arc.0040015g003

Plate 3. *Nyctixalus pictus.*
DOI: 10.1514/journal.arc.0040015g004

Plate 4. *Staurois natator.*
DOI: 10.1514/journal.arc.0040015g005

Plate 5. *Limnonectes palavanensis.*
DOI: 10.1514/journal.arc.0040015g006

Table 1. Continued.

Amphibians
Philautus petersi (Boulenger, 1900)
Polypedates leucomystax (Gravenhorst, 1829)
Polypedates macrotis (Boulenger, 1891)
Polypedates otilophus (Boulenger, 1893)
Rhacophorus angulirostris Ahl, 1927
Rhacophorus baluensis Inger, 1954
Rhacophorus everetti Boulenger, 1894
Rhacophorus gauni (Inger, 1966)
Rhacophorus pardalis Günther, 1858
Reptiles
Agamidae
Bronchocela cristatella (Kuhl, 1820)
Draco haematopogon Boie in: Gray, 1831
Phoxophrys borneensis Inger, 1960
Phoxophrys cephalum (Mocquard, 1890)
Eublepharidae
Aeluroscalabotes felinus (Günther, 1864)
Gekkonidae
Cosymbotus platyurus (Schneider, 1792)
Cyrtodactylus baluensis (Mocquard, 1890)
Cyrtodactylus matsuii Hikida, 1990
Scincidae
Apterygodon vittatus Edeling, 1864
Mabuya sp.
Sphenomorphus sp.
Tropidophorus mocquardii Boulenger, 1894
Colubridae
Ahaetulla prasina (Boie, 1827)
Asthenodipsas laevis (Boie, 1827)
Asthenodipsas malaccanus Peters, 1864
Amphiesma flavifrons (Boulenger, 1887)
Amphiesma saravacense (Günther, 1872)
Calamaria leucogaster Bleeker,1860
Calamaria suluensis Taylor, 1922
Coelognathus flavolineatus (Schlegel, 1827)
Gongylosoma baliodeirum (Boie, 1827)
Gongylosoma longicauda (Peters, 1871)
Gongylosoma sp.
Gonyophis margaritatus (Peters, 1871)
Hydrablabes periops (Günther, 1872)
Lepturophis albofuscus (Duméril, Bibron & Duméril, 1854)
Lycodon effraenis Cantor, 1827
Lycodon subcinctus Boie, 1827
Oligodon everetti Boulenger, 1893
Pareas nuchalis (Boulenger, 1900)
Psammodynastes pulverulentus (H. Boie in F. Boie, 1827)
Pseudorabdion albonuchalis (Günther, 1896)
Ptyas fusca (Günther, 1858)
Rhabdophis chrysargos (Schlegel, 1827)
Rhabdophis conspicillatus (Günther, 1872)
Rhabdophis murudensis (Smith, 1925)
Sibynophis geminatus (Boie, 1826)
Sibynophis melanocephalus (Gray, 1825)

Continued on page 009.

Plate 6. *Rhacophorus everetti.*
DOI: 10.1514/journal.arc.0040015g007

Plate 7. *Meristogenys kinabaluensis.*
DOI: 10.1514/journal.arc.0040015g008

Plate 8. *Meristogenys whiteheadi.*
DOI: 10.1514/journal.arc.0040015g009

Plate 9. *Rana hosii.*
DOI: 10.1514/journal.arc.0040015g010

Plate 10. *Leptophryne borbonica.*
DOI: 10.1514/journal.arc.0040015g0011

Plate 11. *Phoxophrys borneensis.*
DOI: 10.1514/journal.arc.0040015g012

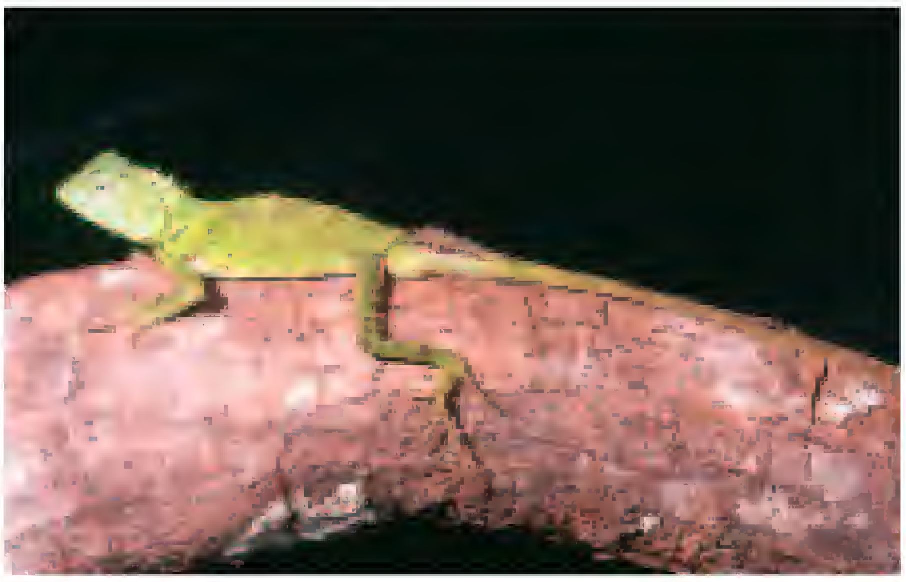

Plate 12. *Phoxophrys cephalum.*
DOI: 10.1514/journal.arc.0040015g013

Plate 13. *Aeluroscalabotes felinus.*
DOI: 10.1514/journal.arc.0040015g014

Table 1. Continued.

Colubridae
Stoliczkia borneensis Boulenger, 1899
Crotalidae
Parias sumatranus (Raffles, 1822)
Popeia sabahi (Regenass & Kramer, 1981)
Trimeresurus borneensis (Peters, 1872)
Tropidolaemus wagleri Wagler, 1830
Elapidae
Calliophis intestinalis (Laurenti, 1768)
Ophiophagus hannah (Cantor, 1836)

DOI: 10.1514/journal.arc.0040015t001

Table 2. Geographical statistics for Borneo. *Total land area figures for Indonesia and Malaysia represent only the sum of the Bornean components (Brunei Darussalam, Malaysia, and Indonesia). Data from Smythies and Davison (1999:6).

	Land Area (km^2)	Human Population (1990)	Population Density (km^2)	Forested Area (km^2) in 1990	Percent Forest Cover
***Brunei Darussalam**	5,760	300,000	52.1	4,360	75.7
***Malaysia**	198,160	3,527,200	17.8	134,214	67.7
Sabah	73,710	1,808,800	24.5	44,367	60.2
Sarawak	124,450	1,718,400	13.8	89,847	72.2
***Indonesia**	539,460	9,096,000	16.9	396,100	73.4
West Kalimantan	146,760	3,228,000	22.0	87,000	59.3
Central Kalimantan	152,600	1,396,000	9.1	111,100	72.8
South Kalimantan	37,660	2,597,000	69.0	8,000	21.2
East Kalimantan	202,440	1,875,000	9.3	180,000	88.9
Total	**743,380**	**12,923,200**	**17.4**	**534,674**	**71.9**

DOI: 10.1514/journal.arc.0040015t002

tresses of tree trunks) were searched. Data on specimens taken from systematic institutions have also been collated. These include the Natural History Museum, London; Field Museum of Natural History, Chicago; Zoological Museum, Gunung Kinabalu National Park Headquarters; "Borneensis Collection" of Universiti Malaysia Sabah, Kota Kinabalu; and the Sabah State Museum, Kota Kinabalu.

Data recorded for each capture include species, sex, stage of growth, and reproductive condition. Voucher specimens were retained to verify identification and eventual deposition in appropriate systematic institutions. Dietary and microhabitat data was recorded in standard pro forma. All species and colour morphs were photographed in life using color slide transparency film, for use in talks, field manuals, and for production of publicity material.

Results and discussions

The known amphibian fauna includes the families Bufonidae (ten species), Megophryidae (seven species), Microhylidae (seven species), Ranidae (21 species), and Rhacophoridae (14 species). The reptile fauna recorded thus far includes Agamidae (four species), Eublepharidae (one species), Gekkonidae (three species), Scincidae (four species), Colubridae (27 species), Crotalidae (four species), and Elapidae (two species). Table 1 lists the herpetofauna of the Crocker Range as known at present.

As may be expected, a large number of species are exclusively montane in distribution. These include *Ansonia anotis*, *A. hanitschi*, *A. longidigita*, *Leptobrachella baluensis*, *L. parva*, *Leptobrachium montanum*, *Leptolalax* cf. *pictus*, *Kalophrynus subterrestris*, *Huia cavitympanum*, *Ingerana baluensis*, *Meristogenys kinabaluensis*, *M. orphnocnemis*, *M. poecilus*, *M. whiteheadi*, *Rana signata*, *Philautus bunitus*, *P. petersi*, *Rhacophorus angulirostris*, *R. baluensis*, *R. everetti*, and *R. gauni*, among amphibians. A few widespread species occur in the lowlands of the Range, including the human-commensal, *Kaloula pulchra*. The number and proportion of reptiles that are essentially montane at this site seemed slightly lower: *Draco haematopogon*, *Phoxophrys borneensis*, *P. cephalum*, *Cyrtodactylus baluensis*, *C. matsuii*, *Sphenomorphus* sp., *Tropidophorus mocquardii*, *Amphiesma saravacense, Stoliczkia borneensis*, and *Popeia sabahi.* On the other hand, there were relatively more lowland species, including human commensals among the reptiles, and these include: *Bronchocela cristatella, Aeluroscalabotes felinus*, *Cosymbotus platyurus*, *Apterygodon vittatus, Mabuya* sp., *Ahaetulla prasina*, and *Coelognathus flavolineatus.*

Of the ecological types (habitat + use of diel time) represented among the amphibian fauna, 36 are exclusively riparian and/or utilize riparian habitats for breeding and 23 are non-riparian. All are active at night, and some (including *Staurois latopalmatus* and *Ansonia longidigita*) also found abroad during the day. Among the reptiles, only four species can be

Plate 14. *Amphiesma saravacense.* DOI: 10.1514/journal.arc.0040015g016

Plate 15. *Sphenomorphus* sp.
DOI: 10.1514/journal.arc.0040015g015

Plate 16. *Stoliczkia borneensis.*
DOI: 10.1514/journal.arc.0040015g017

Plate 17. Logging in the lowlands of the Crocker Range.
DOI: 10.1514/journal.arc.0040015g018

classified as riparian, the rest non-riparian. The reptile fauna of the Range could also be divided into a diurnal community (19 species) and a nocturnal one (25 species); the activity patterns of a few (e.g., the sit-and-wait viperid snakes, as well as their non-venomous colubrid mimic, the so-called Mock Viper, *Psammodynastes pulverulentus*) are difficult to classify into

either of these two categories. Divided into categories based on microhabitat use, 17 were exclusively arboreal, 24 primarily terrestrial, one primarily fossorial, and three aquatic.

A number of rare taxa are known from the Range. These include the third specimen known of the montane colubrid snake, *Stoliczkia borneensis,* hitherto known only from Gunung Kinabalu and Trus Madi (and most recently, from Sarawak's Gunung Murud); *Oligodon everetti*, also known solely from the Gunung Kinabalu massif; and *Rhabdophis murudensis*, known from Gunung Murud, to the south of Crocker Range. Additional specimens of a Crocker Range frog endemic, *Philautus bunitus,* were collected. New species collected from the range include a semi-fossorial skink of the genus *Sphenomorphus* and the colubrid snake of the genus *Gongylosoma.* Another species of snake collected, *Popeia sabahi*, was until recently referred to the mainland Asian population of *Trimeresurus popeiorum*. The 59 species of amphibians and 45 species of reptiles recorded to date from the Range represent 39 and 16.2 percent of the total Bornean amphibian and reptile fauna, respectively.

The high levels of deforestation of countries within Borneo (excluding Brunei Darussalam; see Das 1994) are a cause for concern (Primack and Hall 1992; Table 2). Most of the productive forests of East Malaysia, for instance, have either been already logged or placed under logging concessions (MacKinnon et al., 1996:398).

The uncertain future of tropical rainforests of Borneo in the long term places great importance of protection of montane forests of northern Borneo, such as the Crocker Range of Sabah, for the survival of biodiversity.

Acknowledgments.—I thank Sabah Parks, and its Scientific Officer, Jamili Nais for permission and facilities to work in the Crocker Range National Park. Collections from the Park were made under permit number TS/PTD/5/5Jld. 14(76). Field work was supported by a research grant (UNIMAS 192/99 [4]) administered by Universiti Malaysia Sarawak. I thank Prof. Ghazally Ismail, former Deputy Vice Chancellor, UNIMAS, and Datuk Lamri Ali, Director of Sabah Parks for invitation to participate in the Crocker Range Scientific Expedition (1999); Fatimah Abang and Andrew Alek Tuen, successive Directors at the Institute of Biodiversity and Environmental Conservation (UNIMAS), for support and facilities, and colleagues, past and current, at IBEC (Stuart James Davies, and Nicolas Pilcher) for support. For field companionship, I thank Christopher Cowell Austin, Heok Hui Tan, and Kelvin Kok Peng Lim.

For permission and facilities to examine specimens under their care, I thank the staff of the Field Museum of Natural History, Chicago (Robert Frederick Inger, Alan Resetar, and Cassandra Redhed); Sabah Parks Zoological Museum, Gunung Kinabalu National Park Headquarters (Jamili Nais and Maklarin Lakim); Sabah State Museum, Kota Kinabalu (Anna Wong), and the Borneensis Collection of Universiti Malaysia Sabah, Kota Kinabalu (Maryati Mohammed, Ahmed Sudin, and Lucy Kimsui). Gary Geller, Jet Propulsion Laboratory, National Aeronautics and Space Administration, helped generate the base map of Borneo.

Finally, I'd like to thank Aaron Bauer and Lee Grismer for comments on the manuscript.

References

Beaman, J. H. and Beaman, R. S. 1998. *The Plants of Mount Kinabalu. 3. Gymnosperms and Non-Orchid Monocotyledons.* Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu/Royal Botanic Garden, Kew. xiii + 220 p.; 25 plates.

Briggs, J. 1997. *Parks of Malaysia: a practical guide and manual*. Longman Malaysia Sdn. Bhd., Selangor Darul Ehsan. 134 p.

Das, I. 1994. Evaluating biodiversity: the Batu Apoi experience. *Ambio* **23(4/5)**:238-242.

Flenley, J. R. 1997. The Quaternary in the tropics: an introduction. *Journal of Quaternary Science* **12**:345-346.

Hee, K. B., Sudin, A., Matsui, M., and Mohamed, M. 2004. Notes on the anurans of Crocker Range Park, p. 103-112 *in* Mohamed, M., Hamzah, Z., Tachi, T., and Nais, J. (editors). *Crocker Range Scientific Expedition 2002.* Universiti Malaysia Sabah, Kota Kinabalu. xiv + 268 p.

Inger, R. F. 1966. The systematics and zoogeography of the Amphibia of Borneo. *Fieldiana Zoology* **52**:1-402. [Reprinted 1990. Lun Hing Trading Company, Kota Kinabalu]

Inger, R. F. 1989. Four new species of frogs from Borneo. *Malayan Nature Journal* **42**:229-243.

Inger, R. F. and Stuebing, R. B. 1989. *Frogs of Sabah*. Sabah Parks Trustees, Kota Kinabalu. iv + 132 p.

Inger, R. F. and Stuebing, R. B. 1992. The montane amphibian fauna of northwestern Borneo. *Malayan Nature Journal* **46**:41-51.

Inger, R. F. and Tan, F. L. 1996. *The Natural History of Amphibians and Reptiles of Sabah.* Natural History Publications (Borneo), Sdn. Bhd., Kota Kinabalu. vi + 101 p.

Kitayama, K. 1991. *Vegetation of Mount Kinabalu Park, Sabah, Malaysia. Map of physiognomically classified vegetation.* East-West Center, Honolulu. 45 p.

MacKinnon, K., Hatta, G., Malim, M., and Mangalik, A. 1996. *The Ecology of Kalimantan*. Periplus Editions (HK) Ltd., Singapore. xxiv + 802 p.; 44 plates.

Morley, R. J. and Flenley, J. R. 1987. Late Cenozoic vegetational and environmental changes in the Malay Archipelago, p. 50-59 *in* Whitmore, T. C. (editor). *Biogeographic Evolution of the Malay Archipelago.* Oxford Monographs on Biogeography, Clarendon Press, Oxford. viii + 147 p.

Newsome, J. and Flenley, J. R. 1988. Late Quaternary vegetation history of the Central Highlands of Sumatra. II.: palaeopalynology and vegetational history. *Journal of Biogeography* **15**:555-578.

Primack, R. D. and Hall, P. 1992. Biodiversity and forest change in Malaysian Borneo. *BioScience* **42(11)**:829-837.

Ramlah, Z., Wasly, L., and Ali, H. 2001. An account of anuran at Crocker Range National Park, Sabah, p. 137-146 *in* Ismail, G. and Ali, L. (editors). *A Scientific Journey through Borneo. Crocker Range National Park, Sabah. Volume 1. Natural Ecosystem and Species Components*. ASEAN Academic Press, London. (6) + 267 p.

Smythies, B. E. and Davison, G. W. H. 1999. The Bornean Province, p. 5-37 *in* Smythies, B. E. (author). *The Birds of Borneo*. Fourth edition. Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu. xii + 853 p.

Tan, F. L. 1992. Ecological distribution of amphibians and reptiles in lowlands of Crocker Range National Park, Sabah, p. 496-497 *in* Ismail, G., Mohamed, M, and Omar, S. (editors). *Forest Biology and Conservation in Borneo*. Centre for Borneo Studies Publication No. 2., Yayasan Sabah, Kota Kinabalu. 500 p.

Manuscript received: 18 February 2002; Accepted: 21 July 2004; Published: 26 December 2006

Amphibian and Reptile Conservation 4(1):17-21.
DOI: 10.1514/journal.arc.0040017 (7300KB PDF)

A Brazilian anuran (*Hylodes magalhaesi*: Leptodactylidae) infected by *Batrachochytrium dendrobatidis*: a conservation concern

L. F. TOLEDO[1,5], C. F. B. HADDAD[1], A. C. O. Q. CARNAVAL[2,3], AND F. B. BRITTO[4]

[1]*Departamento de Zoologia, Instituto de Biociências, Unesp, Rio Claro, São Paulo, Caixa Postal 199, CEP 13506-970, BRAZIL* [2]*The Field Museum, 1400 South Lake Shore Drive, Chicago, Illinois 60605, USA* [3]*Museum of Vertebrate Zoology, Valley Life Science Building, University of California, Berkeley, California 94720, USA* [4]*Departamento de Biologia, Instituto de Biociências, Unesp, Rio Claro, São Paulo, Caixa Postal 199, CEP 13506-970, BRAZIL*

Abstract.—**Several studies have associated the chytrid fungus *Batrachochytrium dendrobatidis* with anuran population declines worldwide. To date, the fungus has been found in Africa, the Americas, Australia, and Europe. However, it has never been reported to occur in the Atlantic forest or Brazil. Based on morphological, histological, and molecular data, we encountered evidence of *B. dendrobatidis* infection in a high-altitude stream-dwelling Brazilian anuran species, *Hylodes magalhaesi* (Leptodactylidae). One population (Municipality of Camanducaia, State of Minas Gerais) was surveyed from 2001 to 2005. Tadpoles lacking teeth were observed and collected in 2004. Histological and molecular analyses identified infection by *B. dendrobatidis*. Although infected tadpoles seem nowadays to co-exist with the disease, our results are alarming due to the highly endangered situation of the Brazilian Atlantic forest and its fauna. Effects of the chytrid infection on the studied population are still unknown. Further investigations are needed to provide information on its distribution in relation to other populations of *H. magalhaesi*.**

Key words. *Batrachochytrium dendrobatidis, Hylodes, anuran decline, conservation, Atlantic forest, Brazil*

Citation: Toledo, L. F., Haddad, C. F. B., Carnaval, A. C. O. Q., and Britto, F. B. 2006. A Brazilian anuran (*Hylodes magalhaesi*: Leptodactylidae) infected by *Batrachochytrium dendrobatidis*: a conservation concern. Amphib. Reptile Conserv. 4(1):17-21(e17).

Introduction

Brazil currently figures as the most species-rich country in the world with regard to amphibian diversity (Young et al. 2004; Silvano and Segalla 2005), encompassing two biomes of conservation concern: the Cerrado and the Atlantic forest (Myers et al. 2000). Notwithstanding its striking percentage of endemic species, the Atlantic forest has been seriously threatened by human intervention, reduced to approximately 7% of its original distribution (Morellato and Haddad 2000), and therefore, considered one of the most important biodiversity hotspots for conservation (Myers et al. 2000, Conservation International 2005). Such intense habitat change and fragmentation have been tied to local amphibian population fluctuations and declines (for a recent review, see Eterovick et al. 2005). However, at a global scale, several factors other than habitat disturbance have been associated to amphibian population crashes (Collins and Storfer 2003), particularly emerging infectious diseases such as chytridiomycosis, caused by the fungus *Batrachochytrium dendrobatidis* (review in Daszak et al. 2003). This chytrid fungus is globally widespread (Speare and Berger 2000) and has been tied to amphibian declines in Australia, the Americas, and Europe (Berger et al. 1998, 1999a; Bosch et al. 2001). To date, there have been no reports of *B. dendrobatidis* occurring in the Atlantic forest or in Brazil. Based on morphological, histological, and molecular data, we document infection in *Hylodes magalhaesi*—a high-altitude stream-dwelling leptodactylid endemic to the Brazilian Atlantic rainforest.

Methods

Field survey

From 2001 to 2005, we followed a population of *H. magalhaesi* through yearly 10-day trips to Vila de Monte Verde, Municipality of Camanducaia, State of Minas Gerais (22°52'37.9"S, 46°02'01.8"W, ca. 1,600 m above sea level). Adults and tadpoles of *H. magalhaesi* were observed along a fast rivulet in this montane forest. Males were observed during the day while calling from the water margin (Fig. 1); tadpoles were observed under debris or in crevices under water. Adults were collected by hand during the day. Tadpoles (stage 25 *sensu* Gosner 1960) were collected with wicker fish traps, using raw meat as bait. Specimens were deposited in Célio F. B. Haddad anuran collection, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista, Rio Claro, State of São Paulo, Brazil (CFBH 8287: tadpole lot for molecular analysis, collected in January 2005; CFBH 8288: tadpole lot for histological analysis, collected in

Correspondence. [5]*Email: toledolf2@yahoo.com*

Figure 1. Adult male of *Hylodes magalhaesi*. Municipality of Camanducaia, State of Minas Gerais, Brazil. Photo: Célio F. B. Haddad.
DOI: 10.1514/journal.arc.0040017g001

January 2002). A collecting permit was provided by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA 02001.002792/98-03).

Histology

Four tadpoles with deformed oral disks were fixed in 10% formaldehyde solution for 24 hours (h), and their mouthparts were then transferred to a buffer sodium phosphate solution (pH 7.4), where they were kept for an additional 24 h. Mouthparts were dehydrated through 30-minute (min) immersion in each ethanol solution of a series of increasing concentrations (70, 80, 90, and 95%), then embedded in Leica resin for 24 h at 4°C before inclusion. Resin polymerization was performed in a 37°C chamber. Sections (5 Ìm thick) were stained with two techniques: hematoxylin and eosin (HE) were first used to document the general morphologic aspects of the tissue, and periodic acid Schiff (PAS) was subsequently used to enable better visualization of glycogen, mucin, basal membranes, and the fungus (Junqueira and Junqueira 1983).

Molecular analysis

We used specific DNA-based assay of Annis et al. (2004) to detect infection by *B. dendrobatidis* in two tadpoles preserved in ethanol (100%). From each tadpole, we extracted DNA from a 2 x 2 mm piece of mouth tissue corresponding to approximately half of the oral disk. We dried the material for 1 h at 55°C to allow for ethanol evaporation, then added 20 µl of polymerase chain reaction (PCR) buffer (Perkin-Elmer), and 2 µl of proteinase-K (10 mg/ml), crushing the tissue with a pipette tip to increase the contact surface between the material and the solution. We incubated this mixture for 3 h at 55°C, mixing occasionally. After centrifuging for a few seconds (s) at 6,000 RPM, we incubated the material for 5 min at 100°C as described in Annis et al. (2004). For DNA extraction, we added 20 µl of GeneReleaser (BioVentures) and followed a thermocycle program per manufacturer's protocols on a Peltier Thermal Cycler 200 (PTC-200, MJ Research). After centrifuging samples for 1 min at 6,000 RPM, the DNA-bearing supernatant was transferred to a new tube. To control for contamination, a blank extraction was carried out in a tube containing no sample.

PCR was performed to determine the presence of *B. dendrobatidis* in the extracted material, using primers Bd1a and Bd2a of Annis et al. (2004). We added 3 µl of extracted DNA, 19 µl of water, and 1.5 µl of each primer (10 µM solution) to a tube of PuReTaq Ready-To-Go PCR Beads (Amersham Biosciences). These primers are known to bind specifically to *B. dendrobatidis* DNA as opposed to that of other Chytridiomycota and are expected to result in the amplification of a fragment of approximately 300 base pairs (bp) containing *B. dendrobatidis* 5.8S ribosomal RNA and flanking internal transcriber spacer regions ITS1 and ITS2 (Annis et al. 2004). For amplification, we used a PCR thermocycle program comprising a denaturation step at 95°C for 5 min, 35 cycles of 94°C for 45 s, 60°C for 45 s, and 72°C for 1 min, and final extension at 72°C for 10 min. To ensure that no false

positives were generated due to contamination during the amplification step, we used the blank extraction as a negative control.

We evaporated all amplification products to bring them to final volumes of 10 µl, which were run on a 1% low-melt low-EDTA agarose gel for band visualization. We cut and incubated the bands of interest with 1 µl of GELase (Epicentre Technologies) for 5 min at 50°C, subsequently leaving them at 45°C overnight. We performed cycle sequencing reactions using 2 µl of template, 3 µl of water, 1 µl of BigDye Terminators ver. 3.0 (ABI Prism), 3 µl of BigDye Buffer, and 1 µl of primer. Cycle sequencing profiles comprised a denaturation step at 96°C for 1 min and 25 cycles of 96°C for 10 s, 50°C for 5 s, and 60°C for 4 min. We precipitated final products in ethanol and resuspended in 10 µl of Hi-Di formamide (ABI Prism) per manufacturer's protocols. Sequencing reactions were run on a 3730 Genetic Analyzer (Applied Biosystems). We used Sequencer version 4.1.2 (Gene Codes Corporation) to visualize sequences and to align them to partial sequences of ITS1 and adjacent 5.8S ribosomal RNA sequence of *B. dendrobatidis* available in GenBank (http://www.ncbi.nlm.nih.gov/Genbank/index.html; accession numbers AY598034 and AY997031). We used MegaBLAST (http://www.ncbi.nlm.nih.gov/BLAST/) to align and compare them to sequences of all fungi species available in GenBank. To that end, we retained all alignments with identity percentage higher than 60%, setting log-odd match and mismatch scores to 1 and -1, respectively. Only alignments larger than 40 bp in length and with E-scores equal or smaller than e-04 were considered for the purposes of sequence comparison.

Results

Field survey

The population did not seem to vary in abundance along the rivulet where calling males were found, or over the years of observation. However, no count data were collected to document these observations. Adults showed no apparent physical or behavioral abnormalities. Five tadpoles were collected in 2004, all showing deformed or incomplete mouthparts, with total or partial teeth loss. Most tadpoles also lacked keratinized jaw sheaths or showed partially keratinized jaw sheaths. Gut content observation nonetheless suggests that the lack of keratinized mouthparts seemed not to interfere with feeding ability. All four tadpoles collected in 2005 had completely keratinized mouthparts.

Histology

Fungal structures consistent with *B. dendrobatidis* occurred in the oral region of all four tadpoles, in the epidermis adjacent to tooth rows. Four stages of *B. dendrobatidis* were identified (Fig. 2A and 2B); an early phase containing a central spherical basophilic mass, a zoospore-filled phase with 4-10 round or oval basophilic zoosphores in cross section, empty spherical zoosporangia with internal septa, as well as later stage where the empty zoosporangium had collapsed into an irregular shape. These structures stained strongly with PAS. Zoosporangia were present at greater density in the areas of the epidermis of tooth rows and jaw sheaths that showed the most abnormal histology, consisting of hyperkeratosis and loss of superficial epidermis (Fig. 2C). The prominent keratin plate that forms the jaw sheath in healthy tadpoles was almost completely destroyed (Fig. 2D).

Molecular Analysis

DNA was successfully extracted from the material sampled. No contamination was found in the blank extraction. As expected under the scenario of infection by *B. dendrobatidis*, the PCR procedure resulted in a bright band of approximately 300 bp in both tadpoles (Fig. 3). No amplification was obtained in the negative control tube, thus excluding the possibility of contamination. Direct sequencing of the amplified band resulted in a chromatogram with several multiple peaks, which is not surprising given that these are tandem repeats of ribosomal DNA that are not identical. Yet, a 114-bp piece located at the 5' end of the sequence, excluding primer Bd1a, did not include multiple peaks and was easily aligned to portions of the ITS1+5.8S *B. dendrobatidis* sequences available in GenBank. In total, MegaBLAST encountered 21 GenBank records that aligned to this 114-bp query sequence. All of them correspond to fungi species. The obtained sequence was 100% identical to known partial sequences *B. dendrobatidis* and differed from all remaining fungi species by more than 9% in sequence composition (91% to 67% sequence identity). Based on data available in GenBank, sequences of congeneric species of Chytridiomycota can differ by approximately 5% in composition at this locus.

Discussion

The identification of *B. dendrobatidis* was confirmed by the fact that the morphology of the fungal structures was consistent with previous descriptions, particularly the presence of zoosporangia in four stages of development and the occurrence of colonial morphology in the zoosporangia (Berger et al. 1998, 1999b; Longcore et al. 1999; Pessier et al. 1999; Fellers et al. 2001). The morphological identification as *B. dendrobatidis* was confirmed by PCR showing a match with a partial sequence of the ITS1+5.8S sequence in GenBank.

Hylodes magalhaesi is an Atlantic forest endemic frog restricted to areas of high elevations in southeastern Brazil (> 1,500 m above sea level). To date, it has been known solely from its type locality (Municipality of Campos do Jordão, State of São Paulo; Bokermann 1964; Frost 2004). Our observations provide the second population record of the species, which extends its distribution approximately 50 km northward. They also provide the first record of this species in the State of Minas Gerais. The data represent the first report of the presence of *B. dendrobatidis* in Brazil and in the Atlantic forest. Furthermore, this is one of the southernmost reports of a natural population infected by *B. dendrobatidis* in the Americas (see also Herrera et al. 2005).

Our data are alarming with regard to the status of *H. magalhaesi* given the lack of information about this species (*H. magalhaesi* is classified under the World Conservation Union (IUCN) "Data Deficient" category, AmphibiaWeb

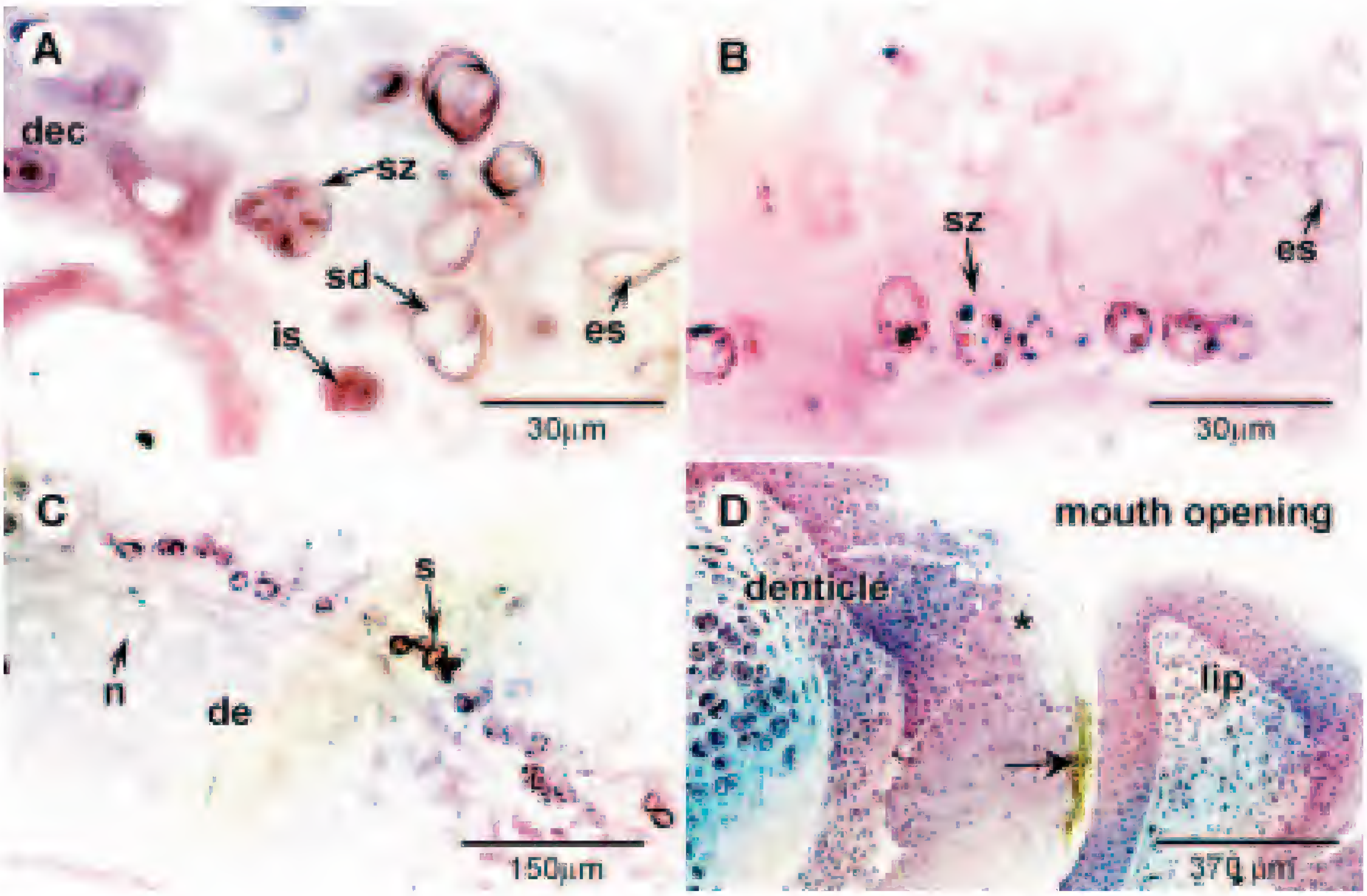

Figure 2. Mouthpart section of *H. magalhaesi* tadpole; keratinized epidermis with various stages of *Bd*. (**A**) Detail of sporangia as shown by HE technique: immature sporangium (**is**), sporangium with zoospores (**sz**), empty sporangium (**es**), and sporangium with internal septum (**sd**); **dec** = denticle epithelial cell. (**B**) Detail of sporangia as shown by PAS technique. (**C**) Fungus infection as shown by PAS technique, arrows point to sporangia (**s**); **de** = denticle epidermis; **n** = nucleus of epithelial cells. (**D**) Region of irregular epidermal surface (*) evidenced by HE technique. Arrow shows remaining keratinized denticle surface.
DOI: 10.1514/journal.arc.0040017g002

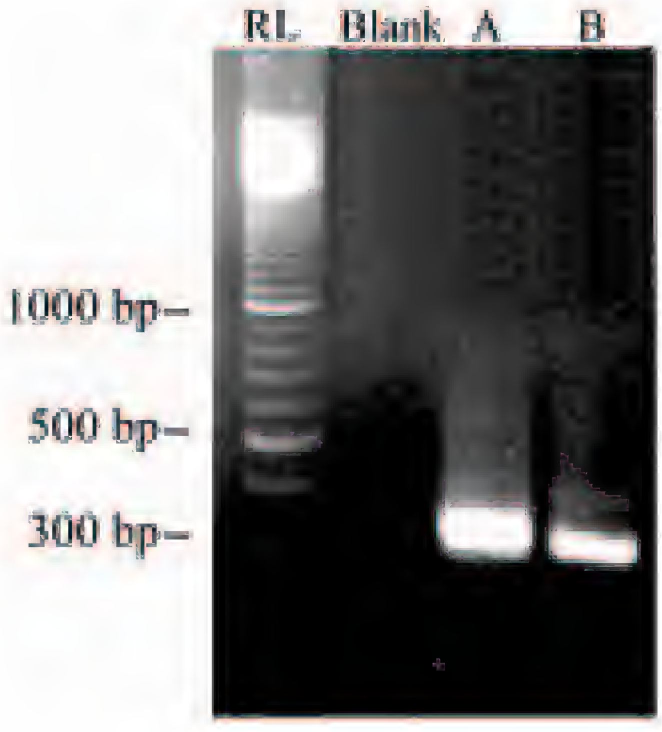

Figure 3. Gel image of PCR results using *Bd*-specific primers Bd1a and Bd2a. A reference DNA ladder is presented (**RL**). Results obtained with a negative control (extraction blank), DNA template from specimen CFBH 8287.1 (**A**), and DNA template from specimen CFBH 8287.2 (**B**) are provided.
DOI: 10.1514/journal.arc.0040017g003

2005), particularly given the increased rate of deforestation faced by the Brazilian Atlantic forest (Myers et al. 2000; Morellato and Haddad 2000). Population declines have been reported for other species of *Hylodes* endemic to this biome (*H. asper*, *H. babax*, *H. phyllodes*, and *H. lateristrigatus*). For *H. asper* and *H. phyllodes*, local extinctions have been attributed to climate change (Heyer et al. 1988; Bertoluci and Heyer 1995). Other decline-leading factors have been suggested for the remaining species of *Hylodes*, as well as for other mountain-stream frogs (cycloramphines, centrolenids, hylids, and dendrobatids), including infectious diseases (Weygoldt 1989). Observations by Weygoldt (1989) of the metamorphosis of individuals of *H. babax* led him to suggest the occurrence of bacterial infections in this species. However, there is a great probability that they could not complete their development due to *B. dendrobatidis* infection, as observed in other infected species (see Berger et al. 1998, 1999a).

Even though we have noticed no apparent decline in the abundance of adult *H. magalhaesi* over the last five years, additional and more intensive studies are necessary to determine the dynamics of the infected population. Tadpoles of *H. magalhaesi* seem to be able to feed normally with unkeratinized tooth rows, which could be caused by the presence of the chytrid (see also Berger et al. 1999a) and may represent a pathogen reservoir (Collins and Storfer 2003), with potential consequences for other less resistant anuran hosts in Brazil (see Daszak et al. 2004). The following questions shall be answered in future studies: Do apparently normal tadpoles also carry *B. dendrobatidis*? Are there differences concerning the trophic ecology of toothless and normal tadpoles? Does *B.*

dendrobatidis infect other stages of tadpole development? Do infected tadpoles metamorphose and reach adult sizes? Are post-metamorphic individuals infected? Are populations of *H. magalhaesi* declining at the study site? What other syntopic high-altitude stream-dwellers are also infected?

Acknowledgments.—C. R. B. Haddad and A. M. Haddad assisted in the field work. C. Hassapakis, R. Speare, R. W. R. Retallick, and an anonymous reviewer greatly improved the manuscript with their comments. DNA-based assays were carried out in the Field Museum Pritzker Laboratory for Molecular Systematics and Evolution thanks to permits issued by Brazil's Conselho de Gestão do Patrimônio Genético (CGEN licenses 037/2004 and 023/2004; deliberation published in Diário Oficial da União, 19/08/2004, section 1, page 116). E. O'Neill provided valuable assistance with the molecular work. FAPESP (proc. 01/13341-3) and CNPq supported the Herpetology lab, Departamento de Zoologia, Unesp, Rio Claro, São Paulo, Brazil. The authors also thank CNPq, CAPES, FAPESP, the National Science Foundation, Idea Wild, and Neotropical Grassland Conservancy for grants, scholarships, and equipment donation.

References

AmphibiaWeb. 2005. Information on amphibian biology and conservation. Berkeley, California. Available from http://amphibiaweb.org/ (accessed 20 November 2005).

Annis, S. L., Dastoor, F. P., Ziel, H., Daszak, P., and Longcore, J. E. 2004. A DNA-based assay identifies *Batrachochytrium dendrobatidis* in amphibians. *Journal of Wildlife Diseases* **40(3)**:420-428.

Berger, L., Speare R., Daszak, P., Green D. E., Cunningham, A. A., Goggin, C. L., Slocombe, R., Ragan, M. A., Hyatt, A. D., McDonald, K. R., Hines, H. B., Lips, K. R., Marantelli, G., and Parkes, H. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. *Proceedings of the National Academy of Sciences* **95(15)**:331-337.

Berger, L., Speare, R., and Hyatt, A. D. 1999a. Chytrid fungi and amphibian declines: overview, implications and future directions, p. 23-33 *in* Campbell, A. (editor). *Declines and Disappearances of Australian Frogs*. Environment Australia, Canberra. 236 p.

Berger, L., Speare, R., and Kent, A. 1999b. Diagnosis of chytridiomycosis of amphibians by histological examination. *Zoos Print Journal* **15(1)**:184-190.

Bertoluci, J. and Heyer, W. R. 1995. Boracéia update. *FrogLog* **14**:3.

Bokermann, W. C. A. 1964. Una nueva especie de *Elosia* de la Serra da Mantiqueira, Brasil (Amphibia, Leptodactylidae). [A new species of *Elosia* in the Serra da Mantiqueira, Brazil] *Neotropica* **10(33)**:102-107.

Bosch J., Martinez-Solano, I., and Garcia-Paris M. 2001. Evidence of a chytrid fungus infection involved in the decline of the common midwife toad (*Alytes obstetricans*) in protected areas of central Spain. *Biological Conservation* **97(3)**:331-337.

Collins, J. P. and Storfer, A. 2003. Global amphibian declines: sorting the hypotheses. *Diversity and Distributions* **9(2)**:89-98.

Conservation International. 2005. Biodiversity Hotspots. Available at http://www.biodiversityhotspots.org/xp/Hotspots (accessed 20 November 2005).

Daszak, P., Cunningham, A. A., and Hyatt, A. D. 2003. Infectious disease and amphibian population declines. *Diversity and Distributions* **9(2)**:141-150.

Daszak, P., Strieby, A., Cunningham, A. A., Longcore, J. E., Brown, C. C., and Porter, D. 2004. Experimental evidence that the bullfrog (*Rana catesbeiana*) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. *Herpetological Journal* **14(4)**:201-207.

Eterovick, P. C., Carnaval, A. C. O. Q., Borges-Nojosa, D. M., Silvano, D. L., and Sazima, I. 2005. Amphibian declines in Brazil: an overview. *Biotropica* **37(2)**:166-179.

Fellers, G. M., Green, D. E., and Longcore, J. E. 2001. Oral chytridiomycosis in the mountain yellow-legged frog (*Rana muscosa*). *Copeia* **2001(4)**:945-953.

Frost, D. R. 2004. Amphibian Species of the World: an online reference. Version 3.0. Electronic database accessible at http://research.amnh.org/herpetology/amphibia/index.html (accessed 20 November 2005). American Museum of Natural History, New York, USA.

Gosner, K. L. 1960. A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* **16(3)**:183-190.

Herrera, R. A., Steciow, M. M., and Natale, G. S. 2005. Chytrid fungus parasitizing the wild amphibian *Leptodactylus ocellatus* (Anura: Leptodactylidae) in Argentina. *Diseases of Aquatic Organisms* **64(3)**:247-252.

Heyer, R.W., Rand, A. S., Cruz, C. A. G., and Peixoto, O. L. 1988. Decimations, extinctions, and colonizations of frog populations in southeast Brazil and their evolutionary implications. *Biotropica* **20(3)**:230-235.

Junqueira, L. C. U. and Junqueira, L. M. M. 1983. *Técnicas básicas de citologia e histologia* [Basic techniques in cytology and histology]. Livraria Santos, São Paulo. 123 p.

Longcore, J. E., Pessier, A. P., and Nichols, D. K. 1999. *Batrachochytrium dendrobatidis* gen. et sp. nov., a chytrid pathogenic to amphibians. *Mycologia* **91(2)**:219-227.

Morellato, L. P. C. and Haddad, C. F. B. 2000. Introduction: the Brazilian Atlantic forest. *Biotropica* **32(1)**:1-7.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Fonseca, G. A. B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403(6772)**:853-858.

Pessier, A. P., Nichols, D. K., Longcore, J. E., and Fuller, M. S. 1999. Cutaneous chytridiomycosis in poison dart frogs (*Dendrobates* spp.) and White's tree frogs (*Litoria caerulea*). *Journal of Veterinary Diagnostic Investigation* **11(2)**:194-199.

Silvano, D. and Segalla, M. 2005. Conservation of Brazilian amphibians. *Conservation Biology* **19(3)**:653-658.

Speare, R. and Berger L. 2000. Global distribution of chytridiomycosis in amphibians. Online database available at: http://www.jcu.edu.au/school/phtm/PHTM/frogs/chyglob.htm (accessed 20 November 2005).

Weldon, C., Preez, L. H., Hyatt, A. D., Muller, R., and Speare, R. 2004. Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* **10(12)**:2100-2105.

Weygoldt, P. 1989. Changes in the composition of mountain stream frog communities in the Atlantic mountains of Brazil: frogs as indicators of environmental deteriorations? *Studies on Neotropical Fauna and Environment* **243(4)**:249-255.

Young, B. E., Stuart, S. N., Chanson, J. S., Cox, N. A., and Boucher, T. M. 2004. *Disappearing Jewels: the status of New World amphibians.* NatureServe, Arlington, Virginia. 54p.

Manuscript received: 07 August 2005; Accepted: 22 September 2005; Published: 26 December 2006

Amphibian and Reptile Conservation 4(1):22-45.
DOI: 10.1514/journal.arc.0040018 (1754KB PDF)

Biodiversity in a forest island: reptiles and amphibians of the West African Togo Hills

ADAM D. LEACHÉ[1, 5], MARK-OLIVER RÖDEL[2], CHARLES W. LINKEM[3], RAUL E. DIAZ[3], ANNIKA HILLERS[4], AND MATTHEW K. FUJITA[1]

[1]*Museum of Vertebrate Zoology and Department of Integrative Biology, 3101 Valley Life Sciences Building, University of California, Berkeley, California 94720-3160, USA* [2]*Department of Animal Ecology and Tropical Biology, Biocenter of the University, Am Hubla nd, D-97074 Würzburg, GERMANY* [3]*Division of Herpetology, Natural History Museum & Biodiversity Research Center and Department of Ecology and Evolutionary Biology, 1345 Jayhawk Boulevard, The University of Kansas, Lawrence, Kansas 66045-7561, USA* [4]*Institute of Biodiversity and Ecosystem Dynamics, University of Amsterdam, Kruislaan, 318, 1098, SM Amsterdam, THE NETHERLANDS*

***Abstract.*—Our recent surveys of the herpetological diversity of the West African Togo Hills documented a total of 65 reptile and amphibian species, making Kyabobo National Park one of the most diverse sites surveyed in Ghana. We provide accounts for all species recorded along with photographs to aid in identification. We recorded 26 amphibians, including six new records for Kyabobo N. P., one of which is a record for the Togo Hills. Our collection of reptile species (22 lizards, 16 snakes, and one crocodile) also provides new records and range extensions for Kyabobo N. P., such as the first observation of the dwarf crocodile, *Osteolaemus tetraspis*. Amphibian species still lacking from our surveys in the Togo Hills include several species that are adapted to fast running water or large closed forests, like the Togo toad, *Bufo togoensis* and the slippery frog, *Conraua derooi*. Appropriate habitat for such species still remains in Kyabobo, highlighting the need for additional survey work. We draw attention to the importance of conserving forest stream habitats, which will in turn help ensure the persistence of forest-restricted species. We also highlight those species that may prove most useful for evolutionary studies of West African rain forest biogeography.**

Key words. *Ghana, reptiles, amphibians, biogeography, conservation, biodiversity, Dahomey Gap, West Africa, Togo Hills, Kyabobo National Park*

Citation: Leaché, A. D., Rödel, M.-O., Linkem, C. W., Diaz, R. E., Hillers, A., and Fujita, M. K. 2006. Biodiversity in a forest island: reptiles and amphibians of the West African Togo Hills. Amphib. Reptile Conserv. 4(1):22-45(e18).

Introduction

The Guinean rain forest of Western Africa is a center of biological diversity with considerable endemism (Myers et al. 2000). The percentage of reptile and amphibian species endemic to this region far exceeds that of other tetrapod groups (reptiles = 33% and amphibians = 77% versus mammals = 8% and birds = 18%; Myers et al. 2000). Concomitant with this impressive diversity is an alarming rate of habitat loss. In Ghana alone, natural forests have diminished to about 11.8–14.5% of their former cover (UICN 1996; Poorter et al. 2004). Worldwide, habitat loss and forest fragmentation are recognized as key factors driving the global extinction of genetically distinct populations and species (Bierregaard et al. 1992; Hughes et al. 1997; Brooks et al. 1999; Stuart et al. 2004).

While the host of factors driving wildlife declines in the Guinean rain forest ecosystem involve some of the usual suspects (i.e., logging and land use conversion for agriculture), several studies have demonstrated that hunting of wildlife for human consumption through the bushmeat trade is among the most immediate threats (Milner-Gulland et al. 2003; Brashares et al. 2004; Cowlishaw et al. 2005). Although these studies focused primarily on mammals and birds, it is clear that reptiles are also harvested for human consumption (Fa et al. 2000; Luiselli 2003). Additional human pressures with possible adverse effects on reptile and amphibian diversity include the collection of animals for medical uses, the pet trade, and the killing of snakes, poisonous or not, out of fear.

It is interesting to compare the current trend of habitat loss with the historical oscillations of the rain forest distribution. The forest probably formed a large belt of continuous habitat extending from West to Central Africa during the early Holocene and the last interglacial (Maley 1991; Dupont et al. 2000). During the last glacial maximum, the expansion of dry forest and savannah resulted in a very restricted and patchy distribution of rain forest (Dupont et al. 2000). Currently, the large West African rain forest blocks are separated by the Dahomey Gap, a stretch of dry savannah extending from central Ghana, through Togo, Benin, and western Nigeria (Fig. 1).

Correspondence. [5]*Tel: (510) 642-7928; fax: (510) 643-8238; email: leache@berkeley.edu*

Table 1. Frogs (Anura), Lizards (Squamata), Snakes (Squamata), and Crocodiles (Archosauria) recorded at Kyabobo National Park and the surrounding areas. Habitat classification types are as follows: S=savannah; F=forest; FB=farmbush.

Family	Scientific Name	Common Name	Habitat
Frogs			
Arthroleptidae			
	Arthroleptis cf. *poecilonotus*	West African Screeching Frog	FB, F
Bufonidae			
	Bufo maculatus	Flat-backed Toad	S, FB
	Bufo regularis	Square-marked Toad	S, FB
Hemisotidae			
	Hemisus cf. *marmoratus*	Marbled Shovel-nosed Frog	S, FB
Hyperoliidae			
	Afrixalus dorsalis	Cameroon Leaf-folding Frog	FB
	Afrixalus vittiger	Savannah Leaf-folding Frog	S, FB
	Afrixalus weidholzi	Weidholz's Leaf-folding Frog	S
	Hyperolius baumanni	Baumann's Reed Frog	F, FB
	Hyperolius concolor	Variable Reed Frog	S, FB
	Hyperolius fusciventris burtoni	Lime Reed Frog	FB
	Hyperolius nasutus	Long-nosed Reed Frog	S
	Hyperolius nitidulus	West African Reed Frog	S
	Hyperolius torrentis	Ukami Reed Frog	F
	Kassina senegalensis	Senegal Running Frog	S, FB
	Leptopelis hyloides	Gbanga Tree Frog	F, FB
	Leptopelis viridis	Rusty Tree Frog	S
Petropedetidae			
	Phrynobatrachus accraensis	Accra Puddle Frog	S, FB
	Phrynobatrachus calcaratus	Horned Puddle Frog	F, FB
	Phrynobatrachus natalensis	Natal Puddle Frog	S
	Phrynobatrachus plicatus	Coast Puddle Frog	F
Ranidae			
	Amnirana albolabris	White-lipped Frog	F
	Amnirana galamensis	Galam White-lipped Frog	S
	Hoplobatrachus occipitalis	Crowned Bullfrog	S, FB
	Ptychadena bibroni	Broad-banded Grass Frog	S, FB
	Ptychadena oxyrhynchus	Sharp-nosed Grass Frog	S
	Ptychadena pumilio	Medine Grass Frog	S, FB
Lizards			
Agamidae			
	Agama agama	Rainbow Lizard	S, FB
	Agama sankaranica	Senegal Agama	S
Chamaeleonidae			
	Chamaeleo senegalensis	Senegal Chameleon	S
Eublepharidae			
	Hemitheconyx caudicinctus	Fat-tail Gecko	S
Gekkonidae			
	Hemidactylus brookii	Brooke's House Gecko	S, FB
	Hemidactylus fasciatus	Banded Leaf-toed Gecko	F
	Hemidactylus mabouia	House Gecko	FB
	Hemidactylus muriceus	Guinea Leaf-toed Gecko	F
	Lygodactylus gutturalis	Uganda Dwarf Gecko	S, FB
Gerrhosauridae			
	Gerrhosaurus major	Rough-scaled Plated Lizard	S, FB
Lacertidae			
	Holaspis guentheri	Sawtail Lizard	F
Scincidae			
	Cophoscincopus cf. *simulans*	Keeled Water Skink	F
	Lygosoma brevicaudis	Short-tailed Writhing Skink	S
	Lygosoma guineensis	Guinea Writhing Skink	S, FB
	Panaspis togoensis	Togo Lidless Skink	F

Continued on page 26

Figure 1. Satellite image of Western Africa. The disjunct distribution of the major blocks of African rain forest (wet lowland and drier and mixed types) and the Togo Hills is highlighted in green (adapted from Schiøtz 1967 and Lawson 1968). Kyabobo National Park, located in the center of the Dahomey Gap in the Togo Hills, is highlighted by the red box and shown in figure 2. Base map downloaded from Google Earth (Google, Inc.).
DOI: 10.1514/journal.arc.0040017g001

Although the Dahomey Gap became established during the late Holocene, it has also experienced fluctuations in range and only reached its current extent within the last 1,100 years (Salzmann and Hoelzmann 2005).

The Dahomey Gap is thought to be a major biogeographic border separating forest faunas restricted to blocks of rain forest in West and Central Africa (Booth 1958; Schiøtz 1967; Hamilton 1976). Situated in the center of the Dahomey Gap are the Togo Hills, a mountainous area with peaks reaching 800 m that receives a substantial amount of rain and includes vegetation composed of moist semi-deciduous forest and montane ravine forest. Thus, the Togo Hills are a virtual "island" of lush forest surrounded by savannah and contain many forest species that are isolated from the more expansive rain forest blocks to the west and east (Fig. 1). The presence of relatively few rainforest endemics in the Togo Hills (e.g., Togo slippery frog *Conraua derooi*, Baumann's reed frog *Hyperolius baumanni*, Ukami reed frog *H. torrentis*) corroborates geological data suggesting that this region has not been isolated for a long period of time and is consistent with the hypothesis that the area served as a forest refugium during dryer periods associated with glacial maximum (Haffer 1982).

Ghana has an excellent national park system that encompasses the major habitat types located in the country. Located in Eastern Ghana, bordered by the Koue River and Togo to the east and the villages of Nkwanta and Shiare to the south, is Kyabobo National Park (Fig. 2). Although Kyabobo is relatively small (~380 km^2) compared to other national parks in Ghana, it is important in terms of biodiversity conservation and biogeography. Situated in the Dahomey Gap, Kyabobo contains much of the residing large tracts of semi-deciduous forest habitat remaining in the Togo Hills. It is crucial to catalog and study the forest species of Kyabobo and the immediate surrounding areas as an important first step toward understanding the evolutionary history and biogeography of the entire West African rain forest ecosystem.

Despite the clear understanding of the Togo Hills as an important area for biodiversity conservation and biogeography, it is surprising that so little is known about the reptiles and amphibians of the area. Ghana has a fascinating history of herpetological research beginning with the exportation of specimens to European countries during the 1800s (Hughes 1988). The most comprehensive synopsis of the reptiles and amphibians of Ghana is a checklist of species compiled by Barry Hughes (1988), but this list is by no means definitive. New country records and new species are still being discovered (Leaché 2005; Rödel et al. 2005).

A recent survey of amphibians of the Togo Hills concluded that, with 31 amphibian species, the area is more diverse than previously assumed and probably contains at least 41 amphibian species (Rödel and Agyei 2003). The periphery of Kyabobo National Park was also surveyed and found to contain a total of 20 frog species (Rödel and Agyei 2003). The reptiles of the area have never been targeted for biological survey.

Here, we summarize the results of our herpetological surveys of Kyabobo National Park. We provide accounts for all species recorded along with photographs to aid in identification. We draw attention to the importance of conserving forest stream habitats, which will in turn help ensure the persistence of forest-restricted species. We also highlight those species that may prove most useful for evolutionary studies of West African rain forest biogeography.

Table 1. Continued.

Family	Scientific Name	Common Name	Habitat
Scincidae (cont.)			
	Trachylepis affinis	Senegal Mabuya	S, FB, F
	Trachylepis buettneri	Buettneri's Long-tailed Mabuya	S, FB
	Trachylepis maculilabris	Speckle-lipped Mabuya	FB, F
	Trachylepis perrotetii	Teita Mabuya	S, FB
	Trachylepis quinquetaeniata	Rainbow Mabuya	S, FB
Varanidae			
	Varanus exanthematicus	Savannah Monitor	S
	Varanus niloticus	Nile Monitor	S, FB, F
Snakes			
Atractaspididae			
	Polemon acanthias	Reinhardt's Snake-eater	F
Colubridae			
	Afronatrix anoscopus	African Brown Water Snake	S, FB, F
	Crotaphopeltis hotamboeia	Herald Snake	S, FB
	Gonionotophis klingi	Matschie's African Ground Snake	F
	Lamprophis lineatus	Striped House Snake	S, FB
	Lycophidion nigromaculatum	Blotched Wolf Snake	F
	Natriciteres variegata	Forest Marsh Snake	FB, F
	Philothamnus heterodermus	Variable Green Snake	FB, F
	Philothamnus semivariegatus	Spotted Bush Snake	S, FB
	Psammophis phillipsi	Olive Grass Racer	S, FB
	Psammophis rukwae	Rukwa Sand Racer	S
	Rhamnophis aethiopissa	Large-eyed Green Treesnake	F
Elapidae			
	Naja melanoleuca	Black Forest Cobra	S, FB, F
Pythonidae			
	Python regius	Royal Python	S, FB
Typhlopidae			
	Typhlops punctatus	Spotted Blind Snake	S, FB, F
Viperidae			
	Causus maculatus	Spotted Night Adder	S, FB, F
Crocodiles			
Crocodylidae			
	Osteolaemus tetraspis	Dwarf Crocodile	F

DOI: 10.1514/journal.arc.0040017t001

Methods

We surveyed six general areas located inside or on the periphery of Kyabobo National Park (Plates 1-6) on three occasions spanning a 5-year period, each during the rainy season. These surveys were conducted on an eight-day visit from 15–22 August, 2001, a nine-day visit from 10–18 June, 2004, and a 20-day visit from 23 June–12 July, 2005. Kyabobo is situated on the boundary between woodland and semi-deciduous forest zones and is extremely hilly (peaks reaching 800 m) with vegetational changes occurring over short distances. Apart from the ridge tops, which are almost bare of trees, the park is generally densely wooded or forested. A small amount of farming activity is still taking place in the park, but most farmers have relocated. We sampled from as many distinct microhabitats as possible at each general survey area including streams, rivers, ponds, savannah grassland, savannah woodland, transition woodland, semi-deciduous rain forest, riparian forest, farm bush, and urbanized areas.

Specimens were found by visual encounter surveys (Heyer et al. 1994; Rödel and Ernst 2004) supplemented with acoustic searching for frogs, turning rocks and logs, peeling bark, digging through leaf litter, and excavating burrows and termite mounds. Surveys were conducted during the day and night to detect both diurnal and nocturnal species. We collected voucher specimens for future systematic and genetic studies. We primarily collected specimens by hand, but many fast moving lizards were captured by blowgun using blunt, plastic plugs as ammunition. Snake tongs were used to capture poisonous snakes. Pitfall trap arrays were installed at four locations (Laboum outpost near Odome, South Repeater Station, Middle Control Camp, and the new Wildlife Headquarters outside of Nkwanta) and monitored over a five-day period. Each pitfall array consisted of five-gallon plastic buckets (seven total) dug into the ground flush with the surface, one-foot-tall plastic drift fence connecting the buckets, and six wire-mesh snake traps set adjacent to the drift fence.

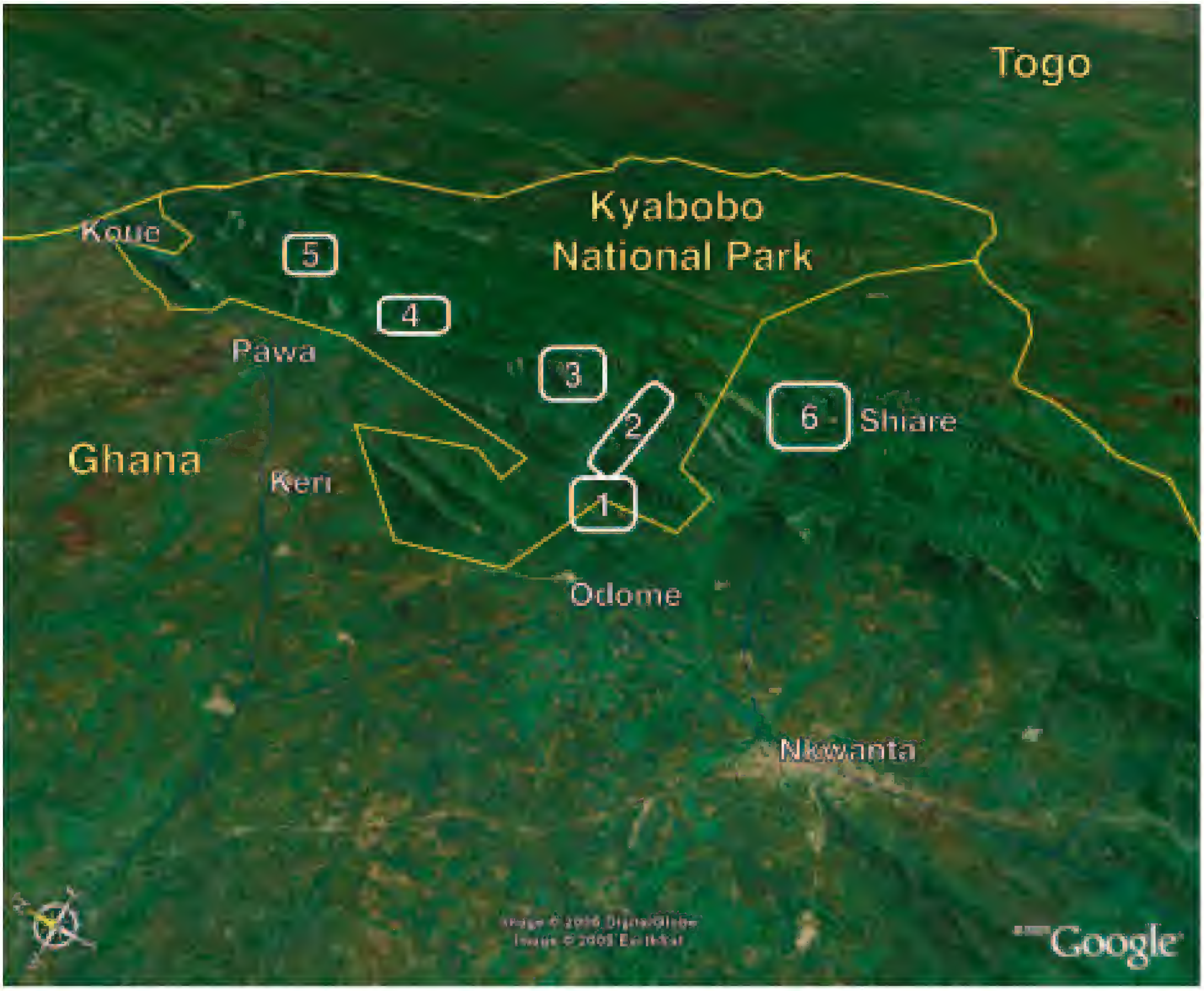

Figure 2. Satellite image of Kyabobo National Park in the Togo Hills, Volta Region, Ghana. White boxes outline key survey sites, and are numbered according to habitat photograph Plates 1-6. Base map downloaded from Google Earth (Google, Inc.).
DOI: 10.1514/journal.arc.0040017g002

Pitfall traps were left open continuously and monitored in the morning and evening.

Digital photographs were taken of representatives of each species and habitats at 5.0 or 6.1 megapixels (Nikon D-70). When possible, calling frogs were recorded using a digital video camcorder (Sony DCR DVD-203) coupled with a directional zoom microphone (Sony ECM-HGZ1). Geographic coordinates for each survey site were determined in the field with a Garmin GPS 72 or a Garmin eTrex receiver. Coordinates were recorded as latitude and longitude in decimal degrees, and referenced to the WGS84 (World Geodetic System of 1984) datum. Voucher specimens and tissue samples are deposited at the Museum of Vertebrate Zoology, University of California, Berkeley, or within the personal collection of Mark-Oliver Rödel. Complete voucher specimen information for most species, including specific locality data and GPS coordinates, is available online at the Museum of Vertebrate Zoology, University of California, Berkeley website (http://mvz.berkeley.edu/).

We identified specimens using the following literature: tree frogs (Schiøtz 1967, 1999), savannah frogs (Rödel 2000), Ghanaian amphibians (Rödel and Agyei 2003; Rödel et al. 2005), snakes (Hughes and Barry 1969; Chippaux 1999), lizards (Spawls et al. 2002), skinks (Horton 1973; Hoogmoed 1974; Greer et al. 1985; Böhme et al. 2000), geckos (Henle and Böhme 2003), and crocodilians (Spawls et al. 2002).

Species list

We recorded a total of 65 species in Kyabobo National Park, including 26 frogs, 22 lizards, 16 snakes, and one crocodile (Table 1). Voucher specimens representing 61 of these species were collected. The records for the savannah monitor (*Varanus exanthematicus*), sawtail lizard (*Holaspis guentheri*), Buettneri's long-tailed mabuya (*Trachylepis buettneri*), and dwarf crocodile (*Osteolaemus tetraspis*) are based on observations.

Plate 1. DOI: 10.1514/journal.arc.0040017g003

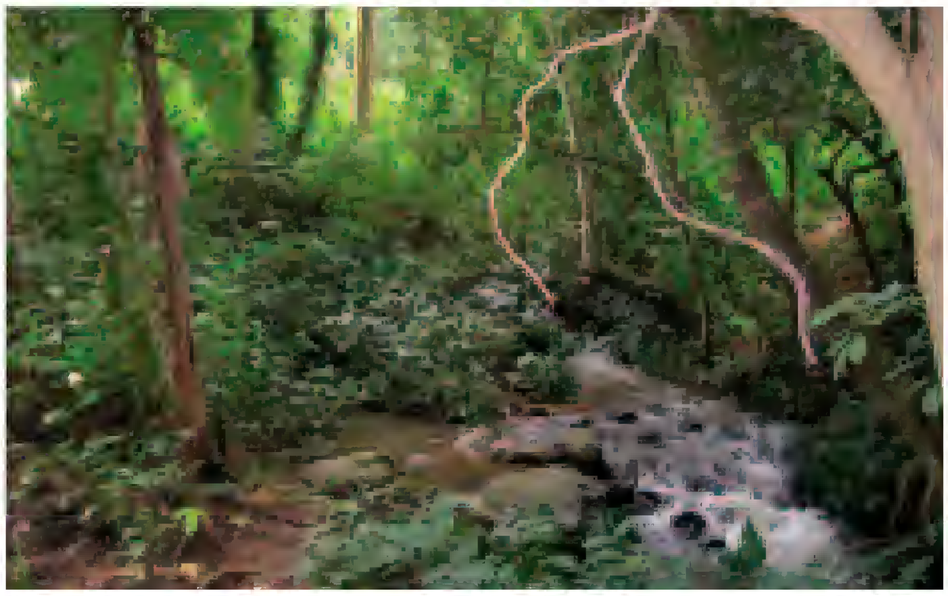

Plate 2. DOI: 10.1514/journal.arc.0040017g004

Plate 3. DOI: 10.1514/journal.arc.0040017g005

Plate 4. DOI: 10.1514/journal.arc.0040017g006

Plate 5. DOI: 10.1514/journal.arc.0040017g007

Plate 6. DOI: 10.1514/journal.arc.0040017g008

Plate 7A. DOI: 10.1514/journal.arc.0040017g009

Plate 7B. DOI: 10.1514/journal.arc.0040017g010

Plate captions: 1. Savannah and farmbush habitat at the Laboum Outpost entrance to Kyabobo. The western edge of the Togo Hills is shown in the background. **2.** Stream (originating from a waterfall) flowing through semi-deciduous forest vegetation at the southern end of Kyabobo. **3.** Savannah vegetation at South Repeater Station in Kyabobo, Togo Hills mountain-top at ~800 meters elevation. The Togo Hills are shown in the background extending to the south. **4.** Semi-deciduous forest and stream adjacent to Middle Control Camp located on the Western edge of Kyabobo. **5.** Overview of the canopy of semi-deciduous forest bordering a stream viewed from Bad-legged Man Camp in Kyabobo. **6.** Shiare Village. Photograph by Martin Weinbrenner (www.eyelustrate.com). **7A.** West African Screeching Frog *Arthroleptis* cf. *poecilonotus,* amplectant pair, South Repeater Station. **7B.** *Arthroleptis* cf. *poecilonotus,* male with elongated third toe, South Repeater Station.

Plate 8A. DOI: 10.1514/journal.arc.0040017g011

Plate 8B. DOI: 10.1514/journal.arc.0040017g0012

Plate 9. DOI: 10.1514/journal.arc.0040017g013

Plate 10. DOI: 10.1514/journal.arc.0040017g014

Plate 11. DOI: 10.1514/journal.arc.0040017g015

Plate 12. DOI: 10.1514/journal.arc.0040017g016

Plate 13. DOI: 10.1514/journal.arc.0040017g017

Plate 14. DOI: 10.1514/journal.arc.0040017g018

Plate captions: 8A. Flat-backed Toad *Bufo maculatus*, South Repeater Station. **8B.** *Bufo maculatus*, calling male, Pawa. **9.** Square-marked Toad *Bufo regularis,* Accra. **10.** Marbled Shovel-nosed Frog *Hemisus* cf. *marmoratus*, Odome. **11.** Cameroon Leaf-folding Frog *Afrixalus dorsalis*, Pawa. **12.** Savannah Leaf-folding Frog *Afrixalus vittiger*, calling male, Pawa. **13.** Weidholz's Leaf-folding Frog *Afrixalus weidholzi,* Pawa. **14.** Baumann's Reed Frog *Hyperolius baumanni,* Middle Control Camp.

Frogs (Anura)

Arthroleptidae

West African Screeching Frog *Arthroleptis* cf. *poecilonotus* Peters 1863 (Plate 7A and 7B). *Arthroleptis* are the most common leaf litter frogs in the Togo Hills. They inhabit degraded forests and farmbush habitats. Their taxonomic status is uncertain (Rödel and Agyei 2003). It is clear that they do not belong to *A. brevipes* Ahl, 1923 (compare Rödel et al. 2005). They might be conspecific with either *A. zimmeri* (Ahl 1925) or *A. poecilonotus*, both described from southern Ghana. However, most West African frogs of the genus *Arthroleptis* (and *Schoutedenella*) cannot be distinguished by morphological criteria, although they are clearly distinct taxa based on genetic and acoustic characters that cannot be assigned to available names (Rödel and Bangoura 2004; Rödel et al. 2005). The frogs from the Togo Hills exhibited the variability in dorsal coloration typical for most of their congeners including: brown or reddish brown dorsal coloration with or without a dark hourglass pattern, a vertebral stripe, or pale dorsolateral bands. The exact range of *A. poecilonotus* is uncertain given this taxonomic confusion, but is reported from southern Sudan westward to Guinea (Rödel 2000).

Bufonidae

Flat-backed Toad *Bufo maculatus* Hallowell 1854 (Plate 8A and 8B). This medium-sized toad is brown or red in appearance, with dark blotches on its warty back. Males in breeding condition are uniform yellowish (Rödel 2000). The parotoid glands are large, yet can be indistinct because they are covered with warts, causing their appearance to blend with the skin. *Bufo maculatus* inhabits savannah and degraded forests, but never primary forest. *Bufo maculatus* has a wide distribution, encompassing most of sub-Saharan Africa.

Square-marked Toad *Bufo regularis* Reuss 1833 (Plate 9). This is a large, robust toad with prominent, long, and smooth parotoid glands. Its dorsal coloration is typically brown with irregular dark blotches. This toad inhabits savannah and frequently occurs in water-filled ditches around human habitations. Its distribution includes sub-Saharan West and East Africa.

Hemisotidae

Marbled Shovel-nosed Frog *Hemisus* cf. *marmoratus* (Peters 1854) [Plate 10]. The subterranean *Hemisus* species with their squat bodies and pig-shaped snouts are unmistakable, but are rarely encountered. Two species are known to occur in West Africa including the forest dwelling *H. guineensis* Cope 1865 and the savannah-dwelling *H. marmoratus*. However, the morphological criteria, as defined by Laurent (1972), are not sufficient for species delimitation (M.-O. Rödel et al., *unpublished data*). Our species assignment should be taken as tentative. *Hemisus marmoratus* is distributed throughout savannah regions south of the Sahara (Rödel 2000).

Hyperoliidae

Cameroon Leaf-folding Frog *Afrixalus dorsalis* (Peters 1875) [Plate 11]. This is a small frog that inhabits degraded forests and farmbush habitats in the forest zone, and gallery forests in the savannah zone (Schiøtz 1967; Rödel 2000). Most frogs have two broad yellowish dorsolateral bands and a brownish back. Occasionally, specimens with a pale vertebral band occur. The latter might be confused with the next species that, however, has a much more slender body shape. *Afrixalus dorsalis* is distributed from Sierra Leone to Angola (Schiøtz 1999).

Savannah Leaf-folding Frog *Afrixalus vittiger* (Peters 1876) [Plate 12]. Two distinct forms of striped *Afrixalus* occur in West Africa. They seem to occur in different habitats, namely savannah and degraded forests or forest edges. The forest form exhibits a fine black line within the paler longitudinal stripes on the back and is considered *A. fulvovittatus* Cope 1860 by Perret (1976) and Rödel (2000). The savannah species lacks the fine black lines and is considered *A. vittiger* by Perret (1976) and Rödel (2000). Schiøtz (1999) considered these forms *A. fulvovittatus* "type A" and "type B". *Afrixalus vittiger* (or *A. fulvovittatus* type A) occurs in Kyabobo, and is widely distributed throughout savannah regions of West Africa.

Weidholz's Leaf-folding Frog *Afrixalus weidholzi* (Mertens 1937) [Plate 13]. A tiny savannah frog with a yellow-gold back and often with a black vertebral line and brownish flanks with minute white spots. Males call from higher grasses several meters from open water. Their buzzing advertisement call can easily be mistaken for an insect (Rödel 2000). It ranges from Senegal into Central Africa.

Baumann's Reed Frog *Hyperolius baumanni* Ahl 1931 (Plate 14). This frog is one of the few endemic species of the Togo Hills. It prefers degraded forests and forest edges, where it often occurs in high densities. Males have brownish backs and whitish dorsolateral bands that begin on the snout and terminate at the groin.

Variable Reed Frog *Hyperolius concolor* Rapp 1842 (Plate 15A and 15B). This is a very common medium-sized reed frog that inhabits farmbush and other open forest habitats. Males often have an indistinct hourglass pattern on their brownish backs, whereas females are most often grass-green. The venter of both sexes is white. At night their dorsal color is more or less uniform yellow. *Hyperolius concolor* is distributed from Guinea to Cameroon.

Lime Reed Frog *Hyperolius fusciventris burtoni* Schiøtz 1967 (Plate 16). *Hyperolius fusciventris burtoni* was reported to occur from western Ghana to eastern Nigeria (Schiøtz 1967). Recently, this subspecies and *H. f. lamtoensis* have been reported to occur in sympatry in southwestern Ghana (Rödel et al. 2005). In western Ivory Coast the latter occurs in sympatry with the nominate form (Rödel and Ernst 2004). We thus think that all three subspecies would be more appropriately treated as full species. Males from the Togo Hills frequently have pale dorsolateral bands. We recorded green and brown males. Brown specimens always had yellow gular flaps, whereas green males have green ones. Most calling sites are right at the border to open water.

Long-nosed Reed Frog *Hyperolius nasutus* Günther 1864 (Plate 17). These small, green reed frogs are common around ephemeral savannah ponds. They might be confused with *H. fusciventris*, but the latter inhabits very different habitats. In comparison, *H. nasutus* has a more slender body shape and a longer, more pointed snout. The taxonomic situation of

Plate 15A. DOI: 10.1514/journal.arc.0040017g019

A.

Plate 15B. DOI: 10.1514/journal.arc.0040017g020

Plate 16. DOI: 10.1514/journal.arc.0040017g021

Plate 17. DOI: 10.1514/journal.arc.0040017g022

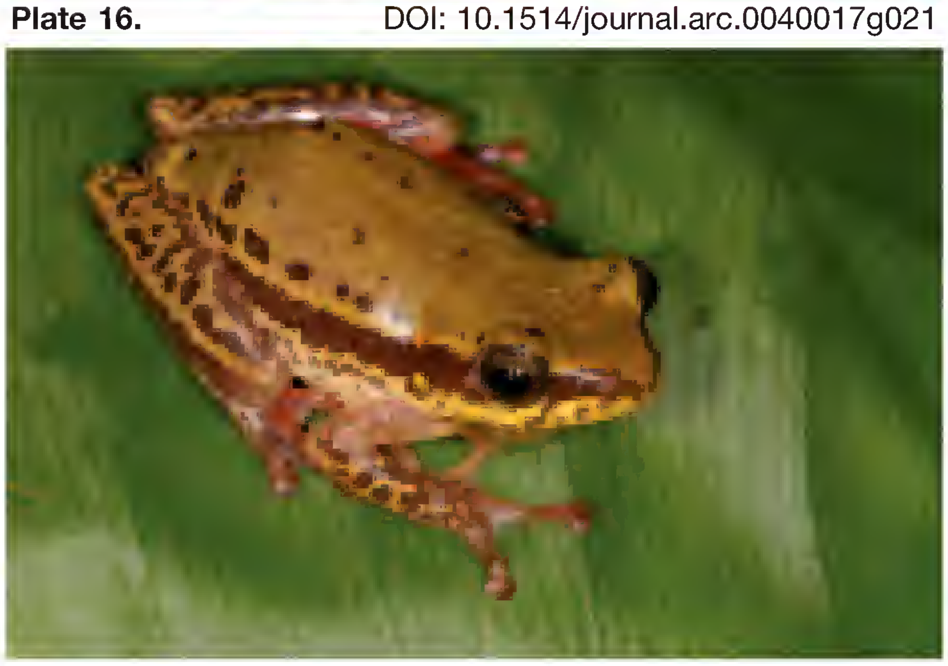

Plate 18. DOI: 10.1514/journal.arc.0040017g023

Plate 19. DOI: 10.1514/journal.arc.0040017g024

Plate 20. DOI: 10.1514/journal.arc.0040017g025

Plate 21A. DOI: 10.1514/journal.arc.0040017g026

Plate captions: 15A. Variable Reed Frog *Hyperolius concolor*, male, Pawa. **15B.** *Hyperolius concolor*, female, Pawa. **16.** Lime Reed Frog *Hyperolius fusciventris burtoni*, calling male, Wli, Volta Region, Ghana. **17.** Long-nosed Reed Frog *Hyperolius nasutus*, Comoé, Ivory Coast. **18.** West African Reed Frog *Hyperolius nitidulus*, male, Pawa. **19.** Ukami Reed Frog *Hyperolius torrentis*, female, forest stream southwest of South Repeater Station. **20.** Senegal Running Frog *Kassina senegalensis*, Laboum outpost. **21A.** Gbanga Tree Frog *Leptopelis hyloides*, male, Wli, Volta Region, Ghana.

this species group is not resolved (compare Channing et al. 2002; Rödel and Ernst 2003; Amiet 2005; Rödel et al., *in press*). We therefore continue to apply the name *H. nasutus*. *Hyperolius nasutus* is widely distributed south of the Sahara (Rödel 2000).

West African Reed Frog *Hyperolius nitidulus* Peters 1875 (Plate 18). *Hyperolius nitidulus* is the most abundant savannah tree frog in West Africa. The brownish frogs are most conspicuous due to their xylophone like sounds of their choruses around all kinds of vegetated, stagnant savannah waters. *Hyperolius nitidulus* is widely distributed in savannah regions from Senegal to Cameroon (Rödel 2000).

Ukami Reed Frog *Hyperolius torrentis* Schiøtz 1967 (Plate 19). *Hyperolius torrentis* is so far believed to be endemic to eastern Ghana and adjacent Togo (Schiøtz 1967; Rödel and Agyei 2003). We have unpublished evidence that this species may range along the Togolese mountains into northern Benin (photo record by T. Moritz). This large reed frog exhibits a variety of color patterns (compare Schiøtz 1967, 1999; Rödel and Agyei 2003). From the similar sized *H. concolor,* it can be best distinguished by its yellowish to greenish venter; from *H. baumanni*, it most conspicuously differs by larger size and the lack of pale dorsolateral bands. *Hyperolius torrentis* seems to occur exclusively on the forested borders of rapidly flowing streams.

Senegal Running Frog *Kassina senegalensis* (Duméril and Bibron 1841) [Plate 20]. This is a small to medium-sized frog that typically inhabits savannah in most of sub-Saharan Africa. Its dorsal coloration is a very pale brown, with five longitudinal stripes. The three central stripes are usually uninterrupted, while the two lateral stripes have a fragmented pattern starting from the snout and extending to the vent. The only specimen we found was inside a hole three meters high in a tree trunk during the day. *Kassina senegalensis* is widely distributed throughout sub-Saharan Africa (Schiøtz 1999).

Gbanga Tree Frog *Leptopelis hyloides* (Boulenger 1906) [Plate 21A and 21B]. A small (male) to medium-sized (female) forest tree frog that is generally brownish in color with a darker hour-glass pattern on the dorsum. The eyes are prominent and contain red pigmentation, a distinguishing character from the savannah species *Leptopelis viridis*. *Leptopelis hyloides* also has more extensive webbing compared to *L. viridis.* A proper name for this species is lacking, since the type specimen actually represents *L. viridis* (Schiøtz 1999). *Leptopelis hyloides* is distributed throughout the forest belt of West Africa west of the Cross River in Nigeria (Schiøtz 1999).

Rusty Tree Frog *Leptopelis viridis* (Günther 1869) [Plate 22]. This fairly large hyperoliid has a compact appearance, with large eyes and a general coloration of light to reddish brown. Darker patches of color form a triangle on the head and continue to form an irregular, and often broken, circle pattern on the back. On each side of its face is a dark mask that starts at the tip of snout and continues to the forelimb. We found individuals at night moving on the ground in savannah habitat, and often heard their "chuck" call from low-lying bushes. This species is abundant throughout West Africa (Schiøtz 1999).

Petropedetidae

Accra Puddle Frog *Phrynobatrachus accraensis* Ahl 1923 (Plate 23). This is a small and extremely common species that occurs in almost all stagnant waters from dry savannah to disturbed rainforest. It is best differentiated from similar puddle frogs by its call and the combination of yellow throats in breeding males, a well-developed webbing, and the lack of an eyelid cornicle. *Phrynobatrachus accraensis* is distributed throughout West Africa.

Horned Puddle Frog *Phrynobatrachus calcaratus* (Peters 1863) [Plate 24]. This widespread West and Central African forest frog differs from other puddle frogs in the Togo Hills by the presence of an eyelid cornicle. Furthermore, the vocal sac of males is dark violet to black. The frogs almost completely lack webbing. The dorsum can be uniform brown or bear a reddish longitudinal or transverse band. *Phrynobatrachus calcaratus* is distributed from Senegal to Cameroon.

Natal Puddle Frog *Phrynobatrachus natalensis* (Smith 1849) [Plate 25]. This widespread savannah frog probably comprises several cryptic species (Rödel 2000; Crutsinger et al. 2004). They most often inhabit and breed in small puddles almost devoid of vegetation. They differ from the similar *P. accraensis* in having a larger size, more compact body, and black throats on breeding males. *Phrynobatrachus natalensis* is widely distributed throughout Africa south of the Sahara.

Coast Puddle Frog *Phrynobatrachus plicatus* (Günther 1859) [Plate 26]. This is a widespread West African forest frog (Lamotte 1966). It differs from all other West African puddle frogs by its large size, exceeding 30 mm snout-vent length, and two very long dorsal ridges that form an "X" pattern. Males have a dark black throat. They most often breed in small ponds in swampy forest or in small puddles on forest roads. This species is distributed from Guinea to Nigeria.

Ranidae

White-lipped Frog *Amnirana albolabris* (Hallowell 1856) [Plate 27]. This is a large, slender frog with enlarged toe discs, noticeably webbed hind feet, and a brown dorsal coloration, often with distinct black spots. The skin appears smooth but is covered with minute spines (Rödel and Bangoura 2004). A white stripe along the upper lip does not extend much past the tympanum, though speckles of white can occur along the sides of the body. We found these frogs near streams and creeks well within forested areas, often clinging to overhanging vegetation and rocks. *Amnirana albolabris* is common in West and Central Africa forests.

Galam White-lipped Frog *Amnirana galamensis* (Duméril and Bibron 1841) [Plate 28]. This is a relatively large ranid frog, typically brown to light brown above with striking golden dorsolateral ridges. Both the upper and lower lips are cream-colored; the stripe on the upper lip continues along the side of the body. We found *A. galamensis* in savannah habitat; at night, they were active and moving on land, and during the day we heard vocalization in pools of water. We also found adults underneath piles of bricks and concrete rubbish near ponds. This wide-ranging frog occurs in West, East, and Central Africa.

Plate 21B. DOI: 10.1514/journal.arc.0040017g027

Plate 22. DOI: 10.1514/journal.arc.0040017g028

Plate 23. DOI: 10.1514/journal.arc.0040017g029

Plate 24. DOI: 10.1514/journal.arc.0040017g030

Plate 25. DOI: 10.1514/journal.arc.0040017g031

Plate 26. DOI: 10.1514/journal.arc.0040017g032

Plate 27. DOI: 10.1514/journal.arc.0040017g033

Plate 28. DOI: 10.1514/journal.arc.0040017g034

Plate captions: 21B. *Leptopelis hyloides*, female, Middle Control Camp. **22.** Rusty Tree Frog *Leptopelis viridis*, male, Pawa. **23.** Accra Puddle Frog *Phrynobatrachus accraensis*, gravid female, Middle Control Camp. **24.** Horned Puddle Frog *Phrynobatrachus calcaratus*, female, note the eyelid cornicle, South Repeater Station. **25.** Natal Puddle Frog *Phrynobatrachus natalensis*, Middle Control Camp. **26.** Coast Puddle Frog *Phrynobatrachus plicatus*, Bad-legged Man Camp. **27.** White-lipped Frog *Amnirana albolabris*, forest stream south-west of South Repeater Station. **28.** Galam White-lipped Frog *Amnirana galamensis*, Accra.

Togo Slippery Frog *Conraua derooi* Hulselmans 1972 (Plate 29A and 29B). This large aquatic frog is one of the few amphibian species that is endemic to the Togo Hills. It is only known from the type locality in Bismarckburg (Misahöhe), Togo (Hulselmans 1971), and a few localities in southeastern Ghana (Schiøtz 1967; Rödel and Agyei 2003). This species was not recorded in the Volta region by Rödel and Agyei (2003), and we did not record it in Kyabobo. However, we were informed by people in Shiare village that the frog might live in nearby Togo (large blackish frogs in flowing water with very slimy skin). Very recently, *C. derooi* was rediscovered in the Volta Region, including voice recordings from Amedzofe and Biakpa (A. Hillers et al., *unpublished data*). Hence its potential occurrence in Kyabobo should be further investigated.

Crowned Bullfrog *Hoplobatrachus occipitalis* (Günther 1859) [Plate 30]. This large frog is highly aquatic and extremely common. It mainly lives in savannah habitats, but penetrates the forest zone in disturbed areas (Rödel 2000). This species inhabits almost all kinds of waters, ranging from small, sun-heated puddles to cold, fast-flowing streams. We found several individuals in small puddles in residential areas, large ponds, and slow-moving streams. The largest specimen measured was a female (124 mm). They are very shy but easily recognized by their furious flights during which they partly run over water. They are olive-green above with dark mottling, and generally pale below. Their dorsally positioned eyes, warty back (but particularly slimy skin), light interorbital stripe, and full webbing of their hind feed are suitable criteria for determination. At night they can be traced by their reflective red eye-shine. This species is not threatened. However, in some areas it is harvested for human consumption. Its range includes much of Africa south of the Sahara (except southern Africa).

Broad-banded Grass Frog *Ptychadena bibroni* (Hallowell 1845) [Plate 31]. A common, medium-sized, West African grass frog that inhabits degraded forests and moist savannahs. A reddish vertebral band is most often present. Pale dorsolateral ridges are absent or fragmented into a few warts.

Sharp-nosed Grass Frog *Ptychadena oxyrhynchus* (Smith 1849) [Plate 32]. A large (snout-vent length 40-68 mm) frog with an extremely pointed snout and enormous hind legs. A pale dorsolateral ridge is present and not interrupted. Breeding frogs most often call from small puddles in open surrounding. This frog is widely distributed throughout Africa.

Medine Grass Frog *Ptychadena pumilio* (Boulenger 1920) [Plate 33]. A widespread frog that inhabits degraded forests and moist savannahs. It is characterized by its small size, uninterrupted pale dorsal ridges, well-developed webbing and a comparatively compact body shape. *Ptychadena pumilio* is distributed from Senegal to Ethiopia, and south to Zambia (Rödel 2000).

Lizards (Squamata)

Agamidae

Rainbow Lizard *Agama agama* (Linnaeus 1758) [Plate 34A and 34B]. An extremely common diurnal lizard found in most types of habitats except for dense primary rain forest and can be found in particularly high abundance around human settlements. Sexual dimorphism in this species is striking. At Kyabobo, adult males are dark blue in coloration with bright orange-red heads and tails, although the color on the tail gradually grades to white and appears as a "rainbow." Adult females are drab grey or brown with distinctive paired orange markings on the back. *Agama agama* are widely distributed in Africa from Senegal to Egypt and south to Tanzania (Spawls et al. 2002).

Senegal Agama *Agama sankaranica* Mocquard 1905 (Plate 35). A common diurnal lizard found in savannah habitats. It is strictly terrestrial and often spotted darting between clumps of vegetation. Both sexes are brown with a thin yellow vertebral line extending from the neck to the base of the tail. Some specimens have iridescent blue scales on the sides of their face and around their ear openings. The local name for *A. sankaranica* is the "bush agama." *Agama sankaranica* is distributed across West Africa from Senegal to Cameroon.

Chamaeleonidae

Senegal Chameleon *Chamaeleo senegalensis* Daudin 1802 (Plate 36). A large green arboreal chameleon with a slightly raised casque at the back of the head and a prehensile tail. Found in moist savannah habitats. They are active during the day and can be found on the ground crossing roads, although they are more easily found at night in bushes and small trees where the reflection of their bodies contrasts with the surrounding vegetation. Possibly threatened by bush fires and collecting for local medicinal use. *Chamaeleo senegalensis* is distributed from Senegal to Cameroon.

Eublepharidae

Fat-tail Gecko *Hemitheconyx caudicinctus* (Duméril 1851) [Plate 37]. A medium-sized terrestrial gecko that can be distinguished from other geckos by the presence of eyelids and the lack of toe-pads. Laterally banded with yellow and black with white bands on the tail. A savannah species distributed throughout West Africa.

Gekkonidae

Brooke's House Gecko *Hemidactylus brookii* Gray 1845 (Plate 38). A common nocturnal gecko that is abundant around anthropogenic habitats. Usually found on building surfaces near cracks or in rafters. Resembles *H. mabouia,* but is distinguishable by a shorter snout and the inability to make a defensive "squeak" sound (Gramentz 2000). It has dorsal tubercles that continue down the tail, but regenerated tails lack tubercles. *Hemidactylus brookii* has a broad distribution throughout West and Central Africa.

Banded Leaf-toed Gecko *Hemidactylus fasciatus* Gray 1842 (Plate 39A and 39B). A medium-bodied nocturnal forest gecko. Juveniles have distinct lateral black bands with yellow borders and a banded white tail. As adults, the black and white bands fade and the yellow bands remain resulting in a uniform dark purple body with thin yellow bands. Commonly found near streams on large rocks and fallen logs, but can also be found on mountaintops away from water. In other areas they

Plate 29A. DOI: 10.1514/journal.arc.0040017g035

Plate 29B. DOI: 10.1514/journal.arc.0040017g036

Plate 30. DOI: 10.1514/journal.arc.0040017g037

Plate 31. DOI: 10.1514/journal.arc.0040017g038

Plate 32. DOI: 10.1514/journal.arc.0040017g039

Plate 33. DOI: 10.1514/journal.arc.0040017g040

Plate 34A. DOI: 10.1514/journal.arc.0040017g041

Plate 34B. DOI: 10.1514/journal.arc.0040017g042

Plate captions: 29A. Togo Slippery Frog *Conraua derooi*, Biakpa, Volta Region, Ghana. **29B.** *Conraua derooi*, Biakpa, Volta Region, Ghana. **30.** Crowned Bullfrog *Hoplobatrachus occipitalis*, Koue River. **31.** Broad-banded Grass Frog *Ptychadena bibroni,* Mole N.P., Ghana. **32.** Sharp-nosed Grass Frog *Ptychadena oxyrhynchus*, Comoé, Ivory Coast. **33.** Medine Grass Frog *Ptychadena pumilio,* Comoé, Ivory Coast. **34A.** Rainbow Lizard *Agama agama*, male, Nkwanta. **34B.** *Agama agama*, female, South Repeater Station.

are common on large forest trees and even in houses within forests (M.-O. Rödel, *unpublished data*). A forest species distributed throughout West Africa.

House Gecko *Hemidactylus mabouia* (Moreau De Jonnés 1818) [Plate 40]. Often referred to as the tropical house gecko. *Hemidactylus maboula* is commonly seen feeding near light sources and is capable of producing a "squeak" sound used for defense (Gramentz 2000). Similar in appearance and behavior to *H. brookii,* but has a longer snout-to-eye distance. This species is distributed throughout Africa, Madagascar, and the Seychelles, and is also found in South and North America (Spawls et al. 2002).

Guinea Leaf-toed Gecko *Hemidactylus muriceus* Peters 1870 (Plate 41). A small forest gecko that prefers terrestrial habitat. Commonly found in leaf debris and under logs. Partially diurnal and forages in fine vegetation (Branch and Rödel 2003). The dorsal surface is highly tuberculate. Its small body size distinguishes it from *H. mabouia* and *H. brookii*. Henle and Böhme (2003) provide characters for identifying *H. muriceus* from species with which it is often confused. *Hemidactylus muriceus* is distributed throughout West and Central Africa.

Uganda Dwarf Gecko *Lygodactylus gutturalis* (Bocage 1873) [Plate 42]. A very small gecko (maximum size up to 9 cm) lacking a claw on the thumb. Mostly diurnal and prefers arboreal habitats. Their cryptic coloration and small size make them difficult to detect on trees. This species is distributed throughout West and Central Africa.

Gerrhosauridae

Rough-scaled Plated Lizard *Gerrhosaurus major* Duméril 1851 (Plate 43). A large lizard with prominently keeled and armor-like scales. The dorsal surface is laterally striped yellow and black, whereas the flanks are red and the ventral surface is cream-colored. The limbs and tail are very powerful. Can be seen basking on termite mounds in which they commonly live. This species has been split into an eastern and western subspecies, *G. m. major*, Duméril, 1851, and *G. m. bottegoi,* Del Prato, 1895, respectively. *Gerrhosaurus major* is widely distributed throughout Africa south of the Sahara.

Scincidae

Keeled Water Skink *Cophoscincopus* cf. *simulans* (Vaillant 1884) [Plate 44]. A small, secretive skink that is the only semi-aquatic skink in the region. Dark brown and black in color with a keeled back and tail. Occurs in muddy seeps of water near streams. Based on their intermediate morphology, it is unclear whether the specimens at Kyabobo represent *C. simulans* or the recently described *C. greeri* (Böhme et al. 2000). *Cophoscincopus simulans* is distributed from Sierra Leone to the Togo Hills.

Short-tailed Writhing Skink *Lygosoma brevicaudis* Greer et al. 1985 (Plate 45). A medium-sized skink with reduced limbs and a thick, chunky appearance, and an especially truncated tail with a tapering end. A savannah species that inhabits seasonally variable and xeric habitat (Greer et al. 1985). Our record of *Lygosoma brevicaudis* in Kyabobo represents a northeastern range extension of ~330 kilometers based on specimen distributions presented in Greer et al. (1985). Formerly known from central Ivory Coast to western and southern Ghana.

Guinea Writhing Skink *Lygosoma guineensis* (Peters 1879) [Plate 46]. A medium-sized leaf litter skink with reduced limbs and a cylindrical body. Easily distinguished from *L. brevicaudis* by the presence of a longer, narrower tail. Greer et al. (1985) note that *L. guineensis* is primarily a forest species that is capable of penetrating more open savannah under certain mesic conditions. Distributed throughout West and Central Africa.

Togo Lidless Skink *Panaspis togoensis* (Werner 1902) [Plate 47]. A small, slim, leaf-litter skink with well developed limbs. This species has a moveable lower eyelid with a transparent disk. The color is a dull grey-brown above that changes to a rusty red color at the hind limbs and tail. Taxonomic changes based on morphological and ecological similarities initiated by Broadley (1989) and followed by Haft (1993) placed many West African species of lidless skinks into the genus *Leptosiaphos,* including *P. togoensis*. A recent molecular phylogenetic analysis by Schmitz et al. (2005) based on specimens from Cameroon clarifies the evolutionary relationships of these groups and recommends the use of *P. togoensis. Panaspis togoensis* is distributed across West and Central Africa.

Senegal Mabuya *Trachylepis affinis* (Gray 1838) [Plate 48]. A medium-sized skink with a moderately long tail and fully developed limbs. Adults have a brown back with dark-brown spots arranged in two pairs of longitudinal rows, and males have an immaculate white throat. The sides of the head and neck can have a dull red color. This species may have a white stripe extending from the upper lip to the groin, but we did not see this condition in any specimens at Kyabobo. They are found in a variety of forested and open savannah habitats. The taxonomic status of *T. blandingii, T. raddonii,* and *T. affinis* is unclear (Hoogmoed 1974), and a rigorous phylogenetic study including all West African *Trachylepis* is needed. *Trachylepis affinis* is distributed across West and Central Africa.

Buettneri's Long-tailed Mabuya *Trachylepis buettneri* (Matschie 1893) [Plate 49]. A medium-sized lizard with a long, slender body and limbs. The tail can reach up to four times the length of the body. Found in small bushes, rocks and vegetation in savannah habitat. Distributed from Ivory Coast to Cameroon.

Speckle-lipped Mabuya *Trachylepis maculilabris* (Gray 1845) [Plate 50]. A medium-sized, heavy built skink with well-developed limbs and a long tail. Dorsal scales of adults have five to seven keels. Adults are brown with dark brown to black flanks with a white stripe extending from under the eye to the forelimbs. The throat is yellow. Diurnal and found in forested areas or around human settlements. *Trachylepis maculilabris* occurs throughout Africa south of the Sahara.

Teita Mabuya *Trachylepis perrotetii* (Duméril and Bibron 1839) [Plate 51]. A large, heavy skink with short, thick limbs and a long tail. The color is olive-brown above, and adults generally have red flanks. Commonly found in savannah areas in grass or basking on low branches and tree trunks. They usually run up trees when chased, but have also been

Plate 35. DOI: 10.1514/journal.arc.0040017g043

Plate 36. DOI: 10.1514/journal.arc.0040017g044

Plate 37. DOI: 10.1514/journal.arc.0040017g045

Plate 38. DOI: 10.1514/journal.arc.0040017g046

Plate 39A. DOI: 10.1514/journal.arc.0040017g047

Plate 39B. DOI: 10.1514/journal.arc.0040017g048

Plate 40. DOI: 10.1514/journal.arc.0040017g049

Plate 41. DOI: 10.1514/journal.arc.0040017g050

Plate captions: 35. Senegal Agama *Agama sankaranica*, Odome. **36.** Senegal Chameleon *Chamaeleo senegalensis*, female, Hoehoe. **37.** Fat-tail Gecko *Hemitheconyx caudicinctus*, Laboum Outpost. **38.** Brooke's House Gecko *Hemidactylus brookii*, South Repeater Station. **39A.** Banded Leaf-toed Gecko *Hemidactylus fasciatus,* gravid female, South Repeater Station. **39B.** *Hemidactylus fasciatus*, juvenile, Middle Control Camp. **40.** House Gecko *Hemidactylus mabouia*, Laboum Outpost. **41.** Guinea Leaf-toed Gecko *Hemidactylus muriceus*, South Repeater Station.

observed to escape into water (Rödel et al. 1997). Distributed throughout West and Central Africa.

Rainbow Mabuya *Trachylepis quinquetaeniata* (Lichtenstein 1823) [Plate 52]. A medium-sized skink with well-developed limbs and long tail. Juveniles and females have a black dorsum with five white lines extending from behind the head to base of the tail. The tail is bright blue. Adult males lose this color pattern and become brown and acquire a black-blue throat. They are common in savannah habitats and abundant around human settlements, but not found in forested areas (Hoogmoed 1974). *Trachylepis quinquetaeniata* is distributed throughout Africa.

Lacertidae

Sawtail Lizard *Holaspis guentheri* Gray 1863. A small arboreal lacertid with a long head and pointed snout. The body and tail are extremely flattened to aid in gliding between trees in the forest (Spawls et al. 2002). The dorsum is black with cream stripes down the sides that fade into a blue tail with black crossbars. We encountered one specimen in Kyabobo that was first spotted on the trunk of a large tree near a stream before it retreated into the forest canopy. *Holaspis guentheri* is widely distributed throughout West and Central Africa (Spawls et al. 2002).

Varanidae

Savannah Monitor *Varanus exanthematicus* (Bosc 1792) [Plate 53]. This large monitor lizard has a broad head with prominent ocular ridges. *Varanus exanthematicus* prefers savannah habitat and can be spotted in agricultural areas around Kyabobo. Active diurnally, mostly terrestrial but can be found under rocks, in termite mounds, and in trees where it rests. We observed one specimen basking on a termite mound near Laboum Outpost. This species is CITES appendix II protected due to its popularity in the pet and skin trade (de Buffrénil 1993). Distributed from Senegal to western Ethiopia (Bayless 2002).

Nile Monitor *Varanus niloticus* (Linnaeus 1758) [Plate 54]. A large black monitor with 6–11 yellow crossbars or ocelli on the body (Dunger 1967; Spawls et al. 2002). The tail is laterally compressed with a prominent vertebral ridge. Commonly found at night sleeping on vegetation overhanging streams or pools. Active diurnally, they are very quick and wary. This species is CITES appendix II protected due to its popularity in the pet and skin trade (de Buffrénil 1993). A study by Bayless and Luiselli (2000) shows microhabitat differences between *V. niloticus* and *V. ornatus* in Nigeria, with the latter being primarily a forest species. *Varanus niloticus* is broadly distributed throughout Africa from Egypt to South Africa, and West to Senegal (Bayless 2002).

Snakes (Squamata)

Atractaspididae

Reinhardt's Snake-eater *Polemon acanthias* (Reinhardt 1860) [Plate 55]. A rare nocturnal burrowing snake with smooth scales and a short, sharp tail. *Polemon acanthias* has grooved rear fangs and is ophiophagous, but probably not dangerous to humans. Many aspects of their natural history remain unknown due to their secretive habits. Lives in forest habitats close to water. Conservation status is uncertain, but is possibly vulnerable due to forest destruction. This snake is distributed from Guinea to Nigeria (Chippaux 1999).

Colubridae

African Brown Water Snake *Afronatrix anoscopus* (Cope 1861) [Plate 56]. A medium-sized snake with an overall olive coloration with yellow ventral coloration. Round and robust in appearance, *A. anoscopus* is an aquatic snake found along streams where it hunts for small vertebrate prey, mainly frogs. Individuals can be found resting under rocks in the stream or basking along the bank in forest and savannah habitat wherever water is available. When captured, individuals do not hesitate to strike and release musk from their cloaca. This snake is distributed from Senegal to Cameroon (Chippaux 1999).

Herald Snake *Crotaphopeltis hotamboeia* (Laurenti 1768) [Plate 57]. A small dark-colored snake, usually black, grey or olive-green with rear fangs. Transverse rows of small white spots are present dorsally. Scales on this species transition from smooth to keeled posteriorly. Commonly active at night, we observed this species feeding on small frogs of the genus *Phrynobatrachus* (in the lab, frogs became incapacitated after being bitten by this snake). Individuals were found in savannah habitat near bodies of water. Defensive displays for this snake include an intricate combination of flattening the head into a triangular form (viper-shaped) followed by hissing and striking (Spawls et al. 2002). This snake is distributed broadly throughout Africa south of the Sahara (Spawls et al. 2002).

Matschie's African Ground Snake *Gonionotophis klingi* Matschie 1893 (Plate 58). *Gonionotophis klingi* is small, dark, and subtriangular in cross section with a prominent longitudinal row of dorsal vertebral scales. Body scales are keeled with ventral scales lighter in coloration than dorsal scales. Members of the genus *Gonionotophis* differ from the very similar and closely related genus *Mehelya* through the presence of a continuous row of maxillary teeth (Loveridge 1939). These snakes are slow-moving and nocturnal. Their diet consists mostly of terrestrial amphibians. Possibly threatened due to destruction of forest habitat. This snake is distributed from Guinea to Nigeria (Chippaux 1999).

Striped House Snake *Lamprophis lineatus* (Duméril et al. 1854) [Plate 59]. A medium-sized snake with smooth scales, a triangular-shaped head and relatively large eyes with vertical pupils. They are nocturnal and feed primarily on lizards and frogs, but occasionally eat small mammals (Chippaux 1999). *Lamprophis lineatus* is distributed throughout West and Central Africa.

Blotched Wolf Snake *Lycophidion nigromaculatum* (Peters 1863) [Plate 60]. A small terrestrial forest snake with a distinct broad head and vertical pupils. The body is sub-triangular in cross section. Individuals are orange dorsally with black diamond-shaped markings staggered down their back. The venter is dark grey. The head and "neck" region are

Plate 42. DOI: 10.1514/journal.arc.0040017g051

Plate 43. DOI: 10.1514/journal.arc.0040017g052

Plate 44. DOI: 10.1514/journal.arc.0040017g053

Plate 45. DOI: 10.1514/journal.arc.0040017g054

Plate 46. DOI: 10.1514/journal.arc.0040017g055

Plate 47. DOI: 10.1514/journal.arc.0040017g056

Plate 48. DOI: 10.1514/journal.arc.0040017g057

Plate 49. DOI: 10.1514/journal.arc.0040017g058

Plate captions: 42. Uganda Dwarf Gecko *Lygodactylus gutturalis*, Nkwanta. **43.** Rough-scaled Plated Lizard *Gerrhosaurus major*, Mole N. P., Ghana. **44.** Keeled Water Skink *Cophoscincopus* cf. *simulans,* Waterfall east of Laboum Outpost. **45.** Short-tailed Writhing Skink *Lygosoma brevicaudis*, South Repeater Station. **46.** Guinea Writhing Skink *Lygosoma guineensis,* Middle Control Camp. **47.** Togo Lidless Skink *Panaspis togoensis*, Comoé, Ivory Coast. **48.** Senegal Mabuya *Trachylepis affinis,* Tai, Ivory Coast. **49.** Buettneri's Long-tailed Mabuya *Trachylepis buettneri,* Comoé N. P., Ivory Coast.

retracted backward onto the body to form an S-shape, which they maintain when striking at a predator. Leston and Hughes (1968) revived this species from synonymy with *L. irroratum*. *Lycophidion nigromaculatum* is distributed from Guinea to Ghana (Chippaux 1999).

Forest Marsh Snake ***Natriciteres variegata*** (Peters 1861) [Plate 61]. A harmless snake with a small head, round pupils, and relatively short tail. Semi-aquatic and eats frogs. We found one juvenile specimen (116 mm snout-vent length; 1.1 g) under leaf litter in the forest. The range spans from Guinea to Cameroon (Hughes and Barry 1969).

Variable Green Snake ***Philothamnus heterodermus*** (Hallowell 1857) [Plate 62]. A green arboreal snake with large, round pupils and a slightly upturned lip. Scales are smooth with 15 midbody scale rows and a relatively long tail (approximately 25% total length). Body scales have a concealed white spot. According to Hughes and Barry (1969), *P. heterodermus* can be distinguished from congeners by the presence of an entire anal plate along with 2+ temporal scales. This is a slender and fast species with both green and brown phases. Spawls et al. (2002) mention a Ghanaian survey of this species where brown individuals spent more time on the ground while green individuals spent more time on trees during the dry season. This is a diurnal snake whose main food consists of frogs. Distribution ranges from Guinea to Uganda and Angola.

Spotted Bush Snake ***Philothamnus semivariegatus*** (Smith 1847) [Plate 63]. A large, slender snake with black dorsal crossbars. The appearance of an eyebrow is given by the presence of its raised supraocular scale. Body is cylindrical with a long tail, ranging from 25–35% of total body length. Scales are smooth with 15 midbody scale rows. Hughes and Barry (1969) diagnose this species from its congeners by the presence of 183–199 ventral scales with 1+ temporal scales. Ventral scales are yellowish or bright green. Ventral scales are also strongly keeled. This is a diurnal snake that is very agile in trees, bushes and shrubs. According to Spawls et al. (2002), the diet of this snake consists mainly of lizards. This snake is widely distributed throughout Africa south of the Sahara.

Olive Grass Racer ***Psammophis phillipsi*** (Hallowell 1844) [Plate 64]. A large, fast diurnal snake that feeds primarily on lizards. Found in savannah habitats and around villages and agricultural areas. This species, as well as others belonging to the genus, have the ability to "break off" their tail when in danger as an escape mechanism (without regeneration). *Psammophis phillipsi* has been considered by many to be a complex of species due to its wide range throughout Africa and seemingly diagnosable characters for groups within.

Rukwa Sand Racer ***Psammophis rukwae*** Broadley 1966 (Plate 65). A fast-moving, rear-fanged diurnal snake that is both terrestrial and arboreal. It is slender with a long tail. Scales are smooth with 17 midbody scale rows and 148 to 183 ventrals. Anal plate is divided. This species is diagnosed from its congeners by its very fine black ventral lines and by having the first five lower labials usually in contact with the anterior sublinguals (Spawls et al. 2002). This species is mainly a savannah inhabitant and distributed from Senegal to Tanzania.

Large-eyed Green Treesnake ***Rhamnophis aethiopissa*** Günther 1862 (Plate 66). A slender arboreal snake with a relatively short snout and large prominent eyes with round pupils and a golden iris. The lip curves upward posteriorly, giving the snake the impression of smirking. Each scale has a black border, which gives the snake a striped or checkered appearance. This snake reaches a length of over one meter, and the tail is approximately 33% of the total length. This species inhabits primary forest. When in defensive posture, this snake laterally compresses its neck, hisses, and strikes. It is suspected to be primarily a frog eater. Distributed throughout West and Central Africa (Chippaux 1999).

Elapidae

Black Forest Cobra ***Naja melanoleuca*** Hallowell 1857 (Plate 67). A large, thick-bodied cobra reaching 2.5 m with a large head and yellow throat with black crossbars. The chin and ventral parts of the belly are cream and/or white. In Ghana it is found in well-forested habitat. This snake is agile and active day and night. It can be found hiding among piles of brush, rocks, hollow logs, and holes. A very deadly snake, which can be aggressive when approached. It eats a wide variety of vertebrates, from frogs to monitor lizards and mammals. Possibly threatened due to intense pressure from humans who view the cobra as a threat and go out of their way to kill them. This snake is widely distributed across the afrotropics (Spawls et al. 2002).

Pythonidae

Royal Python ***Python regius*** (Shaw 1802) [Plate 68]. A very muscular snake that is relatively small (reaching just over one meter) with an elongate snout that is broader at the jaws. The iris is yellow with vertical pupils and has black with golden-yellow marbling dorsally. The tail is short, and males possess spurs lateral to the cloacal opening. It is a slow-moving snake that is active at night when it comes out to hunt for small warm-blooded prey, which it sees with its heat-sensing infrared pits that line its upper lip. This species is mainly found in dry grassland habitat or moist savannahs. It is distributed throughout West and Central Africa and is commonly exported for the pet trade (Spawls et al. 2002).

Typhlopidae

Spotted Blind Snake ***Typhlops punctatus*** (Leach 1819) [Plate 69]. A small and secretive fossorial snake. Its natural history still remains elusive, except for the fact that they are one of the largest typhlopids, reaching up to 66 cm total length. It has an obvious eye under the ocular scale and has 30 to 32 midbody scale rows with 374–465 scales in a mid-dorsal longitudinal series (Spawls et al. 2002). The coloration is dark brown to grey dorsally with a yellow spot on the posterior margin of each scale. Mainly fossorial, but can be found at night when they are active on the surface. Although primarily considered a lowland savannah inhabitant, we found specimens on mountain tops (~800 m) predominated by savannah vegetation. Presumed to feed on termites like other members

Plate 50. DOI: 10.1514/journal.arc.0040017g059

Plate 51. DOI: 10.1514/journal.arc.0040017g060

Plate 52. DOI: 10.1514/journal.arc.0040017g061

Plate 53. DOI: 10.1514/journal.arc.0040017g062

Plate 54. DOI: 10.1514/journal.arc.0040017g063

Plate 55. DOI: 10.1514/journal.arc.0040017g064

Plate 56. DOI: 10.1514/journal.arc.0040017g065

Plate 57. DOI: 10.1514/journal.arc.0040017g066

Plate captions: 50. Speckle-lipped Mabuya *Trachylepis maculilabris*, South Repeater Station. **51.** Teita Mabuya *Trachylepis perrotetii,* Mole N. P., Ghana. **52.** Rainbow Mabuya *Trachylepis quinquetaeniata,* South Repeater Station. **53.** Savannah Monitor *Varanus exanthematicus,* Mole N.P., Ghana **54.** Nile Monitor *Varanus niloticus,* Laboum Outpost. **55.** Reinhardt's Snake-eater *Polemon acanthias,* forest stream near Laboum Outpost. **56.** African Brown Water Snake *Afronatrix anoscopus*, Laboum Outpost. **57.** Herald Snake *Crotaphopeltis hotamboeia*, Comoé, Ivory Coast.

of its family. For a summary of the taxonomic discussion of the *T. punctatus* complex see Branch and Rödel (2003). This snake is distributed throughout West and Central Africa.

Viperidae

Spotted Night Adder *Causus maculatus* (Hallowell 1842) [Plate 70]. A stout, thick-bodied viper with a short tail, round pupils, and a rounded snout. Predominantly found in savannah habitat, but it can also be found in forests. Its dorsal coloration is light brown, dark tan or light olive with dark, diamond-shaped vertebral markings. A V-shape is present on the top of the head with the apex oriented anteriorly. The head is slightly differentiated from the girth of the body, not a distinctive triangular head like most vipers. Nine large scales are present on the top of the head, unlike most vipers (Spawls et al. 2002). Scales are lightly keeled. Belly is white or cream in coloration. Locomotion is very slow, and it is active at various times of the day and night. It inhabits many human disturbed areas and is responsible for many snake bites of humans. Distributed throughout West Africa to Angola (Chippaux 1999).

Crocodiles (Archosauria)

Dwarf Crocodile *Osteolaemus tetraspis* Cope 1861 (Plate 71). Combined with its small size, robust appearance, and broad snout, *Osteolaemus tetraspis* is easily distinguishable from other crocodilians. It inhabits small rivers, and we observed one individual in a remote forest stream in Kyabobo. This is the first report of this CITES appendix I species for Kyabobo National Park. This species is widespread in the forests of West and Central Africa (Spawls et al. 2002).

Results and discussion

With a total of 65 reptile and amphibian species, Kyabobo National Park is one of the most diverse sites surveyed in Ghana. Raxworthy and Attuquayefio (2000) surveyed the herpetofaunal community at Muni Lagoon in the Volta Region of Ghana during the peak of the rainy season and found up to 26 species at a site. Leaché (2005) surveyed three sites located in the Northern, Brong-Ahafo, and Greater Accra Regions of Ghana during the dry season and found up to 30 species at a site. While surveys that focused specifically on amphibian diversity in southwestern Ghana documented up to 47 species, they were not restricted to a single site, but rather encompassed a broad geographic area (Rödel and Agyei 2003; Rödel et al. 2005). All of these studies predicted higher species abundance at their sites based on non-asymptotic species accumulation curves and/or comparisons to historical data. Additional species, especially snakes, certainly inhabit Kyabobo National Park. Their absence from our survey does not necessarily indicate that they are not present, but rather that they are secretive and/or difficult to find. Long-term herpetological surveys in the neotropics indicate that a great deal of effort is necessary to detect every species at a site (Duellman 2005; Myers and Rand 1969). In addition, we only surveyed during the rainy season, and seasonality has some effect on the abundance of different species of reptiles and amphibians in Ghana (Hughes 1988). Thus, continued survey work in Kyabobo National Park is warranted.

A recent biodiversity survey of amphibians of the entire Volta Region recorded 31 amphibian species, including 20 species from the area including Kyabobo National Park (Rödel and Agyei 2003). We found 26 frogs at Kyabobo. Of the six new records, five are a subset of the 31 recorded throughout the entire Volta Region (*Hemisus* sp., *Phrynobatrachus plicatus, Hyperolius baumanni, H. fusciventris,* and *Afrixalus dorsalis*), and one (*Afrixalus weidholzi*) is a new record for the Togo Hills. The amphibians absent from our surveys in the Togo Hills include some that are adapted to fast-running water or large closed forests, like *Conraua derooi* and *Bufo togoensis.* Recently, *C. derooi* was discovered in the Togo Hills (A. Hillers et al., *unpublished data*). In addition, we have unconfirmed reports from people in Shiare village that a frog fitting the description of *C. derooi* might live in nearby Togo. Hence, the presence of suitable habitat in Kyabobo makes the detection of these highly threatened species possible.

We recorded 39 species of reptiles in our survey (22 lizards, 16 snakes, and one crocodile). Unfortunately, a lack of historical data on the diversity of reptiles in the Togo Hills, and no records from Kyabobo National Park, make area comparisons difficult. Some of the reptile species we found at Kyabobo were not surprising, given their occurrence in a broad variety of habitats and wide distribution throughout West Africa. However, we did detect nine forest-restricted reptiles in Kyabobo known primarily from other West African forest blocks (Table 1). In general, we can assume that many of our records are new for the area and therefore represent range extensions. For instance, our observation of the dwarf crocodile (*Osteolaemus tetraspis*) is the first report of this CITES appendix I species for Kyabobo National Park, and our record of *Lygosoma brevicaudis* in Kyabobo represents a range extension of ~330 kilometers based on specimen distributions presented in Greer et al. (1985).

Most reptiles and amphibians in Kyabobo National Park that are connected to forest habitats should be considered threatened. While many reptiles and amphibians thrive in human-disturbed areas, others are restricted to specific microhabitat types and do not persist in the face of habitat destruction. Given this setting, preserving sensitive habitats is the most effective method of conserving reptiles and amphibians. In particular, the forest habitats in Kyabobo, and specifically the forests bordering the streams and rivers, should be considered sensitive areas. Some frogs appear to inhabit and breed exclusively in these areas (e.g., *Hyperolius torrentis, Phrynobatrachus plicatus*, *Amnirana albolabris,* and *Leptopelis hyloides*). We can assume that these species once had widespread distributions throughout the Togo-Volta highlands, but habitat modification has all but eliminated them from most areas. Successful conservation of these species equates to protecting their forest stream habitats. Any destruction to this habitat type, such as clearing of forest or increasing sedimentation in the water, could have damaging effects on the herpetofauna, especially to the breeding amphibian populations. Thus, focusing attention on this specific habitat type could benefit multiple species simultaneously.

Plate 58. DOI: 10.1514/journal.arc.0040017g067

Plate 59. DOI: 10.1514/journal.arc.0040017g068

Plate 60. DOI: 10.1514/journal.arc.0040017g069

Plate 61. DOI: 10.1514/journal.arc.0040017g070

Plate 62. DOI: 10.1514/journal.arc.0040017g071

Plate 63. DOI: 10.1514/journal.arc.0040017g072

Plate 64. DOI: 10.1514/journal.arc.0040017g073

Plate 65. DOI: 10.1514/journal.arc.0040017g074

Plate captions: 58. Matschie's African Ground Snake *Gonionotophis klingi,* forest habitat northeast of South Repeater Station. **59.** Striped House Snake *Lamprophis lineatus,* Comoé, Ivory Coast. **60.** Blotched Wolf Snake *Lycophidion nigromaculatum,* Middle Control Camp. **61.** Forest Marsh Snake *Natriciteres variegata,* forest stream near Laboum Outpost. **62.** Variable Green Snake *Philothamnus heterodermus,* Tai, Ivory Coast. **63.** Spotted Bush Snake *Philothamnus semivariegatus,* near Laboum Outpost. **64.** Olive Grass Racer *Psammophis phillipsi,* male, Nkwanta. **65.** Rukwa Sand Racer *Psammophis rukwae*, Nkwanta.

Plate 66. DOI: 10.1514/journal.arc.0040017g075

Plate 67. DOI: 10.1514/journal.arc.0040017g076

Plate 68. DOI: 10.1514/journal.arc.0040017g077

Plate 69. DOI: 10.1514/journal.arc.0040017g078

Plate 70. DOI: 10.1514/journal.arc.0040017g079

Plate 71. DOI: 10.1514/journal.arc.0040017g080

Plate captions: 66. Large-eyed Green Treesnake *Rhamnophis* cf. *aethiopissa,* Ankasa National Park, Ghana. **67.** Black Forest Cobra *Naja melanoleuca,* Comoé, Ivory Coast. **68.** Royal Python *Python regius,* Keri. **69.** Spotted Blind Snake *Typhlops punctatus,* South Repeater Station. **70.** Spotted Night Adder *Causus maculatus*, Nkwanta. **71.** Dwarf Crocodile *Osteolaemus tetraspis,* Comoé, Ivory Coast.

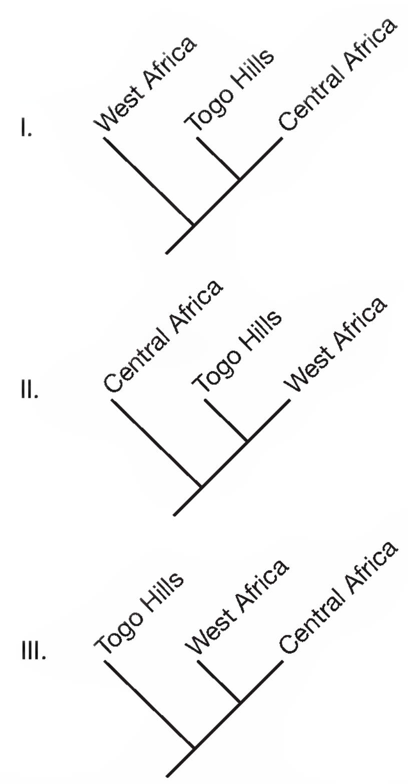

Figure 3. The three resolved phylogenetic hypotheses for the evolutionary history of forest-restricted species in Western Africa, assuming exclusivity of each forest block.
DOI: 10.1514/journal.arc.0040017g081

Compared to the 47 amphibian species documented in the southwestern forests of Ghana (Rödel et al. 2005), the Togo Hills harbor less diversity with 26 species. The climatological and geological history of the forests themselves may explain present day patterns of organismal diversity. During the last glacial maximum the expansion of dry forest and savannah fragmented rain forests reduced the size and extent of rain forest habitat within the Togo Hills to a minimum (Dupont et al. 2000). Larger blocks of forest persisted along the coast to the west of Ghana and in Central Africa. These areas may have experienced less retraction and therefore maintained higher species diversity. Thus, a positive correlation may exist between forest patch size during the Pleistocene and present-day biodiversity. This hypothesis should be scrutinized more closely using genetic data from multiple, co-distributed forest species restricted to forest habitat, but with distributions spanning West Africa. Feasible target species fitting these criteria include *Leptopelis hyloides, Phrynobatrachus plicatus, Amnirana albolabris, Hemidactylus fasciatus, Panaspis togoensis, Gonionotophis klingi, Rhamnophis aethiopissa,* and *Osteolaemus tetraspis*. Genetic data will provide a more sensitive measure of diversity for these forest-restricted species and facilitate the estimation of divergence dates between lineages. In addition, a comparative phylogeographic approach will enable us to determine whether co-distributed forest species have shared evolutionary histories (Fig. 3). Our surveys have contributed to the sampling essential for comparative biogeographic research of the herpetofauna in this complex biodiversity hotspot.

Acknowledgments.—We thank the Wildlife Division in Accra for granting us permission to conduct research in the National Parks of Ghana. We are grateful to Peter Howard, Pete Hartley, and Phil Marshall at the IUCN for their help coordinating and funding our survey work in 2005. We thank John Mason, Executive Director of the Nature Conservation Research Centre, for providing logistical support in Accra. We are also grateful to the Museum of Vertebrate Zoology for supporting our 2004 expedition. We especially want to thank Baturi Ali and Anne Leaché for their help collecting and preparing specimens. We thank Mark Bayless, Robert Drewes, Craig Hassapakis, Jim McGuire, Ted Papenfuss, and Jack Sites for useful discussions and comments on this manuscript.

References

Amiet, J.-L. 2005. Les Hyperolius camerounais du groupe d'*H. nasutus* (Amphibia, Anura, Hyperoliidae). *Revue Suisse de Zoologie* **112(1)**:271-310.

Bayless, M. K. 2002. Monitor lizards: a pan-African check-list of their zoogeography (Sauria: Varanidae: Polydaedalus). *Journal of Biogeography* **29(12)**:1643-1701.

Bayless, M. K. and Luiselli, L. 2000. The ecological distribution of monitor lizards (Reptilia, Varanidae) in Nigeria. *Miscellània Zoològica* **23(1)**:1-8.

Bierregaard, R. O., Lovejoy, T. E., Kapos, V., Dossantos, A. A., and Hutchings, R. W. 1992. The biological dynamics of tropical rain-forest fragments. *BioScience* **42(11)**:859-866.

Böhme, W., Schmitz, A., and Ziegler, T. 2000. A review of the West African skink genus *Cophoscincopus* Mertens (Reptilia: Scincidae: Lygosominae): resurrection of *C. simulans* (Vaillant, 1884) and description of a new species. *Revue Suisse de Zoologie* **107(4)**:777-791.

Booth, A. H. 1958. The Niger, the Volta and the Dahomey Gaps as geographic barriers. *Evolution* **12(1)**:48-62.

Branch, W. R. and Rödel, M.-O. 2003. Herpetological survey of the Haute Dodo and Cavally forests, western Ivory Coast, Part II: trapping results and reptiles. *Salamandra* **39(1)**:21-38.

Brashares, J. S., Arcese, P., Sam, M. K., Coppolillo, P. B., Sinclair, A. R. E., and Balmford, A. 2004. Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science* **306(5699)**:1180-1183.

Broadley, D. G. 1989. Reappraisal of the genus *Panaspis* Cope, with the description of a new species of *Leptosiaphos* (Reptilia: Scincidae) from Tanzania. *Arnoldia Zimbabwe* **9(32)**:439-449.

Brooks, T., Pimm, S., and Oyugi, J. 1999. Time lag between deforestation and bird extinction in tropical forest fragments. *Conservation Biology* **13(5)**:1140-1150.

Channing, A., Moyer, D., and Burger, M. 2002. Cryptic species of sharp-nosed reed frogs in the *Hyperolius nasutus* complex: advertisement call differences. *African Zoology* **37(1)**:91-99.

Chippaux, J.-P. 1999. *Les serpents d'Afrique occidentale et centrale.* IRD Éditions, Paris. 278 p.

Cowlishaw, G., Mendelson, S., and Rowcliffe, J. M. 2005. Structure and operation of a bushmeat commodity chain in southwestern Ghana. *Conservation Biology* **19(1)**:139-149.

Crutsinger, G., Pickersgill, M., Channing, A., and Moyer, D. 2004. A new species of *Phrynobatrachus* (Anura: Ranidae) from Tanzania. *African Zoology* **39(1)**:19-23.

de Buffrénil, V. de. 1993. Les varans africains (*Varanus niloticus* et *Varanus exanthematicus*): données de synthèse sur leur biologie et leur exploitation. Secrétariat de CITES, Genèva, Suisse.

Duellman, W. E. 2005. *Cusco Amazonico: the lives of amphibians and reptiles in an amazonian rainforest*. Cornell University Press, Ithaca. 472 p.

Dunger, G. T. 1967. The lizards and snakes of Nigeria. Part 3: the monitor and a plated lizard. *Nigerian Field* **32**:170-178.

Dupont, L. M., Jahns, S., Marret, F., and Ning, S. 2000. Vegetation change in equatorial West Africa: time-slices for the last 150 ka. *Palaeogeography Palaeoclimatology Palaeoecology* **155(1-2)**:95-122.

Fa, J. E., Yuste, J. E. G., and Castelo, R. 2000. Bushmeat markets on Bioko Island as a measure of hunting pressure. *Conservation Biology* **14(6)**:1602-1613.

Frost, D. R. 1985. *Amphibian Species of the World: a taxonomic and geographical reference*. The Association of Systematics Collections, Lawrence, Kansas. 732 p.

Gramentz, D. 2000. Zur Biologie von *Hemidactylus brooki angulatus* in Ghana sowie *H. mabouia* und *H. muriceus* in Gabun. *Salamandra* **36(3)**:185-198.

Greer, A. E., Grandison, A. G. C., and Barbault, R. 1985. A new species of *Lygosoma* (Lacertilia: Scincidae) from West Africa, with comments on its biology. *Journal of Herpetology* **19(3)**:365-372.

Haffer, J. 1982. General aspects of the refuge theory, p. 6-24 *in* Prance, G. T. *Biological Diversification in the Tropics*. Columbia University Press, New York. 714 p.

Haft, J. 1993. Ein Beitrag zur Biologie der Echsen der Insel Sao Tome (Golf von Guinea), mit naherer Betrachtung zur Systematik von *Leptosiaphos africana* (Gray) (Reptilia: Sauria: Geckonidae et Scincidae). *Faunistische Abhandlungen des Staatlichen Museums für Tierkunde Dresden* **19(6)**:59-70.

Hamilton, A. 1976. The significance of patterns of distribution shown by forest plants and animals in tropical Africa for the reconstruction of Upper Pleistocene palaeoenvironments: a review. *Palaeoecology of Africa and of the Surrounding Islands and Antarctica* **9**:63-97.

Henle, K., and Böhme, W. 2003. A new species of *Hemidactylus* (Squamata: Gekkonidae) from West Africa, and comments on species hitherto confused with *H. muriceus*. *African Journal of Herpetology* **52(1)**:23-38.

Heyer, W. R., Donnelly, M. A., McDiarmid, R. W., Hayek, L.-A. C., and Kent, M. S. 1994. *Measuring and Monitoring Biological Diversity: standard methods for amphibians*. Smithsonian Institution Press, Washington, DC. 364 p.

Hoogmoed, M. S. 1974. Ghanese lizards of the genus *Mabuya* (Scincidae, Sauria, Reptilia). *Zoologische Verhandelingen* **138**:1-68.

Horton, D. R. 1973. Evolution of the genus *Mabuya* (Lacertilia, Scincidae). Unpublished Ph.D. thesis, University of New England, Armidale. 311 p.

Hughes, B. 1988. Herpetology of Ghana (West Africa). *British Herpetological Society Bulletin* **25**:29-38.

Hughes, B., and Barry, D. H. 1969. The snakes of Ghana: a checklist and key. *Bulletin de l'Institut fundamental d'Afrique noire Sér A.* **31(3)**:1004-1041.

Hughes, J. B., Daily, G. C., and Ehrlich, P. R. 1997. Population diversity: its extent and extinction. *Science* **278(5338)**:689-692.

Hulselmans, J. L. J. 1971. Contribution à l'herpétologie de la République du Togo, 4. Description de *Conraua derooi*, n. sp. (Amphibia). *Revue Zoologique Botanique Africaine* **84**:153-159.

Lamotte, M. 1966. Types de répartition géographique de quelques batraciens dans l'Ouest Africain. *Bulletin de l'Institut fondamental d'Afrique noire Sér. A* **28**:1140-1148.

Laurent, R. F. 1972. Tentative revision of the genus *Hemisus* Günther. *Musée Royal d'Afrique Centrale Science Zoologique* **194**:1-67.

Lawson, G. W. 1968. Ghana. *Acta phytogeographica suecica* **54**:81-86.

Leaché, A. D. 2005. Results of a herpetological survey in Ghana and a new country record. *Herpetological Review* **36(1)**:16-19.

Leston, D., and Hughes, B. 1968. The snakes of Tafo, a forest cocoa-farm locality in Ghana. *Bulletin de l'Institut fundamental d'Afrique noire Sér. A* **30**:737-770.

Loveridge, A. 1939. Revision of the African snakes of the genera *Mehyla* and *Gonionotophis*. *Bulletin of the Museum of Comparative Zoology* **86(3)**:131-162.

Luiselli, L. 2003. Comparative abundance and population structure of sympatric Afrotropical tortoises in six rainforest areas: the differential effects of "traditional veneration" and of "subsistence hunting" by local people. *Acta Oecologica* **24(3)**:157-163.

Maley, J. 1991. The African rain forest vegetation and paleoenvironments during late quaternary. *Climatic Change* **19(1-2)**:79-98.

Milner-Gulland, E. J., Bennett, E. L., and the SCB 2002 Annual Meeting Wild Meat Group. 2003. Wild meat: the bigger picture. *Trends in Ecology & Evolution* **18(7)**:351-357.

Myers, C. W. and Rand, A. S. 1969. Checklist of amphibians and reptiles of Barro Colorado Island, with comments on faunal change and sampling. *Smithsonian Contributions to Zoology* **10**:1-11.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403(6772)**:853-858.

Perret, J.-L. 1976. Identité de quelques *Afrixalus* (Amphibia, Salientia, Hyperoliidae). *Bulletin de la Société neuchâteloise des Sciences Naturelles Sér. 3* **99**:9-28.

Poorter, L., Bongers, F., and Lemmens, R. H. M. J. 2004. West African Forests: introduction, *in* Poorter, L., Bongers, F., Kouame, F. N., and Hawthorne, W. D. *Biodiversity of West African Forests: an ecological atlas of woody plant species.* CABI Publishing, Cambridge, Massachusetts. 521 p.

Raxworthy, C. J. and Attuquayefio, D. K. 2000. Herpetofaunal communities at Muni Lagoon in Ghana. *Biodiversity and Conservation* **9(4)**:501-510.

Rödel, M.-O. 2000. *Herpetofauna of West Africa, Volume I: Amphibians of the West African Savanna*. Edition Chimaira, Frankfurt/M., Germany. 335 p.

Rödel, M.-O. and Agyei, A. C. 2003. Amphibians of the Togo-Volta highlands, eastern Ghana. *Salamandra* **39(3)**:207-234.

Rödel, M.-O. and Bangoura, M. A. 2004. A conservation assessment of amphibians in the Forêt Classée du Pic de Fon, Simandou Range, southeastern Republic of Guinea, with the description of a new *Amnirana* species (Amphibia Anura Ranidae). *Tropical Zoology* **17**:201-232.

Rödel, M.-O. and Ernst, R. 2003. The amphibians of Marahoué and Mont Péko National Parks, Ivory Coast. *Herpetozoa* **16(1/2)**:23-39.

Rödel, M.-O. and Ernst, R. 2004. Measuring and monitoring amphibian diversity in tropical forests. I. An evaluation of methods with recommendations for standardization. *Ecotropica* **10**:1-14.

Rödel, M.-O., Gil, M., Agyei, A. C., Leaché, A. D., Diaz, R. E., and Fujita, M. K. 2005. The amphibians of the forested parts of south-western Ghana. *Salamandra* **41(3)**:107-127.

Rödel, M.-O., Grabow, K, Hallermann, J., and Böckheler, C. 1997. Die Echsen des Comoé-Nationalparks, Elfenbeinküste. *Salamandra* **33(4)**:225-240.

Rödel, M.-O., Lampert, K. P., and Linsenmair, K. E. *In press. 2006*. Reproductive biology of the West African savannah frog, *Hyperolius nasutus* Günther, 1864 (Amphibia: Anura: Hyperoliidae). *Herpetozoa* **19(1/2)**.

Salzmann, U., and Hoelzmann, P. 2005. The Dahomey Gap: an abrupt climatically induced rain forest fragmentation in West Africa during the late Holocene. *Holocene* **15(2)**:190-199.

Schiøtz, A. 1967. The treefrogs (Rhacophoridae) of West Africa. *Spolia zoologica Musei haunienses* **25**:1-346.

Schiøtz, A. 1999. *Treefrogs of Africa*. Edition Chimaira, Frankfurt/M. 350 p.

Schmitz, A., Ineich, I., and Chirio, L. 2005. Molecular review of the genus *Panaspis* sensu lato (Reptilia: Scincidae) in Cameroon, with special reference to the status of the proposed subgenera. *Zootaxa* **863**:1-28.

Spawls, S., Howell, K., Drewes, R., and Ashe, J. 2002. *A Field Guide to the Reptiles of East Africa: all the reptiles of Kenya, Tanzania, Uganda, Rwanda and Burundi*. Academic Press, San Diego, California. 543 p.

Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S. L., Fischman, D. L., and Waller, R. W. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* **306(5702)**:1783-1786.

UICN. 1996. L'atlas pour la conservation des forets tropicales d'Afrique. Jean-Pierre de Monza, Paris. 310 p.

Manuscript received: 8 November 2005; Accepted: 20 December 2005; Published: 26 December 2006

Amphibian and Reptile Conservation 4(1):46-59.
DOI: 10.1514/journal.arc.0040014 (2407KB PDF)

Land use and anuran biodiversity in southeast Kansas, USA

LEWIS R. ANDERSON AND JOSEPH A. ARRUDA[1]

Department of Biology, Pittsburg State University, Pittsburg, Kansas 66762-7552, United States of America

***Abstract.*—The relationship of anuran breeding site biodiversity to land use was examined in southeast Kansas, USA. Eight breeding pools or temporary ponds were sampled from March to July 1995. Each site has some adjacent woodland, but varied in the remaining adjacent land use. Two sites were relatively unimpacted reference or "natural" sites, two were impacted by abandoned coal or lead/zinc mines, and four were impacted by cropland. Adult density was determined with visual and audio censuses. Tadpoles were examined for malformations and density was estimated. Eggs were collected from the sites, hatched in the laboratory, and examined for malformations. Total audio anuran density was statistically higher (ANOVA, $P<0.05$) in natural area breeding pools (1,048.7/ha) compared to pools in agricultural (519.0/ha) and mined areas (164.8/ha). Visual densities followed the same pattern (459.9/ha natural > 315.1/ha agricultural > 262.0/ha mined) but were not statistically different. Tadpole densities were significantly ($P<0.05$) higher in natural area breeding pools (137.6/m^2) compared to agricultural (59.4/m^2) and mined areas (28.5/m^2). The percentage of tadpoles with malformations was significantly lower ($P<0.05$) in natural areas (0.4%) compared to agricultural (4.6%) and mining (8.3%). Malformations found in the field included spinal cord, optic, edemas, and tumors. Eggs incubated from natural sites had significantly ($P<0.05$) higher percentages of eggs hatching successfully (98.8%) and lower percentages of tadpoles with malformations (17.5%) than did eggs from agricultural (88.2% and 51.0%, respectively) and mined areas (40.4% and 76.1%, respectively). Eggs incubated from natural sites also had the lowest malformation rate (17.5%) compared to eggs from agricultural sites (51.0%) and mined sites (76.1%), but these differences were not statistically different. These data provide evidence for the link between land use and the individual and population characteristics of anurans in breeding pools.**

Key words. *Amphibian, anuran, land use, tadpole, watershed, biodiversity, malformations*

Citation: Anderson, L. R. and Arruda, J. A. 2006. Land use and anuran biodiversity in southeast Kansas, USA. Amphib. Reptile Conserv. 4(1):46-59(e14).

Introduction

The reasons for declines in amphibian populations (Blaustein and Wake 1990; Wake 1991) are complex, and include diseases, ultraviolet radiation, pollutants, and habitat modifications (Alford and Richards 1999). In spite of many changes to the natural landscape and land use in southeast Kansas, the region supports a greater diversity of anurans — 17 species — than the rest of the state (Conant and Collins 1993). Hecnar and M'Closkey (1996) showed regional differences in amphibian species richness related to land use history. Southeast Kansas is also an ecotone between eastern deciduous forests and prairie, and is at the edge of distribution for many anuran species. Anuran populations that reside in peripheral areas such as this are of considerable interest to many biologists and geneticists who study divergence and speciation (Ptacek 1984).

The conversion of the rural landscape in southeast Kansas, as elsewhere, from pre-settlement conditions may adversely affect breeding and nonbreeding habitats and water quality in anuran breeding pools. Small wetlands are important to juvenile recruitment and their loss and increased isolation can have a negative effect on rescue efforts (Semlitsch and Bodie 1998). Such isolation influences the probability of dispersal among wetlands and is one of the critical factors in managing aquatic-breeding amphibians (Semlitsch 2000). Development of road networks, such as the many rural roads constructed on section lines (Public Land Survey System) in Kansas, can be responsible for fragmentation as well as direct mortality (Fahrig et al. 1995; Vos and Chardon 1998). But direct water quality impacts on breeding pools can occur as well. Agricultural runoff can carry fertilizers, pesticides, and sediments. Underground and strip-mining of coal, lead, and zinc earlier this century in southeast Kansas has left piles of mine tailings. Leachate from mined areas can be acidic and contain elevated concentrations of metals.

The goal of this project was to assess the relationship between adjacent land use and the biodiversity of anurans inhabiting breeding pools. The specific objectives were to (1) identify breeding pools with different surrounding land uses, (2) estimate adult anuran density, (3) estimate the density of and malformation rates in tadpoles, and (4) estimate the hatch-

Correspondence. [1]*Tel: (602) 235-4738, fax: (620) 235-4194, email: jarruda@pittstate.edu*

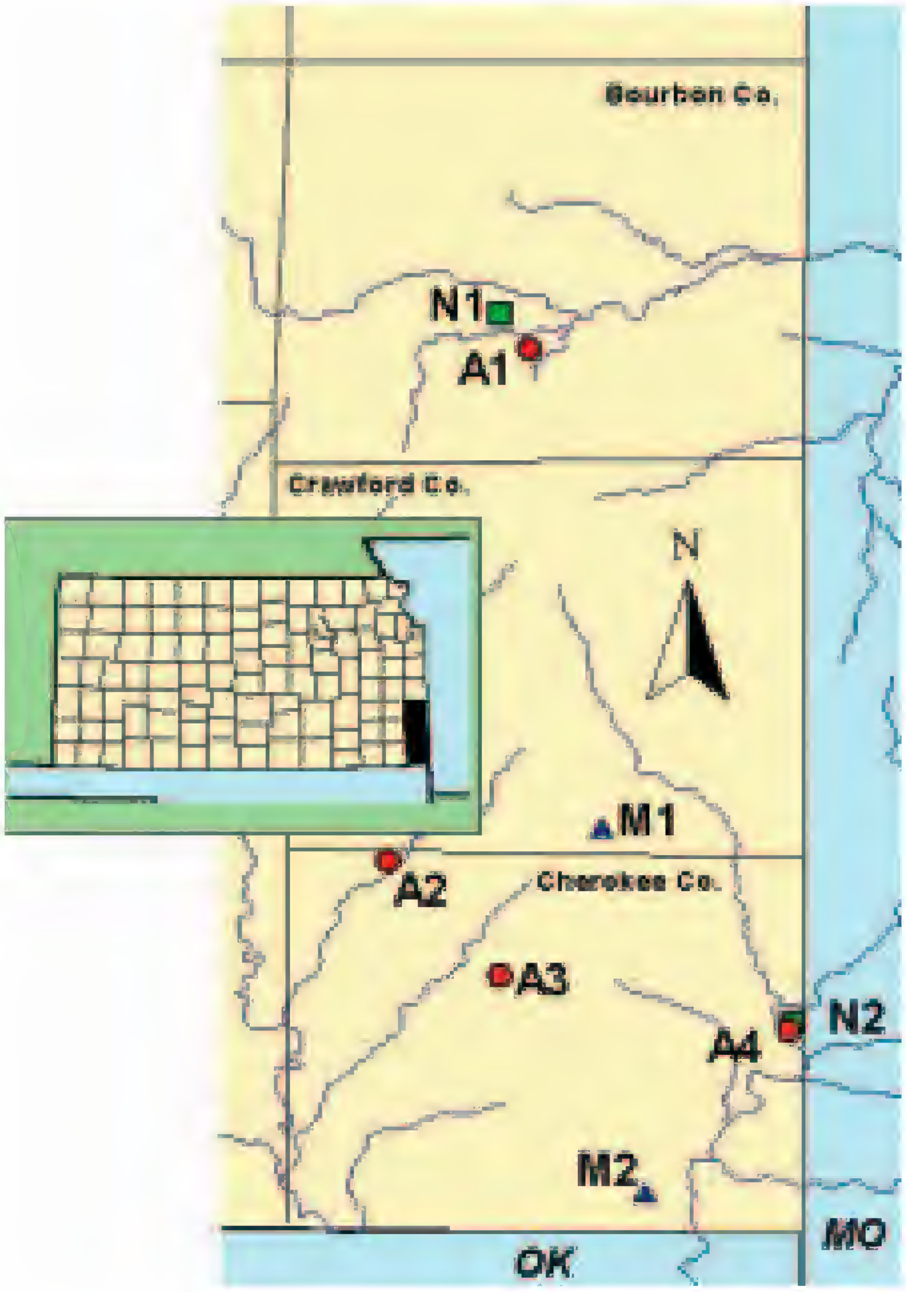

Figure 1. Locations of study sites in southeast Kansas.
DOI: 10.1514/journal.arc.0040014g001

Plate 1. View of site N1 in Bourbon County, Kansas. A shallow artificial pond chiefly fed by a small ephemeral stream that originates in and runs through a meadow and a wooded area.
DOI: 10.1514/journal.arc.0040014g002

ing success of eggs and the malformation rates of their hatched tadpoles incubated in the laboratory.

Methods

Study area and sites

The study area is located in the Osage Cuestas physiographic region in three counties in southeast Kansas USA (Figure 1). Site selection focused on finding anuran breeding pools located in "micro-watersheds" with different immediate surrounding land uses. Three land uses were considered: agricultural, mined, and natural. Agricultural areas were plowed fields and row crops. Areas with live-

Plate 2. View of site N2 in Cherokee County, Kansas. A shallow artificial pond fed by runoff from a mature woodland area.
DOI: 10.1514/journal.arc.0040014g003

Plate 3. View of site A1 in Bourbon County, Kansas. A shallow man-made pond adjacent to a plowed crop field.
DOI: 10.1514/journal.arc.0040014g004

Plate 4. View of site A2 in Cherokee County, Kansas. A natural wetland surrounded on three sides by a plowed crop field.
DOI: 10.1514/journal.arc.0040014g005

Plate 5. View of site A3 in Cherokee County, Kansas. A natural pool on the edge of a plowed crop field.
DOI: 10.1514/journal.arc.0040014g006

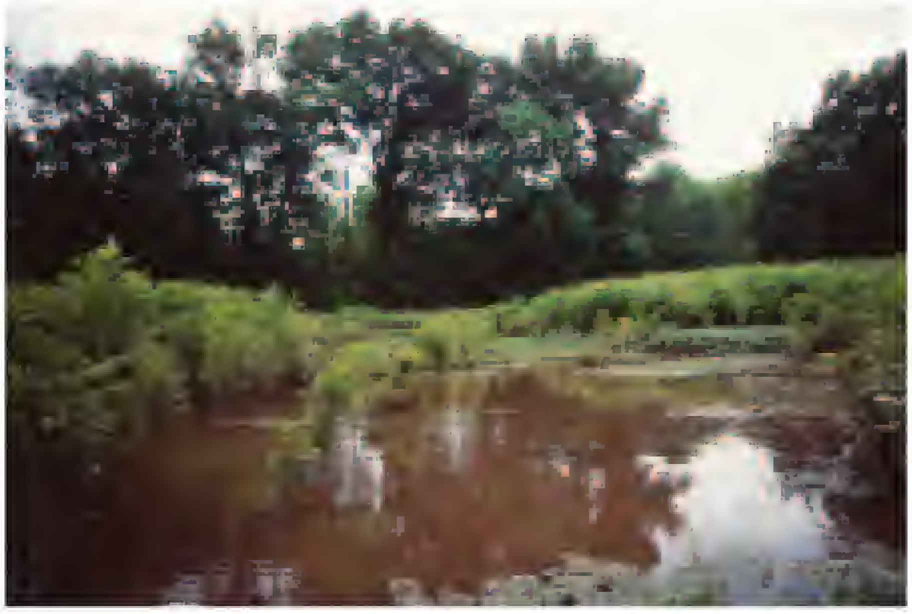

Plate 6. View of site A4 in Cherokee County, Kansas. An artificial wetland in the middle of a plowed crop field.
DOI: 10.1514/journal.arc.0040014g007

Plate 7. View of site M1 in Crawford County, Kansas. A shallow pool chiefly fed by a small ephemeral stream that originates in and runs through land that was previously mined for coal.
DOI: 10.1514/journal.arc.0040014g008

stock were not used. Mined areas were on land that had clear signs of previous mining activity, including mine tailings. Natural areas were defined as lands with no cultivation, grazing, or mining activities occurring within the micro-watershed now or in the recent past, and approximating an undisturbed vegetative cover.

Over 70 potential sites were evaluated according to water depth, vegetation, percentage of the land use category in the micro-watershed, and availability of adjacent non-breeding habitats. The final sites chosen included eight sites in three land use categories: four agricultural sites, two mined land sites, and two natural sites. All sites, except one (A1), are on private property.

The first natural site (N1) is a shallow artificial pond (Plate 1). The pond is fed by a small ephemeral stream that originates in and runs through a meadow and a wooded area before entering the pond. Runoff from the surrounding wooded area also feeds the pond. The area around the pond is undergoing succession and consists of dense cedars, brush, small and medium sized trees, and grasses. Mature forest lies

just to the south and the area has never been cultivated. N2 is a shallow artificial pond (Plate 2). The pond is fed by runoff from a surrounding mature woodland area. An area of grasses mixed with small trees and dense brush is located just north of the pond and a grassed area is located to the south.

The first agricultural site, A1, is a shallow man-made pond adjacent to a plowed crop field on the Hollister Wildlife Area owned by the State of Kansas (Plate 3). The pond is fed by runoff from the field where sunflowers were grown. Adjacent to the other sides of the pond are a prairie, a densely wooded area, and an ephemeral stream. This site is probably the least intensively cultivated site of all the agricultural sites. Agricultural site A2 is a natural wetland (Plate 4) fed by runoff from a crop field where soybeans were grown. The field surrounds the wetland on three sides while small to medium sized trees, aquatic and wet soil plants, and grasses are adjacent to the wetland on the fourth side. Woodlands are nearby to the east and west. Agricultural site A3 is a natural pool at the edge of a plowed crop field (Plate 5). The pool is fed by runoff from the field where soybeans were grown. On the opposite side of the pool from the crop field is a grassed area with dense brush and small trees. Adjacent to the north end are mature woodlands next to a creek. The last agricultural site, A4, is an artificial wetland in the middle of a plowed crop field (Plate 6). The wetland is fed by runoff from the field where soybeans were grown in 1995. A dense growth of small trees is present on both sides in the wetland. A grassed area is adjacent to the wetland, and woodlands lie adjacent to the south, the east, and the west.

The first mined site, M1, is a shallow pool fed by a small ephemeral stream (Plate 7) located on a partially reclaimed coal mine now managed by Pittsburg State University as part of the Monahan Outdoor Education Center. The stream originates in and runs through land that was previously mined for coal and by smaller amounts of runoff from the immediate wooded area. The area adjacent to the pool is undergoing succession with trees of varying sizes and dense brushy vegetation. Native grass areas are adjacent. The last mined site, M2, is a man-made pool at the edge of a pile of mining spoils (chat) left over from lead and zinc mining activities that occurred earlier in this century (Plate 8). The pool is fed by runoff from the chat piles. Adjacent to the pool are cattails, dense brush, grasses, and trees of varying sizes. A wooded area next to a creek is just west of the pool.

Sample collection

Sampling started on 13 March 1995 with each site sampled at two-week intervals for a total of seven samples per site ending on 30 June 1995. Sampling took place in the evenings starting approximately one hour after sunset. All tasks were performed in the same order by the same person during each sample event at each site. A miner's head light was used for illumination.

At each site, the pool was approached quietly with the light dimmed in order to tape record the calls of adult anuran males and count them. If the number of calling anurans was low, it was possible to stand in one or a few spots and count the different individuals. If the number of calling anurans was high, multiple parallel transects were slowly walked with the light dimmed as much as possible (modified from Heyer et al. 1994). Every attempt was made to avoid counting the same individual twice. Anurans were recorded by species and number of individuals in order to estimate density.

Visual census of adults consisted of walking along multiple parallel transects and counting the anurans encountered on both sides of the transect (modified from Heyer et al. 1994). Transects were approximately two meters apart. Anurans were recorded by species and number of individuals in order to estimate density.

During sample period three, the tadpoles in the pools had reached a size large enough to be handled briefly and were sampled. Tadpole sampling was performed throughout the remainder of night sampling periods and in addition, each site was visited and tadpoles sampled during the daylight twice in July approximately two weeks apart.

Tadpole sampling was performed along the edges of two adjacent sides of each sample site. The other two sides of each sample site were sampled during alternate sampling events. Tadpole sampling was performed every five meters (m) at smaller sites and every 10 m at larger sites. Five m is the minimum distance recommended to avoid sampling the same tadpoles more than once (Heyer et al. 1994). Tadpoles were trapped with a plastic storage container with its bottom cut out (24.5 by 38 centimeters, cm). They were removed with a dipnet, counted, examined for malformations, and released. Numbers of individual tadpoles and numbers and types of malformations were recorded. Malformations were classified based on the system in the Frog Embryo Teratogenesis Assay Xenopus (FETAX, Bantle et al. 1991).

When found, the eggs of non-threatened and non-endangered species were collected, brought back to the laboratory, and incubated at 18°C. The eggs were kept in glass beakers with water collected from the site. Water was changed daily using site water kept in a refrigerator (Bantle 1995). Necrotic eggs were removed at the same time.

After the eggs hatched, any remaining necrotic eggs were removed and counted, followed by fixation in 10% formalin for 24 hours (Hull 1995) and preservation in 70% ethanol to preserve them. Newly hatched tadpoles were killed using tricaine methanesulfonate (MS-222) added directly to the beaker to relax the tadpoles and avoid unnatural contortions. Tadpoles were fixed and preserved as for the necrotic eggs.

Preserved tadpoles were then counted and examined for malformations at 15X. Malformation types and number of individuals were recorded in order to calculate the percent of tadpoles hatching successfully and the percent with malformations. Fixation, examination methods, malformation types, and malformation data sheets were modeled after Bantle et al. (1991).

Data analysis

Adult density and field tadpole data were analyzed as a two-way ANOVA with interaction using land use group (natural, agricultural, mined) and sampling period (seven biweekly samples) as main effects. Audio and visual counts (the total count or by individual species) were expressed as density (numbers per hectare, ha) using average breeding pool area.

Table 1. Species present (X) with species richness at each site and land use group. Site codes are mapped in Figure 1.

	Mined		**Agricultural**				**Natural**	
Species	**M1**	**M2**	**A1**	**A2**	**A3**	**A4**	**N1**	**N2**
Acris crepitans	X	X	X	X	X	X	X	X
Bufo americanus	X	X	X		X	X	X	X
Gastrophryne carolinensis						X		X
Hyla versicolor/chrysoscelis			X		X	X	X	X
Pseudacris crucifer			X				X	X
Pseudacris triseriata	X		X	X	X		X	
Rana areolata			X				X	
Rana catesbeiana	X	X	X		X			X
Rana sphenocephala	X	X	X	X	X	X	X	X
TOTAL	**5**	**4**	**8**	**3**	**6**	**5**	**7**	**7**
LAND USE	**5**		**9**				**9**	

DOI: 10.1514/journal.arc.0040014t001

Field tadpole data included tadpole density (numbers per square meter, m^2) and the percentage of field tadpoles with malformations.

Laboratory tadpole data included both percent eggs hatched and percentage tadpoles malformed. These data were analyzed with a one-way ANOVA using land use group as the main effect. Laboratory tadpole data from different sample periods were pooled by site because eggs were not consistently found at all sites in all sample periods. The percentages of types of specific malformations were pooled by land use and so were not analyzed statistically.

All percentage data were arcsine transformed before analysis (Zar 1996). As a result, standard errors from percentage data are asymmetrical and both lower and upper standard errors are presented in data tables. The general linear models procedure in SAS was used for all analyses (SAS 1988) and a significance level of 0.05 was used, except as noted.

Results

Species found

Nine species of anurans were found during visual and audio sampling of adults (Table 1). Overall, agricultural and natural sites both yielded the same nine species but the species present varied at each site. At agricultural sites, species richness varied from three to eight, and while species richness was

Table 2. Adult density by land use group. Data are numbers per hectare. C is census type: A = audio, V = visual. Within each line, means with different lower case letters are significantly different ($P<0.05$, except for northern spring peeper where $P=0.06$).

Species	**C**	**Mined Mean (SE)**	**Agricultural Mean (SE)**	**Natural Mean (SE)**
Rana sphenocephala	A	23.2 (29.8) a	77.2 (21.1) a	59.7 (29.8) a
	V	47.0 (39.8) a	102.7 (28.2) a	65.9 (39.8) a
Pseudacris triseriata	A	3.4 (12.6) a	38.5 (8.9) b	0.0 (12.6) a
	V	3.4 (7.1) a	17.7 (5.0) a	1.9 (7.1) a
Bufo americanus	A	8.4 (24.0) a	29.0 (17.0) a	43.4 (24.0) a
	V	42.1 (19.1) a	28.8 (13.5) a	33.9 (19.1) a
Acris crepitans	A	129.8 (148.0) a	250.9 (104.7) a	546.4 (148.0) a
	V	126.8 (48.6) a	91.0 (34.4) a	186.8 (48.6) a
Pseudacris crucifer	A	0.0 (62.9) b	4.2 (44.5) b	177.1 (62.9) a
	V	0.0 (9.6) b	1.4 (6.8) b	50.5 (9.6) a
Hyla versicolor/chrysoscelis	A	0.0 (41.0) b	106.6 (29.0) a	202.0 (41.0) a
	V	0.0 (13.1) c	38.6 (9.3) b	100.3 (13.1) a
Rana catesbeiana	A	0.0 (7.5) a	7.7 (5.3) a	9.1 (7.5) a
	V	42.7 (13.9) a	28.1 (9.9) a	12.4 (13.9) a
Rana areolata	A	0.0 (5.1) a	4.2 (3.6) a	9.5 (5.1) a
	V	0.0 (4.9) a	6.3 (3.4) a	5.7 (4.9) a
Gastrophryne carolinensis	A	0.0 (0.8) a	0.5 (0.5) a	1.7 (0.8) a
	V	0.0 (0.8) a	0.5 (0.5) a	1.7 (0.8) a
Total density	**A**	**164.8 (198.3) b**	**519.0 (140.2) b**	**1048.7 (198.3) a**
	V	**262.0 (86.0) a**	**315.1 (60.8) a**	**459.0 (86.0) a**

DOI: 10.1514/journal.arc.0040014t002

Plate 8. View of site M2 in Cherokee County, Kansas. A man-made pool at the edge of a pile of mining spoils (chat) left over from lead and zinc mining.
DOI: 10.1514/journal.arc.0040014g009

All landscape photos by Lewis Anderson (Plates 1-8).

seven at both natural sites. The mined sites had only five species, four at one site and five at the second. Only one agricultural site (A1) had more than six species.

Based on overall occurrences, there may be three clusters of species. Cluster one included species generally found at all three groups of sites: the southern leopard frog (*Rana sphenocephala*), western chorus frog (*Pseudacris triseriata*), American toad (*Bufo americanus*), Blanchard's cricket frog (*Acris crepitans*), and the bullfrog (*Rana catesbeiana*) [Table 1]. Cluster two included species not found at the mined sites, less common at the agricultural sites, and common at the natural sites: northern spring peeper (*Pseudacris crucifer*) and gray treefrog (*Hyla versicolor / chrysoscelis*). Cluster three included species uncommon at all sites: northern crawfish frog (*Rana areolata*) and eastern narrowmouth toad (*Gastrophryne carolinensis*).

Adult density

Total audio density was significantly greater in natural sites (1048.7 / ha) than in the agricultural and mined sites (Table 2), but there was no significant difference between the agricultural (519.0 / ha) and mined (164.8 / ha) sites. Total visual density did not vary significantly among the groups of sites, but the rank order was the same as for audio density. Overall, estimates of audio density were about twice the visual densities at agricultural and natural sites, but just over half at the mined sites.

The densities of some species varied with land use group. *P. triseriata* audio density was significantly higher in agricultural sites than in mined and natural sites (Table 2). Natural sites had no *P. triseriata* in the audio census. Visual density was also higher at the agricultural sites, but not significantly so, and *P. triseriata* were found during the visual census at one natural site. The density of *R. sphenocephala* was also higher at agricultural sites in both audio and visual census (Table 2), although the differences were not significant.

Visual density of the *H. versicolor/chrysoscelis* complex was significantly higher in natural sites compared to agricultural sites (Table 2). The same pattern existed for audio density, but was not significant. Audio and visual density of

Plate 9. Eastern Narrowmouth Toad, *Gastrophryne carolinensis*. DOI: 10.1514/journal.arc.0040014g010

Table 3. Field tadpole density (per m2) and percent malformations by land use category. Standard errors for percentage data are asymmetrical upper and lower standard errors. Within each line, means with different lower case letters are significantly different (P<0.05).

	Mined Mean (SE)	Agricultural Mean (SE)	Natural Mean (SE)
Density (per m2)	28.5 (11.1) c	59.4 (7.7) b	137.6 (11.8) a
% Malformed	8.3 (2.2/1.9) b	4.6 (0.8/0.8) b	0.4 (0.5/0.1) a

DOI: 10.1514/journal.arc.0040014t003

Table 4. Percentages of types of malformations in field tadpoles from each land use category.

Category	Spinal Cord	Optic	Edema	Tumor
Mined	78.9	5.3	10.5	5.3
Agricultural	67.5	12.5	13.8	6.3
Natural	92.8	7.2	0.0	0.0

DOI: 10.1514/journal.arc.0040014t004

P. crucifer approached being significantly higher in natural sites (P = 0.06) compared to agricultural sites (Table 2). Mined sites had no *P. crucifer* or *H. versicolor / chrysoscelis* complex individuals in either audio or visual census.

Field-collected tadpoles

Tadpole density was significantly higher in natural sites (137.6/m^2) compared to agricultural (59.4/m^2) and mined sites (28.5/m^2, Table 3). Natural sites also had significantly lower percentage of tadpoles with malformations in the field (0.4%) compared to agricultural (4.6%) and mined sites (8.3%, Table 3). Four different types of malformations were found on tadpoles in the field (Table 4). Spinal cord malformations were the most prevalent in all land use categories varying from 67.5% of malformations found on tadpoles in agricultural sites to 92.8% at natural sites. Optic malformations varied from 5.3% at mined sites to 12.5% at agricultural sites. No tadpoles with edema were found at natural sites compared to 10.5% of tadpoles at mined sites and 13.8% at agricultural sites. No tumors were found on tadpoles at natural sites, but tumors were found on 5.3% of tadpoles with malformations at mined sites and on 6.3% at agricultural sites.

Laboratory-hatched tadpoles

The percentage of eggs hatching successfully in the laboratory was significantly higher in natural and agricultural sites (98.8% and 88.2%, respectively), compared to mined sites (40.4%, Table 5). Natural sites also had the lowest percentage of tadpoles with malformations from eggs incubated in the laboratory (17.5%), compared to agricultural sites (51.0%) and mined sites (76.1%, Table 5); however, these differences were not statistically significant.

Five different types of malformations were found on tadpoles hatched from eggs incubated in the laboratory: notochord / spinal cord, head / face, edema, stunted, and severe (having three or more different malformations) [Table 6]. Notochord / spinal cord and stunted malformations were most prevalent on tadpoles from eggs collected at mined and agricultural sites, and edema was the most prevalent malformation from natural sites.

Discussion

The characteristics of these anuran populations were related to land use. Differences were found with regard to adult anuran total visual and audio density, field tadpole density, tadpoles percent with malformations (field and laboratory), and laboratory eggs percent hatching successfully. In four of these six measurements, differences due to land use were statistically significant, and in all cases the ranks of values were best in natural sites and worst in mined sites, with agricultural sites intermediate.

In addition, although five of the nine species were common to all three land use groups, two other species (*P. crucifer* and *H. versicolor / chrysoscelis* complex) were more common at the natural sites. This difference was not related to geographic distribution, since the natural sites spanned from the region from north to south. Perhaps unassessed habitat requirements or water quality sensitivities were a factor. Two species tended to be denser at the agricultural sites: *P. triseriata* and *R. sphenocephala*. The presence of more grassed areas as non-breeding habitat at the agricultural sites may be a factor in this trend. Although the data were collected from only one season, the replication of sites, the independence of variables, and the consistency of patterns provide evidence of an overall link between land use and characteristics of amphibians and their populations.

Mensing et al. (1998) found relationships between some of six land use types and the species richness or diversity of several biotic groups, including amphibians. Knutson et al. (1999) examined landscape level habitat associations for frogs and toads, and found a consistent negative association with urban land use. Relationships of these anuran populations to agriculture varied, being negative in Iowa, but positive in Wisconsin. The presence of isolated remnant forest patches in Wisconsin may have been responsible for the positive agricultural effect (Knutson et al. 1999).

What factors are associated with this overall relationship of land use to amphibian population diversity? Variability in physical habitat, food, predation, and the availability or quality of nonbreeding and breeding habitats could be specifically influential. However, the impact of land use on water quality can be equally important. For example, while habitat loss has been blamed in general for amphibian population declines, it can not explain differences in tadpole malformation rates or hatching success related to land use among the sites studied here.

Anurans have been shown to bioconcentrate or bioaccumulate pollutants. Tritiated water has been shown to appear

Plate 10. Southern Leopard Frog, *Rana sphenocephala*. DOI: 10.1514/journal.arc.0040014g011

Plate 11. Western Chorus Frog, *Pseudacris triseriata*. DOI: 10.1514/journal.arc.0040014g012

Table 5. Percentage of lab-reared eggs hatching and with malformations as tadpoles by land use category. Standard errors for percentage data are asymmetrical upper and lower standard errors. Within each line, means with different lower case letters are significantly different (P<0.05).

	Mined Mean (SE)	Agricultural Mean (SE)	Natural Mean (SE)
% Hatched	40.4 (10.0/9.7) b	88.2 (4.2/5.0) a	98.8 (1.2/3.2) a
% Malformed	76.1 (17.3/23.6) a	51.0 (17.4/17.5) a	17.5 (22.4/14.3) a

DOI: 10.1514/journal.arc.0040014t005

Table 6. Percentages of types of malformations from lab-reared tadpoles in each land use category.

Category	Notochord Spinal Cord	Head/ Face	Edema	Stunted	Severe
Mined	48.8	2.4	4.9	41.5	2.4
Agricultural	46.8	1.1	9.6	33.5	9.0
Natural	26.9	8.5	36.2	19.2	9.2

DOI: 10.1514/journal.arc.0040014t006

within 2.5 minutes in the lymphatic system and the plasma of a chronically catheterized *Bufo marinus* (Wentzell 1993). Wentzell (1993) also noted the kidney is the first organ exposed to the incoming ambient water. Atrazine has been shown to bioconcentrate in northern leopard frogs (*Rana pipiens*), but no impacts were observed (Allran and Karasov 2000). Russell et al. (1997) surveyed the distribution of the accumulation of PCBs and DDT metabolites in green frogs (*Rana clamitans*) and found variation in the amounts and kinds of contaminants accumulated. Bishop and Gendron (1998) reviewed literature on contaminant levels and effects in amphibians for the Great Lakes basin and reported some population declines could be influenced by exposures to environmental contaminants.

In agricultural areas, pesticides may be present in breeding pools. Several organophosphates caused abnormal pigmentation, abnormal gut development, notochord defects, and reduced growth to embryos of the African clawed frog *Xenopus laevis* (Snawder and Chambers 1989). Organochlorine pesticides impaired the peripheral or central nervous system by the likely inhibition of enzymes or metabolites by substances normally destroyed during nerve action (Livingston 1977). Fenitrothion and carbaryl showed effects such as microcephaly, edema, altered external morphology, heart abnormalities, and notochord / spinal cord abnormalities in *X. laevis* (Elliot-Feeley 1982).

R. pipiens larvae were exposed to atrazine and nitrates in the lab and no significant growth or developmental effects were noted except for slowed larval growth due to nitrates (Allran and Karasov 2000). Bridges and Semlitsch (2000) found significant variation in the time to death among tadpoles of nine species of *Rana* and ten subpopulations of *R. sphenocephala* exposed to carbaryl. Significant variation in the tolerance to carbaryl was found within a population of *H. versicolor* tadpoles (Semlitsch et al. 2000).

At Pelee Island in Canada, hybrid toads (*B. woodhousii* X *B. americanus*) have disappeared from agricultural areas with heavy chemical use (Green 1989). Cooke (1981) caged tadpoles in a potato field sprayed with oxamyl, a carbamate nematicide, and found a very high incidence of deformities of the tail and hind limbs, and high mortality among the deformed tadpoles.

R. pipiens embryos exposed to paraquat in a laboratory situation showed abnormal tail development, reduced muscular response, abnormal swimming behavior, and stunted growth (Dial and Bauer 1984). The types of malformations found in these studies are consistent with those found in agricultural areas in this study including notochord / spinal cord malformations (sometimes also referred to as tail abnormalities or malformations), microcephaly (head/face), and stunted growth (Tables 4 and 6).

In mined areas, problems can arise from the leaching of metals such as lead and zinc, and from low pH. Smelters also have been active in southeast Kansas in the past, sometimes close to mines. Lead concentrations found in tadpoles living in water subject to deposition from smelters and lead mine effluent are much higher than in tadpoles found residing in roadside ditches (Birdsall et al. 1986). Because of differences in the feeding habits of larval and adult amphibians, tadpoles living in roadside drainage accumulate more lead than the adults (Birdsall et al. 1986). Also, *B. americanus* tadpoles have shown no avoidance of water containing lead in octogonal fluvarium tests (Vial 1992).

Niethhammer et al. (1986) showed that *R. catesbeiana* had much higher levels of lead, zinc, and cadmium in their tissues than did reptiles, birds, or mammals collected from a river impacted by metal pollution from abandoned mine tailing piles. Khangarot and Ray (1987) showed that amphibians exposed to heavy metals display a variety of adverse effects such as erratic body movements, slower growth and development rates, morphological deformities and death.

Rowe et al. (1996) found oral deformities in tadpoles from a basin contaminated by coal ash. Loumbourdis et al. (1999) noted a tendency for retarded growth in tadpoles of *R. ridibunda* exposed to cadmium. The metamorphosis of *R. luteiventrus* tadpoles was delayed when they were exposed to soils contaminated with heavy metals (Lefcort et al. 1998). Freda (1991) pointed out the influential roles of pH,

Plate 12. Gray Treefrog, Hyla versicolor/chrysoscelis.

DOI: 10.1514/journal.arc.0040014g013

Plate 13. Northern Cricket Frog, *Acris crepitans*.

DOI: 10.1514/journal.arc.0040014g014

hardness, dissolved organic carbon, developmental stage, and species on the impact of aluminum toxicity. Additionally, Freda (1991) noted the endpoints of toxic effects may vary from early egg mortality to sperm motility or to the success of fertilization.

Tests on anuran embryos under acidic conditions indicate a high survival rate to a certain threshold, and then the survival rate drops drastically. Embryos that do hatch often display developmental abnormalities and more abnormalities at lower pH (Pierce et al. 1984). Larvae of *R. sylvatica* showed greater tolerance to acidic conditions but toxicity of the acidic water does have adverse effects (Pierce et al. 1984). Preest (1993) showed that low pH disrupts osmoregulation in *Ambystoma maculatum* larvae causing slower growth and ultimately reducing fecundity and increasing exposure to predation.

At M2, the lead/zinc mined site, no tadpoles were found during any sample event nor were any tadpoles found during two intensive searches of the entire pool. Tadpoles with stunted growth comprised 41.5% of the total malformations found from eggs originating from mined sites in this study compared to 33.5% at agricultural sites and 19.2% at natural sites (Table 6).

Since land use likely affects water quality, water quality provides a possible explanation for the higher rate of tadpoles with malformations, the lower percentage of eggs hatching successfully, and potentially, the lower density of tadpoles in agricultural and mined land breeding pools. It is less clear what the relative role of water quality is in producing the lower adult anuran densities and species richness in agricultural and mined land breeding pools compared to physical habitat availability or quality.

The application of metapopulation dynamics (Gilpin and Hanski 1991, Fiedler and Jain 1992) and the concepts of sources and sinks to amphibians has been recognized by Hecnar and M'Closkey (1996) and Alford and Richards (1999). Considering the relationship of spatial scale to the species status of green frogs (*R. clamitans*), Hecnar and M'Closkey (1997) detected differences in occupancy and abundance at various spatial scales and concluded that the status of the green frog was dependent on the scale used.

Overall, the higher diversity of amphibians seen in the region of southeast Kansas may be maintained by a heterogeneous landscape, where losses in impacted areas are balanced by survival and recruitment from unimpacted areas. The analysis of Alford and Richards (1999) that habitat patch isolation may be of greater significance on populations of amphibians, compared to other animals is relevant to the consideration of the status of amphibians in southeast Kansas. Alford and Richards (1999) concluded that the dynamics of pond use was primarily affected by breeding pond isolation. The amphibian landscape of southeast Kansas contains many isolated patches of breeding pools, pools isolated not only by physical distance, but by the distance generated by patches of poor water quality. These pools have varied breeding and nonbreeding habitats as well, cast against a background of dispersal pathways and environments.

Even when adult anurans from neighboring populations migrate into an impacted breeding patch, low juvenile recruitment due to poor tadpole survivorship can result in reduced adult density and diversity in the patch. Freda (1991), Bishop and Gendron (1998) and Loumbourdis et al. (1999) show the key role of pollutants on the tadpole stage. If water quality is sufficiently poor over a larger regional area, there may be no immigration at all into central breeding pools and overall biodiversity may decrease as observed by Hecnar and M'Closkey (1996) for the effect of habitat loss. Species having shorter life spans may be the first to disappear from an area and any differential tolerances of the adults, larvae, and eggs from different species (Bridges and Semlitsch 2000 and Semlitsch et al. 2000) may also play a role. The limited travel range of anurans and the consideration that some tend to be patrophilic may explain localized extirpations of anuran populations such as observed here.

Acknowledgments.—We wish to thank Dan VanLeeuwen for assistance in both the field and laboratory and Drs. James Triplett and Alexander Bednekoff for assistance in guiding the project. The project would not have been possible without access to land owned or managed by: Vernon and Carmen Anderson, Kate Wade, and Verne Leeper, the Terry Best family, the Brewster brothers, Augustus Clark, the Pittsburg State University Biology Department, the Kansas Department of Wildlife and Parks, and the Farmers Home Administration. This project was funded by the Kansas Department of Wildlife and Parks. Suzanne Collins and Joseph Collins of The Center for North American Herpetology graciously provided species images.

References

Alford, R. A. and Richards, S. J. 1999. Global amphibian declines: a problem in applied ecology. *Annual Review of Ecology and Systematics* **30**:133-165.

Allran, J. W. and Karasov, W. H. 2000. Effects of atrazine and nitrate on northern leopard frog (*Rana pipiens*) larvae exposed in the laboratory from posthatch through metamorphosis. *Environmental Toxicology and Chemistry* **19**:2850-2855.

Bantle, J. A. 1995. Oklahoma State University FETAX Laboratory. Personal communication.

Bantle, J. A., Dumont, J. N., Finch, R. A., and Linder, G. 1991. *Atlas of Abnormalities, a Guide for the Performance of FETAX.* Oklahoma State University, Publications Department, Stillwater, Oklahoma. 68 p.

Birdsall, C. W., Grue, C. E., and Anderson, A. 1986. Lead concentrations in bullfrog *Rana catesbeiana* and green frog *Rana clamitans* tadpoles inhabiting highway drainages. *Environmental Pollution Series A* **40**:233247.

Bishop, C. A. and Gendron, A. D. 1998. Reptiles and amphibians: shy and sensitive vertebrates of the Great Lakes basin and St. Lawrence River. *Environmental Monitoring and Assessment* **53**:225-244.

Blaustein, A. R. and Wake, D. B. 1990. Declining amphibian population: a global phenomenon? *Trends in Ecology and Evolution* **5**:203-204.

Bridges, C. M. and Semlitsch, R. D. 2000. Variation in pesticide tolerance of tadpoles among and within species of ranidae and patterns of amphibian decline. *Conservation Biology* **14**:1490-1499.

Conant, R. and Collins, J. T. 1993. *Reptiles and Amphibians, Eastern/Central North America.* Houghton Mifflin, Boston, Massachusetts. 450 p.

Cooke, A. S. 1981. Tadpoles as indicators of harmful levels of pollution in the field. *Environmental Pollution Series A* **25**:123133.

Dial, N. A. and Bauer, C. A. 1984. Teratogenic and lethal effects of

Plate 14. Crawfish Frog, *Rana areolata*. DOI: 10.1514/journal.arc.0040014g015

Plate 15. Spring Peeper, *Pseudacris crucifer*. DOI: 10.1514/journal.arc.0040014g016

Plate 16. Bullfrog, *Rana catesbeiana*. DOI: 10.1514/journal.arc.0040014g017

Plate 17. American Toad, *Bufo americanus*. DOI: 10.1514/journal.arc.0040014g018

paraquat on developing frog embryos (*Rana pipiens*). *Bulletin of Environmental Contamination and Toxicology* **33**:592597.

Elliot-Feeley, E. 1982. Effects of fenitrothion and carbaryl on *Xenopus laevis* development. *Toxicology* **22**:319335.

Fahrig, L., Pedlar, J. H., Pope, S. E., Taylor, P. D., and Wegner, J. F. 1995. Effect of road traffic on amphibian density. *Biological Conservation* **73**:177-182.

Fielder, P. L. and Jain, S. K. (editors). 1992. *Conservation Biology: the theory and practice of nature conservation, preservation, and management.* Chapman and Hall, New York, New York. 507 p.

Freda, J. 1991. The effects of aluminum and other metals on amphibians. *Environmental Pollution* **71**:305-328.

Gilpin, M. and Hanski, I. (editors). 1991. *Metapopulation dynamics: empirical and theoretical investigations.* Academy Press, London, United Kingdom. 336 p.

Green, D. M. 1989. Fowler's toad *Bufo woodhousii fowleri* in Canada: biology and population status. *Canadian Field-Naturalist* **103**:486496.

Hecnar, S. J. and M'Closkey, R. T. 1996. Regional dynamics and the status of amphibians. *Ecology* **77**:2091-2097.

Hecnar, S. J. and R. T. M'Closkey. 1997. Spatial scale and determination of species status of the green frog. *Conservation Biology* **11**:670-682.

Heyer, W. R., Donnelly, M. A., McDiarmid, R. W., Hayek, L. A. C., and Foster, M. S. 1994. *Measuring and Monitoring Biological Diversity: standard methods for amphibians.* Smithsonian Institution Press, Washington, D.C. 364 p.

Hull, M. 1995. Oklahoma State University FETAX Laboratory. Personal Communication.

Khangarot, B. S. and Ray, P. K. 1987. Sensitivity of toad tadpoles, *Bufo melanostictus* (Schneider), to heavy metals. *Bulletin of Environmental Contamination and Toxicology* **38**:523527.

Knutson, M. G., Sauer, J. R., Olsen, D. A., Mossman, M. J., Hemesath, L. M., and Lannoo, M. J. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. *Conservation Biology* **13**:1437-1446.

Lefcort, H., Meguire, R. A., Wilson, L. H., and Ettinger, W. F. 1998. Heavy metals alter the survival, growth, metamorphosis, and antipredatory behavior of Columbia spotted frog (*Rana luteiventris*) tadpoles. *Archives of Environmental Contamination and Toxicology* **35**:447-456.

Livingston, R. J. 1977. Review of the current literature concerning the acute and chronic effects of pesticides on aquatic organisms. *CRC Critical Reviews in Environmental Control.* November:325-351.

Loumbourdis, N. S., Kyriakapoulou-Sklavounou, P., and Zachariadis, G. 1999. Effects of cadmium exposure on bioaccumulation and larval growth in the frog *Rana ridibunda*. *Environmental Pollution* **104**:429-433.

Marsh, D. M., Fegraus, E. H., and Harrison, S. 1999. Effects of breeding pond isolation on the spatial and temporal dynamics of pond use by the tungara frog, *Physalaemus pustulosus*. *Journal of Animal Ecology* **68**:804-814.

Mensing, D. M., Galatowitsch, S. M., and Tester, J. R. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a north temperate landscape. *Journal of Environmental Management* **53**:349-377.

Niethammer, K. R., Atkinson, R. D., Baskett, T. S., and Samson, F. B. 1985. Metals in riparian wildlife of the lead mining district of southeastern Missouri. *Archives of Environmental Contamination and Toxicology* **14**:213224.

Pierce, B. A., Hoskins, J. B., and Epstein, E. 1984. Acid tolerance in Connecticut wood frogs (*Rana sylvatica*). *Journal of Herpetology* **18**:159167.

Preest, M. R. 1993. Mechanisms of growth rate reduction in acid-exposed larval salamanders, *Ambystoma maculatum. Physiological Zoology* **66**:686707.

Ptacek, M. S. 1984. Reproductive ecology and habitat analysis of the northern spring peeper (*Hyla c. crucifer*) in southeastern Kansas. Unpublished M.S. Thesis, Emporia State University, Emporia, Kansas. 75 p.

Rowe, C. L., Kinney, O. M., Fiori, A. P., and Congdon, J. D. 1996. Oral deformities in tadpoles (*Rana catesbeina*) associated with coal ash deposition: effects on grazing ability and growth. *Freshwater Biology* **36**:723-730.

Russell, R. W., Gillan, K. A., and Haffner, G. D. 1997. Polychlorinated byphenyls and chlorinated pesticides in southern Ontario, Canada, green frogs. *Environmental Toxicology and Chemistry* **16**:2258-2263.

SAS Institute Inc. 1988. *SAS/STAT™ User's Guide, Release 6.03 Edition.* Cary, North Carolina. SAS Institute, Inc. 1028 p.

Semlitsch, R. D. 2000. Principles for management of aquatic-breeding amphibians. *Journal of Wildlife Management* **64**:615-631.

Semlitsch, R. D. and Bodie, J. R. 1998. Are small, isolated wetlands expendable? *Conservation Biology* **12**:1129-1133.

Semlitsch, R. D., Bridges, C. M., and Welch, A. M. 2000. Genetic variation and a fitness tradeoff in the tolerance of gray treefrog (*Hyla versicolor*) tadpoles to the insecticide carbaryl. *Oecologia* **125**:179-185.

Snawder, J. E. and Chambers, J. E. 1989. Toxic and developmental effects of organophosphorus insecticides in embryos of the South African clawed frog. *Journal of Environmental Sciences and Health Part B Pesticide, Food Contamination and Agricultural Wastes* **24**:205218.

Vial, J. 1992. *Froglog*. Declining Amphibian Populations Task Force, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. Number 4.

Vos, C. C. and Chardon, J. P. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. *Journal of Applied Ecology* **35**:44-56.

Wake, D. B. 1991. Declining amphibian populations. *Science* **253**:860.

Wentzel, L. A. 1993. The role of the lymphatic system in water balance processes in the toad *Bufo marinus* (L.). *Physiological Zoology* **66**:307321.

Zar, J. H. 1996. *Biostatistical Analysis.* Third Edition. Prentice Hall, Upper Saddle River, New Jersey. 662 p.

Manuscript received: 30 September 1997; Accepted: 27 October 2001; Published: 26 December 2006

The authors are responsible for the facts presented in this article and for the opinions expressed therein, which are not necessarily those of UNESCO and do not commit the Organisation. The authors note that important literature which could not be incorporated into the text has been published following the drafting of this article.

Amphibian and Reptile Conservation 4(1):60-87.
DOI: 10.1514/journal.arc.0040016 (2329KB PDF)

Conservation of amphibians and reptiles in Indonesia: issues and problems

DJOKO T. ISKANDAR[1] * AND WALTER R. ERDELEN[2]

[1]*School of Life Sciences and Technology, Institut Teknologi Bandung, 10, Jalan Ganesa, Bandung 40132 INDONESIA*
[2]*Assistant Director-General for Natural Sciences, UNESCO, 1, rue Miollis, 75732 Paris Cedex 15, FRANCE*

Abstract.—**Indonesia is an archipelagic nation comprising some 17,000 islands of varying sizes and geological origins, as well as marked differences in composition of their floras and faunas. Indonesia is considered one of the megadiversity centers, both in terms of species numbers as well as endemism. According to the Biodiversity Action Plan for Indonesia, 16% of all amphibian and reptile species occur in Indonesia, a total of over 1,100 species. New research activities, launched in the last few years, indicate that these figures may be significantly higher than generally assumed. Indonesia is suspected to host the worldwide highest numbers of amphibian and reptile species. Herpetological research in Indonesia, however, has not progressed at a rate comparable to that of neighboring countries. As a result, the ratio of Indonesian species to the entirety of Southeast Asian and Malesian species has "declined" from about 60% in 1930 to about 50% in 2000, essentially a result of more taxa having been described from areas outside Indonesia. Many of these taxa were subsequently also found in Indonesia. In the last 70 years, 762 new taxa have been described from the Southeast Asia region of which only 262 were from Indonesia. In general, the herpetofauna of Indonesia is poorly understood compared to the herpetofauna of neighboring countries. This refers not only to the taxonomic status, but also to the basic biological and ecological characteristics of most of the species. Moreover, geographic distribution patterns for many species are only poorly known. In view of the alarming rate of forest loss, measures for more effective protection of the herpetofauna of Indonesia are urgently required. The status of virtually all of the Indonesian species, e.g. in terms of IUCN categories, remains unknown, and no action plans have been formulated to date. In addition, research results on Indonesia's amphibian and reptile fauna have often not been made available in the country itself. Finally, there is a clear need to organize research activities in such a way that a larger segment of the Indonesian population becomes aware of the importance of the herpetofauna as an essential component of the country's biodiversity. To address these issues, this paper (1) gives an overview of the herpetofauna as part of Indonesia's biodiversity, (2) outlines the history of herpetological research in the region, (3) identifies major gaps in our knowledge of the Indonesian herpetofauna, and (4) uses this framework for discussing issues and problems of the conservation of amphibians and reptiles in Indonesia. In particular, the contents and shortcomings of compilations of lists of protected or threatened species by national and international authorities are discussed, major threats to the Indonesian herpetofauna or certain components thereof are described, and a set of measures for better long-term conservation is proposed.**

Abstrak.—**Indonesia adalah suatu negara kepulauan yang terdiri dari sekitar 17.000 pulau dengan ukuran bervariasi dan mempunyai asal usul geologi yang kompleks seperti yang terlihat dalam komposisi tumbuhan dan hewannya. Indonesia, sebagai salah satu pusat keanekaragaman yang terbesar di dunia, baik dari segi kekayaan alam jenisnya maupun dari segi tingkat endemisitasnya. Menurut Biodiversity Action Plan for Indonesia, 16% dari amfibi dan reptil dunia terdapat di sini, dengan jumlah lebih dari 1100 jenis. Kegiatan penelitian yang dilaksanakan pada masa yang baru lalu menunjukkan bahwa jumlah tersebut di atas masih jauh di bawah keadaan yang sebenarnya. Indonesia mungkin sekali sebuah negara yang mempunyai jumlah amfibi dan reptil terbesar di dunia. Yang patut menjadi pertimbangan ialah bahwa penelitian amfibi dan reptil di Indonesia jauh lebih lambat di bandingkan dengan kemajuan di negara tetangga. Sebagai gambaran, jumlah jenis di Indonesia apabila dibandingkan dengan jumlah jenis di seluruh Asia Tenggara dalam kurun waktu 70 tahun telah merosot dari 60% menjadi 50%. Hal ini terjadi karena jumlah taksa baru kebanyakan ditemukan di luar Indonesia. Banyak diantara jenis-jenis tersebut kemudian ditemukan di Indonesia. Dalam 70 tahun terakhir, 762 jenis taksa dipertelakan dari luar Indonesia dan hanya 262 pertelaan dari Indonesia.**

Correspondence. * [1]*Tel/fax: ++62-22-250.0258, email: iskandar@sith.itb.ac.id* [2]*Tel: +33 (0) 1 45 68 40 78, email: w.erdelen@unesco.org; *Corresponding author.*

Pada umumnya herpetofauna Indonesia tidak banyak dikenal, baik dari segi taksonomi, ciri-ciri biologi maupun ciri-ciri ekologinya. Daerah penyebaran suatu jenis sangat sedikit diketahui. Meninjau dari cepatnya penebangan dan pengalihan fungsi hutan, usaha untuk melindungi komponen biologi (dalam hal ini amfibi dan reptil) sangat diperlukan. Hampir semua status perlindungan baik secara nasional maupun dengan mengikuti kategori IUCN atau CITES tidak banyak diketahui atau dipahami. Kebanyakan informasi mengenai organisme Indonesia sulit diperoleh di dalam negeri. Sebagai akibat, maka diperlukan suatu mekanisme untuk mengatur kegiatan penelitian sedemikian rupa sehingga timbul kesadaran bahwa amfibi dan reptil merupakan salah satu komponen yang sangat berharga dari kekayaan keaneka-ragaman Indonesia. Makalah ini memberikan (1) gambaran komponen biodiversitas herpetofauna Indonesia, (2) memaparkan sejarah perkembangan herpetologi di Indonesia, (3) mengidentifikasi kekosongan dalam pengetahuan herpetologi di Indonesia, (4) memaparkan masalah dan jalan keluar dalam konseravsi keanekaragaman herpetofauna Indonesia. Daftar herpetofauna Indonesia yang dilindungi undang-undang, CITES dan IUCN dibahas, hewan-hewan yang mulai terancam dan kiat untuk melindunginya dibahas.

Key words. *Conservation, biodiversity, current knowledge, Indonesia, Amphibia, Reptilia, IUCN*

Citation: Iskandar, D. T. and Erdelen, W. R. 2006. Conservation of amphibians and reptiles in Indonesia: issues and problems. Amphib. Reptile Conserv. 4(1):60–87(e16).

Introduction

Indonesia, an archipelagic nation with a population of some 210 million people, comprises about 17,000 islands of varying sizes and geological origins, as well as marked differences in composition of their floras and faunas. Indonesia is one of the 17 megadiversity countries (Mittermeier and Mittermeier 1997) with two of the world's 25 hotspots for conservation priorities, viz. Sundaland and Wallacea (Mittermeier et al. 1999; Myers et al. 2000), important ecoregions and endemic bird areas. According to the biodiversity action plan for Indonesia (BAPPENAS 1993), 16% of the world's amphibian and reptile species occur in Indonesia, a total of over 1100 species.

One of the earliest comprehensive descriptions of the herpetofauna of Indonesia, formerly referred to as Dutch East India or the Dutch East Indies, is the two volume work by de Rooij (1915, 1917). The first volume covers the lizards, turtles, and crocodiles; 267 species of lizards, 35 chelonians, and four species of crocodilians are described. The second volume on snakes lists 84 genera and 318 species. De Rooij's nomenclature is based on the catalogues of the British Museum published in several volumes by Boulenger (see Das 1998, for references). The region covered in this work is the Indo-Australian Archipelago, stretching from Sumatra in the west to New Guinea and the Solomon Islands in the east. The next landmark publication on the herpetofauna of the Indo-Australian Archipelago was the work of van Kampen (1923) on amphibians. This work was an extension of his earlier work—he had published a list of 194 amphibian species for the same region in 1907—which brought the total number of amphibian species described to 254 species. In 1950, more than 30 years after de Rooij's publication (de Rooij 1917), de Haas published a checklist of the snakes of the Indo-Australian Archipelago (de Haas 1950). This checklist contained additions to the snake fauna and also some nomenclatorial changes. De Haas (1950) stressed the imperfect knowledge of the geographic distribution of many species, even from Java, where much of the early research had been carried out. This, to some extent, was covered by van Hoesel's work on the snakes of Java (van Hoesel 1959). Later work either focused on specific taxonomic groups or on parts of the Indonesian region or neighboring countries (Iskandar 1998, 2000). As a consequence, discussed in further detail below, much of our increasing knowledge of the Indonesian herpetofauna was a result of work performed outside of Indonesia itself. Only within the last decade new work on the Indonesian herpetofauna has appeared, e.g., on turtles and crocodiles (Iskandar 2000), the snakes of Sumatra (David and Vogel 1996), the snakes of Borneo (Stuebing and Inger 1999), the snakes of Sulawesi (de Lang and Vogel 2005), the amphibians of Java and Bali (Iskandar 1998), the lizards of Borneo (Das 2004), and the amphibians and reptiles of the Sunda region (Manthey and Grossmann 1997). Checklists of all amphibian and snake species of Southeast Asia and New Guinea have been compiled (Iskandar and Colijn 2000, 2002); the other reptile checklists are still in press. Other publications of regional relevance include work on Philippine amphibians (Alcala and Brown 1998), on the herpetofauna of Sabah (Inger and Stuebing 1989; Inger and Tan 1996), and publications focusing on Borneo (e.g., Inger and Stuebing 1997; ITTO 1998), peninsular Malaysia and Thailand (Chan-Ard et al. 1999; Cox et al. 1998), peninsular Malaysia and Borneo (Lim and Das 1999), and Singapore (Lim and Lim 1992).

Das (1998) and recently Iskandar and Colijn (2003), published a comprehensive bibliography of herpetological publications about Indonesia (excluding the Moluccas and New Guinea). These bibliographies clearly illustrate how difficult it is to compile the relevant published material for certain taxonomic groups. Moreover, updating of taxonomic and systematic relationships of certain amphibian and reptile species groups occurring in Indonesia faces a few other problems as well. Some of the most crucial points are discussed more in detail below. The fact that new amphibians and reptiles are still being described from Indonesia, not only from lesser known areas such as Papua (formerly known as Irian Jaya) and from more remote islands, but also from Java (examples for amphibians in Iskandar (1998) and a lizard in Iskandar (1994)), clearly underscores our fragmentary knowledge of the herpetofauna of Indonesia.

Concern about conservation of Indonesian species is quite a recent phenomenon. An exception may be early focus on the Komodo dragon (*Varanus komodoensis*), the first Indonesian reptile species for which protection and population management were considered vital for its survival (e.g., Hoogerwerf 1953). Conservation activities have always been biased toward better known and more showy bird and mammal species. Amphibians and reptiles have largely been ignored. This changed only recently, after it was noticed that some reptile species, particularly from Indonesia, were heavily exploited for their skins and other products such as meat, gall bladders, etc., and when evidence for a worldwide and poorly understood decline of amphibian species became available. To the general public in Indonesia, however, amphibians and reptiles are not considered groups that are in specific need of protection. As a result of the bias of conservation-related research in Indonesia, again toward larger mammal and particular bird species, our data on the herpetofauna of Indonesia are still poor. This applies despite the fact that Indonesia harbors the second-most, if not the most diverse herpetofauna worldwide. Our ignorance is not only limited to amphibians and reptiles. In the Agenda 21-Indonesia, it is estimated that 30% of the plant species and 90% of the animal species of Indonesia have not been adequately described and scientifically documented (State Ministry for Environment 1997). Trained herpetologists are virtually non-existent in Indonesia, and conservation and management activities only occasionally extend to amphibian and reptile species. More recent work on the ecology of certain islands or island groups within the Indonesian archipelago (e.g., Monk et al. 1997; Whitten et al. 1996) and work on amphibians and reptiles in trade (Erdelen 1998a; Erdelen 1998b), however, indicate that amphibians and reptiles are gaining momentum as groups that need to be considered important components of Indonesia's biodiversity.

This paper (1) gives an overview of the herpetofauna as part of Indonesia's biodiversity, (2) outlines the history of herpetological research in the region, (3) identifies major gaps in our knowledge of the Indonesian herpetofauna, and (4) uses this framework for discussing issues and problems of the conservation of amphibians and reptiles in Indonesia. In particular, the contents and shortcomings of compilations of lists of protected or threatened species by national and international authorities are discussed, major threats to the Indonesian herpetofauna or certain components thereof are described, and a set of measures for better long-term conservation is proposed.

Knowledge of amphibians and reptiles of Indonesia: a historical perspective

As already indicated above, with the publications of de Rooij (1915, 1917) and van Kampen (1923), for the first time, overviews of the herpetofauna of the Indo-Australian Archipelago were available. Therefore, our analysis starts with the year 1930 (Fig. 1-3). During the last 70 years, the number of Malesian (Insular Southeast Asia and New Guinea) reptile species, described principally from outside Indonesia, increased from 942 to 1238 species. During the same period comparatively few taxa were described from Indonesia. This discrepancy in species described is even more evident in the amphibians; whereas the Malesian and the whole Southeast Asian taxa show a marked increase, especially after 1955, the Indonesian "increment" in taxa is only between one-half and one-third of the Malesian and of the whole Southeast Asian figures (Fig. 1-3).

Comparatively little new information was added during World War II and during the periods of major political unrest in Indonesia, i.e., between 1940 and 1960 (Fig. 1-3: data points at the mid-intervals of 1945 and 1955). The decade 1960 to 1970 is characterized by the description of many new taxa from the Malesian region. Most of these taxa had been described from studies that were not carried out in Indonesia but in neighboring countries (especially from Malaysia, Philippines, Papua New Guinea and the Solomon Islands). This indirectly contributed to the increase in our knowledge of the Indonesian herpetofauna after many of these new forms were also found in Indonesia.

A closer look shows that not only new species of monitor lizards (Böhme et al. 2002; Böhme and Jacobs; 2001; Böhme and Ziegler 1997, 2005; Harvey and Barker 1998; Jacobs, 2003; Philipp et al. 1999; Sprackland 1999; Ziegler et al. 1999) but also new species of land and freshwater tortoises (McCord et al. 1995; McCord and Pritchard, 2002; van Dijk 2000; Rhodin 1994) were described from Indonesia. Figures for total species numbers will probably still increase (Rhodin and Genorupa 2000). For instance, some of the so-called better known species may comprise species complexes (e.g., *Limnonectes macrodon*), and quite a few new taxa are already known but still await their scientific description (Emerson et al. 2000; Evans et al. 2003).

Need for conservation of Indonesian amphibians and reptiles

Threatened species, CITES, and protected species, IUCN, CITES, and PKA lists: a comparison

Three major compilations give an outline of the present status of national and international conservation and protection measures. These are the 2000 IUCN Red List of Threatened Animals (Baillie and Groombridge 1996), into which the new IUCN categories and criteria are incorporated (as adopted by IUCN in 1994), the CITES lists of species listed in the appendices, and the list of Indonesian protected species (Ministry of Forestry 2004). The 1996 IUCN list comprises a total of 30 reptile species occurring in Indonesia (Table 1). Of these reptile species, 22 are considered threatened, i.e., belonging to the category "critically endangered," "endangered," or "vulnerable." The remaining eight species are either grouped under "data deficient" (five species) or "lower risk" (three species). These threat categories differ only in quantitative aspects, e.g., in population decline rates.

The 2000 IUCN Red List (IUCN 2000) shows a dramatic increase in the numbers of turtle species included (Table 1). This has largely been due to information and recommendations from a workshop on conservation and trade of freshwater turtles and tortoises in Asia (van Dijk et al. 2000). In the IUCN Red List (IUCN 2000), no turtle species is further listed as data deficient, and nearly all Indonesian and New Guinean species are included, in addition to a number of other Asian turtle and tortoise species. The pres-

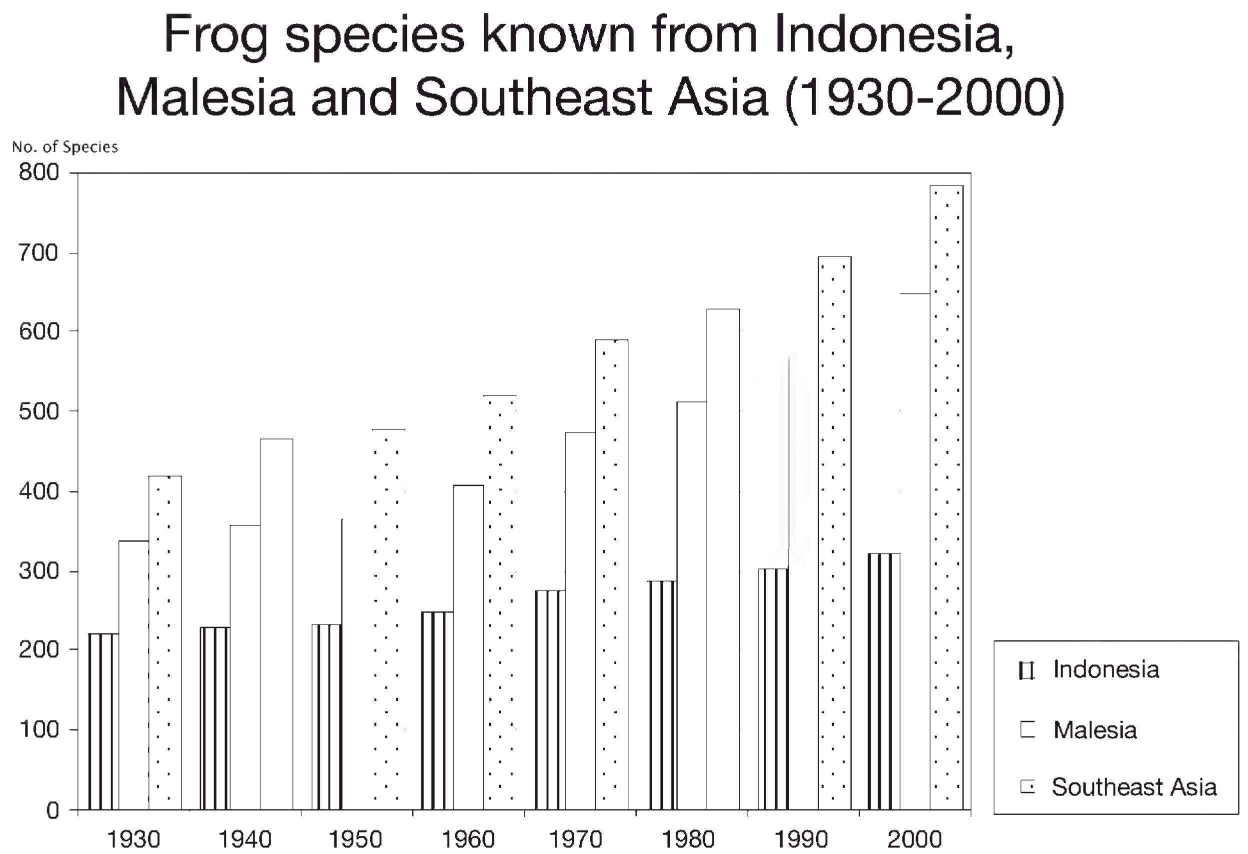

Figure 1.

DOI: 10.1514/journal.arc.0040014g001

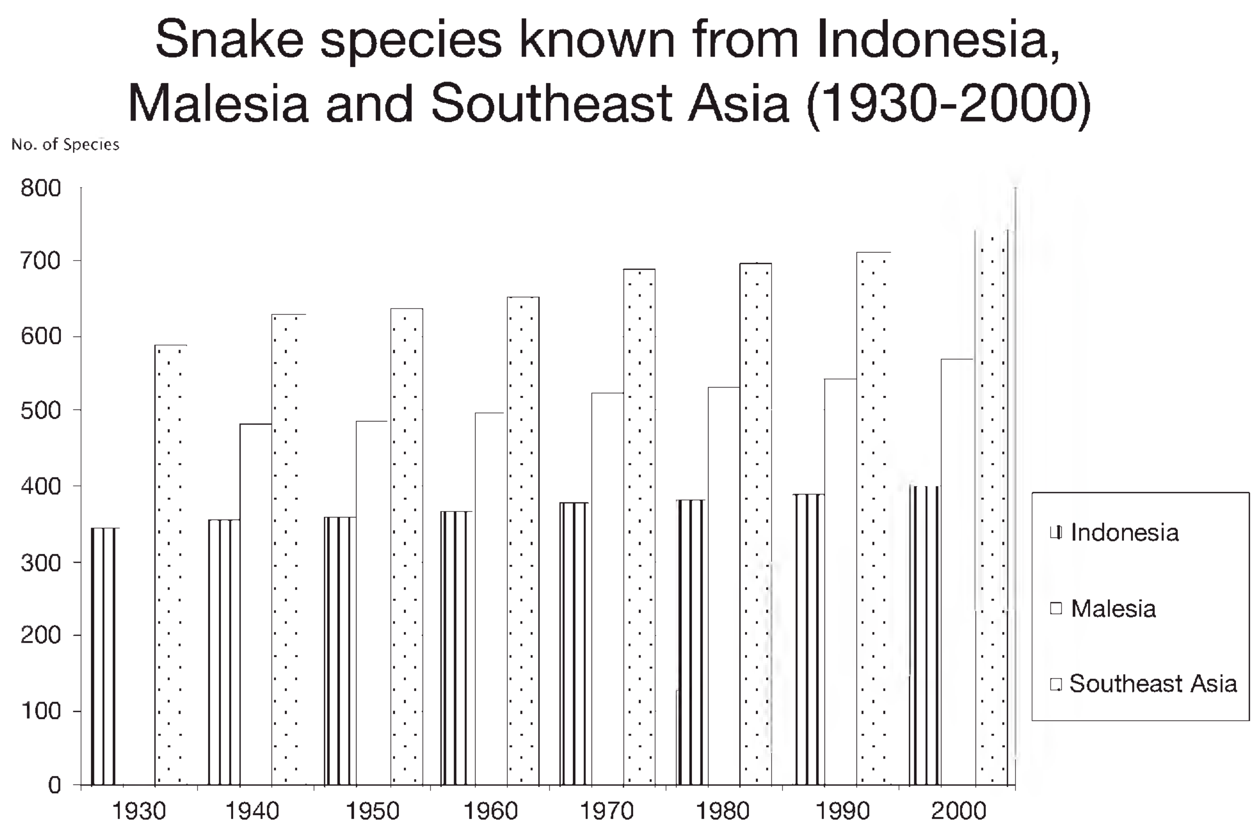

Figure 2.

DOI: 10.1514/journal.arc.0040014g002

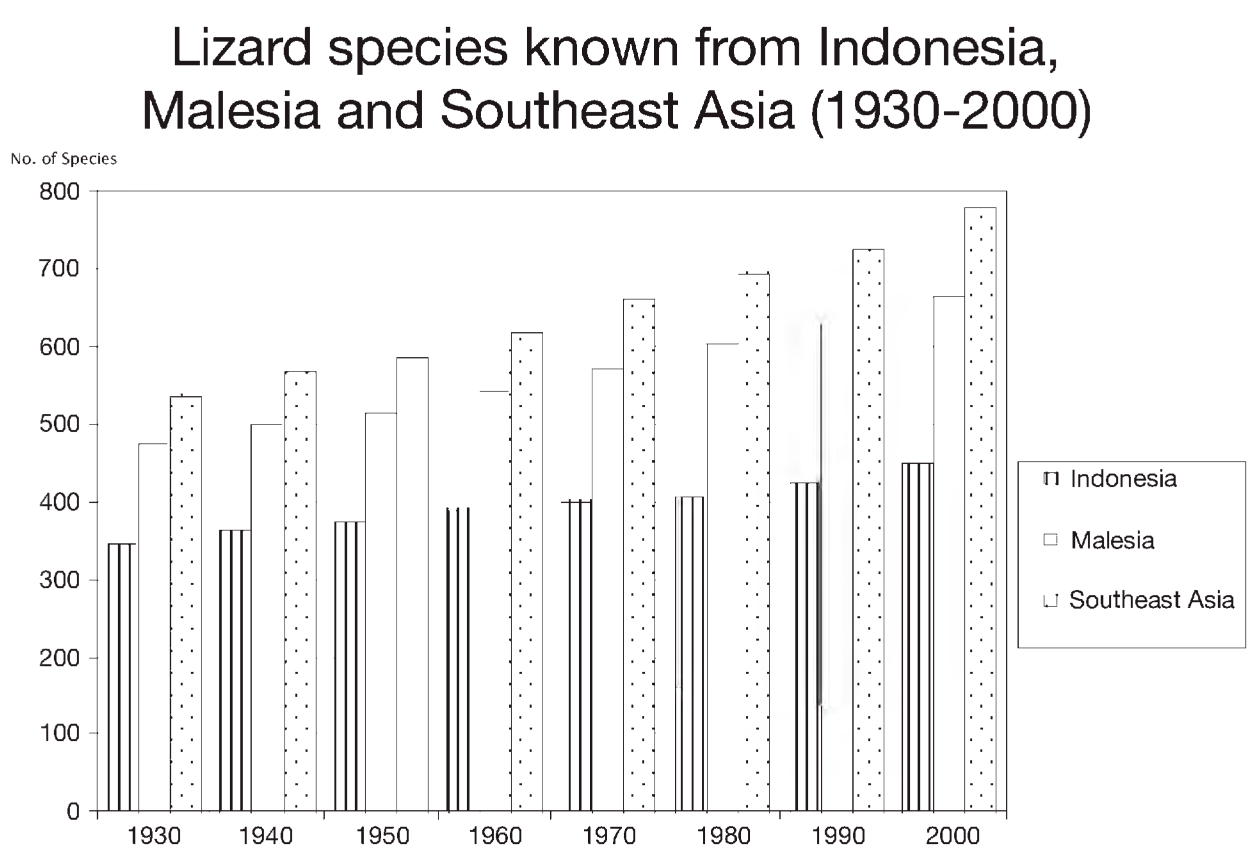

Figure 3.

DOI: 10.1514/journal.arc.0040014g003

Table 1. Indonesian reptiles listed in the IUCN Red Lists of threatened animals (Baillie and Groombridge 1996; IUCN 2000), in the CITES Appendices I or II, and protection status in Indonesia. For comparison, threat proposals of the Asian turtle trade workshop (ATT 1999, see van Dijk et al. 2000) are included. IUCN categories of threat: CR = critically endangered, DD = data deficient, EN = endangered, LR = lower risk: near threatened, VU = vulnerable, — = not listed. CL = listed in CITES Appendices (I, II; - = not listed). PI = protection status of species in Indonesia (P = protected; - = not protected). Quota = Quota issued by PKA for skin trade (QS) and live export or pet trade (QL). Note: Quota categories given according to major use category. *) Including *Cyclemys oldhami*. **) Export stopped since 1994 (see text for details). Note: At least three new species of the chelid genus *Elseya*, none of them listed here, will be described from New Guinea. ***) The different subspecies of *Python curtus* are now in the process of being split into three distinct species. Note: Since this table was prepared several new species and subspecies have been described, including *Chitra vandjiki* and *Chitra chitra javanensis* (McCord and Pritchard 2002), *Varanus böhmei* (Jacobs 2003), *V. macraei* (Böhme and Jacobs 2001), *V. reisingeri* (Eidenmüller and Wicker 2005), and *V. zugorum* (Böhme and Ziegler 2005), *Pelochelys signifera* (Webb 2001), *Candoia paulsoni* and *Candoia superciliosa* (Smith et al. 2001)

Taxon	IUCN 1996	ATT 1999	IUCN 2000	CL	PI	Quota
Testudines - Turtles and Tortoises						
Carrettochelyidae						
Carrettochelys insculpta	VU	VU	VU	-	P	
Chelidae						
Chelodina mccordi	VU	CR	CR	-	-	
Chelodina novaeguineae	——	LR	——	-	P	
Chelodina parkeri	——	VU	VU	-	-	
Chelodina reimanni	DD	LR	LR	-	-	
Chelodina siebenrocki	——	LR	LR	-	-	
Elseya branderhorstii	——	VU	VU	-	-	
Elseya novaeguineae	——	LR	——	-	P	
Emydura subglobosa	——	LR	——	-	-	
Cheloniidae						
Caretta caretta	EN		EN	I	P	
Chelonia mydas	EN		EN	I	P	
Eretmochelys imbricata	CR		CR	I	P	
Lepidochelys olivacea	EN		EN	I	P	
Natator depressus	VU		VU	I	P	
Dermochelyidae						
Dermochelys coriacea	EN		CR	I	P	
Bataguridae						
Batagur baska	EN	CR	CR	I	P	
Callagur borneoensis	CR	CR	CR	II	-	QL
Cuora amboinensis	LR	VU	VU	-	-	
*Cyclemys dentata *)*	——	LR	LR	-	-	
Heosemys spinosa	VU	EN	EN	-	-	
Leucocephalon yuwonoi	DD	CR	CR	-	-	
Malayemys subtrijuga	——	VU	VU	-	-	
Notochelys platynota	DD	VU	VU	-	-	
Orlitia borneensis	LR	EN	EN	-	P	
Siebenrockiella crassicollis	——	VU	VU	-	-	
Testudinidae						
Indotestudo forstenii	VU	EN	EN	II	-	QL
"Indotestudo elongata"	VU	EN	EN	II	-	QL
Manouria emys	VU	EN	EN	II	-	QL
Trionychidae						
Amyda cartilaginea	VU	VU	VU	-	-	
Chitra chitra	CR	CR	CR	-	-	
Pelochelys bibroni	VU	VU	VU	-	-	
Pelochelys cantorii	VU	EN	EN	-	-	
Crocodylia - Crocodiles						
Crocodylidae						
Crocodylus mindorensis	CR		CR	I	-	
Crocodylus novaeguineae	——		——	II	P	QS

Continued on page 065.

Table 1. Continued.

Taxon	IUCN 1996	ATT 1999	IUCN 2000	CL	PI	Quota
Crocodylia - Crocodiles						
Crocodylidae						
Crocodylus porosus	——		——	II	P	QS
Crocodylus raninus	——		——	II	-	
Crocodylus siamensis	CR		CR	I	P	
Tomistoma schlegelii	DD		EN	I	P	
Sauria - Lizards						
Agamidae						
Chlamydosaurus kingii	——		——	-	P	
Hydrosaurus amboinensis	——		——	-	P	
Hypsilurus dilophus	——		——	-	P	
Lanthanotidae						
Lanthanotus borneensis	——		——	-	P	
Scincidae						
Tiliqua gigas	——		——	-	P	
Varanidae						
Varanus auffenbergi	——		——	II	-	
Varanus beccarii	——		——	II	-	QL
Varanus bengalensis nebulosus	——		——	I	P	
Varanus caerulivirens	——		——	II	-	
Varanus cerambonensis	——		——	II	-	
Varanus doreanus	——		——	II	-	QL
Varanus dumerilii	——		——	II	-	QLL
Varanus indicus	——		——	II	P	
Varanus jobiensis	——		——	II	-	QL
Varanus komodoensis	VU		VU	I	P	
Varanus melinus	——		——	II	-	
Varanus "panoptes" (gouldii)	——		——	II	P	
Varanus prasinus	——		——	II	P	
Varanus rudicollis	——		——	II	-	QL
Varanus salvadorii	——		——	II	-	QL
Varanus salvator	——		——	II	-	QS
Varanus salvator togianus	——		——	II	P	
Varanus timorensis	——		——	II	P	
Varanus yuwonoi	——		——	II	-	
Serpentes - Snakes						
Anomochilidae						
Anomochilus leonardi	DD		DD	-	-	
Boidae						
Candoia aspera	——		——	II	-	QL
Candoia carinata	——		——	II	-	QL
Colubridae						
Iguanognathus werneri	VU		VU	-	-	
Ptyas mucosa	——		——	II	-	(QS)**)
Elapidae						
Naja sputatrix	——		——	II	-	QL
Naja sumatrana	——		——	II	-	
Ophiophagus hannah	——		——	II	-	QL
Pythonidae						
Apodora papuana	——		——	II	-	QL
Leiopython albertisii	——		——	II	-	QL
Liasis fuscus	——		——	II	-	QL
Liasis mackloti	——		——	II	-	QL

Continued on page 066.

Table 1. Continued.

Taxon	IUCN 1996	ATT 1999	IUCN 2000	CL	PI	Quota
Serpentes - Snakes						
Pythonidae						
Morelia amethistina	——		——	II	-	Q
Morelia boeleni	——		——	II	-	QL
Morelia clastolepis	——		——	II		
Morelia nauta	——		——	II		
Morelia spilota variegata	——		——	II	-	QL
Morelia tracyae	——		——	II		
Morelia viridis	——		——	II	P	
*Python curtus***)*	——		——	II	-	QS
Python molurus bivittatus	LR		LR	II	P	
Python reticulatus	——		——	II	-	QS
Python timoriensis	——		——	II	P	

DOI: 10.1514/journal.arc.0040016t001

ent list contains 85 species, of which 31 species, including most turtles and crocodiles, are considered threatened. For other reptile groups such as varanid lizards and pythons, however, we urgently need assessment of their status. Except for highly localized knowledge of some of the most common species such as *Varanus salvator*, *Python curtus*, and *Python reticulatus*, we hardly know anything about the other Indonesian species.

None of the Indonesian amphibian species was listed in the 2000 IUCN Red List of Threatened Animals. However, by the 2004 Red List of Threatened Species, the status of amphibians had changed dramatically, and the report noted that they "are currently the most threatened class of vertebrates on the IUCN Red List" (Baillie et al. 2004, p. 11). This is reflected in the 2006 Red List, which lists 39 threatened amphibian species in Indonesia (IUCN 2006). All this new information on amphibians certainly requires further detailed analysis, which could not be carried out for this paper.

The IUCN criteria and subcriteria provide information on the underlying reasons why a species may be threatened. For the Indonesian taxa, most are given *criterion A*, i.e., populations are declining. *Subcriteria 1* and *2* (for *criterion A*) indicate that decline has been observed or suspected in the past (subcriterion 1) or will be in the future (subcriterion 2). *Subcriteria a* and *b* only point out the evidence available, i.e., direct observation or an index of abundance. More important is that *subcriteria c* and/or *d* are listed for virtually all of the

Plate 2. DOI: 10.1514/journal.arc.0040016g004

Plate 1. DOI: 10.1514/journal.arc.0040016g005

Plate 3. DOI: 10.1514/journal.arc.0040016g006

Plate captions: 1. *Ingerophrynus celebensis.* **2.** *Pelophryne signata.* **3.** *Litoria infrafrenata.*

Species plates 1–3 taken by Djoko T. Iskandar.

Plate 4. DOI: 10.1514/journal.arc.0040016g007

Plate 5. DOI: 10.1514/journal.arc.0040016g008

Plate 6. DOI: 10.1514/journal.arc.0040016g009

Plate 7. DOI: 10.1514/journal.arc.0040016g010

Plate 8. DOI: 10.1514/journal.arc.0040016g011

Plate 9. DOI: 10.1514/journal.arc.0040016g012

Plate 10. DOI: 10.1514/journal.arc.0040016g013

Plate 11. DOI: 10.1514/journal.arc.0040016g014

Plate captions: 4. *Litoria* sp. **5.** *Leptolalax hamidi.* **6.** *Leptobachium hasseltii.* **7.** *Limnonectes* sp. with a black tympanum. **8.** *Limnonectes* cf *modestus.* **9.** *Limnonectes* sp. that laid tadpoles. **10.** *Limnonectes shompenorum.* **11.** *Limnonectes modestus.*

Species plate 6–9 taken by Jim A. McGuire. Species plates 4–5, 10, & 11 taken by Djoko T. Iskandar.

threatened taxa; that is, either the area occupied by the species is shrinking or the habitat quality is decreasing (*subcriterion c*) or the species is heavily exploited (*subcriterion d*). In the case of the Komodo monitor, it is well-known that, except for Flores, the species is restricted only to a few smaller islands, Komodo being the most extensive, and that the Flores populations are threatened (for distributional details see Auffenberg 1981, Murphy et al. 2002; Ciofi and de Boer 2004). The species under *criterion D* and *subcriterion 2* all have susceptible populations. For instance, the chelid turtle *Chelodina mccordi* occurs only on Roti Island, south of Timor (Rhodin 1994), and *Chelodina parkeri* seems to have a very restricted distribution in Irian Jaya (Iskandar 2000; Samedi and Iskandar 2000). The colubrid snake *Iguanognathus werneri* is known only from a single specimen from Sumatra. *Leucocephalon* (formerly *Heosemys*) *yuwonoi* from northern Sulawesi, was only described within the last decade or so (McCord et al. 1995; McCord et al. 2000). The false gharial (*Tomistoma schlegelii*), in the 1996 IUCN list classified as DD is now (IUCN 2000) considered endangered. This change in threat status is supported by many studies in Sumatra, Borneo, and peninsular Malaysia (Bezujien et al., 1998; Ramono and Rahardjo 1993; Ross et al. 1996; Simpson et al. 1998; Stuebing et al. 1998).

In sum, as already indicated in the IUCN list (Baillie 1996), the overall conservation status of amphibians and reptiles cannot be assessed. As a consequence, this also applies to the lower national level of this analysis. The IUCN list largely reflects the fact that of the six orders of reptiles only the crocodiles (Crocodylia), the tuataras (Rhynchocephalia), and, at least in part, the turtles (Testudines) have been assessed. However, the majority of the reptile species, i.e., the lizards and snakes, do not fall into any of these groups. This bias in available assessment data is also clearly seen in the list for the Indonesian species. The majority of the species are turtles of which all of the species found in Indonesia are listed. Of the six crocodile species found in Indonesia, three appear in the IUCN list, all are listed in Appendix I or II of CITES (Table 1). Of the lizards, only the Komodo monitor, being the largest extant lizard species, is mentioned. As an endemic flagship species, it has the highest protection status among Indonesia's reptiles. The speciose group of snakes is only represented by a single python species (*Python molurus*) and a single colubrid snake species (*Iguanognathus werneri*).

By definition, CITES covers international trade issues. Therefore, the IUCN and CITES lists are not congruent but have only certain species in common (Table 1). For example, except for one species of monitor lizard (*Varanus bengalensis*), all species of CITES Appendix I are also listed as

Plate 12. DOI: 10.1514/journal.arc.0040016g015

Plate 13. DOI: 10.1514/journal.arc.0040016g016

Plate 14. DOI: 10.1514/journal.arc.0040016g017

Plate 15. DOI: 10.1514/journal.arc.0040016g018

Plate captions: 12. *Limnonectes* cf. *grunniens*. **13.** *Occidozyga lima*. **14.** *Rhacophorus gauni*. **15.** *Nyctixalus pictus*.

Species plates 13 & 15 taken by Jim A. McGuire. Species plate 12 & 14 taken by Djoko T. Iskandar.

Plate 16. DOI: 10.1514/journal.arc.0040016g019

Plate 17. DOI: 10.1514/journal.arc.0040016g020

Plate 19. DOI: 10.1514/journal.arc.0040016g022

Plate 18. DOI: 10.1514/journal.arc.0040016g021

Plate captions: 16. *Nyctixalus margaritifer*. **17.** *Rhacophorus edentulus*. **18.** *Rhacophorus margaritifer*. **19.** *Staurois guttatus*.

Species plate 18 taken by Jim A. McGuire. Species plates 16 & 19 taken by Djoko T. Iskandar. Species plate 17 taken by Graeme Gillespie.

Plate 20. DOI: 10.1514/journal.arc.0040016g023

Plate 21. DOI: 10.1514/journal.arc.0040016g024

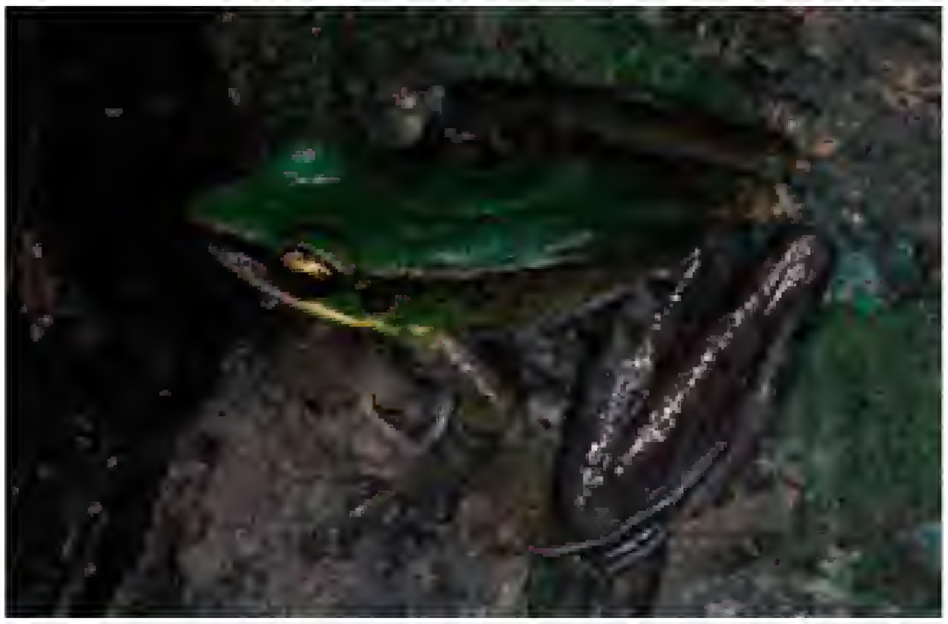

Plate 22. DOI: 10.1514/journal.arc.0040016g025

Plate 23. DOI: 10.1514/journal.arc.0040016g026

Plate 24. DOI: 10.1514/journal.arc.0040016g027

Plate 25. DOI: 10.1514/journal.arc.0040016g028

Plate 26. DOI: 10.1514/journal.arc.0040016g029

Plate 27. DOI: 10.1514/journal.arc.0040016g030

Plate captions: 20. *Sylvirana picturata*. **21.** *Hydrophylax chalconota*. **22.** *Odorrana hosii*. **23.** *Hydrophylax nicobariensis*. **24.** *Sylvirana celebensis*. **25.** *Kaloula baleata*. **26.** *Kaloula pulchra*. **27.** *Microhyla achatina*.

Species plate 20 taken by Djoko T. Iskandar. Species plates 21–27 taken by Jim A. McGuire.

Plate 28. DOI: 10.1514/journal.arc.0040016g031

Plate 29. DOI: 10.1514/journal.arc.0040016g032

Plate 30. DOI: 10.1514/journal.arc.0040016g033

Plate 31. DOI: 10.1514/journal.arc.0040016g034

Plate 32. DOI: 10.1514/journal.arc.0040016g035

Plate 33. DOI: 10.1514/journal.arc.0040016g036

Plate 34. DOI: 10.1514/journal.arc.0040016g037

Plate 35. DOI: 10.1514/journal.arc.0040016g038

Plate captions: 28. *Oreophryne* sp. **29.** *Bronchocela jubata*. **30.** *Gonocephalus kuhlii*. **31.** *Gonocephalus grandis* (male). **32.** *Bronchocela cristatella*. **33.** *Draco bourouniensis*. **34.** *Draco haematopogon*. **35.** *Cyrtodactylus jellesmae*.

Species plate 31 taken by Djoko T. Iskandar. Species plates 29, 30, & 32–35 taken by Jim A. McGuire. Species plate 28 taken by Graeme Gillespie.

threatened by IUCN. For *Tomistoma schlegelii* this has applied only since the IUCN 2000 list was published (see Table 1). As shown in Table 1, except for species protected in Indonesia (P) and *Crocodylus raninus* and *C. mindorensis*, both species virtually unknown by Indonesian authorities to occur in Indonesia, all species listed under CITES are subject to quota that limit the annual catch. These may be quota referring to skin trade (QS) or quota for trade of live specimens (QL). In addition, a few species of reptiles are protected in Indonesia but appear neither in the IUCN list nor in the CITES appendices. These are two species of side-necked turtles (Chelidae), three showy and large species of agamid lizards, the monotypic genus *Lanthanotus*, and the scincid species *Tiliqua gigas*. The agamids belong to the genera *Chlamydosaurus*, *Hydrosaurus*, and *Hypsilurus*. These are either species with restricted ranges within Indonesia (*Hydrosaurus amboinensis*) or are elements of the Australian realm, found in Indonesia only in Papua and on small islands on the Sahul Shelf (*Chlamydosaurus kingii* and *Hypsilurus dilophus*).

Conclusions

Internationally protected species such as marine turtles may experience considerable exploitation in Indonesia. Species not adequately considered by any national or international regulations are exploited in enormous numbers in Indonesia. This presently particularly applies to freshwater turtles (”freshwater turtles” or “tortoises”—tortoises by definition do not occur in the water). The taxonomic status of many species is neither clear to scientists nor, as a consequence, to Indonesian conservation authorities. For instance, what is considered *Indotestudo elongata* is in fact *I. forsteni*, which shows intraspecific variation in presence or absence of nuchal scales, the major character by which the two species are distinguished by CITES. The species complex of *Crocodylus siamensis* and the taxonomic status of *C. raninus* are only poorly understood although recorded from Brunei Darussalam (Das and Charles 2000). In addition, varanid nomenclature is presently undergoing such rapid modification that the official authorities cannot keep pace with revisions published and new species described in the scientific literature (Pianka et al. 2004). Moreover, traders have identified the need for more taxonomic studies as specimens were collected that showed significant deviation from “classical” species descriptions (see, e.g., Yuwono 1998, for more specific information). In extreme cases, taxa later described as new species have already (under other names) been traded for some time before they were officially described in the literature. This, for instance, applies to virtually all recently described new species such as, among reptiles, the monitor lizards, pythons, and turtles.

Threats to Indonesian amphibians and reptiles

General remarks

Most of the information needed for conservation measures for the amphibians and reptiles of Indonesia is not available. In particular, habitat requirements are little known, population sizes are unknown for virtually all species, and, as a consequence, recent trends in population sizes also remain unknown. Generally, most of the fundamental data on species biology and ecology are lacking. Our knowledge, however, is not zero. We do know that certain species are typical forest dwellers and that habitat destruction and trade have affected species and local populations. Some of the potential threatening factors, however, we are only beginning to understand. These are, for instance, the questions as to what extent the global decline in amphibian species also applies for Indonesian species and to what extent extreme climatic fluctuations, mostly associated with El Niño Southern Oscillation (ENSO) events, cause disturbances in natural reproductive patterns in amphibians that may affect population sizes and densities in the long run. A study in Papua New Guinea, for instance, has shown that drought conditions affect frogs with terrestrial breeding modes and with direct development to such an extent that reproduction almost ceased (Bickford 1998). In addition, it was found that rare and uncommon arboreal species descend from their arboreal sites and frog densities seem to increase near streams. The effects of the latter two phenomena on the respective communities remain unknown. A similar situation may be expected for frogs in other parts of Indonesia, not only for the Indonesian part of New Guinea (Papua).

Studies in Kalimantan have shown that, as a result of the intense fires during the long drought in 1998 and the concomitant haze that affected the whole region, amphibian reproductive cycles normally triggered by the moon phases may have been completely out of synchronization with natural cues, and it is possible that reproduction may not have taken place (Iskandar et al. 1999). Similar observations have been made for other taxonomic groups such as birds and primates, which showed very limited activities and reduced vocalizations during such periods (Gurmaya et al. 1999, Raharjaningtrah and Prayogo 1999).

Habitat destruction

Habitat destruction and the resulting fragmentation of populations is the most important factor affecting the indigenous amphibian and reptile species of Indonesia. For instance, Sumatra has experienced a drastic loss of lowland forests during the past two decades. Many of the Indonesian endemics are species occurring in forests. We do not know to what extent these species can tolerate human impacts without severe population reductions. This situation is particularly acute in those parts of Indonesia where island sizes are small and, as a consequence, extension of natural vegetation and absolute numbers of individuals for most of the species are already low. This applies, for instance, to eastern Indonesia, e.g., the Lesser Sunda Islands and the Moluccas. But even on the larger islands such as Sumatra, Kalimantan, Sulawesi, and Irian Jaya, localized endemism and species with narrow geographical ranges are automatically prone to extinction. This applies to most of the New Guinean microhylid frogs such as the genera *Oreophryne* and *Xenobatrachus* and most tree frogs of the genus *Litoria*. In many cases, species are known only from the type specimen or species have not been found again for decades. Examples of such very poorly known species are the amphibians *Ichthyophis hypocyaneus, Rana debussyi, R. persimilis,* and

Plate 36. DOI: 10.1514/journal.arc.0040016g039

Plate 37. DOI: 10.1514/journal.arc.0040016g040

Plate 38. DOI: 10.1514/journal.arc.0040016g041

Plate 39. DOI: 10.1514/journal.arc.0040016g042

Plate 40. DOI: 10.1514/journal.arc.0040016g043

Plate 41. DOI: 10.1514/journal.arc.0040016g044

Plate 42. DOI: 10.1514/journal.arc.0040016g045

Plate 43. DOI: 10.1514/journal.arc.0040016g046

Plate captions: 36. *Cyrtodactylus* sp. **37.** *Gehyra mutilata*. **38.** *Gekko smithi*. **39.** *Gekko vittatus*. **40.** *Lepidodactylus lugubris*. **41.** *Cyrtodactylus* sp. **42.** *Ptychozoon kuhlii*. **43.** *Tribolonotus gracilis*.

Species plates 36–38, 40 & 42 taken by Jim A. McGuire. Species plate 39 taken by Alain Compost. Species plates 41 & 43 taken by Djoko T. Iskandar.

Philautus jacobsoni; the lizards *Harpesaurus tricinctus, H. modigliani,* and *Thaumatorhynchus brooksi*; and the snakes *Iguanognathus werneri* and *Anoplohydrus aemulans*.

The present rate of habitat destruction in Indonesia is alarming. In 1996, logging concessions covered an area of about 54 million hectares (Sunderlin and Resosudarmo 1996), and earlier reports by the United Nations Food and Agriculture Organisation and the World Bank estimated an increase in annual deforestation from 300,000 hectares in the 1970s to about 1 million hectares in 1990. In 1998, logging activities were still estimated to cover an area of some 51.5 million hectares, carried out by over 421 private companies, most of them operating under 33 leading business groups (Jakarta Post, 15 January 1999).

Agenda 21-Indonesia estimates that up to 1.3 million hectares of forest are cleared annually in Indonesia and that habitat loss in Java and Bali is about 91% (State Ministry for Environment 1997). Between 1985 and 1997 about 18 million hectares of forest have been lost in Indonesia, mostly lowland rain forests. It is estimated that by the year 2010 Kalimantan will have lost all of its lowland forests, as has largely occurred on Sumatra.

Studies in man-made habitats have shown that these contain only a small segment of the original diversity in amphibian and reptile species. Even in oil palm plantations which superficially resemble forests, i.e., in terms of shade conditions and microclimate, most of the amphibian and reptile taxa found are typical human commensals or species occurring in agricultural landscapes. For instance, no typical forest-dwelling species was found in oil palm plantations studied in north Sumatra (Gaulke et al. 1997, 1998). Accordingly, conversion of natural forest to agroecosystems or urban areas will result in the extermination of most of the species that formerly occurred in the given area.

Trade

General remarks on wildlife trade in Indonesia

Indonesia has a long history of wildlife trade, particularly in birds, live reptiles, reptile skins, and corals. Indonesia ranks among the world's leading nations in export of wildlife and wildlife products (Nash 1993). Early conservationists in Indonesia already saw a considerable danger for certain wild species through the largely uncontrolled export of wild animal species in those days, particularly the export of mammal and bird skins (e.g., Dammerman 1928). Trade in live plants and animals in Indonesia has received critical attention by the international community for many years. This particularly applies to trade in mammals, birds, and reptiles. For instance, enormous quantities of reptile skins were exported from Indonesia in the 1980s (see Jenkins and Broad 1994), and live export of birds and mammals had also reached new dimensions. The 1991 figures for Indonesian wildlife exports, as compiled by Nash (1993), list almost 80,000 parrots, 1.9 million reptiles including reptile skins, over 14,000 primates, and over 1 million pieces of coral. These figures certainly no longer apply, but nevertheless the question as to whether trade in certain species of Indonesian wild flora and fauna meets the criterion of sustainability still persists. In this section a few of the most important issues related to trade and conservation of amphibians and reptiles in Indonesia are discussed. A thorough analysis of the overall situation in wildlife trade in Indonesia is, in our opinion, long overdue.

Since 1978, Indonesia has been party to CITES, the Convention on International Trade in Endangered Species of Fauna and Flora. Indonesian CITES authorities are the Indonesian Institute of Sciences, the Scientific Authority (LIPI: Lembaga Ilmu Pengetahuan Indonesia); and the Directorate General of Protection and Nature Conservation (PKA: Direktorat Jenderal Perlindungan dan Konservasi Alam), the Management Authority.

CITES Appendix I species may be harvested for domestic use (see e.g., the non-protected CITES Appendix I species in Table 1). In international trade they are treated according to the rules and regulations in CITES. Appendix II species that are traded are subject to annual quota, i.e., PKA determines the number of specimens that may be caught for trade, both skin and live specimen trade (see Table 1 for species under the quota regulation). This "annual allowable catch" is determined newly for each calendar year. Quotas are then set on a provincial level. At present 30 reptile species are protected by Indonesian law, and, of these, quotas are issued for 27 species (Table 1).

Since Indonesia has been party to CITES, concern has been repeatedly stated over the implementation of Article IV of the Convention (Nash 1993). Article IV refers to Appendix II species and to the fact that export should not be detrimental to the survival of the respective species (paragraph 2a) and that export should "*be limited in order to maintain that species throughout its range at a level consistent with its role in the ecosystems in which it occurs and well above the level at which that species might become eligible for inclusion in Appendix I* ..." (paragraph 3). Subsequently, several reviews of the trade situation for particular species groups were carried out. For Indonesia, the most important ones were on Asian monitor lizards (Luxmoore and Groombridge 1990) and on Asian pythons (Groombridge and Luxmoore 1991). Information on trade in Indonesian lizards and snakes has been compiled documenting the many different facets of relevance for achieving sustainable harvests of the species in question (Erdelen 1998b). Still, the problem of setting appropriate quotas, as already discussed in Nash (1993), has not been solved for most of the taxa in trade in Indonesia. Confusion is also widespread over the term "non-detrimental" as given in the Convention (see above). This is underscored by the holding of an IUCN workshop to develop guidance for CITES scientific authorities on the making of "non-detriment findings".

Amphibian and reptile trade in Indonesia: conservation implications

As indicated above, an overall analysis of wildlife trade in Indonesia is not available. This also applies for the herpetofauna of Indonesia. As pointed out in an IUCN workshop on Asian turtles trade (van Dijk et al. 2000), determining trade levels for a species that should not have short-term or long-term negative effects on natural populations is a complex subject. This is exacerbated in amphibians and reptiles because of our lack of knowledge of their biology and ecolo-

Plate 44. DOI: 10.1514/journal.arc.0040016g047

Plate 45. DOI: 10.1514/journal.arc.0040016g048

Plate 46. DOI: 10.1514/journal.arc.0040016g049

Plate 47. DOI: 10.1514/journal.arc.0040016g050

Plate 48. DOI: 10.1514/journal.arc.0040016g051

Plate 49. DOI: 10.1514/journal.arc.0040016g052

Plate 50. DOI: 10.1514/journal.arc.0040016g053

Plate 51. DOI: 10.1514/journal.arc.0040016g054

Plate captions: 44. *Cryptoblepharus balinensis.* **45.** *Emoia artrocostata.* **46.** *Emoia caeruleocauda.* **47.** *Lamprolepis smaragdinum.* **48.** *Eutropis multifasciata* (male). **49.** *Eutropix rudis.* **50.** *Glaphyromorphus nigricaudis.* **51.** *Papuascincus stanleyanus.*

Species plates 44–49 taken by Jim A. McGuire. Species plates 50 & 51 taken by Djoko T. Iskandar.

gy and the exploitation patterns, even in the so-called "better known" species (Erdelen 1998a). How difficult it is to collect the relevant field data to estimate sustainability was shown in a study of three of the most heavily exploited reptiles in Indonesia, the water monitor (*Varanus salvator*), the reticulated python (*Python reticulatus*), and the blood python (*Python curtus*) (Erdelen et al. 1997).

Reptile and amphibian trade is a comparatively recent phenomenon in Indonesia. Before the late 1980s, Indonesia had no professional collectors of live reptiles (Yuwono 1998). Generally, reptile trade may be subdivided into two major components, i.e., skin trade, including trade in other organs such as gall bladders, and pet trade. The former covers a few species harvested in large numbers, the latter about 30 species of amphibians, about 18 species of non-marine turtles, about 50 species of lizards, and about the same number of snake species (for details, see Yuwono 1998). Skin trade, on the other hand, essentially comprised five species in Indonesia, viz. the water monitor (*Varanus salvator*), two species of python (the reticulated python *Python reticulatus* and the blood python *P. curtus*), the rat snake (*Ptyas mucosa*), and the spitting cobra (*Naja sputatrix*). In the case of cobras, however, most specimens are caught for the food market, and skins are largely by-products (Saputra, pers. comm.). Since 1991, all quotas were reduced for these species, and international concern about the numbers of rat snakes harvested led to a total ban of trade in this species in Indonesia in 1994. In 1998, LIPI undertook a survey on *Ptyas mucosa*, and an EU project on this species is currently on its way to providing data on whether the international ban should be lifted or not. The latest (for the year 2000) quota for the remaining four species are 150,000 (*Naja sputatrix*), 46,400 (*Python curtus*), 176,000 (*Python reticulatus*), and 496,000 (*Varanus salvator*). One of the major questions arising from studies on the habitats from where specimens are collected is how to evaluate whether a species is collected from anthropogenic habitats such as paddy fields, rubber plantations or oil palm plantations, or from natural forest. Of these species, blood pythons are virtually exclusively collected from rubber and especially oil palm plantations (see e.g., Erdelen et al. 1997), and cobras and rat snakes are collected mostly from paddy field areas (Sugardjito et al. 1998). However, to what extent reticulated pythons are caught in forested areas or in open areas following deforestation remains unknown. Moreover, these pythons often are caught near human dwellings where they can easily find prey (Auliya, pers. comm. and own observations). The same applies for the water monitor, which may be caught in habitats ranging from urban areas to mangrove forests (e.g., Erdelen 1991). Surprisingly, these high harvest rates have obviously not led to large-scale extinctions of certain populations. This may be a result of high reproductive rates of species such as the water monitor and the reticulated python (Shine et al. 1998a, 1998b, 1998c, 1999a, 1999b).

This better understanding of the impact of harvesting on the populations of species in the skin trade is in no way matched by information available on the species used for live exports for the pet trade. To meet the demands of the pet market, however, rare species are captured only occasionally; mostly common species are traded to ensure a constant supply for the customers (see Yuwono 1998, for details). International customers are more interested in species from the Australian Realm rather than from the Southeast Asian Realm of Indonesia. This is possibly related to the fact that Australia and Papua New Guinea have rigorous export regulations for amphibians and reptiles, and so the limited availability increases the demand.

Toward improved conservation of amphibians and reptiles in Indonesia

Summary of the present situation

General issues

Amphibians and reptiles in Indonesia remain a poorly understood group. Although, in recent years, considerable effort has been put into obtaining a better understanding of the composition, taxonomic relationships, and geographic distribution of the amphibians and reptiles of Indonesia, we are still far from a complete knowledge of species numbers and the basic biogeographic patterns and their evolution. In particular, we need a better understanding of (1) the number of species occurring in Indonesia, (2) their relationships to closely related taxa found in the region, (3) the geographic distribution patterns within the Indonesian archipelago, (4) the closeness of association between certain species and specific vegetation or ecosystem types, and (5) the habitat and particularly microhabitat requirements for most of the Indonesian amphibian and reptile species.

These may appear as needs from a purely scientific perspective, but this information is also essential for approaching the problem of long-term conservation of Indonesian amphibians and reptiles. Conservation measures need to be launched now, despite the fact that our knowledge of the herpetofauna is still rather fragmentary. For instance, 71 amphibian species, 63 lizard species, 73 snake species, and one crocodilian; i.e., a total of 208 species of herpetofauna, are known from fewer than ten specimens. In most cases, these species are known only from the type specimens. How this translates into the conservation status of these taxa is difficult to assess. For instance, many species listed may be newly described taxa and not necessarily rare species. Others have questionable taxonomic status such as some of the species of the genus *Ichthyophis* and may also be naturally rare. Most species known only from the type specimen were collected from remote areas, and the status of these species remains unknown. Other species, particularly snakes, may be naturally rare but may have a wide geographic range within Indonesia or on the island(s) where they are found.

Local aspects

Studies carried out in Indonesia have been largely conducted by foreign scientists, in part due to the fact that there is a general lack of trained herpetologists in Indonesia, as well as a lack of funding facilities to conduct herpetological research. Both issues need to be addressed by Indonesian universities. Herpetology could, for instance, be much better represented in the curricula.

Plate 52. DOI: 10.1514/journal.arc.0040016g055

Plate 53. DOI: 10.1514/journal.arc.0040016g056

Plate 54. DOI: 10.1514/journal.arc.0040016g057

Plate 55. DOI: 10.1514/journal.arc.0040016g058

Plate 56. DOI: 10.1514/journal.arc.0040016g059

Plate 57. DOI: 10.1514/journal.arc.0040016g060

Plate 58. DOI: 10.1514/journal.arc.0040016g061

Plate 59. DOI: 10.1514/journal.arc.0040016g062

Plate captions: 52. *Sphenomorphus nigrilabris*. **53.** *Tropidophorus baconi*. **54.** *Varanus melinus*. **55.** *Varanus indicus*. **56.** *Typhlops lineatus*. **57.** *Cylindrophis melanotus*. **58.** *Xenopeltis unicolor*. **59.** *Chrysopelea rhodopleuron*.

Species plates 52, 53, 55, 58, & 59 taken by Jim A. McGuire. Species plate 54 taken by Djoko T. Iskandar. Species plate 58 taken by Graeme Gillespie. Species plate 56 taken by Alain Compost.

Only slowly are projects and studies planned and carried out that have amphibians and/or reptiles as the major target group. Up to now, these were groups only occasionally sampled within programs that were primarily aimed at broader conservation issues as, for example, conservation of natural forest ecosystems or wetlands in Indonesia. The only exception may have been trade-related surveys and studies and some work on marine turtles.

Most of the work carried out by local organizations involved species inventories. This work had to face problems of species identification and comparisons with reference collections. In this context, a strengthening of the role of the leading museum in Indonesia, the Museum Zoologicum Bogoriense, is urgently required. This refers to the setting up of reference collections for researchers, better infrastructure, and collection materials, and an increase in the number of highly qualified staff for the different taxonomic groups.

There is still a lack of basic information materials such as simple field guides or color guides for the most important taxa of Indonesian amphibians and reptiles. This information is urgently needed by various groups, especially the local communities and the official authorities (such as PKA and Customs Control). An internationally sponsored program for writing local language field guides is a promising step toward providing a better information basis for professionals, interested laymen, and the Indonesian authorities. Several agencies have taken up this issue, including EMDI, Fauna Malesiana, GEF Biodiversity, IUCN, and the World Bank. As a result, books about mammals, birds, reptiles, and amphibians have been published or are presently being prepared.

Taxa-specific issues

Amphibians

Most information about the status of amphibians in Indonesia is based on studies from neighboring areas, such as Sarawak, where Stuebing (1994, 1997) studied habitats and microhabitats of the herpetofauna, including the amphibian families Bufonidae, Megophryidae, Microhylidae, Ranidae, and Rhacophoridae. Stuebing's work is of particular relevance for Indonesia as it was carried out in a proposed connected protected area system in Sarawak and Kalimantan, jointly to be managed by Malaysian and Indonesian authorities (Lanjak-Entimau and Betung Kerihun, respectively; the latter until recently known as Bentuang Karimun). Moreover, Stuebing (1994, 1997) had developed a management plan that focused on the herpetofauna. Comparable work on the protected area management level is still lacking in Indonesia. A second example is the study on the effects of ENSO events on frog species in New Guinea (Bickford 1998), already discussed above. To date, we have only cursory information on the likely effects of prolonged droughts, fire, and haze on populations of Indonesian amphibians and, in particular, on impacts on reproductive cycles. For instance, Iskandar (1998) described the decline in the endemic toad *Leptophryne cruentata* (Bufonidae) from the slopes of Gede-Pangrango (West Java), most likely caused by the 1981 eruptions of the volcano Mt. Galunggung which lasted for about six months. Detailed longitudinal studies of population changes in Indonesian amphibian species have not been carried out yet. Accordingly, we do not know whether a general decline in amphibian numbers as observed elsewhere is also taking place in Indonesia. Because of our poor knowledge of the Indonesian amphibian species, we do not have any information against which to "calibrate" observed changes or trends. This database needs to be created, possibly as a joint venture between Indonesian universities and the Museum Zoologicum Bogoriense. Moreover, there is a strong need for more detailed taxonomic studies. This is best illustrated in the frog leg trade (mostly *Limnonectes macrodon* and *L. blythii*) for which actually many species are harvested; some of them have not even been described scientifically (for details see Emerson et al. 2000; Iskandar 1996).

Turtles and crocodiles

Although, among reptiles, sea turtles have received the most attention by international conservation organizations, the situation of the domestic trade in Indonesia and the smuggling of specimens or products from Indonesia still remain unknown. This particularly refers to the green turtle (*Chelonia mydas*), the species most commonly caught (Suwelo et al. 1995). In a study by Limpus (1995) it is stated that the "*largest slaughter of green turtles globally occurs within the Australasian region, including Indonesia*" ...., that "*near-total egg harvest still characterizes the green turtle nesting populations of Indonesia*", and that, for the hawksbill turtle (*Eretmochelys imbricata*), "*substantial harvest for domestic consumption of meat and scale continues in Cuba, Indonesia*" ... Mass collection of eggs of all marine turtle species still occurs throughout Indonesia (Tomascik et al. 1997). With the present economic situation in Indonesia these trends have been exacerbated and have been underscored in numerous articles that have appeared in the media. A national strategy and action plan for the conservation of marine turtles, already outlined in the early 1990s, has not been implemented, and current exploitation of marine turtles and their eggs in Indonesia is not sustainable (Tomascik et al. 1997). The conservation priority issues compiled by Tomascik et al. include, among others, improvement of fishing regulations and fishing techniques to the benefit of marine turtles, better planning of coastal development activities and avoidance of pollution in nesting areas, law enforcement, research on basic biology and ecology, production of education materials on conservation of marine turtles for the general public, and the launching of the relevant conservation programs by the Government of Indonesia.

Among turtles, least understood is the current situation of the live export of non-marine chelonians. Already in 1988, official export statistics for the Asiatic softshell turtle (*Amyda cartilaginea*) reached 66,500 kg for Sumatra only (details in Jenkins 1995; Shepherd 2000). During the past decade, volume in trade has reached enormous dimensions. The species affected, their relative percentages in the shipments, and their precise origin within Indonesia are virtually unknown. Moreover, to what extent protected or threatened species are exported as "by-catch" is not known either. For 1994, Jenkins (1995) listed quota for the Southeast Asian box turtle (*Cuora*

Plate 60. DOI: 10.1514/journal.arc.0040016g063

Plate 61. DOI: 10.1514/journal.arc.0040016g064

Plate 62. DOI: 10.1514/journal.arc.0040016g065

Plate 63. DOI: 10.1514/journal.arc.0040016g066

Plate 64. DOI: 10.1514/journal.arc.0040016g067

Plate 65. DOI: 10.1514/journal.arc.0040016g068

Plate 66. DOI: 10.1514/journal.arc.0040016g069

Plate 67. DOI: 10.1514/journal.arc.0040016g070

Plate captions: 60. *Morelia tracyae*. **61.** *Morelia boeleni*. **62.** *Morelia viridis* (juvenile). **63.** *Morelia viridis*. **64.** *Python breitensteini*. **65.** *Boiga irregularis*. **66.** *Calamaria* sp. **67.** *Calamaria* sp.

Species plates 60, 62, & 65 taken by Djoko T. Iskandar. Species plates 66 & 67 taken by Graeme Gillespie. Species plates 61, 63, & 64 taken by Alain Compost.

amboinensis) of 10,000 specimens, and for *Amyda cartilaginea* of 50,000 specimens. However, other sources as quoted in Jenkins (1995) indicate that the real and actual figures may be much higher. Annual exports for *Cuora amboinensis* were estimated at 200,000 specimens or, more precisely, plastrons, which were exported from Sulawesi to Hong Kong as turtle paste (Samedi and Iskandar 2000).

The alarming trends in freshwater and marine turtle exploitation, particularly in Southeast Asia, have drawn attention to more rigorous protection measures and implementation of CITES, respectively. Although a first action plan for tortoises and freshwater turtles was already formulated more than a decade ago (IUCN/SSC Tortoise and Freshwater Turtle Specialist Group 1989), the situation has dramatically worsened. As pointed out by Jenkins (1995), exploitation patterns of non-marine chelonians have shifted from harvests for domestic consumption to large-scale international trade, mainly for meat consumption, covering hundreds of thousands of individuals annually. Imports by mainland China are increasing, including massive smuggling, and there are drastically increased exports from Indonesia, in particular from Sumatra, Kalimantan, and Sulawesi.

In his introductory remarks to the proceedings of the 1993 international conference on conservation, restoration, and management of tortoises and turtles, John Behler (1997), chairman of the respective IUCN/SSC specialist group, stated that "The great Asian river turtles (*Batagur baska*, *Callagur borneoensis*, and *Orlitia borneensis*) and the giant softshells (*Chitra* spp. and *Pelochelys bibroni*) are seriously depressed and will not long survive without heroic intervention" and that "Today, there is no more serious turtle crisis than that which is taking place in Southeast Asia and southern China. Some species are very likely being lost in nature before they can be described" (p. xix). Several of the papers in the same proceedings addressed questions of tortoise and non-marine turtle conservation in the Asian region, but not a single paper dealt with an analysis of the situation in Indonesia where populations are most heavily exploited for these turtle groups. In a workshop on trade of freshwater turtles and tortoises in Asia (van Dijk et al. 2000) a number of recommendations to lessen impacts on natural populations were formulated. The same appeal is addressed in the book about the turtles and crocodiles of insular Southeast Asia (Iskandar 2000). These are not repeated here, but it is hoped that they will be implemented in the respective countries of the region, thus reducing or eliminating collecting from the wild and curtailing demand in consumer countries. If this cannot be achieved in the near future, then the further existence of many of the species will be at stake.

Presently six species of crocodiles have been described from Indonesia, viz. the estuarine crocodile (*Crocodylus porosus*), the New Guinea crocodile (*C. novaeguineae*), the Bornean crocodile (*C. raninus*, Ross et al. 1998), the Siamese crocodile (*C. siamensis*), and the tomistoma or false gharial (*Tomistoma schlegelii*). The Philippine crocodile (*C. mindorensis*) has been sighted in East Sulawesi, and its occurrence in Indonesia has been confirmed through observation of specimens in a crocodile farm near Makassar (Iskandar 1998, 2000). *Crocodylus porosus* and *C. novaeguineae* are bred in captivity and caught from the wild for the skin trade. The status of their wild populations would need to be re-evaluated. Over ten years ago, Thorbjarnarson (1992) had already found that the estuarine crocodile had become rare in Java and Sumatra and that more information was needed about wild populations in Kalimantan and the smaller island groups (see Ross et al. 1996, for discussion). The status of *C. raninus* has been confirmed only recently, and it remains unclear whether this "species" consists of a species complex or not (for details see Ross et al. 1996). Moreover, the status of this species in the wild in Indonesia is unknown. The Siamese crocodile and *Tomistoma* were already listed as endangered in the Conservation Action Plan for crocodiles (Thorbjarnarson 1992). Next to Thailand, Indonesia was considered the highest priority for action regarding these two species. This is reflected in their protection status in Indonesia (Table 1). The fact that *Tomistoma schlegelii* is now considered endangered only indicates the need for further surveys on the status of this species, particularly with regard to its occurrence in Sulawesi. In addition, the status of *C. siamensis* in Indonesia – it was only reported from Kalimantan in the mid-1990s (Ross et al. 1996) – is unknown. According to Ross et al. (1996) the Siamese crocodile has not been "imported" to Kalimantan but occurs there naturally. In sum, more work on the systematic status of some of the Indonesian crocodilians as well as detailed studies of the status of their wild populations are urgently needed.

Lizards and snakes

Probably the least understood groups among Indonesian amphibians and reptiles are the lizards and snakes. Accordingly, for these groups only scanty information that was available was included into the lists compared here (Table 1). The reasons why, for instance, only some of the larger agamid species have been considered, remain unclear. For *Lanthanotus* no published evidence exists (yet) that this species occurs in Indonesia. To date, it has only been reported from Sarawak, in the East Malaysian state of Borneo, but according to information from traders and local people, it also occurs in West Kalimantan. Efforts are presently being undertaken to publish a series of guides with color photographs to facilitate identification of the most common amphibian and reptile species utilized in Indonesia. Long-term experience in the pet trade has shed light on taxonomic uncertainties, especially in taxa that are distributed in eastern Indonesia such as the *Tiliqua gigas* and *T. scincoides* species complex or species (see Yuwono 1998; Shea, 2000). *Candoia carinata* had been known as a very variable species, and is now split into three species. Two of them have two subspecies and the other has six subspecies (Smith et al. 2001). *Morelia amethistina* shows considerable morphological and color variation (Yuwono 1998) and was recently split into four species (Harvey et al. 2000). Most new monitor lizards from East Indonesia that were described after the year 1997 first appeared in trade under the identity of other species due to the lack of regulation to control undescribed species (i.e. Böhme et al. 2002; Böhme and Jacobs 2001; Böhme and Ziegler 1997; Eidenmüller and Wicker 2005; Harvey and Barker 1998; Jacobs, 2003; Philipp et al. 1999; Sprackland 1999; Ziegler et al. 1999). The criteria that led to the inclusion of *Iguanognathus werneri* and *Anomochilus leonardi* into the IUCN list remain unclear. There is virtually no information available on these species, and quite a number of similarly poorly known species should be included on the list if ignorance

Plate 68. DOI: 10.1514/journal.arc.0040016g071

Plate 69. DOI: 10.1514/journal.arc.0040016g072

Plate 70. DOI: 10.1514/journal.arc.0040016g073

Plate 71. DOI: 10.1514/journal.arc.0040016g074

Plate 72. DOI: 10.1514/journal.arc.0040016g075

Plate captions: 68. *Cerberus rynchops*. **69.** *Candoia carinata*. **70.** *Chrysopelea paradisii celebensis*. **71.** *Dendrelaphis caudalineatus*. **72.** *Dendrelaphis punctulatus*.

Species plates 68–70, & 72 taken by Jim A. McGuire. Species plate 69 & 71 taken by Djoko T. Iskandar.

Plate 73. DOI: 10.1514/journal.arc.0040016g076

Plate 74. DOI: 10.1514/journal.arc.0040016g077

Plate 75. DOI: 10.1514/journal.arc.0040016g078

Plate 76. DOI: 10.1514/journal.arc.0040016g079

Plate 77. DOI: 10.1514/journal.arc.0040016g080

Plate captions: 73. *Elaphe erythrura*. **74.** *Enhydris matannensis*. **75.** *Rhabdophis chrysargoides*. **76.** *Rhabdophis subminiatus*. **77.** *Acantophis praelongus*.

Species plates 74 & 76 taken by Djoko T. Iskandar. Species plates 73, 75, & 77 taken by Jim A. McGuire.

Plate 78. DOI: 10.1514/journal.arc.0040016g081

Plate 79. DOI: 10.1514/journal.arc.0040016g082

Plate 80. DOI: 10.1514/journal.arc.0040016g083

Plate 81. DOI: 10.1514/journal.arc.0040016g084

Plate 82. DOI: 10.1514/journal.arc.0040016g085

Plate 83. DOI: 10.1514/journal.arc.0040016g086

Plate captions: 78. *Stegonotus modestus*. **79.** *Aspidomorphus mulleri*. **80.** *Ophiophagus hannah*. **81.** *Tropidolaemus wagleri*. **82.** *Chelodina reimannii*. **83.** *Chelodina siebenrocki*.

Species plates 78, 79, 82, & 83 taken by Djoko T. Iskandar. Species plates 80 & 81 taken by Alain Compost.

about a taxon is a criterion for inclusion into IUCN Red Lists, particularly as a threatened species.

As far as skin trade is concerned, further studies on *Ptyas mucosa* are planned to eventually provide evidence that skin trade in this species could be resumed again after the ban in 1994. For skins that had been on stock for sometime, export permits have recently been issued by PKA. Another problem refers to the cobras. Whereas several species are listed as one taxon in the IUCN list, only for one species (*Naja sputatrix*) are quota issued by the Indonesian authorities. Although the greater number of specimens are certainly *N. sputatrix*, nevertheless an unknown number of other cobra species may be harvested from Sumatra and Kalimantan. In short, although surveys on harvest levels of cobras have already been undertaken (Boeadi et al. 1998; Sugardjito et al. 1998), we need more information for an overall assessment of harvest levels, especially for the island of Java, where most of the cobras are caught for the food market and skins are used as byproducts.

A set of measures for the future

Generally, much more research is needed to provide better information on which to base conservation measures for amphibians and reptiles in Indonesia. This should be carried out both by local and foreign scientists and should involve both basic and applied research components. The latter should place emphasis on conservation of herpetological diversity as part of ongoing and future programs in biodiversity conservation and sustainable use in Indonesia. The most pressing problems amphibians and reptiles in Indonesia are facing at the moment are, in our opinion, either related to their conservation and/or to their sustainable use. More specific recommendations regarding the trade situation have been made (Erdelen 1998b) and are not further discussed here.

A "research-coordinating" and "information-disseminating" body might be useful to identify research needs and ensure that information on ongoing research and published results are made available in Indonesia. This coordinating body should consist of representatives of the official Indonesian authorities such as LIPI and PKA, as well as representatives of universities, nongovernmental organizations, the trade community, and other interest groups (e.g., from the industrial sector).

For future research programs and the dissemination of information, as indicated above, an overview of project reports and other unpublished materials, so-called "gray literature," available from various Indonesian authorities, and an analysis of conservation-related results already reported in these sources might make further research more effective by avoiding duplication of work already carried out earlier in Indonesia. These efforts, however, would require the creation and management of a centralized database. Location of this database, combined with a library that contains other relevant published information, as well as staffing, would need funding, the greater part of which would naturally have to come from external sources. Several specific initiatives have been launched already, such as the LIPI database which contains information on plants and animals in its collections. In addition, Conservation International has launched a CD-ROM with comprehensive environmental information about Papua.

To develop necessary local expertise, Indonesian universities need to put more emphasis on teaching amphibian and reptile biology and systematics. This might require changes in the curriculum as well as good working groups in zoological systematics. The major aim should be to train more students in field techniques and methodology in zoological systematics for later degree work in herpetology. Teaching needs could be met either by Indonesian scientists only or in cooperation with visiting foreign scientists.

A basis for regular exchange of information among all people interested in herpetology in Indonesia is clearly needed. This may eventually lead to the development of public awareness programs aimed at making amphibians and reptiles a more ”popular“ group of animals in Indonesia. This exchange of information could be arranged by the formation of a herpetological working group and/or by providing and exchanging this information through the Internet.

Conclusions and outlook

Without doubt we need to put more efforts in improving our understanding of the composition, the geographic distribution, and habitat and microhabitat requirements of the herpetofauna of Indonesia. In addition, however, amphibians and reptiles need to be seen as an important component of the megadiversity of Indonesia and thus need to be more explicitly included into conservation measures such as setting aside protected areas or giving species a particular protection status. The more we learn about the herpetofauna, the more we will probably realize that many species comprise genetically different units, which should be the target of conservation genetic approaches to biodiversity conservation. Last, but certainly not least, amphibians and reptiles with their general low mobility and great evolutionary age may prove to be key groups toward an understanding of the biogeography of the world's largest archipelago.

Acknowledgments.—The authors are grateful to Aaron Bauer, Wolfgang Böhme, L. Anathea Brooks, Indraneil Das, Alfred Gramstedt, Bob Inger, and Tony Whitten for providing useful information and for constructive comments on earlier drafts of the manuscript. We thank Linny Ayunahati and Pilar Chiang-Joo for drawing the figure and Boeadi, Ed Colijn, George Saputra, and Frank Yuwono for many discussions on issues raised in our paper. We wish to express our sincere gratitude to Alain Compost, Graeme Gillespie, and Jim McGuire who provided many of the excellent color photographs.

References

Alcala, A. C. and Brown, W. C. 1998. Philippine Amphibians: an illustrated field guide. Bookmark, Makati City, Philippines. 116 p.

Auffenberg, W. 1981. *The Behavioral Ecology of the Komodo Monitor*. University Presses of Florida, University of Florida, Gainesville, Florida, USA. 406 p.

Baillie, J. E. M. 1996. Analysis, p. 24-43 *in* Baillie, J. E. M and Groombridge, B (compilers and editors). *1996 IUCN Red List of Threatened Animals*. International Union for the Conservation of Nature and Nature Resources, Gland, Switzerland. 368 p.

Baillie, J. E. M. and Groombridge, B. (compilers and editors). *1996 IUCN Red List of Threatened Animals*. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland. 368 p.

Baillie, J. E. M., C. Hilton-Taylor, C. and Stuart, S. N. (compilers and editors), 2004. *IUCN Red List of Threatened Species: A Global Species Assessment*. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland. 191 p.

BAPPENAS (Badan Perencanaan Pembangunan Nasional) 1993. *Biodiversity Action Plan for Indonesia*. Ministry of National Development Planning/National Development Planning Agency, Jakarta, Indonesia. 141 p.

Behler, J. L. 1997. Troubled times for turtles, p. xviii-xxii *in* Abbema, J. V. and Pritchard, P. C. H. (editors). *Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—an international conference*. New York Turtle and Tortoise Society and the Wildlife Conservation Society, Turtle Recovery Program, New York, New York, USA. 494 p.

Bezujien, M. R., Webb, G. J. W., Hartoyo, P., Samedi, Ramono, W. S., and Manolis, S. C. 1998. The false gharial (*Tomistoma schlegelii*) in Sumatra, p. 10-31 *in Crocodiles: proceedings of the 14th working meeting of the Crocodile Specialist Group*. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland and Cambridge, United Kingdom. 410 p.

Bickford, D. P. 1998. Effects of the El Niño drought on the frogs of Papua New Guinea. *Froglog* **27**:1.

Boeadi and Shine, R., Sugardjito, J., Amir, M., and Sinaga, M. H. 1998. Biology of the commercially-harvested rat snake (*Ptyas mucosus*) and cobra (*Naja sputatrix*) in central Java, p. 99-104 *in* Erdelen, W. (editor). *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia. Mertensiella* **9**. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e. V., Rheinbach, Germany. 144 p.

Böhme, W. and Jacobs, H. 2001. *Varanus macraei* sp. n., eine neue Waranart der *V. prasinus*-Gruppe aus West Irian, Indonesien, *Herpetofauna* (Weinstadt) **23(133)**:5-10.

Böhme, W., Philipp K. M., and T. Ziegler. 2002. Another new member of the *Varanus* (*Euprepiosaurus*) *indicus* group (Sauria, Varanidae): an undescribed species from Rennell Island, Solomon Islands. *Salamandra* **38(1):**15-26.

Böhme, W. and Ziegler, T. 1997. *Varanus melinus* sp. n., ein neuer Waran aus der *V. indicus*-Gruppe von den Molukken, Indonesien. *Herpetofauna* **19(111)**:26-34.

Böhme, W. and Ziegler, T. 2005. A new monitor lizard from Halmahera, Moluccas, Indonesia (Reptilia: Squamata: Varanidae). Salamandra, Rheinbach **41(1/2)**: 51-59.

Chan-Ard, T., Grossmann, W., Gumprecht, A., and Schulz, K.-D. 1999. *Amphibians and Reptiles of Peninsular Malaysia and Thailand: an illustrated checklist/Amphibien und Reptilien der Halbinsel Malaysia und Thailands: eine illustrierte Checkliste*. Bushmaster Publications, Würselen, Germany. 240 p.

Ciofi, C. and de Boer, M. E. 2004. Distribution and Conservation of the Komodo Monitor (*Varanus komodoensis*). *Herpetological Journal* **14(2)**:99-107.

Cox, M. J., van Dijk, P. P., Nabhitabhata, J., and Thirakhupt, K. 1998. *A Photographic Guide to Snakes and Other Reptiles of Thailand and Southeast Asia*. Asia Books, Bangkok, Thailand. 144 p.

Dammermann, K. W. 1928. Preservation of wild life and nature reserves in the Dutch East Indies, p. 1103-1111 *in Proceedings of the 3rd Pan Pacific Science Congress* Volume **I**. National Research Council of Japan.

Das, I. 1998. *Herpetological Bibliography of Indonesia*. Krieger Publishing Company, Malabar, Florida, USA. 92 p.

Das, I. 2004. *Lizards of Borneo*. Natural History Publication, Kota Kinabalu, Malaysia. 83 p.

Das, I. and Charles, J. K. 2000. A Record of *Crocodylus raninus* Müller & Schlegel, 1844 from Brunei, North-western Borneo. *Sabah Parks Nature Journal* **3(2000)**:1-5.

David, P. and Vogel, G. 1996. *The Snakes of Sumatra: an annotated checklist and key with natural history notes*. Edition Chimaira, Frankfurt, Germany. 259 p.

van Dijk, P. P. 2000. The status of turtles in Asia, p. 15-13 *in* van Dijk, P. P., Stuart, B. L., and Rhodin, A. G. J. (editors). *Asian Turtle Trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs* **2.** Chelonian Research Foundation, Lunenburg, Massachusetts, USA. 164 p.

van Dijk, P. P., Stuart, B. L., and Rhodin, A. G. J. (editors). 2000. *Asian Turtle Trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs* **2**. Chelonian Research Foundation, Lunenburg, Massachusetts, USA. 164 p.

Eidenmüller, B. and Wicker, R. 2005. Eine weitere neue Waranart aus dem *Varanus prasinus*-Komplex von der Insel Misol. *Sauria* (Berlin) **27(1)**:3-8.

Emerson, S. B., Inger, R. F., and Iskandar, D. T. 2000. Molecular systematics and biogeography of the fanged frogs of Southeast Asia. *Molecular Phylogenetics and Evolution* **16(1)**:131-142.

Erdelen, W. 1991. Conservation and population ecology of monitor lizards: the water monitor *Varanus salvator* (Laurenti, 1768) in south Sumatra. *Mertensiella* **2**:120-135.

Erdelen, W. 1998a. Trade in lizards and snakes in Indonesia: biogeography, ignorance, and sustainability, p. 69-83 *in* Erdelen, W. (editor). *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia. Mertensiella* **9**. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e.V., Rheinbach, Germany. 144 p.

Erdelen, W. 1998b. (editor). *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia. Mertensiella* **9**. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e. V., Rheinbach, Germany. 144 p.

Erdelen, W., Abel, F., and Riquier, M. 1997. Status, Populationsbiologie und Schutz von Bindenwaran (*Varanus salvator*), Netzpython (*Python reticulatus*) und Blutpython (*Python curtus*) in Sumatra und Kalimantan, Indonesien. Final Report to the Federal Agency for Nature Conservation (BfN) and the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU), Germany. Unpublished. 158 p.

Evans, B. J., Brown, R. M., McGuire, J. A., Supriatna, J., Noviani, E., Diesmos, A., Iskandar, D. T., Melnick, D. J., and Canatella, D. C. 2003. Phylogenetics of fangeds frogs; testing biogeographical hypotheses at the interface of the Asian and Australian faunal zones. *Systematic Biology* **52(4):** 794-819.

Gaulke, M., Abel, F., and Erdelen, W. 1997. Zur Herpetofauna Nord-Sumatras. Teil 2: Herpetofaunengemeinschaft einer Ölpalm-Plantage. *Herpetofauna* **19(111)**:5-15.

Gaulke, M., Abel, F., Erdelen, W., and Fritz, U. 1998. Notes on the herpetofauna of north Sumatra. *Hamadryad* **23(1)**:78-82.

Groombridge, B. and Luxmoore, R. 1991. *Pythons in South-East Asia: a review of distribution, status and trade in three selected species*. Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Lausanne, Switzerland. 127 p.

Gurmaya, K. J., Boeadi, Iskandar, S., Susilo, A., and Sudradjat, A. R. 1999. Keanekaragaman Mamalia di Taman Nasional Bentuang Karimun, Kalimantan Barat. *Prosiding Lokakarya Rencana Pengelolaan Taman Nasional Bentuang Karimun* **2000-2004**:320-338.

de Haas, C. P. J. 1950. Checklist of the snakes of the Indo-Australian archipelago (Reptilia, Ophidia). *Treubia* **20**:511-625.

Harvey, M. B., Barker, D. G., Ammerman L. K., and Chippindale, P. T. 2000. Systematics of pythons of the *Morelia amethistina* complex (Serpentes: Boidae) with the description of three new species. *Herpetological Monographs* **14**:139-185.

Harvey, M. B. and Barker, D. G. 1998. A new species of blue-tailed monitor lizard (Genus *Varanus*) from Halmahera Island, Indonesia. *Herpetologica* **54(1)**:34-44.

van Hoesel, J. P. K. 1959. *Ophidia Javanica*. Museum Zoologicum Bogoriense, Bogor, Indonesia. 144 p.

Hoogerwerf, A. 1953. Nature protection and wildlife management in the Indonesia of today, p. 149-159 *in Proceedings of the 8th Pacific Science Congress*. National Research Council of the Philippines, University of the Philippines, Quezon City, Philippines.

ICSBD 1993. *Indonesian Country Study on Biological Diversity*. Ministry of State for Population and Environment, Jakarta, Indonesia. 217 p.

Inger, R. F. and Stuebing, R. B. 1989. *Frogs of Sabah*. Sabah Parks Publication No. 10. Sabah Parks Trustees, Kota, Kinabalu, Malaysia. 129 p.

Inger, R. F. and Stuebing, R. B. 1997. *A Field Guide to the Frogs of Borneo*. Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu, Malaysia. 205 p.

Inger, R. F. and Tan, F. L. 1996. *The Natural History of Amphibians and Reptiles in Sabah*. Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu, Malaysia. 101 p.

Iskandar, D. T. 1994. A new lizard of the genus *Sphenomorphus* from Central Java. *Treubia* **31(1):** 25-30.

Iskandar, D. T. 1996. The biodiversity of the amphibians and reptiles of the Indo-Australian archipelago: assessment for future studies and conservation, p. 353-365 *in* Turner, I. M., Diong, C. H., Lim, S. S. L., and Ng, P. K. L. (editors). *Biodiversity and the Dynamics of Ecosystems* (DIWPA Series) Volume **1**.

Iskandar, D. T. 1998. *Amfibi Jawa dan Bali*. Puslitbang Biologi-LIPI, Bogor, Indonesia. 117 p.

Iskandar, D.T. 1998. *The Amphibians of Java and Bali.* Research and Development Centre for Biology – LIPI, Bogor, Indonesia. 117 p.

Iskandar, D. T. 2000. *The Turtles and Crocodiles of Insular Southeast Asia and New Guinea*. Institute of Technology, Bandung and Palmedia, Bandung, Indonesia. 191 p.

Iskandar, D. T. and Colijn, E. 2000. Preliminary Checklist of Southeast Asian and New Guinean Herpetofauna. I. Amphibians. *Treubia* **31(3)** (Supplement):1-133.

Iskandar, D. T. and Colijn, E. 2002. *Checklist of Southeast Asian and New Guinean Reptiles. I. Snakes*. Biodiversity Conservation Project BCP 2000, Japan International Cooperation Agency (JICA), Institut Teknologi Bandung (ITB) and the Gibbon Foundation. Jakarta, Binamitra, Indonesia. 195 p.

Iskandar, D.T. and Colijn, E. 2003. *Bibliography of Southeast Asian and New Guinean Herpetofauna*, Biodiversity Conservation Project BCP 2000, Japan International Cooperation Agency (JICA), Institut Teknologi Bandung (ITB) and the Gibbon Foundation. Bogor, Bina Laksana. v + 310 p.

Iskandar, D. T., Setyanto, D. Y., and Liswanto, D. 1999. Keanekaragaman herpetofauna di Taman Nasional Bentuang Karimun, Kalimantan Barat. *Prosiding Lokakarya Rencana Pengelolaan Taman Nasional Bentuang Karimun* **2000-2004**:358-364.

ITTO. 1998. ITTO *Borneo Biodiversity Expedition 1997*. International Tropical Timber Organization, Yokohama, Japan. xvi + 282 p.

IUCN. 2000. *IUCN Red List of Threatened Species*. http://www.redlist.org/ (accessed on 27 November 2005).

IUCN. 2006. *IUCN Red List of Threatened Species*. http://www.redlist.org/ (accessed on 13 June 2006).

IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. 1989. *Tortoises and Freshwater Turtles: an action plan for their conservation.* International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland. 47 p.

Jacobs, H. J. 2003. A further new emerald tree monitor lizard of the *Varanus prasinus* species group from Waigeo, west Irian. *Salamandra Rheinbach* **39(2)**:65-74.

Jenkins, M. D. 1995. *Tortoises and Freshwater Turtles: the trade in Southeast Asia.* TRAFFIC International, Cambridge, United Kingdom. 48 p.

Jenkins, M. D. and Broad, S. 1994. *International Trade in Reptile Skins: review and analysis of the main consumer markets, 1983-91*. TRAFFIC International, Cambridge, United Kingdom. 68 p.

van Kampen, P. N. 1923. *The Amphibia of the Indo-Australian Archipelago*. E. J. Brill, Ltd., Leiden. 304 p.

Keogh, J.S., D.G. Barker and Barker, Shine, R. 2001. Heavily exploited but poorly known: systematics and biogeography of commercially harvested pythons (*Python curtus* group) in southeast Asia. *Biological Journal of the Linnean Society* **73**:113-129.

de Lang, R. and Vogel, G. 2005. *The Snakes of Sulawesi. A Field Guide to the Land Snakes of Sulawesi with Identification Keys*. Frankfurt Contributions to Natural History Vol. 25. Edition Chimaira, Frankfurt am Main, Germany. 312 p.

Lim, B. L. and Das, I. 1999. *Turtles of Borneo and Peninsular Malaysia*. Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu, Malaysia. 151 p.

Lim, K. K. P. and Lim, F. L. K. 1992. *A Guide to the Amphibians & Reptiles of Singapore*. Singapore Science Centre, Singapore. 160 p.

Limpus, C. J. 1995. Global overview of the status of marine turtles: a 1995 viewpoint, p. 605-609 *in* Bjorndal, K. A. (editor). *Biology and Conservation of Sea Turtles*. Revised Edition. Smithsonian Institution Press, Washington, D.C., USA. 615 p.

Luxmoore, R. and Groombridge, B. 1990. *Asian Monitor Lizards: a review of distribution, status, exploitation and trade in four selected species*. Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Lausanne, Switzerland. 195 p.

Manthey, U. and Grossmann, W. 1997. *Amphibien & Reptilien Südostasiens*. Natur und Tier - Verlag, Münster, Germany. 512 p.

McCord, W. P., Iverson, J. B., and Boeadi. 1995. A new Batagurid turtle from northern Sulawesi, Indonesia. *Chelonian Conservation and Biology* **1(4)**:311-316.

McCord, W. P., Iverson, J. B., Spinks, P. Q., and Shaffer, H. B. 2000. A new genus of Geoemydid turtle from Asia. *Hamadryad* **25(2)**:86-90.

McCord, W. C. and Pritchard, P. C. H. 2002. A review of the softshell turtles of the genus *Chitra*, with the description of new taxa from Myanmar and Indonesia (Java). *Hamadryad* **27(1)**:11-56.

Ministry of Forestry. 2004. Indonesian Government Regulation No. 7 and No. 8, 1999, about conservation of plants and animals, p. 204-286 in *Peraturan Perundang-undangan Bidang Perlindungan Hutan dan Konservasi Alam.* Jakarta, Indonesia. 617 p.

Mittermeier, R. A. and Mittermeier, C. G. 1997. *Megadiversity: earth's biologically wealthiest nations*. CEMEX, S.A., Mexico City, Mexico. 501 p.

Mittermeier, R. A., Myers, N., Gil, P. R., and Mittermeier, C. G. 1999. *Hotspots: earth's biologically richest and most endangered terrestrial ecoregions*. CEMEX, S.A., Mexico City, Mexico. 430 p.

Monk, K. A., de Fretes, Y., and Reksodiharjo-Lilley, G. 1997. *The Ecology of Nusa Tenggara and Maluku*. The Ecology of Indonesia Series Volume V. Periplus Editions, Singapore. 966 p.

Murphy, J. B., Ciofi, C., de la Panouse, C., and Walsh, T. (editors) 2002. Komodo Dragons: biology and conservation. Smithsonian Institution Press, Washington D.C., USA and London, United Kingdom. 268 p.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403(6772)**:853-858.

Nash, S. V. 1993. Problems with implementation of CITES Article IV in Southeast Asia. *Review No. 1: Indonesia. TRAFFIC Southeast Asia*. 34 p.

Philipp, K. M., Böhme, W., and Ziegler, T. 1999. The identity of *Varanus indicus*: redefinition and description of a sibling species coexisting at the type locality (Sauria, Varanidae, *Varanus indicus* group). *Spixiana* **22(3)**:273-287.

Pianka, E. R., King, D. R., King, R. A. (editors) 2004. *Varanoid Lizards of the World*. Indiana University Press, Bloomington and Indianapolis, Indiana, USA. 588 p.

Raharjaningtrah, W. and Prayogo, H. 1999. Keanekaragaman, dis-

tribusi, ekologi serta aspek konservasi burung di Taman Nasional Bentuang Karimun, Kalimantan Barat. *Prosiding Lokakarya Rencana Pengelolaan Taman Nasional Bentuang Karimun* **2000-2004**:339-357.

Ramono, W. S. and Raharjo, Y. C. 1993. Management of crocodiles in Indonesia: a current status, *in Crocodiles: proceedings of the 2nd regional (Eastern Asia, Oceania, Australasia) meeting of the Crocodile Specialist Group*. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Rhodin, A. G. J. 1994. Chelid turtles of the Australasian archipelago II: a new species of *Chelodina* from Roti Island, Indonesia. *Breviora* **498**:1-31.

Rhodin, A. G. J. and Genorupa, V. R. 2000. Conservation status of freshwater turtles in Papua New Guinea, p. 129-136 *in* van Dijk, P. P., Stuart, B. L., and Rhodin, A.G. J. (editors). *Asian Turtle Trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs* **2**. Chelonian Research Foundation, Lunenburg, Massachusetts, USA. 164 p.

de Rooij, N. 1915. *The Reptiles of the Indo-Australian Archipelago*. I. Lacertilia, Chelonia, Emydosauria. E. J. Brill, Ltd., Leiden. 384 p.

de Rooij, N. 1917. *The Reptiles of the Indo-Australian Archipelago*. II. Ophidia. E. J. Brill, Ltd., Leiden. 334 p.

Ross, C. A., Cox, J., and Kurniati, H. 1996. Preliminary Survey of Palustrine Crocodiles in Kalimantan. A LIPI/SI Cooperative Project. *Project Progress Report Phase 1 - 1995*. Unpublished. 45 p. plus annexes.

Ross, C. A., Cox, J., Kurniati, H., and Frazier, S. 1998. Preliminary surveys of Palustrine crocodiles in Kalimantan, p. 46-79 *in Crocodiles: proceedings of the 14th working meeting Crocodile Specialist Group*. The World Conservation Union, Gland, Switzerland. 410 p.

Samedi and Iskandar, D. T. 2000. Freshwater turtle and tortoise conservation and utilization in Indonesia, p. 106-111 *in* van Dijk, P. P., Stuart, B. L., and Rhodin, A.G. J. (editors). *Asian Turtle Trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs* **2**. Chelonian Research Foundation, Lunenburg, Massachusetts, USA. 164 p.

Shea, G.M. 2000. Die Neuginea-Blauzunge, *Tiliqua gigas* (Schneider, 1801): Ökologie und Übersicht über die Unterarten nebst Beschreibung einer neuen Unterart, *Tiliqua gigas evanescens* subsp. nov., p. 177-189 *in* Hauschild, A., Henle, K., Jiotz, R., Shea, G.M., and Werning, H. (editors). *Blauzungenskinke. Beiträge zu* Tiliqua *und* Cyclodomorphus. Terrarien Bibliothek, Natur und Tier – Verlag, Münster, Germany. 287 p.

Shepherd, C. R. 2000. Export of live freshwater turtles and tortoises from North Sumatra and Riau, a case study, p. 112-119 *in* van Dijk, P. P., Stuart, B. L., and Rhodin, A.G. J. (editors). *Asian Turtle Trade: proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia. Chelonian Research Monographs* **2**. Chelonian Research Foundation, Lunenburg, Massachusetts, USA. 164 p.

Shine, R., Ambariyanto, Harlow, P. S., and Mumpuni. 1999a. Ecological attributes of two commercially-harvested python species in northern Sumatra. *Journal of Herpetology* **33(2)**:249-257.

Shine, R., Ambariyanto, Harlow, P. S., and Mumpuni 1999b. Reticulated pythons in Sumatra: biology, harvesting and sustainability. *Biological Conservation* **87(3)**:349-357.

Shine, R., Ambariyanto, Harlow, P. S., and Mumpuni. 1998a. Ecological traits of commercially harvested water monitors, *Varanus salvator*, in northern Sumatra. *Wildlife Research* **25(4)**:437-447.

Shine, R., Harlow, P. S., Ambariyanto, Boeadi, Mumpuni, and Keogh, J. S. 1998b. Monitoring monitors: a biological perspective on the commercial harvesting of Indonesian reptiles, p. 61-68 *in* Erdelen, W. (editor). *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia. Mertensiella* **9**. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e. V., Rheinbach, Germany. 144 p.

Shine, R., Harlow, P. S., Keogh, J. S., and Boeadi. 1998c. The influence of sex and body size on food habits of a giant tropical snake, *Python reticulatus*. *Functional Ecology* **12(2)**:248-258.

Simpson, B. K., Lopez, A., Latif, S. bin A., and Yusoh, A. bin M. 1998. Tomistoma (*Tomistoma schlegelii*) at Tasek Bera, Peninsular Malaysia, p. 32-45 *in Crocodiles: proceedings of the 14th working meeting of the Crocodile Specialist Group*. The World Conservation Union, Gland, Switzerland. 410 p.

Smith, H. M., Chizar, D., Tepedelen, K., and van Breukelen, F. 2001. A revision of the bevel-nosed boas (*Candoia carinata* Complex) (Reptilia: Serpentes). *Hamadryad* **26(2)**:283-315.

Sprackland, R. G. 1999. New species of monitor (Squamata: Varanidae) from Indonesia. *Reptile Hobbyist*, February, **4(6)**:20-27.

State Ministry for Environment. 1997. *Agenda 21–Indonesia: a national strategy for sustainable development*. State Ministry for Environment, Republic of Indonesia, Jakarta. 601 p.

Stuebing, R. B. 1994. *Draft management plan for herpetofauna for the development of Lanjak-Entimau Wildlife Sanctuary as a totally protected area*. International Tropical Timber Organization, Forestry Headquarters, Sarawak, East Malaysia. 63 p.

Stuebing, R. B. 1997. Lanjak Entimau Wildlife Sanctuary – A totally protected area. *ITTO Tropical Forest Update* **7(1)**:10-12.

Stuebing, R. B. and Inger, R. F. 1999. *A Field Guide to the Snakes of Borneo*. Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu, Malaysia. 254 p.

Stuebing, R. B., Lading, E., and Jong, J. 1998. The status of the false gharial (*Tomistoma schlegelii* Müller) in Sarawak, p. 1-9 in *Crocodiles: proceedings of the 14th working meeting of the Crocodile Specialist Group*. The World Conservation Union, Gland, Switzerland. 410 p.

Sugardjito, J., Boeadi, Amir, M., and Sinaga, H. M. 1998. Assessment of harvest levels and status for the spitting cobra (*Naja sputatrix*) and the rat snake (*Ptyas mucosus*) in central Java, p. 105-110 *in* Erdelen, W. (editor). *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia. Mertensiella* **9**. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e. V., Rheinbach, Germany. 144 p.

Sunderlin, W. D. and Resosudarmo, I. A. P. 1996. Rates and causes of deforestation in Indonesia: towards a resolution of the ambiguities. *CIFOR Occassional Paper* **9**:1-19.

Suwelo, I. S., Nuitja, N. S., and Soetrisno, I. 1995. Marine turtles in Indonesia, p. 349-351 *in* Bjorndal, K. A. (editor). *Biology and Conservation of Sea Turtles*. Revised Edition. Smithsonian Institution Press, Washington, D.C., USA. 615 p.

Thorbjarnarson, J. (compiled) and Messel, H., King, F. W., and Ross, J. P. (editors). 1992. *Crocodiles: an action plan for their conservation*. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland. 136 p.

Tomascik, T., Mah, A. J., Nontji, A., and Moosa, M. K. 1997. *The Ecology of the Indonesian Seas*. Part Two. The Ecology of Indonesia Series, Volume VIII. Periplus Editions, Singapore. 1388 p.

Webb, G. 2002. Observation on the giant softshell turtle *Pelochelys cantorii* with description of a new species. *Hamadryad* **27(1)**:99-107.

Whitten, T., Soeriaatmadja, R. E., and Afiff, S.A. 1996. *The Ecology of Java and Bali*. The Ecology of Indonesia Series Volume II. Periplus, Singapore. 969 p.

Yuwono, F. B. 1998. The trade of live reptiles in Indonesia, p. 9-15 *in* Erdelen, W. (editor). *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia. Mertensiella* **9**. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e. V., Rheinbach, Germany. 144 p.

Ziegler, T., Böhme, W., and Philipp, K. M. 1999. *Varanus caerulivirens* sp. n., a new monitor lizard of the *V. indicus* group from Halmahera, Moluccas, Indonesia (Squamata: Sauria: Varanidae). *Herpetozoa* **12(1/2)**:45-56.

Manuscript received: December 2001; Accepted: 2005; Published: 26 December 2006