HAMADRYAD

Vol. 31, No. 2, August 2007.
Date of issue: 31 August 2007.
ISSN 0972-205X

CONTENTS

OVERVIEW

NOTES

BOOK REVIEWS

Hamadryad Vol. 31, No. 2, pp. 176 – 201, 2007.

AMPHIBIANS AND REPTILES OF NEW BRITAIN ISLAND, PAPUA NEW GUINEA: DIVERSITY AND CONSERVATION STATUS

Johannes Foufopoulos[1,2,4] and Stephen Richards[3]

[1] Department of Zoology, University of Wisconsin,
Madison, WI 53706, U.S.A.

[2] Department of Ecology and Evolutionary Biology, Princeton University,
Princeton, NJ 08544, U.S.A.

[3] Vertebrates Department, South Australian Museum, North Terrace,
Adelaide, S.A. 5000, Australia.
Email: richards.steve@saugov.sa.gov.au

[4] Present Address: School of Natural Resources & Environment, Dana Hall, 440 Church St.,
University of Michigan, Ann Arbor, MI, 48109–1041, U.S.A.
Email: jfoufop@umich.edu

(with 37 text-figures)

ABSTRACT.– **During herpetological surveys of the Nakanai Mountains, Willaumez Peninsula, and Wide Bay areas of New Britain Island we documented 29 species of reptiles and 21 species of amphibians. At least five undescribed frog taxa were discovered during these expeditions. The beaked blind snake, *Typhlops depressiceps* and the ranid frog, *Platymantis magna,* are reported from New Britain for the first time. Species richness in the Nakanai/Willaumez area was highest in lowland primary rainforests and declined with increasing altitude. The rate of decline was steeper for reptiles than for amphibians, resulting in a relatively larger component of amphibian taxa in the fauna at higher elevations. Endemicity (defined as the percentage of species unique either to New Britain or to the Bismarck Archipelago) increased with elevation (between sea level and 1,000–1,500 m asl), from 78% to 90% for amphibians but remained virtually unchanged for reptiles (22% vs. 18%). Species overlap between the surveyed lowland sites on the north and south coasts was 46%. Data accumulated during these surveys indicate that the herpetofauna of the island is not only richer than thought previously, but also contains a large proportion of endemic frog species that are of particular conservation interest. The majority of endemic species was found only in primary tropical rainforest; they are likely to be sensitive to the ongoing large-scale habitat destruction. A complete checklist of the herpetofauna for New Britain Island is presented.**

KEY WORDS.– **Herpetofauna, biodiversity survey, Melanesia, island endemics, deforestation.**

INTRODUCTION

Covering an area of nearly 40,000 km^2, New Britain is the largest island in the Bismarck Archipelago. Little research has been conducted on the reptiles and amphibians of New Britain and the island's herpetofaunal diversity remains poorly documented. Allison (1996) reported 66 species of frogs and reptiles from New Britain, most of which have wide regional distributions in lowland forests. Sixty two percent of species are shared with mainland New Guinea (Allison, 1996). However, there is also a significant endemic element, especially among frogs. Mounting evidence points to a remarkable evolutionary radiation among platymantine frogs in the Melanesian island arcs (Brown, 1997), and six of the eight *Platymantis* recorded previously from New Britain were endemic to the island (Allison, 1996).

Most information about the New Britain herpetofauna is based on collections and observations made along the northern and eastern coasts. The mountainous interior of the island and most of the south coast remain some of the biologically least known regions of Papua New Guinea. The highland regions are likely to be disproportionately rich in endemic taxa (Allison, 1996). This paper reports the results of surveys in the Nakanai Mountains and the Willaumez Peninsula, and in the Wide Bay area on the south coast of the island. An overview of the New Britain herpetofauna is presented and the conservation status of the fauna is assessed.

Past collections.– Herpetological collections from New Britain have focused primarily on the Gazelle Peninsula at the far eastern end of the island (Werner, 1900; Zweifel, 1966; 1975; Frodin and Gressitt, 1982). Additional collections were made in the region around Kimbe Bay and the Willaumez Peninsula (e.g., Brown and Tyler, 1968) and small numbers of specimens were collected from the north (Brown, 1983) and south (Hediger, 1934) coasts of the island. The only substantial collections from the highlands of New Britain were made in the Whiteman Range by the Gilliard expedition (Zweifel, 1960). Because past collections were frequently made in an opportunistic manner and in the immediate vicinity of the coast, the herpetofauna of the highlands and the remote southern coast regions remains virtually unstudied.

MATERIALS AND METHODS

The two surveys reported here were conducted using similar methods. Because an important focus of the expeditions was to raise awareness among the local people of the biological heritage of New Britain, we held extensive discussions with Papua New Guinean students and involved local communities in field collecting.

Collection localities.– The first survey was conducted during March–April 1999 in two highland sites in the Nakanai Mountains, and a lowland site on the Willaumez Peninsula (West New Britain Province) (Fig. 1, Appendix 1). In the Nakanai Mountains, collecting centered on two sites along a ridge separating the Ivule and Sigole rivers (Fig. 2) on the north side of the mountain range (05°32.3'S; 151° 03.1'E). Nakanai Site 1 was 800–980 m asl and Nakanai Site 2 was 980–1,200 m asl (Fig. 3). Limited collecting was also conducted in the cloud forest on the top of the Nakanai Plateau (05°33.112'S; 151°04.269'E; 1,500 m asl) (Figs. 4, 5).

Sites 1 and 2 were located in relatively undisturbed mid-montane forest. However, a significant portion of the steepest mountain slopes was covered with secondary vegetation including dense climbing ferns and bamboo thickets (Fig. 3). There was little evidence of human activity at either site, and this vegetation probably develops as a result of frequent landslides that prevent establishment of primary rainforest. In contrast, flatter areas were covered with closed-canopy forest (average canopy height > 20 m) with a fairly open understorey. We collected at Nakanai Site 1 from 20–27 March 1999 and at Nakanai Site 2 from 29 March–5 April 1999.

The Willaumez Peninsula survey focused on the area above the Walindi Plantation (05°26.04'S; 150°03.81'E) between the coastal towns of Kimbe and Talasea. The coastal region is dominated by oil palm and coconut plantations. Small gardens occur ca. 1 km from the coast and grade into disturbed and eventually primary forest towards the interior. The Willaumez site was surveyed 12–19 April 1999. Although disturbed habitats were sampled, our collecting effort focused mostly on the rainforest habitat between Taranara (195 m asl) and Mapmasika (400 m asl).

The south-coast survey was conducted in the vicinity of Sampun village, in the Wide Bay area on the south coast of the island (East New Britain Province) (Fig. 1, Appendix 1). Voucher specimens of frogs and reptiles were collected at three sites: Camp 1 was a garden in the vicinity of Sampun, surrounded by heavily disturbed forest at an altitude of less than 50 m asl (05°22.276'S; 152°06.645'E). This site was sampled during 13–14 March 2000. Wanui Camp was in primary forest, two hours walk from Camp 1 (05°21.638'S; 152°05.266'E). It was located in moist foothill forest next to the Wanui River at an altitude of 310 m asl (Fig. 6.). Trails were established on two ridges adjacent to Wanui Camp giving access to altitudes up to ca. 500 m asl. These ridges were noticeably drier than the camp and were dominated by *Nothofagus* forest with a rather open understorey. This site was sampled for 14 days (14–28 March 2000). Finally, additional observations were made at Sampun Village on the evening of March 28.

Collection methods.– Specimens were collected using a variety of methods. During the day we searched for heliothermic (basking) reptiles along forest trails, clearings, and stream banks. Small lizards were collected after being stunned with a large rubber band or were caught using a handheld noose. Large lizards and snakes were captured by hand. Non-heliothermic reptiles and amphibians were sampled by searching through suitable hiding places in deeply shaded forest, during rain, or at dusk. During the 1999 survey we erected at each site, one or two short drift fences made from plastic sheeting with 5-gallon buckets sunk in the ground. Several interesting specimens were caught in snap, Sherman and Conibear traps set for small mammals. During our stays in inhabited areas, we purchased specimens that were brought in by local villagers. Whenever possible, we recorded for each animal the date and time of day of capture, and ecological data including habitat, perch characteristics and activity. We conducted visual-encounter and aural surveys for nocturnal reptiles and calling frogs. Whenever possible we recorded the advertisement calls of frogs with a Sony Pro-Walkman Tape Recorder and a Sony ECM–Z200 microphone. For a subset of calling frogs, we recorded body temperature and weight, collected tissue samples and took photographs.

Amphibians and small reptiles were euthanized by submersion in chlorotone (McDiarmid, 1994) and larger reptiles were anaesthetized with chloroform. After taking morphological and body mass measurements, all specimens were either fixed in 10% formalin solution, and then stored in 70% ethanol, or fixed and stored in 70% ethanol. Liver samples for DNA analysis were extracted from 2–3 specimens of most species, and preserved either in tissue buffer (250 mM disodium EDTA and 20% dimethylsulfoxide in a saturated NaCl solution - 1999 Survey) or in 90% ethanol (2000 Survey). Ectoparasites and internal parasites found during these procedures were preserved separately in 90% ethanol (1999 Survey). Blood-smears and blood dots were prepared from a number of specimens for future blood parasite identification. Specimens, field notes and voice recordings from the 1999 survey are deposited in the University of Wisconsin Museum of Zoology (UWZM). Tissue samples have been deposited at the UWZM and are available to researchers. Specimens and tissues from the 2000 survey are deposited in the South Australian Museum (SAMA). Additional specimens from both surveys will be deposited at the University of Papua New Guinea (UP).

RESULTS

Species Accounts

AMPHIBIANS

Family Bufonidae

Bufo marinus (Linnaeus, 1758)

A large (SVL up to 150 mm) toad introduced to New Britain in 1939 to control pest insects (Bailey, 1976). Although commonly encountered during both surveys, no specimens have yet been deposited in museum collections. The species was found in a variety of disturbed habitats including gardens, lawns, and oil palm and coconut plantations. At Wanui, it was encountered only in lowland primary rainforest, whereas in Walindi, it was also found in plantation gardens. The species was also seen at low densities at altitudes up to at least 1,100 m in the Nakanai Mountains. According to locals, the cane toad has been present around Wanui since 1990. At Walindi, reproduction occurred after heavy evening rain with groups of up to 20 adults clinging to each other in a single "mass". The advertisement call is a soft purring sound. Long strings of black eggs were deposited into small water puddles and ditches. By day, adults sought shelter in shady areas but juveniles remained active in the full sun.

Family Hylidae

Litoria infrafrenata (Günther, 1867) (UWZM H.23810–13)

A large (SVL to 135 mm) green tree frog that is widespread at low elevations across the islands of the Bismarck Archipelago (Tyler, 1968) (Fig. 7). The species was relatively common in gardens and secondary vegetation around Walindi Plantation, but most calling males were in the canopy of rainforest fragments. Males call at night with a deep double-note call that resembles the bark of a dog.

Litoria sp.

One frog observed, but not captured, at the Walindi Plantation probably represents the undescribed *L. bicolor*-group species mentioned in Zweifel and Tyler (1982). This medium-sized, dark green individual was calling after heavy rains from a water-filled depression in the lawn ca. 100 m from the beach.

Family Microhylidae

Austrochaperina novaebritanniae Zweifel, 2000 (SAMA R60209–11)

A small species (SVL to 21 mm; Zweifel, 2000), common in leaf litter and under rotting logs at Wanui camp. Less common in drier, disturbed forest at Camp 1. This frog was frequently observed hopping in wet litter at night after rain, but no vocalizations were heard.

Oreophryne brachypus (Werner, 1898) (SAMA R60235–37, UWZM H.23779–80)

A small species (male SVL < 24 mm) reported previously from East New Britain (Tyler, 1967) (Fig. 8). This taxon was encountered in primary rainforest at Walindi and was also common at Camp 1 and Wanui Camp on the south coast. Males called at night after rain from between 0.5 and 5 m high on leaves, particularly, broad-leafed gingers. The call is a high-frequency chirp resembling the stridulations of a katydid.

Family Ranidae

Genus *Platymantis*

This genus has undergone extensive adaptive radiation on New Britain and is the most speciose genus of frogs on the island. Some species are terrestrial, others have large toe-pads and live exclusively in trees, and two species have long, slender limbs but only small toe pads indicating a scansorial rather than arboreal lifestyle. Many species possess long, raised ridges of skin on the dorsum. All species, for which the reproductive strategy is known, produce large unpigmented eggs and embryonic development is completed within the egg capsule. Colouration and patterning are, in many species, exceedingly variable; toe morphology and call structure are the most reliable identification characters.

Platymantis adiastola Brown, et al. 2006b (SAMA R57044)

A moderate-sized species (male SVL ~ 41 mm) that was abundant at Wanui, occurring at ~ 8–10 times the density of *P. schmidti* (Brown et al. 2006b). Shares with *P. schmidti* a variable back pattern including individuals with unmarked backs and animals with two distinct dorsal stripes. This frog called from elevated perch sites, on leaves and branches up to 2 m above forest floor. Call is a series of loud yapping notes, reminiscent of, but harsher than, *P. papuensis*.

Platymantis akarithyma Brown and Tyler, 1968 (SAMA R57017–21)

A small (male SVL < 24.2 mm; Brown and Tyler, 1968) species with variable dorsal markings. This frog was abundant at Camp 1 and Wanui Camp. Males called most intensively at dusk during overcast or rainy conditions, from within thick leaf litter on the forest floor. The species is endemic to New Britain.

Platymantis boulengeri (Boettger, 1892) (SAMA R57033–39, UWZM H.23767–74)

A large (SVL to > 70 mm), broad-headed species, with fan-shaped dorsal ridges and a dark brown band between tympanic membrane, eye and upper lip (Fig. 9). The colour is variable, ranging from pale ochreous yellow to purplish brown, usually with small yellow dots on the rear of thighs. The belly is generally some shade of red, ranging from a pale orange dusting to a bright brick red. This was the most common primary rainforest frog at Walindi; at Wanui Camp, it was found on wet nights foraging on forest floor or perched on logs. Only two individuals were encountered at 980 m (Nakanai campsite), possibly indicating proximity to upper altitudinal limit. Adults were seen most commonly away from water and less than 20 cm above the forest floor, but juveniles occurred in vegetation over 1 m high. We encountered no calling males and the voice of this species remains unknown. One small individual (UWZM H.23767) from Nakanai Site 1 was reported by local assistants to be calling when captured, and may represent *P. rhipiphalca* (Brown and Tyler, 1968). Further studies are required to determine its taxonomic status.

Platymantis browni Allison and Kraus, 2001 (SAMA R57022–32)

This is a small (male SVL 21–25 mm) scansorial species that called from low vegetation (particularly ginger) between 0.5 and 2 m above the ground after heavy rain (Fig. 10). Call is a series of harsh clicks. This species was common in the primary forest at Wanui site, but uncommon at Camp 1, and was not seen or heard during one night at Sampun Village. *Platymantis browni* was recently described from southern New Ireland (Allison and Kraus, 2001). This material represents the first record of this species from New Britain.

Platymantis gilliardi Zweifel, 1960 (UWZM H.23787–808)

This was the most abundant amphibian at the middle elevations (980 m) of the Nakanai Mountains. The species is morphologically similar to, but significantly smaller (SVL < 38 mm) than, *P. schmidti*. The dorsal pattern tends to be variable; the pink-fleshy ground colour and dark urn-shaped folds on the anterior of the back described by Zweifel (1960) and Brown and Tyler (1968) are not consistently present (Figs. 11A, 11B). Nakanai Mountains population possibly includes specimens of several morphologically similar taxa, including *P. mimica*. The call is relatively quiet and resembles the bleating of a lamb ('meeeeeh'). In chorusing aggregations, call of one individual prompts calls from many nearby males, producing a "wave-like" effect. The species uses lower perches than *P. schmidti* and was most often found in the leaf-litter or in low herbaceous vegetation (< 20 cm high); this is reflected it its relatively short, stubby toes. Encountered only at middle elevations in the Nakanai Mountains (800–1,100 m asl).

Platymantis macrosceles Zweifel, 1975 (UWZM H.23721, UPNG 10007)

This is a moderately small (SVL < 35 mm) species previously known from a single specimen collected in the Nakanai Mountains more than 25 years ago (Zweifel, 1975) and is redescribed elsewhere (Foufopoulos and Brown, 2004). Two individuals were encountered, both calling in primary rainforest habitat at Nakanai Site 1 (ca. 900 m asl). This frog is in life mottled green with two distinct brown patches on each side of spine (see also Foufopoulos and Brown, 2004) (Fig. 12). Mottled colour, narrow body and elongated soft warts over eyes and on rear legs produce a cryptic effect that makes *P. macrosceles* difficult to see on mossy substrates. Found on plants approximately 1 m high and 3 m from a small stream flowing over large, moss-covered boulders. Advertisement call an unmusical and monotonously rasping 'pulse train' ('krrrrr… …rrrr, krrrr... …rrrr').

Platymantis magna Brown and Menzies, 1979 (SAMA R60238–41)

This large species (males to 63.4 mm SVL) called at the Wide Bay sites from the forest floor or logs, 20–50 cm high, after heavy night rain (Fig. 13). This is the first record of *P. magna*, previously considered a New Ireland endemic, from New Britain. In size, morphology, and call characteristics (reminiscent of the yelp of a dog) the New Britain frogs are indistinguishable from *P. magna* populations on New Ireland (Brown and Menzies, 1979).

Platymantis mamusiorum Foufopoulos and Brown, 2004 (UWZM H.23719–20, H.23722, UPNG.9992)

This recently described, moderately small species (SVL < 31 mm), superficially resembles *P. macrosceles* but has different colouration and advertisement call (Foufopoulos and Brown, 2004) (Fig. 14). Four calling males were captured in cloud forest on top of Nakanai Plateau (above approx. 1,550 m asl), where the dominant vegetation was a dense bamboo-*Pandanus* thicket, ca. 5 m high (Figs. 4, 5). The colouration is similar to *P. macrosceles* except that the green colour is darker and with an olive tinge, while the brown patches on the dorsum were absent. The species lacks elongated tubercles on the side of the body and on the eyelids. All individuals were found on bamboo shoots and leaves less than 1 m high. All animals encountered were cryptic and difficult to see even when calling. The call of this species is a quiet 'creq-creq-creq.' Calling started at approx. 1700 h with peak calling activity occurring around 1900 h. Calling intensity then decreased, and ceased around midnight.

Platymantis nakanaiorum Brown, Foufopoulos and Richards 2006 (UWZM H. 23897–98, UPNG UP10010–11)

This common, medium-sized (male SVL < 44 mm) species was encountered only above ~ 1,500 m on the Nakanai Plateau. It can be distinguished from other arboreal *Platymantis* in New Britain by its call and light brown colour (Fig. 18), and is currently being described elsewhere (Brown et al. 2006a). The species is most common in *Pandanus* palms, which at 1,500 m asl constitute a dominant feature of the forest communities. The advertisement call is a musical, ethereal 'clui - clui - clui - clui'. Males call in response to another individual, producing a wave of calls that 'rolls' across the landscape (a rolling chorus). Population densities were highest in moist ravines and lowest in areas of mature forest with extensive tree-fall gaps.

Platymantis nexipus Zweifel, 1975 (SAMA R56783–84)

This is a moderately large (male SVL 38.9 mm; female SVL 56.6 mm) arboreal frog with greatly expanded finger and toe discs (Fig. 15). The species was fairly common at the Nakanai Sites 1 and 2 (800–1,200 m asl). Specimens from Wanui are tentatively assigned to this poorly understood species, which was previously known from one adult female (Brown et al. 2006a, Zweifel, 1975). Further studies are required to confirm the status of these Wide Bay specimens. Males normally called from > 3 m above the ground, making collection of specimens extremely difficult. The call is a loud, explosive 'krüüüüh - krüüüüh' that carries a few hundred meters through the rainforest. The species started calling later and called less frequently than terrestrial platymantines, but also continued calling later into the night. Apparently not as common as terrestrial congeners because calling males were generally ~200 m apart. Densities of calling individuals were higher in moist sheltered valleys close to water than on exposed forest ridges.

Platymantis schmidti Brown and Tyler, 1968 (SAMA R57040–43, UWZM H.23775–78, H.23781–86, H.23890)

A medium sized species (SVL up to 46 mm) with two colour forms (Menzies, 1976); one with uni-coloured dorsum, and another with two pale longitudinal stripes on dorsum (Fig. 16). Specimens attributed to this species exhibited substantial variation in call structure. Like most other *Platymantis*, males start calling at dusk and calling intensity decreases over the course of the night. However, some individuals called after midnight or even during the day, especially after heavy rain. The repetitive pulsating call is reminiscent of a pencil being drawn over a wooden washboard (see also Menzies, 1982a, b). Calls of the Nakanai Mountains population sounded like long bursts of bullets fired from a miniature machine-gun and may represent an unidentified cryptic species. The species is normally found on the ground and in rainforest undergrowth (20 cm – 1 m high) but calling males appear to prefer tree-fall gaps and other impenetrable thickets. Females were most commonly encountered sitting on the forest floor.

Platymantis sp. A (UWZM H. 23894)

A single specimen of this undescribed, medium-sized species (male SVL 45 mm) was collected in the Nakanai Mountains (Fig. 17)(Brown et al. 2006a). The species is morphologically similar to *P. nexipus* from which it can be distinguished by its wide-ringing advertisement call, a series of 6 –7 'klüh' calls resembling a glass marble hitting a stone floor and then bouncing at progressively shorter intervals: 'klüüüüh - klüüüh - klüüh - klüh - klüh - klüh'. This wide-toed species called exclusively from high (4–5 m) perches. The ground colour was cinnamon with broad light yellow patches on the sides of the snout and dorsal surface. The sole specimen was found 4 m high in a sapling ca. 10 m from a creek in a small valley in primary forest at 900 m asl. Other individuals were calling at altitudes between 800 and 1,200 m asl.

Discodeles guppyi (Boulenger, 1884) (SAMA R60213–16, R60218, UWZM H.23814–19, H.23835–37)

A large aquatic frog (male SVL 94.6 mm; female 145 mm) that is widespread in the lowlands of New Britain (Fig. 19). It was encountered commonly along creeks at Camp 1 and Wanui Camp, Walindi, and at the confluence of the Ivule and Sigole rivers (ca. 10 km inland from the north coast). The species is apparently absent from higher altitudes in the Nakanai Mountains that lack extensive surface water. Adult frogs reach body masses of several hundred grams and hind legs are a prized delicacy among local communities. Most frequently encountered in rocky, boulder-strewn white-water stretches of rivers. They are powerful swimmers and capable of clinging to logs and rocks in fast flowing water. Males called from exposed positions on stream banks or from within dense vegetation adjacent to streams at night. Females were encountered in forest up to 20 m from streams. Newly metamorphosed frogs were active during the day on stream banks at Wanui. The call can be best described as a loud squawk. A population of intermediate-sized frogs with mottled grey-green and rugose dorsums were sympatric with large adults at Walindi and may represent a different taxon; however they are tentatively considered to be subadults of this species. Several tiny, light green individuals (SVL < 29 mm, body mass < 2.5 g) collected at this site require further study to determine their taxonomic status.

Rana daemeli (Steindachner, 1868) (UWZM H.23760)

Several specimens of this medium-sized species were heard calling from dense vegetation in a slow-flowing creek at Sampun Village on the south coast - voucher recordings were obtained but no specimens were collected. One specimen was collected during the 1999 survey. The species appears to be restricted to the immediate vicinity of running water and most individuals were found in primary rainforest streams with moss-covered boulders (Fig. 20). This species generally called at night although a few individuals were also heard during an overcast mid-morning. Preferred calling sites were located on the underside of large streamside boulders that were frequently further excavated to provide additional shelter. The call of the species is a series of quacking notes reminiscent of the call of a mallard.

Rana novaebritanniae Werner, 1894 (SAMA R60243–48, UWZM H.23764–66)

This moderately large (male SVL 59.5 mm) frog appears to be widespread on New Britain (Fig. 21). During the 1999 survey, we found the species both in the lowland Walindi River, as well as in the small tributary of the Sigole River (950 m asl). It was also heard calling from the base of dense vegetation in a large swamp downstream of Wanui Camp. The species is morphologically similar to *R. daemeli*, the only species of *Rana* currently recognized in New Britain. However, the call, a bi-phasic "plonk" differs from both the call of *R. daemeli* and from the call of *R. kreffti*, which is known from New Ireland and the Solomon Islands (Menzies, 1987). The name *Rana novaebritanniae* Werner, 1894, is available for this species. These data confirm the presence of 2 species of *Rana* on the island of New Britain.

REPTILES

Family Agamidae

Hypsilurus godeffroyi (Peters, 1867) (UWZM H.23875)

This large (SVL ~ 200 mm) species has a wide distribution across the New Guinea region (Moody, 1980). We encountered this secretive arboreal lizard only at our low elevation census site (ca. 100 m asl) near Walindi. The species appears to be limited to primary rainforest where it lives high in the canopy. One specimen, a juvenile male, was taken from a Torresian crow (*Corvus orru*) that had just captured it. The second animal, a substantially larger male, became entangled in a mist-net set up to capture birds. The species is sexually dimorphic with males reaching more than twice the size of females (Hediger, 1934). Males can also be distinguished by a large dewlap and a prominently serrated dorsal crest.

Hypsilurus modestus (Meyer, 1874) (SAMA R60230)

A moderately sized (SVL up to 100 mm), arboreal lizard that is widespread across New Guinea and New Britain (Fig. 22). Documented at Walindi on the north coast and above Wanui camp on the south coast. Lives in the rainforest canopy, although it appears to prefer somewhat lower vegetation than *H. godeffroyi*. As a result, it is seen more often than its congener. Four individuals were collected at night while they were sleeping at the end of long branches, 2–3 m above the ground. In addition, one juvenile was caught in a bat net at night. Judging from the frequency of captures within a small area, this species probably occurs at fairly high densities. The species is vivid green but after capture changes rapidly to a dull brown.

Family Gekkonidae

Gehyra oceanica (Lesson, 1826) (SAMA R60228–29, UWZM H.23821)

This large (SVL ~ 80 mm) gecko has a wide distribution throughout the Indo-Pacific and is largely a human commensal. All individuals encountered during the 1999 survey were found at night on buildings within the Walindi Plantation. At Wanui, this arboreal gecko was common in trees on the drier ridges at Wanui camp. Several specimens were also seen in mist nets.

Gekko vittatus (Houttuyn), 1782 (UWZM H.23820)

One individual of this widespread, large gecko (SVL to at least 140 mm) (Fig. 23) was caught at night 1.5 m above the ground in a *Heliconia* plant at the Walindi plantation. Like the two previous taxa, this species seems to be closely associated with human habitations.

Hemidactylus frenatus Duméril and Bibron, 1836 (UWZM H.23838–41)

This small (SVL ~ 60 mm) widespread gecko was encountered in large numbers at night on illuminated house walls in the Walindi Plantation. The species was not seen at higher altitudes or in rainforest habitat. This lizard is a human commensal that has extended its range throughout the South Pacific region as the result of human activities.

Nactus sp. (SAMA R60231–34) (UWZM H.23842–44)

This was the only gecko commonly encountered in the rainforest. A medium-sized (to 65.5 mm SVL), nocturnal species that was frequently seen climbing on the buttress roots of large forest trees (Fig. 24). All individuals collected were foraging in vegetation less than 3 m high. This species was found both at low elevations at Walindi, as well as on drier ridges adjacent to Wanui camp. The systematics of this genus remains unresolved; it contains a mosaic of sexually (as in New Britain) and asexually reproducing (all female) island populations (Zug and Moon, 1995).

Family Scincidae

Emoia bismarckensis Brown, 1983 (SAMA R60219–220, UWZM H.23856–60)

This medium-sized skink (SVL to 72 mm) is known only from New Britain and New Ireland (Brown, 1983; 1991) (Fig. 25). The species is common in sunny patches in understorey of primary rainforest at altitudes between about 300 m asl at Wanui and 1,100 m asl in the Nakanai Mountains. This lizard was also frequently encountered in mixed foraging aggregations with *Sphenomorphus simus* and was common at Wanui Camp in sunny patches on the forest floor. The species is sexually dimorphic, with males easily recognized by their large heads. One female contained two eggs.

Emoia caeruleocauda (de Vis, 1892) (SAMA R60221–25)

A small (SVL to 54 mm), slender skink with a shiny dark brown dorsum that in males is offset by three parallel golden dorsal stripes (Fig. 26). The tail is of an iridescent turquoise colour. The species is fairly common in sunny patches formed in forest by tree-falls and landslides, as well as in secondary or disturbed vegetation close to human habitations, but is absent from closed-canopy habitats. This skink is active on the ground and in low vegetation. Males wave their conspicuous tail during activity. Found from sea level at Walindi Plantation and Silali village (at the base of the Nakanai Mountains) to ~ 1,300 m asl on the north slope of these mountains. The species was also abundant in sunny patches at Camp 1 and Wanui Camp on the south coast where they were active in vegetation between about 0.5 and 1.5 m high.

Emoia jakati (Kopstein, 1926) (UWZM H.23845–55, H.23891)

Probably the most common lizard in the areas surveyed during the 1999 survey, this skink was abundant in open, disturbed vegetation, such as gardens and plantations. This small (SVL to 53 mm) terrestrial species with chestnut-brown dorsum, rarely uses perches above the ground (Fig. 27). We encountered this species at various locations ranging from sea level (e.g., Silali village, the lower valley of the Ivule river and the Walindi Plantation) up to at least 500 m asl in the Nakanai Mountains.

Emoia kordoana (Meyer, 1874) (SAMA R60226–27)

Three specimens of this active arboreal species (SVL to 60 mm) were found in bushes in sunny patches inside primary forest at Wanui Camp. One lizard seen in the crown of a downed tree in the Nakanai Mountains (altitude ~ 900 m asl) is tentatively referred to this species.

Lamprolepis smaragdina (Lesson, 1826) (UWZM H.23823–26)

An attractive green skink (SVL < 98 mm) that is widespread across New Guinea, the Bismarcks, and the Solomon Islands, as well as many Wallacean islands (Fig. 28). It is one of the most common reptiles in villages, secondary vegetation and gardens where it occurs on tree trunks and in foliage of bushes and trees. The species was also found in the Nakanai Mountains and the Walindi area, at altitudes between 0–400 m asl. On the south side of New Britain one individual was found at Camp 1, and the species was abundant in trees in and around Sampun Village. All individuals seen or collected belong to the subspecies *L. s. smaragdina,* which is characterized by green colouration anteriorly and greyish colouration posteriorly.

Sphenomorphus wolfi (Sternfeld, 1918) (UWZM H.23827, H.23830–31)

This medium-sized (SVL to 77 mm) species, previously known as *S. maindroni*, is currently considered restricted to the Bismarck and Admiralty archipelagos (Mys, 1988) (Fig. 29). We encountered this skink in primary rainforest between 500 and 1,100 m altitude in the Nakanai Mountains, but Hediger (1934) also reports it from sea level. This species was usually found in forest leaf-litter under which it rapidly disappeared when threatened. Males have a striking orange belly and one female was carrying two eggs.

Sphenomorphus cf. *jobiensis* (Meyer, 1874) (SAMA R60249, UWZM H.23828–29, H.23832–34)

This is a moderately large (SVL up to 101 mm), crepuscular and nocturnal skink (Fig. 30). Because this species exhibits a great deal of variability in scalation and other morphological measurements (Donnellan and Aplin, 1989, Mys, 1988), the taxonomic identity of New Britain specimens remains uncertain. Most individuals were caught in pitfall traps or in snap-traps set to catch small mammals. The species lives on the forest floor and when disturbed, escapes with great speed into root masses, fallen logs or holes in the ground. One female had a single oviductal egg. This skink appears to occur at fairly high densities in primary rainforest both in the Nakanai Mountains and in the area around Walindi. It was also found at Wanui Camp where an animal was observed foraging on the forest floor at night. This species occurs from sea level to at least 1,100 m asl.

Sphenomorphus simus (Sauvage, 1879) (SAMA R60250–52, UWZM 23867–74)

A moderate-sized (SVL to 58 mm) species (previously known as *S. variegatus* and *S. stickeli*) that is widely distributed in mainland New Guinea (Fig. 31). This was probably the most abundant lizard at Nakanai Sites 1 and 2. In this mountainous environment, it was observed either motionless in a head-down position on tree trunks, or active in sunny forest floor patches. In contrast, at the lower elevation sites of Camp 1 and Wanui Camp, this species was most commonly encountered in the forest in the evening or under overcast conditions. It is possible that under cooler conditions at higher elevations, *S. simus* shifts to behaviour more typical of heliothermic taxa. In contrast to other *Sphenomorphus,* which are predominantly terrestrial or semi-fossorial, this species was more likely to perch slightly above the forest floor. Gravid females carried two oviductal eggs. *S. simus* inhabits forested habitats across a broad elevational zone from sea level to at least 1,100 m asl.

Family Varanidae

Varanus finschi Böhme, Horn & Ziegler 1994 (UWZM H.23883, H.23885, H.23889)

This is the largest species of lizard on New Britain (SVL of collected animals up to 370 mm but known to grow larger) and occurs in a wide range of forested or moderately disturbed habitats (Fig. 32). The New Britain population was only recently recognized as a species distinct from the more widespread *V. indicus* (Harvey and Barker, 1998). Monitor lizards and amethystine pythons are the top terrestrial predators in most areas of New Britain. Although these lizards appear to be relatively common in most habitats in New Britain, they seem to occur at particularly high densities close to the coast where they feed on crabs, reptiles, birds and even fish. The species tolerates at least some habitat disturbance; it was found in the Walindi Plantation, and a garden near rainforest edge at Walindi. Two individuals were trapped in a Sherman and a Conibear trap, respectively, within primary rainforest in the Nakanai Mountains. Occurs from sea-level to at least 1,100 m asl in the Nakanai Mountains.

Family Colubridae

Boiga irregularis (Merrem, 1802) (UWZM H.23886)

This slender, arboreal species reaching > 2 m in length, is widespread across Northern Australia, New Guinea, and the Bismarck and Solomon archipelagos. Several large dead specimens were seen on the coastal road between Kimbe Bay and the Walindi Plantation. This nocturnal snake is common in villages, gardens and other secondary vegetation where it feeds on rats and other small mammals. Its Mamusi language name 'Peng' refers to the species' explosive strike.

Dendrelaphis calligastra (Günther, 1867) (UWZM H.23877, H.23879, H.23881)

This slender species (to ~ 1.3 m length) is perhaps the most common snake in coconut plantations and other disturbed habitats on New Britain (Fig. 33). It is an arboreal and agile diurnal predator that feeds predominately on frogs and various reptiles (O'Shea, 1996). We collected one individual in the Nakanai Mountains (950 m asl.). All other specimens were brought in by locals from the vicinity of the Walindi Plantation.

Dendrelaphis punctulatus (Gray, 1827)

A single specimen of this widespread, moderately large (to ~ 1.6 m) species was killed by local villagers at Camp 1, on the south side of New Britain, in disturbed forest adjacent to the river. The specimen was in poor shape and was not collected.

Stegonotus heterurus (Boulenger, 1893) (SAMA R60253)

This is a moderately small (to ~ 1 m) terrestrial species. Two specimens of this Bismarck endemic were found on the drier ridges adjacent to Wanui Camp during the 2000 survey. One was hiding under a log on the forest floor during the day, while the second was climbing a tree trunk at night.

Stegonotus cf. *parvus* (UWZM H.23878)

The taxonomic status of the New Britain population is unclear (O'Shea, 1996). Two individuals (length to > 300 mm) of this species were caught in primary rainforest during the 1999 survey (Fig. 34). Both animals were found on the ground, one under a fallen log in the Nakanai Mountains, and the other, next to the Walindi River (~ 150 m asl), while foraging in the rain at night.

Tropidonophis sp.

Several specimens of an unidentified *Tropidonophis* were observed in the vicinity of Wanui Camp and on the trail between Wanui and Camp 1. We were unable to obtain any specimens of this fast-moving species.

Family Elapidae

Aspidomorphus muelleri (Schlegel, 1837) (UWZM H.23882)

This is the only species of poisonous snake on New Britain (O'Shea, 1996) (Fig. 35). Two specimens of this small (to ~ 600 mm) snake were collected in primary rainforest, one on the ridge seperating the Ivule and Sigole rivers (350 m asl) and one on the Willaumez Penninsula (150 m asl). Despite their great fear of snakes, the locals do not recognize this species as being particularly poisonous.

Family Boidae

Candoia aspera (Günther, 1877) (UWZM H.23887)

This is a short (to ~ 1 m) robust snake (Fig. 36). As its name implies, the New Guinea Ground Boa is generally found either on or close to the ground. Specimens collected during the 1999 expedition (one adult close to Nakanai Site 2 [1,100 m asl] and a juvenile at Willaumez) were caught on a low log and under stones, respectively. Examination of gut contents indicates that this species feeds frequently on rodents (Hediger, 1934). The specimen collected at Nakanai Site 2 had healed rodent bite marks on its back, possibility from a struggle between the snake and its rodent prey. All animals were caught in primary rainforest, but it is known to also occur in disturbed habitats such as plantations and gardens.

Candoia carinata tepedeleni Smith and Chiszar, 2001 (SAMA R60212)

One specimen of this small (to ~ 600 mm; Smith et al., 2001) widespread snake was encountered during the 2000 survey. It was collected from a small bush in the forest clearing at Camp 1.

Family Pythonidae

Morelia amethistina (Schneider, 1801) (UWZM H.23888, H.23880)

The largest snake species encountered, *M. amethistina* has been reported to reach lengths of 8.5 m (O'Shea, 1996). The New Britain population has been reported to be predominantly arboreal (Hediger, 1934), but the species also frequents gardens and other areas with disturbed vegetation. It is loathed and feared by local people along the north coast and on the Willaumez Penninsula. Amethystine pythons appear to be fairly common and several large dead individuals were seen on roads in a variety of lowland habitats. Two individuals were collected in primary rainforest, one on the ridge between Ivule and Sigole rivers (600 m asl) and one on Mt. Garbuna behind the Walindi Plantation (500 m asl).

Bothrochilus boa (Schlegel, 1837) (UWZM H.23884)

This attractive species (length to 1.7 m) is relatively common in primary rainforest and secondary vegetation (Fig. 37). Based on our observations, it appears to be terrestrial and strictly nocturnal. Ringed pythons were encountered in the Nakanai Mountains (300 m asl), and in the Walindi area (up to 250 m asl) where two animals were seen at night foraging in the forest and in a plantation garden.

Family Typhlopidae

Acutotyphlops subocularis (Waite, 1897) (SAMA R60208)

This sharp-snouted species reaches about 250 mm length and is known only from the Bismarcks and neighbouring Umboi Island (Wallach, 1995). A single specimen was found among dead logs collected for firewood at Wanui Camp.

Ramphotyphlops depressus (Peters, 1880) (SAMA R 60242)

A terrestrial blind-snake (to ~ 260 mm) known only from the Solomon Islands and islands to the north and east of mainland Papua New Guinea

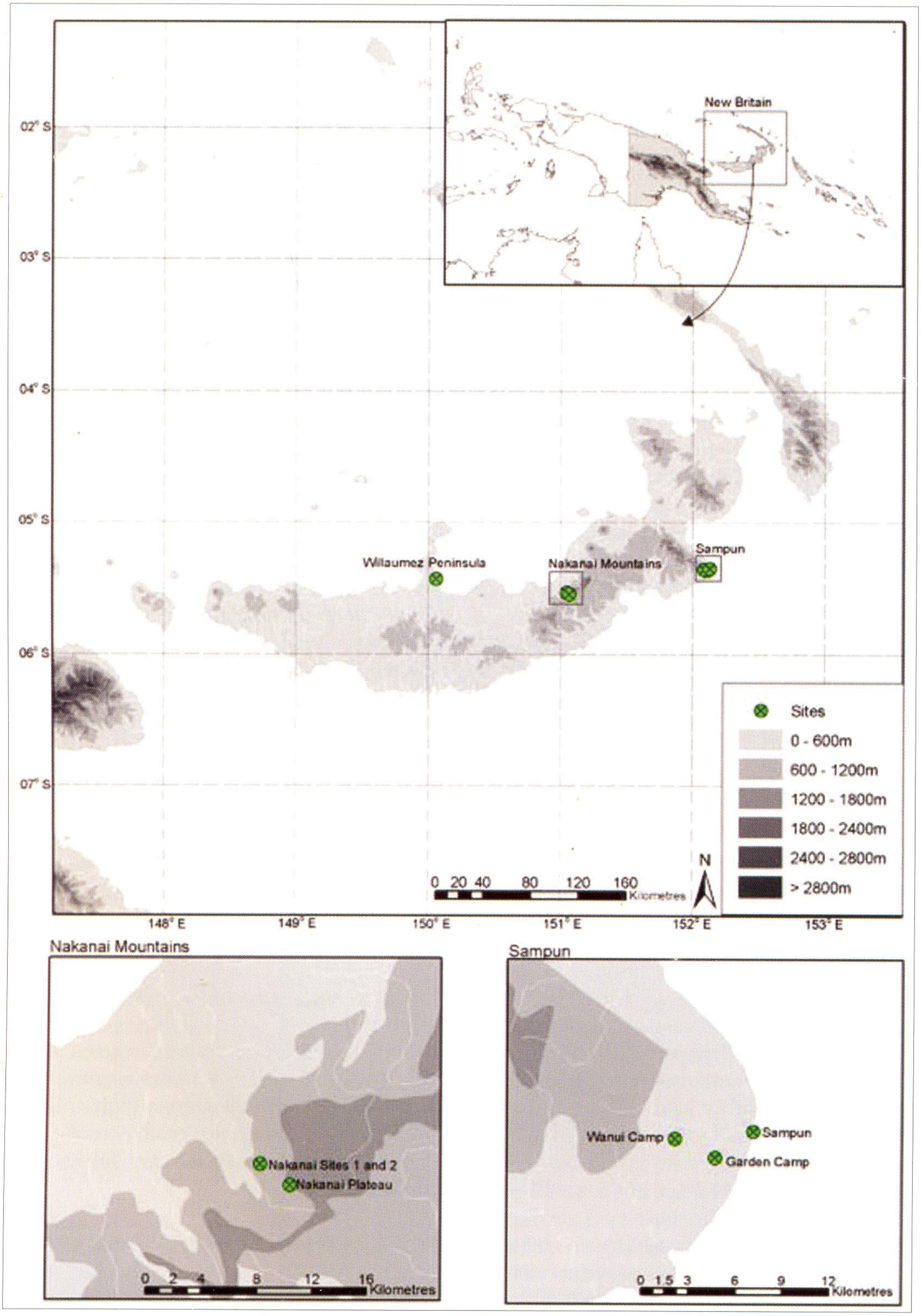

Figure 1. Map of New Britain Island showing locations of survey sites.

Figure 2. Confluence of the Ivule and Sigole Rivers in the northern foothills of the Nakanai Mountains; typical habitat for *Discodeles guppyi*.

Figure 3. Northern slopes of the Nakanai Mountains in the vicinity of Sites 1 and 2. Note lack of primary forest on the steepest slopes as the result of frequent landslides in this geologically active region.

Figure 4. Cloud forest on top of the Nakanai Plateau. Habitat of the newly described *Platymantis mamusiorum*. Note *Pandanus* (screw palm) which forms an important understorey component.

Figure 5. Cloud forest on the edge of the Nakanai Plateau. *Nothofagus* constitutes the predominant canopy tree.

Figure 6. Stream at Wanui on the south side of New Britain. Habitat for *Platymantis magna, P. adiastola, Discodeles guppyi* and *Rana novaebritanniae.*

Figure 7. Adult *Litoria infrafrenata* from Walindi.

Figure 8. *Oreophryne brachypus* from East New Britain.

Figure 9. *Platymantis boulengeri* from East New Britain. Most individuals from West New Britain have a more tan rather than purplish dorsal colour.

Figure 10. *Platymantis browni* from East New Britain.

Figure 11a. *Platymantis gilliardi*. An individual with broad brown dorsal band.

Figure 11b. *Platymantis gilliardi*. An individual lacking dorsal patterning. A third type of the species, with two longitudinal dorsal stripes (similar to Fig. 16) is not shown.

Figure 12. *Platymantis macrosceles* from Site 1. Individuals encountered in the field have brown dorsal patches not visible in this picture.

Figure 13. *Platymantis magna* from East New Britain.

Figure 14. *Platymantis mamusiorum* from the top of the Nakanai Plateau.

Figure 15. *Platymantis nexipus* from Site 2.

Figure 16. *Platymantis schmidti* – striped form from East New Britain.

Figure 17. *Platymantis* sp. A. from Site 1.

Figure 18. *Platymantis nakanaiorum* from the top of the Nakanai Plateau.

Figure 19. *Discodeles guppyi* from East New Britain.

Figure 20. *Rana daemeli* from East New Britain.

Figure 21. *Rana novaebritanniae* from East New Britain.

Figure 22. *Hypsilurus modestus* from East New Britain.

Figure 25. *Emoia bismarckensis* from Site 2.

Figure 23. *Gekko vittatus* from the Walindi Plantation.

Figure 26. *Emoia caeruleocauda* from East New Britain.

Figure 24. *Nactus* sp. from East New Britain.

Figure 27. *Emoia jakati* from the Walindi Plantation.

Figure 28. *Lamprolepis smaragdina* from the Willaumez Peninsula.

Figure 29. *Sphenomorphus wolfi* from Site 2.

Figure 30. *Sphenomorphus* cf. *jobiensis* from Site 1.

Figure 31. *Sphenomorphus simus* from Site 1.

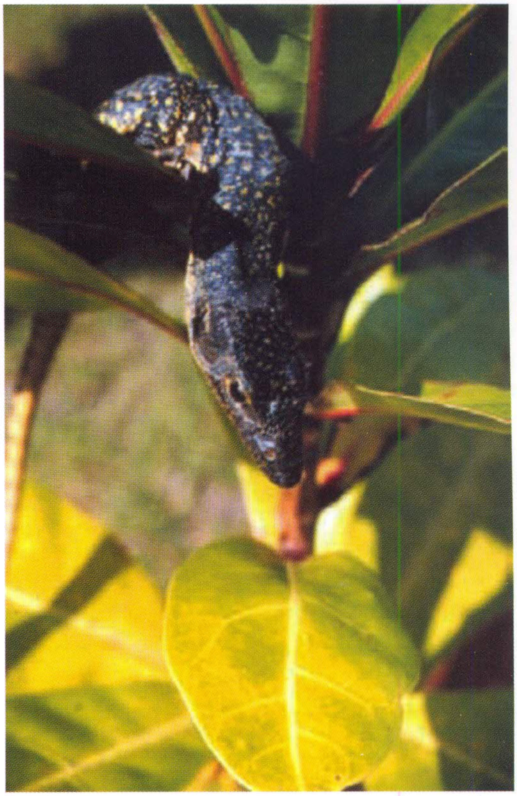

Figure 32. *Varanus finschi* from the Walindi Plantation.

Figure 33. *Dendrelaphis calligastra* from the Walindi Plantation.

Figure 34. *Stegonotus* cf. *parvus* from Site 1.

Figure 35. *Aspidomorphus muelleri* from the northern foothills of the Nakanai Mountains.

Figure 36. *Candoia aspera* from Site 2.

(O'Shea, 1996). The sole specimen was active at night on the forest floor at Camp 1.

Typhlops depressiceps Sternfeld, 1913 (UWZM H.23647)

One individual of this moderately large (to ~ 330 mm) species was collected in the primary rainforest next to the Walindi River at an elevation of ~ 150 m asl. This is the first record of this secretive species for New Britain (Foufopoulos, 2001). Its occurrence on the island was expected, however, given that it is widespread on the New Guinea mainland (O'Shea, 1996) and recently discovered on New Ireland (Allison and Bigilale, 2001). The sole specimen was collected inside a rotten log.

DISCUSSION

During the surveys reported here, we documented a total of 29 species of reptiles and 21 species of amphibians. In terms of species richness, New Britain is intermediate between the richer faunas of New Guinea to the west, and the relatively depauperate faunas of New Ireland and the Admiralty islands in the northeast (Allison, 1996). However, in terms of endemicity, the New Britain herpetofauna is of exceptional biological significance. The herpetofauna of the Bismarck Archipelago is a product of the complex geological history of the area (Allison, 1996; Taylor, 1979) and the environmental conditions and topographic relief present today on the islands. Some New Britain taxa, especially reptiles, are widespread throughout New Guinea and the eastern Pacific basin, while others are restricted to the Bismarck Sea. The first group includes several skinks in the genus *Emoia, Carlia,* and the gekkonid genera *Gehyra*, *Gekko* and *Hemidactylus* (Brown, 1991; Zug, 2004). These taxa occur on almost every major island group in Melanesia. A different pattern is exhibited by New Britain species in the genera *Platymantis* and *Discodeles*, which have distributions predominately limited to this island and only sometimes to neighbouring areas. All of the new frog species discovered on these two expeditions are known only from New Britain and some may have distributions restricted to the highlands of this island.

Figure 37. *Bothrochilus boa* juvenile from the northern foothills of the Nakanai Mountains.

A striking feature of the New Britain herpetofauna is the difference in levels of endemicity between reptiles and amphibians. Although the overall number of amphibians is much smaller (23 species) than reptiles (51 species), a majority of these amphibians are restricted either to New Britain (14/23, 61%) or the greater Bismarck Archipelago (18/23, 78%). In contrast, only a small fraction of the reptiles is endemic to New Britain (4/51, 7.8%) or to the Bismarck Archipelago (9/51, 17.6%). These differences are best explained by the different dispersal abilities of the two groups. Because of their permeable skin, amphibians are generally poor dispersers over seawater. In contrast, a number of reptile groups including skinks and geckos have excellent over-water dispersal abilities, sometimes aided by humans (Adler et al., 1995; Austin, 1999). The strait that separates New Britain from New Guinea has therefore presented a much greater barrier to dispersal for amphibians than for reptiles. The presence of many endemic amphibians on New Britain reflects the reduced gene flow from surrounding landmasses, and has probably been promoted by the island's large size, steep topography, and relative environmental stability. In contrast, neighbouring New Ireland, with a depauperate frog fauna and low endemism, appears to have been at least partially submerged in the recent past (Allison and Bigilale, 2001).

The second striking feature of the New Britain herpetofauna is that most frog genera that are widespread on nearby mainland New Guinea are absent or poorly represented on the island. In contrast, the ranid genus *Platymantis* has undergone an extensive adaptive radiation on the island and constitutes 61% (14/23) of amphibian species on the island. Mainland New Guinea harbors only six species of *Platymantis* (Zweifel, 1969; Menzies, 1976; Günther, 1999), all of them terrestrial forms. In New Britain, this genus includes at least a dozen terrestrial (e.g., *P. boulengeri*), scansorial (e.g., *P. macrosceles*) and arboreal (e.g., *P. nexipus*) forms. Platymantine ranids have diversified on New Britain into ecological niches that are occupied on mainland New Guinea by hylid and microhylid frog genera.

The unusual reproductive mode of the genus *Platymantis* may have helped them thrive in the peculiar environmental conditions of the Bismarck islands. Platymantine frogs lay large, yolk-rich eggs in moist areas away from water (Allison, 1993). As a result, they have become largely independent of surface water. Although both New Britain and New Ireland receive large amounts of rainfall, surface water in the upland regions is scarce because porous limestone substrates directly absorb any precipitation. Raised limestone regions pose a challenge to most amphibians that depend on free-standing water for reproduction, but appear to offer many ecological opportunities for platymantines which were the only taxa present there.

We found relatively little overlap between the herpetofaunas of the north and south sides of New Britain. A comparison between Walindi and Wanui, the two low elevation sites, reveals that while the same number of taxa (28) was encountered in both sites, only 13 (46%) of these were common. This is probably not indicative of different species communities on the two sites of the island, as the north and south slopes appear ecologically similar, but rather the spotty distribution of many taxa. Similar patterns of patchy distributions have been observed for other vertebrates on New Guinea (Diamond, 1986).

Altitudinal distributions.– The herpetofauna found at the highest elevations of New Britain is different from that encountered at the coast. We examined altitudinal patterns by dividing the island into elevational bands and counting the number of species occurring in each zone. Based on the amount of data at hand, the island was divided into three broad zones (0–500 m, 500–1,000 m, and 1,000–1,500+ m). Because reptiles and amphibians have different physiological requirements (Navas, 2003), distributional patterns were examined separately for each group. Moving from the lowest (0–500 m) to the intermediate (500–1,000 m), and then the highest (> 1,000–1,500 m) zone, amphibian species richness decreases from 15 to 10 and 10 species respectively, while for reptiles it drops from 27 to 15 and 11 species. These results mirror similar reductions in species richness with increasing elevation on the New Guinea mainland (Allison, 1982). At low elevations, there are substantially fewer species of amphibians than reptiles, but this relationship changes to near parity at the highest elevations. This can be probably best attributed to the cool, wet and almost perpetually overcast conditions at high elevations, which favour amphibians.

Endemicity, calculated as the percentage of species within an elevational zone that are endemic to New Britain or the Bismarck Archipelago, increases with altitude from 78% to 90% for amphibians but remains relatively unchanged (22% vs. 18%) for reptiles. However, because total diversity is higher in the lowlands, more island endemics still occur at low elevation sites.

Conservation recommendations.– New Britain has a rich and unique herpetofauna. Although some species can persist in disturbed habitats, many species depend primarily on mature tropical forest. Crocodiles, some snakes and *Discodeles* frogs are dependent on intact riparian ecosystems. The main danger for terrestrial and aquatic species is uncontrolled logging, and conversion of forests to oil palm and coconut plantations. Logging is currently occurring on a large scale and vast areas in the lowlands of the island have already been cleared. Many forests on New Britain were severely degraded when large-scale forest fires occurred following the 1997–98 ENSO (El Niño - Southern Oscillation) event. Once the forest is cleared, few species of reptiles and amphibians are able to persist, especially in oil-palm monocultures (see Appendix 2). None of the island endemics, with the possible exception of *Varanus finschi*, appear to be able to survive in heavily modified habitats. The impacts of soil erosion and river siltation on aquatic herpetofauna after forest conversion are poorly understood. Hunting for skins or meat may be an additional concern for crocodiles, monitor lizards and perhaps large *Discodeles* frogs. Nonetheless, recent hunting regulations appear to have had a positive effect on crocodile populations (Shannon Seeto, pers. com.).

Endemic species and other taxa of conservation interest can be found in all natural habitats and elevational zones of the island. Nevertheless, the habitats that are in need of the most urgent conservation attention are high altitude cloud forests (such as the unique relict *Nothofagus* forests on top of the Nakanai Plateau) and the coastal rainforests that are now being logged at an alarming rate. Given the spotty distribution of many species, preservation of all reptile and amphibian species will require the protection of large areas of primary forest. Hence successful conservation efforts need to focus on the protection of high quality (mature) forest at altitudes ranging from sea level to the highest peaks, while incorporating all habitats between coastal mangroves and high-altitude moss forest. The best approach will be to target regions with high levels of connectivity between coastal habitats and the highest elevations. Such continuous areas not only protect daily or seasonal altitudinal migrants but can best buffer local biodiversity from a changing global climate by allowing altitudinal shifts in a species' range.

ACKNOWLEDGEMENTS

We thank the PNG National Research Institute, the Department of Environment and Conservation, and the government of West New Britain Province, for issuing research, collection, and export permits necessary for this study. Financial support for JF's field work on New Britain was provided by the University of Wisconsin Natural History Museum Council, the Quixote Foundation, and Fauna and Flora International. Shannon Seeto (Mahonia na Dari/The Nature Conservancy), Peter Dam (European Union–IR-ECDP), and Max and Cecil Benjamin (Walindi Resort) provided crucial assistance on New Britain. We are particularly grateful to the people of Silali and Sulu villages (especially Lakoti and his son Phillip) for allowing us to work on their land and generously leading us in the field, and we thank Kenn Mondiai and Goldi for helping negotiate a collecting agreement with our hosts.

Philip Sionia, Thomas Tary, Paul Wanga, Alphonse Kul, Kenneth Molem, Friday, Bulisa, Iova, Kevin, Marcos, Kevo and Moses provided invaluable field assistance. George Allez, Nicky Anthony, Deanna Byrnes, and Mike Putnam helped organize collections and we received important advise on field logistics and conditions from Allen Allison, John Kirsch, Gregory Mayer, Pavel Drozd, Max Henderson (Pacific Heritage Foundation), Vojtech Novotny (Insect Ecology Project, Madang), Larry Orsak, and Debra Wright (WCS). In Port Moresby, we were aided by Frank Bonnacorso, Ilaiah Bigilale (National Museum of PNG), Greg Williams (NAQIA), James Menzies, Rose Singadan, and Paulus Kei (UPNG), Wep Kanawi and Peter Thomas (TNC). We also thank Tony Ives, John Kirsch, Frank Iwen, Holly McEntee (Univ. Wisconsin) for helpful comments and guidance. The Wanui survey was supported by Conservation International and ENBSEK, and we are particularly grateful to Maureeen Ewai of CI, and the people of Sampun Village, for their support.

For the loans of specimens, advice, and assistance with species identifications, we thank the following individuals and their respective institutions: Jens Vindum, Ron Crombie, Alan Leviton, Bob Drewes (CAS), Addison Wynn, George Zug (USNM), David Cannatella (TNHC), José Rosado, Van Wallach (MCZ), Glenn Shea (AMS), Linda Ford, Darrel Frost (AMNH), John Kirsch (UWZM), James Menzies, Rose Singadan (UPNG), Mark Hutchinson and Carolyn Secombe (SAMA), Allen Allison and Carla Kishinami (BPBM). Allen McIlwee produced the map. During preparation of this manuscript JF received support from the Cleveland–Dodge Foundation, Princeton Environmental Institute and the University of Michigan; SJR received support from the Violet Scott Estate, The Mark Mitchell Research Foundation and Conservation International.

LITERATURE CITED

ADLER, G. H., C. C. AUSTIN & R. DUDLEY. 1995. Dispersal and speciation of skinks among archipelagos in the tropical Pacific Ocean. Evolutionary Ecology 9:529–541.

AUSTIN, C. C. 1999. Lizards took express train to Polynesia. Nature, London 397:113–114.

ALLISON, A. 1982. Distribution and ecology of New Guinea lizards. Monographiae Biologicae 42:803–813.

____. 1993. Biodiversity and conservation of the fishes, amphibians and reptiles of Papua New Guinea. In: Papua New Guinea conservation needs assessment. Vol. 2. pp:157–225. B. M. Beehler (Ed). Biodiversity Support Program, Washington, D.C.

____. 1996. Zoogeography of amphibians and reptiles of New Guinea and the Pacific region. In: The origin and evolution of Pacific Island biotas, New Guinea to eastern Polynesia: patterns and processes. pp:407–436. A. Keast & S. E. Miller (Eds). SPB Academic Publishing, Amsterdam, Netherlands.

____ & I. BIGILALE. 2001. The herpetofauna of southern New Ireland. In: Southern New Ireland, Papua New Guinea: a biodiversity assessment. B. Beehler & L. Alonso (Ed). Conservation International: New Ireland RAP assessment. Washington, D.C.

____ & F. KRAUS. 2001. New species of *Platymantis* (Anura: Ranidae) from New Ireland. Copeia 2001:194–202.

BAILEY, P. 1976. Food of the marine toad, *Bufo marinus*, and six species of skink in a cacao plantation in New Britain, Papua New Guinea. Australian Wildlife Research 1976:185–188.

BEEHLER, B. M. (ED). 1993. Papua New Guinea conservation needs assessment. Volume 2. Biodiversity Support Program, Washington, D. C. 434 pp.

BROWN, R. M., FOUFOPOULOS, J. AND RICHARDS, S. 2006. New Species of *Platymantis* (Amphibia; Anura; Ranidae) from New Britain and redescription of the rare *Platymantis nexipus*. Copeia 2006(4): 674-695.

____, RICHARDS, S., SUKUMARAN, J., & FOUFOPOULOS, J. 2006. A new, morphologically cryptic species of forest frog (genus *Platymantis*) from New Britain Island, Bismarck Archipelago. Zootaxa 1334: 45-68

BROWN, W. C. 1983. A new species of *Emoia*, Sauria (Scincidae) from New Britain. Steenstrupia 8:317–324.

____. 1997. Biogeography of amphibians in the islands of the southwest Pacific. Proceedings of the California Academy of Sciences 50:21–38.

____. 1991. Lizards of the genus *Emoia* (Scincidae) with observations on their evolution and biogeography. Memoirs of the California Academy of Sciences 15:1–94.

____ & M. J. TYLER. 1968. Frogs of the genus *Platymantis* (Ranidae) from New Britain with descriptions of new species. Proceedings of the Biological Society of Washington 81:69–86.

____ & J. I. MENZIES. 1979. A new *Platymantis* (Anura: Ranidae) from New Ireland, with notes on the amphibians of the Bismarck Archipelago. Proceedings of the Biological Society of Washington 91:965–971.

DIAMOND, J. 1986. The design of a nature reserve system for Indonesian New Guinea. In: Conservation biology: the science of scarcity and diversity. pp:485–503. M. E. Soulé (Ed). Sinauer Associates, Sunderland, Massachusetts.

DONNELLAN, S. C. & K. P. APLIN. 1989. Resolution of cryptic species in the New Guinean lizard *Sphenomorphus jobiensis* (Scincidae) by electrophoresis. Copeia 1989:81–88.

FRODIN, D. G., & J. L. GRESSITT. 1982. Biological exploration of New Guinea. Monographiae Biologicae 42:759–801.

FOUFOPOULOS, J. 2001. *Typhlops depressiceps.*

Herpetological Review 32:61–62.

____ & **R. M. BROWN. 2004.** New frog of the genus *Platymantis* (Amphibia; Anura; Ranidae) from New Britain and redescription of the poorly known *Platymantis macrosceles*. Copeia 2004:825–841.

GÜNTHER, R. 1999. Morphological and bioacoustic characteristics of frogs of the genus *Platymantis* (Amphibia, Ranidae) in Irian Jaya, with descriptions of two new species. Mitteilungen aus dem Zoologischen Museum in Berlin 75:317–335.

HARVEY, M. B. & D. G. BARKER. 1998. A new species of blue-tailed monitor lizard (genus *Varanus*) from Halmahera island, Indonesia. Herpetologica 54:34–44.

HEDIGER, H. 1934. Beiträge zur Herpetologie und Zoogeographie Neu-Britanniens und einiger umliegenden Gebiete. Zoologische Jahrbücher. Abteilung für Systematik, Őkologie und Geographie der Tiere, Jena 65:441–582.

McDIARMID, R. W. 1994. Preparing amphibians as scientific specimens. In: Measuring and monitoring biological diversity: standard methods for amphibians. pp:289–297. W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L.-A. Hayek & M. S. Foster (Eds). Smithsonian Institution Press, Washington, D.C.

MENZIES, J. I. 1976. Handbook of common New Guinea frogs. Wau Ecology Institute, Wau, Papua New Guinea. viii + 75 pp.

_____. **1982a.** Systematics of *Platymantis papuensis* (Amphibia: Ranidae) and related species of the New Guinea region. British Journal of Herpetology 6:236–240.

_____. **1982b.** The voices of some male *Platymantis* species of the New Guinea region. British Journal of Herpetology 6:241–245.

_____. **1987.** A taxonomic revision of Papuan *Rana* (Amphibia: Ranidae). Australian Journal of Zoology 35:373–418.

MOODY, S. M. 1980. Phylogenetic and historical biogeographical relationships of the genera in the family Agamidae (Reptilia: Lacertilia). Unpublished Ph. D. Dissertation, University of Michigan, Ann Arbor. 390 pp.

MYS, B. 1988. The zoogeography of the scincid lizards from the north Papua New Guinea (Reptilia: Scincidae). I. The distribution of the species. Bulletin du Musée Royal d'Histoire Naturelle de Belgique 58:127–184.

NAVAS, C. A. 2003. Herpetological diversity along Andean elevational gradients: links with physiological ecology and evolutionary physiology. Comparative Biochemistry and Physiology A 133:469–485.

O'SHEA, M. 1996. A guide to the snakes of Papua New Guinea. Independent Publishing, Independent Group Pty Ltd, Port Moresby. xii + 239 pp.

SHEA, G. M., & A. E. GREER. 1999. Two senior synonyms and a name change for the New Guinea skink *Sphenomorphus stickeli* (Loveridge, 1948). Journal of Herpetology 33:136–141.

TAYLOR, B. 1979. Bismarck Sea: evolution of a back-arc basin. Geology 7:171–174.

TYLER, M. J. 1967. Microhylid frogs of New Britain. Transactions of the Royal Society of South Australia 91:187–190.

_____. **1968.** Papuan hylid frogs of the genus *Hyla*. Zoologische Verhandelingen 96:3–20.

WALLACH, V. 1995. A new genus for the *Ramphotyphlops subocularis* species group (Serpentes: Typhlopidae), with description of a new species. Asiatic Herpetological Research 6:132–150.

WERNER, F. 1900. Die Reptilien- und Batrachierfauna des Bismarck-Archipels. Mitteilungen aus dem Zoologischen Museum in Berlin 1:1–132.

ZUG, G. R. 2004. Systematics of the *Carlia "fusca"* lizards (Squamata: Scincidae) of New Guinea and nearby islands. Bishop Museum Bulletin of Zoology 5:1–84.

____ & **B. R. MOON. 1995.** Systematics of the Pacific slender-toed geckos, *Nactus pelagicus* complex: Oceania, Vanuatu, and Solomon Islands populations. Herpetologica 51:77–90.

ZWEIFEL, R. G. 1960. Results of the 1958–1959 Gilliard New Britain Expedition. 3. Notes on the frogs of New Britain. American Museum Novitates 2023:1–27.

_____. **1966.** A new lizard of the genus *Tribolonotus* (Scincidae) from New Britain. American Museum Novitates 2264:1–12.

_____. **1969.** Frogs of the genus *Platymantis* (Ranidae) in New Guinea, with the description of a new species. American Museum Novitates 2374:1–19.

_____. **1975.** Two new frogs of the genus *Platymantis* from New Britain. American Museum

APPENDIX I

Amphibian and reptile taxa known from New Britain with collection localities. The last three columns contain names in three local languages (Mamusi and Ata from the Nakanai sites, Bakovi from Walindi). Each species is accompanied by distributional information: *W*: Widespread throughout the general New Guinea Region, *BIS*: Restricted to the Bismarck Archipelago in general, *NB*: Distribution restricted to New Britain Island. *An unidentified *Tropidonophis* was observerd at Wanui; Xa Collected only on top (> 1,300 m) of the Nakanai Plateau; Xb Collected only at low elevations (< 500 m) in the Nakanai Mountains; X^ Observed only; no collected specimen.

Species	Walindi	Nakanai	Wanui	Mamusi name	Ata name	Bakovi name
AMPHIBIANS						
Bufonidae						
Bufo marinus (W)	X	X^	X	–	–	–
Hylidae						
Litoria infrafrenata (W)	X				Karu-karu	Búro
Litoria thesaurensis (W)						
Litoria cf. *bicolor* (NB)	X^					
Microhylidae						
Austrochaperina novaebritanniae (NB)			X			
Oreophryne brachypus (NB)	X		X			
Ranidae						
Platymantis akarithyma (NB)			X			
Platymantis boulengeri (NB)	X	X	X	Mi-kána-pája moing	Kole-kolei, Kole-kolu-lega	Pépe (adults: Pugonaru)
Platymantis browni (BIS)			X			
Platymantis gilliardi/mimica (BIS/NB)		X		Savala-é (belly of rat)	Ko-úlo	
Platymantis macrosceles (NB)		X				
Platymantis magna (BIS)			X			
Platymantis mamusiorum (NB)		Xa		Gureng-gureng		
Platymantis nexipus (NB)		X	X	Peve-vili-puna	Vae-so-laólu	
Platymantis rhipiphalca (NB)		X (?)				
Platymantis schmidti (BIS)	X	X	X	Tájo-tájo, Peve-mapúna (striped form)	Tájo-tájo, Vóriko-so	Pájo (*Platymantis* in general)
Platymantis adiastola (NB)			X			
Platymantis sp. A. (NB)		X				
Platymantis nakanaiorum. (NB)		Xa		Momólo-kúna (Momólo = *Pandanus palm*)		

Discodeles guppyi (W)	X	Xb	X	Pe-we	Wáe	Póko-na-náru
Rana daemeli (W)	X^		X^			
Rana novaebritanniae (NB)	X	X	X	Peve-miana	Wáe	
REPTILES						
Crocodylidae						
Crocodylus porosus (W)						
Agamidae						
Hypsilurus godeffroyi (W)	X			Tuje	Tuje-mana	Mii-jo
Hypsilurus modestus (W)	X		X	Kuru-poi		Aréga-béne (man who climbs old tree)
Gekkonidae						
Hemidactylus frenatus (W)	X					Káva-padóle (for all peridomestic geckos)
Lepidodactylus guppyi (W)						
Lepidodactylus lugubris (W)						
Gehyra mutilata (W)						
Gehyra oceanica (W)	X		X			Kapore
Gekko vittatus (W)	X					
Nactus sp. (W)	X		X			
Pygopodidae						
Lialis jicari (W)						
Scincidae						
Carlia mysi (W)						
Cryptoblepharus poecilopleurus (W)						
Emoia atrocostata (W)						
Emoia caeruleocauda/impar (W/W)	X	X	X	Má-lesang	Lága-vále	
Emoia cyanura (W)						
Emoia cyanogaster (W)						
Emoia bismarckensis (BIS)		X	X	´Ile-via	Tapale-ávu, Sinaunaja	
Emoia jakati (W)	X	Xb				

Emoia kordoana (W)		X^	X			
Eugongylus albofasciolatus (W)						
Eugongylus rufescens (W)						
Lamprolepis smaragdina (W)	X	Xb	X	Sakendrang	Bólo-lili	Káva
Lipinia noctua (W)						
Sphenomorphus wolfi (BIS)		X		Kana	´Auluao	
Sphenomorphus cf. *jobiensis* (W)	X	X	X	Soápe, Kaána (probably all *Sphenomorphus/Eugongylus* taxa)	Valu-luga, ´Aa-ulu-aü (enemy of the dog)	Lúva
Sphenomorphus pratti (W)						
Sphenomorphus simus (W)		X	X	Má-lesang	Sá-ape	
Sphenomorphus solomonis (W)						
Sphenomorphus tanneri (W)						
Tiliqua gigas (W)						
Tribolonotus annectens (NB)						
Varanidae						
Varanus finschi (W)	X	X				Tabéle-báko (two tongues)
Colubridae						
Boiga irregularis (W)	X			Peng (explosive attack)	Heli	Mavíta-bira
Dendrelaphis calligastra (W)	X	X		Kala-toto-vi-nono (it cures boils)		Máta-rea
Dendrelaphis punctulatus (W)			X			
Stegonotus cf. *parvus* (NB)	X	X		Síla-bandung	Silanga-vevéni	Katona
Stegonotus heterurus (BIS)			X			
Tropidonophis dahlii (NB)			*			
Tropidonophis hypomelas (BIS)			*			
Acrochordidae						
Acrochordus granulatus (W)						
Elapidae						
Aspidomorphus mulleri (W)	X	Xb				
Boidae						

Candoia aspera (W)	X	X		Korona-kena, (short body only) Sipu-mana (dusky skin)	Balalo-kú (lazy man)	Rogo
Candoia carinata (W)			X			
Pythonidae						
Morelia amethistina (W)	X^	X		Kai-matana, Yó-ung, (big snake) Kasove (for black-specimens)	Asojió, (eye like the sun) Yaulu	Pate (python in general)
Botrochilus boa (BIS)	X	Xb		Kiwone-ra (lady snake)	Mi-pakisi (jump fast)	Mápa-káto
Typhlopidae						
Acutotyplops subocularis (BIS)			X			
Typhlops depressiceps (W)	X			Saa-iliong (all Typhlopid species)	Laa-sile (all Typhlopid species)	Kambe (all Typhlopid species)
Ramphotyphlops braminus (W)						
Ramphotyphlops depressus (W)			X			

Novitates 2582:1–7.

____. **2000.** Partition of the Australopapuan microhylid genus *Sphenophryne* with descriptions of new species. Bulletin of the American Museum of Natural History 253:1–130

____ **& M. J. TYLER. 1982.** Amphibia of New Guinea. Monographiae Biologicae 42:759–801.

Received: 15 June 2005.
Accepted: 29 November 2005.

NOTE ADDED IN PROOF:

Manthey and Denzer (2006; Hamadryad 30: 1-40) have argued that the correct name for the lizard referred to here as *Hypsilurus godeffroyi* is *Hypsilurus longii* (Macleay, 1877).

Manthey, U. & W. Denzer. 2006. A revision of the Melanesian - Australian angle head lizards of the genus *Hypsilurus* (Sauria: Agamidae: Amphibolurinae) with description of four new species and one new subspecies Hamadryad 30:1-40.

Kraus and Allison (2007) recently described two new fossorial species of Platymantis from New Britain:

FRED KRAUS & A. ALLISON. 2007. Two new species of *Platymantis* (Anura: Ranidae) from New Britain Zootaxa 1485: 13-32.

APPENDIX II

Reptiles and amphibians documented from disturbed habitats such as villages, gardens and plantations. With the exception of *Platymantis schmidti* and the monitor lizard *Varanus finschi,* none of the island endemics appear to be able to persist in heavily modified habitats. This list is not complete as the herpetofauna of disturbed habitats also depends on the history of use of the particular area and on the proximity to other habitats such as primary rainforest. (?): regular occurrence in modified habitats is unclear.

Frogs
- *Bufo marinus*
- *Litoria infrafrenata*
- *Platymantis schmidti* (?)

Lizards
- *Gehyra oceanica*
- *Gehyra mutilata*
- *Gekko vittatus*
- *Hemidactylus frenatus*
- *Lepidodactylus lugubris*
- *Lepidodactylus guppyi*
- *Carlia mysi*
- *Emoia jakati*
- *Emoia cyanura / impar*
- *Lamprolepis smaragdina*
- *Sphenomorphus solomonis* (?)
- *Varanus finschi* (?)

Snakes
- *Boiga irregularis*
- *Dendrelaphis calligastra*
- *Morelia amethistina* (?)
- *Ramphotyphlops braminus* (?)

Hamadryad Vol. 31, No. 2, pp. 202 – 211, 2007.

NOTES ON THE OCCURRENCE, NATURAL HISTORY, AND CONSERVATION STATUS OF TURTLES IN CENTRAL RAKHINE (ARAKAN) STATE, MYANMAR

Steven G. Platt[1,3], Kalyar[1], Win Ko Ko[1], Khin Myo Myo[1],
Lay Lay Khaing[1] and Thomas R. Rainwater[2]

[1]Wildlife Conservation Society, Bldg. C-1, Aye Yeik Mon 1st Street, Yadanamon Housing Ave.,
Hlaing Township, Yangon, Myanmar.

[2]The Institute of Environmental and Human Health, Department of Environmental Toxicology,
Texas Tech University, P.O. Box 764, Jefferson, Texas, 75657, U. S. A.

[3]Present address: Department of Biology, P.O. Box C-64, Sul Ross State University,
Alpine, Texas 79832, U.S.A.
Email: sgplatt@gmail.com

(with five text-figures)

ABSTRACT.– We investigated the occurrence and conservation status of turtles in central Rakhine State, Myanmar during January and February 2000. During this survey, we verified the occurrence of six species of chelonians (*Amyda cartilaginea, Cyclemys dentata, Heosemys depressa, Indotestudo elongata, Manouria emys,* and *Eretmochelys imbricata*) and received reliable reports of three others (*Batagur baska, Chelonia mydas, Lepidochelys olivacea*). Turtles have always been harvested as a subsistence resource by villagers using a variety of techniques, including trained dogs, fire hunting, and traps. However, recent demand from wildlife markets in southern China has commercialized this harvest, and we found commercial exploitation widespread in central Rakhine State during our investigation. While some species remain common (e.g., *I. elongata, C. dentata*), current harvest levels are probably unsustainable making future population declines of most species likely. Moreover, a significant number of marine turtles drown in fishing nets each year and eggs are collected for sale in local markets.

KEY WORDS.– Turtles, Arakan Yoma Hills, Rakhine State, Myanmar, conservation, *Amyda cartilaginea*, *Batagur baska*, *Cyclemys dentata*, *Indotestudo elongata*, *Manouria emys*, marine turtles.

INTRODUCTION

Rakhine (formerly known as "Arakan") State in western Myanmar is one of the most rugged and sparsely populated regions in mainland Southeast Asia (Salter, 1983a). Surprisingly, little is known about the biodiversity of this remote region, and most of the available reports are over 50 years old. Colonial era big game hunters and administrators (often the same individuals) provide anecdotal descriptions of charismatic mammals (e.g., Pollock and Thom, 1900; Thom, 1933, 1934; Marshall, 1947) and avifauna (Hopwood, 1912; Kinnear, 1910), and British Officers serving in World War II published reports on large mammals (Christison, 1945), birds (Christison et al., 1946), and butterflies (Gladman, 1946; Emmet, 1948). In contrast to other taxa, little information is available on the reptiles of Rahkine State, and in particular, virtually nothing is known regarding the chelonians of this region. The few specimens of Arakan forest turtle (*Heosemys depressa*) collected prior to 1990 are believed to have originated in Rakhine State, although specific locality data are unavailable (Iverson and McCord, 1997). However, the occurrence of other species is largely speculative owing to a paucity of museum specimens (Iverson, 1992) and lack of detailed field observations from the region

(Platt, 2000). It should be noted that this situation is not unique to Rakhine State for despite high levels of endemism (23 species; 6 endemic), the chelonian fauna of Myanmar remains among the least known in Asia (Kuchling, 1995; van Dijk, 1997; Platt et al., 2000). The lack of even basic information is lamentable because accurate distributional data are an essential prerequisite for conservation (Dodd and Franz, 1993; Oliver and Beattie, 1993; Stuart and Thorbjarnarson, 2003). Here we present the results of an investigation into the chelonian biodiversity of central Rakhine State, provide natural history observations, describe exploitation of chelonians by indigenous people, and comment on the sustainability of this harvest.

STUDY AREA AND METHODS

Rakhine State encompasses much of the Arakan Yoma Hill range, which extends for 500 km along the western coast of Myanmar (Fig. 1), and represents a southern extension of the Himalayas (Henderson et al., 1971; Salter, 1983a). These hills (Fig. 2) consist of parallel north-south ridges separated by streams flowing within restricted valleys (Stamp, 1930; Henderson et al., 1971). Maximum elevation ranges from 915 to 1,150 m, while valley bottoms are often less than 100 m above sea level; thus a wide range of slope, aspect, and elevational conditions often exist within a small area (Salter, 1983a). A narrow alluvial belt occurs along the coast (Henderson et al., 1971). Mean annual precipitation ranges from 4,500—5,300 mm with a pronounced wet season extending from early June to late October (Smythies, 1953).

Table 1. Geographic coordinates of localities mentioned in the text.

Locality	Latitude (N)	Longitude (E)
Kyaukphyu	19° 26.16’	93° 32.65’
Mae Village	19° 20.64’	94° 08.33’
Mae Sadwe Village	19° 20.64’	94° 08.33’
Min Pyin Village	19° 17.26’	93° 31.69’
Min Tone Village	19° 20.97’	94° 44.31’
Padan Village	19° 58.60’	94° 32.63’
Pyaung Chaung	19° 32.64’	94° 06.70’
Pyin Chaung	19° 22.78’	94° 07.66’
Pyin Won	19° 20.94’	94° 07.73’
Ramree Town	19° 05.57’	93° 51.72’
Zin Chaung Village	19° 08.76’	93° 38.11’

The evergreen forests of the Arakan Yoma Hills (Fig. 3) have been variously described as rainforest (de Terra, 1944), semi-evergreen rainforest (Salter, 1983a), tropical semi-evergreen forest (Champion, 1936), and evergreen tropical forest (Stamp, 1924, 1930); however, their floristic composition remains poorly documented (Salter, 1983a). Extensive tracts of bamboo (*Melocanna bambusoides* Trin.) occur throughout the region, developing in response to anthropogenic disturbances such as shifting cultivation, fire, or both (Stamp, 1924, 1930; de Terra, 1944: Platt, 2000). Small tracts of deciduous forest are restricted to porous soils in the foothills of the coastal alluvial belt. This habitat is rare on the western side of the Arakan Yoma Hills and characterized by vegetation typically found in the dry zone of central Myanmar (Stamp, 1930; de Terra, 1944). The coastal alluvial belt has largely been converted to permanent flooded rice agriculture (Stamp, 1930). Rakhine State is sparsely populated by ethnic Chin who grow upland rice under a system of shifting or *taungya* cultivation; hillside vegetation is cleared, burned, and planted with rice. Fields are then cultivated for several seasons before being left fallow for up to 20 years, after which the cycle begins anew (Platt, 2000).

Two large islands occur along the coast of central Rakhine State: Ramree and Man Aung (formerly known as Cheduba) Islands (Fig. 1). Ramree Island (ca. 80 × 30 km) is separated from the mainland by a network of estuarine rivers and extensive mangrove swamps (Platt et al., 2001a). Much of the island is under cultivation; other areas support secondary vegetation and bamboo (*Cephalostachyum pergracile* Munro.) scrub (Fig. 4; Platt, 2000). The principal population centers are Kyaukphyu in the north and Ramree Town in the south. Man Aung Island (ca. 32 km × 20 km) is located approximately 10 km west of Ramree Island and separated from the latter by the Cheduba Strait. Man Aung is the principal population center. We are unaware of any reports describing the vegetation of this island. Rakhine State has few roads and travel by foreigners has been prohibited by governmental authorities for many years.

We conducted fieldwork in Rakhine State from 21 January to 16 February 2000 within the watersheds of An and Mae Chaungs, and in the vicinity of Padan Village, on the western and eastern slopes respectively, of the Arakan Yoma Hills (Fig. 1). Additionally we visited Kyauphyu and Ramree Town on Ramree Island. During this period we interviewed hunters, farmers, and village-level wildlife traders regarding the local occurrence of turtles, collecting methods, levels of exploitation, and general knowledge of turtles. Such individuals are typically an excellent source of information on local chelonians (Thirakhupt and van Dijk, 1994; Platt et al., 2004). Transcripts of all interviews are contained in fieldnotes archived in the Campbell Museum, Clemson University, Clemson, South Carolina, USA. Available specimens were examined, measured, and photographed. Vouchers were obtained if possible and deposited in the natural history collection of the Wildlife Conservation Society Myanmar Program (Yangon). We also accompanied hunters to specific sites where turtles were captured or observed to obtain information on habitat and search for additional specimens. Place names are in accordance with 1927 Survey of India topographical maps, although local names are given for villages not labeled; geographic coordinates were determined with a Garmin GPS 48 (Table 1). Straight-line carapace length (CL) is presented as mean ± 1 SD.

RESULTS AND DISCUSSION

We verified the occurrence of six species of chelonians (*Amyda cartilaginea, Cyclemys dentata, Heosemys depressa, Indotestudo elongata, Manouria emys*, and *Eretmochelys imbricata*) and received reliable reports of three other species (*Batagur baska, Chelonia mydas, Lepidochelys olivacea*) during this survey. An account for each species except *Heosemys depressa* is presented below. Our findings with regards to the latter are discussed elsewhere (Robbins and Platt, 2001; Platt et al., 2003a).

Testudinidae

Indotestudo elongata (Blyth, 1853).- We examined 28 *I. elongata* (11 living tortoises and 17 shells) at various sites in the Arakan Yoma Hills. Additionally, villagers indicate that *I. elongata* is present on Ramree Island, although we were unable to verify its occurrence there. Our sample of shells included three complete specimens, seven carapaces lacking a plastron, and seven plastrons without a carapace. For the latter we used plastron length (PL in mm) to estimate CL with the equation CL = 1.37(PL) – 16.6 ($r^2 = 0.97$; $p<0.001$; Platt et al., unpubl. data). The mean CL of our sample was then calculated as 234 ± 44 mm (range = 134 to 295 mm; $n = 28$). Our sample was dominated by larger tortoises with lesser numbers of intermediate and small specimens (Fig. 5). Males (CL = 244 ± 35 mm; range = 190 to 295 mm; $n = 8$) were larger than females (CL = 221 ± 54 mm; range = 134 to 285 mm; $n = 12$), but our small sample size precluded statistical comparisons.

Hunters employ a variety of techniques to capture *I. elongata*. Foremost is the use of dogs to locate tortoises. This is an extremely effective method as dogs are much more efficient than humans at finding terrestrial chelonians (Platt et al., 2001b, 2003b). Tortoises are also taken during the late dry season (March – May) when hunters burn bamboo forest. Fires are ignited along ridgelines and burn slowly downslope; tortoises moving away from the flames are intercepted by waiting hunters. Additional tortoises are taken opportunistically by villagers while engaged in the collection of forest products or clearing *taungya* fields. During the wet season villagers seek *I. elongata* in bamboo forest where it is often found feeding on mushrooms. Large numbers of *I. elongata* are apparently being collected; one hunter stated that during the early wet season (June and July) it is possible to find one tortoise/hunter/day, hunters in Pyin Won Village reportedly collected 60 tortoises during an eight day period in 1999, and others reported an annual harvest of 50 to 300 tortoises.

Indotestudo elongata is subject to intense exploitation in central Rakhine owing to the relatively high prices paid by village-level wildlife traders for living tortoises, plastrons, and to a lesser extent, carapaces. Indeed, hunters regard *I. elongata* as the most commercially valuable chelonian in the region. In addition, *I. elongata* is heavily utilized as a food source by local villagers. All size classes of *I. elongata* are

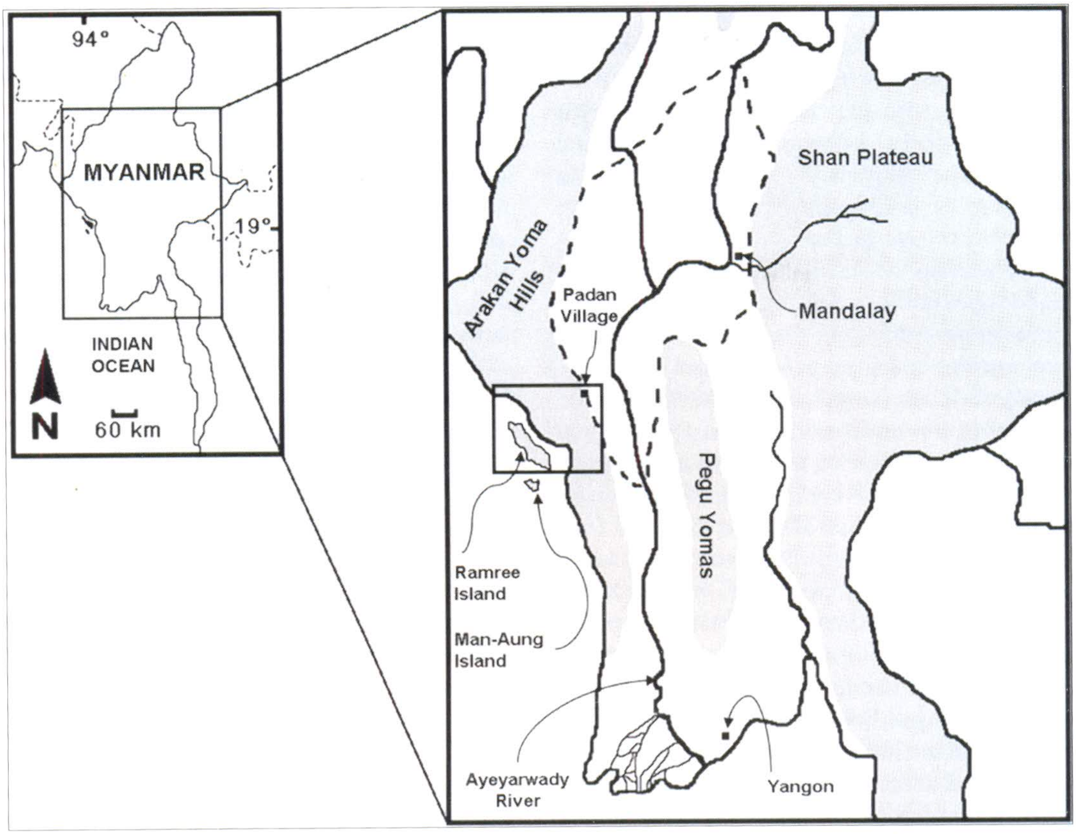

Figure 1. Map of Myanmar. Box encompasses general area surveyed during January – February 2000. Principal hill and mountain ranges are indicated by shading. Dashed line denotes approximate extent of central dry zone.

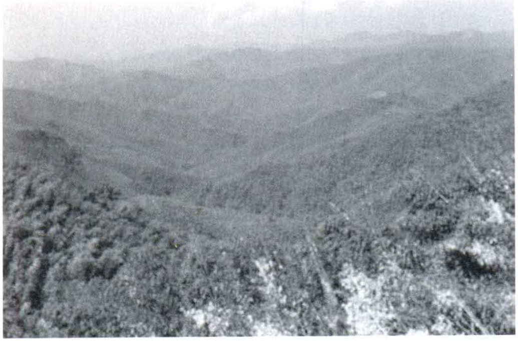

Figure 2. Rugged topography of the Arakan Yoma Hill range west of Padan Village. Extensive bamboo (*Melocanna bambusoides* Trin.) brakes and scattered evergreen forest on slopes. Maximum elevation in this region is approximately 1100 m. Haze in the photograph is due to smoke from fires of slash-and-burn agriculturalists.

harvested for both commercial and subsistence purposes, including small juveniles.

Despite intense hunting pressure, hunters contend that *I. elongata* remains common and can still be found in close proximity to villages. The large number of tortoises that are readily collected is suggestive of a population that remains relatively unexploited. Furthermore, the mean CL of tortoises in central Rakhine (CL = 234 ± 44 mm) is significantly larger than that of tortoises from a heavily exploited and declining population in Shwe Settaw Wildlife Sanctuary, Myanmar (CL = 71 ± 42 mm; Platt et al., 2001b) (ANOVA; F = 150.2; df = 1, 69; p <0.001). Moreover, a comparison of the size distribution from the two areas indicates that the Shwe Settaw population is dominated by intermediate size tortoises with larger animals being notably absent (Fig. 5). In contrast, large tortoises are well represented in our sample from central Rakhine. Similarly, Close and Seigel (1997) found that the mean CL of *Trachemys scripta elegans* from protected populations was significantly larger than in exploited populations, and van Dijk (1993) noted that the carapace length of *I. elongata* in a heavily exploited population near Mandalay never exceeded 25 cm.

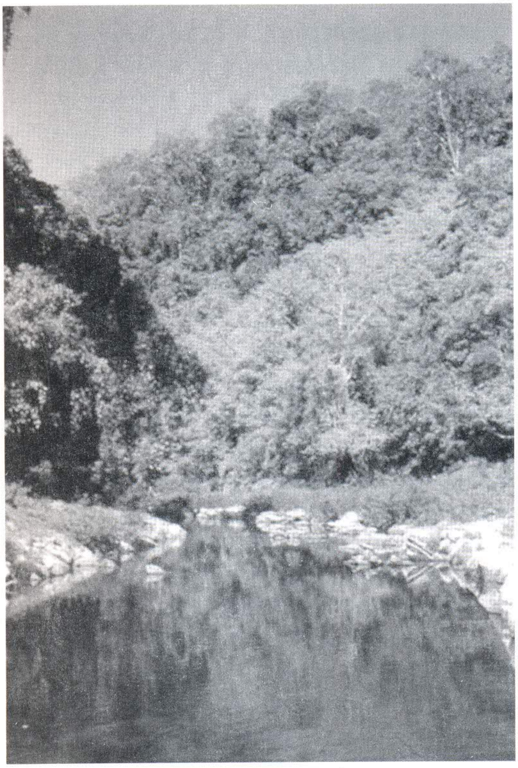

Figure 3. Vegetation along Pyaung Chaung in the Arakan Yoma Hills. Note evergreen forest on upper slope and ridge, and bamboo brake on lower slope. Tortoises (*Indotestudo elongata* and *Manouria emys*) occur on slopes and *Cyclemys dentata* is found in the river.

Figure 4. Open bamboo (*Cephalostachyum pergracile* Munro.) scrub that covers much of Ramree Island. *Indotestudo elongata* reportedly occurs in this habitat.

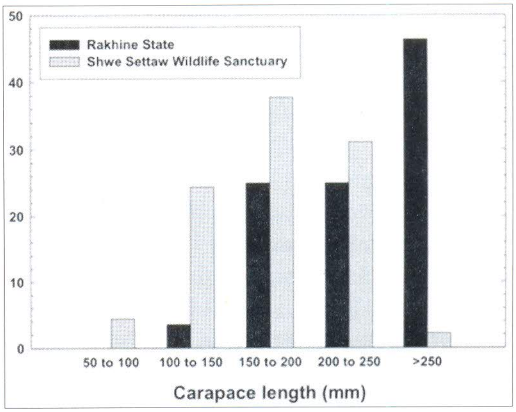

Figure 5. A comparison of the size distribution (carapace length in mm) of *Indotestudo elongata* from a relatively unexploited population in the Arakan Yoma Hills (n = 28), and a heavily exploited and declining population in Shwe Settaw Wildlife Sanctuary (n = 45). Shwe Settaw data from Platt et al. (2001b).

We attribute the continued abundance of *I. elongata* in central Rakhine to several factors. First, although tortoises have long been harvested for local consumption, other wildlife resources were abundant and tortoise meat comprised only a small portion of a varied diet. Second and perhaps most importantly, few people live in central Rakhine, resulting in a subsistence harvest that was relatively minor on a regional scale. Finally, the current commercially driven harvest is a relatively recent phenomenon (see Conclusion), and it is likely that significant negative impacts are simply not yet obvious.

Manouria emys (Schlegel and Müller, 1844).– We examined three carapaces (CL = 341, 499, and 568 mm) and a single plastron (PL = 350 mm) from four adult *Manouria emys* in Mae and Padan Villages, respectively. These tortoises were collected locally and according to hunters, occur in evergreen and bamboo forests. *Manouria emys* has also been found in *indaing* forest on the eastern side of the Arakan Yoma Hills where local informants regard it as extremely rare due to intense hunting pressure (Platt et al., 2001c). Collectively these records complement an earlier report by Theobald (1876) of *M. emys* in Rakhine State, and represent the only recent observations from western Myanmar.

Our interview data suggest that most *M. emys* are captured by hunters while searching for *I. elongata* with dogs; others are opportunistically taken by villagers collecting forest products. The large body size of *M. emys* renders it particularly vulnerable to hunters who reported capturing from one to 10 of these tortoises annually. All size classes are harvested, including small juveniles. *Manouria emys* meat is consumed locally and plastrons are sold to wildlife traders. However, demand is not particularly high among traders, and hunters receive less for *M. emys* plastrons than for those of *I. elongata*. Regardless, *M. emys* is harvested whenever encountered resulting in intense exploitation pressure on the population remaining in central Rakhine State.

Geoemydidae

Batagur baska (Gray, 1831).- Large numbers of *Batagur baska* formerly nested on offshore islands at the mouth of the Ayeyarwady River (Maxwell, 1911), but this population is no longer extant and verified records from elsewhere in Myanmar are lacking (Thorbjarnarson et al., 2000). Interestingly, villagers told Salter (1983b) that large river turtles occasionally nest on sandbanks along Tanlwe Chaung in central Rakhine State. Although an adequate description of this species could not be obtained, Salter (1983b) speculated that these reports referred to *B. baska*. Likewise, we received reports of a large hard-shelled turtle inhabiting estuaries in central Rakhine. One hunter in Pyin Chaung stated that he encountered "nine or ten" large turtles in mangrove creeks over the last 10 years. Another person reportedly recovered about 25 eggs from a dead female, each approximately the size and general shape of a domestic duck egg, a description somewhat consistent with the pliable-shelled eggs of *B. baska*. These large turtles are known locally as *pyin tha*, a name also applied to *Chelonia mydas*. However, villagers stated that unlike *C. mydas*, these turtles were capable of completely withdrawing into their shells. More convincingly, when presented with an array of photographs these villagers readily distinguished between *B. baska* and *C. mydas*, and indicated that the former was the species they occasionally encountered. Together these reports strongly suggest that a small, remnant population of *B. baska* may occur along the Rakhine coast. Specific information regarding nesting was unavailable; villagers believed the turtles nest on nearby Ramree Island, but marine turtle egg dealers there had not encountered *B. baska* eggs.

Cyclemys dentata (Gray, 1831b).- In a recent revision of the genus *Cyclemys*, Fritz et al. (1997) contend that *C. dentata* is actually a complex of cryptic species, and the species occurring in western Myanmar is *C. oldhamii*. However, pending resolution of the on-going debate concerning species boundaries in *Cyclemys* (Fritz et al., 1997; Fritz and Ziegler, 1999; Guicking et al., 2002; Stuart and Platt, 2004), we here follow traditional taxonomy (e.g., Smith, 1931; Iverson, 1992) and refer to *Cyclemys* from the Arakan Yomas as *C. dentata*.

Hunters contend that *C. dentata* remains common in central Rakhine where it is found in a variety of habitats, including rivers and creeks, and terrestrially in evergreen and bamboo forests. We examined 13 specimens (7 living turtles and 6 shells) with a mean CL of 174 ± 38 mm (range = 68 to 207 mm). In addition we recovered numerous shell fragments from village trash middens. Two nematodes found in faeces collected from a *C. dentata* were identified as female *Falcaustra* spp. (Charles Bursey, *in litt.*). We also captured a juvenile (CL = 68 mm) in a small forest stream flowing into Pyaung Chaung (19°34.091'N; 94°08.151'E) on 26 January 2000. The turtle was found basking in direct sunlight on the edge of a deep pool (> 2 m) at the base of a waterfall. Water temperature at the time of capture was 16°C. Faeces collected from the turtle were composed primarily of filamentous green algae, which was growing abundantly on submerged rocks in the pool.

Hunters use dogs to locate *C. dentata* in terrestrial habitats. Along rivers, hunters often find *C. dentata* in holes beneath overhanging banks where turtles seek refuge during the dry season. *Cyclemys dentata* are also taken in bamboo traps built at the base of fruiting *mau* trees (*An-*

thocephalus indica A. Rich.) growing along riverbanks. Traps are constructed on sandbars during October and November when turtles emerge from the river to feed on fallen fruit. The trap consists of two wings, each about 5 m long and 0.3 m high, and constructed of split bamboo that function as a drift fence, angling inwards towards the tree and directing foraging turtles into a pitfall (ca. 45 cm wide × 30 cm deep) excavated in the sand. Vertical pieces of split bamboo line the walls of the pitfall and prevent captured turtles from climbing out.

Cyclemys dentata is subject to intense hunting pressure near villages, and individual hunters reported catching from 30 to 350 turtles annually. The majority of these turtles are consumed locally and very few are purchased by wildlife traders. The disposition of the plastron varies; some traders will not purchase them citing low demand, while others pay villagers a small amount.

Cheloniidae

Chelonia mydas (Linnaeus, 1758), *Eretmochelys imbricata* (Linnaeus, 1766), and *Lepidochelys olivacea* (Eschscholtz, 1829).- Salter (1983b) provides the only recent information on the occurrence and population status of marine turtles along the central Rakhine coast. During the early 1980's *Chelonia mydas* and *Lepidochelys olivacea* nested at several beaches on Ramree and Cheduba Islands from November through February. Villagers opportunistically collected turtle eggs for domestic consumption and sale in the markets of Taungup and Kyaukphyu. Small numbers of *Eretmochelys imbricata* were also present in offshore waters, but not believed to nest in the area. Salter (1983b) further noted that large numbers of marine turtles, primarily *L. olivacea* were accidentally drowned each year by prawn trawls.

We collected a limited amount of data on the current status of marine turtles during our visit to Ramree Island. Fishermen identified two principal nesting beaches on the island; one located about 10 km south of Zin Chaung Village and another in the vicinity of Min Pyin. Marine turtles are also said to nest on nearby Tancrow Taung Island. According to fishermen, *C. mydas* is the only marine turtle that currently nests in the region. *Eretmochelys imbricata* and *L. olivacea* are often accidentally taken by prawn trawlers and fishing boats, and we obtained the carapace of an immature *E. imbricata* (CL = 299 mm) from Min Pyin that drowned in a net during 1999.

Villagers continue to collect marine turtle eggs for both personal consumption and sale to egg dealers. We found marine turtle eggs in the markets of Zin Chaung and Kyaukphyu; others are reportedly shipped by air from Kyaukphyu to markets in Yangon. The consensus among villagers we interviewed is that the daily harvest of marine turtle eggs has steadily declined each year. Several egg collectors stated that in the early 1990's it was possible to find seven to eight nests each day, while now it is difficult to find even one. Marine turtles are not deliberately harvested for food, but those that drown in prawn nets are salvaged and eaten. One fisherman stated that he recovers about one turtle each month from lobster and prawn nets. Given the large number of trawlers operating in coastal waters, this incidental harvest undoubtedly constitutes a significant source of mortality for regional marine turtle populations.

Trionychidae

Amyda cartilaginea (Boddaert, 1770).- We examined three living *Amyda cartilaginea* (CL = 171 to 399 mm) at a trading post in Min Tone Village at the eastern base of the Arakan Yomas, but within the central dry zone. These turtles were reportedly captured locally in Min Tone Chaung, a creek originating on the eastern slopes of the Arakan Yoma Hills and within the Ayeyardwady River watershed. *Amyda cartilaginea* has not previously been reported from the dry zone (Iverson, 1992), and according to Annandale (1912) is restricted to the Arakan Hills and mountainous regions of eastern and peninsular Myanmar. Thus, our observations constitute an eastward range extension for *A. cartilaginea* within Myanmar and provide continuity with the record of Pawar and Choudhury (2000) from Mizoram in north-eastern India.

Amyda cartilaginea are taken on baited hooks and occasionally in bamboo fish traps, incidental to fishing activities. As with other species of softshell turtles in Myanmar, *A. cartilaginea* is in great demand for export markets and commands a high price among traders, resulting in an unsustainable level of harvest and the near-extirpation of many wild populations (Platt et al., 2000, 2004). According to traders in Min Tone Village, monthly purchases of *A. cartilaginea* declined from about 500 kg in 1999, to less than 100 kg in 2000, strongly suggesting that local populations are being rapidly depleted. Similarly, villagers in Mae Sadwe and Pyaung Chaung indicated that *A. cartilaginea* are becoming increasingly difficult to find.

CONCLUSIONS

In common with much of Myanmar, historical data needed to assess the past abundance and contemporary trends among chelonian populations in central Rakhine State are lacking. Although tortoises and freshwater turtles have always served as food for the indigenous people of central Rakhine, the low human population density meant that impacts from subsistence harvesting were local in scale and there was little likelihood of region-wide declines among chelonian populations. However, since the mid-1990's demand from wildlife markets in southern China (Platt et al., 2000) has commercialized what was formerly the subsistence harvest of a common resource (*sensu* Hardin, 1968), and now provides an economic incentive for hunters to collect turtles in numbers greatly exceeding their immediate needs.

Our investigation indicates that commercial hunting is now widespread in central Rakhine, particularly in more accessible areas such as the coastal region and eastern periphery of the Arakan Yoma Hills. Despite the lack of roads and general inaccessibility of the region, wildlife traders also operate in the remote interior of the Arakan Yoma Hills. While some species appear to remain relatively common (e.g., *I. elongata* and *C. dentata*), current harvest levels are clearly unsustainable making future population declines probable. Ominously, commercial harvesting of all species of chelonians in central Rakhine will likely intensify as turtle populations in more accessible regions of Myanmar become depleted. Furthermore, road construction and large-scale bamboo harvesting associated with a proposed papermill pose a serious threat to regional chelonian populations by providing increased market access and destroying large tracts of bamboo forest. Finally, the situation with regards to marine turtles is particularly alarming; chronic over-harvesting of eggs appears to be eliminating recruitment and a significant number of immature and adult turtles drown in fishing nets each year. Collectively, these threats call into doubt the continued regional viability of marine turtle populations in western Myanmar.

As we have emphasized elsewhere (Platt et al., 2000, 2003a, 2004), it is imperative that officials in Myanmar and China make further efforts to curb the trans-border wildlife trade between the two countries. The commercial collecting of any species of chelonian is illegal in Myanmar according to domestic fisheries and forestry laws, and most of the international trade is in clear violation of CITES, which Myanmar signed on 13 June 1997 (Platt et al., 2000). Unless protective legislation is enforced, a region-wide collapse of turtle populations in Rakhine State and indeed throughout much of Myanmar is to be expected.

ACKNOWLEDGEMENTS

Fieldwork in Myanmar was funded by grants from the Walt Disney Company Foundation. The assistance of U Saw Tun Khaing and U Than Myint of the WCS Myanmar Program was instrumental in ensuring the success of our fieldwork. The Department of Forestry is thanked for granting us permission to conduct research in Rakhine State and providing a departmental escort. An initial draft of our manuscript was improved by comments from Peter Paul van Dijk, Robert Parker, and Harry Longabaugh. We thank the interlibrary loan staff at Texas Tech University and Rapid City Public Library for assistance with obtaining obscure references.

LITERATURE CITED

ANNANDALE, N. 1912. The Indian mud turtles (Trionychidae). Records of the Indian Museum 7:151–179.

CHAMPION, H. G. 1936. A preliminary survey of the forest types of India and Burma. Indian Forest Records, Sylviculture 1:1–287.

CHRISTISON, P. 1945. A note on the present distribution of the Sumatran rhinoceros (*Dicerorhinus sumatrensis*) in the Arakan District of Burma. Journal of the Bombay Natural History Society 45:604–605.

____, A. BUXTON, A. M. EMMET & D. RIPLEY. 1946. Field notes on the birds of coastal Arakan and the foothills of the Yomas. Journal of the Bombay Natural History Society 46:13–32.

CLOSE, L. M. & R. A. SEIGEL. 1997. Differences in body size among populations of red-eared sliders (*Trachemys scripta elegans*) subject to different levels of harvesting. Chelonian Conservation and Biology 2:563–566.

DE TERRA, H. 1944. Component geographic factors of the natural regions of Burma. Annals of the Association of American Geographers 32:67–96.

DODD, C. K., JR. & R. FRANZ. 1993. The need for status information on common herpetofaunal species. Herpetological Review 24:47–50.

EMMET, A. M. 1948. More butterflies of the Arakan coast. Journal of the Bombay Natural History Society 48:62–74.

ERNST, C. H. & R. W. BARBOUR. 1989. Turtles of the world. Smithsonian Institution Press, Washington, D.C. 313 pp.

FRITZ, U., M. GAULKE & E. LEHR. 1997. Revision der südostasiatischen Dornschildkröten-Gattung *Cyclemys* Bell, 1834, mit Beschreibung einer neuen Art. Salamandra 33: 183–212.

____ & T. ZIEGLER. 1999. Contribution to the knowledge of *Cyclemys tcheponensis* (Bourret, 1939) and the distribution of *Cyclemys* in the Indochinese region (Reptilia: Testudines: Bataguridae). Revue Francaise de Aquariologie 26:71–78.

GLADMAN, J. C. 1946. Some butterflies of the Arakan coast. Journal of the Bombay Natural History Society 46:516–524.

GUICKING, D., U. FRITZ, M. WINK & E. LEHR. 2002. New data on the diversity of the Southeast Asian leaf turtle genus *Cyclemys* Bell 1834. Molecular results (Reptilia: Testudines: Geoemydidae). Faunistische Abhandlungen Staatliches Museum für Tierkunde Dresden 23:75–86.

HARDIN, G. 1968. The tragedy of the commons. Science 162:1234–1238.

HENDERSON, J. W., J. M. HEIMANN, K. M. MARTINDALE, R. SHINN, J. O. WEAVER & E. T. WHITE. 1971. Area handbook for Burma. DA Pam 550–61. U. S. Government Printing Office, Washington, D.C. 304 pp.

HOPWOOD, J. C. 1912. A list of birds from Arakan. Journal of the Bombay Natural History Society 21:1196–1201.

IVERSON, J. B. 1992. A revised checklist with distribution maps of the turtles of the world. Privately printed, Richmond, Indiana. 363 pp.

____ & W. P. McCORD. 1997. Redescription of the Arakan forest turtle *Geoemyda depressa* Anderson 1975 (Testudines: Bataguridae). Chelonian Conservation and Biology 2:384–389.

KINNEAR, N. B. 1910. Pied imperial pigeon and sheldrake in Arracan. Journal of the Bombay Natural History Society 20:518–520.

KUCHLING, G. 1995. Turtles at a market in western Yunnan: possible range extensions for some Asiatic chelonians in China and Myanmar. Chelonian Conservation and Biology 3:223–226.

MARSHALL, E. 1947. Shikar and safari: reminiscences of jungle hunting. Farrar, Straus, and Company, New York. 263 pp.

MAXWELL, F. D. 1911. Report on the inland and sea fisheries in the Thongwa, Myaungmya, and Bassein Districts and the turtle banks of the Irrawaddy Division. Government Printing Office, Rangoon. 57 pp.

OLIVER, I. & A. J. BEATTIE. 1993. A possible method for the rapid assessment of biodiversity. Conservation Biology 7:562–568.

PAWAR, S. S. & B. C. CHOUDHURY. 2000. An inventory of chelonians from Mizoram, northeast India: new records and some observations on threats. Hamadryad 25:144–158.

PLATT, S. G. 2000. An expedition into central Rakhine State, Myanmar. Unpubl. report to Wildlife Conservation Society, Bronx, New York. 64 pp.

____, KALYAR & T. R. RAINWATER. 2004. Inle Lake turtles, Myanmar with notes on Intha and *Pa-O* ethnoherpetology. Hamadryad 29:5–14.

____, WIN KO KO & KALYAR. 2000. Exploitation and conservation status of tortoises and freshwater turtles in Myanmar. Chelonian Research Monograph 2:95–100.

____, ____, ____, MYO MYO, LAY LAY KHAING & T. R. RAINWATER. 2001A. Man eating by estuarine crocodiles: the Ramree Island massacre revisited. Herpetological Bulletin 75:15–18.

____, ____, ____, ____, ____ & ____. **2003a.** Ecology and conservation status of the Arakan forest turtle, *Heosemys depressa*, in western Myanmar. Chelonian Conservation and Biology 4:678–682.

____, ____, **LAY LAY KHAING, KHIN MYO MYO, THANDA SWE, TINT LWIN & T. R. RAINWATER. 2003b.** Population status and conservation status of the Critically Endangered Burmese star tortoise *Geochelone platynota* in central Myanmar. Oryx 37:464–471.

____, **SAW TUN KHAING, WIN KO KO & KALYAR. 2001b.** A tortoise survey of Shwe Settaw Wildlife Sanctuary, Myanmar, with notes on the ecology of *Geochelone platynota* and *Indotestudo elongata*. Chelonian Conservation and Biology 4:172–177.

____, ____, ____ & ____. **2001c.** Distributional notes on the turtles of western Myanmar. Journal of the Bombay Natural History Society 98:117–120.

POLLOCK, C. & W. S. THOM. 1900. Wild sports of Burma and Assam. Hurst and Blackett, Ltd., London. 507 pp.

ROBBINS, R. G. & S. G. PLATT. 2001. First report of *Amblyomma supinoi* Neumann (Acari: Ixodida: Ixodidae) from the Arakan forest turtle, *Geoemyda depressa* Anderson (Reptilia: Testudines: Emydidae), with additional records of this tick from the Union of Myanmar. Proceedings of the Entomological Society of Washington 103:1023–1024.

SALTER, J. A. 1983a. Wildlife in the southern Arakan Yomas. Survey report and interim conservation plan. FO:BUR/80/006, Field Report 17/83. Unpublished report to FAO, Rome. 24 pp.

____. **1983b.** Report on a preliminary survey of the Tanlwe – Ma-e Chaung area, central Arakan State. FO:BUR/80/006. Field Report 16/83. Unpublished report to FAO, Rome. 22 pp.

SMITH, M. A. 1931. The fauna of British India. Vol. 1. Loricata and Testudines. Taylor and Francis, London. 185 pp.

SMYTHIES, B. E. 1953. The birds of Burma. Oliver and Boyd, Edinburgh. 668 pp.

STAMP, L. D. 1924. Notes on the vegetation of Burma. Geographical Journal 64:231–237.

____. **1930.** Burma: an undeveloped monsoon country. Geographical Review 20:86–109.

STUART, B. L. & S. G. PLATT. 2004. Recent records of turtles and tortoises from Laos, Cambodia and Vietnam. Asiatic Herpetological Research 10:129–150.

____ **& J. THORBJARNARSON. 2003.** Biological prioritization of Asian countries for turtle conservation. Chelonian Conservation and Biology 4:642–647.

THEOBALD, W. 1876. Descriptive catalogue of the reptiles of British India. Thacker, Spink & Co., Calcutta. ix + 238 pp + xxxviii + xiii + 6 pl.

THIRAKHUPT, K. & P. P. VAN DIJK. 1994. Species diversity and conservation of turtles in western Thailand. Natural History Bulletin of the Siam Society 42:207–259.

THOM, W. S. 1933. Some experiences amongst elephant and the other big game of Burma from 1887 to 1931. Journal of the Bombay Natural History Society 36:321–333.

____. **1934.** Tiger shooting in Burma. Journal of the Bombay Natural History Society 37:573–603.

THORBJARNARSON, J. B., S. G. PLATT & SAW TUN KHAING. 2000. Conservation status of freshwater turtles in Meinmahla Kyun Wildlife Sanctuary and vicinity, Myanmar. Natural History Bulletin of the Siam Society 48:185–191.

VAN DIJK, P. P. 1993. Myanmar turtles: report on a preliminary survey of the Testudines of the Ayeyarwady Basin. Unpubl. report to Turtle Recovery Program, The World Conservation Union-IUCN SSC Tortoise & Freshwater Turtle Specialist Group. 34 pp.

____. **1997.** Turtle conservation in Myanmar: Past, present, and future. In: Proceedings: Conservation, restoration, and management of tortoises and turtles– An international conference. pp. 265–271. J. V. Abbema (Ed). New York Turtle and Tortoise Society.

Received: 11 July 2005.
Accepted: 17 October 2005.

Hamadryad Vol. 31, No. 2, pp. 212 – 215, 2007.

ESTIMATED ANNUAL INCIDENTAL CAPTURES OF *LEPIDOCHELYS OLIVACEA* (ESCHSCHOLTZ, 1829) IN TRAWL NETS ALONG THE ORISSA COAST, INDIA

G. V. Gopi[1], B. Pandav and B. C. Choudhury

Department of Endangered Species Management, Wildlife Institute of India,
Post Box 18, Chandrabani, Dehradun 248 001, Uttranchal, India.
[1]Email: gopigv@gmail.com

(with one text-figure)

ABSTRACT.– **The incidental capture of sea turtles in marine trawl fishing has been identified as a major source for their large-scale mortalities worldwide. Since trawl operators in Orissa are reluctant to concur, we provide empirical data on incidental captures in the Orissa coastal waters. A total number of 76 trawling efforts were carried out between 6–35 fathoms between November 2001 to March 2002, which resulted in the capture of 26 *Lepidochelys olivacea*. An estimate has been made to extrapolate the number of turtles drowned annually during the nesting season. Of the three stratified study zones, estimates were higher in the Debi zones with 2,439, followed by the Gahirmatha zone with an estimate of 1,254, and lastly, the Paradip zone, with an estimate of 1,086 turtles.**

KEYWORDS.– **Trawl fishing, incidental capture, *Lepidochelys olivacea*, experimental trawling, Catch Per Unit Effort.**

INTRODUCTION

A major threat identified for the survival of the olive ridley, *Lepidochelys olivacea*, population along the Orissa coast of eastern India is trawl fishing, and counts during last five years show mortality of over 45,000 turtles (Pandav, 1997). There have been estimates of incidental captures of sea turtles in trawl fisheries worldwide. Robin and Mayer (1998) compiled data on worldwide annual estimates of turtle mortalities through trawling. Gove et al. (2001) estimated 1,932–5,436 incidental captures annually in Safola bank. Henwood and Stuntz (1987) estimated an annual mortality of 5,000–50,000 turtles due to incidental capture along the Gulf of México and along the US Atlantic coast. There have been reports of incidental captures of sea turtles due to uncontrolled mechanized fishing in areas of high sea turtle concentration, resulting in large-scale mortality of adult sea turtles during the last two decades in Orissa (James et al., 1989; Dash and Kar, 1990; Pandav et al., 1994; Pandav et al., 1997). As of now, there are no empirical data available on the impact of mechanized fishing, particularly trawl fishing, on *Lepidochelys olivacea*. Trawl owners deny the fact that trawling is the sole cause of the large scale mortality.

This study was initiated to estimate the number of captures annually due to fishing trawlers along the Orissa coast.

STUDY AREA

Orissa, an important maritime state on the east coast of India, has a coastline of 480 km, representing 8% of the coastline of India. The continental shelf, up to a depth of 200 m, covers an area of 25,000 km^2 which is 4.5% of the total area of the Indian continental shelf. Orissa accounts for an annual production of 6,858 tones of shrimp and 125,000 tonnes of other marine annual production (Anon., 1997). The marine fishing activities here are dominated by migrating fishermen from West Bengal (between West Bengal–Orissa border to Paradip) and Andhra Pradesh (between Konark to Andhra Pradesh border), marine fishing by the native Oriya fishermen being minimal. During the early 1990s as part of the Bay of Bengal Program, most of the

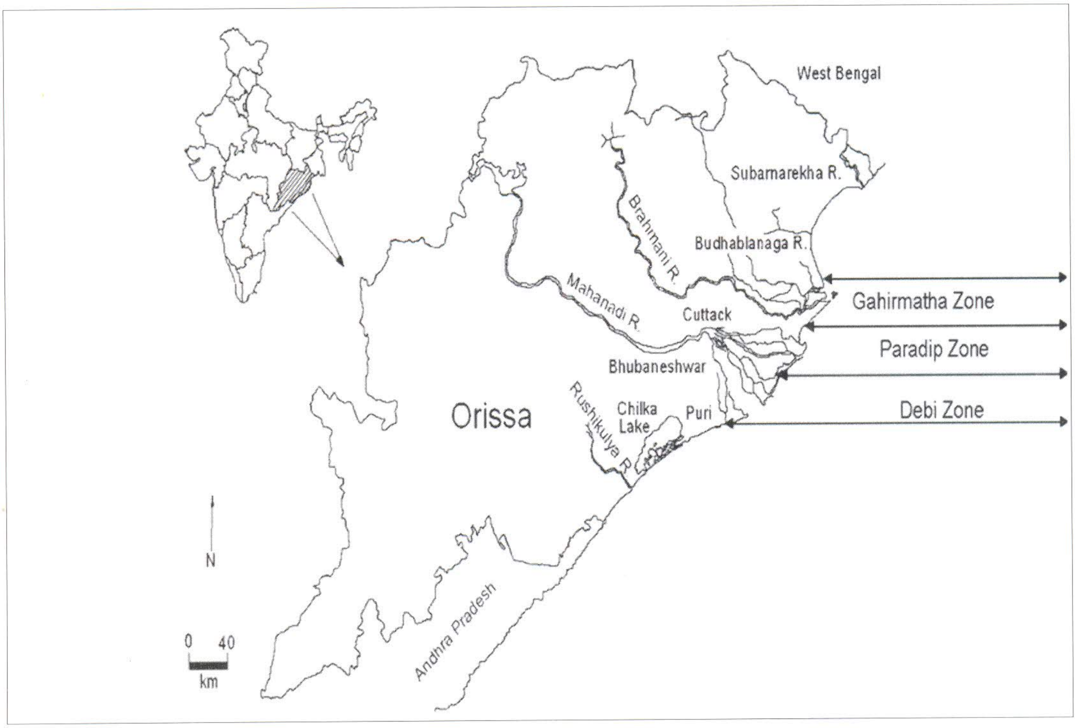

Figure 1. Map of coastal Orissa, eastern India, showing the study zones.

traditional crafts were replaced with fibre glass boats with outboard motors. Mechanized fishing along the Orissa coast is characterized by trawl and gill net fishing. The northern part of Orissa coast is subjected to heavy mechanized fishing activities. Mechanized gill netters from neighbouring West Bengal also fish in this area. Trawlers from Andhra Pradesh often come and fish along the southern Orissa coast. Past studied revealed high sea turtle concentrations along the Brahmini–Bhaitarini, Debi and Rushikulya river mouths (Pandav, 1994). The coastline between Brahmini– Baitarini and Debi river mouth (150 km) was chosen for sampling (Fig. 1), and the same was stratified as; Zone I: Gahirmatha (35 km) which extends from Dhamra river to Barunei, Zone II: Paradip (55 km) extending from Barunei to Jatadhara and Zone III: Debi (60 km), from Jatadhra river to Kadua river. The numbers of mechanized and non-mechanized boats operating in the areas are given in Table 1 (from Anon., 1997).

Table 1. Mechanized and non-mechanized boats operated along the coastal districts of Orissa.

Base	Wooden trawlers	Gill netters	Motorized country crafts
Balosore	293	322	592
Bhadrak	59	220	335
Balasore	1207	1500	475
Jagtsingpur	267		282
Kendrapara	28	48	
Puri	39	18	854
Ganjam	686	1702	938

METHODS

Experimental trawling was carried out between November 2001 and March 2002. A total of 52 trawling efforts were carried out in the research vessel M.V. Telaban obtained from the Fisheries Department of Orissa, resulting in 21 turtles, and occasionally, private trawlers were accompanied and trawling attempted. In all, 24 trawl-

Table 2. Estimated incidental catch of *Lepidochelys olivacea* along the Orissa coast by trawl fishing during the peak fishing season (November to March).

Zone	CPUE ± 95% C.I on CPUE	Trawling effort (h)	Estimated capture of ridleys
Gahirmatha	0.258 ± 0.0119	5000	1254 ± 60
Paradip	0.0724 ± 0.0001	15000	1086 ± 15
Debi	0.4878 ± 0.0011	5000	2439 ± 6

ing efforts were carried out in the observer vessel which resulted in five turtle captures.

For each trawls sampled, effort (E) was standardized to reflect hours towed with a 50 m net per hour using the formula:

$$E = (n X l/50m)X (t/60?)$$

where

n = number of nets towed in a trawler and this is a test

l = head rope length of the net

t = min. fished

$$R = \sum N/ \sum E$$

where

R = Capture Per Unit Effort (CPUE)

N = number of turtles captured

E = Effort (standardized to 50 m net hours)

95% C.I on $R = R \pm 1.96 (1/\bar{x}) \sqrt{}\Sigma(Y-RX)2/(n(n-1))$

Annual incidental sea turtle capture was calculated as follows.– In Gahirmatha and Debi zones, 100 and 300 trawlers were taken, respectively, to calculate the incidental captures of the sea turtles during peak fishing season using the formula given below:

Estimated captures = (CPUE X trawling effort) ± (95% C.I on CPUE X trawling effort)

Trawling effort of fishing vessels was calculated as follows:

- Minimum time per day per boat spent fishing in sea
  (t) = 15 h.
- Minimum number of fishing days in an average year
  (Oct. to Apr.) (d) = 100 days
- therefore, minimum trawling per year per boat (N) is
  t X d = 1500 h.
- Trawling effort (E) / boat was calculated with the formula given earlier
  = 50

Minimum number of boats operating in

Zone I	=	100
Zone II	=	300
Zone III	=	100

Total trawling effort in the study area

Zone I	=	5,000
Zone II	=	15,000
Zone III	=	5,000
Total	**=**	**25,000**

RESULTS AND DISCUSSION

In Zone I, 12 experimental trawls were carried out. Depth in which trawls were carried out varied from 6 to 10 fathoms with mean value of 7.72 ± 0.2085. Average duration of the trawls was 1.24 ± 0.1090 hrs. Average trawl distance in Zone I varied from 3.39–14.36 km, with a mean of 6.68 ± 0.9339 and distance of trawl path from nearest shore line varied from 0.77–23.48 km, with a mean of 5.85 ± 1.9851 km.

In Zone II, 29 experimental trawls were carried out. Depth in which trawls were carried out varied from 5 to 20 fathoms with mean value of 10.13 ± 0.47. Average duration of the trawl was 1.21 ± 0.065 hrs. The trawl distance covered during trawling in Zone II varied from 1.7 to 8.8 km with an average of 4.4 ± 0.29 km and the distance of trawl path from nearest shoreline varied from 0.43 to 14.07 km with a mean of 4.9 ± 1.08 km.

In Zone III, 11 experimental trawls were carried out. Depth in which trawls were carried out varied from 6 to 13 fathoms with mean value 9.5455 ± 0.46 fathoms. Average duration of the trawl was 1.24 ± 0.0916 hrs. The distance covered during trawling in Zone III varied from 1.02 to 7.75 km with mean value 4.5 ± 0.53 and the distance of trawl path from nearest shoreline varied from 1.4 to 5.8 km with a mean of 3.19 ± 0.533.

Data from 24 trawls were taken from the observer vessel. Depth at which trawls were carried out varied from 9–35 fathoms, with mean value of 17.41 ± 0.82. Duration of the trawls varied from 1.45–6.45 h., with mean of 4.29 ± 0.22. Distance covered during trawling in the observer vessel varied from 0.8–24.02 km, with mean of 13.42 ± 1.17 and the distance of trawl path from nearest shoreline varied from 3.42–46.47 km, with a mean of 26.40 ± 2.28.

Males and females of *Lepidochelys olivacea* migrate en-masse to breeding grounds from their feeding grounds— a distance sometimes exceeding 1,000 km. *L. olivacea* migrate in aggregations and start arriving in the coastal waters of Orissa by early October. It is known to aggregate in enormous numbers off nesting beaches. They form mating pairs, mostly concentrated in the inshore waters. These congregations, consisting of reproductively active adults, are termed 'reproductive patches' (Ram, 2000). In Orissa, the turtles congregate in shallow coastal waters (under 50 fathoms), close to the nesting beaches. Turtle congregations have been observed in the Gahirmatha coastal waters (between the Dhamra and Mahanadi river mouths), in the Devi coastal waters (between Jatadhar *muhana* and Kadua *muhana*) and in the Rushikulya coastal waters (the Chilka mouth or the Magarmukh to Rushikulya river mouth) (Chadha and Kar, 1999).

The estimated annual incidental capture was found to be the highest in the Debi followed by Gahirmatha zone (Table 2). Gahirmatha and Debi are the two major mass nesting grounds where congregation patches have already been observed during breeding season. Since the breeding season coincides with the peak fishing season, the intensity of the incidental capture is also higher, whereas in Paradip, no such congregation patches have been recorded so far and that may be the reason for the comparatively lower estimate. These estimated captures are for just 150 km (stratified study zones), and since Orissa has a coastline of 480 km the incidence of incidental capture must be relatively much higher for the entire coast than the study suggests. A total number of 11,593 (2,714– male, 7147– female, 1,732– unknown) stranded turtles were counted along the southern coast between Paradip and Sunpur. Due to lack of feasibility the entire coastal stretch of the study zone were not covered. The current estimate obtained attempts to provide a minimal estimate of probable turtle captures during the peak fishing season which coincides with the *Lepidochelys olivacea* breeding season.

ACKNOWLEDGEMENTS

This study would not have been possible without the continued support of the Director, Wildlife Institute of India. We thank the many field assistants for their work on this project. We express our thanks to Orissa Fisheries Department and Orissa Forest Department for providing necessary permits and logistic support while in Field. For helpful discussion and comments on the manuscript, we thank Rajah Jayapal and S. Bhupathy.

LITERATURE CITED

ANONYMOUS. 1997. Handbook on fisheries statistics Orissa, 1996–97. Director of fisheries, Government of Orissa, Cuttack. 138 pp.

CHADHA, S. & C. S. KAR. 1999. Bhitarkanika, myth and reality. Nataraj Publishers, Dehradun. 338 pp.

DASH, M. C. & C. S. KAR. 1990. The turtle paradise – Gahirmatha. Interprint, New Delhi. 295 pp.

GOVE, D. Z., H. PACULE & M. GONCALVES. 2001. The impact of Sofala Bank (Central Mozambique) shallow water shrimp fishery on marine turtles and the effects of introducing TED (Turtle Excluder Device) on shrimp fishery. EAME (Eastern Africa Marine Eco-Region Programme). World Wide Fund for Nature. 24 pp.

HENWOOD, T. A & W. E. STUNTZ. 1987. Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fisheries Bulletin (85):813–817.

JAMES, P. S. R. B., M. RAJAGOPALAN, S. S. DAN, A. BASTAN FERNANDO & V. SELVARAJ. 1989. On the mortality and stranding of marine mammals and turtles at Gahirmatha, Orissa from 1983 to 1987. Journal of the Marine Biological Association, India 31:28–35.

PANDAV. B., B. C. CHOUDHURY & C. S. KAR. 1994. A status survey of olive ridley sea turtle (*Lepidochelys olivacea*) and their nesting beaches along the Orissa coast, India. Report to the Wildlife Institute of India, Dehradun. 48 pp.

____, ____ & ____. 1997. Mortality of olive ridley sea turtle (*Lepidochelys olivaceae*) due to incidental capture in fishing nets along Orissa coast, India. Oryx 31(1):32–36.

RAM, K. 2000. Behavioural ecology of the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz, 1827). during the breeding period. Unpublished M. Sc. dissertation, Sálim Ali School of Ecology, Pondicherry University Pondicherry. 60 pp.

ROBINS, J. B. & D. G. MAYER. 1998. Monitoring the impact of trawling on sea turtle populations of the Queensland east coast. Queensland Department of Primary Industries Project Report Series No. Q098012. Fisheries Research Development Corporation Project No. T93/229. 59 pp.

Received: 6 March 2006.
Accepted: 12 April 2006.

Hamadryad Vol. 31, No. 2, pp. 216 – 241, 2007.

THE HERPETOFAUNA OF THE PHNOM AURAL WILDLIFE SANCTUARY AND CHECKLIST OF THE HERPETOFAUNA OF THE CARDAMOM MOUNTAINS, CAMBODIA

L. Lee Grismer[1], Thou Chav[2], Thy Neang[3], Perry L. Wood, Jr.[1], Jesse L. Grismer[4], Timothy M. Youmans[1], Armando Ponce[1], Jennifer C. Daltry[5] and Hinrich Kaiser[5]

[1]Department of Biology, La Sierra University, 4500 Riverwalk Parkway,
Riverside, California 92515, U.S.A.

[2]Wildlife Division, Department of Forestry and Agriculture, Phnom Penh, Cambodia.

[3]Ministry of Environment, Phnom Penh, Cambodia.

[4]Museum of Natural Sciences, Louisiana State University, Baton Rouge,
Louisiana 70820, U.S.A.

[5]Fauna and Flora International, Cambodia Field Office, 8b Phlauv 398, Boueng Keng Kang I,
Phnom Penh, Cambodia.

[5]Department of Biology, Victor Valley College,
18422 Bear Valley Road, Victorville, California 92395, U.S.A.

(with 38 text-figures)

ABSTRACT.– **A survey of the Phnom Aural Wildlife Sanctuary in the eastern Cardamom Mountains augments and complements previous herpetological surveys of this mountain range, adding one new species record for frogs, five new species records for lizards and seven new records of snakes, one of which (*Dendrelaphis subocularis*) is a new record for the Cardamom Mountains. A checklist of the herpetofauna of the Cardamom Mountains is provided.**

KEY WORDS.– **Cambodia, Cardamom Mountains, Phnom Aural, herpetofauna.**

INTRODUCTION

Cambodia is centrally located in the southern portion of the Indochinese Peninsula and owing to its position at the northern end of the Indo-Malayan Forest (Webb, 2005), it serves as an important biogeographical link between south-east and east Asian herpetofaunas. Several recent studies have demonstrated that many wide-ranging lineages previously considered to be single species, are actually composed of multiple species and the species boundaries within many of these complexes occur within this general region of Indochina (e.g., Bain et al., 2003; Matsui, et al., 1996, 2001, 2005a,b; Ota et al., 2001; Wüster et al., 1995). Therefore, in order to understand the historical biogeography of the Indochinese herpetofauna and to implement effective measures of conservation, groundwork from baseline field surveys and alpha-taxonomic investigations must first be laid. However, years of political turmoil and genocide have all but halted any field-based studies in Cambodia, and as such, it lags behind neighbouring countries of Indochina, namely Vietnam, Laos, and Thailand (see Campden-Main, 1970; Cox, 1991; Deuve, 1970; Inger et al., 1999; Manthey and Grossmann, 1997; Stuart, 2005; Teynie et al., 2004; Ziegler, 2002 and references therein). Only within the last few years has the political situation in Cambodia stabilized enough to enable reasonably safe field work in some areas.

Cambodia for the most part, is a large floodplain whose central basin receives drainage from the Khorat Plateau of north-eastern Thailand in the north and the Langbian and Kontum Plateaus from the east. The southern portion of Cambodia, along the northern edge of the Gulf of Thailand, is physiographically unique, being dominated by the isolated Cardamoms (*sensu* Stuart and Emmett, 2006, which also include the Elephant Mountains of the extreme south-east). Cardamom Mountains generally run from the Thai/Cambodia border in the west in the Palin Province, south-eastwards for approximately 311 km to the Kampong Bay in the Kampot Province and span more than 10,000 km^2 (Fig. 1). They comprise four, distinct massifs; the Phnom Samkos massif in the north-west (north-western Cardamoms), the central Cardamom Mountains (central Cardamoms), the relatively isolated Elephant and Bokor Mountains in the south-east (south-eastern Cardamoms), and the relatively isolated Phnom Aural Massif in the north-east (north-eastern Cardamoms). The Cardamom Mountains range in height from approximately 69 m above sea level to 1,831 m at the summit of Phnom Aural, Cambodia's highest peak (Peakbagger.com http://peakbagger.com, 2006). They receive the highest amount of annual rainfall (3,000–5,000 mm; Weiler, 1998) than anywhere in Cambodia, which comes mainly from the south-westerly monsoon moving onshore out of the Gulf of Thailand from May through October (Maxwell, 2001).

Herpetofaunal reports from the Cardamom Mountains appear in early, scattered publications and the regional works of Bourret (1934, 1941, 1942), Smith (1935, 1943), and Saint Girons (1972). Additionally, Taylor's (1962b, 1963, 1965) monographic series included species from the Thai portion of the Cardamom Mountains. Only recently have the results from field surveys specifically focused in the mountainous south-western portion of Cambodia and surrounding regions been published (e.g., Daltry and Chheang, 2000; Long et al., 2001; Ohler et al., 2002; Swan and Daltry, 2002; Daltry and Traeholt, 2003; Chuaynken et al., 2004; Stuart and Platt, 2004; Stuart and Emmett, 2006). Stuart and Emmett's (2006) report was unique in that, for the first time, it provided diagnostic characteristics of every species collected and thus, laid a foundation of morphological profiles for this herpetofauna. Additionally and of extreme importance, is the fact that the species accounts of the aforementioned surveys were based on vouchered material and those of Stuart and Emmett (2006) were also accompanied by diagnoses open to scrutiny.

The results of this survey come from the Phnom Aural Wildlife Sanctuary in the north-eastern Cardamoms and build primarily upon the previous contributions of Ohler et al. (2002) and Daltry and Traeholt (2003). This study was a continuation of the Cambodian Government's request for biodiversity surveys for purposes of conservation management (Daltry and Momberg, 2000).

SURVEY SITES

Our survey from 4–10 August 2005, focused on the eastern flank of Phnom Aural within the Phnom Aural Wildlife Sanctuary in the eastern Cardamoms during the peak of the rainy season. Phnom Aural reaches 1,831 m in elevation and supports three distinct vegetation types that align themselves along an altitudinal gradient: dry dipterocarp forest occupies the lowland basins surrounding the base of Phnom Aural; hill evergreen forest covers the mountain's slopes up to 1,200 m; and montane evergreen forest ranges from 1,200 m to the summit. The latter two regions have been placed in a distinct bioclimatic region referred to as the Cardamom Evergreen Forest Ecoregion (Fontanel, 1972). Phnom Aural and its surrounding lowlands have been placed in the Phnom Aural Wildlife Sanctuary (12°00'N, 104°10'E), a nominally protected area that still suffers from considerable illegal logging. The primary localities of our survey within this sanctuary were Aural Village, two camps at different elevations on the south-east-facing flank of Phnom Aural, and the summit of Phnom Aural. Specimens were also collected in transit from one study site to the next.

Aural Village (11°57'N, 104°65'E; 175 m asl; Fig. 2).– Aural Village lies in a flat, wide valley crisscrossed by small streams. The vegetation has been characterized as dry dipterocarp forest (Boyce et al., 2002) and is highly degraded from illegal logging. Daytime temperatures exceed 35°C with nighttime lows near 28°C. Temporary puddles within, and alongside a road running through the village and leading to the base of Phnom Aural, provided ample habitat for many species of frogs common in anthropogenically-modified environments.

Camp I (12°01'N, 104°08'E; 549 m asl; Fig. 3).– Camp I was near a small, rocky, ephemeral stream situated on a hillside in hill evergreen forest. Daytime temperatures reached 26°C with nighttime lows of 21°C. Recent logging activity near this camp provided access into the forest as well as forest-edge habitats where much collecting was done. Decaying logs and debris left over from felled trees provided ample surface litter under which a number of species were collected.

Camp II (12°01'N, 104°09'E; 1,121 m asl; Fig. 4).– Camp II lies at the lower edge of the montane evergreen forest near a small, shallow, sandy stream. At this elevation no evidence of logging was present and many of the dipterocarp trees had trunk diameters exceeding 1 m with buttressed roots that provided microhabitats for some species. Daytime temperatures reached 24°C with nighttime lows of 18°C. The understory was relatively open but the streamside vegetation was thick and bushy.

Summit of Phnom Aural (12°03'N, 104°10'E; 1,831 m asl; Fig. 5).– The summit of Phnom Aural is characterized by stunted, lichen and moss-covered trees supported by fog-induced humidity. During our brief visit, the daytime temperatures did not exceed 14°C and there was heavy fog and light rain.

MATERIALS AND METHODS

Surveys were done throughout all hours of the day and night and collections were made by hand or with the aid of blowpipes. Local dogs were used in some cases, to search for turtles and snakes. Specimens were photographed prior to euthanasia, after which they had liver tissue removed, preserved and fixed with 10% formalin, and transferred into 70% ethanol for storage. All specimens were identified and compared to descriptions in the literature and, in some cases, to material on hand from the Field Museum of Natural History, Chicago, Illinois, U.S.A. (FMNH), The Natural History Museum, London, United Kingdom (BMNH), and the La Sierra University Herpetological Collection, Riverside, California, U.S.A. (LSUHC). Voucher photographs are deposited in the La Sierra University Digital Photograph Collection (LSUDPC). Measurements were taken with dial calipers to the nearest 0.1 mm under a binocular, dissecting microscope. We follow the scholarly example of Stuart and Emmett (2006) in that all species reported are accompanied by previously published morphological diagnoses and/or descriptions of that species, thus rendering our identifications open to scrutiny. Additionally, this practice begins the important process of building morphological profiles of these populations. All material is temporarily deposited in the LSUHC.

RESULTS

Bufonidae

Bufo macrotis Boulenger, 1887

LSUHC 7469–71: base of Phnom Aural approximately 15 km west of Aural Village, 11°58,N, 104°08'E, 202 m asl, dry dipterocarp forest, 10 August.

Two gravid females and one adult male with nuptial pads on digits I, II, and III agree with the expanded diagnosis of Taylor (1962b) in lacking cranial crests; having low parotoid glands slightly larger than eyelid; tympanum large, equal or slightly smaller than eye; body covered with tubercles of varying size, those on head smallest; lacking a tarsal fold but having a row of enlarged tarsal tubercles; inner metatarsal tubercle slightly smaller than outer; large, rounded palmar tubercle; first finger longer than second; and subarticular tubercles on hand bifid or trifid.

All individuals were collected during the day in moist, tall (ca. 30 cm) grass in the vicinity of fallen trees and stumps.

Megophryidae

Megophrys auralensis Ohler, Swan & Daltry, 2002

LSUHC 7385: Camp I, 4 August and LSUHC 7428: Camp II, 7 August.

The two juvenile specimens correspond to the diagnosis of Ohler et al. (2002) in having a vomerine ridge lacking vomerine teeth; broad head; well-developed tympanum; no white band on the upper lip; and a relatively long tibia.

LSUHC 7385 (SVL 21 mm) was collected during the day from leaf litter adjacent to a small stream. LSUHC 7428 (SVL 29 mm) was found moving across the forest floor in the leaf litter during the early evening. Ohler et al. (2002) reported calling males perched on rocks in the splash zone along swiftly flowing streams. No males were heard calling during our survey.

Microhylidae

All microhylids were collected from temporary puddles in Aural Village and along the road to the base of Phnom Aural. All are common to anthropogenically modified environments.

Kaloula pulchra Gray, 1831

LSUHC 7359: Aural Village, 6 August and LSUHC 7481: base of Phnom Aural, 7 August.

Both specimens agree with Parker's (1934) expanded description and Taylor's (1962b) diagnosis in having widened, expanded, truncate toe tips; brown dorsum with wide, darkly-edged, light dorsolateral stripes; no vertebral stripe; and webbing on foot very weak.

The juvenile (LSUHC 7359, SVL 16 mm) was collected during the evening beneath a log. An adult (LSUHC 7481, SVL 67 mm) was collected during the day, while sitting in a road-side puddle.

Microhyla butleri Boulenger, 1900

LSUHC 7326: between Aural Village and base of Phnom Aural, 5 August.

The single specimen is in accord with Parker's (1934) diagnosis and a series from northern Malaysia (LSUHC 7184–89) in having a snout no longer than twice the diameter of the eye; toes at least 1/3 webbed with distinct discs possessing a medial groove; a palatine bone; two metatarsal tubercles; and a diagonal fold along the underside of the tarsus.

One adult (SVL 23 mm) was collected during the day from a roadside puddle.

Microhyla heymonsi Vogt, 1911

LSUHC 7356–57: between Aural Village and base of Phnom Aural, 4 August 2005.

Both specimens are in accord with Parker's (1934) diagnosis and specimens from northern Malaysia (LSUHC 6511–12, 6654, 6658) in having a snout no longer than twice the diameter of the eye; toes not more than 1/3 webbed with small discs with a medial groove; palatine bone absent; outer metacarpal tubercle divided; and a continuous dark band from snout to groin.

Both specimens were collected during the evening along roadside puddles. LSUHC 7357 is gravid (SVL 28 mm) and LSUHC 7356 is an adult male (SVL 21 mm). Other males were heard calling nearby.

Microhyla pulchra (Hallowell, 1861)

LSUHC 7338: between Aural Village and base of Phnom Aural; 4 August 2005.

This specimen is in accord with Parker's (1934) diagnosis and specimens from Hainan Island, China (LSUHC 4118–19, 4166, 4183) in having a snout no longer than twice the diameter of the eye; toes not more than 1/3 webbed with no discs; two, non-shovel-shaped metatarsal tubercles; and no palatine bones.

An adult male (SVL 25 mm) was collected during the evening from along the edge of a roadside puddle.

Ranidae

Fejervarya cancrivora (Gravenhorst, 1829)

LSUHC 7351–53: 4 August and LSUHC 7472–76: 10 August; all between Aural Village and base of Phnom Aural.

Eight specimens match Taylor's (1962b) and Berry's (1975) diagnoses and material from northern Malaysia (LSUHC 5245–49, 5202, 5210) in lacking a dorsolateral fold; the tips of the digits being slightly swollen and lacking a fleshy lateral fringe on the inside of the first finger; having a free flap of skin along the outside edge of fifth toe; no outer metatarsal tubercle; and no vocal slits in males.

All individuals were juveniles (SVL 22–32 mm) found within or sitting along roadside puddles during the day. Although this species is common in anthropogenically altered habitats, it was not reported by Ohler et al. (2002) or Stuart and Emmett (2006).

Limnonectes kohchangae (Smith, 1922)

LSUHC 7388: Camp I, 6 August and LSUHC 7431–41, 7448–49: Camp II, 7 August 2005.

Thirteen specimens agree with Smith's (1922) and Taylor's (1962b) diagnoses of material from the type locality of Koh Chang Island in having a pair of enlarged, fang-like odontoids at the front of the mandible in males; an obtuse canthus rostralis; distance between nostrils greater than interorbital width which is greater than width of upper eyelid; first finger as long as second; no outer metatarsal tubercle; tarsal fold present; and no flap in interorbital or occipital area. They also agree with Stuart and Emmett's (2006) expanded description of a series from the central Cardamoms and Elephant Mountains in having a light coloured interorbital bar bordered posteriorly in black; the frontal region lighter than dorsum; 23% (3 of 13) having a white vertebral line; males lacking vocal slits and males having enlarged heads and tympani the size of the eye—characteristics lacking in females.

LSUHC 7388 (female, SVL 38 mm) was collected on the forest floor during the day hundreds of meters from the nearest stream. The remaining specimens were common along and within the stream at Camp II. Males called at night and occasionally during the day.

Occidozyga lima (Gravenhorst, 1829)

LSUHC 7358: Aural Village, 4 August.

This specimen agrees with the diagnosis of Taylor (1962b) in lacking vomerine teeth; having a narrow tongue with an elongate, pointed tip; pointed fingers with the first as long as the second; two distinct metacarpal tubercles; an inner and outer metatarsal tubercle; a large tubercle at the posterior end of the tarsus; tubercular or spiny skin; linear series of small warts on the belly, flanks, and chin; continuous dark and light longitudinal stripes on posterior margins of thighs (Taylor [1962b] erroneously refers to their orientation as transverse]); fingers slightly webbed; and toes fully webbed.

LSUHC 7358 (female, SVL 27 mm) was collected at night, while sitting at the edge of a puddle along the road. This species is common to anthropogenically modified environments.

Occidozyga martensii (Peters, 1867)

LSUHC 7477–79: between Aural Village and base of Phnom Aural, 10 August.

Three specimens are in accord with the diagnosis of Taylor (1962b) and specimens from Malaysia (LSUHC 6881–84, 7197) in lacking vomerine teeth; having a rounded, posterior tongue margin; small, terminal discs on the tips of the digits; no longitudinal dorsal grooves; and relatively small size (SVL 21–29 mm in our series).

All specimens were collected during the day from puddles along the road. This species is common to anthropogenically modified environments.

Paa fasciculispina (Inger, 1970)

LSUHC 7339: Camp I, 5 August.

An immature female (SVL 50 mm) agrees with the original description of this species (Inger, 1970) from the Thai Cardamom Mountains in Chantaburi Province and Stuart and Emmett's (2006) expanded description of a male and a female from the central Cardamoms. It is similar to Stuart and Emmett's (2006) female in having single asperities on tubercles from the upper parts of the chest and throat that are not grouped into clusters. In life, the dorsum was brownish and the flanks and tibial region greenish, both of which were mottled with lightened areas. The venter was dull-white.

This specimen was found at night sitting in a shallow pool below a small waterfall.

Rhacophoridae

Chirixalus nongkhorensis (Cochran, 1927)

LSUHC 7349–50: Aural Village, 4 August.

The two specimens agree with Cochran's (1927) description of the type series from Nong Khor in south-eastern Thailand and Stuart and Emmett's (2006) description of specimens from the central Cardamoms in having the two outer fingers (digits III and IV) nearly opposable to the inner two (digits I and II); interorbital distance much greater than the width of the upper eyelid; SVL greater than 20 mm (SVL 27 and 29 mm in our sample); dorsum reddish-brown with dark, transverse blotches and barred limbs; head slightly wider than body; tibiotarsal articulation reaches eye or slightly beyond it; toes nearly completely webbed; canthus angular; tympanum distinct. Taylor (1962b) stated that the outer two fingers are 2/3 webbed but in our specimens, webbing is restricted to the base, toes 1/4–1/2 webbed at most.

Both specimens were calling while seated on the small leaves of low bushes adjacent to roadside puddles.

Philautus parvulus (Boulenger, 1893)

LSUHC 7422–27: 7 August 2005; LSUHC 7460: 8 August; all from Camp II.

Seven adult males (SVL 17–19 mm) agree with the descriptions of Taylor (1962b) of Thai specimens and largely with Stuart and Emmett's (2006) description of central Cardamom specimens in lacking vomerine teeth; having a snout shorter than the diameter of the orbit; slanted loreals; an interorbital region wider than the upper eyelids; hidden tympanum; slight finger webbing (Stuart and Emmett [2006] report no webbing and Taylor [1962b] reports webbing restricted to the base); webbing of third and fifth toe reaching the distal, subarticular tubercles; tibiotarsal articulation reaching eye; large digital discs; granular venter; large vocal sac in males.

All specimens were heard calling from bushes and small trees no more than 2 m above the ground. Most were seated on leaves. One male was observed in an inverted position on the underside of a leaf and two others were observed sidelong on small branches. During a cool, cloudy, windy day with light rain on 9 August, we heard *Philautus* calls while at the summit of Phnom Aural, at 1,813 m. The calls were coming from within tangled, moss-covered root masses at the bases of small trees. We were unable to collect any material and thus, can not equivocally state that the call was of *P. philautus* and not *P. cardamonus* which is known from 1,650 m on Phnom Samkos and 1,250 m from Phnom Tumpor in the western Cardamoms (Ohler et al., 2002).

Polypedates cf. *leucomystax* (Gravenhorst, 1829)

LSUHC 7347–48, 7354–55: Aural Village, 4 August.

Three specimens (LSUHC 7347–48, 7354) match the description of *Polypedates leucomystax leucomystax* in Taylor (1962b) in that the skin of the head is fused to the frontoparietal and nasal bones; vocal sac present in males; interorbital space wider than the upper eyelid; tympanum distinct; fingers with small (nearly absent in our sample) webbing; toes at least 2/3 webbed; digital discs smaller than tympanum; tibiotarsal articulation reaching from eye to end of snout; vomerine teeth; hourglass-shaped, dark marking on head and occiput reaching shoulders. LSUHC 7354 has all the above characteristic except in having four, dark, dorsal stripes instead of an hourglass marking, thus matching the description of *P. l. sexvirgatus* (Taylor, 1962b).

The *Polypedates leucomystax* complex is remain incompletely known, with many distinct forms from various regions masquerading under a single name (Inger et al., 1999; Inger and Tan, 1996; Matsui et al., 1986; Orlov et al., 2001; Trepanier et al., 1999; Zhao and Adler, 1993). The four individuals reported here were collected at night, while sitting on the leaves of low bushes next to roadside puddles. Many others were heard calling from nearby vegetation.

Rhacophorus bipunctatus Ahl, 1927

LSUHC 7420–21: Camp II, 7 August.

Two adult males (SVL 37 and 38 mm) agree with the description of an adult male described by Stuart and Emmett (2006) from the central Cardamoms in that the webbing on the third finger extends beyond the distal margin of the distal subarticular tubercle; the dermal projection of the tibiotarsal joint is almost non-existent as opposed to just being small; and the lack of a dark, axillary blotch as opposed to having one.

Both specimens were heard calling during the early evening and located on the branches of small trees adjacent to a stream, approximately 3–4 m above the ground.

Testudinidae

Indotestudo elongata Blyth, 1854

LSUDPC 1202–03: Camp I, 5 August.

One individual was found by our guide's dogs, as it was crawling through leaf litter and brought to camp, was photographed and released.

Agamidae

Acanthosaura crucigera Boulenger, 1885

LSUHC 7337, 7393–95, 7406: Camp I, 5 August. LSUHC 7446–47, 7451, 7457: Camp II, 8 August. LSUHC 7466: above Camp II at 1400 m, 9 August.

A series of 10 specimens agrees reasonably well with Boulenger's (1885) description of a male and female from Tavoy, Myanmar and Stuart and Emmett's (2006) description of a series of eight specimens from the central Cardamoms, except Boulenger's (1885) description mentioned *A. crucigera* as having 9 or 10 supralabial and infralabial scales. In the Cardamom series from this survey, supralabial scales range from 12–14 and infralabials from 10–13. This is in accord with nine specimens of *A. crucigera* examined from southern Thailand and northern Malaysia (FMNH 177677, 177892–98, LSUHC 6831) whose supralabials are 12 or 13 in number and infralabials range from 11–14. Additionally, our series shows remarkable colour pattern variability and some lack the diagnostic, black, diamond-shaped nuchal blotch (Taylor, 1963). LSUHC 7447 (male; SVL 155 mm; Fig. 19 upper) has a nearly uniform, blonde-coloured dorsum; uniform, light-greenish limbs; a black eye patch that does not contact the nostril and ends posteriorly dorsal to the tympanum; a beige, nearly unpigmented gular sac; and a dark vertebral blotch on the nape lacking ventrally projecting "arms" which in other populations, connect to a dark, antebrachial blotch. In contrast, LSUHC 7393 (female; SVL 118 mm; Fig. 19 middle) has the typical colour pattern of *A. crucigera* with a black eye patch extending from the nostril through the tympanum; a dark diamond-shaped nuchal blotch with ventrally projecting arms; a black gular sac; and a greenish-yellow dorsum with grey reticulations enclosing yellow spots. A juvenile female (LSUHC 7394; SVL 62 mm; Fig. 19 lower) has a colour pattern similar to that of LSUHC 7393 except for being more boldly contrasted and having a spotted as opposed to an immaculate venter. Smith (1935) noted that the gular sac attained its greatest development in populations from south-eastern Thailand and southern Indochina. The southern Thai and northern Malaysia specimens examined here are in accord with Smith's (1935) assessment of gular sac geographic variation in that they are less than one-half the size of those from the Cardamom Mountains.

All specimens from Camp I were captured at night, while sleeping on low branches and the trunks of trees. Some lizards from camp II were also collected at night but LSUHC 7451 and 7457 were found beneath logs during the day. LSUHC 7466 was collected at 1,400 m in elevation during mid-morning, while basking in a sun-spot on the side of a large tree. LSUHC 7447 (SVL 155 mm) contained 18 eggs.

Calotes versicolor (Daudin, 1802)

LSUHC 7360: Aural Village, 4 August. LSUHC 7327, 7487: between Aural Village and base of Phnom Aural, 5 August. LSUHC 7408: Camp I, 6 August and LSUHC 7483, 10 August.

Two subadults (SVL 64–75 mm) and three juveniles (SVL 26–43 mm) match Taylor's (1963) diagnosis and specimens from Malaysia (LSUHC 7230–31, 7245–47) in having posterodorsally-directed, keeled scales on the flanks; no fold anterior to the shoulders; a pair of spines above the tympanum; nuchal and dorsal crests continuous, the spines of which diminish in size posteriorly; gular region with dark, oblique lines; dark lines radiating from eye; and a faded, dark median line in pectoral and abdominal region.

This species was relatively common during the day on shrubs and fences in Aural Village and in the branches of small trees in the disturbed forest between Aural Village and the base on Phnom Aural. *Calotes versicolor* is common in anthropogenically modified habitats. The specimens collected at Camp I were found on logs and branches or in grassy areas in forest edge situations.

Draco maculatus (Gray, 1845)

LSUHC 7321–22: between Aural Village and base of Phnom Aural, 5 August. LSUHC 7342–44, 7389–90: Camp I, 6 August and LSUHC 7411, 7 August.

Eight specimens (five males, SVL 34–70 mm; three females, SVL 66–72) agree closely with Muster's (1983) diagnosis in having outwardly directed nostrils; a series of keeled scales on the rostrum forming an inverted Y; two enlarged, median, maxillary teeth; 9–11 (instead of 7–11), smooth supralabials; a low superciliary spine; tympanum covered in scales; lateral pouches with enlarged scales; nuchal crest present; unequal dorsals; five ribs in patagium; hind limbs as long as distance between limbs; and strongly keeled caudal scales with a low crest.

All specimens were found 3–8 m up on the sides of trees. We noted considerable variation in wing pattern between males and females (Figs. 22, 23) not reported in Taylor (1963) or Musters (1983), both of whom described only males. Males had sulphur yellow patagia with orange outer margins, whereas females had grey patagia with thin, white lines and large, dull, yellow blotches. Males reported by Stuart and Emmett (2006) from the central Cardamoms and Elephant Mountains apparently lacked the extensive red and orange reported here.

Draco taeniopterus Günther, 1861

LSUHC 7332: base of Phnom Aural, Camp I, 6 August: LSUHC 7336, 7340, 7366–68, 7372–73, 6 August. LSUHC 7412–19: between Camp I and Camp II between 847 and 913 m, 7 August. LSUHC 7456: Camp II, 8 August.

A series of 13 males (SVL 71–83 mm) and four females (SVL 74–78 mm) agrees closely with Muster's (1983) diagnosis in having upwardly directed nostrils; a row of keeled scales on the rostrum; two enlarged, median maxillary teeth; 7–10 (instead of 6–10) keeled supralabials; no superciliary spine; tympanum naked; lateral pouches with enlarged scales in both sexes; nuchal fold present in males; unequal, weakly-keeled dorsals; five ribs in patagium; hind limbs as long as distance between limbs; and strongly keeled caudal scales with no crest. Muster (1983) reports 77 mm as the largest male SVL. LSUHC 7412 SVL 83 mm.

All specimens were observed during the day on tree trunks, 3–10 m above ground. *Draco taeniopterus* was most common in undisturbed forest between Camps I and II.

Physignathus cocincinus Cuvier, 1829

LSUHC 7486: between Aural Village and base of Phnom Aural, 10 August.

A juvenile specimen agrees with Taylor's (1963) diagnosis and Stuart and Emmett's (2006) slightly expanded description of specimens from the central Cardamoms in having a laterally compressed body and tail; continuous nuchal and dorsal crests separated from caudal crest by a hiatus of smaller scales; sublabials larger than infralabials; tympanum partly covered with scales; enlarged scales posterior to angle of jaw; nuchal fold present; femoral pores in short series; keeled subcaudals; and dorsum green with four, oblique, thin, white bands.

This specimen was collected during the day, while resting on a branch overhanging a small stream.

Gekkonidae

Cosymbotus platyurus (Schneider, 1792)

LSUHC 7323–24: between Aural Village and base of Phnom Aural, 5 August.

Two adult females (SVL 31–33 mm) match Taylor's (1963) diagnosis of Thai specimens and material from Malaysia (LSUHC 3874, 5564, 6430, 6636, 6732, 7146) in having partially webbed digits with expanded lamellae on the proximal half of toes; distal phalanges long, slender, arising from an angle from the toe pads; two pairs of chin shields; a fringe of skin from axilla to groin covered with small scales; no fringe on the neck or head; and a broad fringe along the posterior margin of the hind limb.

Both specimens were found during the day, on the trunks of trees, approximately 3 m above the ground. This species is common in anthropogenically modified environments throughout most of south-east Asia (Manthey and Grossmann, 1997).

Cyrtodactylus intermedius (Smith, 1917)

LSUHC 7346, 7365: Camp I, 5 August. LSUHC 7396–7401, 7490–10: Camp II, 8 August. LSUHC 7459: Camp II, 8 August.

A series of 11 specimens match the original description of Smith (1917) based on Thai material, the diagnosis of Taylor (1963) based on a topotype, and the abbreviated description of Stuart and Emmett (2006) based on a large series from the central Cardamoms, in adult males having 8 or 9 preanal pores in an angular series; enlarged preanal scales; 7–12 enlarged femoral scales in adult males lacking pores which may or may not be continuous with the preanal pore series; distinct ventrolateral folds; ear opening less than half diameter of eye; transversely enlarged subcaudals; preanal groove absent; cream-edged, dark-brown, wide nuchal loop;

four dark body bands edged in yellow to white; and dark and light bands on the tail.

All specimens were collected at night in microhabitats ranging from rocks along edges of streams, tree trunks, up to 2 m above ground in vegetation, to leaf litter. However, rocks were the most common substrate. This is in accord with the observations made by Stuart and Emmett (2006) of populations from the central Cardamoms. This species was far more abundant at Camp I than at Camp II.

Dixonius siamensis (Boulenger, 1898)

LSUHC 7328: base of Phnom Aural, 5 August. LSUHC 7378: Camp I, 6 August.

One adult male (LSUHC 7378, SVL 40 mm) and one subadult female (LSUHC 7328 SVL 28 mm) agree closely with the original description of Boulenger (1898) of a specimen from the Dong Paya Fai Mountains in eastern Thailand, the extended description of Smith (1935) based on a series of approximately 80 specimens from throughout Thailand (see Smith, 1930), and the diagnosis of Taylor (1963) in having expanded subdigital lamellae at the tip of the digit only; a vertebral series of fine body scales flanked by 5–7 rows of enlarged, keeled scales that blend ventrally into the large, imbricate, cycloid ventral scales; ventral scales with minute posterior serrations, 18 and 20 longitudinal rows (20–25 in Smith, 1935); six preanal pores in an angular series; caudal scales irregular (as in Smith [1935], not in segmented whorls as in Taylor [1963]) and keeled; subcaudals transversely widened; and head, back and sides with numerous black spots and lacking a dark lateral stripe on head.

Both specimens were found during the day on rocks. Smith (1935) and Taylor (1963) mentioned that this species is widespread throughout Thailand.

Gehyra cf. *fehlmanni* Taylor, 1962

LSUHC 7376, 7379, 7392: Camp I, 6 August.

Two subadult females (SVL 34 and 45 mm) and one adult male (SVL 47 mm) agree with Taylor's (1962a, 1963) descriptions of specimens from Ronpibon, Nakhon Si Thammarat, western Thailand in having flat dorsal body scales; scales of snout twice the size of those in interorbital region and occiput; slight webbing on hands and feet; medial row of enlarged subcaudals; largest body scales in preanal region; dorsal caudals somewhat irregular not forming distinct transverse rows; and third pair of chin shields separated from the infralabials. They differ, however, from Taylor's (1962a, 1963) descriptions as follows: the scales on the snout are granular as opposed to being subimbricate; the subcaudal scales at the base of the tail are not enlarged; the femoropreanal pore series extends nearly the entire length of the femurs, as opposed to just one-half their lengths and is composed of 37, rather than 22 pores; the seventh, eighth, or ninth supralabial is below the pupil, as opposed to only the seventh; and the fifth, sixth, or seventh infralabial is below the pupil as opposed to only the seventh.

All three specimens were collected during the day beneath loose bark. Additional specimens were observed at night on rocks. *Gehyra fehlmanni* is known from Thailand and Vietnam (Manthey and Grossmann, 1997) so it would be expected to occur in Cambodia and this series may constitute the first record. The differences in scale morphology and femoropreanal pore characters between these specimens and the type require further study to adequately ascertain the species status of this population.

Gekko gecko (Linnaeus, 1758)

LSUHC 7364: Aural Village, 4 August.

An adult female (SVL 142 mm) matches Taylor's (1963) diagnosis of Thai specimens in having a head covered with polygonal scales; rostral scale not bordering nostril; 3–5 small dorsal scales between larger tubercles; no webbing; undivided subdigital lamellae; 5 or 6 transverse scale rows in caudal segments; and a grey dorsum with orange and white spots.

This specimen was found in the wood rafters of a hut in Aural Village. This species is a common human commensal.

Hemidactylus frenatus (Schlegel, 1863)

LSUHC 7361: Aural Village, 6 August.

An adult male with a continuous series of 28 femoropreanal pores agrees with Taylor's (1963) diagnosis of Thai specimens in having small dorsal body granules intermixed with larger tubercles; two pairs of equally sized postmentals contacting the labials; and whorls of caudal spines.

Besides the specimen collected in Aural village, many others were seen at Camp I beneath bark, under logs, on tree trunks and rocks. This species is a common human commensal and an inhabitant of anthropogenically modified environments.

Scincidae

Eutropis macularius (Blyth, 1853)

LSUHC 7329: Camp I, 5 August, LSUHC 7331, 6 August, LSUHC 7430, 7 August. LSUHC 7363: between Aural Village and base of Phnom Aural, 4 August. LSUHC 7482: base of Phnom Aural, 8 August.

Five specimens (three juveniles, SVL 27–36 mm; one gravid female, SVL 62 mm; one adult male, SVL 62 mm) agree with Smith's (1935) description of his number "1" population in having a scaly lower eyelid; a postnasal; small anterior loreal and large posterior loreal; dorsal scales with 5–9 keels; 14–15 lamellae beneath fourth toe; a mite patch on the thigh; bronze above with small, black spots; light, anterior dorsolateral stripe; flanks dark with light spots; and a white line from angle of jaw to anterior margin of flanks.

Eutropis macularius is a widely distributed, highly variable species (Smith, 1935) ranging from Pakistan to Indochina and throughout south-east Asia (Manthey and Grossmann, 1997) that is common in anthropogenic habitats. Ota et al. (2001) demonstrated that populations from eastern and western Thailand had trenchant differences in karyotype morphology and suggested they were probably different species. One of the eastern populations they sampled came from Sakaerat, just north of the Chanthaburi Mountains of southern Thailand which are continuous with the Cardamom Mountains. It is likely the *E. macularius* from the Cardamom Mountains has the same karyotype as those from eastern Thailand.

Eutropis multifasciatus (Kuhl, 1820)

LSUHC 7370: Camp I, 6 August.

An adult female (SVL 87 mm) is largely in accord with Taylor's (1963) diagnosis of Thai specimens and a series from northern Malaysia (LSUHC 6811, 6843, 7080, 7101, 7106, 7113–14, 7118–19, 7121–22, 7151, 7170–72) in having the supranasals slightly separated; a postnasal; prefrontals in contact; first loreal higher than second; no transparent disc in lower eyelid; dorsals tricarinate; 31 longitudinal scale rows around midbody (30–34 in Taylor's material); and sides dark with ocelli.

The specimen was observed foraging in an open area near small rocks. This species is common in both disturbed and undisturbed environments.

Lipinia vittigera (Boettger, 1901)

LSUHC 7375, 7391: Camp I, 6 August.

An adult male (SVL 43 mm) and female (SVL 38 mm) closely match Taylor's (1963) diagnosis of Thai specimens and Stuart and Emmett's (2006) description of material from the central Cardamoms in having a pointed snout; prefrontals in contact; ear opening smaller than lower eyelid disc and lacking lobules; median pair of dorsal vertebral scales widened; two large preanals; transversely widened subcaudals; light golden vertebral stripe extending from tip of snout to base of tail bordered by black body fields; and flanks light with black flecks.

Both specimens were collected during the day, one specimen was collected 3 m above the ground on trunk of a tree and the other was caught while foraging in an open area on the ground.

Lygosoma bowringii (Günther, 1864)

LSUHC 7325: between Aural Village and base of Phnom Aural, 5 August, LSUHC 7362, 4 August. LSUHC 7730: Camp I, 5 August.

Three specimens (two adult females, SVL 33–32 mm and one juvenile, SVL 24 mm) match Taylor's (1963) diagnosis of Thai specimens and specimens from northern Malaysia (LSUHC 6837–38) in having limbs separated by one arm length when adpressed; a pair of nuchals present; lower eyelid scaly; 27–28 longitudinal scale rows around midbody; dorsal scales smooth; and a black dorsolateral stripe.

All specimens were found beneath surface debris in disturbed areas.

Scincella melanosticta (Boulenger, 1887)

LSUHC 7334–35, 7374, 7380–82, 7386, 7402–05, 7407: Camp I, 6 August. LSUHC 7452–53, 7458: Camp II, 8 August.

Eighteen specimens (eight adult females SVL 44–52 mm; two adult males SVL 52–54 mm; eight juveniles, SVL 23–33 mm) agree with the Ouboter's (1986) diagnosis of material from Myanmar, Thailand, and southern Vietnam and Stuart and Emmett's (2006) description of specimens from the central Cardamoms in having a robust head; relatively long limbs; prefrontals in broad contact; small scales between the fifth supralabial and the granules of the lower eyelid; eyes visible as a dark area through the supraoculars; 23–38 scales around midbody; and white markings on dark flanks.

All individuals were collected during the day and were observed foraging in the leaf litter in both open and dense areas of the forest. They were observed in highest concentrations in the vicinity of rocks and logs. LSUHC 7374, 7386, and 7404 were gravid and LSUHC 7407, an adult male, had bright-orange breeding colours on its head, neck, and throat (Fig. 29 upper).

Ouboter (1976) regarded all continental populations of *Scincella melanosticta* as *S. m. melanosticta* and considered its range to extend from eastern Myanmar through all of Thailand and also in southern Vietnam, noting its likely occurrence in Laos and Cambodia. Although not reported by Teynie et al. (2004) from an extensive collection made in southern Laos, it was reported from the central Cardamoms by Stuart and Emmett (2006). Ouboter (1986) listed a number of discrete (*sensu* Grismer 1999, 2000) morphological characters separating *S. m. melanosticta* from *S. m. kohtaoensis,* an endemic to Koh Tao Island in the Gulf of Thailand. Based on this, and its insular distribution, we treat it here as a full species.

Sphenomorphus indicus (Gray, 1853)

LSUHC 7341, 7345, 7369, 7371, 7377: Camp I, 6 August. LSUHC 7445: between Camp I and Camp II at 850 m, 7 August. LSUHC 7454, 7462: Camp II, 8 August.

Two adults (LSUHC 7462, male, SVL 78 mm; LSUHC 7445, female, SVL 84 mm), two juveniles (LSUHC 7454, female, SVL 45 mm; LSUHC 7377, male, SVL 60 mm), and four near hatchlings (SVL 23–29 mm) closely match Taylor's (1963) description of material from northwestern Thailand in having a convex rostral in contact with frontonasal; prefrontals not in contact; 34–36 longitudinal scale rows around midbody; tubercles on soles and palms; limbs well-developed and overlapping when adpressed; and a dark lateral stripe edged above with white (most distinctive in small individuals).

All individuals were collected during the day on the forest floor in leaf litter, usually in the vicinity of rocks or logs.

Leiolepididae

Leiolepis cf. *belliana* (Hardwicke & Gray, 1827)

Several individuals were observed in disturbed areas along the dirt road leading toward the base of Phnom Aural from Aural Village. No specimens were collected and their identification is tentative.

Colubridae

Ahaetulla nasuta (Lacépède, 1789)

LSUHC 7333: Aural Village, 4 August.

An adult female (SVL 654 mm) agrees with Taylor's (1963) description of a specimen from Bangkok, Thailand in having a dermal process on the upper lip extending far beyond the lower jaw and formed entirely from the rostral; loreals absent; canthus rostralis sharp; one preocular contacting the frontal; and eight supralabials. It differs from Taylor's (1963) description in the length of the snout being just over three times the diameter of the eye as opposed to being 2–2.5 times the diameter and the fifth and sixth supralabials contacting the orbit rather than the third and fourth. LSUHC 7333 is lime green in colour with a white, ventrolateral stripe beginning at the angle of the jaw and extending nearly to the tip of the tail.

This species was brought to us by a resident of Aural Village who caught it in some vines near his house. This is the first report of this species from the Cardamom Mountains.

Amphiesma cf. *khasiensis* (Günther, 1875)

LSUHC 7442–44: 7 August, LSUHC 7464–65, 9 August; LSUHC 7484: 19 August; all from Camp II.

The taxonomy of *Amphiesma* in this part of south-east Asia is problematic. Smith (1943) considered *A. modestum* (Günther, 1875) a widespread, highly variable species. Taylor (1934) described *A. deschauenseei* from Chiang Mai in northern Thailand, which he later demonstrated to include part of Smith's (1943) series of *A. modestum* from "N. Siam" [northern Thailand] (Taylor 1965). Additionally, we could find no reliable characters from the literature that differentiate *A. khasiensis* (Boulenger 1890) from *A. modestum,* although *A. deschauenseei* can be separated on the basis of colour pattern (Taylor 1965) and having 140 subcaudal scales as opposed to 143–168 in *A. modestum* and 94–110 in *A. khasiensis*. Smith (1943:283) erroneously indicated that *A. modestum* and *A. khasiensis* could be separated on the basis of labial colouration although his description of this character clearly allows for considerable overlap. Our six specimens closely match the description of *A. modestum* and *A. khasiensis* except in having more ventral scales (163–176) than either species (144–155 in *A. khasiensis* and 148–168 in *A. modestum* [Smith, 1943]). They also do not conform to the original description of *A. khasiensis* (Boulenger, 1890) or Smith's (1943) description of this taxon because they have 112–123 subcaudals as opposed to 80–110. Stuart and Emmett (2006) report a specimen from the central Cardamoms with 160 ventral scales which they refer to as *A. khasiensis.* They indicated that it differs from Boulenger's (1890) description of the type series in having 160 ventral scales (vs. 150–154) and that the light-coloured nuchal stripe arises from the posterior margins of the eyes instead of from the supralabials. The nuchal stripe does arise from the posterior margin of the eyes but then it continues across the posterior three supralabials (seven, eight, and nine), thus "forming a continuation of the series of yellow labial spots" (Boulenger, 1890). This is visible in Boulenger (1893:Plate XIII; Fig. 3) and is the condition observed here in our eastern Cardamom specimens (Fig. 35).

Patrick David (in lit., 2005, 2006) indicates that the Cardamom populations are not *A. modestum* which has a different head and body colour pattern and characters of scalation but are closer to *A. khasiensis* in colour pattern. Therefore, we elect to refer to this population as *A.* cf. *khasiensis* until further investigation.

All specimens were collected along edges of or within a shallow stream near camp, during both day and night.

Chrysopelea ornata (Shaw, 1802)

LSUHC 7387: between base of Phnom Aural and Aural Village, 5 August.

A juvenile female (SVL 323 mm) matches Taylor's (1965) diagnosis of Thai specimens and material from northern Malaysia (LSUHC 7158, 7387) in having median maxillary teeth no larger than the series preceding the enlarged rear teeth; 20–22 maxillary teeth, the last three or four larger and grooved; ventral scales laterally notched; anal shield divided; all light scales of dorsum having a black, median line; and head banded in black and yellow.

This specimen was collected during the day approximately 2 m above ground, while ascending a tree along a road.

Dendrelaphis subocularis (Boulenger, 1888)

LSUHC 7429: on a ridge west of Camp I at 710 m elevation, 7 August.

A juvenile female (SVL 233 mm) matches Taylor's (1965) description of a specimen from northern Thailand in having 15 dorsal scales; eight supralabials; an elongate supralabial bordering the ventral margin of the orbit; single row of slightly enlarged vertebral scales; anterior median series of scales with a series of light-coloured dots tending to form a stripe; and a yellow lateral stripe.

This specimen was collected during the day, while it was crossing a trail in a heavily disturbed secondary forest.

Pareas margaritophorus (Jan, 1866)

LSUHC 7463: Camp II, 8 August.

A juvenile (sex undeterminable, SVL 105 mm) matches Grossmann and Tillack's (2003) generic concept of *Pareas* and is in accord with Taylor's (1965) description of two specimens from northern Thailand and a specimen from northern Malaysia (LSUHC 6876) in having 15 rows of smooth dorsal scales at midbody; an enlarged row of vertebral scales; one or two preoculars; prefrontals not excluded from orbit; two preoculars; suboculars preventing supralabials from contacting eye; three inframaxillaries (= chinshields) with first pair being longer than wide; 151 ventral scales; and a wide nuchal band.

This specimen was collected during the day, while it was moving on the forest floor.

Psammodynastes pulverulentus (Boie, 1827)

LSUHC 7480: on a ridge west of Camp I at 760 m elevation, 10 August.

A juvenile female (SVL 155 mm) matches Smith's (1943) description and Taylor's (1965) diagnosis of Thai specimens in having two enlarged, fang-like, anterior maxillary teeth followed by a diastema; last series of maxillary teeth enlarged, grooved, and fang-like; canthus angular; frontal narrow; internasals smaller than prefrontals; single preocular; eight supralabials with third, fourth, and fifth contacting orbit; and eight infralabials.

This specimen was collected during the day in disturbed forest along a trail on a steep slope, while it was coiled on the surface of a cut tree stump.

Rhabdophis chrysargos (Schlegel, 1837)

LSUHC 7461: Camp II, 8 August.

A juvenile female (SVL 180 mm) matching Smith's (1943) description, Taylor's (1965) diagnosis of Thai material, Stuart and Emmett's (2006) abbreviated description of a specimen from the central Cardamoms, and specimens from Malaysia, (LSUHC 4791, 4955, 5013, 5174, 5176, 6148, 6255, 7252, 7308–10) in lacking nuchal glands and light vertebral and lateral stripes but having 28 maxillary teeth; nine supralabials with the fourth, fifth, and sixth entering the orbit; four post oculars (three in Stuart and Emmett [2006] and Taylor [1965]); 2 + 2 temporals; 19 keeled dorsal scale rows; 155 ventrals; 91 subcaudals; olive-brown dorsum with a row of black-edged, light-coloured, dorsolateral spots connected transversely by a faded dark bar; darkly-edged, yellow supralabials; thin, white, posteriorly-pointed, nuchal band extending posteriorly form the corners of the mouth and confluent with light-coloured supralabials; venter beige with dark lateral spots but lacking the thin mid-ventral stripe described in Taylor (1965).

This specimen was found at night, while crawling on the forest floor near the base of a tree, away from water.

Viperidae

Cryptelytrops albolabris (Gray, 1842)

LSUHC 7468, 7485: Camp I, 6 August.

Two adult females (SVL 384 and 522 mm) match Malhotra and Thorpe's (2004) characterization of the genus in having a fused nasal and first supralabial (no males were collected, hence hemipenis morphology not examined). Additionally, they are in general accord with Taylor's (1965) description in having 10 supralabials; internasals in contact (LSUHC 7468) or not (LSUHC 7485); supraocular narrow (divided on right side in LSUHC 7485); diameter of eye roughly equal to distance from ventral edge of eye to margin of upper lip; 183–186 ventrals; 60–62 subcaudals; head and body uniform lime-green with a cream-coloured to white ventrolateral stripe; venter light-green; tail reddish-brown.

Both specimens were found at night, while coiled in the branches of small trees in a disturbed portion of the forest, 1.5–3 m above ground. Stuart and Emmett (2006) report on a specimen from the central Cardamoms with 160 ventrals.

Viridovipera vogeli (David, Vidal & Pauwels, 2001)

LSUHC 7467: Camp II, 9 August.

A juvenile female (SVL 298 mm) matches Malhotra and Thorpe's (2004) characterization of the genus in part in that the nasal and first supralabial are not fused (no males were collected so hemipenis morphology could not be checked). Additionally, it is in accord with David et al.'s

(2001) description and Malhotra et al.'s (2004) re-description in having separated internasals; 12 supralabials; 21 dorsal scale rows; 172 ventrals; 60 subcaudals; body generally uniform, light-green with faint banding anteriorly; a white, ventrolateral line; ventral scales yellowish laterally and pale green centrally; tail brick-red. David et al. (2001) noted that the holotype from Thailand has two small triangular postnasal scales whereas LSUHC 7467 has one. Stuart and Emmett (2006) reported on a specimen from the central Cardamom Mountains which has 163–165 ventrals as opposed to 172 ventrals in LSUHC 7467.

This specimen was collected at night just above Camp II, while coiled on the branch of a small tree, 1 m above the ground.

DISCUSSION

We report 16 species of frogs representing five families, one species of turtle (Testudinidae), 18 species of lizards representing four families, and nine species of snakes representing two families (Table 1). All four species of microhylids, as well as *Occidozyga lima, O. martensii* and *Polypedates* cf. *leucomystax* are species common to anthropogenically modified habitats and have previously been reported as occurring

Table 1. Checklist of the herpetofauna of the Cardamom Mountains. Each species is followed by the most recent or first reporting author. 1 = Daltry and Chheang (2000); 2 = Ohler et al., (2002); 3 = Stuart and Emmett (2006); 4 = this report; 5 = Stuart and Platt (2004); 6 = seen during survey but not vouchered; 7 = Long et al. (2001); 8 = Swan and Daltry (2002); 9 = Daltry and Traeholt (2003); and 10 = Chuaynkern et al. (2004).

	Northwestern Cardamoms	Central Cardamoms	Northeastern Cardamoms	Southeastern Cardamoms
CAECILIANS				
Ichthyophiidae				
Icthyophiid sp.		BMNH 2005. 1498–99		
FROGS				
Megophryidae				
Leptolalax sp.			2,8	
Megophrys auralensis Ohler, Swan & Daltry 2002		3	2,8	
Bufonidae				
Bufo macrotis Boulenger 1887	2	2,3,7,9	2,4	
Bufo melanostictus Schneider 1799	2	2,3,7	2,4,8	
Bufo parvus Boulenger 1887	2	9		
Microhylidae				
Calluela guttulata (Blyth 1855)		3		
Kalophrynus interlineatus (Blyth 1855)		2,3,7	2	
Kaloula pulchra Gray 1831	2	2,7,9	2,4,8	
Microhyla annamensis Smith 1923	2	2		
Microhyla berdmorei (Blyth 1856)	2	2		3
Microhyla butleri Boulenger 1900		2,3,7	2,4,8	
Microhyla heymonsi Vogt 1911	2	2,3,7	2,4,8	
Microhyla fissipes (Duméril, Bibron & Duméril 1841)	2	2		
Microhyla pulchra (Hallowell 1861)	2	2,3	2,4,8	
Micryletta inornata (Boulenger 1890)	2	3		
Ranidae				
Fejervarya cancrivora (Gravenhorst 1829)			4	
Fejervarya limnocharis (Gravenhorst 1829)	1,2	2,7,9	2,8	
Hoplobatrachus chinensis (Osbeck 1765)	2	7	2,8	

Limnonectes gyldenstolpei (Anderson 1916)	1,2			
Limnonectes kochangae (Smith 1922)	2	2,3,9	2,4,8	3
Occidozyga lima (Gravenhorst 1829)	2	3	2,4,8	
Occidozyga martensii Peters 1867	2	2,3,7,9	2,4,8	
Paa fasciculispina (Inger 1970)	2	3	2,8	
Rana erythraea (Schlegel 1837)		2,3,7,9	2,8	
Rana faber Ohler, Swan & Daltry 2002	2	2,3,7	2,8	3
Rana macrodactyla (Günther 1859)		2,7		
Rana milleti Smith 1921		3	10	
Rana mortenseni Boulenger 1903	2	2,7	2,8	3
Rana taiphensis van Denburgh 1909	2	2		
Rhacophoridae				
Chirixalus doriae Boulnger 1893		2,7		
Chirixalus nongkhorensis (Cochran 1927)		3	4	3
Chirixalus vittatus (Boulenger 1887)	2	3,7	2,8	
Philautus cardamonus Ohler, Swan & Daltry 2002	2			
Philautus parvulus (Boulenger 1893)		1	2,4,8	3
Polypedates cf. leucomystax (Gravenhorst 1829)		2	2,4,8	
Rhacophorus bipunctatus Ahl 1927		3	2,4,8	
Rhacophorus bisacculus Taylor 1962	2	3		3
Theloderma asperum (Boulenger 1886)			2,8	
Theloderma stellatum Taylor 1962		3		
TURTLES				
Bataguridae				
Batagur baska (Gray 1831 "1830–35")		5		
Cuora amboinensis (Daudin 1802)	1	1,5	4,8	
Cyclemys atripons Iverson and McCord 1997		1,5,7		
Heosemys grandis (Gray 1860)		5		
Malayemys subtrijuga (Schlegel and Müller 1844)		5		
Siebenrockiella crassicollis (Gray 1831)		5		
Testudinidae				
Indotestudo elongata (Blyth 1853)	1	1,5,7	4,8	
Manouria impressa (Günther 1882)	1	1		
Trionychidae				
Amyda cartilaginea (Boddaert 1770)	1,5	1,9	8	
Pelochelys cantori Gray 1864		1		
CROCODYLIA				
Crocodylidae				
Crocodylus siamensis (Müller 1838)	unpubl. data	1,7,9		
SQUAMATA (LIZARDS)				
Agamidae				
Acanthosaura crucigera Boulenger 1885	1	3,9	4,8	3
Calotes emma Gray 1845	1	1,3,7,9	8	
Calotes mystaceus Duméril & Bibron 1837	1	3,9	8	3
Calotes versicolor (Daudin 1802)	1	3,7,9	4,8	
Draco maculatus (Gray 1845)	1	3,9	4,8	3
Draco taeniopterus Günther 1861	1	3	4,8	

Physignathus cocincinus Cuvier 1829	1	1,3,7	4,8	3
Lacertidae				
Takydromus sexlineatus Daudin 1802		3		3
Gekkonidae				
Cosymbotus platyurus (Schneider 1792)			4	
Cyrtodactylus intermedius (Smith 1917)	1	3	4,8	3
Dixonius siamensis (Boulenger 1898)	1	1,7	4	
Gehyra cf. fehlmanni (Taylor 1962)			4	
Gekko gecko (Linnaeus 1758)	1	3,7	4,8	
Hemidactylus frenatus Duméril & Bibron 1836	1	1	4,8	
Ptychozoon lionatum Annadale 1905		3		3
Scincidae				
Eutropis macularius (Blyth 1853)	1	3,7,9	4,8	
Eutropis multifasciatus (Kuhl 1820)		1,3,7,9	4	
Lipinia vittigera (Boulenger 1894)	1	1,3,7	4,8	3
Lygosoma bowringii (Günther 1864)	1	3	4,8	3
Lygosoma quadrupes (Linnaeus 1766)	1			
Scincella melanosticta (Boulenger 1887)	1	1,3,7,9	4	3
Scincella rufocaudata (Darevsky & Nguyen 1983)		3		
Sphenomorphus indicus (Gray 1853)	1	9	4,8	
Sphenomorphus maculatus (Blyth 1853)	1	3,7	8	3
Sphenomorphus stellatum (Boulenger 1900)		3		
Leiolepdidae				
Leiolepis cf. belliana (Lacépede 1789)			6	
Leiolepis reevesii (Gray 1831)			8	
Varanidae				
Varanus salvator Laurenti 1768	1	1,7	8	
Varanus nebulosus Gray 1831	1		8	
SQUAMATA (SNAKES)				
Typhlopidae				
Ramphotyphlops braminus (Daudin 1803)	1			
Typhlops muelleri Schlegel 1839		1,3,7		3
Xenopeltidae				
Xenopeltis unicolor Reinwart in Boie 1827		3		3
Colubridae				
Ahaetulla nasuta (Lacépede 1789)	1		4	
Ahaetulla prasina (Reinwart in Boie 1827)	1	1,3,7	8	
Amphiesma cf. khasiensis (Boulenger 1890)	1	3	4	
Boiga cyanea (Duméril, Bibron & Duméril 1854)		3		3
Boiga dendrophila (Boie 1827)		3		3
Boiga multomaculata (Boie 1827)		3	8	3
Boiga siamensis Nootpand 1971		3		
Chrysopelea ornata (Shaw 1802)	1	3	4	3
Dendrelaphis pictus Gmelin (1789)	1		8	
Dendrelaphis subocularis (Boulenger 1888)			4	

Dryocalamus davisonii (Blanford 1878)		3		3
Dryophiops rubescens (Gray in Gray and Hardwicke 1835)			1	
Elaphe porphyracea	1			
Elaphe radiata (Boie 1827)		1,7		
Elaphe taeniura (Cope 1861)	1			
Enhydris plumbea (Boie 1827)		1,7,9		
Enhydris bocourti (Jan 1865)		3		
Gonyosoma oxycephalum (Boie 1827)		1,3		
Homalopsis buccata (Linnaeus 1758)	1	1,3,7		3
Lycodon cardamomensis Daltry & Wüster 2002	1			
Lycodon laoensis Günther 1864			8	
Oligodon barroni (Smith 1916)	1			
Oligodon inornatus (Boulenger 1914)	1	3		
Pareas carinatus (Boie 1828)		1,3,9		3
Pareas margaritophorus (Jan 1866)		3	4	
Psammodynastes pulverulentus (Boie 1827)	1	1,3,7,9	4	
Ptyas korros (Schlegel 1837)	1	9	8	
Ptyas mucosus (Linnaeus 1758)	unpubl. obs.			
Rhabdophis chrysargos (Schlegel 1837)	1	1,3,7	4	
Rhabdophis nigrocinctus (Blyth 1856)	1	3	unpubl. obs.	
Rhabdophis subminiatus (Schlegel 1837)	1	1,7	8	
Sibynophis collaris (Gray 1853)	1			
Xenochrophis flavipunctatus (Hallowell 1860)	1	1,7	8	
Xenochrophis trianguligerus (Boie 1827)		3		
Elapidae				
Bungarus candidus (Linnaeus 158)	1	1,7		
Bungarus fasciatus (Schneider 1801)	1	unpubl. obs.		
Naja kaouthia Lesson 1831	1		8	
Ophiophagus hannah (Cantor 1836)	1			
Viperidae				
Calloselasma rhododstoma (Boie 1827)	unpubl. obs.	3	8	
Cryptelytrops albolabris (Gray 1842)	1	3	4,8	
Cryptelytrops macrops (Kramer 1997)	1	3	8	3
Viridovipera vogeli (David, Vidal & Pauwels 2001)	1	3	4,8	

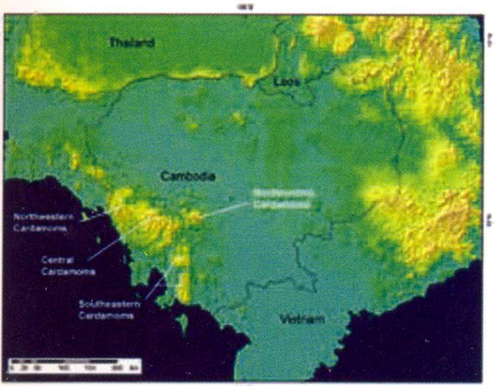

Figure 1. Location of the three sections of the Cardamom Mountains and Phnom Aural. Area above 330 m only is shown. Map adapted from Daltry and Momberg (2002).

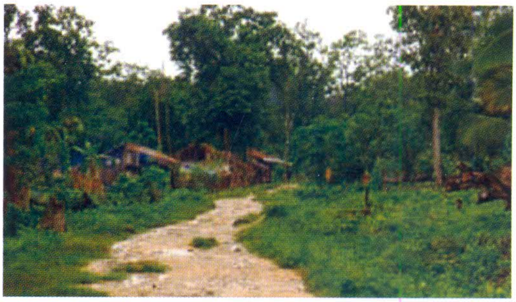

Figure 2. Habitat along the road in Aural Village at 100 m elevation.

Figure 3. Camp I at 500 m elevation in hill evergreen forest.

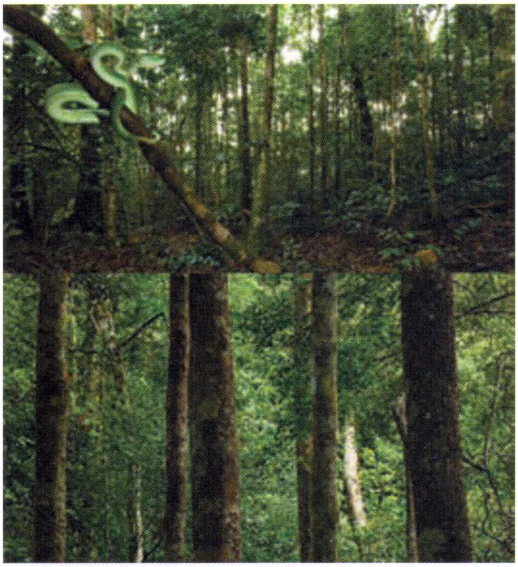

Figure 4. Camp II at 1,100 m elevation on the edge of montane evergreen forest. Upper: open understory of forest. Lower: large dipterocarp trees common at this elevation.

Figure 5. Summit of Phnom Aural at 1,813 m in elevation in cloud forest of the montane evergreen forest.

Figure 6. *Bufo macrotis* from the base of Phnom Aural. Upper; adult male (LSUHC 7470) and lower; adult female (LSUHC 7469).

Figure 7. Juvenile *Megophrys aurelensis* from Camp II (LSUHC 7428).

Figure 8. Adult female *Kaloula pulchra* (LSUHC 7359) from Aural Village.

Figure 9. Adult male *Microhyla heymonsi* (LSUHC 7356) from Aural Village.

Figure 12. Adult female *Occidozyga lima* (LSUHC 7358) from Aural Village.

Figure 10. Adult male *Microhyla pulchra* (LSUHC 7338) from Aural Village.

Figure 13. Adult male *Occidozyga martensii* (LSUHC 7477) from between Aural Village and Phnom Aural.

Figure 11. *Limnonectes kohchangae* from Camp II. Upper; adult male (LSUHC 7431) and lower; adult female (LSUHC 7448).

Figure 14. Adult male *Paa fasciculispina* (LSUHC 7339) from Camp I.

Figure 15. Adult male *Chirixalus nongkhorensis* (LSUHC 7349) from Aural Village.

Figure 16. Adult male *Philautus parvulus* (LSUHC 7423) from Camp II.

Figure 17. Adult male *Rhacophorus bipunctatus* (LSUHC 7420) from Camp II.

Figure 18. Adult male *Indotestudo elongata* (LSUDPC 1202) from Camp I.

Figure 19. *Acanthosaura crucigera* from Camp I. Upper, adult male (LSUHC 7447); middle, adult female (LSUHC 7393) and lower, juvenile female (LSUHC 7395).

Figure 20. Juvenile *Calotes versicolor* (LSUHC 7408) from Camp I.

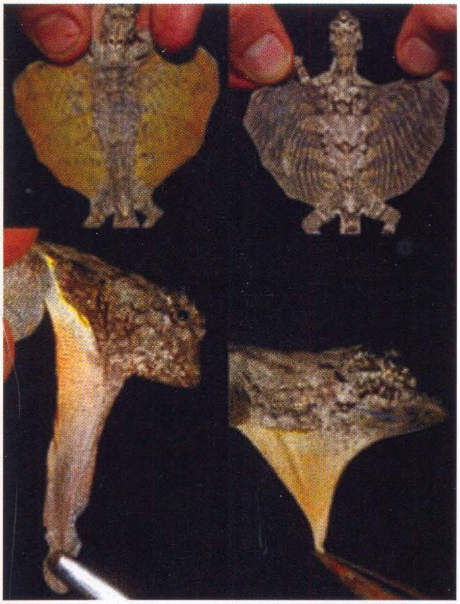

Figure 21. *Draco maculatus* from Camp I. Left, adult male (LSUHC 7389) and right, adult female (LSUHC 7411).

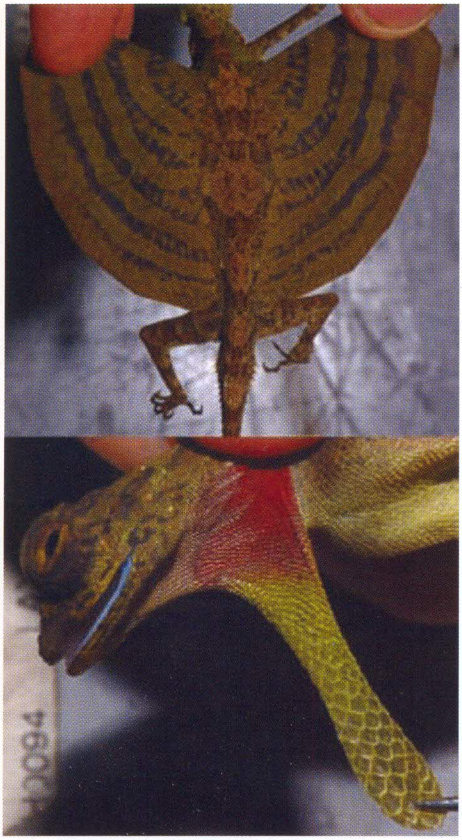

Figure 22. Adult male *Draco taeniopterus* (LSUHC 7456) from Camp II.

Figure 23. Juvenile female *Physignathus cocincinus* (LSUHC 7486) from between Aural Village and base of Phnom Aural.

Figure 24. *Cyrtodactylus intermedius* from Camp I. Upper, adult male (LSUHC 7346) and lower, juvenile female (LSUHC 7365).

Figure 25. Adult female *Dixonius siamensis* (LSUHC 7328) from Camp I.

Figure 26. Adult female *Gehyra* cf. *fehlmanni* (LSUHC 7376) from Camp I.

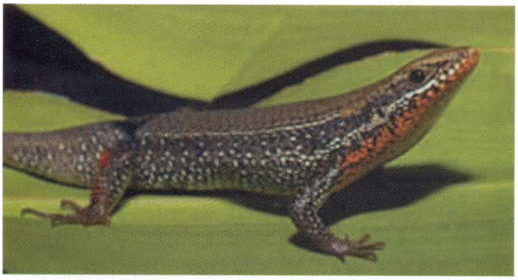

Figure 27. Adult male *Eutropis macularius* (LSUHC 7482) from base of Phnom Aural.

Figure 28. Adult female *Lipinia vittigera* (LSUHC 7375) from Camp I.

Figure 29. *Scincella melanosticta* from Camp I. Upper, adult male (LSUHC 7407) and lower, adult female (LSUHC 7402).

Figure 30. Adult male *Sphenomorphus indicus* (LSUHC 7445) from between Camps I and II at 850 m.

Figure 31. Adult female *Amphiesma modestum* (LSUHC 7442) from Camp II.

Figure 32. Juvenile female *Chrysopelea ornata* (LSUHC 7387) from between Aural Village and the base of Phnom Aural.

Figure 33. Juvenile female *Dendrelaphis subocularis* (LSUHC 7429) from a ridge west of Camp I at 710 m.

Figure 34. Juvenile *Pareas margaritophorus* (LSUHC 7463) from Camp II.

Figure 35. Juvenile female *Psammodynastes pulverulentus* (LSUHC 7480) from a ridge west of Camp I at 760 m.

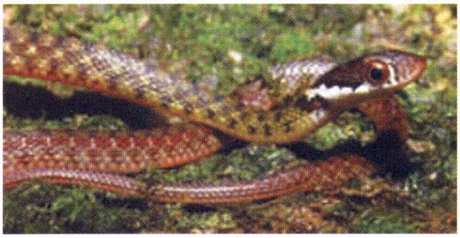

Figure 36. Juvenile female *Rhabdophis chrysargos* (LSUHC 7461) from Camp II.

Figure 37. Juvenile female *Cryptelytrops albolabris* (LSUHC 7485) from Camp I.

Figure 38. Juvenile female *Viridovipera vogeli* (LSUHC 7467) from Camp II.

throughout the Cardamom Mountains (Table 1). We report *Fejervarya cancrivora* as a new record for the Cardamom Mountains which is also common in anthropogenically altered environments. Of the 18 species of lizards collected, five (*Cosymbotus platyurus*, *Dixonius siamensis, Gehyra* cf. *fehlmanni, Eutropis multifasciatus,* and *Scincella melanosticta*) were new to the eastern Cardamoms and *C. platyurus* is the first record from the Cardamom Mountains (Table 1). Of the nine species of snakes recorded, seven (*Ahaetulla nasuta, Amphiesma* cf. *khasiensis, Chrysopelea ornata, Dendrelaphis subocularis, Pareas margaritophorus, Psammodynastes pulverulentus* and *Rhabdophis chrysargos*) are new for the eastern Cardamoms. *Ahaetulla nasuta* is common to anthropogenically-modified habitats and this is the first record of *D. subocularis* from the Cardamom Mountains.

Stuart and Emmett (2006) demonstrated that the herpetofauna of the Cardamom and Elephant Mountains showed a higher biogeographic affinity with each other than to the different herpetofauna of hilly, eastern Cambodia (Stuart et al., 2006). The additional records reported here support this observation.

ACKNOWLEDGEMENTS

We wish to thank Fauna and Flora International and the Department of Nature Conservation and Protection of the Ministry of the Environment, Cambodia, for facilitating our field work through a Memorandum of Agreement. Exportation permits were granted by His Exellency, Kol Vathana, Deputy Director, Department of Nature Conservation and Protection. Bryan Stuart provided comments on the manuscript and stimulating discussions concerning the identification of species. This research was supported in part by a College of Arts and Sciences Grant from La Sierra University to LLG and Rychman Grants from La Sierra University to PLW and TMY.

LITERATURE CITED

BAIN, R. H., A. LATHROP, R. W. MURPHY, N. L. ORLOV & T. C. HO. 2003. Cryptic species of a cascade frog from Southeast Asia: taxonomic revisions and descriptions of six new species. American Museum Novitates 3417:1–60.

BERRY, P. Y. 1975. The amphibian fauna of Peninsular Malaysia. Tropical Press, Kuala Lumpur. 130 pp.

BOULENGER, G. A. 1885. Catalogue of the lizards in the British Museum (Natural History). Second Edition. Volume I. Geckonidae (sic), Eublepharidae, Uroplatidae, Pygopodidae, Agamidae. British Museum (Natural History), London. 575 pp.

_____. **1890.** The fauna of British India, Including Ceylon and Burma. Reptilia and Batrachia. Taylor and Francis. London. 541 pp.

_____. **1893.** Catalogue of snakes in the British Museum (Natural History). Vol. I., Typhlopidae, Glauconiidae, Boidae, Ilysiidae, Uropeltidae, Xenopeltidae, and Colubridae Aglyphae, part. British Museum (Natural History), London. 448 pp.

_____. **1898.** Third report on additions to the lizard collection in the Natural History Museum. Proceedings of the Zoological Society of London 1898: 912–923.

BOURRET, R. 1934. Notes herpétologiques sur l'Indochine Française. IV. Sur une collection d'phidiens de Cochinchine et du Cambodge. Direction de l'Instruction Publique: 1–15.

_____. **1941.** Les tortues de l'Indochine. Institute Océanographique de l'Indochine, 38:1–235.

_____. **1942.** Les batraciens de l'Indochine. Institute Océanographique de l'Indochine, Hanoi. 547 pp.

BOYCE, P., E. KHOU, S. MA & K. SAR. 2002. Higher plants. In: Social and ecological surveys of Phnom Aural Wildlife Sanctuary, Cardamom Mountains, Cambodia. p:255. J. Daltry (Ed). Fauna & Flora International Cambodia Program, Phnom Penh, Cambodia.

CAMPDEN-MAIN, S. M. 1970. A field guide to the snakes of south Vietnam. Smithsonian Institution, Washington, D.C. 114 pp.

CHUAYNKERN, Y., A. OHLER, C. INTHARA, P. KUMTONG & A. DUBOIS. 2004. The recent distribution of *Rana milleti* Smith 1921 in mainland Southeast Asia with the first record of Cambodia. Natural History Journal of Chulalongkorn University 4:1–13.

COCHRAN, D. M. 1927. New reptiles and batrachians collected by Dr. Hugh M. Smith in Siam. Proceedings of the Biological Society of Washington 40:179–192.

COX, M. J. 1991. The snakes of Thailand and their husbandry. Krieger Publishing Company, Malabar, Florida. 526 pp.

DALTRY, J. C. & D. CHHEANG. 2000. Reptiles. In: Cardamom Mountains Biodiversity Survey 2000. p:252. J. C. Daltry & F. Momberg (Eds). Fauna & Flora International, Cambridge.

_____. **& F. MOMBERG (EDS). 2000.** Cardamom mountains biodiversity survey 2000. Fauna & Flora International, Cambridge. 252 pp.

_____. **& C. TRAEHOLT. 2003.** Reptile and amphibian survey. In: Biodiversity assessment of the southern Cardamoms and Botum Sakor Peninsula. pp:82–100 and Appendices III and IV. J. C. Daltry & C. Traeholt (Eds). Wild Aid: Cambodia Program, and Department of Forestry and Wildlife, Phnom Penh.

DAVID, P., N. VIDAL & O. S. G. PAUWELS. 2001. A morphological study of Stejneger's pitviper *Trimeresurus stejnegeri* (Serpentes, Viperidae, Crotalinae), with a description of a new species from Thailand. Russian Journal of Herpetology 8(2):205–222.

DEUVE, J. 1970. Serpentes du Laos. Mémoires OSTROM, Paris. 228 pp.

FONTANEL, J. 1972. Carton des Bioclimats. Notice de la Carte du Cambodge. Travaux, Section Scientifique et Technique, Institut Français de Pondicherry, Honors Series 11:1–238.

GRISMER, L. L. 1999. An evolutionary classification of reptiles on islands in the Gulf of California, México. Herpetologica 55:446–469.

_____. **2001.** An evolutionary classification and checklist of amphibians and reptiles on islands along the Pacific Coast of Baja California, México. Bulletin of the Southern California Academy of Sciences 100:12–23.

GROSSMANN, W. & F. TILLACK. 2003. On the taxonomic status of *Asthenodipsas tropidonotus* (Van Lidth de Jeude, 1923) and *Pareas vertebralis* (Boulenger, 1900) (Serpentes: Colubridae: Parentinae). Russian Journal of Herpetology 10(3):175–190.

INGER, R. F., N. ORLOV & I. DAREVSKY. 1999. Frogs of Vietnam: a report on new collections. Fieldiana: Zoology (New series) 92:1–46.

INGER, R. F. & F.-L. TAN. 1996. Checklist of the frogs of Borneo. Raffles Bulletin of Zoology 44:557–574.

LONG, B., S. R. SWAN, B. TITH & R. AY. 2002. Rapid conservation assessment of the large mammals, birds, reptiles and amphibians of the Veal Veng wetland. In: Social and ecological surveys of the Veal Veng Wetland, Cardamom Mountains, Cambodia, with special reference to the conservation of the Siamese crocodile. pp:34–37. J. C. Daltry (Ed). Cambodia Programme, Fauna & Flora International, Phnom Penh.

MALHOTRA, A. & R. S. THORPE. 2004. A phylogeny of four mitochondrial gene regions suggests a revised taxonomy for Asian pitvipers (*Trimeresurus* and *Ovophis*). Molecular Phylogenetics and Evolution 32:83–100.

____, ____ **& B. STUART. 2004.** A morphometric analysis of *Trimeresurus vogeli* (David, Vidal and Pauwels, 2001), with new data on diagnostic characteristics, distribution and natural history. Herpetological Journal 14:65–77.

MANTHEY, U. & W. GROSSMANN. 1997. Amphibien & Reptilien Südostasiens. Natur und Tier - Verlag, Munster. 512 pp.

MATSUI, M., T. CHAN-ARD & J. NABHITABHATA. 1996. Distinct specific status of *Kalophrynus pleurostigma interlineatus* (Anura, Microhylidae). Copeia 1996:440–445.

____**, K. NISHIKAWA, W. KHONSUE, S. PANHA & J. NABHITABHATA. 2001.** Allozymic variation in *Rana nigrovittata* (Amphibia: Anura) within Thailand with special reference to the taxonomic status of *R. mortenseni.* The Natural History Journal of Chulalongkorn University 1(1):15–22.

____**, H. ITO, T. SHIMADA, H. OTA, S. K. SAIDAPUR, W. KHONSUE, T. TANAKA-UENO & W. GUAN-FU. 2005a.** Taxonomic relationships within the Pan-Oriental narrow-mouth toad *Microhyla ornata* as revealed by mtDNA analysis (Amphibia, Anura, Microhylidae). Zoological Science 22:489–495.

____**, T. SHIMADA, H. OTA & T.-U. TOMOKO. 2005b.** Mutiple invasions of the Ryukyu Archipelago by Oriental frogs of the subgenus *Odorrana* with phylogenetic reassessment of the related subgenera of the genus *Rana.* Molecular Phylogenetics and Evolution 37:733–742.

MAXWELL, A. L. 2001. Holocene monsoon changes inferred from lake sediment pollen and carbonate records, northeastern Cambodia. Quaternary Research 56:390–400.

MUSTERS, C. J. M. 1983. Taxonomy of the genus *Draco* L. (Agamidae, Lacertilia, Reptilia). Zoologische Verhandelingen 199:1–120.

NUTPHUND, W. 2004. Amphibians of Thailand. Amarin Printing and Publishing Public Co., Ltd., Bangkok. 191 pp.

OUBOTER, P. E. 1986. A revision of the genus *Scincella* (Reptilia: Sauria: Scincidae) of Asia, with some notes on its evolution. Zoologische Verhandelingen 229:1–65.

OHLER, A., S. R. SWANN & J. C. DALTRY. 2002. A recent survey of the amphibian fauna of the Cardamom Mountains, southwest Cambodia with descriptions of three new species. The Raffles Bulletin of Zoology 50:465–481.

ORLOV, N. L., A. LATHROP, R. W. MURPHY & H. T. CUC. 2001. Frogs of the family Rhacophoridae (Anura: Amphibia) in northern Hoang Lien Mountains (Mount Fan Si Pan, Sa Pa District, Lao Cai Province), Vietnam. Rusian Journal of Herpetology 8(1):17–44.

OTA, H., T. HIKIDA, J. NABHITABHATA & S. PANHA. 2001. Cryptic taxonomic diversity in two broadly distributed lizards of Thailand (*Mabuya macularia* and *Dixonius siamensis*) as revealed by chromosomal investigations (Reptilia: Lacertilia). The Natural History Journal of Chulalongkorn University 1(1):1–7.

PARKER, H. W. 1934. A monograph of the frogs of the family Microhyldae. British Museum, London. vi + 208 pp.

SAINT GIRONS, H. 1972. Les serpents du Cambodge. Mémoires du Muséum National d'Histoire Naturelle, Paris, Nouvelle série, A, Zoologie 74:1–170.

SMITH, M. A. 1917. Descriptions of new reptiles and a new batrachian from Siam. Journal of the Natural History Society of Siam 2:221–225.

____**. 1920.** The frogs allied to *Rana doriae.* Journal of the Natural History Society of Siam 4:215–229.

____**. 1935.** The fauna of British India, including Ceylon and Burma. Reptilia and Amphibia. Vol. II Sauria. Taylor and Francis, London. 440 pp.

____**. 1943.** The fauna of British India, including Ceylon and Burma, including the whole of the Indo-Chinese sub-region. Reptilia and Amphibia. Vol. III Serpentes. Taylor and

Francis, London. 583 pp.

STUART, B. L. 2005. New frog records from Laos. Herpetological Review 36:473–479.

____ **& D. A. EMMETT. 2006.** A collection of amphibians and reptiles from the Cardamom Mountains, southwestern Cambodia. Fieldiana Zoology (New series): (109):(3) + 1–27.

____ **& S. G. PLATT. 2004.** Recent records of turtles and tortoises from Laos, Cambodia, and Vietnam. Asiatic Herpetological Research 10:129–150.

____**, K. SOK & T. NEANG. 2006.** A collection of amphibians and reptiles from hilly eastern Cambodia. Raffles Bulletin of Zoology 54:129–155.

SWAN, R. S. & J. C. DALTRY. 2002. Reptiles and amphibians. In: Social and ecological surveys of Phnom Aural Wildlife Sanctuary, Cardamom Mountains, Cambodia. pp:23–40. J. C. Daltry (Ed). Cambodia Programme, Fauna & Flora International, and the Ministry of Environment, Phnom Penh.

TAYLOR, E. H. 1934. Zoological results of the third De Schauensee Siamese Expedition, part III. Amphibians and Reptiles. Proceedings of the Academy of Natural Sciences of Philadelphia 86:281–310

____**. 1962a.** New Oriental reptiles. University of Kansas Science Bulletin 43(8):209–263.

____**. 1962b.** The amphibian fauna of Thailand. University of Kansas Science Bulletin 43(8):265–599.

____**. 1963.** The lizards of Thailand. University of Kansas Science Bulletin 44(14):687–1077.

____**. 1965.** The serpents of Thailand and adjacent waters. University of Kansas Science Bulletin 45(9):609–1096.

TEYNIE, A., P. DAVID, A. OHLER & K. LAUANGLATH. 2004. Notes on a collection of amphibians and reptiles from southern Laos, with a discussion of the occurrence of Indo-Malayan species. Hamadryad 29(1):33–62.

TREPANIER, T. L., A. LATHROP & R. W. MURPHY. 1999. *Rhacophorus leucomystax* in Vietnam with acoustic analysis of courtship territorial calls. Asiatic Herpetological Research 8:102–106.

WEBB, C. O. 2005. Vegetation mapping in Phnom Samkos and Phnom Aural Wildlife Sanctuaries, Cardamom Mountains, Cambodia. Unpublished report to the Fauna & Flora International, Phnom Penh. 31 pp.

WEILER, H. 1998. The distribution of tiger, leopard, elephant and wild cattle (gaur, banteng, buffalo, Khting Vor and kouprey) in Cambodia. Cat Action Treasury/Wildlife Protection Office, Phnom Penh. 28 pp.

WÜSTER, W., R. S. THORPE, M. J. COX, P. JINTAKUNE & J. NABHITABHATA. 1995. Population systematics of the snake genus *Naja* (Reptilia: Serpentes: Elapidae) in Indochina: multivariate morphometrics and comparative mitochondrial DNA sequencing (cytochrome oxidase I). Journal of Evolutionary Biology 8:493–510.

ZIEGLER, T. 2002. Die Amphibien und Reptilien eines Tieflandfeuchtwald-Schutzgebietes in Vietnam. Natur und Tier – Verlag, Münster. 342 pp.

ZHAO E.-M. & K. ADLER. 1993. Herpetology of China. Society for the Study of Amphibians and Reptiles. Oxford, Ohio. 522 pp.

Received: 6 March 2006.
Accepted: 5 June 2006.

PROOFS NOT SEEN BY AUTHORS

Hamadryad Vol. 31, No. 2, pp. 242 – 249, 2007.

BUFO MELANOSTICTUS, AN ANURAN AMPHIBIAN, AS A NOVEL MODEL FOR BIOMONITORING OF ENVIRONMENTAL MUTAGENS AND CARCINOGENS

Samar Chakrabarti[1] and Samarendra N. Banerjee[2, 3]

[1]Cancer Cytogenetics Unit, Department of Zoology, Burdwan University,
Burdwan 713 104, India.

[2]Department of Zoology, Rammohan College, 102/1 Raja Rammohan Sarani,
Kolkata 700 009, India.

[3]Corresponding author. Email: samban2kcal@yahoo.com

samar_banerjee@rediffmail.com

(with four text-figures)

ABSTRACT.– **Contamination of water sources by pesticides and industrial effluents has made it essential to find out a dependable and convenient mutagenicity/carcinogenicity bioassay system for aquatic and amphibious organisms. Earlier attempts to assess mutagenicity of polluted water sources by application of sister chromatid exchange (SCE) analysis in fishes have shown limited success. Amphibian system (not only in having much longer, elongated metaphase complements but also for possessing low diploid numbers), on the other hand, is suitable for such studies. We have used *Bufo melanostictus* as novel model for cytogenetic assay of environmental mutagens and carcinogens. In separate sets of experiment, specimens kept in the laboratory condition were exposed to test chemicals (mitomycin C [MC] and cyclophosphamide [CP]) and the rate of chromosomal aberrations was evaluated and compared against suitable controls. In the other set of experiment, *in vivo* SCE rates were analysed in *B. melanostictus* procured from pesticide infested water sources and mitomycin C treated specimens and the data were compared with that of the control specimens. The present study clearly points out the advantages of using amphibian specimens as novel model for mutagenicity/carcinogenicity bioassay.**

KEY WORDS.– **Mutagenicity, chromosomal aberrations, sister chromatid exchange, *Bufo melanostictus,* mitomycin C, cyclophosphamide.**

INTRODUCTION

During the last few decades, there had been a growing awareness on the contamination of water sources by pesticides and industrial effluents. Increasing deposition in the environment of industrial, agricultural and domestic toxicants, many of which are mutagens, and carcinogens or procarcinogens, has made it essential to find out dependable and convenient biomonitoring system for aquatic or semiaquatic vertebrates (Greenhouse, 1976; Chakrabarti et al., 1984; Jaylet et al., 1986; Fernandez et al., 1989; Root, 1990; Banerjee, 1991; Banerjee and Chakrabarti,1994; Jha et al., 2000). Attempt has been made to assess the mutagenicity by evaluating the rate of sister chromatid exchanges (SCEs) in fishes exposed to various polluted water samples (Kligerman, 1979; Mohanty and Prasad, 1982). But the smaller size of fish chromosomes and the higher diploid number hamper the clarity of SCEs and thus cause inconvenience to such studies. Amphibian system, on the other hand, though suitable for such study, remained unnoticed. This is probably due to difficulties in obtaining sufficient number of metaphases with well spread chromosome complements. With the introduction of improved technology in amphibian cytogenetics (Morescalchi, 1975;

Schmid, 1978; Chakrabarti, 1979; Manna, 1983; Banerjee, 1986; Banerjee and Chakrabarti, 1989a, 1989b), it has now become possible to accumulate a large number of metaphases in any amphibian specimen. Additional advantages for considering the Amphibia as novel model for biomonitoring of environmental mutagens and carcinogens include:

i) satisfactory karyotypes consisting of elongated metaphase chromosomes with low diploid number (2n = 22–26);
ii) smaller size with easy maintenance in the laboratory;
iii) freely available and very suitable for the field study;
iv) can be bred and reared in the laboratory;
v) able to withstand experimental stress;
vi) life cycle is fully known;
vii) fecund and mature rapidly; and
viii) inexpensive and low maintenance cost.

Micronucleus assays in several aquatic organisms, including zebra mussels (Mersch et al., 1996), oysters (Burgeot et al., 1995), fishes (Al-Sabti and Metcalfe, 1995) and amphibians (Jaylet et al., 1986; Fernandez, 1993) have been developed for biomonitoring clastogens in the aquatic environment. Recently, micronucleus test has also been developed in sea urchin embryo to assess water pollution (Saotome et al., 1999). The present study has been oriented not only to gather basic experimental cytogenetic information but also to use anuran amphibian specimens –*Bufo melanostictus* as novel model for biomonitoring of environmental mutagens and carcinogens.

MATERIALS AND METHODS

All experiments were performed *in vivo* on common Indian toad *Bufo melanostictus*. Specimens of both sexes, weighing ca. 30–40 gm, were collected at night locally. A total of 90 specimens (female: male; 1:1) were used for collecting data in the present investigation. Two different chemicals of diverse nature, Mitomycin C (MC) and Cyclophosphamide (CP), were used in separate sets. The stock solution of MC was prepared by dissolving 2 mg potency of MC crystal (manufactured in India by Biochem Pharmaceutical Industries, Mumbai, India, under licence of Kyowa Hokkokogyo Co. Ltd., Japan) into 5 ml sterile distilled water just before injection. The stock solution of CP was prepared by dissolving 200 mg of powered CP (Khandelwal Laboratories Pvt. Ltd., Mumbai, India) in 10 ml of sterile distilled water prior to injection.

In two separate sets of experiment, each specimen received an intraperitoneal injection of either MC or CP stock solution @ 0.5 ml /100 gm body weight. In either case, the specimens were sacrificed at 4 different post treatment time intervals, namely, 4, 24, 48 and 72 h after chemical exposure. A parallel control was made to analyse the effect of the solvent, if any, by injecting sterile distilled water at the same rate and in the same route (Table 1).

Somatic chromosomes from both treated and control specimens were prepared from critical tissues (bone marrow, spleen and intestinal epithelium) by mitotic division inhibition technique as standardized by Chakrabarti et al. (1983). In brief, all specimens received i.p. injection of 0.3 % Colchicine (Sigma, St Louis, U.S.A.) solution at a rate of 1 ml /100 gm body weight 2.5 h prior to sacrifice. Cells from bone marrow, spleen and intestinal epithelium were collected in sterile distilled water and aspirated gently to form a homogenous cell suspension. Then cell suspension was incubated for 40 min. at room temperature and followed by centrifugation at 1500 rpm for 15 min. The pellet was fixed in fresh methanol: acetic acid fixative (3:1 v/v). The whole process was repeated thrice. Three drops of cell suspension were dropped on clean grease-free slide (soaked previously in chilled 50% ethanol) and allowed to dry in air. For conventional staining, slides were dipped into 5% phosphate buffered Giemsa stain (pH 6.8) for 10 min. and washed in tap water for observation.

The chromatid and isochromatid breaks, deletions and fragments have been grouped under a single heading 'true breaks' because of the involvement of chromosomal DNA into damage. The different forms of structural rearrangements like bi-radial, tri-radial and quadri-radial configurations including complex chromosomal rearrangements have been incorporated into single broad heading 'exchanges'. The despiralization, PCC, unequal condensation, pulverization, centric fission are included under 'other abnormalities'.

For *in vivo* sister chromatid differentiation (SCD) 5–BrdU labelling and Fluorescence plus Giemsa (FPG) staining technique, as demonstrated by Schneider et al. (1976) and later on modified by Chakrabarti et al. (1984) for amphibian system, was followed. In brief: specimens pretreated with MC were subjected to hourly ip. injection of 5–BrdU (Sigma Chemical Co., St. Louis, U.S.A.) at a rate 100 mgm/kg body weight. *In vivo* BrdU exposure was made for various lengths of time– 15, 20, 25, 30, 35, 40, 45 and 50 h, to allow the cells to pass at least two consecutive DNA replication cycles. A similar protocol was followed in the control series. The metaphase chromosomes of BrdU exposed specimens were prepared by mitotic division-inhibition technique as described earlier (Chakrabarti et al., 1983). For differential staining of sister chromatids, the slides were bathed in Hoechst 33258 (10 µg/ml in distilled water) for 20 min at room temperature and washed in distilled water. The slides were mounted in 2 x SSC and exposed to direct sunlight for 1 h. After photolysis, the slides were washed in distilled water, stained in 5% phosphate buffered Giemsa (pH 6.8) for 5 min and washed in distilled water. In a separate set of experiment, specimens collected from pesticide infested water sources, were subjected to BrdU exposure at the same rate and same duration for analysis of SCD and SCE rates.

Criteria for selecting metaphases for scoring of data: only those metaphases displaying well differentiated dark and light stained sister chromatids and in which chromosomes showed good spread with little or no overlapping were chosen for the purpose. Statistical analyses of data were made by student's *t*-test (Panse and Sukhatme, 1985).

RESULTS

Conventional stained metaphase chromosomes of *Bufo melanostictus* in both control and treated series revealed the existence of 22 long biarmed chromosomes. An examination of well spread metaphase stages from specimens treated separately either with MC or CP at four different post-treatment intervals revealed a variety of chromosomal abnormalities both in the form of simple (SCA) and complex chromosomal abnormalities (CCA) at all post fixation time points. The abnormalities were in the form of chromatid and isochromatid breaks, gaps, deletions, pulverization, unequal condensations and centric fissions. The occurrence of various exchange and translocation figures, despiralisations, premature chromosome condensation (PCC) were also encountered in the treated specimens (Fig. 1A–D). However, quantitative analysis revealed a slightly different pattern because the frequencies of different aberrations were much meagre at early (i.e., 4 h) post-treatment intervals of CP exposure. The frequency of affected metaphases and the distribution of different forms of chromosomal abnormalities recorded at different post-treatment time points were statistically evaluated using Student's *t*-test (Fig. 3A–D).

Sister Chromatid Differentiation (SCD) and Sister Chromatid Exchange (SCE) study: an examination of Fluorescence plus Giemsa (FPG) stained metaphase chromosomes from different specimens exposed *in vivo* to BrdU for various lengths of time revealed that the frequency of second cycle cells with clearly differentiated sister chromatids (Fig. 2A–B) was highest (ca. 50% at 35 h in control, field and MC treated specimens). Therefore, SCEs were scored from samples processed after 35 h of *in vivo* BrdU exposure.

Frequencies of SCE in different experimental series: Examination of metaphase stages with clearly differentiated sister chromatids in all experimental series showed a large number of cells with variable number of chromosomes carrying SCEs. The maximum frequency of cells (66.15%) with SCEs in one or more chromosomes was noted in MC treated specimens at 48 h of drug exposure and a minimum frequency (49%) of cells with SCEs was noted in control.

The results pertaining to the frequencies of SCEs are presented in Fig. 4. The frequency of SCEs in control specimens was 1.04 ± 0.1/cell while there was a slight increase in SCEs in the field specimens, i.e., 1.96 ± 0.2/cell. A t-test showed that this difference between control and field specimens was significant ($p < 0.001$). The frequency of SCEs in MC treated specimens was 4.08 ± 0.4/cell. The difference between SCE rate in MC treated and control series was highly significant ($p < 0.001$). The number of SCEs per cell ranged from 1–6 in control, 1–11 in field specimens and 1–17 in MC treated specimens, respectively.

DISCUSSION

The prime objective of the study is to introduce the common Indian toad– *Bufo melanostictus* as an ideal model for mutagenicity/carcinogenicity bioassay. In order to achieve the goal, the speci-

Figure 1. Metaphase spread from intestinal epithelial cell of *Bufo melanostictus* showing normal metaphase stage (2n = 22) and abnormal plate with various chromosomal abnormalities recorded in experimental series.
A – Normal metaphase stage showing 2n = 22 (one small chromosome is overlapped). **B** – Metaphase stage showing G_1 PCC in MC treated specimen. Translocation figure (straight arrow); metaphase chromosome (bent arrow); induced condensation of chromosomes from G_1 plate cell (curved left arrow) noted. **C** – Metaphase stage showing chromatid break (arrow) in CP treated specimen. **D** – Metaphase stage showing unequal condensation (arrow) in CP treated specimen.

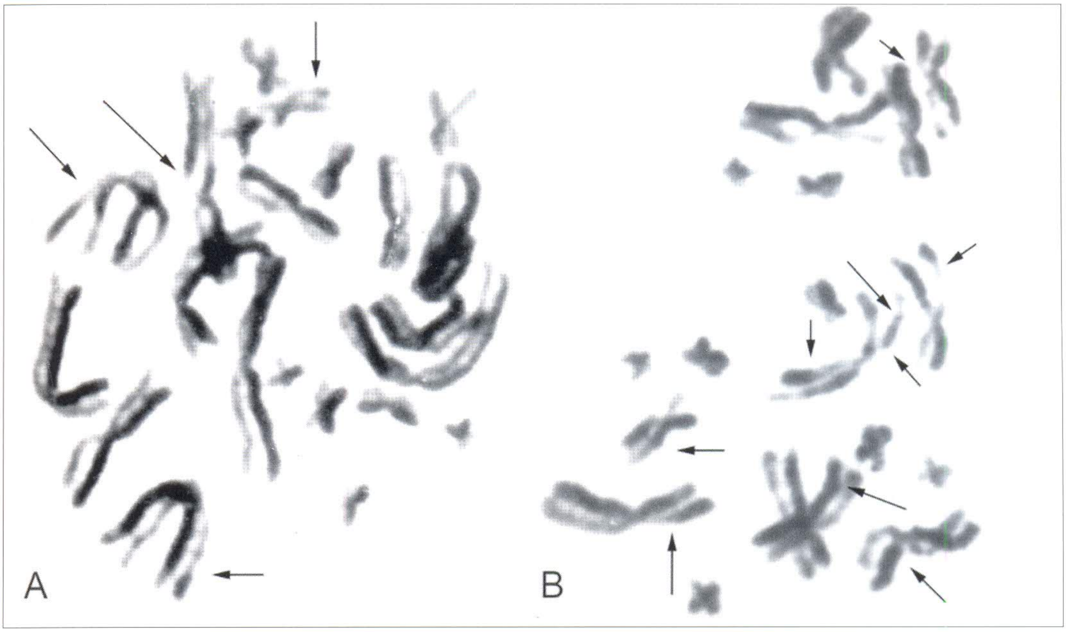

Figure 2. Bromodeoxyuridine (BrdU) labeled metaphase chromosome showing sister chromatid differentiation (one chromatid darkly stained and other chromatid lightly stained) and sister chromatid exchange (SCE). **A** – Metaphase stage with minimum number of SCE (arrow) in the field specimen. **B** – Metaphase stage with maximum number of SCE (arrow) in the MC treated specimen.

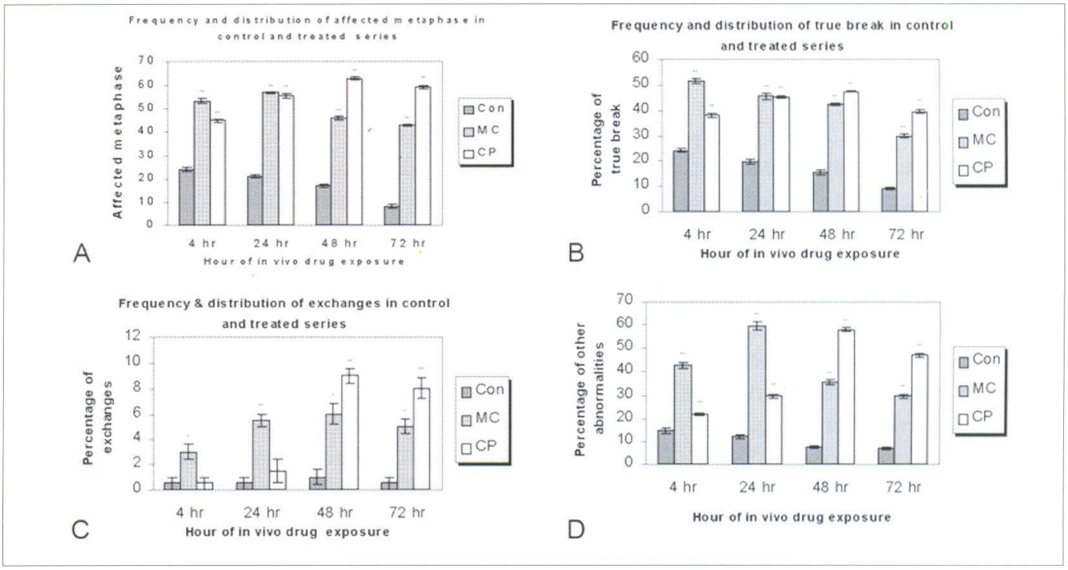

Figure 3. Percentage and distribution of affected metaphase (**A**), true break (**B**) exchanges (**C**) and other abnormalities (**D**) at different time intervals (4, 24, 48 and 72 h) in control and treated series (MC and CP). 200 metaphases studied from four specimens (for 4 replications) in each case.
** $P < 0.001$, * $P < 0.05$, when compared to the control value. Each entry represents the mean ± SE.
True break = chromatid break, isochromatid break, deletion, etc.
Exchanges = different types of tri-radial, quadri-radial type of figures, etc.
Other abnormalities = pulverisation, PCC, centric fission, unequal condensation, etc.

Table 1. Details of experimental protocol (including mode and dose of test materials and the number of specimens used) followed to study chromosomal aberrations.

Index	Experimental animal	Test materials	Mode of exposure	Dose	No. of animals	Tissue fixed
Treated Series	*Bufo melanostictus* (♂ : ♀ ; 1 : 1)	Mitomycin C (MC)	Intraperitoneal injection (i.p.)	0.5 ml/100 gm body weight	32	Intestine, Spleen, Bone marrow
	B. melanostictus (♂ : ♀; 1 : 1)	Cyclophosphamide (CP)	i.p.	0.5 ml/100gm body weight	32	Intestine, Spleen, Bone marrow
Control Series	*B. melanostictus*	sterilised distilled H_2O	i.p	0.5ml/100gm body weight	16	Do

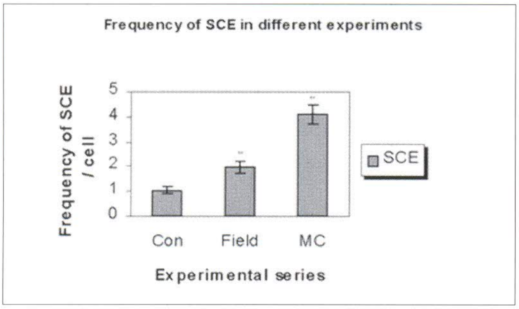

Figure 4. The frequency of SCEs in different experimental (control, field = pesticide infested water sources & Mitomycin-C treated) series. ** $P < 0.001$, * $P < 0.05$, when compared to the control SCE value. Each entry represents the mean ± SE. 100 metaphases were scored for each experiment. BrdU solution was injected to the specimens at the start of MC treatment.

men in question, in separate sets of experiment, has been treated with known chemical clastogens of diverse nature, namely Mitomycin C and Cyclophosphamide and the clastogenic sensitivity has been assessed considering both chromosomal aberration and SCE as end points.

MC, CP are potent clastogens which are known to cause chromosome damage and induce SCEs in many mammalian systems (Cohen and Shaw, 1964; Adler, 1973, 1974; Takehisa and Kanaya, 1983; Takehisa et al., 1988). However, the effect of these agents on amphibian system has not been studied so far. But report on the occurrence of chromosome damage by x-ray (Banerjee and Chakrabarti, 1989c) has been published.

An examination of data from MC and CP treated experimental series (Fig. 3A–D) indicated that administration of MC and CP caused a significant increase in the frequency of chromosomal abnormalitites. It is also evident from the present study that both the agents produced a similar clastogenic effect on the somatic cells of *B. melanostictus*. However, quantitative analysis revealed a slightly different pattern because the frequencies of different aberrations were lower at early (i.e., 4 h) post-treatment time point (4 h of exposure) in CP treated series. A similar trend has not been observed in MC treated series. In subsequent intervals, however, the types and the frequency of chromosomal abnormalities in both CP and MC treated series showed a more or less similar trend (24, 48, 72 h). The induction of different types of chromosomal abnormality in a high frequency in MC treated series even at early hours, and their absence in CP treated series at the identical post-treatment interval is not unlikely if we consider the mode of action of these two chemicals. CP being an indirect mutagen/carcinogenic promutagen needs metabolic activation through liver enzyme system (Cohen and Jao, 1970; Colvin et al., 1973; Stetka and Wolff, 1976) for its conversion into active form. MC, on the other hand, is known to act directly in its original form and needs no metabolic activation in cellular system. Perhaps for this reason, considerable time was required for CP to produce chromosomal abnormalities in the somatic cells of *Bufo*.

The present study, for the first time, has provided evidence in favour of the fact that amphibian specimens like mammalian ones are also equipped with liver enzyme system that can convert promutagens (CP in the present case) into active forms. These findings have strengthened the possibility of using amphibian specimen as a novel model for mutagenicity/carcinogenicity bioassay.

The occurrence of a remarkably high number of cells with SCEs as well as with different chromosomal abnormalities in different treated series can be attributed to the concentration of mutagens/clastogens/carcinogens in the tissues of the animals used in the present study. Therefore, amphibian systems can be used as a model for efficient biomonitoring of environmental mutagens or carcinogens.

ACKNOWLEDGEMENTS

Financial support from the University Grants Commission, New Delhi, is gratefully acknowledged. SNB is grateful to Dipasree Roychowdhury, Rammohan College, Kolkata, for encouragement.

LITERATURE CITED

ADLER, I. D. 1973. Cytogenetic effect of mitomycin C on mouse spermatogonia. Mutation Research 21:20–21.

____. 1974. Comparative cytogenetic study after treatment of mouse spermatogonia with mitomycin C. Mutation Research 23:369–379.

Al-SABTI, K. & C. D. METCALFE. 1995. Fish micronuclei for assessing genotoxicity in water. Mutation Research 343:121–135.

BANERJEE, S. N. 1986. Chromosomal endophenotype of some Indian Anura with reference to C-band distribution and sensitivity of heterochromatin to induced aberration. Unpublished Ph. D. thesis, Burdwan University, Burdwan. 149 pp.

____. 1991. Amphibian biomonitors. BioScience 41:371.

____. & S. CHAKRABARTI. 1989a. Heteromorphic sex chromosome in Indian water frog *Rana cyanophlyctis* with notes on the distribution of C-band positive constitutive heterochromatin. Genetica Polonica 309(3):177–180.

____ & ____. 1989b. *In vivo* sister chromatid differentiation in Amphibia. Current Science 58:401–403.

____ & ____. 1989c. Differential clastogenic sensitivity of heterochromatin and euchromatin: evidence from an *in vivo* study made on a submammalian vertebrate. In vivo 3:55–60.

____ & ____. 1994. Introducing amphibian as novel model for mutagenicity/carcinogenicity bioassay. 16th International Cancer Congress New Delhi, India 30 October – 5 November 1994. pp:398. Abstract Book No. 1. Monduzzi Editore, International Proceedings Division, Bologna.

BURGEOT, T., E. HIS & F. GALGANI. 1995. The micronucleus assay in *Crassostrea gigas* for the detection of seawater genotoxicity. Mutation Research 342:125–140.

CHAKRABARTI, S. 1979. Somatic chromosomes of Indian burrowing frog *Uperodon globulosum* (Günther Anura; Amphibia). Experientia 35:743–744.

____, S. N. BANERJEE & A. CHAKRABARTI. 1984. *In vivo* sister chromatid exchanges in Amphibia – a convenient model for mutagenicity bioassay. Indian Journal of Experimental Biology 22:347–349.

____, ____, L. N. NEOGI & S. ROYCHOWDHURY. 1983. C-band positive W-chromosome in female Indian frog *Rana tigrina.* Experientia 39:321–322.

COHEN, J. L. & J. Y. JAO. 1970. Enzymatic basis of cyclophosphamide activation by hepatic microsomes of the rat. Journal of Pharmacology & Experimental Therapeutics 174:206.

COHEN, M. M. & M. W. SHAW. 1964. Effects of mitomycin C on human chromosomes. Journal of Cell Biology 23:386–395.

COLVIN, M. C., C. A. PADGETT & C. A. FENSELAU. 1973. A biologically active metabolite of cyclophosphamide. Cancer Research 33:915–918.

FERNANDEZ, M. L., J. L. HARIDON, L. GAUTHIER & C. ZOLL–MOREUX. 1993. Amphibian micronucleus test(s): a simple and reliable method for evaluating *in vivo* genotoxic effects of freshwater pollutants and radiations. Initial assessment. Mutation Research 292:83–99.

FERNANDEZ, M. L., L. GAUTHIER & A. JAYLET. 1989. Use of newt larvae for *in vivo* genotoxicity testing of water: results on 19 compounds evaluated by the micronucleus test. Mutagenesis 4:17–26.

GREENHOUSE, G. 1976. The evaluation of toxic effects of chemicals in fresh water by using frog embryos and larvae. Environmental Pollution 11:303–315.

JAYLET, A., P. DEPARIS., V. FERRIER, S. GRINFELD & R. SIBOULET. 1986. A new micronucleus test using peripheral blood erythrocytes of the newt *Pleurodeles waltl* to detect mutagens in fresh water pollution. Mutation Research 164:245–257.

JHA, A. N., V. V. CHEUNG, M. E. FOULKES, S. J. HILL & M. H. DEPLEDGE. 2000. Detection of genotoxins in the marine environment: adoption and evaluation of an integrated approach using the embryo – larval stages of the marine mussel, *Mytilus edulis*. Mutation Research 464:213–228.

KLIGERMAN, A. D. 1979. Induction of sister chromatid exchanges in the central mudminnow following *in vivo* exposure to mutagenic agents. Mutation Research 64:205–217.

MANNA, G. K. 1983. Cytogenetic studies on fish and Amphibia. In: Genetical research in India. pp:243–273. P. L. Jaiswal (Ed). XV International Genetics Congress, New Delhi.

MERSCH, J., M. BEAUVAIS & P. NAGEL. 1996. Induction of micronuclei in haemocytes and gill cells of zebra mussels, *Dreissena polymorpha*, exposed to clastogens. Mutation Research 371:47–55.

MOHANTY, L. & R. PRASAD. 1982. Sister chromatid exchanges in a live fish *Channa punctatus*. Nucleus 25:161–164.

MORESCALCHI, A. 1975. Chromosome evolution in the caudate amphibians. Evolutionary Biology 8:338–387.

PANSE, V. G. & P. V. SUKHATME. 1985. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi. 359 pp.

ROOT, M. 1990. Biological monitors of pollution. BioScience 40:83–86.

SAOTOME, K., T. SOFUNI & M. HAYASHI. 1999. A micronucleus assay in sea urchin embryos. Mutation Research 446:121–127.

SCHMID, M. 1978. Chromosome banding in Amphibia. I. Constitutive heterochromatin and nucleolus organizer regions in *Bufo* and *Hyla*. Chromosoma 66:361–388.

SCHNEIDER, E. L., J. R. CHAILLET & R. R. TICE. 1976. *In vivo* BrdU labeling of mammalian chromosomes. Experimental Cell Research 100:396–399.

STETKA, D. G. & S. WOLFF. 1976. Sister chromatid exchange as an assay for genetic damage induced by mutagen-carcinogens, II. *In vitro* test for compounds requiring metabolic activation. Mutation Research 41:343–350.

TAKEHISA, S. & N. KANAYA. 1983. A comparison of *Vicia faba* root S10 and rat liver S9 activation of ethanol, maleic hydrazide and cyclophosphamide as measured by sister chromatid exchange induction in Chinese hamster ovary cells. Mutation Research 124:145–151.

_____, _____ & R. RIEGER. 1988. Promutagen activation by *Vicia faba*: an assay based on the induction of sister chromatid exchanges in Chinese hamster ovary cells. Mutation Research 197:195–205.

Received: 10 April 2006.
Accepted: 15 May 2006.

Hamadryad Vol. 31, No. 2, pp. 250 – 257, 2007.

REDESCRIPTION OF THE GEKKONID LIZARD *CYRTODACTYLUS SWORDERI* (SMITH, 1925) FROM SOUTHERN PENINSULAR MALAYSIA

L. Lee Grismer[1], Perry L. Wood, Jr. and Timothy M. Youmans

Department of Biology, La Sierra University, 4500 Riverwalk Parkway, Riverside,
California 92515-8247, U.S.A.
[1]Email: lgrismer@lasierra.edu

(with two text-figures)

ABSTRACT.– **A redescription of *Cyrtodactylus sworderi* (Smith 1925), previously known only from an adult female with a regenerated tail, is presented based on four additional specimens (three adult females [one with an original tail] and one adult male with an original tail). The examination of an adult male and specimens with complete, original tails is particularly useful because some of the diagnostic characters separating various species of Sundaland *Cyrtodactylus* are found only in males and on original tails. New locality records are presented, extending the distribution of *C. sworderi* approximately 84.5 km to the north from the type locality near Kota Tinggi to just south of the Pahang State border in Endau-Rompin, Johor and to Jemaluang, Johor in the northeast .**

KEY WORDS.– ***Cyrtodactylus sworderi,* Endau-Rompin, Johor, redescription, Malaysia.**

INTRODUCTION

Cyrtodactylus is rapidly becoming recognized as one of the most speciose gekkonoid genera (Kluge, 2001) with several new species being discovered and described every year (e.g., Bauer, 2002, 2003; Bauer et al., 2002, 2003; David et al., 2004; Grismer 2005; Grismer and Leong, 2005; Youmans and Grismer, 2005). Its extensive distribution from Asia to the South Pacific, ranges across the Indo-Australian Archipelago, within which the continental areas and islands of the Sunda Shelf harbour at least 24 species (Das and Lim, 2000; Grismer 2005; Grismer and Leong, 2005; Youmans and Grismer, 2005; Grismer et al., 2006; Manthey and Grossmann, 1997). Many of these species are common and widespread, yet others are endemics with extremely localized distributions (e.g., Das and Lim, 2000; Dring, 1979; Grismer, 2005; Grismer and Leong, 2005; Hikida, 1990; Inger and King, 1961; Youmans and Grismer, 2005). One such species, *C. sworderi* (Smith, 1925) was described on the basis of a single female with a regenerated tail collected approximately 20 km north of Kota Tinggi, Johor, in southern Peninsular Malaysia. As the mountainous southern regions of Peninsular Malaysia are still unexplored relative to other areas of Malaysia (see Grismer and Leong, 2005; Grismer, 2006), no recent vouchered material of *C. sworderi* had been reported subsequent to the collection of the holotype. Daicus and Hashim (2004) reported a specimen of *C. sworderi* from Lubok Tapah in the western region of Endau-Rompin, Johor, but the specimen was released (Daicus, pers. comm. 2006).

During a survey of the Peta region in the Endau-Rompin National Park, Johor, from 28 August to 1 September 2005, we observed five individuals of *C. sworderi,* three of which we were able to collect. The examination of this new material, along with a specimen from Gunung Panti, Johor and a photograph of a living specimen from Jemaluang, provides the basis for a more adequate characterization of this species. Furthermore, the examination of an adult male and specimens with original tails is particularly useful because some of the diagnostic characters separating various species of Sundaland *Cyrtodactylus* are found only in males and on original tails. With these new data, we can now place *C. sworderi* in a broader, phylogenetic context including all other species of *Cyrtodactylus* (Bauer, Jackman, and Grismer, in prep.).

MATERIALS AND METHODS

Measurements used follow Grismer and Leong (2005) and were taken with Mitutoyo digital calipers to the nearest 0.1 mm: snout-vent length (SVL), from tip of snout to vent; trunk length (TrunkL), from posterior margin of forelimb insertion to anterior margin of hind limb insertion; crus length (CrusL), from base of heel to knee; tail length (TailL), from vent to tip of original tail; tail width (TailW), measured at widest part of tail; head length (HeadL), measured from retroarticular process of jaw to tip of snout; head width (HeadW), measured at widest part of head; head height (HeadH), measured from occiput to underside of lower jaws; ear length (EarL), taken as longest vertical dimension of ear; forearm length (ForeaL), from base of palm to elbow; orbit diameter (OrbD), measured as greatest diameter of orbit; nares to eye distance (NarEye), distance between anteriormost part of eye and nares; snout to eye distance (SnEye), measured from anteriormost point of eye to tip of snout; eye to ear distance (EyeEar), from anterior edge of ear opening to posterior edge of eye; internarial distance (Internar), taken between nares; and interorbital distance (Interorb), measured as shortest distance between left and right superciliary scale rows.

Scale counts taken were postmentals (and their degree of medial contact); supralabials, counted to midpoint of eye; infralabials; scales bordering nostril (number and types); number of longitudinal rows of tubercles counted from one side of body across dorsum to other side; number of paravertebral tubercles counted along right side of vertebral axis from midpoint of forelimb and hind limb insertions; number of ventral scales counted between ventrolateral body folds; and number of subdigital lamellae on the fourth toe.

All three specimens from Endau-Rompin are temporarily deposited in the La Sierra University Herpetological Collection (LSUHC), Riverside, California. The Gunung Panti specimen is deposited in the Raffles Museum of Biodiversity Research (ZRC), National University of Singapore, Singapore.

RESULTS

The following diagnosis and description are based on LSUHC 7685 (adult female, SVL 80 mm), LSUHC 7700 (adult male, SVL 69 mm), and LSUHC 7732 (adult female, SVL 80 mm) from the Peta region of Endau-Rompin, Johor, and ZRC 2.5505 (adult female, SVL 71 mm) from the foothills of Gunung Panti, Johor. The colour pattern description is based on LSUHC 7685, 7700, 7732 while they were alive, and on a photograph of a living specimen from Jemaluang, Johor, deposited in the La Sierra University Digital Photograph Collection (LSUDPC 900) taken and donated by H. H. Tan. The holotype was unavailable for examination due to the British Museum's overseas loan policy of type material.

Cyrtodactylus sworderi (Smith, 1925)

(Figs. 1–2)

Gymnodactylus sworderi Smith 1925. Type locality: "9 miles north of Kota Tinggi, Johore [Johor]", Peninsular Malaysia. Holotype: The Natural History Museum, London (BMNH1946.8.23.24).

Diagnosis.– Table 1 indicates that *Cyrtodactylus sworderi* can be distinguished from all other Sundaland species by having the following suite of character states: 69–80 mm SVL; large, conical, keeled, body tubercles; tubercles present on top of head, occiput, nape, and limbs, and extend posteriorly beyond base of tail; 42–49 midventral longitudinal scale rows; no transversely enlarged median, subcaudal scales; proximal subdigital lamellae transversely expanded; 18 subdigital lamellae on fourth toe; smooth transition between posterior and ventral femoral scales; no enlarged femoral scales; no femoral pores; preanal groove absent; triangular series of enlarged preanal scales with 8 or 9 preanal pores in males; banding pattern on body absent; dark brown ground colour on dorsum overlain with a series of longitudinally arranged yellow spots.

Description.– Measurements and counts of each specimen is presented in Table 2. Head

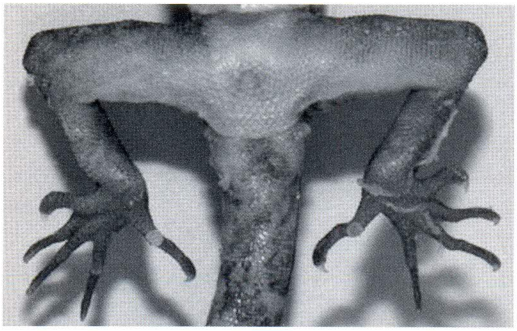

Figure 1. Preanal and femoral region of adult male *Cyrtodactylus sworderi* (LSUHC 7700).

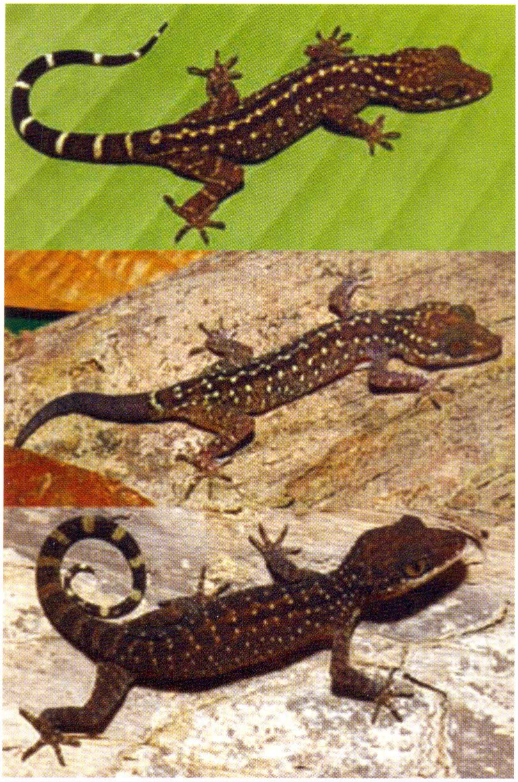

Figure 2. Upper: light colour phase of a gravid adult female *Cyrtodactylus sworderi* (LSUHC 7732) with a complete, unregenerated tail from Sungai Semawak, Peta region, Endau-Rompin, Johor. Middle: light colour phase of a non-gravid adult female *C. sworderi* (LSUHC 7685) with a regenerated tail from Sungai Kawal, Peta region, Endau-Rompin, Johor. Lower: Dark colour phase of an adult *C. sworderi* (LSUDPC 900) from Jemaluang, Johor. Sex unknown. Photograph by H. H. Tan.

moderately long (HeadL/SVL 0.26–0.27) and wide (HeadW/HeadL 0.66–0.69), somewhat depressed (HeadH/HeadL 0.41–0.46), distinct from neck, and triangular in dorsal profile; lores weakly inflated, prefrontal region slightly concave; canthus rostralis smoothly rounded; snout elongate (SnEye/HeadL 0.41–0.43) and sharply rounded in dorsal profile; eye large (OrbD/HeadL 0.23–0.26); ear opening elliptical and small (EarL/HeadL 0.09–0.10); eye-to-ear distance greater than diameter of eye; rostral subrectangular with a deep dorsomedial furrow containing a slightly enlarged postrostral; rostral partially divided dorsally, bordered posteriorly by large left and right supranasals and three medial postrostrals (= internasal); external nares bordered anteriorly by rostral, dorsally by two supranasals, posteriorly by 3–6 postnasals and ventrally by first supralabial; 10–13 (R, L) square supralabial scales extend ventrally, and taper smoothly below posterior margin of eye; 10 (R, L) infralabial scales tapering smoothly posteriorly to below posterior margin of orbit; scales of rostrum, lores, top of head, and occiput small and granular; scales on top of head and occiput intermixed with slightly enlarged tubercles; dorsal and ventral superciliaries cone-shaped and bluntly rounded; mental triangular, bordered laterally by first infralabial and posteriorly by left and right rectangular postmentals contacting medially for approximately 20–50% of their length posterior to mental; one enlarged row of sublabials extending posteriorly to 4–6th infralabial; gular scales small and granular, grading posteriorly into slightly larger, flatter, throat scales, and into large, flat, imbricate pectoral and ventral scales.

Body relatively short (TrunkL/SVL 0.41–0.50) with weak, ventrolateral folds; dorsal scales small and granular, interspersed with large, conical, semi-regularly arranged, keeled tubercles; tubercles extending from top of head between eyes to anterior one-third of tail; tubercles on top of head, occiput, and nape relatively small, those on body largest; approximately 17–26 longitudinal rows of dorsal tubercles and 36–38 paravertebral tubercles; 40–49 flat, imbricate ventrals, which are much larger than dorsals; slightly enlarged patch of preanal scales bearing 5–9 pores, that are better developed in male; preanal groove absent (Fig. 1).

Forelimbs moderate in stature, relatively short (ForeL/SVL 0.14–0.16); granular scales

Table 1. Mensural and meristic data from Sunda Shelf species of *Cyrtodactylus* from peninsular Malaysia, Borneo, Java, and Sumatra. 1 = presence of character state, 0 = absence of character state. Data from Grismer (2005) and Grismer and Leong (2005).

	aurensis	*baluensis*	*brevipalmatus*	*cavernicolous*	*consobrinus*	*elok*	*fumosus*	*ingeri*	*lateralis*	*malayanus*	*marmoratus*	*matsuii*
SVL	92–95	72–86	64–73	64–81	97–121	56–68	71–75	65–76	85	70–73	76	105
tuberculation moderate to strong	0	1	1	1	1	0	1	1	1	1	1	1
tubercles on forelimbs	0	1	1	0	1	1	1	1	1	1	1	1
tubercles on hind limbs	0	1	1	1	1	1	1	1	1	1	1	1
tubercles on head and/or occiput	0	1	0	1	1	0	1	1	1	1	1	1
tubercles on at least 1/3 of tail	0	0	1	1	1	1	0	1	—	1	0	1
ventral scales	45–51	40–45	35–45	51–58	58–65	44	35–40	40–43	60–64	58–62	40–50	51
enlarged median subcaudals	1	1	0	0	1	0	0	1	0	1	0	0
proximal subdigital lamellae broad	1	1	1	1	1	1	1	1	1	1	1	1
subdigital lamellae on 4th toe	18–23	21–23	16–19	22–26	23–28	18–19	20–22	23–27	21–22	21–23	23-24	22
contact of posterior thigh scales abrupt	0	1	1	0	0	0	0	0	—	0	1	1
enlaged femoral scales	0	1	1	0	1	0	1	0	—	1*	1	0
femoral pores	0	6–9	6–7	0	1–6	0	42–52	0	0	0	3–10	0
preanal groove	1	0	0	1	0	0	0	0	0	0	1	0
enlarged preanal scales	1	1	1	1	1	1	1	1	—	1	1	0
preanal pores	7	9–10	9–10	4	9–10	8	42–52	8	13	8–10	12–16	7
preanal and femoral pores/scales continuous	0	0	0	0	0	0	1	0	0	0	0	0
reticulate pattern on head	1	1	0	1	1	0	0	1	0	1	0	1
body banded	1	0	0	1	1	0	0	0	0	1	0	0
body blotched	0	1	1	0	0	1	1	1	1	0	1	1
body striped	0	0	0	0	0	0	0	0	0	0	0	0

Table 1. *Continued*

	oldhami	*pubisulcus*	*peguensis*	*pulchellus*	*quadrivirgatus*	*semenanjungensis*	*seribuatensis*	*sworderi*	*thirakhupti*	*tiomanensis*	*yoshii*
SVL	63–77	59–74	85	115	51–71	59–69	75	63-80	80	84	75–96
tuberculation moderate to strong	1	1	1	1	1	1	1	1	1	1	1
tubercles on forelimbs	1	0	1	1	1	1	1	1	1	1	1
tubercles on hind limbs	1	1	1	1	1	1	1	1	1	1	1
tubercles on head and/or occiput	1	1	1	1	1	1	1	1	1	1	1
tubercles on at least 1/3 of tail	1	1	1	1	1	—	1	1	0	0	1
ventral scales	34–38	43–55	29–38	33–35	34–42	48-53	28–39	42–49	38	36–40	50–58
enlarged median subcaudals	1	0	1	1	0	0	0	0	1	0	0
proximal subdigital lamellae broad	1	1	1	1	1	1	1	1	1	1	0
subdigital lamellae on 4th toe	12–17	17–22	16–18	19–20	19–20	17-21	19–22	18	20–21	20–22	25–30
contact of posterior thigh scales abrupt	1	0	—	1	0	1	1	1	1	1	0
enlaged femoral scales	1	0	0	1	1	0	1	1	1	1	0
femoral pores	0	0	0	14–18	0	0	42–45	0	0	0	0
preanal groove	0	1	0	1	0	0,1	0	0	0	1	0
enlarged preanal scales	1	1	1	1	1	1	1	1	1	1	0
preanal pores	0–4	7–9	7–9	6–8	0–4	0	42–45	5–9	0	3–5	8–12
preanal and femoral pores/scales continuous	0	0	0	1	0	0	1	0	1	0	0
reticulate pattern on head	0	0	1	0	0	0	0	0	1	0	0
body banded	0	0	1	1	0	0,1	0	0	1	1	0
body blotched	0	1	0	0	0	0,1	1	1	0	0	1
body striped	1	0	0	0	1	0	0	0	0	0	0

of forearm larger than those of body and interspersed with large tubercles; palmar scales rounded; digits well-developed, inflected at basal interphalangeal joints; subdigital lamellae transversely expanded proximal to joint inflections, digits narrow distal to joints; claws well-developed, sheathed by a dorsal and ventral scale.

Table 2. Selected counts and measurements of individuals of *Cyrtodactylus sworderi*. sn = supranasal scale; pn = postnasal scale; L = labial scale.

	LSUHC 7685 Enadu-Rompin	LSUHC 7700 Enadu-Rompin	LSUHC 7732 Enadu-Rompin	ZRC 2.5505 G. Panti
Sex	female	male	female	female
SVL	80	69	80	62.8
postmentals	2	2	2	2
degree of contact of postmetals	20%	33%	20%	50%
supralabials	13	12	12	10
infralabials	10	10	10	10
scales bordering nostril	1r, 2sn, 6pn, L1	1r, 2sn, 5pn, L1	1r, 2sn, 3pn, L1	1r, 2sn, 3pn, L1
longitudinal rows of tubercles	19	26	20	17
paravertebral tubercles	36	38	38	36
longitudinal rows of ventral scales	49	40	42	46
expanded subdigital 4th toe lamellae	7	7	6	5
narrow lamellae on 4th toe	11	11	12	13
number of preanal pores	8	8	9	5
TrunkL	34.5	28.3	40	31
CrusL	13.9	12.8	13.9	11.1
TailL	47 (reg.)	77	86	58 (reg.)
TailW	6.6	4.5	6.1	4.4
HeadL	21.7	18.3	21.6	16.5
HeadW	15	12.2	15	11.1
HeadH	9.9	7.2	8.9	7.5
EarL	2.2	1.7	2.2	1.3
ForeaL	13.3	10.7	11.1	9.8
OrbD	5	4.8	5.6	4.4
NarEye	6.7	5.8	6.7	4.9
SnEye	8.9	7.8	8.9	7.1
EyeEar	7.2	5.2	7.7	4.8
Internar	2.8	2.3	2.8	1.8
Interorb	7.3	6.2	7.2	4.4

Hind limbs more robust than forelimbs, moderate in length (CrusL/SVL 0.17–0.19), covered dorsally by granular scales interspersed with larger tubercles and anteriorly by granular scales; ventral scales of femora flat and larger than dorsals; ventral tibial scales flat and imbricate; no enlarged femoral scales or femoral pores; dorsal and ventral femoral scales meeting smoothly on posteroventral margin of thigh; plantar scales low and slightly rounded; digits well-developed, inflected at basal interphalangeal joints; subdigital lamellae transversely expanded proximal to inflected joints, digits narrow distal to joints; 5–7 expanded subdigital lamellae and 11–13 non-expanded subdigital lamellae on right 4th toe; claws well-developed, sheathed by a dorsal and ventral scale.

Original tail widest at base, tapering to a point; dorsal scales at base of tail granular, becoming flatter posteriorly; no median row of transversely enlarged subcaudal scales; scales of regenerated tails small, granular, and not arranged in hemi-whorls; tubercles not extending onto regenerated portion of tail; 2 or 3 enlarged, blade-like tubercles at base of tail; base of tail with lateral, bulbous swellings in male (Fig. 1); all postanal scales moderately sized, flat, and imbricate.

Colouration in life (Fig. 2).– *Cyrtodactylus sworderi*, like many other gekkos, has the ability to lighten and darken its colour pattern. When abroad at night, specimens are in their light phase, which is described below (Fig. 2:Upper and Middle). In the dark phase, the colour pattern is the same, only far less contrasting (Fig. 2:Lower).

Ground colour of dorsum dark brown; slight degree of yellowish mottling on rostrum and top of head; iris copper-coloured; upper lip white or mottled with dark brown; series of yellow spots beginning in postorbital region and extending diagonally across nape to meet on midline at the level of the forelimb insertions; spots continuing as a vertebral stripe of regularly or varying width, or as separate spots, to base of tail; less prominent series of paravertebral yellow spots extending from posterior margin of eye opening along flanks to base of tail; tubercles and some granular scales of flanks yellow, giving flanks much lighter overall appearance; ground colour of original tail nearly solid black;10–11 caudal bands on tail, anterior two or three yellow, all others white; most caudal bands encircle tail; ground colour of regenerated tail nearly uniform brown, lacking bands. Lower lip white, gular region, throat, pectoral region, belly, and underside of limbs immaculate beige; subcaudal region mottled with dark brown, especially anteriorly.

Distribution and natural history.– *Cyrtodactylus sworderi* is known only from the West Malaysian state of Johor at the southern end of the Malay Peninsula. It ranges from approximately 20 km north of Kota Tinggi in the south (Smith, 1925) to Jemaluang in the northeast and to Peta, just south of the Pahang border in Endau-Rompin, in the north. It extends west to at least Lubuk Tapah (Daicus and Hashim, 2004) in the western portion of Endau-Rompin.

All three specimens from the Peta region of Endau-Rompin were found at night on vegetation in riparian habitats within lowland dipterocarp forest. LSUHC 7685 was observed facing head-down approximately 0.75 m above the ground on the trunk of a small tree (diameter ca. 200 cm; 26 August 2005). LSUHC 7700 was found clinging to a twig, head-up, 1 m above the ground (29 August 2005). An additional individual was observed facing head down on a large tree (diameter ca. 0.5 m), ca. 5 m above the ground, and a juvenile was seen running along an earthen stream bank before escaping into a burrow. All were in the dry stream bed of Sungai Kawal. LSUHC 7732 was a gravid female with two eggs and found on a thin branch 1.5 m above the rocky stream bed of Sungai Semawak (31 August 2005).

DISCUSSION

As noted by Grismer (2005) and Grismer and Leong (2005), there has been no comprehensive phylogenetic analysis of the genus *Cyrtodactylus* and even demonstrating the monophyly of the genus has proven difficult. Thus, determining the species to which *C. sworderi* is most closely related is not possible. *Cyrtodactylus sworderi* superficially resembles *C. quadrivirgatus* and *C. semenanjungensis* (with which it is sympatric) in general aspects of colouration, body size and scale counts (Grismer and Leong, 2005:Table 1), but to hypothesize at this point, that these three species share a relationship exclusive of other *Cyrtodactylus* would be conjectural.

The presence of endemic species such as the newly discovered frogs *Ansonia endauensis* Grismer 2006b and *Ingerophrynus gollum* Grismer 2007 and the lizards *Cyrtodactylus semenanjungensis* Grismer and Leong 2005 and *C. sworderi* in the lowland rainforests of sourthern peninsular Malaysia underscore the underexplored nature of this region which is under threat from the encroachment of oil palm plantations.

ACKNOWLEDGEMENTS

For field assistance, we wish to thank Nurol Nasir and Juliana Senawi. For the access to material and photographs, we are indebted K. K. P. Lim (ZRC). We would like to thank the officials of the Environmental Planning Unit, Prime Minister's Department for permission to do research in Malaysia and for the issuance of a research permit (40/200/19 SJ.1105). Aaron Bauer provided helpful comments on the manuscript.

LITERATURE CITED

BAUER, A. M. 2002. Two new species of *Cyrtodactylus* (Squamata: Gekkonidae) from Myanmar. Proceedings of the California Academy of Sciences 53:75–88.

____**. 2003.** Descriptions of seven new *Cyrtodactylus* (Squamata: Gekkonidae) with a key to the species of Myanmar. Proceedings of the California Academy of Sciences 54:463–498.

____**, O. S. G. PAUWELS, & L. CHANHOME. 2002.** A new species of cave-dwelling *Cyrtodactylus* (Squamata: Gekkonidae) from Thailand. Natural History Journal of the Chulalongkorn University 2:19–29.

_____, **M. SUMONTHA & O. S. G. PAUWELS. 2003.** Two new species of *Cyrtodactylus* (Reptilia: Squamata: Gekkonidae) from Thailand. Zootaxa 376:1–18.

DAICUS, B. & R. HASHIM. 2004. Herpetofauna of the western region of Endau-Rompin, Johore, Peninsular Malaysia. Malaysian Journal of Science 23:65–72.

DAS, I. & L. J. LIM. 2000. A new species of *Cyrtodactylus* (Sauria: Gekkonidae) from Pulau Tioman, Malaysia. Raffles Bulletin of Zoology 48(2):223–231.

DAVID, P. A. TEYNIÉ & A. OHLER. 2004. A new species of *Cyrtodactylus* Gray, 1827 (Reptilia: Gekkonidae) from southern Laos. Raffles Bulletin of Zoology 52(2):621–627.

DRING, J. C. M. 1979. Amphibians and reptiles from northern Trengganu, Malaysia, with descriptions of two new geckos: *Cnemaspis* and *Cyrtodactylus*. Bulletin of the British Museum of Natural History. 34:181–241.

GRISMER. L. L. 2005. A new species of bent-toed gecko (*Cyrtodactylus* Gray 1827) from Pulau Aur, Johor, West Malaysia. Journal of Herpetology 39:424–432.

GRISMER, L. L. 2006a. A new species of *Ansonia* Stoliczka 1872 (Anura: Bufonidae) from central Peninsular Malaysia and a revised taxonomy for *Ansonia* from the Malay Peninsula. Zootaxa 1327:1-20.

GRISMER, L. L. 2006b. A new species of *Ansonia* Stoliczka, 1870 (Anura: Bufonidae) from a lowland rainforest in southern peninsular Malaysia. Herpetologica 62(4):466-475.

GRISMER, L. L. 2007. A new species of *Ingerophrynus* (Anura: Bufonidae) from a lowland rain forest in southern Peninsular Malaysia. Journal of Herpetology 41(2):224-229.

_____ **& T.-M. LEONG. 2005.** New species of *Cyrtodactylus* (Squamata: Gekkonidae) from southern Peninsular Malaysia. Journal of Herpetology 39:64–71.

_____, **T. M. YOUMANS, P. L. WOOD, Jr. & J. L. GRISMER. 2006.** Checklist of the herpetofauna of the Seribuat Archipelago, West Malaysia with comments on biogeography, natural history and adaptive types. Raffles Bulletin of Zoology 54(1):157–180.

HIKIDA, T. 1990. Bornean gekkonid lizards of the genus *Cyrtodactylus* (Lacertilia: Gekkonidae) with descriptions of three new species. Japanese Journal of Herpetology 13:91–107.

INGER, R. F. & F. W. KING. 1961. A new cave-dwelling lizard of the genus *Cyrtodactylus* from Niah. Sarawak Museum Journal 10:274–276.

KLUGE, A. G. 2001. Gekkotan lizard taxonomy. Hamadryad 26:1–209.

MANTHEY, U. & W. GROSSMANN. 1997. Amphibien & Reptilien Südostasiens. Natur und Tier Verlag, Münster. 512 pp.

SMITH, M. A. 1925. A new ground-gecko (*Gymnodactylus*) from the Malay Peninsula. Journal of the Malayan Branch of the Royal Asiatic Society 3:87.

YOUMANS, T. M. & L. L. GRISMER. 2005. A new species of bent-toed gecko (*Cyrtodactylus* Gray 1827) from the Seribuat Archipelago, West Malaysia. Herpetological Natural History 10(1):61–70.

Received: 20 January 2006.
Accepted: 28 March 2006.

Hamadryad Vol. 31, No. 2, pp. 258 – 264, 2007.

DIET RECORDS FOR THE DWARF CROCODILE, *OSTEOLAEMUS TETRASPIS TETRASPIS* IN RABI OIL FIELDS AND LOANGO NATIONAL PARK, SOUTHWESTERN GABON

Olivier S. G. Pauwels[1,2], Brady Barr[3], Mei Len Sanchez[4] and Marius Burger[5]

[1]Smithsonian Institution, National Zoological Park, Monitoring and Assessment
of Biodiversity Program, Gamba, Gabon.
[2]Mailing address: Department of Recent Vertebrates, Institut Royal des Sciences Naturelles
de Belgique, Rue Vautier 29, 1000 Brussels, Belgium; Email: osgpauwels@yahoo.fr

[3]National Geographic Channel, 1145 17th Street NW, Washington, D.C. 20036, U.S.A.
Email: Bradybarr@aol.com

[4]National Aquarium in Baltimore, 501 E. Pratt Street, Baltimore, Maryland 21202, U.S.A.

[5]Zoology Department, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa.

ABSTRACT.– **The objective of this study was to investigate the diets of *Osteolaemus tetraspis tetraspis* from two biotopes in south–western Gabon: inland lowland rainforest (14 samples) and mangrove forest (eight samples). Stomach contents included vegetation (including leaves, fruits, etc.) and animal matter (Gasteropoda, Arachnida, Diplopoda, Insecta, Crustacea, Osteichthyes, Amphibia, Reptilia, Mammalia), and confirm a varied, partly terrestrial, diet. Gastroliths numbered from 0 to 42, and their wet mass did not exceed 0.33% of the crocodile mass, and seem too low to serve a hydrostatic function. Maximal total length observed was 1.8 m.**

KEY WORDS.– **Reptilia, *Osteolaemus tetraspis tetraspis*, diet, gastrolith, Rabi oil fields, Loango National Park, Ogooué-Maritime, Gabon.**

INTRODUCTION

Osteolaemus tetraspis tetraspis Cope, 1861 was described from Gabon where the species is still common and widely distributed. Hunting of *Osteolaemus t. tetraspis* for food consumption has been reported from several provinces of Gabon: Estuaire, Ngounié, Nyanga, Ogooué-Lolo and Woleu-Ntem (Blaney et al., 1997; Gossmann et al., 2002; Pauwels et al., 2002a–c). In Gabon, these crocodiles are hunted mainly at night, through detection by their eye reflection with torch light, and then killed by machete or gun. They are also caught on land in snare traps (as illustrated by Maran, 2002) installed near streams, or entrapped by fishing nets. Specimens are often exported in numbers from remote villages to larger cities in the bush meat trade. The species can regularly be found in the Lambaréné, Libreville, Makokou, Oyem and Port Gentil markets (Gramentz, 1999; Lahm, 1993; Steel, 1994), and may also be kept as a pet (Pauwels et al., 2002a). Despite evidence of intensive human predation on *Osteolaemus* and hence its obvious economic importance in Gabon, little or no data on its biology in this country exists. During a three week expedition to southwestern Gabon, we had the opportunity to collect data on its diet, as well as other ecological observations.

MATERIALS AND METHODS

The stomach contents of 22 subadult and adult specimens were analyzed from two localities: Rabi oil fields (freshwater swamps in inland dense lowland rainforest), and Loango National Park (mangrove/brackish water). Both are in the Gamba Complex of Protected Areas, Ogooué-Maritime Province, southwestern Gabon (Alonso et al., 2006). The survey took place in the second half of June (Rabi) and the first week of July 2003 (Loango), i.e., at the beginning of the dry season. Data on the environment and herpetological communities of these localities were presented by Pauwels et al. (2004, 2006a–b). All crocodiles were captured by the authors by hand at night, using lights to detect their eye-shine. Upon capture, each individual was measured to the nearest cm for total length (TL) and snout-vent length (SVL), sexed, and body mass recorded to the nearest 0.1 g. Within three hours following capture, the stomach of each crocodile was flushed, using the hose-Heimlich method to remove all stomach contents. The hose-Heimlich method involves inserting a hose carefully down the esophagus and into the crocodile's stomach. An electric water pump is used to gently fill the crocodile stomach with water. With the hose still in place and running, a person beside the specimen vigorously squeezes its belly up towards its spine and forward in a motion analogous to the Heimlich maneuver. A mixture of stomach contents and water is expelled, thus emptying the stomach. This procedure was repeated several times until only water free of stomach contents was obtained. Our *Osteolaemus* stomach flushing was illustrated in a National Geographic movie (Anonymous, 2003a). Following stomach flushing, crocodiles were released at their exact capture site unharmed. Recovered stomach contents were preserved in 70% ethanol, sorted, counted, and identified to the lowest possible taxonomic class with the help of a light microscope. Insects were identified using keys in Delvare and Aberlenc (1989). The maximal diameters of gastroliths were measured with a dial-caliper (precision 0.1 mm).

RESULTS

Detailed stomach contents for the 14 Rabi and the eight Loango *Osteolaemus* are presented in Tables 1–2 and 3–4, respectively.

DISCUSSION

Tests have shown that the hose-Heimlich method is 100% effective in removing all food contents from the stomach (Fitzgerald, 1989; Barr,

Table 1. Stomach contents of 14 *Osteolaemus t. tetraspis* from Rabi oil fields (inland lowland forest), south-western Gabon. A = animal preys; P = parasite; V = vegetable matter; G = gastroliths. Rabi gastroliths are detailed in Table 2.

Crocodile #	SVL + Tail L (cm)	Sex	Stomach contents
1	72 + >31	M	A: millipede trunk segments (Julidae); 3 claws of juvenile *Varanus ornatus* (Varanidae); V: 1 small fern leaf (Pteridophyta); 3 pieces of unident. leaves and a 5 cm stick; 1 fruit, prob. *Sacoglottis gabonensis* (Humiriaceae); P: 1 2 cm nematod worm
2	63 + 51	F	A: partly digested shrew (Soricidae)
3	48 + 42	M	A: remains of 1 frog leg bones; G
4	42 + 36	M	A: millipede trunk segments (Julidae); 1 pair of Coleoptera elytra
5	56 + 44	M	A: whole millipede, diameter 1.3 cm (Julidae); 1 whole Coleoptera Dytiscidae, TL 3.5 cm; 1 head of unident. aquatic Coleoptera; G
6	49 + 45	F	A: remains of 1 Julidae; remains of 1 Dytiscidae; G
7	38 + 35	F	A: 4 aquatic snails opercula + remains of 1 snail shell; 1 Dictyoptera Blattellidae; 1 Hydrophilidae, TL 14.5 mm; remains of 1 Dytiscidae; 1 unident. Coleoptera; 1 Formicidae, TL 1.8 mm; remains of 1 unident. insect; remains of 2 small crabs; remains of 1 fish, TL ca 30 mm
8	41 + 37	M	A: remains of 1 aquatic Coleoptera; 1 small crab; V: two 8 mm sticks; G
9	32 + 28	M	A: 1 Ensifera Tettigoniidae; 1 Carabidae, TL 11 mm; 3 pairs of Dytiscidae elytra; 4 pairs of Coleoptera elytra; G
10	66 + >45	F	A: remains of 1 shrimp; elytra of 1 Coleoptera; remains of 4 unident. fishes; remains of 1 Clarias sp. (Clariidae); V: small wood pieces
11	38 + 37	F	A: remains of 1 Julidae; 1 whole caterpillar (Lepidoptera); remains of 1 crab; G
12	36 + 33	M	A: remains of 3 aquatic Coleoptera; part of 1 fish backbone; V: 32 cm long stem; G
13	42 + 42	F	A: remains of 1 Julidae; 1 Araneae; 1 Orthoptera; 1 Orthoptera Tettigoniidae; remains of 1 Lepidoptera; 2 Dytiscidae, LT ca. 2 cm; remains of 2 Dytiscidae, LT > 3 cm; part of 1 fish backbone; remains of 1 frog; P: two 2 cm nematod worms; V: unident. vegetal remains; G
14	78 + 63	M	A: 2 whole Julidae; G

Table 2. Description of the gastroliths sets found in Rabi oil fields *Osteolaemus t. tetraspis* stomachs, south-western Gabon. Ø = diameter.

Crocodile #	Crocodile mass (g)	# gastroliths	Nature of gastroliths	Max. Ø of smallest gastrolith (mm)	Max. Ø of largest gastrolith (mm)	Total wet mass of gastroliths (g)
1	10800	0	/	/	/	0
2	5130	0	/	/	/	0
3	2570	3	Limonite (1) + quartz (2, incl. smallest)	5.6	8.5	0.6
4	1260	0	/	/	/	0
5	3290	8	Limonite	7.8	21.4	2.9
6	3650	15	Limonite	5.4	19.1	11.1
7	1220	0	/	/	/	0
8	1440	5	Limonite	6.0	9.2	0.9
9	500	3	Limonite	6.4	10.3	0.6
10	4190	0	/	/	/	0
11	1080	11	Limonite	4.9	12.3	2.9
12	1030	7	Quartz (1, smallest) + limonite (6)	4.8	13.2	2.5
13	1760	1	Limonite	/	10.5	0.6
14	11700	20	Limonite	6.6	24.7	17.9

Table 3. Stomach contents of eight *Osteolaemus t. tetraspis* from Loango National Park (mangrove), south-western Gabon. A = animal preys; V = vegetal matter; G = gastroliths. Loango gastroliths are detailed in Table 4.

Crocodile #	SVL + Tail L (cm)	Sex	Stomach contents
1	93 + > 60	M	A: 1 whole crab, thorax maximal width 29.1 mm; 1 fish scale; V: 23 wood debris of various sizes, incl. 1 stick of 48 mm long and 7.6 mm diameter; G
2	80 + 66	M	A: remains of 1 crab; remains of 1 insect; V: unident. vegetal matter
3	49 + 43	M	Empty
4	40 + 32	M	A: remains of 1 small crab; G
5	45 + 43	F	G
6	58 + 49	F	G
7	78 + 59	M	A: remains of 2 crabs; remains of 2 shrimps; G
8	98 + > 72	M	A: remains of 1 crab carapace; V: remains of 2 fruits

Table 4. Description of the gastroliths sets found in Loango National Park *Osteolaemus t. tetraspis* stomachs, south-western Gabon. Ø = diameter.

Crocodile #	Crocodile mass (g)	# gastroliths	Nature of gastroliths	Max. Ø of smallest gastrolith (mm)	Max. Ø of largest gastrolith (mm)	Total wet mass of gastroliths (g)
1	18450	2	Quartz	5.6	7.6	0.2
2	11250	0	/	/	/	0
3	2610	0	/	/	/	0
4	11300	14	Quartz	4.8	16.2	3.1
5	2030	8	Limonite (1, smallest) + quartz (7)	5.4	13.7	6.8
6	3690	2	Quartz	12.0	16.3	0.6
7	11250	42	Limonite (11) + quartz (31, incl. smallest and largest)	2.4	16.8	3.1
8	27900	0	/	/	/	0

1997). Only one of the 22 stomachs flushed was empty. Two contained only gastroliths, both from Loango. Our sampling illustrated a varied diet, with a marked difference in prey diversity between Rabi (nine prey classes: Gasteropoda, Arachnida, Diplopoda, Insecta, Crustacea, Osteichthyes, Amphibia, Reptilia, Mammalia) and Loango (three prey classes: Insecta, Crustacea, Osteichthyes). For the Rabi samples (n = 14), percentages of total food mass for prey classes were distributed as follows: Insecta + Diplopoda 70.9%, Osteichthyes 8.7%, Crustacea 8.2%, Mammalia 7.4%, Amphibia 3.8%, others 1% (total food mass recovered from all stomachs = 108.7 g). In Loango, for the 8 samples clustered, Crustacea represented 99.9% of the total prey mass. Frequencies of occurrences for prey items per classes in Rabi samples (*n* stomachs = 14; total number of prey items = 62) was: Insecta 51.6%, Diplopoda 12.9%, Osteichthyes 12.9%, Crustacea 8.1%, Gasteropoda 6.5%, Amphibia 3.2%, Arachnida 1.6%, Reptilia 1.6% and Mammalia 1.6%. Both localities clustered, among the 19 stomachs with contents, 58% contained Insecta (11 samples), 47% Crustacea (9), 37% Diplopoda (7), 26% Osteichthyes (5), 11% Amphibia (2), 5% Gasteropoda (1), 5% Arachnida (1), 5% Reptilia (1) and 5% Mammalia (1). At least part of the insect material in the guts may result from secondary ingestion, via the stomach contents of soft-bodied predators (frogs and fish) that the crocodiles may have eaten, and which were completely digested leaving the hard-bodied insect remains.

Limonite and/or quartz gastroliths were found in 9 out of 14 (64%) of the Rabi samples (see Table 2), and in 5 out of 8 (63%) of the Loango samples (Table 4). Wet mass of the gastroliths represents 0 to 0.33% (n = 22, mean = 0.08%) of the crocodile mass. This mass seems too low to play any role in buoyancy, therefore a possible role in trituration of food or aid against parasites seems more probable, as was also suggested for *Crocodylus cataphractus* (Pauwels et al., 2003). Limonite and quartz are common on the bottom of waters at both localities surveyed. Both minerals had also been found in the stomachs of *Crocodylus cataphractus* from Lake Divangui (Pauwels et al., 2003, 2007), ca. 15 km from Rabi.

Vegetable matter was present in 8 of 22 stomachs (36%). Accidental ingestion during prey capture is probable, but intentional ingestion cannot be ruled out. Hard wood sticks and seeds could serve as substitutes for gastroliths (as was suggested with palm nuts for Congolese *Crocodylus cataphractus* by Eaton and Barr, 2005). Parasitic worms were found in only two stomach contents, both from Rabi (Table 1), and numbered only one or two.

No other data on the diet of *Osteolaemus* in Gabon was previously available, except a report from local fishermen of predation on the aquatic colubrid snake *Grayia ornata* in Ogooué-Lolo Province (Pauwels et al., 2002c). E. Truter (pers. com.) provided additional information about the feeding of *Osteolaemus*. He observed at ca 10 p.m., along Iguéla Lagoon, about 8 km upland from its estuary (Etimboué Dpt, Ogooué-Maritime Prov.), an adult preying on a crab on land, at ca. 2 m from the shore. In another observation (M. Eaton, pers. comm.) at night in late Sept. 2005, a juvenile specimen (TL 48 cm) had a millipede in its mouth. The crocodile was found out of water, in the forest along Echira River, near Akaka village, Ogooué-Maritime Province. Luiselli et al. (1999) recorded Gasteropoda, Crustacea, Osteichthyes, Amphibia and Mammalia from stomachs of *Osteolaemus t. tetraspis* inhabiting swamp rain forest in southeastern Nigeria, crabs being the most abundant resource locally, and the commonest prey item.

Osteolaemus t. tetraspis is the only crocodile species found in the Rabi forest swamps and small streams where our specimens were collected. The closest known locality for another crocodile, *Crocodylus cataphractus*, is Lake Divangui, where a large population exists (Pauwels et al., 2003). The vegetated and swampy littoral zones around the lake also harbour *Osteolaemus* (see Anonymous, 2003b; Barr, 2004), although apparently in small numbers. In these shallow waters it lives syntopically with juvenile *C. cataphractus*, while the subadult and adult *C. cataphractus* occupy deeper waters in the middle of the lake, where no juvenile *C. cataphractus* nor any *Osteolaemus* were observed. In Loango National Park, mangroves are syntopically inhabited by both *Osteolaemus* and *Crocodylus niloticus*. More inland in the park, in the shallow, seasonal ponds, only *Osteolaemus* is found, but it seems absent from the open lagoons and beaches along the sea where *C. niloticus* is locally common (Pauwels et al., 2004; this work). The biotope preferences of *Osteolaemus* thus only partly overlap with those of the two other crocodile species. No diet study for *C. niloticus* is available for Loango N.P.'s mangroves (nor for any locality in Gabon), and at Lake Divangui, while diet data exist for *C. cataphractus*, none is locally available for *Osteolaemus*, so there are currently no comparative diet data for localities where they live in syntopy with *Osteolaemus* in south-western Gabon. Luiselli et al. (1999) showed a wide diet overlap between *Varanus ornatus* and *Osteolaemus t. tetraspis* in southeastern Nigeria. Both species coexist in Loango and Rabi and competition might occur as well, but no data are currently available for the diet of *Varanus ornatus* in these two localities (except a case of predation by *Varanus* on *Dermochelys coriacea* eggs in Loango N. P., see Pauwels et al., 2004).

The sex ratio among the specimens examined was in favor of males (64%, see Table 1 and 3). Rabi and Loango samples clustered, the ratio Tail L/TL ranged from 0.45 to 0.50 in females (n = 7, mean = 0.48) and from 0.43 to 0.48 in males (n = 11, mean = 0.46) (incomplete tails excluded; see Tables 1 and 3). The largest specimen encountered, a male (SVL 98 cm), had an incomplete tail of 72 cm with only 11 single caudal scutes. Through extrapolation, the complete tail should have measured ca. 83 cm, giving a total length of ca. 181 cm.

Riley and Huchzermeyer (2000) suggested a possible role of *Clarias* catfish in the transmission of pentastomid infections in the lungs of *Osteolaemus tetraspis osborni*, but the condition of the fish they found in stomach contents did not allow an identification even at the family level. Our data at least confirm *Clarias* in the diet of *Osteolaemus*. In the Rabi region, only two *Clarias* species are known: *Clarias buthupogon* Sauvage, 1879 and *Clarias* sp. (Mamonekene et al., 2006). During the dry season, when *Osteolaemus* retire in deep holes in the river and swamp banks (as observed in Loango by OSGP and MB), predation on fish, and thus fish-crocodile parasite transmission, may be especially high. Fish entrapped in these water holes represent a food stock for *Osteolaemus* during the dry season, and one of us (OSGP) observed in the dry season in Rabi tracks of *Osteolaemus* that came to visit open, isolated, small drying pools where fish densities were especially high.

CONCLUSION

In Gabon, *Osteolaemus t. tetraspis* inhabits a large variety of habitats, from mangroves, swamps, to forest streams at mid-altitude. In some Gabonese localities it lives in syntopy with *C. cataphractus* (medium-sized forest rivers, lakesides with vegetated shores) or *C. niloticus* (mangroves), but it also inhabits a number of temporary, shallow water body types from which the two other crocodile species are ecologically excluded. Our dietry data show that it has a varied and seemingly opportunistic diet, and that it hunts on land as well as in water. Although commonly hunted in Gabon, its ubiquity in the country, its ecological plasticity, together with its poor quality skin (Abercrombie, 1978; Knoepffler, 1974), contribute to make it the least endangered crocodile species in the country. It is partly protected in Gabon, and has already been recorded from six of the 13 national parks, but should be found in all (Pauwels, 2006; Pauwels et al., 2006b). Gabonese populations are very important in view of the global decline of the species, and their use in bushmeat trade and habitat degradation should be carefully monitored.

ACKNOWLEDGEMENTS

This research was supported by the National Geographic Television, the Smithsonian Institution/Monitoring and Assessment of Biodiversity Program and grants from Shell Foundation and Shell Gabon. This publication is contribution 55 of the Gabon Biodiversity Program (contribution 54 was made by Pauwels et al., 2007). We are grateful to Michelle E. Lee, Alfonso Alonso, Patrick Campbell and Francisco Dallmeier (SI/MAB, Washington), Faustin Bangole, Frank Denelle and Pieter Keemink (Shell Gabon), David Hamlin and Bryan Harvey (NGC) and Jose Luis Bonnin (CBG-Rabi) for working facilities, and to Mitchell Eaton (University of Colorado), Luca Luiselli (Centre of Environmental Studies Demetra, Rome) and Edward Truter (Opération Loango) for useful information or literature. William R. Branch (Port Elizabeth Museum) reviewed the manuscript. Research authorizations were kindly provided by Adèle Sambo (CENAREST, Libreville) and Adrien Noungou (Direction de la Faune et de la Chasse, Libreville).

LITERATURE CITED

ABERCROMBIE, C. L. 1978. Notes on West African crocodilians (Reptilia, Crocodilia). Journal of Herpetology 12(2):258–260.

ALONSO, A., M. E. LEE, P. CAMPBELL, O. S. G. PAUWELS & F. DALLMEIER (EDS). 2006. Gamba, Gabon: biodiversity of an equatorial African rainforest. Bulletin of the Biological Society of Washington, Washington, 12. (i–xii +) 436 pp. + 32 pl.

ANONYMOUS. 2003a. Croc Chronicles III. Episode 9. Crocs of Darkness. National Geographic Television & Film.

____. 2003B. Croc Chronicles III. Episode 12. Forest Crocs. National Geographic Television & Film.

BARR, B. 1997. Food habits of the American alligator *Alligator mississippiensis*, in the southern Everglades. Unpublished Ph. D. thesis, University of Miami, Coral Gables. 243 pp.

____. 2004. Brief population survey of *C. cataphractus* in Lake Divangui, southwest Gabon. Crocodile Specialist Group Newsletter 23(1):4–5.

BLANEY, S., S. MBOUITY, J.-M. NKOMBÉ & M. THIBAULT. 1997. Complexe d'Aires Protégées de Gamba. Caractéristiques socio-économiques des populations des départements de la Basse-Banio et de la Mougoutsi (Mouenda). Unpublished report presented to the "WWF-Programme pour le Gabon", Libreville: i–vi + 1–75 + annexes + map + plates.

DELVARE, G. & H.-P. ABERLENC. 1989. Les insectes d'Afrique et d'Amérique tropicale. Clés pour la reconnaissance des familles. CIRAD, Montpellier. 302 pp.

EATON, M. & B. BARR. 2005. Africa. Republic of Congo. Crocodile Specialist Group Newsletter 24(3):18–20.

FITZGERALD, L. A. 1989. An evaluation of stomach flushing techniques for crocodilians. Journal of Herpetology 23(2):170–172.

GOSSMANN, V., S. LÖTTERS, F. OBAME & W. BÖHME. 2002. Zur Herpetofauna Gabuns. Teil II: Kommentierte Artenliste der gefundenen Reptilien, Bemerkungen zur Artenvielfalt. Herpetofauna 24(136):19–33.

GRAMENTZ, D. 1999. Schwere Zeiten für Reptilien in Gabun. Elaphe 7(2):57–61.

KNOEPFFLER, L.-P. 1974. Faune du Gabon (Amphibiens et Reptiles). II. – Crocodiles, Chéloniens et Sauriens de l'Ogooué-Ivindo et du Woleu N'tem. Vie Milieu 24(1), sér. C:111–128.

LAHM, S. A. 1993. Ecology and economics of human/wildlife interaction in northeastern Gabon. Unpublished Ph. D. thesis, Department of Anthropology, New York University. i–xix + 1–325 pp.

LUISELLI, L., G. C. AKANI & D. CAPIZZI. 1999. Is there any interspecific competition between dwarf crocodiles (*Osteolaemus tetraspis*) and Nile monitors (*Varanus niloticus ornatus*) in the swamps of central Africa? A study from south-eastern Nigeria. Journal of Zoology, London 247:127–131.

MAMONEKENE, V., S. LAVOUÉ, O. S. G. PAUWELS, J.-H. MVE BEH, J.-E. MACKAYAH & L. TCHIGNOUMBA. 2006. Fish diversity at Rabi and Gamba, Ogooué-Maritime Province, Gabon. In: Gamba, Gabon: biodiversity of an equatorial African rainforest. pp:285–296. A. Alonso, M. E. Lee, P. Campbell, O. S. G. Pauwels & F. Dallmeier (Eds). Bulletin of the Biological Society of Washington, Washington 12.

MARAN, J. 2002. Les tortues continentales du Gabon. La Tortue 58–59:46–67.

PAUWELS, O. S. G. 2006. Crocodiles and national parks in Gabon. Crocodile Specialist Group Newsletter 25(1):12–14.

____, B. BARR & M. L. SANCHEZ. 2007. Diet and size records for *Crocodylus cataphractus* (Crocodylidae) in south-western Gabon. Hamadryad 31(2):360-361.

____, W. R. BRANCH & M. BURGER. 2004. Reptiles of Loango National Park, Ogooué-Maritime Province, south-western Gabon. Hamadryad 29(1):115–127.

____, M. BURGER, W. R. BRANCH, E. TOBI, J.-A. YOGA & E.-N. MIKOLO. 2006a. Reptiles of the Gamba Complex of Protected Areas, southwestern

Gabon. In: Gamba, Gabon: biodiversity of an equatorial African rainforest. pp:309–318. A. Alonso, M. E. Lee, P. Campbell, O. S. G. Pauwels & F. Dallmeier (Eds). Bulletin of the Biological Society of Washington, Washington, 12.

____, **P. CHRISTY & A. HONOREZ. 2006b.** Reptiles and national parks in Gabon, western central Africa. Hamadryad 30(1):180–195.

____, **A. KAMDEM TOHAM & C. CHIMSUNCHART. 2002a.** Recherches sur l'herpétofaune du Massif du Chaillu, Gabon. Bulletin de l'Institut Royal des Sciences naturelles de Belgique, Biologie 72:47–57.

____, ____ **&** ____**. 2002b.** Recherches sur l'herpétofaune des Monts de Cristal, Gabon. Bulletin de l'Institut Royal des Sciences naturelles de Belgique, Biologie 72:59–66.

____, ____ **& V. MAMONEKENE. 2002C.** Ethnozoology of the *dibomina* (Serpentes: Colubridae: *Grayia ornata*) in the Massif du Chaillu, Gabon. Hamadryad 27(1):136–141.

____, **V. MAMONEKENE, P. DUMONT, W. R. BRANCH, M. BURGER & S. LAVOUÉ. 2003.** Diet records for *Crocodylus cataphractus* (Reptilia: Crocodylidae) at Lake Divangui, Ogooué-Maritime Province, southwestern Gabon. Hamadryad 27(2):200–204.

RILEY, J. & F. W. HUCHZERMEYER. 2000. Diet and lung parasites of swamp forest dwarf crocodiles (*Osteolaemus tetraspis osborni*) in the Northern Congo Republic. Copeia 2000(2):582–586.

STEEL, E. A. 1994. Etude sur le volume et la valeur du commerce de la viande de brousse au Gabon. Unpublished report presented to the "WWF Programme pour le Gabon", Libreville. i–v + 1–84 pp.

Received: 31 December 2005.
Accepted: 21 April 2006.

Hamadryad Vol. 31, No. 2, pp. 265 – 273, 2007.

REDISCOVERY OF *DINODON GAMMIEI* (BLANFORD, 1878) (SERPENTES, COLUBRIDAE), WITH DISCUSSION OF ITS VALIDITY

Viral Mistry[1], Gernot Vogel[2] and Frank Tillack[3]

[1]A/8 Vishwakarma Society, V. P. Road, Andheri West,
Mumbai 400 058, Maharashtra, India.
Email: mistry.viral@rediffmail.com

[2]Im Sand 3, 69115 Heidelberg, Germany.
Email: gernot.vogel@t-online.de

[3]Draesekestrasse 8, 12487 Berlin, Germany.
Email: frank-tillack@t-online.de

(with six text-figures)

ABSTRACT.– **The species *Dinodon gammiei* (Blanford 1878), formerly known from four specimens originating from Darjeeling District, West Bengal, eastern India, was rediscovered in Arunachal Pradesh. Two more specimens were found in museum collections. *Dinodon gammiei* is shown to be a valid species. It is redescribed and colouration in life is given for the first time.**

KEY WORDS.– ***Dinodon gammiei*, Serpentes, Colubridae, rediscovery, India, Arunachal Pradesh, distribution, colour in life.**

INTRODUCTION

In 1878, Blanford described in the Proceedings of the Asiatic Society of Bengal *Ophites gammiei* from a specimen reported to come "from the Cinchona plantations, British Sikkim". The sole specimen was collected by J. A. Gammie and given to the Indian Museum in the same year (Anonymous, 1879). Later, Blanford (1878b) gave a more detailed description of the holotype and corrected the type locality to "Cinchona plantation in South-eastern Sikkim". For dates of publication of the Proceedings and Journals of the Asiatic Society of Bengal, see Das (2000).

The first *Cinchona* plantation (a tree for the production of quinine, used as a treatment against fever and malaria), was in Lebong below Darjeeling (town). In 1864, the plantation spread up to Rangjo valley at Rangbi and Senchal, ca. 20 km south-east of Darjeeling (see map in Waddell, 1899, ca. 88°20´–88°30´N, 26°56´–27°06´E). This area was already part of the Darjeeling District at the time, so the correct citation of the type locality was (and is also now) "Cinchona plantation, Darjeeling" Darjeeling [District, state of West Bengal, eastern India], as already noted by Sclater (1891b:15) and Wall (1923:615). This species was then cited as *Lycodon gammiei* by Boulenger (1890, 1893) and Sclater (1891a–b). Gammie (1928) no longer listed this species for Sikkim, being obviously aware that the type locality was in Darjeeling District.

No additional specimens were reported until D'Abreu (1911) recorded a second specimen of this species from Goomtee Tea Estate near Kurseong, Darjeeling District, under the name *Lycodon fasciatus*. Several months later, Wall (1911) synonymized *Lycodon fasciatus* with *L. gammiei*, stating that the holotype of *Ophites gammiei* was an aberrant *Lycodon fasciatus* (Wall, 1911b). As *O. gammiei* was the older name, it has priority over *L. fasciatus*. Later, Wall (1923) accepted this species as valid and even proposed to transfer it to the genus *Dinodon.* He recorded a third specimen (now registered as ZSI 17129) that was deposited in the Indian Museum and transferred D´Abreu´s *L. fasciatus* from Kurseong to *D. gammiei*. Smith (1943) recognised the validity of this species in his monumental work, and mentioned a fourth specimen (perhaps BMNH 1903.7.16.1). He noted that the species *D. gammiei* and *L. fasciatus* connect the genera *Dinodon* and *Lycodon* (Wall, 1925). Mahendra (1984) synonymized this species again, this time with *Dinodon septentrionale* (Günther, 1875), considering it a colour variety of the latter. This action was not followed by subsequent authors. More recently, two specimens from "Darjeeling, North Bengal" (ZSI 17129 and ZSI 23431) were mentioned by Ahmed and Dasgupta (1992).

Since that time *Dinodon gammiei* has been cited in several checklists and faunal works (e.g., Das et al., 1998; Das, 2000, 2003; Ryabov et al. 2003; Whitaker and Captain, 2004; Orlov and Ryabov, 2004), although no further specimens have been reported. To date only five specimens of *Dinodon gammiei* have been mentioned in the literature.

1. ZSI 8447 (holotype)
2. D'Abreu`s specimen from Goomtee Tea Estate, near Kurseong, 1,220 m.
3. BMNH 1903.7.16.1 (Smith, 1943) juvenile, from Darjeeling, 1,067 m, pres. Gammie.
4. ZSI 23431 from Darjeeling, North Bengal, leg. ? K. K. Tiwari.
5. ZSI 17129 from Darjeeling, North Bengal, leg. ? Lord Carmichael.

This species is included in the Wildlife (Protection) Act, (1972), amended 1991, Schedule IV (Anonymous, 1997).

According to Wall (1923), who only had preserved specimens at hand, *Dinodon gammiei* and *Lycodon fasciatus* are similar in colouration but differ in the following scale counts: *Dinodon gammiei* has 17 or 19 dorsal scale rows around midbody, whereas *Lycodon fasciatus* has 17 rows. *Dinodon gammiei* has a greater number of ventrals (206–222 vs. 201–213) and also, greater number of subcaudals (98–105 vs. 74–94). In *D. gammiei,* the loreal does not enter the orbit, whereas it is normally in contact with the orbit in *L. fasciatus*. The teeth are also different in these species (*Dinodon gammiei* having 3 cranterian teeth which reduce progressively, whereas *Lycodon fasciatus* has 2 cranterian teeth) giving Wall reason to transfer *Ophites gammiei* Blanford, 1878 to the genus *Dinodon.*

Wall (1911 b, 1923) erroneously gave 222 as ventral scale count for the holotype. Blanford (1878a, 1878b), Boulenger (1890, 1893) and Smith (1943) gave 214. VM counted 212.

MATERIAL AND METHODS

A living specimen of *Dinodon gammiei* was encountered at Bompu (ca. 27°03'58.1N–92°24'22.9E), Eaglenest Wildlife Sanctuary, West Kameng District, Arunachal Pradesh, north-eastern India. It was photographed, its scalation data recorded and released. A search in the Bombay Natural History Society's collections revealed one more specimen: BNHS 1257, collected at Kurseong, Darjeeling District, West Bengal, eastern India. Another specimen (ZMB 18959) was discovered in the collection of the "Museum für Naturkunde" in Berlin, Germany. This specimen was collected between Kurseong and Siliguri in Darjeeling District (West Bengal, eastern India) by Kurt Boeck in 1891. All of these specimens and two specimens from ZSI were examined.

In the present paper, only populations from Myanmar and India are considered for the variation in *Lycodon fasciatus*. This species is known from localities much further to the east, but the various sources for scale counts of Chinese or Vietnamese populations are not appropriate for this comparison, as there is a lot of confusion in the determination of this species from the aforementioned regions. Furthermore, this species shows some geographical variation (Vogel and Brachtel, in prep.).

Ventral scales were counted according to Dowling (1951); the terminal scute is excluded from the number of subcaudals. Values for symmetric head characters are given in left/right order.

Values in brackets give exceptional values. Data on the colouration of body and eyes are derived from our observations of the living specimen and photographs of the same.

Abbreviations.– DSR: dorsals; SC: subcaudals; SL: supralabials; Svl: snout to vent length; Tal: tail length; Te: temporal plates; TL: total length; V: ventrals.

Museum abbreviations are as follows:

BMNH (The Natural History Museum, London, U.K.); BNHS (Bombay Natural History

Museum, Mumbai, India); MNHN (Muséum National d'Histoire Naturelle, Paris, France); PSGV (Gernot Vogel's private collection, Heidelberg, Germany); ZFMK (Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn, Germany); ZMB (Museum für Naturkunde Berlin, Germany) and ZSI (Zoological Survey of India, Reptilia Section, Kolkata, India).

RESULTS

Our live specimen and the two preserved specimens in ZSI (Fig. 1) and BNHS match the original description and the specimens of *Dinodon gammiei* known so far. A summary of our scale counts is given in Table 1. As there is more material available now, differences between *Dinodon gammiei* and *Lycodon fasciatus* can be clearly seen and support the distinct specific status of these two taxa.

The statements of Wall (1911b) mentioned above are in contradiction to most of our findings. Wall (1911b:280) remarked that preserved specimens of both species shows "....great similarity in colour and lepidosis". In fact, the colouration of live specimens of *Dinodon gammiei* and *Lycodon fasciatus* differ greatly.

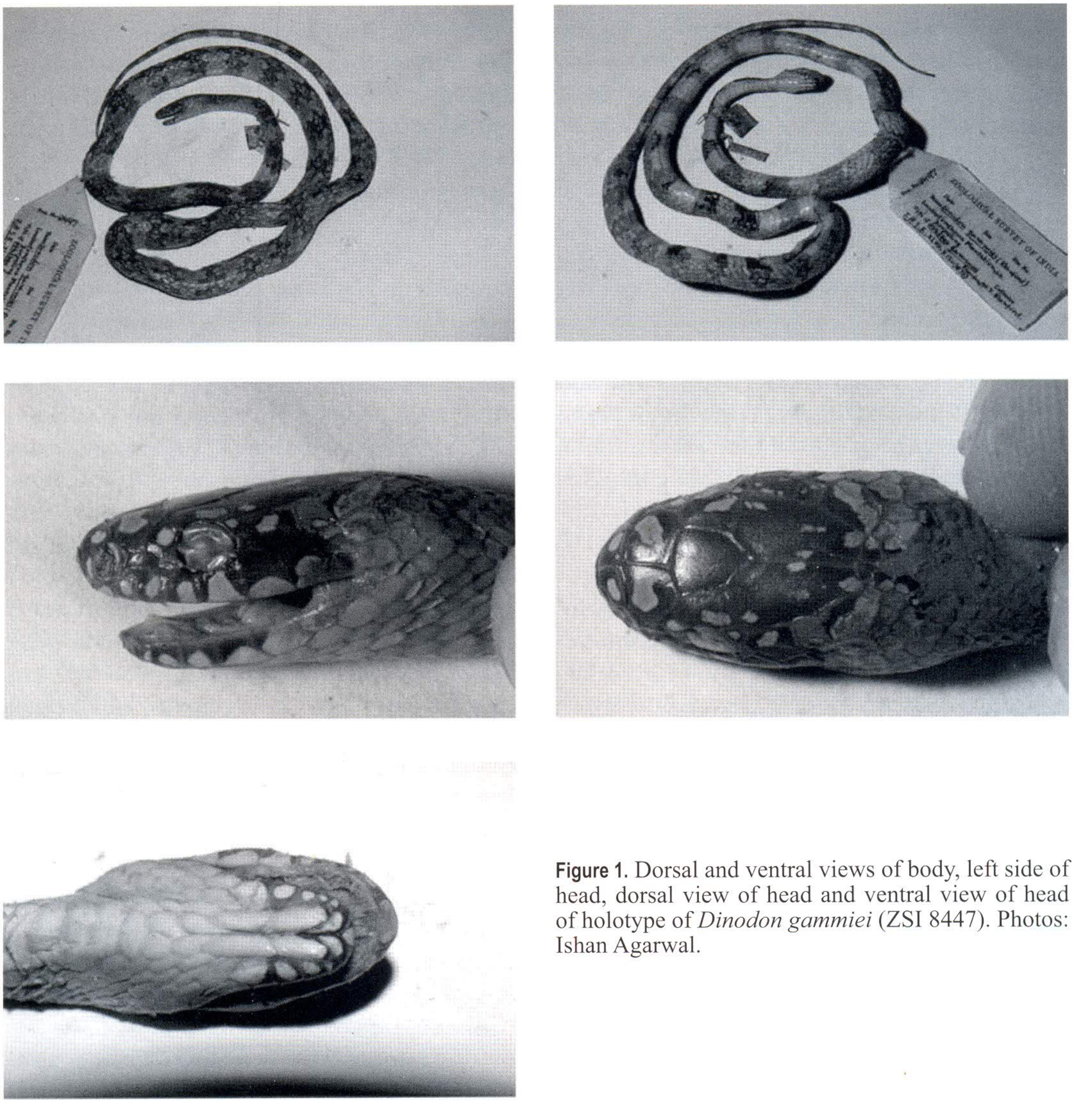

Figure 1. Dorsal and ventral views of body, left side of head, dorsal view of head and ventral view of head of holotype of *Dinodon gammiei* (ZSI 8447). Photos: Ishan Agarwal.

Figure 2. Left side head close-up and half the body of the living specimen of *Dinodon gammiei* frm West Kameng District (Arunachal Pradesh, India), showing the details of head scalation. Photo: Viral Mistry.

Figure 4. View of the ventral side of the living specimen of *Dinodon gammiei*, from West Kameng District (Arunachal Pradesh, India). Figure also shows the colour and pattern of the throat. Photo: Viral Mistry.

Figure 3. Dorsal head close-up of the living specimen *Dinodon gammiei*, from West Kameng District (Arunachal Pradesh, India). Photo: Viral Mistry.

Figure 5. Dorsal view showing full body of living specimen of *Dinodon gammiei*, from West Kameng District (Arunachal Pradesh, India). Photo: Viral Mistry.

1. The head colouration of *D. gammiei* is characterized by distinct light irregular markings on nearly all scales of the pileus and the head sides (Figs. 2, 3); this is in contrast to *L. fasciatus* which has a mostly black head except for some markings on the neck.
2. In *D. gammiei,* the venter is yellow and black (Fig. 4); in *L. fasciatus,* it is white and black.
3. The supralabials in *Dinodon gammiei* are light with dark sutures (Fig. 2); in *L. fasciatus*, only the edge of the lips is light, the other parts are dark.
4. There are irregular light markings around the yellow bands in *D. gammiei* (Fig. 5); these are missing in *L. fasciatus*. This is difficult to see in preserved animals as the yellow colour vanishes rapidly.
5. Anterior and posterior genials equal in size in *Dinodon gammiei* (Fig. 4); in *Lycodon fasciatus* the posterior genials are longer than the anterior pair (Shaw and Shebbeare, 1929).

A redescription of the colouration and pattern of *Dinodon gammiei* follows:

Head.– Black with irregular dirty yellow markings on nasal, internasal, prefrontal, frontal, loreal, preocular, postocular and temporal scales. Supralabials yellow with thick black markings along the sutures. Patch of dirty yellow scales posterior to the angle of jaw. An 'X' shaped dirty yellow marking covering the pa-

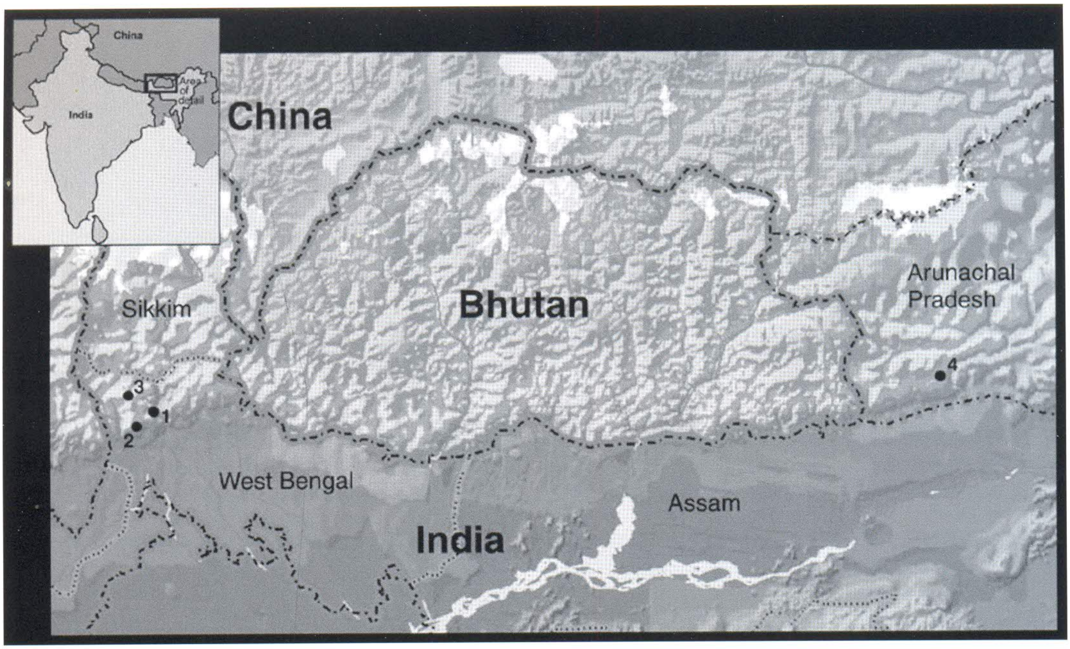

Figure 6. Map of north-eastern India and adjacent regions showing the distribution of *Dinodon gamiei* in the Darjeeling District, West Bengal, India and West Kameng District, Arunachal Pradesh, India. 1: *Cinchona* plantation (Type locality), 2: Kurseong, 3: Darjeeling (town), and 4: Bompu.

rietal scales and the scales posterior to it may or may not be present. Infralabials yellow with black along the sutures of the first few.

Body.– Covered with alternate black and dirty yellow rings with irregular margins from the neck onwards to the tail. First few black rings are incomplete at the level of the ventrals, which are yellow. Dorsal and dorsolateral portion of the black rings, except for the first few, speckled with bright yellow markings. Dorsal and dorsolateral portion of the dirty yellow rings, the exception of the first few ones, have many scales with black sutures.

Ventrally the black rings retain the same colour covering 2 to 3 ventrals. The dirty yellow rings are paler than the dorsal, covering 2 to 4 ventrals.

The two species differ as follows:

Dinodon gammiei has a higher ventral count, though with an overlap: 205–220 (vs. 200–213 in *L. fasciatus*).

The subcaudal counts of *Dinodon gammiei* are much higher, with no overlap: 98–113 (vs. 74–88 in *L. fasciatus*).

The loreal shield is separated from the orbit by the preocular and the third supralabial in *Dinodon gammiei* In contrast, although a preocular is present, the loreal is in contact with the orbit in *L. fasciatus*.

Differences in the hemipenes of *Dinodon gammiei* and *Lycodon fasciatus* and the shape of the maxillary bone (strongly arched in *Lycodon* vs. not arched in *Dinodon*) were described by Smith (1943).

DISCUSSION

As there are distinct differences in colouration, pholidosis, and number of cranterian teeth and maxillary bone, we reconfirm the validity of these two species. The only other species of the genus *Dinodon* found in India is *Dinodon septentrionale*. This species has fewer subcaudal scales (81–92) (Smith, 1943), than *Dinodon gammiei*. It also has a different colouration with narrower white bands. Thus these two species do not seem to be closely related. In terms of geography, the next closest species is *Dinodon meridionale*, with substantial morphological differences, in addition to greater number of ventrals and 15–17–17 dorsal scale rows with a reduction in the anterior part of the body instead of the posterior one (Orlov and Ryabov, 2004). *Dinodon gammiei* is not similar to any of the other species of the genus *Dinodon*.

Table 1. Summary of collection data and scale counts of known specimens of *Dinodon gammiei*. Abbreviations: n. n. = not noted. [1]damaged in the midbody section; [2]all information of this specimen from Ahmed and Dasgupta (1992); [3]tail incomplete; [4]all information of this specimen from D'Abreu (1911, 1912); [5]Smith (1943); this work; [6]Wall (1911a); [7]BMNH1903.7.16.1, from Darjeeling.

Collection Number	**ZSI 8447 Holotype**	**ZSI 17129**	**ZSI 23431[2]**	**BNHS 1257**	**ZMB 18959**	**not located[4]**	**live specimen**	***Dinodon gammiei* total[5]**	**Lycodon fasciatus**
Locality	Cinchona Plantation, Darjeeling	Darjeeling, North Bengal	Darjeeling, North Bengal	Kurseong, Darjeeling	between Kurseong and Siliguri (Terai)	Goomtee Tea Estate nr. Kurseong	Bompu, West Kameng, Arunachal Pradesh	West Bengal and Arunachal Pradesh, India	Indian and Myanmar populations[6]
Altitude	n. n.	n. n.	n. n.	n. n.	n. n.	1220 m	1940 m	1067[7] – 1940 m	900–2100 m
V	1 + 212	3 + 205	n. n.	216	205	214	220	205–220	200–213
SC	101	104	n. n.	101+ [3]	101	98	112	98–112	74–88
DSR	17 –19 – 15	17 – ?17[1] – 15	? – 17 – ?	17 – 17 – 15	17 – 17 – 15	17 – 17 – 15	17 – 17 – 15	17–17(19) – 15	17–17–15
Anal shield	single	single	n. n.	Single	single	single	single	single	single
SL	8 /8	8 / 9	n. n.	8 / 8	8 / 8	8 / 7	8 / 8	8 (7, 9)	8
SL touching orbit	3,4,5 / 3,4,5	3,4,5 / 3,4,5	n. n.	3,4,5 / 3,4,5	3,4,5 / 3,4,5	3,4,5 / 3,4	3,4,5 / 3,4,5	3,4,5 (3,4)	3,4,5
Loreal shield touching eye	no / no	no / no	n. n.	no / no	no / no	no / no	no / no	no	normally yes
PreOc	1 / 1	1 / 1	n. n.	1 / 1	1 / 1	1 / 1	1	1	1
PostOc	2 / 2	2 / 2	n. n.	2 / 2	2 / 2	1 / 2	2	2 (1)	2
T	1 + 3 / 2 + 3	2 + 2 / 2 + 3	n. n.	2 + 3 / 2 + 2	2 + 2 / 2 + 2	2 + 2 / 2 + 3	2+2	2+2 or irregular	2+3
Light rings on body and tail	47	58	n. n.	52	57	52	52	47–58	37–58
Light rings on tail	17	20	n. n.	16 + [3]	18	16	n. n.	15 – 20	14–20
TL	750 mm	1100 mm	n. n.	1040 mm	539 mm	914 mm	880 mm	max. 1150 mm	933 mm
TaL	190 mm	280 mm	n. n.	245 + [3] mm	132 mm	215 mm	225 mm	max. 290 mm	n.n.
TaL/TL	0,253	0,254			0,244	0,235	0,255	0,235–0,255	n.n.

The closest relative to *Lycodon fasciatus* is without doubt *Lycodon ruhstrati*. These two species are sometimes difficult to tell apart, but in *Lycodon fasciatus* the rings encircle the whole body, whereas they do not continue on the belly in *L. ruhstrati* (Vogel and Brachtel, in prep.).

Dinodon gammiei is currently known only from a small area of the Eastern Indian Himalaya, in the Darjeeling District, West Bengal State and West Kameng District, Arunachal Pradesh State, India (Fig. 6). Despite the fact that some authors include Sikkim in the distribution of the species (e.g., Sclater, 1891b; Smith, 1943; Murthy et al., 1993; Das, 2000; Jha and Thapa, 2002 Sharma, 2003), there is no specimen definitely known from this east Indian state. Our living specimen is the only animal found at some distance from the type locality (ca. 400 airline km) in Arunachal Pradesh. We can expect this species to be found in other parts of the eastern Himalayan mountain complex, from East Nepal eastwards to Bhutan and south-eastern Tibet. Perhaps this species has up to now been overlooked due to misidentification or insufficient collecting.

The ecological data for this species are sparse. D'Abreu's specimen was found at an elevation of 1,220 m. Another specimen (BMNH 1903.7.16.1) was found at 1,660 m a.s.l. in Darjeeling. The holotype was collected at a *Cinchona* plantation (Blanford, 1878a–b).

Our specimen was caught on 23 September 2004 at 18.20 h. It was active above the window of a stone house, trying to enter a hole above the window at lintel level ca. 2.5–3 m above the ground. The elevation was 1,940 m. When handled it tried to bite. While posing it for photographs, it was shy, showed no aggression and tried to escape. Nothing else is known of the natural history of *Dinodon gammiei*.

ACKNOWLEDGEMENTS

We wish to thank the following persons for their help: Ashok Captain (Pune) brought the team together and helped with advice at every stage of the publication. He furthermore checked the pholidosis of some specimens. Patrick David (MNHN) and Van Wallach (MCZ) reviewed the manuscript and gave much advice. Ishan Agarwal (Bombay) photographed the preserved specimens and helped checking the pholidosis of the ZSI specimens. Varad Giri helped us with the work in the BNHS. Mirko Barts (Berlin) helped with the map. Joshua Thompson (Berlin) checked the English language. Hendrik Müller checked the catalogue and collection of the BMNH for us. Naresh Chaturvedi allowed access to the BNHS collection. M. S. Ravichandran, Channa Keshava Murthy and Gouri Dasgupta of ZSI (Kolkata) gave us access to the ZSI specimens. Rainer Günther (ZMB) and Wolfgang Böhme (ZFMK) allowed us to examine material in their collections. Alain Dubois and Annemarie Ohler (MNHN) allowed GV to examine specimens deposited in the MNHN. The field work was funded by a grant from Rufford–Maurice–Laing Foundation to Ramana Athreya (Pune). Our study would have not been possible without the help of the State Forest Department, Arunachal Pradesh for giving permissions to carry out study in the Eagle Nest Wildlife Sanctuary. Nima Shring (Ramaling, Arunachal Pradesh) the field guide was a big help during the field work.

LITERATURE CITED

AHMED, S. & G. DASGUPTA. 1992. Reptilia. In: Fauna of West Bengal. Part 2 (Reptilia, Amphibia, Fishes, Hemichordata and Archaeozoology): A. K. Ghosh (Ed). Zoological Survey of India, Calcutta. State Fauna Series 3:1–65.

ANONYMOUS. 1879. Appendix A. Accessions to the Indian Museum from 1st April 1878 to 39th June 1878. Reptilia. Annual report and lists of accessions, April 1878 to March 1879, Indian Museum:6–7.

_____**. 1997.** Checklist of the reptiles in India with regard to the Wildlife Protection Act. In: Conservation Assessment & Management Plan (C.A.M.P.) Workshop for Reptiles of India. Section 2: Assorted Reptile Reference Material. Biodiversity Conservation Prioritisation Project (B.C.P.P.) held from 19–23 May 1997, T.N. Forest Dept., Coimbatore. 10 pp.

BLANFORD, W. T. 1878a. Notes on Reptilia from the Himalayas and Assam. Proceedings of the Asiatic Society of Bengal 6:141–142.

_____**. 1878b.** Notes on some Reptilia from the Himalayas and Burma. Journal of the Asiatic Society of Bengal 47(3):125–131.

BOULENGER, G. A. 1890. The fauna of British India, including Ceylon and Burma. Reptilia and Batrachia. Taylor & Francis, London. xviii + 541pp.

____. **1893.** Catalogue of the snakes in the British Museum (Natural History). Volume I. Containing the families Typhlopidae, Glauconiidae, Boidae, Ilysiidae, Uropeltidae, Xenopeltidae and Colubridae aglyphae, part. British Museum (Natural History), London. xiii + 448 pp + Pl. I–XXVIII.

D'ABREU, E. A. 1911. Extension of the habitat of *Lycodon fasciatus*. Journal of the Bombay Natural History Society 20(3):857–858.

____. **1912.** Is *Lycodon gammiei* (Blanford) an aberrant specimen of *Lycodon fasciatus*? Journal of the Bombay Natural History Society 21(4):1335–1336.

DAS, I. 2000 "1999". The dates of publication of amphibian and reptile names by Blanford and Stoliczka in the Journal and Proceedings of the Asiatic Society of Bengal. Asiatic Herpetological Research 8:18–24.

____. **2003.** Growth of knowledge on the reptiles of India, with an introduction to systematics, taxonomy and nomenclature. Journal of the Bombay Natural History Society 100(2&3):446–501

____**, B. DATTAGUPTA & N. C. GAYEN. 1998.** History and catalogue of reptile types in the collection of the Zoological Survey of India. Journal of South Asian Natural History 3(2):121–172.

DOWLING, H. G. 1951. A proposed standard system of counting ventrals in snakes. British Journal of Herpetology 1(5):97–99.

GAMMIE, J. 1928. Reptiles: 188–190. In: The gazetteer of Sikhim. H. H. Risley (Ed). Bengal Secretariat Press, Calcutta. xxii + 397 pp. [Reprinted 2001, Low Price Publ., Delhi.]

JHA, A. & K. THAPA. 2002. Reptiles and amphibians of Sikkim. Shila Jha Publication, Raipur. v + 100 pp.

MAHENDRA, B. C. 1984. Handbook of the snakes of India, Ceylon, Burma, Bangladesh and Pakistan. The Annals of Zoology, Agra (B) 22: i–xvi + 1–412.

MURTHY, T. S. N., D. P. SANYAL & B. DUTTAGUPTA. 1993. Rare snakes of India. The Snake 25:135–140.

ORLOV, N. L. & S. A. RYABOV. 2004. Revalidization and change of taxonomic status of *Dinodon rufozonatum meridionale* Bourret, 1935 (Serpentes: Colubridae: Colubrinae). Russian Journal of Herpetology 11(3):181–197.

RYABOV, S., S. KUDRJAVZEV & A. OGNEV. 2003. Pflege und Zucht der Ryukyu-Großzahnnatter, *Dinodon semicarinatus* (Cope, 1861). Sauria, Berlin 25(3):25–28.

SCLATER, W. L. 1891a. List of snakes in the Indian Museum. Baptist Mission Press, Indian Museum, Calcutta. x + 79 pp.

____. **1891b.** Notes on the collection of snakes in the Indian Museum with descriptions of several new species. Journal of the Asiatic Society of Bengal 60(2):230–250, Pl. VI.

SHARMA, R. C. 2003. Handbook: Indian snakes. Zoological Survey of India, Kolkata. xx + 340 pp.

SHAW, G. E. & O. SHEBBEARE. 1929. The snakes of northern Bengal and Sikkim. Journal of the Darjeeling Natural History Society 3(3):51–57.

SMITH, M. A. 1943. The fauna of British India, Ceylon and Burma, including the whole of the Indo-Chinese subregion. Reptilia and Amphibia. Vol. III, Serpentes. Taylor & Francis, London. xii + 583 pp.

VOGEL, G. & N. BRACHTEL (IN PREP). Zur Kenntnis von *Lycodon ruhstrati* (Fischer, 1886) in Vietnam. Taxonomie und Biologie einer wenig bekannten Art.

WADDELL, L. A. 1899. Among the Himalayas. Constable, Westminster. xvi + 452 pp. [Reprinted, 1978, Pilgrims Book Pvt. Ltd., Kathmandu).

WALL, F. 1911a. A popular treatise on the common Indian snakes. Part 15. Journal of the Bombay Natural History Society 20(4):933–953.

____. **1911b.** Is *Lycodon gammiei* (Blanford) an aberrant specimen of *Lycodon fasciatus*? Journal of the Bombay Natural History Society 21(1):279–281.

____. **1923.** A hand-list of the snakes of the Indian Empire. Part II. Journal of the Bombay Natural History Society 29(3):598–632.

WHITAKER, R. & A. CAPTAIN. 2004. Snakes of India, the field guide. Draco Books, Chengalpattu. xiv + 483 pp.

Received: 20 September 2005.
Accepted: 21 November 2005.

APPENDIX I

Material examined

Dinodon gammiei: BNHS 1257, Kurseong, Darjeeling; ZMB 18959, between Kurseong and Siliguri (Terai); ZSI 8447 Holotype, Cinchona Plantation, Darjeeling; ZSI 17129, Darjeeling, North Bengal; 1 living specimen, Bompu, West Kameng, Arunachal Pradesh.

Lycodon fasciatus: BNHS 1220, Shillong, Assam, India; BNHS 1223–1224, Maymyo, Myanmar; BNHS 1228, Thandung Hills, Myanmar; BNHS 1230, Gyabari, Darjeeling, India; MNHN 1928.69, "Xieng-Khouang, Haut Laos", Xiengkhuang Province, Laos; MNHN 1919.148, Yunnan, China.

Lycodon ruhstrati: MNHN 1928.67–68, "Xieng-Khouang, Haut Laos", Xiengkhuang Province, Laos; MNHN 1935.99–100, Tam Dao, Vietnam; MNHN 1938.130, Ngan-Son, Vietnam; PSGV 495 2 specimens, Tam Dao, Vietnam; PSGV 651 2 specimens; Tam Dao, Vietnam; PSGV 590 1 juvenile; Tam Dao, Vietnam; PSGV 676 1 adult, 5 juvenile specimens; Tam Dao, Vietnam; ZFMK 23363, Fujian: Kuatun, China.

Dinodon septentrionale: MNHN 1893.411, Mts. Karin, Myanmar 900–1000 m; MNHN 1933.11, type of *Dinodon septentrionalis chapaensis*, Sa Pa, Vietnam.

Hamadryad Vol. 31, No. 2, pp. 274 – 280, 2007.

NESTING OF *LEPIDOCHELYS OLIVACEA* ALONG THE SOUTHERN CHENNAI COAST, WITH EMPHASIS ON HABITAT CHARACTERISTICS

S. Bhupathy[1], J. Subramanean[2] and M. Vijay[1]

[1]Sálim Ali Centre for Ornithology and Natural History, Anaikatti,
Coimbatore 641 108, India.
[1]Email: sb62in@yahoo.co.uk

[2]Sálim Ali School of Ecology and Environment, Pondicherry University,
Kalapet, Pondicherry 605 014, India.

(with three text-figures)

ABSTRACT.– **The nesting of olive ridley turtles (*Lepidochelys olivacea*) along a 50 km of beach south of Chennai, Tamil Nadu, India, was studied from January to March 2004. Fortnightly surveys were done on foot between 0600 and 0830 h on five consecutive days to locate tracks, nests, and carcasses of turtles that had been washed ashore. Nest location with respect to the distance from high tide line, river mouth and nearest village were recorded. Coastal vegetation was sampled every 500 m and at each site used for nesting. Peak nesting was observed in the first fortnight of March, and estimated nesting density was 10.8 nests/km. A total of 135 carcasses of ridleys were located and mortality was largely from incidental catch in fishing gears. Number of nests located was negatively correlated with various distance categories from nearest village (r = -0.443, p = 0.050, n = 20), high tide (r = -0.628, p = 0.039, n = 11) and river mouth (r = -316, p = 0.034, n = 44). Turtles preferred to nest near *Ipomoea pescaprae* (*sw* = 0.445) compared to *Spinifex littoreus* (*sw* = 0.207). Further studies on nest site selection would provide pertinent information for both sea turtle conservation and plans for coastal development.**

KEY WORDS.– **Sea turtle, nest site preference, coastal vegetation, environmental factors, stranding.**

INTRODUCTION

Globally, seven species of sea turtles are recognized (Pritchard and Mortimer, 1999) five (*Dermochelys coriacea*, *Caretta caretta*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, *Chelonia mydas*) of which are found in Indian waters. All five species are listed in the Indian Wildlife Protection Act, 1972. It is reported that marine turtles are declining worldwide largely due to egg collection, catching turtles on land and in the sea, marine pollution, and incidental catch in fishing gear (Limpus, 1995, Renaud et al., 1997). The nature of the offshore approach to nesting beaches, slope of the beach, vegetation, texture of the sand and illumination from inland are important factors influencing the selection of nesting sites by sea turtles (Mortimer, 1995). For many areas, habitat characteristics of turtle nesting beaches are poorly understood and available information is sketchy, although remarkably in the case of Tamil Nadu, there is mention in 4th Century Tamil Sangam poem that turtles nest among the ground glory, *Ipomoea* sp. (Sanjeevaraj, 1958). Based on the locations of mass nesting areas in Orissa, it is speculated that ridleys nesting in other parts of India would select beaches close to river mouths, but data, in this regard, are lacking (Tripathy et al., 2003a). The olive ridley sea turtle (*Lepidochelys olivacea*) is widely distributed throughout the tropics and subtropics, and it nests sporadically all over coastal India, with the exception of Orissa, where mass nesting occurs at three localities (Pandav, 2000; Shanker et al., 2003). While information on the nesting of ridleys in India is available with some details for mass nesting areas (Kar and Bhaskar, 1982; Pandav et al., 1997, 1998; Pandav, 2000; Tripathy et al., 2003b), data from other areas are limited (Banugopan and Davidar, 1999; Bhupathy and Karunakaran, 2003; Tripathy et al., 2003a).

Monitoring of turtle nesting was initiated three decades ago along the Chennai coast, and has been continued on a yearly basis with relocation of eggs to beach hatcheries and release of hatchlings into the sea (Valliapan and Whitaker, 1974; Whitaker, 1977; Silas and Rajagopalan, 1984; Abraham, 1990; Shanker, 2003). Information on turtle nesting sites in relation to the location of villages, river mouths and plantations are pertinent for both sea turtle conservation and coastal area development. In the present paper, we provide data on the ridleys nesting along the southern Chennai coast and relate these to select habitat parameters.

MATERIALS AND METHODS

The Mamallapuram–Pondicherry coast is an extension of the southern Chennai coast, Tamil Nadu (Fig. 1), and 50 km coast (12° 31'–12° 8'N; 80° 10'–79° 56'E) was monitored for turtle nesting from January to March 2004. This coast is sandy without notable rocky outcrops. The Palar and Marakkanam backwaters are major fresh/ brackish water bodies that join the sea (Bay of Bengal). Twenty-one fishing villages are located along the study zone, and the density of all fishing vessels averaged 63/village, including 33.8 *catamarans* and 29.2 mechanised boats. The dominant coastal vegetation of the area includes *Ipomoea pescaprae*, *Spinifex littoreus*, *Pandanus tectornis* and *Casuarina equisetifolia*.

The study area (50 km) was divided into five equal (10 km) sectors using a Global Positioning System (GPS). Fortnightly surveys were done on foot between 0600 and 0830 h and each sector was covered on five consecutive days for locating turtle tracks, nests and carcasses washed ashore. Turtle carcasses were marked with enamel paint to avoid repeat counts. Nesting was confirmed following tracks, nesting site, body pit and egg chamber, and status of the same was assessed based on signs of predation including nest exploitation by humans. None of the nest was opened as it would spoil the developing eggs and enhance predation. However, presence of eggs in the nest was confirmed. Crawls or nests counted during each surveys

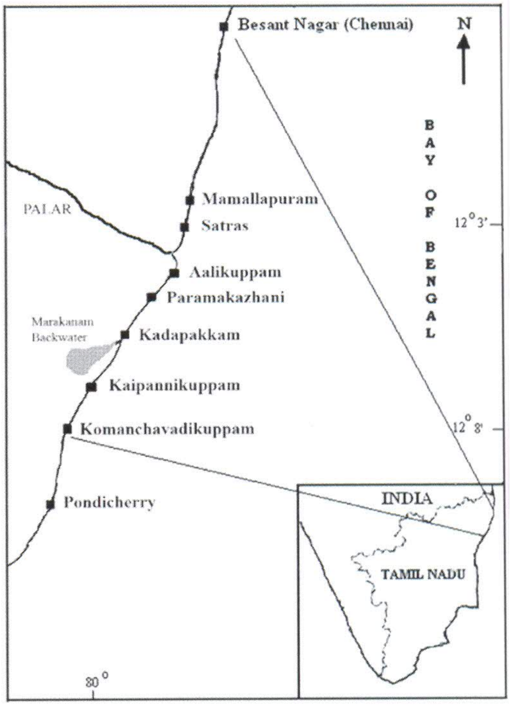

Figure 1. Map of the southern Chennai coast, Tamil Nadu, showing study area and major localities mentioned in the text.

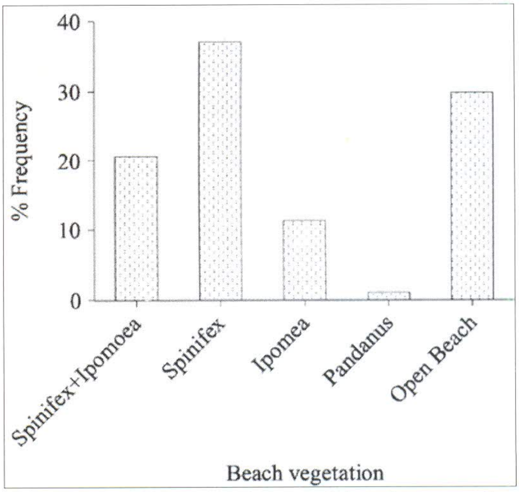

Figure 2. Relative abundance of beach vegetation along the southern Chennai coast, Tamil Nadu, based on point sample method; sample size (n) = 101.

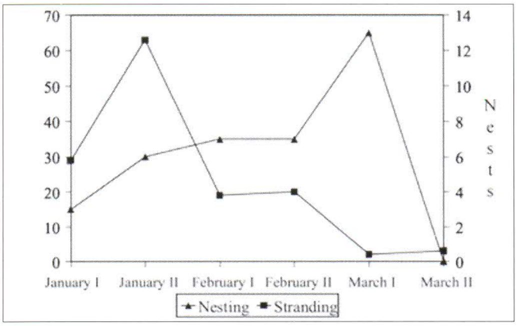

Figure 3. Nesting and stranding of *Lepidochelys olivacea* along the southern Chennai coast, Tamil Nadu during January – March 2004.

were considered new, as the interval between surveys was 10–15 days and tracks were obliterated during the survey.

Vegetation was evaluated at every 500 m along the entire beach using point sample method. At each site, the presence of vegetation along the perpendicular line from the high tide up to 25 m inland was noted. Based on the representation of each or combination of plant species in the samples (n = 101), proportion of the same was calculated and considered as their availability. Plant species found within a 5 m radius of each nesting site was enumerated and proportion of the same was considered as utilization by turtles. Data on nest site with respect to distance from high tide line was measured using a flexible tape and nearest river mouth and village in most cases were recorded using a GPS.

Number of nests (estimated) along the beach surveyed during the study was calculated as

$$N = n X d X t$$

(Bhupathy and Karunakaran, 2003),

where N = total nesting, n = average nesting of the day/10 km, d = number of sectors surveyed, and t = study period (in days).

Preference of nesting sites by turtles with respect to ground vegetation was calculated based on the availability and utilization of ground vegetations.

$w = r/a$ and, further standardized as $B = w/\sum w$, where a = ratio of availability of one or combination of plant species and r = ratio of utilization of the locations with one or combination of plant species by turtles for nesting.

The beach was divided into various sectors such as 0–50 m, 50–100 m, etc, with respect to the distance from river mouth and village, and inland perpendicular to high tide line as 5 m, 10 m, 15 m, etc. Number of nests located in the above sectors was correlated with distance categories using Pearson correlation (SPSS, version 6).

RESULTS

Beach vegetation.– About 70% of the sample points had vegetation within 25 m from the high tide line. Major shore vegetations of the area were *Spinifex littoreus* followed by a mixture of *S. littoreus* and *Ipomoea pescaprae* (Fig. 2). Sand bars without any terrestrial vegetation was found near river mouth. About 50–100 m away from high tide line, *Casuarina* plantations and *Pandanus* were common. *Casuarina* plantations are a part of the coastal shelterbelt programme for protecting the mainland from natural calamities, such as cyclones. Human settlements and agriculture largely affect the area farther inland in the area. Major occupations of the inhabitants of the coastal villages are fishing, and their fishing boats were left on the shore itself. Nest predators, such as jackals (*Canis aureus*) and domestic dogs (*Canis familiaris*) inhabit the *Casuarina* plantations and human settlements, respectively.

Nesting and mortality.– A total of thirty eight turtle tracks was recorded in the fortnightly sampling from January to March 2004, of which 36 nests had eggs. Egg shells found nearby predated nests and signs of animals/humans indicated the status of the nest. Number of eggs in the nests robbed by humans was confirmed through interviews with villagers with the help of the field assistant from this study. Peak nesting was observed in the first fortnight of March (Fig. 3). Estimated number of nests for January–March was 540, which worked out to be 10.8 nests / km (Table 1).

Of the 36 nests observed, 25 (69.4%) were found depredated. Among the depredated nests, based on signs found nearby, jackals and domestic dogs contributed 54.2% and 33.3%, respectively, and human about 12.5% of the nests pilfered eggs. Native communities such as Irulas consume turtle eggs occasionally. Carcasses of 134 ridleys and five green turtles, *Chelonia mydas* were observed during this investigation.

Turtle mortality was mainly due to drowning in the fishing gears as fresh carcasses had injuries and prolapsed internal organs. Fishermen in this region often chop off the flippers or club the head of the entangled turtles to remove them without damage to the nets or to the fishermen themselves. Peak mortality of turtles was observed during January, which gradually reduced (Fig. 3).

Nest site characteristics.– Data on nest site with respect to distance from the nearest river mouth, village and high tide line are given in Table 2. Distance from the nest to village varied from 10 to 2000m (mean = 758.6 m, SD = 586 m, n = 36). The correlation of number of nests located and various distance categories from the closest village was negative, but weakly significant (r = -0.443, p = 0.05, n = 20). Similarly, the number of nests found and various distance category from river mouth was also negatively related (r = -0.316, p = 0.034, n = 44) showing more turtle nests were found in close vicinity to river mouth. The mean distance of the location turtle nest from the high tide line was 17.2 m (range 0–100 m). Significant negative correlation was obtained between number of nests located and distance categories from high tide line (r = -0.628, p = 0.039, n = 11, Table 2), indicating that the number of nests were reduced with distance.

Vegetation data based on point sampling showed that *Spinifex littoreus* covered a larger proportion of the area followed by open sandy beaches without any vegetation (Table 3). Preference index calculated from available proportion of various ground vegetations with respect to nest location (utilization) showed that locations with *Ipomoea pescaprae* was most preferred (*sw* = 0.445) for nesting, followed by open beach without any ground vegetation (*sw* = 0.256). Use of locations with *I. pescaprae* for nesting was high compared to its availability (Table 3). *S. littoreus* covered a considerable proportion (38%) of the beach studied, but were poorly utilized (*sw* = 0.207) by turtles for nesting.

DISCUSSION

Nesting of ridleys during January–March along the southern Chennai coast is similar to other parts of the east coast of India, including the mass nesting areas in Orissa (Pandav et al., 1997; Banugopan and Davidar 1999; Bhupathy and Saravanan, 2002). Sea turtle nesting on this coast is sporadic, and the density is estimated at about 10.8 nests/km during this period. Three decades of monitoring on 6 km Chennai coast showed a density of about 9.5 nests/km (Shanker, 2003). The estimated nesting density based on fortnightly sampling in the present study is similar to that of the daily monitoring by the Students' Sea Turtle Conservation Network (SSTCN) along a small sector (6 km) Chennai coast.

Kar and Bhaskar (1982) estimated 100 nests/km along the southern Chennai coast during early eighties. Drastic reduction of nests within two decades is to be noted, and this reduction could be largely due to incidental mortality of a large number of adult turtles in fishing gears. Decline of ridley populations worldwide have been largely attributed to incidental mortality (Limpus, 1995; Renaud et al., 1997; Hays et al., 2003; Shanker et al., 2003). Based on studies along the Virginia, North Carolina and Gulf of Mexico coasts, it has been estimated that the number of dead turtles that have been washed ashore represented a maximum of 7–13% of the total mortality (Epperly et al., 1996). This indicates that carcasses found on the beaches are only a fraction of the number of turtles that died in high seas. A record of 134 ridley carcasses in 50 km sporadic nesting area within one breeding season is a matter of concern and requires conservation attention.

Table 1. Nesting of *Lepidochelys olivacea* along the southern Chennai coast, Tamilnadu during January – March 2004. For nest estimation procedures, see data analysis

Fortnight	Number of nests	Average nesting/ day/10km
January I	3	0.6
January II	6	1.2
February I	7	1.4
February II	7	1.4
March I	13	2.6
March II	0	0
Total	36	7.2
Average nesting/ day/10km		1.2
Estimated nests (for January– March)		540
Nest/km		10.8

Table 2. Relationship of nests of *Lepidochelys olivacea* with various habitat parameters along the southern Chennai coast, Tamil Nadu. SD= Standard deviation, n = sample size, *r* = correlation, *p* = significance.

Distance from nest (m)	Mean	SD	Range	Pearson correlation		
				n	r	p
Nearest village	758.6	586.7	10–2000	20	-0.443	0.050
River mouth	4783.3	3973.6	100–13000	44	-0.316	0.034
High tide line	17.2	21.01	0–100	11	-0.628	0.039

Table 3. Nest site preference of *Lepidochelys olivacea* with respect to ground vegetation along the southern Chennai coast, Tamil Nadu.

Beach vegetation	Proportion of availability *(a)*	Proportion of use *(r)*	Preference (w) Index	Standardised Index (B)
Spinifex littoreus	0.375	0.343	0.92	0.207
Ipomoea pescaprae	0.115	0.228	1.98	0.445
Mixed vegetation (*Spinifex* + *Ipomoea*)	0.210	0.086	0.41	0.092
Open sandy beach (No vegetation)	0.300	0.343	1.14	0.256

Nest depredation by both wild and domestic animals, and pilfering by humans have been reported in sporadic nesting areas along the Chennai (Whitaker, 1977) and Nagapattinam (Bhupathy and Karunakaran, 2003) coasts, and predation may be as high as 90% in localities such as the latter one. However, the present study area (southern Chennai coast) appears largely undisturbed with respect to illegal egg collection. Native communities, such as Irulas, occasionally use turtle eggs, but do not consume turtles, as done by the inhabitants around Gulf of Mannar (Bhupathy and Saravanan, 2003). Human consumption of turtle eggs is common throughout the nesting area of the ridleys, including the Indian coast (Frazier, 1980).

Factors such as beachfront illumination, topography, grain size of the sand, and vegetation may influence the selection of nest site by turtles (Mortimer, 1995). However, in general, studies on these aspects are scanty. Nest sites that provide optimum condition for developing eggs and hatchling dispersal are important for the survival of populations. In the present study, relationship between the nest location and distance from coastal villages was marginally significant, but negative (r = - 0.443, p = 0.05). This could be due to the limited impact of these coastal villages on nesting turtles as they were devoid of artificial illumination during night. It has been reported that artificial beachfront illuminations disorient both adults and hatchlings (Mortimer, 1995; Tripathy et al., 2003b). Selection of nest sites close to high tide line would have greater chance of inundation, but farther inland would result in higher predation of hatchlings during their emergence and movement towards the sea. Apart from this, sites further inland from the high tide line may be dry and this condition would lead to desiccation of eggs and poor hatching. Other factors, such as topography (elevation) of the beach, which were not studied during this study, may play a role in the selection of nest sites by turtles. Significant negative correlation (r = -0.316, p = 0.034, n = 45) between number of nests located in various distance categories from river mouth showed that turtles nested close to river mouth, and this corroborates the popular belief that ridleys largely nest close to river mouths. Factors such as grain size, moisture content and chemical nature of the sand would also be deterministic in this regard. However, further investigations are required on this direction.

Vegetation of the southern Chennai coast is largely psammophytes, which are similar to other parts of the east coast (Pandav et al., 1997; Bhupathy and Karunakaran, 2003). The role of beach vegetations in nest site selection by turtles is unclear, but views on the same are contradictory (see Mortimer, 1995). We speculate that the root of *Ipomoea pescaprae* may help bind the sand and prevent collapse of nests while under construction. The grass *Spinifex littoreus* has runners and grows in comparatively drier zones of the beach, and has a thick network of roots.

The grass may hinder the movement of both adults and hatchlings as reported recently (Tripathy et al., 2003b). This may partially explain the presence of a fewer nests near *S. littoreus*. Nesting of turtles near *Ipomoea* had been mentioned in the Tamil Sangam literature (~400 AD; Sanjeevaraj, 1958), which is perhaps the oldest literature available hitherto on turtle nesting.

The southern Chennai coast is an important area for sea turtle conservation along the east coast as human disturbance to turtle nests is low and artificial illumination on the beach is absent. The negative aspect of this area is high mortality of turtles due incidental catch in gill nets and trawlers. Turtle mortality due to fishing activities is a global concern and must be addressed continually to prevent further population decline (Renaud et al., 1997). One of the options available is effective use of Turtle Excluder Device (TED) in trawlers. Indigenously developed TED is being promoted along the Andhra Pradesh coast (Bhavani Sankar and Raju, 2003) and may be expanded to other Indian states. Effect of TED in minimizing the mortality of *Caretta caretta* and *Lepidochelys kempii* has been reported recently (Lewison et al., 2003). Sea turtle awareness programmes along coastal areas, involving local communities, would yield the desired results. Information on the relationship between nest site preference and various environmental parameters are pertinent, with respect to both sea turtle conservation and coastal area development.

ACKNOWLEDGEMENTS

The present work is part of a project, "Tracing the Migration of Indian Marine Turtles: Towards an Integrated and Collaborative Conservation Programme" sponsored by the Convention of Migratory Species (CMS) and Madras Crocodile Bank Trust (MCBT). Harry Andrews and Kartik Shanker of MCBT helped us at various points during this study. We thank Sukhdev Thakur, Chief Wildlife Warden, Tamil Nadu for permission to undertake surveys along the Chennai coast, and V. S. Vijayan for providing facilities at SACON. Critical comments on the manuscript by Jack Frazier were useful in improving the quality of this paper. We appreciate the support extended by the villagers of the southern Chennai coast during the fieldwork.

LITERATURE CITED

ABRAHAM, C. 1990. Preliminary observations on the nesting of the olive ridley sea turtle (*Lepidochelys olivacea*) on the Madras coast, south India. Hamadryad 15(1):10–12.

BANUGOPAN, K. & P. DAVIDAR. 1999. Status of sea turtles along the Pondicherry coast, India. Hamadryad 24 (1):43.

BHAVANI SANKAR, O. & M. ANATH RAJU. 2003. Implementation of Turtle Excluder Device in Andhra Pradesh. Kachhapa 8:2–5.

BHUPATHY, S. & R. KARUNAKARAN. 2003. Conservation of olive ridley sea turtle *Lepidochelys olivacea* (Reptilia/Chelonia) along the Nagapattinam coast, southeast coast of India. Indian Journal of Marine Science 32(2):168–171.

____ & S. SARAVANAN. 2002. Status of sea turtles along the Tamil Nadu coast, India. Kachhapa 7:7–13.

____ & ____. 2003. Exploitation of sea turtles along the southeast coast of Tamil Nadu, India. Journal of the Bombay Natural History Society 100(2&3):628–631.

EPPERLY, S. P., J. BRAUN, A. J. CHESTER, F. A. CROSS, J. V. MERRINER, P. A. TESTER & J. H. CHURCHILL. 1996. Beach strandings as an indicator of at-sea mortality of turtles. Bulletin of Marine Science 59(2):289–297.

FRAZIER, J. 1980. Exploitation of marine turtles in the Indian Ocean. Human Ecology 8(4):329–370.

HAYS, G. C., A. C. BRODERICK, B. J. GODLEY, P. LUSCHI & W. J. NICHOIS. 2003. Satellite telemetry suggests high levels of fishing-induced mortality in marine turtles. Marine Ecology Progress Series 262:305–309.

KAR, C. S. & S. BHASKAR. 1982. Status of sea turtles in the Eastern Indian Ocean. Revised edition. In: Biology and conservation of sea turtles. pp:365–372. K. A. Bjorndal (Ed). Smithsonian Institution Press, Washington, D.C.

LEWISON, R. L., L. B. CROWDER & D. J. SHAVER. 2003. The impact of Turtle Excluder Devices and fisheries closures on Loggerhead and Kemp's ridley strandings in the western Gulf of Mexico. Conservation Biology 17(4):1089–1097.

LIMPUS, C. J. 1995. Global overview of the status of marine turtles: a 1995 view point. In: Biology and conservation of sea turtles. Revised edition. pp:605–609. K. A. Bjorndal (Ed). Smithsonian Institution Press. Washington, D.C.

MORTIMER, J. A. 1995. Factors influencing beach selection by nesting sea turtles. In: Biology and conservation of sea turtles. Revised edition. pp:45–51. K. A. Bjorndal (Ed). Smithsonian Institution Press, Washington, D.C.

PANDAV, B. 2000. Conservation and management of olive ridley sea turtles on the Orissa coast. Unpublished Ph. D. dissertation, Utkal University, Bhubaneswar. 106 pp.

____, B. C. CHOUDHURY & C. S. KAR. 1997. Mortality of olive ridley turtles *Lepidochelys olivacea* due to incidental capture in fishing nets along the Orissa coast, India. Oryx 31:32–36.

____, ____ & ____. 1998. The olive ridley sea turtle (*Lepidochelys olivacea*) in Orissa: an urgent call for an intensive and integrated conservation programme. Current Science 75:1323–1328.

PRITCHARD, P. C. H. & J. A. MORTIMER. 1999. Taxonomy, external morphology, and species identification. In: Research and management techniques for the conservation of sea turtles. pp:21–38. K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois & M. Donnelly (Eds). IUCN/SSC Marine Turtle Specialist Group Publication No. 4, Blanchard, Pennsylvania.

RENAUD, M. L., J. M. NANCE, E. SCOTT-DENTON & G. R. GITSCHLAG. 1997. Incidental capture of sea turtles in shrimp trawls with and without TEDs in U.S. Atlantic and Gulf waters. Chelonian Conservation and Biology 2(3):425–427.

SANJEEVA RAJ, P. J. 1958. Egg-laying habits of sea turtles described in the Tamil Sangam literature. Journal of the Bombay Natural History Society 55(2):361–363.

SHANKER, K. 2003. Thirty years of sea turtle conservation on the Madras coast: a review. Kachhapa (8):16–19.

____, B. PANDAV & B. C. CHOUDHURY. 2003. An assessment of the olive ridley turtle (*Lepidochelys olivacea*) nesting population in Orissa, India. Biological Conservation 115:149–160.

SILAS, E. G. & M. RAJAGOPALAN. 1984. Recovery programme for olive ridley *Lepidochelys olivacea* (Eschscholtz 1989) along Madras coast. Bulletin of the Central Marine Fisheries Research Institute 35:9–21.

TRIPATHY, B., K. SHANKER & B. C. CHOUDHURY. 2003a. Important nesting habitats of olive ridley turtles *Lepidochelys olivacea* along the Andhra Pradesh coast of eastern India. Oryx 37(4):454–463.

____, B. PANDAV & R. C. PANIGRAHY. 2003b. Hatching success and orientation in *Lepidochelys olivacea* (Eschscholtz, 1829) at Rushikulya Rookery, Orissa, India. Hamadryad 27(2):185–192.

VALLIAPAN, S. & R. WHITAKER. 1974. Olive ridleys on the Coramandel Coast. Madras Snake Park Trust, Madras. 10 pp.

WHITAKER, R. 1977. A note on sea turtles of Madras. Indian Forester 103(11):733–734.

Received: 13 October 2005.
Accepted: 27 March 2006.

Hamadryad Vol. 31, No. 2, pp. 281 – 287, 2007.

A REVIEW OF *ENHYDRIS MACULOSA* (BLANFORD, 1879) AND THE DESCRIPTION OF A RELATED SPECIES (SERPENTES, HOMALOPSIDAE)

John C. Murphy

Division of Amphibians and Reptiles, Field Museum of Natural History,
1400 South Lake Shore Drive, Chicago, Illinois 60605 USA
Email: fordonia1@comcast.net

(with one text-figure)

ABSTRACT.– ***Hypsirhina maculosa*** **Blanford, 1879 is known from one specimen and a lost type specimen. Both appear to be from the Ayeyarwady River's delta in southern Myanmar. Nine specimens, previously confused with *Enhydris maculosa* represent a second, undescribed species from the same river delta, and are described here as a new species. The new *Enhydris* can be distinguished from all other *Enhydris* exhibiting 25 rows of scales at mid-body by having eight upper labials with the first three contacting the loreal and the fourth entering the orbit; the only exception is *E. maculosa.* The new species can be distinguished from *E. maculosa* by its depressed head, 26–28 dorsal scale rows on the neck (25 in *E. maculosa*), higher ventral count (142–152 compared to 122 in *E. maculosa*), the presence of a cream stripe on scale rows 2–4 that is dorsally bordered by dark spots on the dorsal edge, and by the uniform colouration in the center of each ventral scale.**

KEY WORDS.– **Reptilia; Serpentes; Homalopsidae; *Enhydris maculosa*; Myanmar; Ayeyarwady Delta; new species.**

INTRODUCTION

Aquatic snakes of the genus *Enhydris* are distributed in a north-west–south-east axis from the Indus River Valley of Pakistan to the east coast of Queensland, Australia. Of the 22 taxa recognized by Gyi (1970), only two (9%) are widespread (*Enhydris enhydris* and *Enhydris plumbea*), and the remaining 20 species (91%) are restricted to either single drainage systems, specific sections of coastline, an island, or ecoregion.

The genus *Enhydris* Sonnini and Latreille, 1802 is composed of species with large head shields, mostly smooth scales, nasals in contact behind the rostral, a single or double internasal posterior to the nasals, 19–33 rows of dorsal scales at midbody, 105–172 ventrals, and 23–92 subcaudals. Recently, Voris et al. (2002) used mtDNA sequencing of three genes (cyt*b*, 12s, and 16s) to demonstrate that the genus *Enhydris* is polyphyletic, but that study included only seven of the 22 species Gyi recognized in his revision of the homalopsid snakes.

Blanford (1879a) described *Hypsirhina maculata* on the basis of a single specimen "…sent from Bassein in Pegu by Captain Spearman," that had 25 scale rows at midbody and 125 ventral scales. Later, Blanford (1879b) described the same species again and stated it was "…collected by Dr. Baker in Pegu, I believe, in the neighbourhood of Bassein and sent to me…by Captain Spearman." Das ("1999" 2000) reported that this locality is now known as Bago, Bago Division, in southern Myanmar's Ayeyarwady Delta. The location (about 17.33°N 96.50°E) is west of the Ayeyarwady River in the northern portion of the river's delta.

Blanford (1881) noted that the name *Hypsirhina maculata* was previously used by Duméril, Bibron and Duméril (1854) and that their name had been placed in the synonymy of the Chinese salt marsh dwelling *Hypsirhina bennettii* Gray

1842. Thus, Blanford proposed the replacement name *Hypsirhina maculosa*. This name was overlooked by Boulenger (1890) when he proposed a second replacement name for *maculata*, *Hypsirhina blanfordi*. Boulenger's name was used in numerous works (Sclater, 1891; Boulenger, 1896; Mocquard, 1907; Phisalix, 1922; Werner, 1923; Wall, 1924; Bourret, 1935, 1936) until Smith (1943) recognized *Enhydris* Sonnini and Latreille, 1802 as having priority over *Hypsirhina* Wagler 1830 and recognized the priority of Blanford's replacement name. Smith (1943) rightfully applied the new combination *Enhydris maculosa* (Blanford).

Sclater (1891) gave the Indian Museum (Calcutta) catalog number for the *H. maculata* Blanford type as 8207, this same number was reported by Das et al. (1998) as a ZSI (Zoological Survey of India) number, but the specimen was said to be "not extant." However, Wall (1924) listed a ventral range of "122 to 125" and a subcaudal range of "33 to 45," implying that he had seen a second specimen, since 125 ventrals and 45 subcaudals were the numbers reported by Blanford (1879a, b). When Gyi (1970) published his revision of the Homalopsinae, he reported on 10 specimens of *Enhydris maculosa* he had collected at Maubin, Ayeyarwady Division, Myanmar an area east of the Ayeyarwady River on the northern edge of the river's delta.

METHODS AND MATERIALS

Measurements reported here include those taken with a meter stick to the nearest mm [total length (LOA) and tail length] or with dial calipers to the nearest 0.1mm. Sex was determined by visual inspection of the everted hemipenes, tail shape, or probing. Scale counts from opposite sides of the same specimen are separated with a slash (/) as opposed to a dash (-) which is used to report ranges of scales on one specimen or more than one specimen. Institutional abbreviations follow McDiarmid et al. (1999). The specimens were photographed with a Scalar Digital-1 Microscope. All specimens observed were stored in 70% ethanol. Specimens examined: Maubin, Myanmar: BMNH 1972.887–888; KU 92364–69, 92397. No Data: BMNH 1913.6.12.1; MCZ 18390.

RESULTS

The specimen examined by Wall appears to be BMNH 1913.6.12.1 and my examination demonstrates it is not conspecific with Gyi's Maubin specimens. The specimen is 308 mm LOA with a 43 mm tail and bears a field tag that reads "R17A4." The museum's registry gives the origin as "Loveridge." This specimen agrees well with Blanford's description of *maculosa*, with the exception of the subcaudal count. And, my ventral and subcaudal counts are similar to those obtained by Wall (1924). Table 1 compares Gyi's Maubin specimens and one specimen without data with the only available specimen of *Enhydris maculosa* (BMNH 1913.6.12.1) for a variety of commonly used characters. Gyi's Maubin specimens are distinct from *Enhydris maculosa* and are described here as a new species.

Enhydris maculosa (Blanford, 1879)

(Figure 1a bottom, 1b, 1d)

1879 *Hypsirhina maculata* (non-Duméril and Bibron) Blanford, Journal of the Asiatic Society of Bengal. 48:130. TYPE LOCALITY: Blanford (1879a) gave the type locality as "Bassein in Pegu" in 1879b he stated, "Pegu…in the neighbourhood of Bassein" Das et al. (1998) stated that this locality is now known as Bajo, in southern Myanmar. COLLECTOR: Dr. Baker. HOLOTYPE: Zoological Survey of India, Calcutta. Das et al. (1998) reported the catalogue number as ZSI8207 but describe the specimen as not extant. BMNH 1913.6.12.1 is here designated as the neotype for *Enhydris maculosa*. No locality data are available for this specimen.

1881 *Hypsirhina maculosa* – Blanford, Proceedings of the Zoological Society of London 1881:226. [Substitute name for *H. maculata* which was preoccupied by *H. maculata* Duméril and Bibron, 1854.]

1890 *Hypsirhina blanfordii* – Boulenger, Fauna of British India…Reptilia and Batrachia, p. 377. [Note that Boulenger (1890) proposed this name as the replacement name because *H. maculata* was preoccupied and he was apparently unaware of the replacement name proposed by Blanford in 1881. His description is based entirely on Blanford's original description and he stated that he had not seen the specimen.]

1935 *Hypsirhina Blanfordii* – Bourret, Bulletin Général de l'Instruction Publique 3:26.

1943 *Enhydris maculosa* – Smith, Fauna of British India…Reptilia and Amphibia, 3:387.

Description of the neotype. Head distinct from neck; body cylindrical, but about 30 ventral scales anterior to the vent, it becomes laterally compressed; tail relatively short, ca. 12% SVL. Description based on a single female specimen, BMNH 1913.6.12.1, total length 308 mm, tail 43 mm.

On the depressed head, the rostral scale is pentagonal, notched, and about as broad as it is tall (Plate 21, Figure A). The nasals are in contact and are semi-divided; the nasal cleft touches the first labial. The nare is located in the middle of the nasal scale. The internasal scale is single, diamond-shaped, and isolated from the loreal. The two large prefrontal scales make broad contact with the loreal. The frontal is pentagonal and almost as long at the parietals. There is a single supraocular, a single preocular, a single postocular on the right and two postoculars on the left. Upper labials number eight on both sides; none of these are divided; number eight is the smallest, number seven is largest; 1–3 contact the loreal; the fourth enters the orbit. The primary temporal scale is single and taller than broad. There are two secondary temporal scales and the ventral scale is larger than the dorsal scale. The primary temporal contacts the seam of upper labials 6–7. On the chin, the lower labials number nine on the left and 10 on the right, number six is the largest. There are three pairs of chin shields, the first pair is broad and is contacted by lower labials 1–4. The second pair is much smaller than the first and separated by a pair of smaller scales. The third pair is barely distinguishable from the gulars.

On the body, the dorsal scale rows on neck number 25, 25 at midbody, and 22 in front of the vent. The dorsal scales are smooth, lacking keels, apical pits, and striations. The scales are ovate particularly those in the first few rows (Figure 1b). The ventral scales are narrow (about twice the height of a nearby dorsal scale) on the anterior and posterior of the body, and broad (about 3.5 times the length of a nearby dorsal scale) at midbody, they number 122. On the tail, there are 11 dorsal scale rows. The subcaudal scales number 32/33 in the single female. The dorsal scales on the tail are similar to those anterior to the vent.

The pattern on the outer edges of the ventral scales and the first row of dorsal scales have a zigzag stripe that runs the length of the body. The dorsum has six irregular rows of spots. Each spot is a cluster of three to five scales with dark brown pigment. They are found on scale rows 2–4, 5–6, and 8–10. Each ventral scale has a mid scale spot of dark pigment (Figure 1d). Thus, the overall appearance of the ventral surface is that the snake has three stripes. The neotype is most likely a juvenile specimen. Homalopsid snakes, as a rule, do not show great ontogenetic change from juvenile to adult in pattern, but differences in the colour and colour intensity may be expected. Unfortunately, this specimen has faded from light and chemicals.

Enhydris vorisi sp. nov.

(Figure 1a top, 1c, 1e)

***Enhydris maculosa* [in part].–** Gyi (1970) University Kansas Publ. Mus. Nat. Hist. 20(2):113, Figures 14 and 16.

Holotype.– KU92465, adult female, from Maubin, Ayeyarwady Division, Myanmar (about 16.73°N 95.65°E). Collector: Ko Ko Gyi.

Paratypes.– Maubin, Ayeyarwady Division, Myanmar – BMNH 1972.887–888; KU 92364–69, 92397, collector Ko Ko Gyi. No data – MCZ 18390.

Diagnosis.– *Enhydris vorisi* can be distinguished from all other *Enhydris* exhibiting 25 rows of scales at midbody by having eight upper labials with the first three contacting the loreal and the fourth entering the orbit. *E. maculosa* is the exception. *Enhydris vorisi* can be distinguished from *E. maculosa* by its higher ventral count (142–152 as opposed to 122 in *E. maculosa*), the presence of a cream stripe on scale rows 2–4 that is dorsally bordered by dark spots on the dorsal edge, and by the uniform colouration in the center of each ventral scale.

Description of holotype.– Female, total length 586 mm, 84 mm tail. Head depressed (Fig. 1a top); rostral twice as broad as tall, visible from above; nasals semi-divided with nasal groove contacting first labial, nare in center, about same diameter as orbit; internasal small, quadrangu-

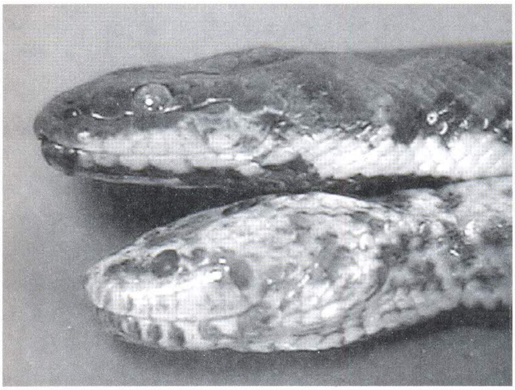

Figure 1a. Profiles of holotype of *Enhydris vorisi* sp. nov. (KU 92465) and the neotype of *Enhydris maculosa* (BMNH 1913. 6.12.1).

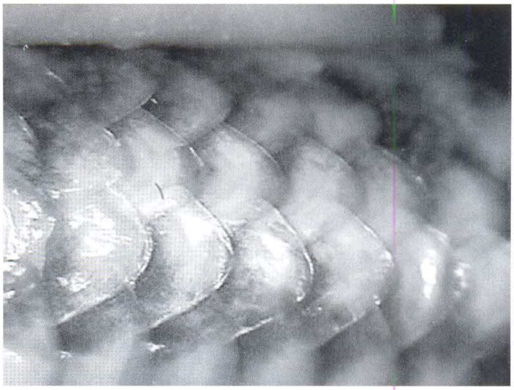

Figure 1b. The first three dorsal scale rows at midbody of the *Enhydris maculosa* neotype. Note the ovate shape.

Figure 1c. The first three dorsal scale rows at midbody of the holotype of *Enhydris vorisi* sp. nov. Note the square shape.

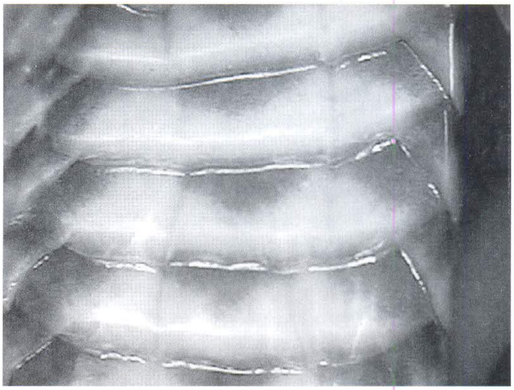

Figure 1d. The ventral pattern of the *Enhydris maculosa* neotype.

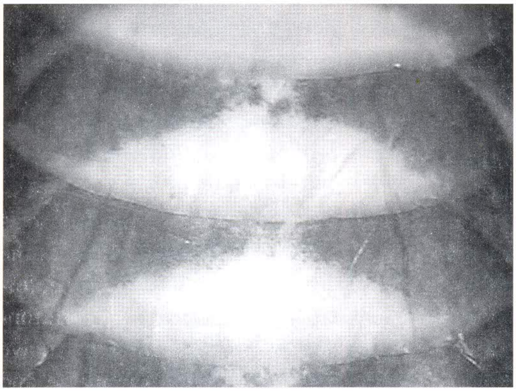

Figure 1e. The ventral pattern of the *Enhydris vorisi* sp. nov. holotype.

lar, not in contact with loreal; loreal quadrangular, in contact with first three upper labials; two prefrontals make broad contact with each loreal; frontal pentagonal and 1.2 x longer than supraocular; parietals entire; temporal scale formula 1 + 2 + 3; upper labials 8/8, sixth largest, eighth the smallest, fourth enters orbit; lower labials 10/10, seventh elongate, first four contact anterior chin shield; anterior pair of chin shield largest and elongated, second pair small. Dorsal scales rows: 26 on neck, 25 at midbody, 22 in front of vent. Dorsal scales in the first several rows are almost square (Fig. 1c). Ventral scales 142, the first nine are narrow, the last ventral is divided. Anal plate divided. Subcaudal scales paired 41/41. Colour pattern: center of each ventral is a uniform cream (Figure 1e); the outer edge of ventrals, the first row and the lower portion of scale row two of dorsal scales have a broad, dark brown zig-zag stripe that runs the length of the body and tail extends onto the chin. Upper portion of scale row two, row three, and lower portion of row four have a cream stripe. Rows 5–7 have a series of black spots that fuse together in places to form a dark stripe. Rows

10–14 have a series of black vertebral spots (about 29) that involve 5–8 scales and may fuse to form an intermittent stripe.

Variation.– Four males had SVLs that ranged from 378–406 mm ($\bar{x}$ = 390.2 mm, SD 12.4) and tails that were 90–102 mm ($\bar{x}$ = 95.8 mm, SD 4.9); male tails were 24–25% of the SVL. Seven females had SVLs ranging from 371–505 mm ($\bar{x}$ = 429.6 mm, SD 48.3) and tails that were 73–86 mm ($\bar{x}$ = 81.1, SD 5.2); female tails were 16–24% of the SVL. Dorsal scales on the neck ranged from 26–28, but were usually 27 (72%); and rows were reduced in front of the vent to 23–21 rows, usually 22 (64%). Ventral scales were 142–152, with males having 147–152 ($\bar{x}$ = 148.8, SD 2.2) and females having 142–148 ($\bar{x}$ = 145.2, SD 2.6). Subcaudal scales were 41–58, with males having 51–58($\bar{x}$ = 54.3, SD 2.9) and females having 41–53 ($\bar{x}$ = 46.6, SD 5.1). The temporal formula was usually 1 + 2 + 3, but one side had 1 + 3 + 3 and another had 1 + 3 + 4.

Etymology.– I am honored to name this snake after my friend and colleague Harold K. Voris, Curator of Amphibians and Reptiles at the Field Museum of Natural History, Chicago, in recognition of his many contributions to the study of the ecology and evolution of the herpetofauna of south-east Asia.

Table 1. A comparison between the one known specimen of *Enhydris maculosa* and 11 specimens of *Enhydris vorisi* sp. nova collected near Maubin, Myanmar.

Characteristics	*Enhydris maculosa* **(n = 1) BMNH 1913.6.12.1**	*Enhydris vorisi* **sp. nov. (n = 11) Maubin**
scale rows neck	25	26–28
scale rows midbody	25	25
scale rows near vent	22	21–23
scale shape in first 3 rows	ovate	square
upper labials	8	8
ventral scales males	no data	147–152
ventral scales females	122	142–148
subcaudal scales males	no data	51–58
subcaudal scales females	32/31	41–53
central spot on each ventral	present	none
stripe on dorsal rows 2–4	not present	present
rows of spots on dorsum	5–6	3
width of rostral scale	narrow	broad

Geographical distribution.– This species is known only from the vicinity of Maubin, Ayeyarwady Division, Myanmar.

Natural history.– The Maubin area is located in the Ayeyarwady Freshwater Swamp Forest ecoregion of Wikramanayake et al. (2002). None of the specimens examined contained prey. A 450 mm SVL female (KU 92397) contained five oviductal eggs.

DISCUSSION

The possibility exists that the specimen of *Enhydris maculosa* (BMNH 1913.6.12.1) used in this study, and most likely examined by Wall (1924), is actually Blanford's type specimen. The size, scale counts and description are similar with the exception of the subcaudal count which he gave as "45 pairs" in his (1879b) account. Also, the BMNH specimen has fused postoculars of the left side and this was not mentioned in the original description. Blanford gave the tail length as 1.75 inches and this is remarkably close to 45 mm, thus he may have confused the tail length in mm with the number of subcaudal scales. In fact, Boulenger (1896) reports the tail length as 45 mm.

It should also be noted that Smith's (1943) statement that the female *E. maculosa* obtained by Flower at Kedah (Malaysia) gave birth to 17 young, is in error. Flower was discussing *Enhydris bocourti*, not *maculosa*.

Both *Enhydris maculosa* and *Enhydris vorisi* inhabit what is now a severely degraded habitat, the Ayeyarwady Freshwater Swamp Forest. Wikramanayake et al. (2002) report the sedimentation rate of the Ayeyarwady River is the fifth highest in the world because of the deforestation that has occurred upstream. Additionally, the mangrove and deciduous forests have been overexploited for timber, agriculture and aquaculture. This situation is not unlike that faced by *Enhydris jagorii* and other *Enhydris* species in Thailand's Chao Phraya River's delta (Murphy and Voris, 2005).

The Bassein type locality for *E. maculosa* is ca. 90 km from the Maubin type locality for *E. vorisi*. Given the similar morphology and geography, it is reasonable to hypothesize that these two taxa are sister species pending molecular studies.

ACKNOWLEDGEMENTS

At the Field Museum of Natural History (FMNH), I would like to thank Harold K. Voris, Alan Resetar, and Jamie Ladonski for lab space and ongoing support. Bryan Stuart (FMNH), Daryl R. Karns (Hanover College), Van Wallach (MCZ), Olivier S. G. Pauwels (IRSNB), and Patrick David (MNHN) read the manuscript and provided useful comments. I would also like to thank Colin McCarthy at The Natural History Museum, London (BMNH), for generously opening the museum's homalopsid collection to me and providing specimens on loan. I also appreciate the loan of specimens from W. Duellman, J. Simmons, and A. Nieto at the University of Kansas (KU); and from José Rosado and Van Wallach at the Museum of Comparative Zoology (MCZ).

LITERATURE CITED

BLANFORD, W. T. 1879a. Notes on reptiles. Proceedings of the Asiatic Society of Bengal (8):216–217.

_____. **1879B.** Notes on reptiles. Journal of the Asiatic Society of Bengal 48(3):127–132.

_____. **1881.** On a collection of reptiles and frogs, chiefly from Singapore. Proceedings of the Zoological Society of London 1881:215–227.

BOULENGER, G. A. 1890. The fauna of British India, including Ceylon and Burma. Reptilia and Batrachia. Taylor and Francis, London. xviii + 541 pp.

_____. **1896.** Catalogue of the snakes in the British Musum (Natural History). Volume III., containing the Colubridae (Opisthoglyphae and Proteroglyphae), Amblycephalidae, and Viperidae. British Museum, London. xiv + 727 pp + Pl. I–XXV.

BOURRET, R. 1935. Comment déterminer un serpent d'Indochine. Bulletin Générale de l'Instruction Publique, Hanoi November (3):1–28.

_____. **1936.** Les serpents de l'Indochine. Tome 1. Études sur la faune. Henri Basuyau & Co., Toulouse. 505 pp.

DAS, I. "1999" 2000. The dates of publication of amphibian and reptile names by Blanford and Stoliczka in the Journal and Proceedings of the Asiatic Society of Bengal. Asiatic Herpetological Research. 8:18–24.

_____, **B. DATTAGUPTA & N. C. GAYEN. 1998.** History and catalogue of reptile types in the collection of The Zoological Survey of India. Journal of South Asian Natural History 3:1–52.

DUMÉRIL, A.-M.-C., G. BIBRON & A.-H.-A. DUMÉRIL. 1854. Érpétologie générale ou histoire naturelle complète des reptiles. Volume 7. Roret, Paris. xii + 782–1536 pp.

GYI, K. K. 1970. A revision of colubrid snakes of the subfamily Homalopsinae. University of Kansas Publications. Museum of Natural History, Lawrence 20:47–223.

McDIARMID, R. W., J. A. CAMPBELL & T'S. A. TOURÉ. 1999. Snake species of the world. A taxonomic and geographical reference. Volume 1. The Herpetologists League, Washington, D.C. xi + 511 pp

MOCQUARD, F. 1907. Les reptiles de l'Indo-Chine. Revue Coloniale, Paris. 59 pp.

MURPHY, J. C. & H. K. VORIS. 2005. A new Thai *Enhydris* (Serpentes, Colubridae, Homalopsinae). The Raffles Bulletin of Zoology 53:143–147.

PHISALIX, M. 1922. Animaux venimeux et venins: la fonction venimeuse chez tous les animaux; les appareils venimeux, les venins et leurs propriétés; les fonction et usages des venins; l'envenimation et son traitement. 2 vols. Masson et Cie, Paris. 864 pp.

SCLATER, W. L. 1891. List of snakes in the Indian Museum. The Indian Museum, Calcutta. 79 pp.

SMITH, M. A. 1943. The fauna of British India, Ceylon and Burma, including the whole of the Indo–Chinese region. Vol. III. Serpentes. Taylor and Francis, London. xii + 583 pp. + 1 map.

VORIS, H. K., M. E. ALFARO, D. R. KARNS, G. L. STARNES, E. THOMPSON & J. C. MURPHY. 2002. Phylogenetic relationships of the Australasian rear-fanged water snakes (Colubridae: Homalopsinae) based on mitochondrial DNA sequences. Copeia 2002:906–915.

WALL, F. 1924. A hand-list of the snakes of the Indian Empire. Part 3. Journal of the Bombay Natural History Society 29:864–878.

WERNER, F. 1923. Über der Gattungen und Arten der Schlangen der Familie Colubridae. I. Teil mit einem Nachtrang zu den übrigen Familien. Archiv für Naturgeschichte, Berlin 89A, 8:138–199.

WIKRAMANAYAKE, E., E. DINERSTEIN, C. J. LOUCKS, D. M. OLSON, J. MORRISON, J. LAMOREUX, M. MCKNIGHT & P. HEDAO. 2002. Terrestrial ecoregions of the Indo-Pacific, A conservation assessment. Island Press, Washington, D.C. 643 pp.

Received: 5 December 2005.
Accepted: 29 March 2006.

Hamadryad Vol. 31, No. 2, pp. 288 – 298, 2007.

A RESURRECTION OF *HYDROPHIS PACHYCERCOS* FISCHER 1855 (SERPENTES: ELAPIDAE) WITH A NEW NEOTYPE FROM THE SOUTH CHINA SEA

Arne Redsted Rasmussen[1], Peter Gravlund[1], Cao Van Nguyen[2] and Lawan Chanhome[3]

[1]The Royal Danish Academy of Fine Arts, School of Conservation,
Esplanaden 34, DK–1263, Copenhagen K, Denmark
Email: arr@kons.dk

[2]Institute of Oceanography, Nha Trang, Vietnam.

[3]The Thai Red Cross, Queen Saovabha Memorial Institute, Bangkok, Thailand.

(with four text-figures)

ABSTRACT.– *Hydrophis pachycercos,* a species only known from a lost type (during the Second World War) is resurrected and redescribed using external and internal morphological characters. A neotype is described together with seven other specimens from a market in Vietnam selling trawl catches from the South China Sea and one specimen from "E. Ind. Archipelago". *Hydrophis pachycercos* is compared with its congeners using both morphological and DNA characters.

KEY WORDS.– Sea snakes, *Hydrophis pachycercos*, resurrection, neotype, morphological and DNA characters.

INTRODUCTION

Since the publication of the "Monograph of the sea-snakes (Hydrophiidae)" by Smith (1926), the contents of the genus *Hydrophis* have increased from 23 to 35 species. The following eight species have been described after Smith's monograph (1926): *H. parviceps* (Smith, 1935), *H. macdowelli* (Kharin, 1983), *H. vorisi* (Kharin, 1984a), *H. coggeri* (Kharin, 1984b), *H. czeblukovi* (Kharin, 1984b), *H. walli* (Kharin, 1989), *H. laboutei* (Rasmussen and Ineich, 2000) and *H. sibauensis* (Rasmussen et al., 2001). *H. pacificus* and *H. lamberti* have been resurrected respectively by Kharin (1984b) and Rasmussen (1989). *H. cantoris* and *H. gracilis* were moved from the genus *Microcephalophis* to the genus *Hydrophis* by McDowell (1972) and *mertoni* was removed from the genus *Hydrophis* to the genus *Parahydrophis* by Burger and Natsuno (1974). *H. atriceps* has been upgraded from subspecies to species level (Cogger et al., 1983). See also Rasmussen (1997) for a review on the generic level.

In 1855, Fischer described *Hydrophis pachycercos* as a new species of sea snake based on a specimen from the Hamburg Museum. The specimen was from a "Naturalienhändler" and the locality was mentioned as "Indisches Meer" (Fischer, 1855). In 1856, Fischer published the description of *Hydrophis pachycercos* again, and here, he included a colour plate based on the type specimen. During the Second World War, the type and only known specimen of *H. pachycercos* was destroyed (Hans-Wilhelm Koepcke, ZMH, pers.comm. 1990).

During sea snake surveys in Vietnam in the year 2000 and 2001, we found eight specimens identical to Fischer's type description and plate (1855; 1856). They were found sympatrically with the following morphologically similar *Hydrophis* species: *H. belcheri, H. cyanocinctus, H. lamberti, H. melanocephalus,* and *H. ornatus*. The specimens were collected by trawling boats and landed in Phan Thiet and Ham Tan, ca. 200 km and 250 km south of Nha Trang, respectively. We compared the type description and the plate of *H. pachycercos* with the eight specimens collected in Vietnam and one specimen from BMNH. The nine specimens were compared with their congeners using external and internal morphological characters and for a selection of *Hydrophis* species, segments of the mitochond genes 16s and cytochrom *b* were sequenced and compared.

MATERIALS AND METHODS

Measurements and counts follow Smith (1926) with some alterations as described below. Scale rows are counted directly around the body (Thomas, 1976). When counting the scale rows around neck and body, the count around the neck is a minimum count and the count around the body is a maximum count. The position of the posterior tip of the heart and the anterior tip of the liver were determined in relation to the number of the adjacent ventral scales (VS-heart and VS-liver). The relative position of the posterior tip of the heart and the anterior part of the liver are expressed as a percentage of the total number of ventral scales (%VS-heart and %VS-liver). Vertebral counts were obtained from soft radiographs. Three counts were obtained from each snake: number of body vertebrae (VB-body), number of tail vertebrae (VB-tail) and number of vertebrae from the head to the posterior tip of the heart (VB-heart). The relative position of the posterior tip of the heart is expressed as a percentage of the total number of body vertebrae (%VB-heart). Body and tail are separated by the presence of the first pair of forked ribs in the cloacal region; this pair of ribs is included in the number of tail vertebrae. The posterior tip of the heart was indicated on the x-ray radiographs by inserting a needle perpendicular to the long axis of the body pointing at the vertebrae opposite the tip of the heart.

Institutional abbreviations follow (Leviton et al., 1985). For specimens examined, see Rasmussen, 1989, 1992, 1993, 1994, 2002; Ineich and Rasmussen, 1997; Rasmussen & Smith, 1997; Rasmussen & Ineich, 2000 and Rasmussen et al., 2001.

Twenty four specimens of hydrophine sea snakes, representing eight species (see Table 1) were sequenced for the mitochondrial gene 16s. In case a taxon showed very little or no genetic divergence from *H. pachycercos,* we also sequenced a fragment of the cytochrome *b* gene for these species.

Tissue samples.– Samples from the specimens investigated (Table 1) comprised muscle-tissue or blood and were stored in 25% DMSO in a saturated solution of NaCl (Amos and Hoelzel, 1991) or in 96% ethanol. Voucher specimens were fixed in 4% formaldehyde and stored in 70% ethanol at ZMUC. Table 1 lists the specimens used and include tissue collection numbers and museum voucher numbers.

DNA Extraction, PCR Amplification, and Sequencing.– DNA was extracted from the muscle tissue or blood using QIAmp Tissue Kit from QIAGEN following the supplier's tissue protocol. Subsequently, a standard double-stranded 50 µl (ds) PCR was carried out using 1 microliter of the extracted DNA as template.

PCR-Conditions for the 16s fragment were: One initial cycle of denaturation (94°C for 2 minutes), followed by 30 cycles (94°C for 30 sec, 51°C for 30 sec, 72°C for 40 sec) and finally, one cycle (94°C for 30 sec, 51°C for 30 sec, 72°C for 10 min). Primers used for amplification of the 16s fragment were: 16L1-CTG ACC GTG CAA AGG TAG CGT AAT CAC T-3' (Hedges, 1994) and 16H1-CTC CGG TCT GAA CTC AGA TCA CGT AGG-3' (Hedges, 1994).

For the amplification of the cytochrome *b* fragment, the following conditions were applied: One initial cycle of denaturation (94°C for 2 minutes), followed by 30 cycles (94°C for 1 min, 50°C for 1 min, 72°C for 1 min) and finally one cycle (94°C for 30 sec, 50°C for 30 sec, 72°C for 5 min). Primers for cytochrome *b*: GLU-(L)-TGA CTT GAA GAA CCA C/TCG TTG-3' (Palumbi, 1996) and CB2-(H)-AAA CTG CAG CCC CTC AGA ATG ATA TTT GTC CTC A-3' (Kocher et al., 1989).

The dsPCR was carried out on a Techne Gene E Thermal Cycler. The PCR products were visualised on a low-melting point agarose gel containing ethidium bromide. In cases of sharp but faint bands, a subsample was taken from the gel, dissolved in 100 µl 1 × TE and a new dsPCR carried out using 1 µl of the resolved PCR-product as template and applying the same PCR conditions as above, except for a 1°C raise in annealing temperature. The dsPCR products were then cleaned using QuiaAmp columns. The purified dsPCR products were used as templates (1 µl) for a 10 μl cyclic sequencing (cs) reaction using ABI prism™ DNA Sequencing Kit (dRhodamine Terminator Cycle Sequencing Ready Reactions). For the cs reaction, the same primers as for the initial dsPCR reaction were used. Cs PCR conditions for both cytochrome *b* and 12S: one initial cycle (96°C, 2 min) followed by 34 cycles (96°C, 20 sec, X°C, 10 sec, 60°C, 2 min) and finally, one cycle (96°C, 20 sec, X°C, 10 sec, 60°C, 7 min). Annealing temperatures (denoted X°C) were identical to the dsPCR annealing temperatures. After cyclic sequencing, the products were purified using ethanol precipitation. The purified sequencing products were run on a Perkin Elmer ABI Prism™ 377 DNA Sequencer in a 5% Polyacryl amid gel. The chromatographs resulting from laser spectroscopy of the fluorescent labelled nucleotides (Shera et al., 1990) were aligned manually using the computer program Sequencer (Perkin Elmer).

Selection of taxa, genes and genetic distances.– For the 16s analysis, we sequenced a 402bp fragment for the sympatric mentioned species of *Hydrophis* together with morphologically similar species. In a mitochondrial scale, the 16s-gene evolves relatively slowly (Palumbi, 1996). These results were used to identify a reduced number of taxa, which showed the smallest genetic divergence from *H. pachycercos*. For these taxa, we also sequenced a 760bp fragment of the relatively more rapidly evolving mitochondrial gene cytochrome *b*.

Genetic distances between the taxa were calculated using the computer program PAUP* (Swofford, 1998).

RESULTS

Hydrophis pachycercos Fischer 1855.

Figure 1–2

Hydrophis pachycercos Fischer 1855:44–46; Fischer, 1856.

H. pachycercus, Günther, 1864; Jan and Sordelli, 1872.

Distira pachycercus, Boulenger, 1896.

D. ornata, Wall, 1909 (part.).

Hydrophis belcheri, Smith, 1926 (part.).

Hydrophis bituberculatus, McDowell, 1972 (part.); Golay et al., 1993 (part.).

Neotype.– ZMUC R 661230, adult female, obtained at Phat Thien fish market at the harbour, Vietnam by the authors on September 2000. The specific locality is unknown

Additional specimens.– 4 males: ZMUC R 661231 and Institute of Oceanography, Nha Trang X0–1048, both collected at Ham Tan fish market, August 2001, ZMUC R 661232 obtained at Phat Thien fish market, August 2001 and BMNH 64.4.7.3 from "E. Ind. Archipelago" (Dr. Bleeker). 4 females: ZMUC R 661233–661236, all obtained at Phat Thien fish market, September 2000.

Fischer's original description of *Hydrophis pachycercos* is from 1855 and printed by "Gymnasiums und Johanneums Buchdrucker, Hamburg". About a year later (1856), the same description was published in "Abhandlungen aus dem Gebiete der Naturwissenschaften" vol 3, and most authors incorrectly cite this publication as the type description.

Basis for generic allocation.– *Hydrophis pachycercos* has a combination of characters that place it in the genus *Hydrophis* as defined by Smith (1926): maxillary bone not extending forward beyond the palatine; poison-fang is followed, after a diastema, by 1–18 teeth; palatine straight; nostrils superior; nasal shields in contact with each other; head shields large, regular (Fig. 2); and ventrals small, distinct throughout and normally entire (except *H. cantoris* and *H. gracilis*, which have ventrals divided posteriorly; McDowell, 1972).

Diagnosis at species level.– *Hydrophis pachycercos* is distinct from all other species in the genus *Hydrophis* by a combination of number of teeth, scalation, number of vertebrae, placement of internal organs, body and head shape and colour pattern. *Hydrophis pachycercos* is further distinct from most morphologically similarly species using DNA- cytochrome *b* mitochondrial gene.

Hydrophis pachycercos differs from the following *Hydrophis* species in having more maxillary teeth after the poison-fangs, fewer ventrals and fewer vertebrae (see Table 2): *H. atriceps, H. brookii, H. elegans, H. fasciatus, H. kingi, H. klossi, H. macdowelli, H. mamillaris, H. melanocephalus, H. nigrocinctus, H. obscurus, H. parviceps, H. stricticollis, H. vorisi* and *H. walli. Hydrophis pachycercos* also differs from the two species *H. cantoris* and *H.*

Figure 1. Habitus of the neotype of *Hydrophis pachycercos* (ZMUC R 661230), adult female collected at Phat Thien fish market, Vietnam.

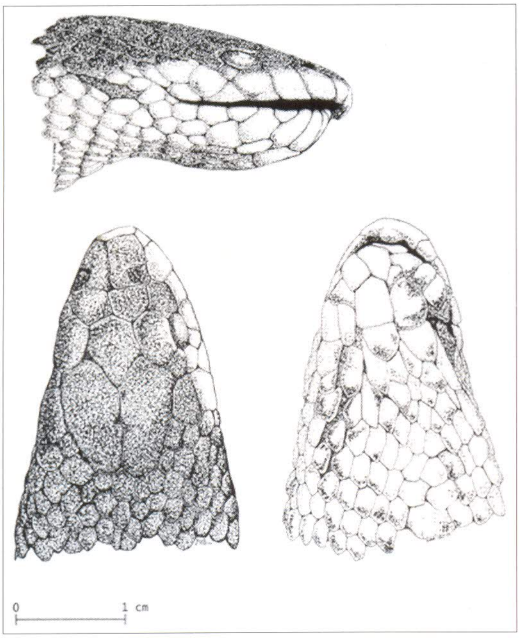

Figure 2. Lateral, dorsal and ventral sides of the head of the neotype of *Hydrophis pachycercos* (ZMUC R 661230). Drawing by M. H. Post.

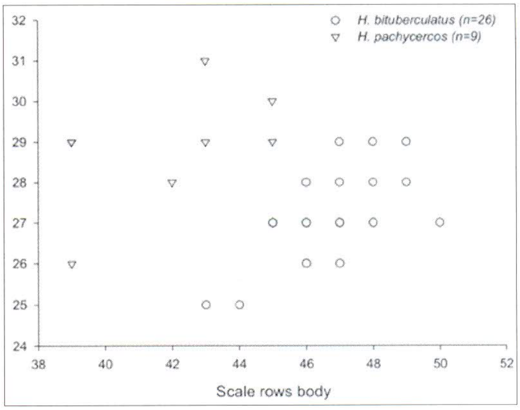

Figure 3. Scattergram of scale rows on neck against scale rows on body in *Hydrophis bituberculatus* and *H. pachycercos* (authors data and data from Rasmussen, 1992).

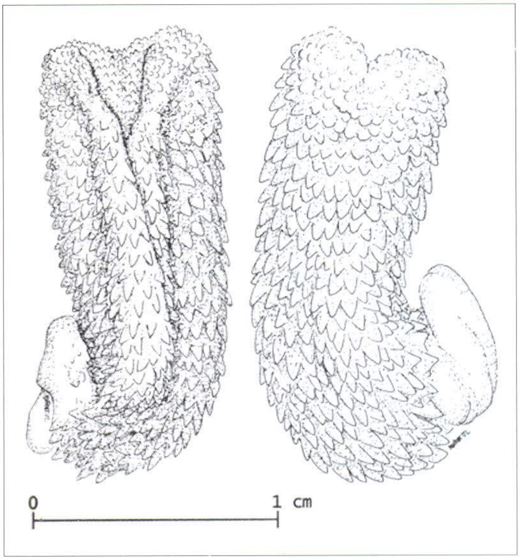

Figure 4. Sulcate and asulcate side of everted hemipenis of *Hydrophis pachycercos* (ZMUC R 661231) from Ham Tan fish market, Vietnam.

gracilis, which have the ventrals divided posteriorly (undivided in *H. pachycercos)* and 5–6 maxillary teeth (7–8 in *H. pachycercos*) after the poisons fang. *H. pachycercos* differs from the following species in having a lesser number of maxillary teeth, a fewer number of scale rows around neck and a different colour pattern (Table 3): *H. caerulescens, H. inornatus, H. lamberti* and *H. ornatus. Hydrophis pachycercos* differs from the following species in number of scale rows around body, number of vertebrae and colour pattern (Table 4): *H. coggeri, H. czeblukovi* and *H. spiralis*. The following species differ from *Hydrophis pachycercos* in number of VS-heart, % VS-heart, VB-body and VB-heart (table 5): *H. belcheri, H. cyanocinctus, H. major, H. melanosoma, H. semperi, H. sibauensis* and *H. torquatus*. The last four species of *Hydrophis* differ in the following characters: *H. bituberculatus* has a higher position (71–82) of VB-heart (*H. pachycercos* 64–70), dissimilarity in number of scale rows on body in relation to number of scale rows on neck (Fig. 3) and a different colour pattern (Rasmussen, 1992) (see also the cytochrome *b* comparison). *H. laboutei* has a higher number (186–187) of VB-body (*H. pachycercos* 163–172), a higher position (81–82) of VB-heart (*H. pachycercos* 64–70), a higher number (8–16) of ventrals between posterior tip of heart and anterior part of liver (*H. pachycercos* 0–3), and a different colour pattern (Rasmussen and Ineich, 2000). *H. lapemoides* has a higher position (106–155) of VS-heart (*H. pachycercos* 81–101), a higher position (73–94) of VB-heart (*H. pachycercos* 64–70), and a different colour pattern (Rasmussen, 1993) (see also the 16s comparison). *H. pacificus* has a higher number (324–421) of ventrals (*H. pachycercos* 247–297), three supralabials in contact with the eye (*H. pachycercos* two supralabials in contact with the eye), and a different colour pattern (Cogger, 1975). The morphological comparison indicates that *H. pachycercos* is most morphological similar with *H. bituberculatus* and *H. lapemoides* (see above) in the genus *Hydrophis*. Therefore, a comparison on microscopic scales using DNA has also been conducted (see "DNA results").

Description of neotype (ZMUC R 661230).– External morphological characters.– Seven maxillary teeth behind poison-fang. One pre- and three postocular on each side. Seven supralabials on each side, supralabials one and two in contact with nasals, supralabials two and three in contact with preocular, superlabials three and four in contact with eye. Three anterior temporal on both sides. Eleven infralabials on right side and ten on left side, first, second and third in contact with anterior pair of sublinguals, which are well developed and in contact with each other; posterior pair of sublinguals are slightly reduced compared with anterior pair of sublinguals. Cuneated scale at oral margin after third infralabials. Neotype damaged on the left part ventrally, maybe from a hook. 30 scale rows around neck, 45 scale rows around body, 36 scale rows around body 10 ventral scales before vent. 24 scale rows around midtail. 258 ventrals, distinct throughout, about twice as broad as adjacent scales. 42 subcaudals. 92 cm. in snout-vent length (SVL). 11 cm in tail.

Internal morphological characters.– Posterior tip of heart extending to ventral scale number 90, %VS-heart 34.88%. Anterior end of liver situated at ventral scale number 93, % VS-liver 36.05%. Heart and liver distance 3 ventrals. Number of body vertebrae 168. Number of tail vertebrae 37. Posterior tip of heart extending to vertebra number 69. % VB-heart 41.07%.

Variation in examined specimens and the missing type (based on Fischer, 1855): External morphological characters. – Seven to eight maxillary teeth behind poison-fang (missing type 8), 16 dentary teeth, 17–19 pterygoid teeth, and 7–8 palatine teeth, only counted on ZMUC R 661236 and BMNH 64.4.7.3. One pre- and three postocular on each side in four specimens, 1/2 in three specimens, 1/2–1/3 in one specimen (missing type 1/2). Seven supralabials in four specimens, 8 in three specimens and one damaged (missing type 7), supralabials one and two in contact with nasals in all specimens, supralabials two and three in contact with preocular in six specimens, 2, 3 and 4 in two specimens (missing type 2 and 3), superlabials three and four in contact with eye in five specimens, 4 and 5 in two specimens, 4 (5 is divided) in one specimens (missing type 3 and 4). Two anterior temporal on both sides in four specimens, 3 in three specimens, 1 in one specimen (missing type 2). Teen infralabials in six specimens, 9 in two specimens (missing type no data), first, second and third in contact with anterior pair of sublinguals, which are well developed and in contact with each other (all same); posterior pair of sublinguals are slightly reduced compared with anterior pair of sublinguals (missing type no data). Cuneated scale at oral margin after third infralabials (all same).

Males 26–29 scale rows around neck, females 28–31 (missing type no data), males 39 scale rows around body, females 42–45 (missing type 39), males 32–36 scale rows around body 10 ventral scales before vent, females 34–37 (missing type

Table 1. DNA specimen-voucher list.

species (n = no specimens)	Museum collection voucher number	16s	cytochrome *b*
1. *H. pachycercos* (n = 8)	ZMUC R 661230-36; Nha Trang X01048	yes	yes
2. *H. belcheri* (n = 5)	ZMUC R 661273-77	yes	no
3. *H. bituberculatus* (n = 1)	ZMUC R 661136	yes	yes
4. *H. cyanocinctus* (n = 2)	ZMUC R 661271-72	yes	no
5. *H. lamberti* (n = 2)	ZMUC R 661269-70	yes	no
6. *H. lapemoides* (n = 1)	ZMUC R 661278	yes	no
7. *H. melanocephalus* (n = 3)	ZMUC R 661263-65	yes	no
8. *H. ornatus* (n = 3)	ZMUC R 661266-68	yes	no

Table 2. External and internal characters used to distinguish *Hydrophis pachycercos* from 15 species of *Hydrophis*. See "Materials and Methods" for abbreviations.

Species	Maxillary teeth	Ventrals	VB-body	Literature
H. pachycercos	7–8	247–297	163–172	
H. atriceps	5–6	323–453	215–240	Cogger et al., 1983; Smith 1926; our data
H. brookii	5	328–414	216–229	Smith, 1926; Smith, 1943
H. elegans	5–7	345–432	>210	Cogger, 1975; our data
H. fasciatus	5–6	410–514	228–255	Bussarawit et al., 1989; Smith, 1926; our data
H. kingi	3–4	324–360	>270	Smith, 1926; our data
H. klossi	5–6	360–430	219–228	Taylor, 1965
H. macdowelli	5–6	235–290	176–193	Kharin, 1983; Cogger, 1992; our data
H. mamillaris	8–10	302–390	188–1195	Smith, 1926; our data
H. melanocephalus	5–8	289–358	218–232	Smith, 1926; our data
H. nigrocinctus	1–2	296–330	–	Smith, 1926; our data
H. obscurus	5–7	298–346	210–228	Our data
H. parviceps	6	343–348	204	Smith, 1935; Taylor, 1965; our data
H. stricticollis	8–11	374–452	204	Smith, 1926; our data
H. vorisi	6	331	–	Kharin, 1984a; McDowell, 1972
H. walli	0 (1)	318	–	Kharin, 1989

Table 3. Maxillary teeth, scale rows around neck and dorsal ground colour used to distinguish *Hydrophis pachycercos* from four species of *Hydrophis*.

Species	Maxillary teeth	Scale rows neck	Ground colour dorsals	Literature
H. pachycercos	7–8	26–31	Light yellow/weak bands	
H. caerulescens	13–18	31–43	Bluish white/black bands	Smith, 1926; Taylor, 1965
H. inornatus	10–12	29–34	Dark or white with bands	Smith, 1926; Rasmussen, 1989
H. lamberti	9–12	37–45	White/brown bands	Rasmussen, 1989
H. ornatus	9–13	31–43	White/grey bands	Rasmussen, 1989

Table 4. External and internal characters used to distinguish *Hydrophis pachycercos* from three species of *Hydrophis*. See "Materials and Methods" for abbreviation.

Species	Scale rows body	VB-body	Ground colour/bands	Literature
H. pachycercos	39–45	163–172	Light yellow/light brown	
H. coggeri	31–37	192–214	Creamy white/black or brown	Kharin, 1984b; our data
H. czeblukovi	51–58	168–174	Black with pentagons on flank	Rasmussen and Smith, 1997
H. spiralis	33–38	> 220	Clear yellow/black	Smith, 1926; our data

Table 5. *Hydrophis pachycercos* can be distinguished from seven species of *Hydrophis* using internal characters (our data). See "Materials and Methods" for abbreviations.

Species	VS-heart	%VS-heart	VB-body	VB-heart
H. pachycercos	81–101	31.0–34.8	163–172	64–70
H. belcheri	106–126	38.1–41.6	176–185	79–85
H. cyanocinctus	>114	>40.1	220–238	104–119
H. major	87–118	38.6–44.0	172–178	75–82
H. melanosoma	126–150	44.6–51.3	192–210	106–126
H. semperi	136–166	43.1–49.2	205–221	103–115
H. sibauensis	108–109	41.2–42.1	164–167	87–89
H. torquatus	108–148	41.1–47.4	181–199	88–109

Table 6. Pair wise comparison of the *Hydrophis* species investigated for the 16s gene. Percent wise difference adjusted for missing data shown above diagonal and number of nucleotide differences below.

Species	1	2	3	4	5	6	7	8
H. pachycercos (n = 8)	0	2.74	0.25	2.24	1.75	1.75	2.24	1.00
H. belcheri (n = 5)	11	0	2.49	1.00	2.00	1.50	1.00	1.75
H. bituberculatus (n = 1)	1	10	0	2.49	2.00	2.00	2.49	1.25
H. cyanocinctus (n = 2)	9	4	10	0	1.50	1.00	0.00	1.25
H. lamberti (n = 2)	7	8	8	6	0	0.50	1.50	0.75
H. lapemoides (n = 1)	7	6	8	4	2	0	1.00	0.75
H. melanocephalus (n = 3)	9	4	10	0	6	4	0	1.25
H. ornatus (n = 3)	4	7	5	5	3	3	5	0

Table 7. The size of five gravid females of *Hydrophis pachycercos* with the number of embryos in each specimen (investigated by x-ray).

Females	Size (body/tail)	No. embryos
Neotype	920 mm/110 mm	6
ZMUC 661234	1000 mm/110 mm	5
ZMUC 661235	940 mm/100 mm	6
ZMUC 661233	590 mm/70 mm	0
ZMUC 661236	870 mm/90 mm	0

no data). Males 25–26 scale rows around midtail, females 23–24 (missing type 22). Males 247–261 ventrals, , females 258–297 (missing type 260), distinct throughout, about twice as broad as adjacent scales. Males 40–44 subcaudals, females 37–42 (missing type 41). Males 79–88 cm in snout-vent length (SVL), females 59–100. Males 10–12 cm in tail, females 7–11.

Internal morphological characters (missing type no data).– Posterior tip of heart extending to ventral scale number 81–87 in males, 86–101 in females, %VS-heart 32.8–33.33% in males, 31.5–34% in females. Anterior end of liver situated at ventral scale number 81–89 in males, 86–102 in females, % VS-liver 32.8–34.1% in males, 31.05–34.98% in females. Heart and liver distance 0–2 ventrals in males, 0–2 in females. Number of body vertebrae 163–168 in males, 167–172 in females. Number of tail vertebrae 39–42 in males, 35–37 in females. Posterior tip of heart extending to vertebra number 64–66 in males, 67–70 in females. % VB-heart 39.39–40.49% in males, 38.95–41.67% in females.

Hemipenis.– Feebly bilobed with a bifurcate sulcus spermaticus (Fig. 4). Bifurcation near apical end of organ. Organ covered with spines gradually decreasing in size and form, becoming denser at the distal end. A finger like folding at the proximal portion opposite the sulcus spermaticus (Fig. 4).

Colour pattern (based on fresh dead specimens).– Head black/dark dorsally, with light superlabials, the black/ dark colour dorsally gets gradually greener on nasals. Head white ventrally. The black/dark colour dorsally continues posterior to the neck, about 1–2 head length behind the head. Ground colour of dorsum and upper part of flanks light yellow, with light brown bands. The bands broadest dorsally, vanishing on the upper part of the flanks and are more distinct in juveniles than adults. Ventral surface of the body white. Tail black/dark on the posterior part, and like the body colour on the anterior part. The colour pattern is in good agreement with the description by Fischer (1855,1856) and the plate by the same author.

DNA results.– Mitochondrial gene 16s: A total of 402bp were aligned for the 25 specimens sequenced. Alignment was done by eye and rendered unproblematic since no indels were observed. Within the 16s data set several species were represented by more than one specimen often representing geographically distant localities. As can be seen in Table 6 no intraspecific diversity in the 16s gene was observed for any of the 8 *Hydrophis* species investigated. The highest interspecific diversity observed between *H. pachycercos* and the other species was 2.74% to *H. belcheri* and the lowest 0.25% to *H. bituberculatus*.

Mitochondrial gene cytochrome *b*: Since *H. bituberculatus* diverged very little from *H. pachycercos* (1bp, 0.25%) we further investigated a 760 bp long fragment of the mitochondrial gene cytochrome *b* for these two species. The intraspecific diversity within *H. pachycercos* was observed to be between 0% and 0.66% and the interspecific diversity between *H. pachycercos* and *H. bituberculatus* varied between 3.84% and 4.24%.

DNA discussion.– The observed diversity within *H. pachycercos* both for the 16s gene (0%) and the cytochrome *b* gene (0.0–0.66%) is so limited and also in agreement with the morphological data that we find it reasonable to conclude that the specimens investigated and identified as *H. pachycercos* belong to the same species. The DNA-data fall well within what has previously been observed in snake species, e.g., 0.2–6.1% within *Crotalus viridis* using 758bp cyt b & 900bp ND4 (Pook et al., 2000), and in *Corallus enydris* up to approximately 8% using 271bp cyt b (Henderson and Hedges, 1995).

Morphologically, *Hydrophis pachycercos* mostly resembles *H. bituberculatus* and *H. lapemoides*. The results from the 16s gene (see Table 6) revealed limited interspecific divergence between *H. pachycercos* and *H. bituberculatus* in the 16s gene (1 bp, 0.25%) which led us to use additional data from the more rapidly evolving cytochrome *b* gene. These results revealed a divergence of 3.84%–4.24%. This level of genetic diversity is observed within species and between "good" morphological species, e.g., the Caucasian rock lizards, *Lacerta mixta* vs. *L. alpina*, is as little as 1.44% using 625bp cytochrome *b* (Fu et al., 1997). In the 16s gene, *H. lapemoides* was observed to differ from *H. pachycercos* by 1.75% (7 nucleotides) and therefore was not investigated further using molecular techniques.

No universal consensus exists regarding what level of DNA sequence diversity corresponds to species level. This leads to a need to evaluate both morphological and genetic data in order to reach a taxonomic conclusion. Here we find that the combination of the cytochrome *b* data (3.84–4.24%) and the morphological results (no overlap in VB-heart, dissimilarity in number of scale rows on neck in relation to number of scale rows on body and a different colour pattern) clearly supports the species status of both *H. pachycercos* and *H. bituberculatus*.

Distribution.– *Hydrophis pachycercos* was obtained in September 2000 and August 2001 from Phan Thiet and Ham Tan fish markets together with other sea snake species. According to the fishermen, these sea snakes were caught mainly by sea-going trawlers operating in the South China Sea. No further information are available. One specimen from BMNH was mentioned as collected in "E. Ind. Archipelago' by Dr. Bleeker, no further information is available.

Breeding biology.– The neotype (ZMUC R 661230) is gravid and contains six embryos (investigated by x-ray). Two other specimens (ZMUC 661234–35) collected in September 2000 are also gravid and contain five and six embryos, respectively (Table 7). The month of collection (September) and the development of the embryos indicate that these three snakes would have given birth in October or November.

Etymology.– Greek: Pachy = thick, cercos = hale. The species name *pachycercos* has been latified by Günther (1864) and followed by later authors. However, following the International Code of Zoological Nomenclature §31.3.2,: a name which is not originally a Latin name can keep its original spelling. We therefore prefer to keep the name *pachycercos* instead of the later used name *pachycercus*.

ACKNOWLEDGEMENTS

The authors were supported by RUF Danida (*Enhydrina schistosa* serum project) and by

Højgaards Fond during the two surveys in Vietnam. Also a great thank you to Somchai Bussarawit from PMBC, Thailand and Vo Si Tuan and the people at the Oceanographic Institute at Na Trang for their help during our survey in 2000 and 2001, to Jakob Hallermann looking after sea snake specimens in the Hamburg Museum and Christina Lund for linguistic help.

LITERATURE CITED

AMOS, W. & A. R. HOELZEL. 1991. Long-term preservation of whale skin for DNA analysis. In: Genetic ecology of whales and dolphins. Reports of the International Whaling Commission, Special Issue 13. pp:99–111. A. R. Hoelzel (Ed). Cambridge.

BOULENGER, G. A. 1896. Catalogue of the snakes in the British Musum (Natural History). Volume III., containing the Colubridae (Opisthoglyphae and Proteroglyphae), Amblycephalidae, and Viperidae. British Museum, London. xiv + 727 pp + Pl. I–XXV.

BURGER, W. L. & T. NATSUNO. 1974. A new genus for the Arafura smooth seasnake and redefinitions of other sea snake genera. The Snake 6:61–75.

BUSSARAWIT, S., A. R. RASMUSSEN & M. ANDERSEN 1989. A preliminary study on sea snakes from Phuket Habour Phuket Island, Thailand. The Natural History Bulletin of the Siam Society 37:209–225.

COGGER, H. G. 1975. Sea snakes of Australia and New Guinea. In: The biology of sea snakes. pp:59–139. W. A. Dunson (Ed). University Park Press, Baltimore London & Tokyo.

_____. **1992.** Reptiles and amphibians of Australia. Fifth edition. Reed International Books, Chatswood, New South Wales and Cornell University Press, Ithaca, New York 775 pp.

_____, **E. E. CAMERON & H. M. COGGER. 1983.** Hydrophiidae. In: Zoological catalogue of Australia. Amphibia and Reptilia Volume 1. pp:241–256. D. W. Walton (Ed). Australian Government Publishing Service, Canberra.

FISCHER, J. G. 1855. Die Familie der Seeschlangen systematisch beschrieben. Zu der Öffentlichen Prüfung, welche mit den Zöglingen der Realschule. Gymnasiums und Johanneums Buchdrucker, Hamburg. 78 pp.

_____. **1856.** Die Familie der Seeschlangen systematisch beschrieben. Abhandlungen und Gebiet der Naturwissenschaften in Hamburg 3:1–78.

FU, J. R., W. MURPHY & I. S. DAREVSKY. 1997. Toward the phylogeny of Caucasian rock lizards: implications from mitochondrial DNA gene sequences (Reptilia: Lacertidae). Zoological Journal of the Linnean Society 121:463–477.

GOLAY, P., H. M. SMITH, D. G. BROADLEY, J. R. DIXON, C. McCARTHY, J. C. RAGE, B. SCHÄTTI & M. TORIBA. 1993. Endoglyphs and other major venomous snakes of the world. A checklist. Herpetological Data Centre, Azemiops, Aïre-Geneve. xv + 478 pp.

GÜNTHER, A. C. L. G. 1864. The reptiles of British India. Ray Society, London. xxvii + 452 pp. + I–XXVI pl. Reprinted around 1982 Oxford and IBH Publishing Co., New Delhi, Bombay and Calcutta.

HEDGES, S. B. 1994 Molecular evidence for the origin of birds. Proceedings of the National Academy of Sciences, USA 91:2621–2624.

HENDERSON, R.W. & S. B. HEDGES. 1995. Origin of West Indian populations of the geographically widespread *Boa corallus enhydris* inferred from mitochondrial DNA sequences. Molecular Phylogenetics and Evolution 4:88–92.

INEICH, I. & A. R. RASMUSSEN. 1997. Sea snakes from New Caledonia and the Loyalty Islands (Elapidae, Laticaudinae and Hydrophiinae). Zoosystema 19:185–192.

JAN, G. & F. SORDELLI. 1872. Iconographie générale des ophidiens. Atlas. J.-B. Balliere et fils, Paris. 39–42 pp.

KHARIN, V. E. 1983. A new species of the genus *Hydrophis* sensu lato (Serpentes: Hydrophiidae) from the north Australian shelf. Zoological Zhurnal 62:1751–1753.

_____. **1984a.** Sea snakes of the genus *Hydrophis* sensu lato (Serpentes, Hydrophiidae). On taxonomic status of the New Guinean *H. obscurus*. Zoological Zhurnal 63:630–632.

_____. **1984b.** A review of sea snakes of the group *Hydrophis* sensu lato (Serpentes, Hydrophiidae). 3. the genus *Leioselasma*. Zoological Zhurnal 63:1535–1546.

_____. **1989.** A new sea snake species of the genus *Disteira* (Serpentes, Hydrophiidae) from the waters of the Malay Archipelago. Vestnik Zoologi 1989:29–32.

KOCHER, T. D., W. K. THOMAS, A. MEYER, S. V. EDWARDS, S. PÄÄBO, F. X. VILLABLANCA & A. C. WILSON. 1989. Dynamics of mitochondrial DNA evolution in animals: amplification and sequencing with conserved primers. Proceedings of the National Academy of Sciences, USA 86:6196–6200.

LEVITON, A. E, R. H. GIBBS, E. HEAL & C. E. DAWSON. 1985. Standards in herpetology and ichthyology. Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia 1985:802–832.

MACKESSY, S. P. & A. T. TU. 1993. Biology of the sea snakes and biochemistry of their venoms. In: Toxin-related diseases: poisons originating from plants, animals and spoilage. pp:305–351. A. T. Tu (Ed). Intercept Ltd., Andover.

McDOWELL, S. B. 1972. The genera of sea-snakes of the *Hydrophis* group (Serpentes: Elapidae). Transactions of the Zoological Society of London 32:189–247.

PALUMBI, S. R. 1996. Nucleic acids II: The polymerase chain reaction. In: Molecular systematics. pp:205–247. D. M. Hillis, C. Moritz & B. K. Mable (Eds). Sinauer Associates Inc, Massachusetts.

POOK, C. E., W. WÜSTER & R. S. THORPE. 2000. Historical biogeography of the Western Rattlesnake (Serpentes: Viperidae: *Crotalus viridis*), inferred from mitochondrial DNA sequence information. Molecular Phylogenetics and Evolution 15:269–282.

RASMUSSEN. A. R. 1989. An analysis of *Hydrophis ornatus* (Gray), *H. lamberti* Smith, and *H. inornatus* (Gray) (Hydrophiidae, Serpentes) based on samples from various localities, with remarks on feeding and breeding biology of *H. ornatus*. Amphibia-Reptilia 10:397–417.

_____**. 1992.** Rediscovery and redescription of *Hydrophis bituberculatus* Peter 1872 (Serpentes: Hydrophiidae). Herpetologica 48:85–97.

_____**. 1993.** The status of the Persian Gulf sea snake *Hydrophis lapemoides* (Gray, 1849) (Serpentes, Hydrophiidae). Bulletin of the Natural Histtory Museum, London (Zoology) 59:97–105.

_____**. 1994.** A cladistic analysis of the *Hydrophis* subgenus *Chitulia* (McDowell, 1972) (Serpentes, Hydrophiidae). Zoological Journal of the Linnean Society 111:161–178.

_____**. 1997.** Systematics of sea snakes a critical review. Symposium of the Zoological Society of London 70:15–13.

_____**. 2002.** Phylogenetic analysis of the "true" aquatic elapid snakes Hydrophiinae (sensu Smith et al, 1977) indicating two independent radiations into water. Steenstrupia 27:47–63.

_____**, M. AULIYA & W. BÖHME. 2001.** A new species of the sea snake genus *Hydrophis* (Serpentes: Elapidae) from a river in West Kalimantan (Indonesia, Borneo). Herpetologica 57:23–32.

_____ **& I. INEICH. 2000.** Sea snakes of New Caledonia and surrounding waters (Serpentes: Elapidae): first report on the occurrence of *Lapemis curtus* and description of a new species from the genus *Hydrophis*. Hamadryad 25:91–99.

_____ **& L. SMITH. 1997.** The taxonomic status of the sea snake *Hydrophis czeblukovi* (Kharin, 1984) from north-west Australian waters. Amphibia-Reptilia 18:419–425.

SHERA, E. B., L. M. SEITZINGER, L. M, DAVIS, R. A. KELLER & S. A. SOPER. 1990. Detection of single fluorescent molecules. Chemical Physics Letters 175:553–557.

SMITH, M. A. 1926. Monograph of the sea-snakes (Hydrophiidae). British Museum, Natural History, London. xvii + 130 + (1) pp; Pl I–II.

_____**. 1935.** The sea snakes (Hydrophiidae). Dana-Report 8:1–6.

_____**. 1943.** The fauna of British India Ceylon and Burma, including the whole of the Indo-Chinese sub-region. Reptilia and Amphibia. Volume III.- Serpentes. Taylor and Francis Ltd., London. xii + 583 pp. + 1 map. Reprinted 1970 Ralph Curtis Books, Hollywood, Florida and 1980 Today and Tomorrow's Publishers, Dehradun.

SWOFFORD, D. L. 1998. Phylogenetic Analysis Using Parsimony (and other methods) PAUP Version 4. Sunderland, M.A.

TAYLOR, E. H. 1965. The serpents of Thailand and adjacent waters. University of Kansas Science Bulletin 9:609–1096.

THOMAS, R. A. 1976. Dorsal scale row formulae in snakes. Copeia 1976:837–841.

WALL, F. 1909. A monograph of the sea snakes. Memoirs of the Asiatic Society Bengal 2:169–251.

Received: 21 June 2005.
Accepted: 27 March 2006.

Appendix I

Specimens examined

For specimens examined see Rasmussen,1989, 1992, 1993, 1994, 2002; Ineich and Rasmussen, 1997; Rasmussen & Smith, 1997; Rasmussen & Ineich, 2000 and Rasmussen et al., 2001.

Hamadryad Vol. 31, No. 2, pp. 299 – 303, 2007.

A NEW SPECIES OF MONTANE STREAM-DWELLING *LITORIA* FROM PAPUA, INDONESIA (ANURA: HYLIDAE)

Paul M. Oliver[1] and Stephen J. Richards

Vertebrates Department, South Australian Museum,
North Terrace, Adelaide, S.A. 5000, Australia.

[1]Corresponding author, Email. paul.oliver@student.adelaide.edu.au

(with five figures)

ABSTRACT.– **A new species of small brown torrent-dwelling *Litoria* is described from the Derewo River headwaters (1,890 m asl) of Papua Province, Indonesia. It can be distinguished from all known torrent-dwelling *Litoria* by the combination of moderately small size (29.3–30.0 mm), poorly developed vomerine teeth, extensively webbed feet, widely spaced nares (EN/IN = 0.71–0.73) and relatively short tibiae (TL/SVL = 0.52–0.54).**

KEY WORDS.– **Hylidae, *Litoria*, new species, New Guinea, Indonesia.**

INTRODUCTION

The mountains of New Guinea harbour a diverse assemblage of stream-dwelling hylid frogs (Hyndman and Menzies, 1990; Richards et al., 2000). The genus *Litoria* is well represented in torrential stream habitats and Tyler and Davies (1978) recognised seven species-groups of *Litoria* which inhabit these environments. However, the taxonomy and relationships of many species remain obscure and new species continue to be discovered (e.g., Richards, 2001).

During a Rapid Assessment Program biodiversity survey (RAP) in a mid-montane rainforest in Papua Province, Indonesia, two specimens of a small brown torrent dwelling *Litoria* were collected. A number of morphological characters distinguish these animals from all described taxa. Because there is little chance of revisiting the region, they are herein described as new.

MATERIALS AND METHODS

Measurements (to the nearest 0.1 mm) were taken with dial calipers and a stereomicroscope fitted with an ocular micrometer, and follow Menzies (1993). They are: SVL (snout-vent length), TL (tibia length), HW (head width at tympanum), HL (head length from tip of snout to posterior edge of tympanum), EYE (horizontal eye diameter), TYM (horizontal tympanum diameter), IN (inter-narial distance), EN (distance between anterior edge of eye and posterior edge of naris), 3FD (transverse diameter of 3rd finger disc) and 3FP (narrowest horizontal width of penultimate phalanx), 4TD (transverse diameter of 4th toe disc) and 4TP (penultimate phalanx, as for 3rd finger). Specimens are deposited in the Museum Zoologicum Bogoriense, Indonesia (MZB) and the South Australian Museum, Australia (SAMA).

SYSTEMATICS

Litoria fuscula sp. nov.

Figs. 1–3

Holotype.– MZB 11822, adult male, 1890 m altitude, unnamed mountain range, Derewo River Basin, Papua Province, Indonesia, (03°26.527'S; 136°28.365'E), collected by Stephen Richards, 5 April 1998. Paratype.– SAMA R60724, adult male, same locality and collector as holotype, 8 April 1998.

Diagnosis.– A slender brown torrent-dwelling *Litoria* that can be distinguished from congeners by a combination of: i) moderately small adult size (two males 29.3 and 30.0 SVL), ii) short hind limbs (TL/SVL = 0.52–0.54), iii) fingers half-webbed, iv) toes extensively webbed, v) vomerine teeth poorly developed, vi) snout rounded in dorsal view and vii) dorsum, heel and tarsus without prominent tubercles or lappets.

Description of holotype.– Adult male with vocal slits and nuptial pads. A slender *Litoria*, head marginally wider than long (HW/HL = 1.043). Snout rounded in dorsal view, prominent and protruding slightly in lateral view. Canthus rostralis indistinct, rounded; loreal region steeply sloping, slightly concave. Nares much closer to tip of snout than to eyes, widely separated (EN/IN = 0.71), directed laterally, barely visible dorsally. Eyes moderately small (EYE/SVL = 0.103), protruding distinctly in lateral view, slightly in dorsal view. Tympanum distinct, (TYM/SVL = 0.05), annulus slightly raised, obscured dorsally by straight supratympanic fold that extends from posterior edge of orbit to point above axillae. Tongue ovoid, lacking posterior indentation; choanae circular, separated by a distance over three times their width; vomerine teeth medial to the choanae, indistinct, detectable only as slight bumps. Dorsum shagreened, legs smooth dorsally; ventral surfaces of throat and legs smooth, stomach coarsely granular; scattered low, large round tubercles laterally.

Fingers moderately long, relative lengths 3 > 4 > 2 > 1, fingers 1–2 with vestigial webbing, finger 3 webbed to penultimate subarticular tubercle, finger 4 webbed to proximal edge of penultimate subarticular tubercle. Ultimate subarticular tubercles indistinct, unilobed and largely unpigmented; penultimate subarticular tubercles on fingers 2–4 bilobed; other subarticular tubercles uni-lobed, heavily pigmented and indistinct. Inner metacarpal tubercle large, low and ovoid; outer metacarpal tubercle smaller, low and more rounded. Finger discs moderately enlarged (3FP/3FD = 0.67) with distinct circummarginal grooves. Legs slender and moderately short (TL/SVL = 0.54). Toes slender, relative lengths 4 > 5 > 3 > 2 > 1, with thin transluscent webbing extending to base of disc on digits 2, 3 and 5, and to penultimate tubercle on digit 4, where it continues as a broad fringe to base of disc; webbing between toes 1 and 2 extends to distal edge of penultimate tubercle on toe 1 and half way to penultimate subarticular tubercle on toe 2. Ultimate subarticular tubercles on all digits indistinct, unilobed and with small amount of light brown spotting; penultimate subarticular tubercles low, round, indistinct and slighty bifid; inner metatarsal tubercle ovoid, distinct, raised and darkly pigmented; outer metatarsal much smaller, low, round and darkly pigmented. Discs marginally wider than penultimate phalanx (4TP/4TD = 0.80) with prominent circummarginal grooves.

Colour in preservative uniform dark chocolate brown on dorsum. Ventral surfaces very pale brown with scattered tiny brown spots; a series of larger white spots laterally between fore- and hind-limbs. Arms dorsally off-white, densely spotted with brown, digits and hands less densely spotted; arms ventrally with dense brown spotting that extends onto palmar surfaces and subarticular tubercles. Dorsal surfaces of legs densely spotted with brown, especially on tibia which is predominately brown; ventrally pale brown with extensive brown spotting on thighs forming an indistinct network of darker areas surrounding lighter patches; a similar pattern is present below the vent. Ventral surfaces of finger and toe discs off-white without pigment spots.

Variation.– The single paratype is similar to the holotype. It differs in having the supratympanic fold slightly curved, the dorsal surfaces of the disks not as heavily pigmented, some very light brown mottling on the throat and substantially more white patterning on lateral surfaces. Measurements of both types are presented in table 1.

Etymology.– From the Latin *fusca* for brown, -*ula* suffix for diminutive, in reference to the small size and brown colour of the new taxon.

Distribution.– Known only from the type locality (Fig. 4).

Natural history.– Both specimens were collected in extremely wet mid-montane rainforest at about 1900 metres altitude after several days without rain. The holotype was collected from vegetation along a steep rocky creek at night in misty conditions, while the paratype was collected from a rock at the base of a waterfall on the same creek (Fig. 5). No individuals were heard calling and nothing further is known of the natural history of this species. However, the close association of the two known specimens with this torrential stream and the lack of lentic water-bodies in the area suggest that this species is a stream-breeder.

Table 1. Mensural data (mm) for the holotype and paratype of *Litoria fuscula* n. sp.

	MZB 11822	SAMA R60724
SVL	30.0	29.3
EN	2.4	2.4
HW	9.6	9.5
HW/SVL	0.32	0.32
EYE	3.1	3.1
EYE/SVL	0.10	0.11
TL	16.2	15.3
TL/SVL	0.54	0.52
IN	3.4	3.3
EN/IN	0.71	0.73
HL	9.2	9.3
HL/SVL	0.31	0.32
HL/HW	0.96	0.98
TYM	1.5	1.6
TYM/SVL	0.05	0.06
4TD	1.5	1.4
4TP	1.2	1.2
3FP/3FD	0.67	0.73
3FD/SVL	0.05	0.05
3FD	1.5	1.5
3FP	1.0	1.1

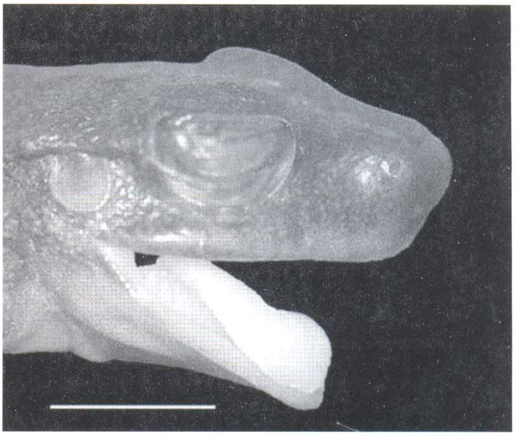

Figure 1. Lateral view of snout of *Litoria fuscula* n. sp. holotype (MZB 11822). Scale bar = 5 mm.

COMPARISONS

The following torrent-dwelling *Litoria* are within or close to the size range of *L. fuscula*: *Litoria brongersmai*, *L. dorsivena*, *L. micromembrana*, *L. napaea*, *L. modica* and *L. pratti*. *Litoria brongersmai*, *L. dorsivena*, *L. napaea*, and *L. pratti* share with *fuscula* a predominantly brown colouration, half-webbed hands and high altitude torrent-dwelling habitat. *Litoria brongersmai* can be distinguished by its smaller size (adult males 22.8–24.8 vs. 29.3–30.0 mm) and higher ratio of eye-nares distance to internarial distance (EN/IN = 0.84–1.05 vs. 0.71–0.73) (Tyler, 1968; Richards, unpubl.). *Litoria napaea* differs in its smaller size (SVL = 18.8–22.7 mm (males)), longer tibiae (TL/SVL = 0.59–0.68 vs. 0.52–0.54) more acuminate snout in dorsal profile and much lighter dorsal colouration (Tyler, 1968).

The remaining species can be distinguished from *Litoria fuscula* by the presence of distinct vomerine teeth and the following characters: *Litoria dorsivena* is approximately the same size as *L. fuscula* (males 26.4–29.0 mm), but has a more acuminate snout in both dorsal and lateral views, a sharply defined canthus rostralis, a larger eye (EYE/SVL = 0.11–0.14 vs. 0.10–0.11) and longer tibiae (TL/SVL = 0.58–0.64 vs. 0.52–0.54); *L. modica* differs in having distinctly tuberculate skin dorsally, and comparatively larger eyes (0.11–0.15 vs. 0.10–0.11); *L. micromembrana* is larger than *L. fuscula* (SVL 31.7–35.9 mm vs. 29.3–30.0 mm (for males), has at most basal finger webbing, has longer tibiae (TL/SVL = 0.58–0.69 vs. 0.52–0.54), has larger eyes (EYE/SVL = 0.11–0.14 vs. 0.10–0.11) and a strongly concave canthus rostralis; the syntypes of *Litoria pratti* have basally webbed fingers, a less curved canthus rostralis and larger eyes (EYE/SVL = 0.11–0.12 vs. 0.10–0.11).

DISCUSSION

The general external morphology and ecological features exhibited by *Litoria fuscula* ally it most closely with the *Litoria dorsivena* species-group of Tyler and Davies (1978). Characters supporting this association are moderately small size, predominately brown colour, half-webbed fingers, and torrent-dwelling habits. However, existing species-groups in the genus *Litoria* were originally given as functional groupings (Tyler and Davies, 1978), and may well be paraphyletic. Thus, it must be emphasized that the assignation of *L. fuscula* to this group is purely for convenience and does not represent an evolutionary hypothesis.

Litoria fuscula occurred syntopically with three other torrent-dwelling *Litoria* (Richards et al., 2000), two of which also appear to be undescribed. This emphasizes the diverse na-

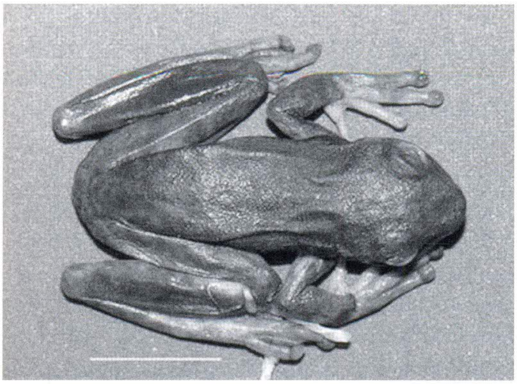

Figure 2. Dorsal view of *Litoria fuscula* n. sp. holotype (MZB 11822). Scale bar = 10 mm.

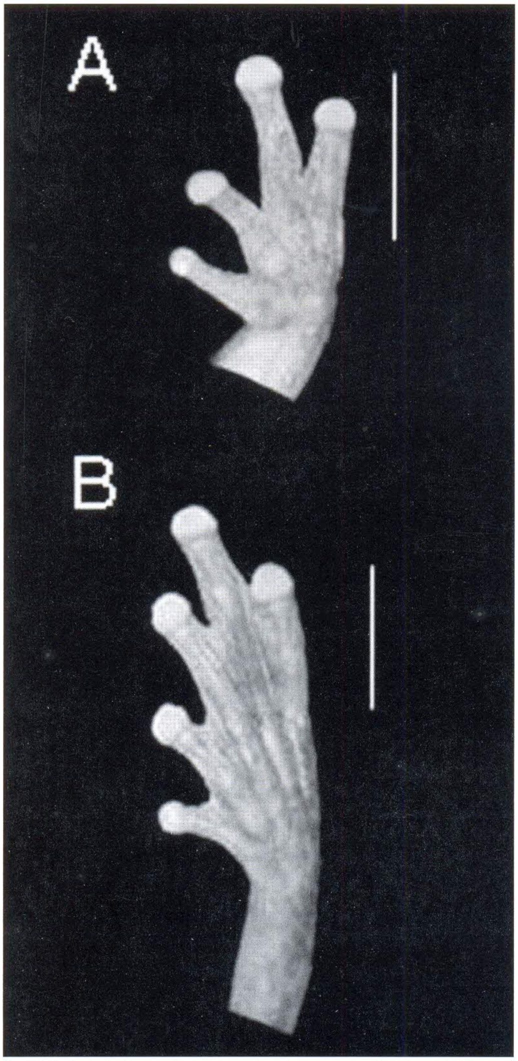

Figure 3. Palmar (A) and plantar (B) views of *Litoria fuscula* n. sp. paratype (SAMA R60724). Scale bar = 5 mm.

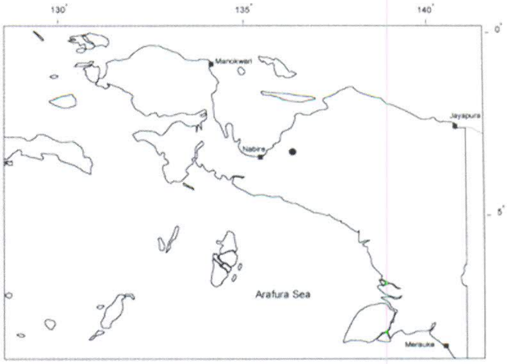

Figure 4. Map of western New Guinea showing type locality of *Litoria fuscula* n. sp. in northern Papua.

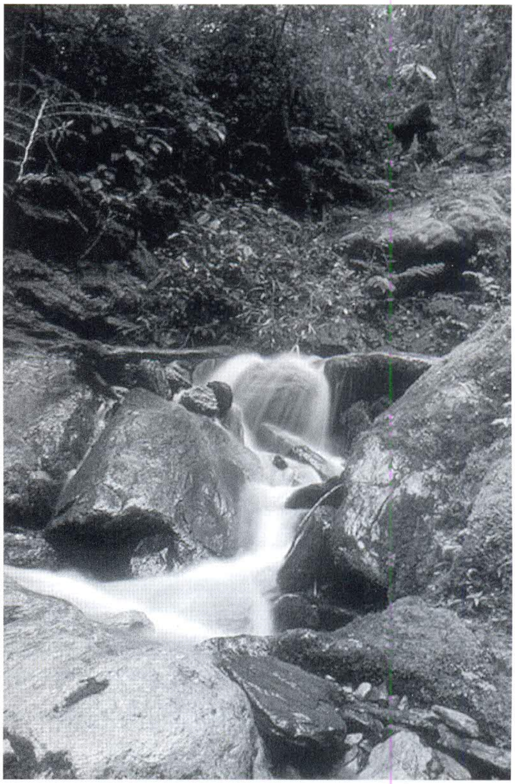

Figure 5. Rocky stream habitat at the type locality of *Litoria fuscula* n. sp.

ture of hylid assemblages along New Guinea mountain streams and the poor state of current knowledge of this component of the anuran fauna. Four new taxa have been described from torrential stream habitats since 2001 (Richards, 2001; Günther and Richards, 2005) and numerous additional undescribed species are known (Richards, unpubl.). There is no doubt that further exploration of the remote mountains of New Guinea will substantially add to this number.

ACKNOWLEDGEMENTS

SJR is extremely grateful to LIPI for permission to undertake research in Papua Province (then Irian Jaya) and for providing export permits. Ibu Mumpuni and Ibu Lili at the Museum Zoologicum Bogoriense were particularly helpful with approving export permits and registering specimens. This research was part of Conservation International's Rapid Assessment Program, and their assistance is greatly appreciated. Funding support was provided by the CI–USAID Cooperative Agreement #PCE–5554–A–00–4028–00. SJR is especially grateful to Andy Mack, Dr Yatna Supriatna, and Burke Burnett of CI for their support and assistance during the survey and to Djoko Iskandar for his support in the field. P. T. Freeport Indonesia provided invaluable logistical support. Preparation of this manuscript was supported by a grant from Conservation International. Additional support was provided by the Mark Mitchell Foundation, the Winifred Violet Scott Trust and the South Australian Museum Board. We are grateful to the following persons for access to specimens in their care and other hospitality that made this project possible: Mark Hutchinson and Carolyn Kovach (SAMA), Barry Clarke (BMNH), Linda Ford, Jay Savage and Darrel Frost (AMNH), Rainer Günther (ZMB), José Rosado (MCZ), Marinus Hoogmoed and Pim Arntzen (RMNH), Giuliano Doria (MSNG) and Miguel Vences and Axel Groenveld (ZMA). We thank Fred Kraus and Djoko Iskandar for their comments on the manuscript.

LITERATURE CITED

GÜNTHER, R. & S. J. RICHARDS. 2005. Three new species of mountain stream dwelling *Litoria* from Western New Guinea. Russian Journal of Herpetology 12:195–212.

HYNDMAN, D. C. & J. M. MENZIES. 1990. Rain forests of the Ok Tedi headwaters, New Guinea: an ecological analysis. Journal of Biogeography 17:241–273.

MENZIES, J. I. 1993. Systematics of *Litoria iris* (Anura; Hylidae) and its allies in New Guinea and a note on sexual dimorphism in the group. Australian Journal of Zoology 41:225–55.

RICHARDS, S. J. 2001. A new torrent-dwelling frog (Anura, Hylidae, *Litoria*) from the mountains of Indonesian New Guinea (West Papua). Memoirs of the Queensland Museum 47:733–739.

_____, D. T. ISKANDAR & A. ALLISON. 2000. Amphibians and reptiles of the Wapoga River Area, Irian Jaya, Indonesia. In: A biological assessment of the Wapoga River Area of northwestern Irian Jaya, Indonesia. pp:54–57. A. L. Mack & L. E. Alonso (Eds). Conservation International, Washington, D.C.

TYLER, M. J. 1968. Papuan hylid frogs of the genus *Hyla*. Zoologische Verhandelingen, Leiden 96:3–203.

____ & M. DAVIES. 1978. Species-groups within the Australopapuan hylid frog genus *Litoria* Tschudi. Australian Journal of Zoology Supplementary Series No.63:1–47.

Received: 12 October 2005.
Accepted: 10 May 2006.

Appendix 1

Specimens examined
Abbreviations refer to the following institutions

AMNH – American Museum of Natural History, New York
BMNH – The Natural History Museum, London
MCZ – Museum of Comparative Zoology, Harvard University
MZB – Museum Zoologicum Bogoriense, Bogor
SAMA – South Australian Museum, Adelaide

Litoria brongersmai, MCZ 15203 Snow Mountains, Papua, Indonesia, holotype; MZB 11824–27, SAMA R61630–32, Wapoga River Headwaters, northern Papua, Indonesia.

Litoria dorsivena, SAMA R7902–R7911, Telefomin, Sandaun Province, PNG, holotype and paratypes.

Litoria micromembrana, SAMA R4150, Mount Podamp, PNG, holotype; SAMA R61629, SAMA R61637–40, UPNG 10031, Finimterre, Hindenberg Range, Western Province, PNG; SAMA R61599–01, UPNG 10029, UPNG 10032, SAMA R61602, Abalgamut, SAMA R61603, Kikiapa, both localities on the Huon Peninsula, PNG.

Litoria modica, SAMA R8108, Oruge, PNG, Paratype; SAMA R61616–19, UPNG 10030, Mount Akrik, Star Mountains, Western Province, PNG; SAMA R61609–12, UPNG 10035–36, Mount Binnie Summit, Western Province, PNG; SAMA R61604–07, UPNG 10033, Mount Sisa, Southern Highlands Province, PNG; SAMA R61608, UPNG 10030, Mount Stolle, Sandaun Province, PNG.

Litoria napaea, AMNH 49575 Idenburg River, Snow Mountains, Papua Province, Paratype; SAMA R61620–28, MZB 11833–42 Wapoga LS21, Papua.

Hamadryad Vol. 31, No. 2, pp. 304 – 314, 2007.

A NEW SPECIES OF *MICROHYLA* (ANURA: MICROHYLIDAE) FROM THE MALAY PENINSULA

Indraneil Das[1], Norsham Yaakob[2] and Jeet Sukumaran[3]

[1]Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak,
94300, Kota Samarahan, Sarawak, Malaysia.
Email: idas@ibec.unimas.my

[2]Forest Research Institute Malaysia, Kepong, 52109 Selangor, Malaysia.
Email: norsham@frim.gov.my

[3]Natural History Museum and Department of Ecology and Evolutionary Biology,
University of Kansas, Dyche Hall, 1345 Jayhawk Blvd,
Lawrence, Kansas 66045–7561, U.S.A.
Email: jeetsukumaran@frogweb.org

(with three text-figures)

ABSTRACT.– **A new species of microhylid of the genus *Microhyla* is described from the Malay Peninsula. *M. mantheyi* new species, was formerly assigned to *M. borneensis,* and has been earlier reported from southern Thailand, Peninsular Malaysia and Singapore. It can be distinguished from the Bornean endemic in showing cream coloured top of snout (vs. top of snout undifferentiated from the brown forehead); a dark flank stripe on entire lateral aspect of body (vs. on only about half of lateral aspect of body); the pale postocular stripe is with a dark posterior edge (vs. pale postocular stripe lacking dark posterior edge); a thin vertebral stripe consistently present in all individuals (vs. absent); snout long, tapering (vs. rounded); and webbing on toe IV to below level of penultimate subarticular tubercle (vs. to level of penultimate subarticular tubercle). Tadpoles differ in showing greater contrast, with a dark interorbital bar and dark terminal filament of tail (missing in its Bornean congener). The new species is diagnosable from other congeners in south-east Asia in showing the following combination of characters: SVL 29.2 mm in the largest of the 22 specimens; no dermal fold across forehead; tympanum absent; toe tips with disks; webbing on toe IV broad up to median subarticular tubercle; webbing reaching tip of all toes as narrow fringes; outer metatarsal tubercle present; dorsum brown, with top of snout distinctly paler; and a pale interorbital mark.**

KEYWORDS.– ***Microhyla*, new species, *Microhyla mantheyi*, Microhylidae, systematics, new species, Thailand, Malaysia, Singapore.**

INTRODUCTION

The genus *Microhyla* (Anura: Microhylidae) includes 29 nominal species, distributed from the Indian subcontinent, Indo-Malaya and Indo-China (Frost, 1985; Inger, 1999; Iskandar and Colijn, 2000; Bain and Nguyen, 2004). Seven species have been reported from the Malay Peninsula. Because of their small size and ecologically cryptic nature, a number of species have been recognised or revived in recent years. For instance, Matsui et al. (2005) showed that the name *M. ornata* should be restricted to the Indian region, and two names that were in synonymy were revived for populations extralimital to the type locality. In another landmark paper, Bain and Nguyen (2004) described two new species from Vietnam.

Microhyla borneensis Parker, 1928 was described from the “Kidi district, Sarawak” (= Bidi, Bau region of south-western Sarawak, East Malaysia). Smith (1916) discussed *M. annectans* from Patuju (now Chumphon), ca. 60 km north of the Isthmus of Kra, that Grandison (1972:58) showed to be non-conspecific with that taxon, and subsequently, this specimen was referred to *M. borneensis* (see for instance, Dring, 1979). Closer to our time, *M. borneensis* has been reported from various localities in Peninsular Malaysia, Thailand and Singapore. In this paper, we show that the population from the Malay Peninsula are diagnosable from that of Borneo, and supply a name.

We allocate the Malay Peninsula specimens of *Microhyla borneensis* to a new species in this paper. These specimens are allocated to *Microhyla* for showing the following characters diagnostic for the genus (see Parker, 1934; Inger, 1966): wide head and flattened body; eyes reduced; maxillary and vomerine teeth absent; toes of adults with reduced webbing, but those of mature tadpoles with more extensive webbing; pupil circular; tongue large, oval and entire; no dermal ridge across palate; and a large compressed inner metatarsal tubercle under each foot.

MATERIAL AND METHODS

The type material was examined between one month to up to 10 years after collection. The paratype illustrated here was photographed prior to euthanasia, fixed in formalin ca. 8 h after collection and subsequently washed in water and transferred to 70% ethanol. The following measurements were taken with Mitutoyo™ dial vernier callipers (to the nearest 0.1 mm): snout-vent length (SVL, from tip of snout to vent); tibia length (TBL, distance between surface of knee and surface of heel, with both tibia and tarsus flexed); head length (HL, distance between angle of jaws and snout-tip); head width (HW, measured at angle of jaws); head depth (HD, greatest transverse depth of head, taken posterior of the orbital region); eye diameter (ED, horizontal diameter of the eyes); interorbital distance (IO, least distance between upper eyelids; internarial distance (IN, distance between nostrils); eye to snout distance (E-S, distance between anterior-most point of eyes and tip of snout); eye to nostril distance (E-N, distance between anterior-most point of eyes and nostrils); axilla to groin distance (A-G, distance between posterior edge of forelimb at its insertion to body to anterior edge of hind limb at its insertion to body); body width (BW, greatest width of body); and tympanum diameter (TD, vertical and horizontal). In addition, measurements of digits, taken on the left limbs, from the base to tip. Colour notes on one of the paratypes were taken from Fujichrome Velvia 50 ASA 35 mm slide transparency film, and compared with colour swatches of Smithe (1975; 1981). GPS datum used was Kertau.

Additional sources of data on character states and distribution of congeneric species of *Microhyla* include the following works: Bain and Nguyen (2004), Berry (1975), Dutta and Ray (2000), Fei et al. (1999), Fernando and Siriwardhane (1996), Inger (1966), Inger and Frogner (1980), Inger and Stuebing (2005), Iskandar (1998), Kiew (1984), Manthey and Grossmann (1997), Matsui et al. (2005), Nieden (1923), Parker (1928; 1934), Pillai (1977); Smith (1923), Tarkhnishvili (1994), Taylor (1962), van Kampen (1923), Wu et al. (1987) and Yang (1991).

Museum abbreviations include.–

DWNP = Zoological Museum of the Department of Wildlife and National Parks, Kuala Lumpur, Malaysia;
FRIM = Forest Research Institute Malaysia, Kepong, Malaysia;
LSUHC = Department of Biology, La Sierra University, Riverside, California, U.S.A.;
SBC = Sarawak Biodiversity Centre, Semenggoh, Sarawak, Malaysia;
SM = Sarawak Museum, Kuching, Sarawak, Malaysia;
UBD = Zoological Museum, Department of Biology, Universiti Brunei Darussalam, Brunei Darussalam;
ZRC = Raffles Museum of Biodiversity Research, National University of Singapore, Singapore (the abbreviation used for this collection in Leviton et al., 1985, is USDZ*); and
ZSI = Zoological Survey of India, Kolkata and Chennai, India.

In addition, ID refers to the first author's field numbers, and specimens will be eventually accessioned with SM and ZRC.

SYSTEMATICS

Microhyla mantheyi new species

(Figs. 1–3)

Microhyla annectens: M. A. Smith. 1916. J. nat. Hist. Soc. Siam 2(2):169. (nec *Microhyla annectans* Boulenger, 1900.)

Microhyla borneensis: P. Y. Berry. 1975. Amphib. fauna pen. Malaysia:16; 119. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: J. C. M. Dring. 1979. Bull. British Mus. nat. Hist. (Zool.) 34:194. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: B.-H. Kiew. 1984. Malayan Natural. 37(4):10. (in part.)

Microhyla borneensis: D. R. Frost. 1985. Amphibian sp. world:386. (in part.)

Microhyla borneensis: J. Nabhitabhata. 1989. In: Biodiv. Thailand:194. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: B.-H. Kiew. 1990. J. Wildl. & Parks 10:104. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: U. Manthey & W. Grossmann. 1997. Amphib. & Reptil. Südostasiens:46; 61. (in part.)

Microhyla borneensis: R. C. H. Teo & S. Rajathurai. 1997. Proc. nat. Reserv. Surv. Sem. Gardens' Bull. Singapore 49:401; 416. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: T.-M. Leong & L.-M. Chou. 1997. Raffles Bull. Zool. 45(1):97. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: M. Mohamed. 1998. Katak dan kodok:23. (in part.)

Microhyla borneensis: Anon. 1999. Checkl. amphib. Thailand:5. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: T.-M. Leong & L.-M. Chou. 1999. Raffles Bull. Zool. 47(1):123, 128. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: T. Chan-ard, W. Grossmann, A. Gumprecht & K.-D. Schulz. 1999. Amphib. & Rept. Pen. Malaysia & Thailand. An illustr. checkl.:14; 56. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: R. F. Inger. 1999. In: Patterns distrib. amphib.:474. (in part.)

Microhyla borneensis: D.T. Iskandar & E. Colijn. 2000. Treubia 31(3)(Suppl.):61. (in part.)

Microhyla borneensis: T.-M. Leong. 2000. Nature Watch 8(4):3; 6. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: K. Thirakhupt. 2000. In: Rev. biodiv. res. Thailand:158. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: J. Nabhitabhata, T. Chan-ard & Y. Chuaynkern. "2000" [2004]. Checkl. amphib. & rept. Thailand:45. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: W. Nutphand. 2001. Amphib. Thailand:168. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: T.-M. Leong & Z. Z. bin Zainuddin. 2001. Herpetol. Rev. 32(1):55. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: R. F. Inger & H. K. Voris. 2001. J. Biogeogr. 28:884. (in part.)

Microhyla borneensis: W. Khonsue, W. & K. Thirakhupt. 2001. nat. Hist. J. Chulalongkorn Univ. 1(1):79. (in part.)

Microhyla borneensis: K. K. P. Lim & F. L. K. Lim. 2002. Guide amphib. & rept. Singapore:145. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: B.-L. Lim. & K. S. Chai. 2002. J. Wildl. & Parks, Kuala Lumpur 20:130. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: T. Chan-ard. 2003. Photogr. guide amphib. Thailand:102. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: P. L. Wood, T. M. Youmans, J. L. Grismer, J. Wheatley, S. Wright, C. Valdivia, A. Ponce, L. Escobar, S. Amin, P. Baker, J. Bernard, S. Looper, N. Marsh, L. Martin, N. Padilla, R. Rosser, A. Srivastava, V. Srivastava, X. Wright, L. S. Yeen, H. Kaiser & L. L. Grismer. 2004. Hamadryad 28(1&2):118. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: A. Norhayati, J. Senawi & B.-L. Lim, 2004. Photogr. Guide Amphibians Endau Rompin State Park: 56; 116. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: A. Norhayati, J. Senawi & B.-L. Lim, 2005. Amphibians Ulu Muda For. Res.: 48. (nec *Microhyla borneensis* Parker, 1928.)

Microhyla borneensis: L. L. Grismer, T. M. Youmans, P. L. Wood, Jr. & J. L. Grismer. 2006.

Raffles Bull. Zool. 54(1):160. (nec *Microhyla borneensis* Parker, 1928.)

Material examined.– Holotype. ZRC 1.10988, adult male, from road between Jemaluang and Kahang (02° 16N; 103° 52–36'E), Johor, Malaysia, 29 August 2003, Heok Hui Tan. Paratypes. DWNP A.0993, gravid female, DWNP A.1019, gravid female and DWNP A.1028, adult male, from Sungai Relau (04° 40'N; 102° 05'E), Taman Negara, Pahang, Malaysia; 20 October 2001, Lim Boo Liat, Indraneil Das & Norsham Yaakob; DWNP A.1033, from Engkabang Trail, Forest Research Institute Malaysia (03° 14'N; 101° 38'E), Kepong, Selangor, Malaysia, 17 October 2001, Indraneil Das & Norsham Yaakob; FRIM 0033, adult male, from Engkabang Trail, Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 24 August 2002, Norsham Yaakob; FRIM 0166, adult male, from Salleh Trail, Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 7 October 2002, Norsham Yaakob, Kate Merry & Rhys Owen Roberts; FRIM 0171, adult male, from Engkabang Trail, Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 7 October 2002, Norsham Yaakob, Kate Merry & Rhys Owen Roberts; FRIM 0569, adult male, from Pasoh Forest Reserve (02° 59'N; 102° 18'E), Negeri Sembilan Malaysia, 20 July 2003, Norsham Yaakob; ZRC 1.11913, ex-ID 8543, male, from Engkabang Trail, Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 8 May, 2006, Indraneil Das, Norsham Yaakob & Jonathan Murray; LSUHC 06549, adult male, from Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 6 August 2004, Lee Grismer; LSUHC 06555, adult male, from Forest Research Institute Malaysia, Kepong, Selangor, Malaysia, 6 August 2004, L. Lee Grismer; ZRC 1.3451, adult male, from Rifle Range Road (01° 21'N; 47° 02'E), Singapore, 5 December 1996, Tzi Ming Leong; ZRC 1.3865, adult male, from Sungai Dusun (03° 39' N; 101° 00'E), Selangor, Malaysia, 30 March 2000; Tzi Ming Leong; ZRC 1.8037, adult female, from foot of Gunung Panti, along Bunker Trail (01° 51'N; 103° 23'E), Johor, Malaysia, 26 May 2001, Tzi Ming Leong; ZRC 1.10161, adult male, from Sungai Tahan at Lata Berkoh (04° 26'N; °102 23'E), Taman Negara, Pahang, Malaysia, 28 October 2002, Lim Boo Liat; ZRC 1.10224, adult male, from Sime Road forest (01° 20'N; 103 57'E), Singapore, 11 December 2002, Tzi Ming Leong; ZRC 1.10249, adult male, from foot of Gunung Panti, along Bunker Trail, Johor, Malaysia, 14 December 2002, Tzi Ming Leong; ZRC 1.10256, adult female, from Nee Soon swamp forest (01° 24'N; 103° 49'E), Singapore, 24 December 2002, Tzi Ming Leong; ZRC 1.10331–33, from foot of Gunung Panti, along Bunker Trail, Johor, Malaysia, 4 January 2003, Tzi Ming Leong; ZRC 1.10511, adult female, from Taban Valley, Bukit Timah Nature Reserve (01° 20'N; 103° 46'E), Singapore, 13 March 2003, Tzi Ming Leong; ZRC 1.10799, adult female, from Ulu Muda Forest Reserve (06° 05'N; 101° 00'E), Kedah, Malaysia, 19 April 2003, Lim Boo Liat; ZRC 1.10987, adult male, from road between Jemaluang and Kahang, Johor, Malaysia, 29 August 2003, Heok Hui Tan; and ZRC 1.10989, adult male, from road between Jemaluang and Kahang, Johor, Malaysia, 29 August 2003, Heok Hui Tan.

Diagnosis.– A large (SVL 29.2 mm in the largest of the 22 specimens known, an adult male) species of *Microhyla*, differentiated from *M. borneensis* in showing cream coloured top of snout (vs. top of snout undifferentiated from the brown forehead); a dark flank stripe on entire lateral aspect of body (vs. on only about half of lateral aspect of body); pale postocular stripe with a dark posterior edge (vs. pale postocular stripe lacking dark posterior edge); narrow vertebral stripe present in all individuals (vs. absent); snout long, tapering (vs. rounded); and webbing on toe IV to below level of penultimate subarticular tubercle (vs. to level of penultimate subarticular tubercle). Further, the new species is diagnosable from other congeners in the following combination of characters: no dermal fold across forehead; tympanum absent; toe tips with disks; webbing on toe IV broad up to median subarticular tubercle; webbing reaching tip of all toes as narrow fringes; outer metatarsal tubercle present; and dorsum brown, with top of snout distinctly paler and a pale interorbital mark. Tadpoles of the new species differ from *Microhyla borneensis* in showing greater contrast, with orange to reddish-brown tail muscles (vs. pinkish body and tail muscles); distinct dark interorbital bar, postocular stripe and dark lateral stripe present (missing in its Bornean congener).

Description of holotype (adult male).– SVL 18.8 mm; body rounded, subtriangular, depressed; head wider than long (HW/HL ratio 1.4); snout obtusely pointed when viewed dorsally and laterally; projecting slightly beyond mandible; nostrils laterally positioned, nearer tip of snout than to eye (E-N/E-S ratio 0.72); internarial distance equals distance between anterior margin of eye and nostril (IN/E-N ratio 1.0); eye small (ED/HL ratio 0.44); its diameter less than eye to nostril distance (ED/E-N ratio 0.76); supraciliary spine absent; interorbital width greater than upper eyelid width (IO/UE ratio 1.76); canthus rostralis obtuse; loreal region vertical; maxillary teeth absent; a weak 'W'- shaped notch (= symphysial knob) on anterior edge of mandible; gape of jaws extend to posterior corner of eye; choanae located against anterior of palate, partially visible when viewed from below; no dermal ridges across palate; tongue oval, smooth, rounded apically, free for approximately half its length; pupil rounded; tympanum absent; a fold from posterior corner of orbit to before insertion of fore limbs.

Fore limbs short; fingers free of web or skin fringes; fingers number four; finger I less than half finger II; relative length of fingers: 3 > 2 > 4 > 1; finger tips distinctly dilated, disks less than X 2 width of phalanges; longitudinal groove on fingers similar to two scales; subarticular tubercles prominent, rounded, numbering one on first and second fingers, two on third and fourth fingers; fleshy palmar tubercles; nuptial pads absent on fingers.

Hind limbs long; a few scattered tubercles on dorsal surfaces of thigh and tibia; tibia long (TBL/SVL ratio 0.71); toes webbed up to middle of phalanges; webbing on toe 1 to base of disks; on toe II to distal metatarsal tubercle, reaching base of disk as a fringe (inner) and to base of disk (outer); toe III to median subarticular tubercle, reaching base of disk as a fringe (inner and outer); toe IV to median subarticular tubercle, reaching base of disk as a fringe (inner and outer); and toe V, to half way between distal subarticular tubercle and base of disk; relative length of toes: 4 > 3 > 5 > 2 > 1; toe tips distinctly dilated, disks less than X 2 width of phalanges; toe disks wider than those on fingers; longitudinal groove on fingers similar to two scales; subarticular tubercles prominent, rounded, numbering one on first and second toes; two

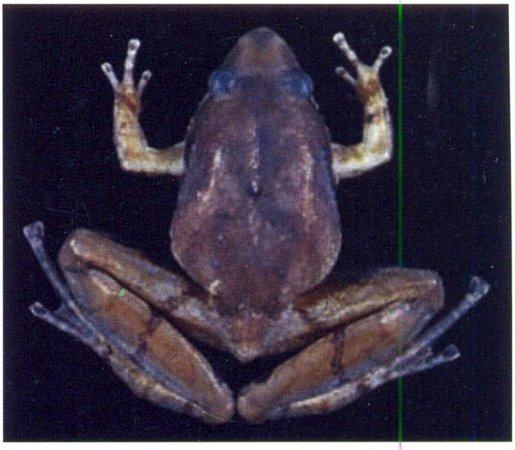

Figure 1. Dorsal view of preserved holotype of *Microhyla mantheyi* new species (ZRC 1.10988). Photo: Kelvin K. P. Lim.

Figure 2. Views of paratype of *Microhyla mantheyi* new species (ZRC 1.11913, ex-ID 8543) in life. Top: Dorso-lateral view; and bottom: Ventral view.

on third and fifth toes; and three on fourth toe; a large, oval inner and a small, oval, compressed outer metatarsal tubercles.

Dorsum granular, with regularly scattered pustules, relatively dense on flanks; an interrupted glandular row extends from back of head and continues along flanks; median subgular vocal sac; eyelids and upper surfaces of limbs smooth; and abdomen and inner side of thighs finely granular.

Colour in preservative.– Dorsum mid-brown, flanks dark brown; snout slightly paler than rest of dorsum; lips with black areas; venter pale grey, except throat, which is dark grey-brown.

Colour in life (from ID 8543).– Dorsum brick red (#132A); changeable to fawn color (#25) with olive brown (#28) variegation, when, under stress, snout, sides of head and upper surface of forearm smoke gray (# 44), interorbital bar paler than rest of forehead or the pale snout; a narrow clay color (# 123B) vertebral stripe from level of interorbital region to over cloaca; paired sepia (# 199) subtriangular flankstripes and marks above vent; upper lips sepia (# 119), a cream postocular stripe, extending to axillary, and edged with a narrow sepia (#199) line; flanks sepia (#199); throat dark brown; belly cream; tibia and shanks fawn cinnamon (#39) with narrow dark cross-bars; webbing olive (#30); pupil black; iris straw yellow (#56).

Measurements of the male types.– In mm; mean, ± SE, range in parentheses ($n = 16$): SVL 19.2 ± 0.87 (15.0–29.2); HL 4.37 ± 0.16 (3.5–5.9); HW 5.63 ± 0.19 (4.5–7.5); HD 3.43 ± 0.11 (2.6–4.3); BW 8.3 ± 0.49 (5.5–12.4); TBL 12.73 ± 0.30 (10.8–14.6); ED 1.66 ± 0.05 (1.3–2.1); UE 0.94 ± 0.04 (0.8–1.2); IN 1.96 ± 0.09 (1.4–2.7); IO 3.46 ± 0.10 (2.7–4.1); E-S 2.94 ± 0.07 (2.6–3.7); E-N 1.79 ± 0.07 (1.4–2.4); and A-G 8.01 ± 0.38 (5.7–12.1).

Measurements of the female paratypes.– In mm; mean, ± SE, range in parentheses ($n = 6$): SVL 18.95 ± 1.58 (14.8–24.1); HL 4.23 ± 0.18 (3.5–4.6); HW 5.33 ± 0.27 (4.4–5.9); HD 3.35 ± 0.18 (2.7–3.9); BW 10.37 ± 1.04 (7.2–13.2); TBL 12.6 ± 0.91 (9.8–15.6); ED 1.75 ± 0.04 (1.6–1.9); UE 1.0 ± 0.03 (0.9–1.1); IN 1.73 ± 0.13 (1.3–2.1); IO 3.43 ± 0.18 (2.7–3.9); E-S 2.87 ± 0.27 (2.0–3.6); E-N 1.85 ± 0.21 (1.2–2.5); and A-G 8.73 ± 1.25 (6.1–13.4).

Variation.– Males have more intense dark gular pigmentation compared to adult females, and although the largest (DWNP A.1028, SVL 29.1 mm) of the sample of 22 individuals was a male, no significant differences between the sexes could be discovered (Mann-Whitney *U*–test, $p > 0.05$). Nonetheless, the size range of males (determined on the basis of presence of vocal sacs), is remarkable.

Etymology.– In naming the new species after Ulrich Manthey, German herpetologist and author, we recognise his important contribution to south-east Asian herpetology.

Ecological notes.– *Microhyla mantheyi* sp. nov. is known from a number of lowland (< 500 m asl) localities throughout the Malay Peninsula, from southern Thailand to Singapore, and including at least one offshore island on the east coast. Although all our sites are within primary forests, Dring (1979) recorded the species from what he described as "secondary trackside growth", and suspected breeding activities to take place in an adjacent flooded rut.

The new species is sympatric with a variety of anuran amphibian species at several of the sites it was collected from. For instance, at Forest Research Institute Malaysia, Kepong, 35 species of amphibians have been recorded (Leong and Norsham, 2001; Norsham unpubl.), including the congeneric *M. berdmorei, M. butleri, M. palmipes* and *M. heymonsi.* At Taman Negara, from where this species has been recorded by Manthey and Grossmann (1997) and Kiew (1990), we recorded *M. berdmorei* and *M. heymonsi*, besides *Micryletta inornata.* All specimens collected by us were found either on the leaf litter or on low vegetation, such as grass, adjacent to standing bodies of water.

Larval stages.– Tadpoles of the new species have been recently described by Leong and Chou (1997 and 1999: as *Microhyla borneensis*) and we will refrain from providing a description. Material we examined include: ZRC 1.3492, from Bukit Timah Nature Reserve, Singapore; ZRC 1.3428, from Rifle Range, Singapore; ZRC 1.3427, from Rifle Range, Singapore; ZRC 1.2221, from Nee Soon, Singapore. Tadpoles of *Microhyla borneensis* that we examined (ID tadpole collection) show less contrast than *M. mantheyi* sp. nov., lacking the distinct dark interorbital bar and dark terminal filament of tail.

Distribution.– The new species of *Microhyla* is distributed over the Malay Peninsula– from Hala-Bala, Narathiwat Province in southern Thailand (Chan-ard et al., 1999; Nutphand, 2001), Peninsular Malaysia (Berry, 1975; Grandison, 1972; Dring, 1979; Chan-ard et al., 1999) and Singapore (Leong, 2000; Leong and Chou, 1997; 1999; Lim and Lim, 2002). In all these (and other publications; see chresonymies above for a comprehensive listing) publications, it has been referred to *Microhyla borneensis*.

COMPARISONS

The new species from the Malay Peninsula differs from the Bornean *Microhyla borneensis* Parker, 1928 (distribution: Sabah, Sarawak, Brunei and Kalimantan in Borneo), in a number of characters. The top of snout of the new species is cream colored, whereas in the Bornean species, the top of snout is not pale, undifferentiated from the brown forehead. It also has a dark flank stripe on entire lateral aspect of body (vs. on only about half of lateral aspect); the pale postocular stripe is with a dark posterior edge (vs. pale postocular stripe lacking dark posterior edge); a thin vertebral stripe consistently present in all individuals (vs. always absent); snout long, tapering (vs. rounded); and webbing on toe IV to below level of penultimate subarticular tubercle (vs. to level of penultimate subarticular tubercle).

The following section enumerates characters that separate the known congeners from eastern, southern and south-eastern Asia from the new species. The dilated disks on fingers in the new species separate the following species: *Microhyla fissipes* Boulenger, 1884 (distribution: southern and central China, including Taiwan and Hainan, north to Shanxi and Shaanxi, Indochina and the northern Malay Peninsula), *M. fowleri* Taylor, 1934 (distribution: northern Thailand, Myanmar and southern China), *M. maculifera* Inger, 1989 (distribution: only known from its type locality– Danum Valley Field Centre, Sabah), *M. okinavensis* Stejneger, 1901 (distribution: Ryukyu Archipelago in Japan), *M. ornata* (Duméril and Bibron, 1841) (distribution: Pakistan, Nepal, India and Sri Lanka), *M. picta* Schenkel, 1901 (distribution: southern Vietnam) and *M. pulchra* (Hallowell, 1861) (distribution: southern China, including Yunnan and Hainan, north-eastern India, Thailand and Indochina). In showing obtusely pointed snout, it differs from the following congeners that show rounded snout profile: *M. annamensis* Smith, 1923 (distribution: Kao Sebab, Thailand, Lam Dong, Dac Lac, Gia Lai, Kon Tum and Quang Nam-Danang Provinces, southern Vietnam, Laos and Cambodia), *M. annectens* Boulenger, 1900 (distribution: Peninsular Thailand, Peninsular Malaysia, Borneo and the southern Sulu Archipelago, Philippines), *M. butleri* Boulenger, 1900 (distribution: southern China, including Hainan and Taiwan, Myanmar, Vietnam, Thailand and the Malay Peninsula), *M. nanapollexa* Bain and Nguyen, 2004 (distribution: Mount Ngoc Linh, Tra My District, Vietnam), *M. palmipes* Boulenger, 1897 (distribution: the Malay Peninsula, Sumatra, Nias, Java and Bali); and *M. superciliaris* Parker, 1928 (distribution: the Malay Peninsula and Sumatra). In addition, *M. fusca* Andersson, 1942 (distribution: Lang Bian Mountain in southern Vietnam), shows acuminate snout profile. Subarticular tubercles in the new species are distinct, but not shovel-shaped, as in *M. rubra* (Jerdon, 1854) (distribution: peninsular and eastern India and Sri Lanka). The developed webbing on hind limbs separate the following species that show basal webbing: *M. achatina* Tschudi, 1838 (distribution: Java, Indonesia), *M. chakrapanii* Pillai, 1977 (distribution: Andaman Islands in India), *M. erythropoda* Tarkhnishvili, 1994 (distribution: Dong Nai in Vietnam), *M. heymonsi* Vogt, 1911 (distribution: southern China (including Hainan and Taiwan), Assam, Myanmar, Thailand, the Malay Peninsula, Sumatra and the Andaman and Nicobar Islands of India). In *M. berdmorei* (Blyth, 1856) (distribution: Yunnan in southern China, Myanmar, northern Thailand, Laos, Vietnam, Cambodia, north-eastern India, the Malay Peninsula, Sumatra and Borneo), *M. marmorata* Bain and Nguyen, 2004 (distribution: Pon-mu Mountains, Huong Son Reserve, Huong Son District, Vietnam), *M. pulverata* Bain and Nguyen, 2004 (distribution: Buon Luoi Village, An Khe District, Vietnam) and *M. petrigena* Inger and Frogner, 1979 (distribution: Brunei, Sabah, Sarawak and Kalimantan), the webbing reaches the base of disks at least on one toe, unlike in the new species. The dorsal median groove on digital disks shown in the new species is absent from *M. mixtura* Liu and Hu in: Hu, Zhao, and Liu, 1966 (distribution: Sichuan to Anhui, southern Shaanxi to Guizhou, China), *M. perparva* Inger and Frogner, 1979 (distribution: Sabah and Sarawak), *M. karunaratnei* Fernando and Siriwardhane, 1996 (distribution: southern Sri Lanka), *M. sholigari* Dutta and Ray, 2000 (distribution: Biligirirangan Hills, Karnataka State, and adjacent Kerala State, south-western India), and in *M. zeylanica* Parker and Osman-Hill, 1949 (distribution: Sri Lanka).

ACKNOWLEDGEMENTS

We thank our respective institutions, the Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Forest Research Institute Malaysia and University of Kansas, for supporting our researches on the herpetology of south-east Asia. L. Lee Grismer, Lim Boo Liat, Kelvin K. P. Lim and Olivier S. G. Pauwels provided publications and information. Permission and facilities to conduct field work in Peninsular Malaysia was provided by Sahir bin Othman, Director of Research and Conservation Division, Jabatan Perlindungan Hidupan Liar dan Taman Negara (PERHILITAN), while field work in Sarawak was conducted under permit from the Sarawak Forestry Corporation and Sarawak Forest Department. Lim Boo Liat has been encouraging of our investigations in Peninsular Malaysia. We are grateful to Margarita Naming (SBC), Peter Kee Lin Ng and Kelvin Kok Peng Lim (ZRC) and Shyamal Kumar Chanda, Ananda and Masagoundanur Sengodan Ravichandran (ZSI) for permitting the examination of specimens under their care. Finally, we thank Raoul Bain, Robert F. Inger, Tzi Ming Leong and Ulrich Manthey for reading the manuscript.

LITERATURE CITED

ANONYMOUS. 1999. Check list. Amphibians of Thailand. Department of Biology, Faculty of Sciences, Chulalongkorn University, Bangkok. 6 pp.

BAIN, R. & T. Q. NGUYEN. 2004. Three new species of narrow-mouth frogs (genus: *Microhyla*) from Indochina, with comments on *Microhyla annamensis* and *Microhyla palmipes*. Copeia 2004(3):507–524.

BERRY, P. Y. 1975. The amphibian fauna of peninsular Malaysia. Tropical Press, Kuala Lumpur. x + 130 pp.

CHAN-ARD, T. 2003. A photographic guide to amphibians in Thailand. Kriangkrai Suwannapak, Bangkok. 176 pp.

_____, W. GROSSMANN, A. GUMPRECHT & K.-D. SCHULZ. 1999. Amphibians and reptiles of Peninsular Malaysia and Thailand. An illustrated checklist. Amphibien und Reptilien der Halbinsel Malaysia und Thailands. Eine illustrierte Checkliste. Bushmaster Publ., Würselen. 240 pp.

DRING, J. C. M. 1979. Amphibians and reptiles from northern Trengganu, Malaysia, with descriptions of two new geckos: *Cnemaspis* and *Cyrtodactylus*. Bulletin of the British Museum of Natural History (Zoology) 34:181–241.

DUTTA, S. K. & P. RAY. 2000. *Microhyla sholigari*, a new species of microhylid frog (Anura: Microhylidae) from Karnataka, India. Hamadryad 25(1):38–44.

FEI, L., C.-Y. YE, Y.-Z. HUANG & M.-Y. LIU (EDS). 1999. Atlas of amphibians of China. Wildlife Protection Association, Henan Publishing House of Science and Technology, Zhengzhou, Henan. (2) + 432 pp. (in Chinese.)

FERNANDO, P. & M. SIRIWARDHANE. 1996. *Microhyla karunaratnei* (Anura: Microhylidae) a new species of frog endemic to Sri Lanka. Journal of South Asian Natural History 2(1):135–142.

FROST, D. R. (ED). 1985. Amphibian species of the world. A taxonomic and geographical reference. Allen Press, Inc., and Association of Systematics Collections, Lawrence. (iv) + 732 pp.

GRANDISON, A. G. C. 1972. The Gunong Benom Expedition 1967. 5. Reptiles and amphibians of Gunong Benom with a description of a new species of *Macrocalamus*. Bulletin of the British Museum of Natural History (Zoology) 23(4):45–101.

GRISMER. L. L., T. M. YOUMANS, P. L. WOOD, Jr. & J. L. GRISMER. 2006. Checklist of the herpetofauna of the Seribuat Archipelago, West Malaysia with comments on biogeography, natural history and adaptive types. Raffles Bulletin of Zoology 54(1):157–180.

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 and 2005, Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu.

____**. 1999.** Distribution of amphibians in southern Asia and adjacent islands. In: Patterns of distribution of amphibians. A global perspective. pp:445–482. W. E. Duellman (Ed). The John Hopkins University Press, Baltimore and London.

____ **& K. FROGNER. "1979" 1980.** New species of narrow-mouth frogs (genus *Microhyla*) from Borneo. Sarawak Museum Journal, New Series 27(48):311–322.

____ **& R. B. STUEBING. 1997.** A field guide to the frogs of Borneo. Natural History Publications (Borneo) Sdn Bhd/Science and Technology Unit, Sabah, Kota Kinabalu. x + 205 pp. Bahasa Malaysia edition, 1999, Panduan lapangan katak-katak Borneo. Natural History Publications (Borneo) Sdn Bhd/Jabatan Muzium Sabah, Kota Kinabalu. x + 225 pp. Second edition, 2005, Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu. viii + 201 pp.

____ **& H. K. VORIS. 2001.** The biogeographic relations of the frogs and snakes of Sundaland. Journal of Biogeography 28:863–891.

ISKANDAR, D. T. 1998. Amfibi Jawa dan Bali. Puslitbang Biologi– LIPI and GEF– Biodiversity Collections Project, Bogor. xviii + 117 pp; 26 pl. English edition, 1998. The amphibians of Java and Bali. Research and Development Centre for Biology– LIPI and GEF– Biodiversity Collections Project, Bogor. xix + 117 pp; 26 pl.

____ **& E. COLIJN. 2000.** Preliminary checklist of southeast Asian and New Guinean Herpetofauna. I. Amphibians. Treubia 31(3)(Suppl.):1–133.

KHONSUE, W. & K. THIRAKHUPT. 2001. A checklist of the amphibians in Thailand. The Natural History Journal of Chulalongkorn University 1(1):69–82.

KIEW, B.-H. 1984. Conservation status of the Malaysian fauna. III. Amphibians. Malayan Naturalist 37(4):6–10.

____**. 1990.** Amphibian fauna of Taman Negara. Journal of Wildlife and Parks, Kuala Lumpur 10:96–108.

LEONG, T.-M. 2000. Amphibian tales. Nature Watch 8(4):2–8.

____ **& L.-M. CHOU. 1997.** New record of the narrow-mouthed frog, *Microhyla borneensis* Parker (Amphibia: Anura: Microhylidae) from Singapore, with taxonomic notes and larval description. Raffles Bulletin of Zoology 45(1):97–103.

____ **& ____. 1999.** Larval diversity and development in the Singapore Anura (Amphibia). Raffles Bulletin of Zoology 47(1):81–137.

____ **& Y. NORSHAM. 2001.** Herpetofauna of a regenerated forest in Peninsular Malaysia. In: Abstracts, 4th World Congress of Herpetology, 3–9 December 2001, Bentota, Sri Lanka. A. de Silva (Compiler). pp:66–67. (Abstract.)

____ **& Z. Z. BIN ZAINUDDIN. 2001.** *Microhyla borneensis*. Geographical distribution. Herpetological Review 32(1):55.

LEVITON, A. E., S. C. ANDERSON, R. H. GIBBS, E. HEAL & C. E. DAWSON. 1985. Standards in herpetology and ichthyology. Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia 1985:802–832.

LIM, B.-L. & K. S. CHAI. 2002. List of amphibians and reptiles from Genting Highlands, Pahang. Journal of Wildlife and Parks, Kuala Lumpur 20:129–132.

LIM, K. K. P. & F. L. K. LIM. 2002. A guide to the amphibians and reptiles of Singapore. Singapore Science Centre, Singapore. 160 pp. Revised edition (with 'Revised checklist of Singapore's herpetofauna', pp:143–152.)

MANTHEY, U. & W. GROSSMANN. 1997. Amphibien & Reptilien Südostasiens. Natur und Tier Verlag, Münster. 512 pp.

MATSUI, M., H. ITO, T. SHIMADA, H. OTA, S. K. SAIDAPUR, W. KHONSUE, T. TANAKA-UENO & G.-F. WU. 2005. Taxonomic relationships within the pan-Oriental narrow-mouth toad *Microhyla ornata* as revealed by mtDNA analysis (Amphibia, Anura, Microhylidae). Zoological Science, 22:489–495.

MOHAMED, M. 1998. Siri haiwan di persikataran kita. Katak dan kodok. Dewan Bahasa dan Pustaka, Kuala Lumpur. ix + 71 pp.

NABHITABHATA, J. 1989. Species diversity of Thai herpetofauna. In: Biodiversity in Thailand. pp:169–204. Biological Science Seminar 7, Chiang Mai University and Science Society of Thailand, Bangkok (in Thai, with English abstract.)

____, T. CHAN-ARD & Y. CHUAYNKERN. "2000" 2004. Checklist of amphibians and reptiles in Thailand. Office of Environmental Policy and Planning, Biodiversity Series, Bangkok. 152 pp.

NIEDEN, F. 1923. Anura I. Subordo Aglossa und Phaneroglossa, Sectio I Arcifera. Das Tierreich 46:i–xxxii + 1–584 pp.

NORHAYATI, A., J. SENAWI & B.-L. LIM. 2004. A photographic guide to amphibians of Endau Rompin State Park, Pahang. Jabatan Perhutanan Semenanjung Malaysia, Kuala Lumpur. 59 pp.

____, ___ & ____. 2005. Amphibians of Ulu Muda Forest Reserve, Kedah. Forestry Department of Peninsular Malaysia, Kuala Lumpur. 120 pp.

NUTPHAND, W. 2001. Amphibians of Thailand. Amarin Printing and Publishing Public Co., Ltd., Bangkok. 192 pp.

PARKER, H. W. 1928. The brevicipitid frogs of the genus *Microhyla*. The Annals and Magazine of Natural History Series 10, 2:473–499.

____. 1934. A monograph of the frogs of the family Microhylidae. British Museum (Natural History), London. (1) + viii + 208 pp. Reprinted 1966, Johnson, New York.

PILLAI, R. S. 1977. On two frogs of the family Microhylidae from Andaman including a new species. Proceedings of the Indian Academy of Sciences 86B(2):135–138.

SMITH, M. A. 1916. On a collection of reptiles and batrachians from Peninsular Siam. Journal of the Natural History Society of Siam 2(2):148–171.

____. 1923. Notes on reptiles and batrachians from Siam and Indo-China. (No. 2). Journal of the Natural History Society of Siam 6(1):47–53; Pl. 5.

SMITHE, F. B. 1975. Naturalist's color guide. Parts I and II. American Museum of Natural History, New York. Part I:8 pp + 18 colour swatches; Part II:xiii + 229 pp.

____. 1981. Naturalist's color guide. Part III. American Museum of Natural History, New York. (iv) + 37 pp.

TARKHNISHVILI, D. N. 1994. Amphibian communities of the southern Viet Nam: preliminary data. Journal of the Bengal Natural History Society New Series, 13(1):3–62.

TAYLOR, E. H. 1962. The amphibian fauna of Thailand. University of Kansas Science Bulletin 63(8):265–599; errata (= 1 p.)

TEO, R. C. H. & S. RAJATHURAI. 1997. Mammals, reptiles and amphibians in the Nature Reserves of Singapore – Diversity, abundance and distribution. Proceedings of the Nature Reserves Survey Seminar. Gardens' Bulletin Singapore 49:353–425.

THIRAKHUPT, K. 2000. Amphibians and reptiles. In: Review of biodiversity research in Thailand. pp:149–171. Biodiversity Research and Training Program (BRT), Bangkok. i–iii + 1–366 pp. (in Thai.)

VAN KAMPEN, P. N. 1923. The Amphibia of the Indo-Australian Archipelago. E. J. Brill, Leiden. xii + 304 pp.

WOOD, P. L., T. M. YOUMANS, J. L. GRISMER, J. WHEATLEY, S. WRIGHT, C. VALDIVIA, A. PONCE, L. ESCOBAR, S. AMIN, P. BAKER, J. BERNARD, S. LOOPER, N. MARSH, L. MARTIN, N. PADILLA, R. ROSSER, A. SRIVASTAVA, V. SRIVASTAVA, X. WRIGHT, L. S. YEEN, H. KAISER & L. L. GRISMER. 2004. First report of the herpetofauna of Pulau Sibu, Johor, West Malaysia. Hamadryad 28(1 & 2):116–119.

WU, L., G. DIONG & R.-H. XU. 1987. [Amphibian fauna of Guizhou.] Guizhou Peoples Press, Guiyang. (7) + 4 + 192 pp, Pls. 46, folding map 1. [in Chinese.]

YANG, D.-T. (ED). 1991. [Amphibian-fauna of Yunnan.] China Forestry Publ. House, Beijing. (1) + (1) + (3) + iv + 259 pp. [in Chinese; authors: S.-M. Li, W.-Z. Liu, S.-Q. Lü, B.-L. Wu & D.-T. Yang.]

Received: 21 July 2006.
Accepted: 5 October 2006.

APPENDIX 1

Comparative material examined

Microhyla annectans

ZRC 1.127–28. Malaysia: Cameron Highlands.

Microhyla berdmorei

ZRC 1.9940–41; 1.9918; 1.9947–61. Vietnam: Nam Cat Tien National Park; ZRC 1.9075, 1.9078. Malaysia: Sarawak: Bario; ZSI 17994, Bangladesh, Chittagong Hill Tracts, Rangamati.

Microhyla borneensis

SBC 00283. Malaysia: Sarawak: Gunung Poing, Bau; UBD 171; 317; 365; 575; 614; ZRC 1.3164. Brunei: Batu Apoi Forest Reserve; ID 8196–1897, 8250, 8508, Malaysia: Sarawak: Kubah National Park; ID 8196–97(tadpole), ZRC 1.11321. Indonesia: Kalimantan.

Microhyla chakrapanii

ZSI Chennai SRS VA/770. India: Andaman Islands, Mayabundar (holotype).

Microhyla heymonsi

ZSI A.9138. India, Great Nicobar, Kopen Heat.

Microhyla ornata

ZSI A.5389. India, Madhya Pradesh, Bastar District.

Microhyla palmipes

FRIM 1236. Malaysia: Selangor, Kepong, Forest Research Institute Malaysia, Engkabang Trail.

Microhyla petrigena

ZRC 1.11281. Indonesia: Kalimantan, Mahakkam; UBD / CR 32, Brunei: Batu Apoi Forest Reserve; ID 8170, Malaysia, Sarawak, Gunung Mulu; (tadpoles), ZRC 1.3780–3826. Indonesia: Kalimantan: Sg. Panan, trib. to Iwan.

Microhyla rubra

ZSI A.9055. India, Goa, Valpoi.

Microhyla sholigari

ZSI Kolkata A.9061. India: Karnataka State (holotype); ZSI Kolkata A.9062–65, India: Karnataka State (four paratypes).

Hamadryad Vol. 31, No. 2, pp. 315 – 329, 2007.

TAXONOMY OF THE INDIAN SNAKE *XYLOPHIS* BEDDOME (SERPENTES: CAENOPHIDIA), WITH DESCRIPTION OF A NEW SPECIES

David J. Gower and Jasmin D. Winkler

Department of Zoology, The Natural History Museum, London SW7 5BD, United Kingdom.
Email: d.gower@nhm.ac.uk

(with seven text-figures)

ABSTRACT.– **A new species of the Western Ghats endemic caenophidian snake *Xylophis* is described based on a type series of 26 specimens from southernmost Kerala and Tamil Nadu. *Xylophis captaini* nov. sp. is most similar to *X. stenorhynchus* but is distinct from that species and *X. perroteti* in several scalation and dental characters. Although *X. indicus* might be a junior synonym of *X. stenorhynchus*, as previously suggested, its taxonomic status is in need of further reassessment. A new key to the species of *Xylophis* is presented.**

KEY WORDS.– **Western Ghats, Xenodermatinae, *Xylophis captaini, X. indicus, X. perroteti, X. stenorhynchus.***

INTRODUCTION

The caenophidian snake genus *Xylophis* Beddome, 1878, is endemic to the southern Western Ghats region of peninsular India, and is considered currently (Smith, 1943; Sharma, 2003; Whitaker and Captain, 2004) to comprise two nominate species, *X. perroteti* (Duméril, Bibron and Duméril, 1854) and *X. stenorhynchus* (Günther, 1875). Very little is known about the biology of *Xylophis*. The genus has been tentatively considered to be a member of the poorly known caenophidian (possibly colubroid) taxon Xenoderminae/Xenodermatinae (McDowell, 1987; Zaher, 1999; Dowling and Pinou, 2003; Lawson et al., 2005), whose phylogenetic position is currently unclear (e.g., Kelly et al., 2003; Lawson et al., 2005). Any additional data on *Xylophis* biology is thus of both immediate and potentially broader interest.

Here, we present a reassessment of the taxonomy of *Xylophis*, focussing on the small, *X. stenorhynchus*-like species (i.e., instead of the larger *X. perroteti*). We report that material previously referred to *X. stenorhynchus* comprises at least two species that differ substantially in external morphology, and we describe a new species. We also present a new key to the species of the genus, and discuss some of the implications of our findings, including the taxonomic status of *X. indicus* Beddome, 1878.

MATERIALS AND METHODS

Previous works on *Xylophis* have been few and brief. We attempt to improve the quantity and quality of the baseline taxonomic and ecological data by writing in more detail here than might be necessary for better-known taxa. We examined type and historical material in the collection of The Natural History Museum, London (BMNH) and mostly more recent material in the Bombay Natural History Society, Mumbai (BNHS). Photographs were examined of specimens in the California Academy of Sciences, San Francisco (CAS) and the Field Museum of Natural History, Chicago (FMNH).

Our ventral scale counts include all unpaired midventral scales lying between the mental and anal shield (as did those by Gans and Fetcho, 1982 for the potentially closely related *Aspidura*). The anteriormost of these midventral scales is adjacent to the first dorsal scale row and so qualifies as the first ventral under Dowling's (1951) scheme, even though this scale clearly lies anterior to the articulation between the skull and vertebral column (see Gower and Ablett, 2006, for discussion of a similar situation in anilioids).

Head length was measured from tip of snout to posterior edge of posteriormost supralabial; head height sagittally from level of corner of mouth to top of head. Numbers of vertebrae were determined by X-ray.

TAXONOMY

Xylophis captaini nov. sp.

(Figs. 1–6, Table 1)

Xylophis stenorhynchus (Günther, 1875): Smith, 1943:343 (part); Inger et al., 1984:566; Murthy, 1990:46 (part); Das, 2002:49 (part); Measey et al., 2003:47; Sharma, 2003:152 (part); Whitaker and Captain, 2004:274 (part).

Holotype.– BNHS 3375. Adult male, collected at Kannam, Kottayam District, in the state of Kerala at approximately 9° 32' N, 76° 41' E and 110 m a.s.l. Collected by O. V. Oommen and colleagues (University of Kerala), 14 August 2000. The specimen was dug from loose soil in a garden/small mixed plantation close to housing. The locality is situated between the Arabian Sea coast of peninsular India and the western foothills of the Western Ghats. This is also the type locality of the syntopic caecilian amphibian *Uraeotyphlus narayani* Seshachar.

Paratypes.– India: Kerala: Thiruvanathapuram District: Palod (8° 45' N, 77° 01' E, 150 m), BMNH 97.2.8.1, 97.2.8.2, 97.2.8.3 (collected before 1898); Cheranikara (8° 39' N, 76° 57' E, 120 m), BNHS 3376 (27.x.1999), 3388 (27.viii.1999), 3392 (12.viii.2000), 3397 (12.viii.2000); Mennookonom (8° 38' N, 77° 02' E, 100 m), BNHS 3389–3391 (29.vi.2000); Azhukkamoozhi, near Kattalakada (approximately 15 km East of Thiruvananthapuram), BNHS 3378 (11.viii.2000); Vanchuvam (8° 39' N, 77° 01' E, 80 m), BNHS 3381–82, 3396 (21.viii.2000); Potugani Junction (8° 28' N, 77° 13' E), BNHS 3383 (21.viii.2000); Chathankodu (8° 39' N, 77° 09' E, 120 m), BNHS 3385–87 (12.x.2005). Kollam District: near Punalur (8° 59' N, 76° 57' E, 150 m), BNHS 3377 (5.viii.1998), 3379 (17.viii.2000); Pathanapuram (9° 06' N, 78° 51' E, 50 m), BNHS 3384 (27.viii.2000). Pathanamthitta District: Mylam (9° 02' N, 76° 48 E, 85 m), BNHS 3393 (13.viii.2000). Kottayam District: Chengalam (9° 37' N, 76° 43' E, 120 m), BNHS 3394 (15.viii.2000). Idukki District: Peralamattayam (9° 55' N, 76° 40' E, 48 m), BNHS 3395 (14.viii.2000). Tamil Nadu: Kanyakumari District: Aarukani (8° 29' N, 77° 12' E, 210 m), BNHS 3380 (19.viii.2000).

Referred material.– BMNH 1924.10.13.6 (female) is from a locality we have been unable to trace (Punakanaad, Travancore), and BNHS 1762 (female) from Ashambu Hills, Tinnevelley is in a very poor state of preservation. We include these two specimens among the referred rather than paratypic material. Several other specimens have not been examined directly by us. These are referred to the new species on the basis of ventral and subcaudal scale counts made by colleagues or recorded from photographs, and relative sizes of prefrontal and internasal scales assessed from photographs. In the absence of detailed comparisons, we refrain from designating them as paratype specimens. These are FMNH 217695 (female) and 217696 (male) from Ponmudi, Thiruvanthapuram District, Kerala (see Inger et al., 1984:566); CAS 17281 (male) from "India".

Diagnosis.– A *Xylophis* resembling *X. stenorhynchus* (and its putative junior synonym *X. indicus* – see below), and differing from *X. perroteti* in having 15 instead of 13 dorsal scale rows at midbody. *X. captaini* differs from *X. stenorhynchus* (and *X. indicus*) in having internasal scales that approach being subequal in midline length to the prefrontal scales, rather than much shorter than them. *X. captaini* is smaller (up to 145 mm total length versus over 200 mm), has a proportionately shorter tail, and fewer ventral (106–122+ versus 120–135) and subcaudal (males 17–22 versus 24–29; females 10–14 versus 15) scales. *X. captaini* also has more teeth – approximately 27–30 in each maxilla and each dentary compared to approximately 18–21 in each in *X. stenorhynchus*. In *X. captaini*, the first and second infralabial scales are short, and together are shorter than the third infralabial, while in *X. stenorhynchus*, the second infralabial is notably longer than the first, and together the first and second approach the length of the third. In *X. captaini* the parietal scales make a much shorter midline contact than in *X. stenorhynchus*.

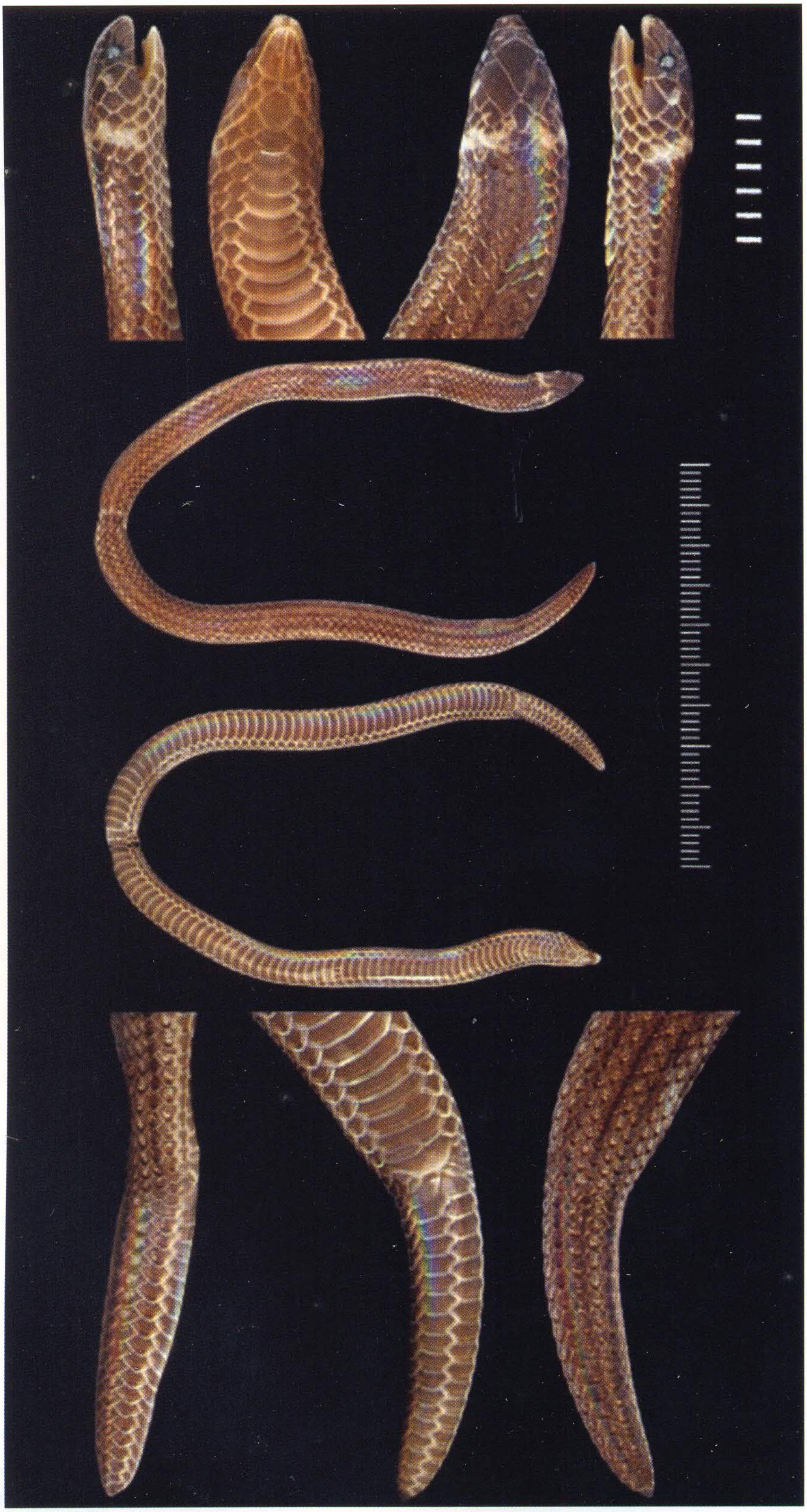

Figure 1. *Xylophis captaini*, photographs of holotype BNHS 3375. Scale in mm.

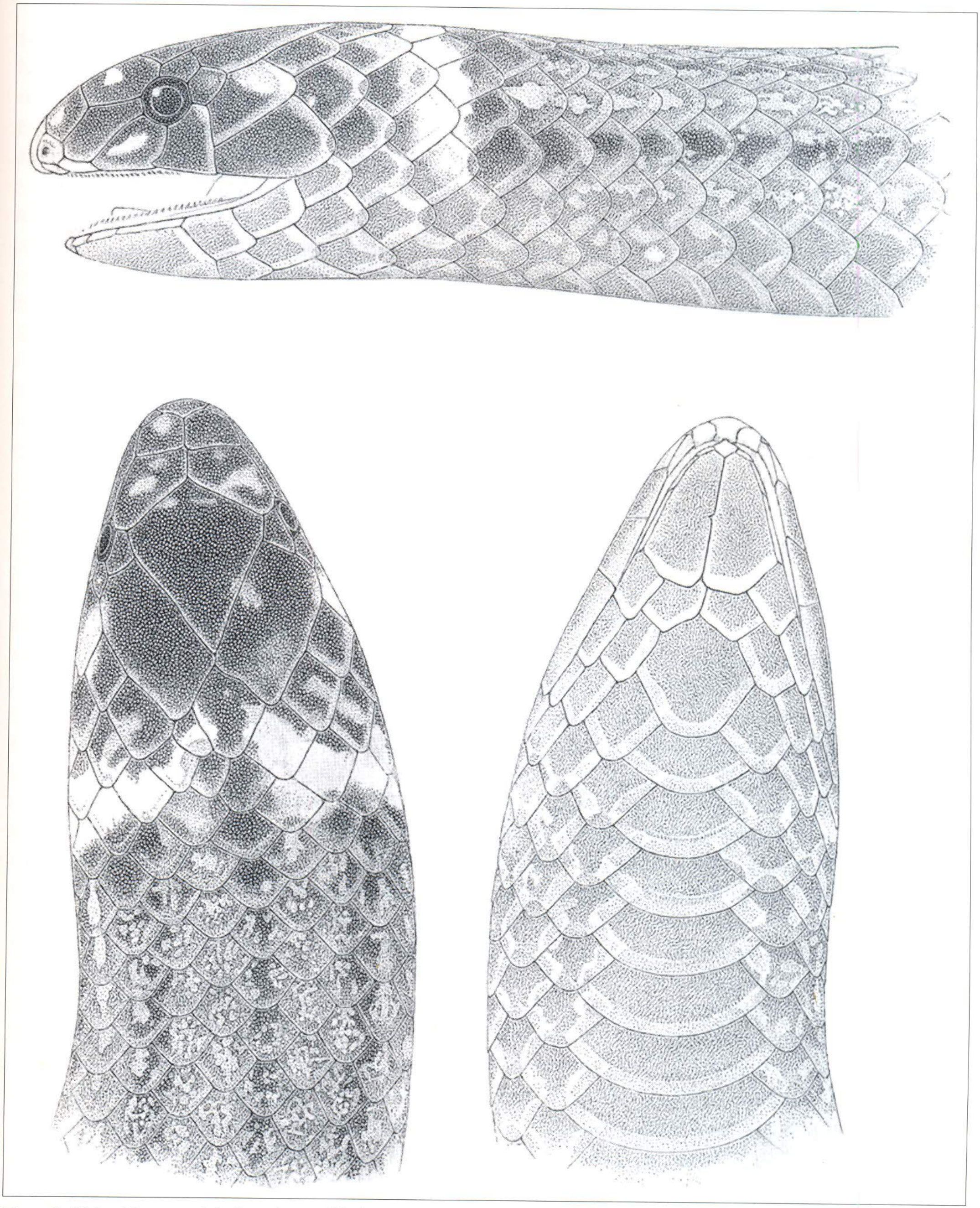

Figure 2. *Xylophis captaini*, drawings of holotype BNHS 3375 by Ed Wade. For scale, see Figure 1 and Table 1.

Description of holotype.– Some morphometric and meristic data are given in Table 1. Specimen in good condition without incisions. The body, preserved in a flat, loose U-shape, is a little dorsoventrally flattened, with a constriction at midbody caused by overly tight tying of a field tag. Colours have not noticeably faded.

No distinct neck, head instead narrowing steadily from uniform anterior of body. Head short, 4.2 mm, and high, 2.2 mm, with steeply domed snout in lateral view. Snout abruptly tapering to blunt, rounded tip in dorsal view. Rounded rostral short in dorsal view - much shorter than distance between it and prefrontal scales. Rostral falls short of level of ventral edges of anterior supralabials, resulting in small median notch at anterior margin of upper lip (Fig. 3). Nasals appear undivided, but some doubt remains because they are small with only thin extranarial margins. Left and right nasals not in contact (Fig. 3), each smaller than intervening rostral. Anteromedial margin of almost anteriorly-directed external naris semicircular, posterior part formed by countersunk, less curved rim. Paired internasals large, much larger than nasals and rostral, approaching dimensions of prefrontals. Although not longer than internasals along midline, prefrontals are greater in area due to elongate posterolateral wings.

Five supralabials, third and fourth entering orbit. First supralabial very small and, apart from second supralabial, contacts only rostral and nasal (Fig. 3). Second supralabial a small, thin strip contacting nasal, large scale between eye and nasal, and first and third supralabials. Third and fourth supralabial scales much larger, taller than long, and contacting approximately hexagonal spectacle. Fourth supralabial also contacts postocular and anterior temporal. Fifth supralabial the largest.

Single, conspicuous and long scale lying between eye and nasal and second supralabial – resembling a loreal (described as such by Günther, 1875; Smith, 1943) more than a preocular in size and shape, despite contacting eye. Kite-shaped diamond frontal notably longer (2.4 mm) than broad (1.7 mm), and about as long as paired parietals, the latter meet only briefly (much less than their and frontal's lengths) along midline behind frontal. Temporals 1 + 2, subequal in size, anterior one inserts deeply between last two supralabials. Small supraocular and postocular, subequal in size and shape.

Anterior of lower jaw dominated by large pair of anterior genials meeting along midline mental groove, prevented from reaching margin of mouth by small mental and three very thin infralabials. Mental short, broad, with tripartite anterior end (Fig. 3). Anterior two infralabials short and thin, second marginally larger. First two infralabials together shorter than long, narrow third, and in lateral view falling notably short of halfway along length of anterior genials. Fourth and fifth infralabials much larger, about same size as each of a pair of posterior genials. First unpaired midventral scale (= first ventral here) immediately behind posterior genials, with approximately equidistant transverse and longitudinal axes. Second ventral scale is first that is wider than long.

Inside of mouth uniform, pale off-white in preservation. Tongue only partially visible, deeply forked with slender, unpigmented tips. Teeth small, evenly sized, gently recurved with pointed tips, barely protruding from surrounding soft tissue. Counting teeth was difficult without further destructive preparation. Approximately 28 maxillary and 29 dentary teeth. No attempt was made to count palatal teeth because rows extend far back into mouth (perhaps twice as long as outer rows). No obvious heterodonty in form or size (including those in palate), but anteriormost teeth slightly smaller in each row.

Body subcylindrical, ventral surface a little flattened. Dorsal scales in 15 rows from at least as far anterior as fifth ventral, up to posteriormost ventral. Dorsals generally regularly arranged, evenly sized across rows at any given point along body, all imbricate. All body scales macroscopically smooth and glossy, lacking keels. Ventral scales 112 in number, all similarly proportioned except for anterior- (as long as broad) and posteriormost (small and offset, lying between right sides of preceding ventral and anal shield) members. Anal shield undivided, similar in size to last ventrals, its posterior margin overlaps four small, irregular scales on right and five on left, in addition to pair of larger subcaudals medially. Subcaudals paired, 18 in number. Tail terminates in bluntly tapering apical spine. Total length 137 mm, tail length 13.6 mm, tail/total length ratio 0.1. Tail with somewhat flattened venter. Anteriorly with 10 to 11 dorsal scale rows, reducing to about eight at mid tail, four surrounding base of terminal spine. Vertebrae 135 in number, 22 confined to anal and postanal region.

Body and tail scales all highly iridescent. Most head and tail scales match this, but very small, unpigmented anterior supra- and infralabials appear matt. Overall, specimen is in various shades of brown mottled with off-white. Collar region and several longitudinal body stripes paler. Ventral scales under head, body ventrals and subcaudals all very similar in colour – main body of each scale a fairly uniform, pale brown with occasionally darker outer edges just inside translucent scale margin. Venter generally paler and more evenly coloured than dorsum. Upper and sides of head are darkest parts of the animal, notably darker than body. Some of dark brown head scales have mottled, irregular, off-white spots, most notably in anterior temporal at juncture with parietal, and towards centres of prefrontal and internasal. Margins of scales contacting spectacle darker around eye, almost black. Otherwise, dorsal and lateral head scales generally with slightly darker bases and unpigmented distal margins. First supralabials, first and second infralabials, third right infralabial, and mental all unpigmented.

Pale, off-white collar band approximately one scale wide, spread across two or three adjacent scales, extending from third dorsal scale row towards dorsal midline, where it bends forward and is incomplete by less than width of single scale. Seven dark stripes run from behind collar to tail tip. Three dorsal stripes darkest, darker and broader just behind collar. Narrowest dorsal stripe mostly confined to midline (eighth) scale row. Pair of dorsolateral stripes slightly broader, extending across most of fifth and sixth dorsal scale rows on each side. Thin dark lateral stripe on third scale row. Paler ventrolateral stripe on first dorsal scale row, appearing slightly intermittent because each scale in row is slightly darker towards tip. Between dark longitudinal stripes, scales in various shades of mottled pale brown and off-white. Broadest and whitest stripes on fourth scale row on each side, each scale bearing large central irregular whitish blotch.

Etymology.– The species is named for Ashok Captain (Pune, India), in recognition of his contributions to the knowledge of Indian snakes.

Suggested common name.– We prefer 'Captain's *Xylophis*'. Alternatively, 'Captain's wood snake'. The etymology of *Xylophis* Beddome, 1878 was not explained on first usage, but probably derives from xylon, the Greek noun for wood (the substance, not an assemblage of trees), perhaps because of this snake's woody colour or its association with dead wood (see quote from Beddome, 1878 below in section on *X. indicus*). *Xylophis* have previously been referred to as "narrow-headed" (Das, 1987; Whitaker and Captain 2004), "small-headed" (Whitaker, 1978) or "dwarf" (Wall, 1919; Gharpurey, 1933) snakes.

Additional information from paratypes.– Twenty-five paratypes, 14 males, 10 females, and one incomplete unsexed specimen, total length 60–145 mm. Morphometric and meristic data for type series given in Table 1. All types share same complement of head scales. No subdivision of nasal scales detected. Distribution of tail length and number of subcaudal scales bimodal and non-overlapping, interpreted as strong sexual dimorphism. Thus, sex determined by counting subcaudal scales and measuring ratio tail:total length, and cross-referencing data with instances of hemipenial eversion in preservation. Males have longer tails.

Only in holotype is there a small preanal scale offset from midline, although last ventral is longitudinally subdivided in two males (BNHS 3379, 3382). One female (BNHS 3391) and two males (BNHS 3383, 3385) with single, partially divided anterior ventral. First supralabial unpigmented in most specimens – lightly pigmented in two females (BNHS 3392, 3394) and three males (BNHS 3382–84). First two infralabial scales unpigmented in all types except BNHS 3385, in which second infralabial is pigmented on left only. Third infralabial usually pigmented, generally greater than twice length of first two infralabials combined, although lengths are subequal in three males (BNHS 3377, 3381, 3384). Number of small scales contacting anal shield (excluding subcaudals, and first dorsal scales between anal and posteriormost ventral) 3–5 per side, totals not indicative of notable dimorphism between males (range 7–9, mean 8.5) and females (range 6–9, mean 7.9). Pale collar band present in all paratypes, matching holotype in being broadly incomplete ventrally, narrowly incomplete middorsally (where left and right sides bend forwards). Only six paratypes match holotype in having left and right parts of band complete, more typically one or both halves intermittent, with incompleteness resulting sometimes (e.g., BNHS 3395, 3384) in conspicuous pale lateral spot. Pale postocular spot present in all types, varying in size and intensity. All types have longitudinal, dark/pale body and tail stripes, varying in intensity and width - dorsal stripes can be inconspicuous (e.g., BNHS 3376, 3383) or accentuated (e.g., BNHS 3392, 3386).

Colour in life generally as described for preserved holotype. *X. captaini* is a light to dark brownish snake with an off-white collar band and other pale specks and blotches (Fig. 4). Based on photographs of one specimen (BNHS 3386) in life, taken in daylight with a flash, pupil is round.

Referred material.– Referred material fits generally within meristic and morphometric variation of type series (Table 1). No notable departures in scalation, although very poorly preserved BNHS 1762 has a high ventral count of c.125.

Hemipenis.– Hemipenes of BNHS 3376 were everted during preservation. One was subsequently cut off and prepared as per method given by Zaher (1999) and Zaher and Prudente (2003). Hemipenis small (c. 6 mm) and difficult to view and handle.

Hemipenis (Fig. 5) bilobed and deeply forked, with each subequal lobe approaching twice length of hemipenis body. Sulcus spermaticus bifurcates towards distal end of hemipenial body, close to lobular crotch. Sulcus branches centrolineal to weakly centrifugal, ending at tips of lobes. Hemipenial body and proximal ends of lobes naked. Most of proximal half of each lobe bears about eight, approximately transverse fleshy flounces that appear to have microscopically spinous or scalloped free edges. Distal half of each lobe bears about seven much less prominent and less complete flounces that might be partly oblique. No spines, papillae or calyces.

Hemipenial morphology was not documented in the original descriptions of other *Xylophis* species, and no information was given by Boulenger (1890). Smith (1943:343) described the hemipenis of *X. perroteti*: "hemipenis forked for 3/4 of its length; it is flounced throughout, the folds on the distal part being oblique, gradually changing until at the fork, where they are transverse; proximal to the bifurcation there are smooth longitudinal folds; there are no spines". Smith (1943:343) also described the hemipenis of *X. stenorhynchus*: "hemipenis deeply forked as in *perroteti*; the proximal end has transverse flounces; distally these are united and form calyces." McDowell (1987:35) described the hemipenis of *Xylophis* (no species mentioned) as "deeply to very deeply forked, with forked sulcus that is partially centrolineal… …without spines". Apart from the purported calyces of *X. stenorhynchus*, these descriptions resemble many aspects of the hemipenis of *X. captaini*. As far as we are aware, Figure 5 is the first published picture of a *Xylophis* hemipenis.

Ecology.– Almost all specimens of *Xylophis captaini* were collected in shady plantations and other disturbed or secondary habitats, and were dug from moist soil at depths of up to about 10 cm. The species is also found in compost or leaf litter in the same habitats. These environments have replaced primary moist forests, which may have been the original habitat of *X. captaini*. Inger et al. (1984:566) reported two *X. captaini* (as *X. stenorhynchus*) from leaf litter in evergreen forest. Other syntopic vertebrates found with *X. captaini*, at least outside forest, include the caecilian amphibians *Gegeneophis ramaswamii, Ichthyophis* cf. *tricolor*, *I.* cf. *bombayensis* and *Uraeotyphlus* spp., small typhlopid snakes, and the uropeltid snakes *Melanophidium* sp. and *Uropeltis* spp. (Measey et al., 2003; DJG, pers. obs.; SD Biju, pers. comm.; OV Oommen, pers. comm.). Measey et al. (2003) found *X. captaini* (reported as *X. stenorhynchus*) occurring at a density of 0.07 m^{-2} in plantations in southern Kerala.

Xylophis captaini are highly iridescent, which is probably a by-product of a dirt-shedding surface microornamentation, an adaptation to life in moist soil (Gower, 2003). When dug out of soil *X. captaini* sometimes play dead (DJG, pers. obs.).

The gut contents of two specimens were examined. BNHS 3392 contained two long (c. 55 and 30+ mm) earthworms, and BNHS 3377 only the digested remains of earthworms. BNHS 3392 holds two large (8.5 x 4 mm), ovoid, yolky ova, BNHS 3377 has turgid testes and enlarged efferent ducts. Both specimens were collected in August, in the wet season. BNHS 3387, collected in October at the end of the wet season, contains four ovoid ova (up to 1.6 mm in length) in each of its well developed oviducts

Distribution.– Specimens of *Xylophis captaini* have been recorded thus far only from low altitudes (300 m or less) on the western side of

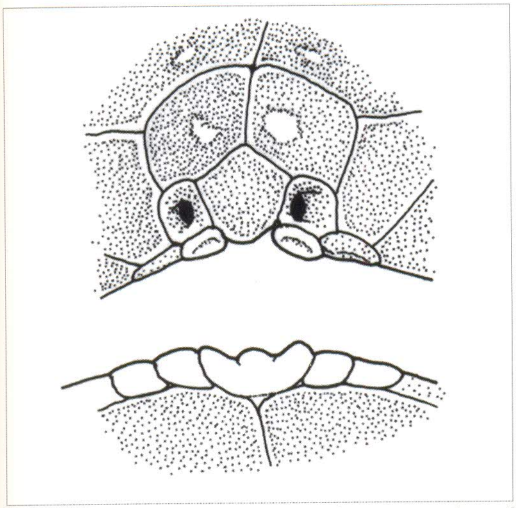

Figure 3. *Xylophis captaini*. Anteriormost scales of snout and lower jaw of holotype (BNHS 3375) in anterior view, showing scalation pattern and distribution of pigmentation. From a drawing made with camera lucida.

Figure 4. *Xylophis captaini*. Photograph of paratype BNHS 3386 in life. Total length of specimen is 135 mm.

the southern part of the Western Ghats (Fig. 6), south of the Palghat Gap– an important biogeographic barrier in the distribution of many taxa (e.g., Gower et al., in press). This is a generally cryptic and inconspicuous snake, so that the known distribution might be expanded both horizontally and altitudinally through new fieldwork.

Conservation.– Although its range of occurrence is not enormous, *Xylophis captaini* occurs in plantations, gardens and other disturbed habitats as well as evergreen forest at low altitudes. Locally, at least, it can be common. Given that agricultural practices will not change markedly, *X. captaini* might be considered 'least concern' under IUCN criteria.

Figure 5. *Xylophis captaini*. Sulcate view of hemipenis of paratype BNHS 3376. Total length of hemipenis c. 6mm.

Xylophis stenorhynchus (Günther, 1875)

Geophis stenorhynchus Günther, 1875:230

Xylophis stenorhynchus (Günther, 1875): Boulenger, 1890:284; Smith, 1943:343 (part); Murthy, 1990:46 (part); Das, 2002:49 (part); Sharma, 2003:152 (part); Whitaker and Captain, 2004:274 (part)

Xylophis stenorynchus [emend.] Wall, 1923:610

Xylophis sterorhynchus [err. Typo.] Whitaker, 1978:116

Xylphis sterorhynchus [err. Typo.] Sharma, 1998:93

Xylophis indicus Beddome, 1878:576

Syntypes.– BMNH 1946.1.14.13 (male), BMNH 1946.1.14.14 (male), and BMNH 1946.1.14.15 (female).

Type locality.– Travancore, India. Travancore is an historical political region corresponding approximately to the southern part of the current state of Kerala (Fig. 6; Biju, 2001).

Referred material.– BMNH 83.1.12.64 (female), Travancore; BNHS 1761, "Paralai, Anamallais" – probably Paralai tea Estate, Valparai, Tamil Nadu, specimen very poorly preserved. Depending on the status of *X. indicus* (see below), referred material of *X. stenorhynchus* possibly also includes BMNH 78.8.2.1 (holotype of *X. indicus* – see below for details), and CAS 17199 and 17200 (both males), Travancore.

Table 1. Morphometric and meristic data for holotype (**), paratypes (*), and referred specimens of *Xylophis captaini*. TL, total length; tL, tail length; w, midbody width; V, ventral scales; SC, subcaudal scales; HL, head length (snout tip to posterior margin of last supralabial scale); Hw, head width at posterior margin of last supralabial scale; F-Snt, midline distance between frontal scale and tip of snout; PrfL, length of prefrontal scales along midline; FL, frontal scale length; Fw, frontal width; PaL, maximum dimension of parietal scale. † data from photos and other colleagues; ‡ data from Inger et al. (1984).

Specimen	Sex	TL	tL	tL as % TL	w	w as % TL	V	SC	HL	Hw	F-Snt	PrfL	F-Snt ÷ PrfL	FL	Fw	PaL
BNHS 3375**	m	137	13.6	9.9	4.2	3.1	110	18	4.4	3.6	1.8	0.6	3	2.5	1.9	2.4
BNHS 3376*	m	125	11.9	9.5	4.6	3.7	108	18	4.2	2.9	1.8	0.5	3.6	2.1	1.6	2.2
BNHS 3377*	m	139	13.8	9.9	4.2	3	108	17	4.5	4	1.8	0.6	3	2.3	1.8	2.5
BNHS 3378*	m	114	11.0	9.6	3.7	3.2	107	17	3.8	2.7	1.5	0.5	3	1.9	1.7	2.1
BNHS 3379*	m	103	10.7	10.4	4.1	4	102	18	4.1	3.6	1.7	0.5	3.4	2	1.5	2
BNHS 3380*	m	115	11.7	10.2	4.6	4	105	17	4.4	3.1	1.7	0.7	2.4	1.9	1.7	2.4
BNHS 3381*	m	73	7.0	9.6	2.7	3.7	108	19	3.6	2.5	1.4	0.5	2.8	1.7	1.4	1.8
BNHS 3382*	m	110	10.5	9.5	3.9	3.5	104	17	3.9	2.8	1.6	0.4	4	1.8	1.5	2.1
BNHS 3383*	m	112	10.4	9.3	3.1	2.8	120	22	3.8	2.9	1.5	0.6	2.5	1.9	1.8	2
BNHS 3384*	m	98	10.3	10.5	4	4.1	106	18	3.8	3.1	1.6	0.5	3.2	1.8	1.5	1.8
BNHS 3385	m	130	14.1	10.8	4.8	3.7	109	18	4	3.7	1.7	0.5	3.4	2	1.6	2.2
BNHS 3386	m	135	15.1	11.2	4.8	3.6	107	20	4.3	3.6	1.8	0.6	3	2.2	1.7	2.4
BNHS 3387	f	145	10.4	7.1	5.4	3.7	112	13	4.6	4	1.9	0.7	2.7	2.2	1.7	2.2
BNHS 3388*	f	72	5.3	7.4	2.8	3.9	108	14	3.4	2.5	1.4	0.5	2.8	1.7	1.4	1.8
BNHS 3389*	f	60	4.4	7.3	1.9	3.2	112	14	3.4	2.2	1.3	0.4	3.3	1.7	1.3	1.9
BNHS 3390*	f	120	7.8	6.5	4.1	3.4	110	13	4.3	3.5	1.7	0.6	2.8	1.9	1.6	2
BNHS 3391*	f	106	6.9	6.5	3.3	3.1	113	13	4.2	3	1.6	0.5	3.2	1.9	1.5	2
BNHS 3392*	f	119	7.1	6	4.7	3.9	109	13	4.1	3.7	1.7	0.6	2.8	2.1	1.5	1.9
BNHS 3393*	f	132	9.2	7	4.8	3.6	108	13	4.7	3.7	2.1	0.7	3	2.2	1.7	2.1
BNHS 3394*	f	126	7.8	6.2	3.8	3	111	10	4.4	2.8	1.7	0.5	3.4	2	1.6	2.2
BNHS 3395*	f	128	8.7	6.8	4.3	3.4	110	12	4.3	3.2	1.7	0.4	4.3	2	1.6	2
BNHS 3396*	f	122	8.5	7	3.9	3.2	113	13	4.1	3.1	1.7	0.5	3.4	1.9	1.6	1.9
BNHS 3397*									3.5	2.9	1.4	0.5	2.8	1.7	1.3	1.9
BMNH 97.2.8.1*	m	118	12.6	10.7	4	3.4	108	18	4.2	2.9	1.6	0.5	3.2	2.2	1.8	2.1
BMNH 97.2.8.2*	m	113	10.8	9.6	4	3.5	110	20	4	2.9	1.4	0.6	2.3	2.1	1.7	2
BMNH 97.2.8.3*	m	79	8.5	10.8	2.7	3.4	110	18	3.6	2.6	1.3	0.5	2.6	1.9	1.5	1.7
BNHS 1762	m	115					c. 125	16								
BMNH 1924.10.13.6	f	139	10.0	7.2	5.5	4	111	13	4.4	3.5	1.7	0.5	3.4	2.2	1.7	2
CAS 17281	m	132	15.3	11.5			112	22								
FMNH 217695	f	135†	10†	7.4†			119‡									
FMNH 217696	m	115†	15†	13†			104‡									

Table 2. Morphometric and meristic data for *Xylophis stenorhynchus*. Abbreviations as for Table 1. * types of *X. stenorhynchus*, † holotype of *X. indicus*.

Specimen	Sex	TL	tL	tL as % TL	w	w as % TL	V	SC	HL	Hw	F-Snt	PrfL	F-Snt ÷ PrfL	FL	Fw	PaL
BMNH 1946.1.14.13*	m	159	20.7	13	4.6	2.9	120	24	5.4	4.9	2.1	1.1	1.9	2.3	2	3
BMNH 1946.1.14.14*	m	165	21.8	13.2	4.6	2.8	122	26	5.3	4	1.9	1	1.9	2.3	2	2.8
BMNH 1946.1.14.15*	f	185	12.7	6.9	5.1	2.8	131	14	6.6	4.6	2.2	1.2	1.8	2.7	2.1	3.2
BMNH 83.1.12.64	f	225	16	7.1	5.6	2.5	134	15	6.2	4.6	2.2	1.2	1.8	2.6	2.3	3.3
BNHS 1761	f	119					c. 130	14								
BMNH 78.8.2.1†	m	237	34	14.3	5.2	2.2	131	29	6.3	4.9	1.8	1.4	1.3	2.8	2.2	3.5
CAS 17199	m	235	34.1	14.5			134	29								
CAS 17200	m	228	32.9	14.4			135	28								

Distribution.– Only one of the known specimens (BNHS 1761) has precise locality information (but see discussion of *X. indicus*, below). Based on the relative sizes of its prefrontal and internasal scales, the specimen figured by Whitaker and Captain (2004:275; see also Das, 2002:49) is referable to *X. stenorhynchus* rather than our new species, and it has the more precise locality data of Valparai, a town at c. 1200 m in Coimbatore District, in the state of Tamil Nadu (Fig. 6). This agrees with the locality of BNHS 1761, and is outside the known altitudinal and horizontal range of *X. captaini*.

Comparison with *Xylophis captaini*.– Superficially, *X. captaini* and *X. stenorhynchus* (Figs. 6, 7, Table 2) are similar, small, brownish snakes with iridescent scales, longitudinal dorsal stripes and a pale collar. *X. stenorhynchus* is known from far fewer specimens, but the total length and tail length are greater in all specimens, and the overall body form is more slender (Table 2). Relative head length is similar in *X. captaini* and *X. stenorhynchus*. *X. stenorhynchus* has the same number and general arrangement of head scales (Fig. 7). Notable differences include a second infralabial that is more like *X. perroteti* (Boulenger, 1890:fig. 90; Smith, 1943:fig. 110) than *X. captaini* in being proportionately longer. The parietal scales of *X. stenorhynchus* are relatively longer and make a longer midline contact behind the frontal. The frontal has a relatively shorter, less pointed posterior part. The prefrontal scales are much longer than the internasals along the midline. The anterior temporal is relatively longer than in *X. captaini*, notably much longer than the posterior temporals. The fifth supralabial of *X. stenorhynchus* is more elongate and slender. Pigmentation of the labial scales is generally more extensive than in *X. captaini*, with some specimens having colour in all supralabials (e.g., BMNH 1946.1.14.15), or even all supra- and infralabials (BMNH 83.1.12.64). Despite being larger, *X. stenorhynchus* have fewer teeth in the maxillary and dentary rows. The dorsal longitudinal bands are less conspicuous in *X. stenorhynchus* than in *X. captaini*. Both species have a similar pale collar band. *X. stenorhynchus* is less likely to have notable pale spots on the head – for example, the type series all lack the pale postocular spot found in all examined *X. captaini*, but one is present in the referred specimen BMNH 83.1.12.64. Sexual dimorphism in tail length is pronounced in both species.

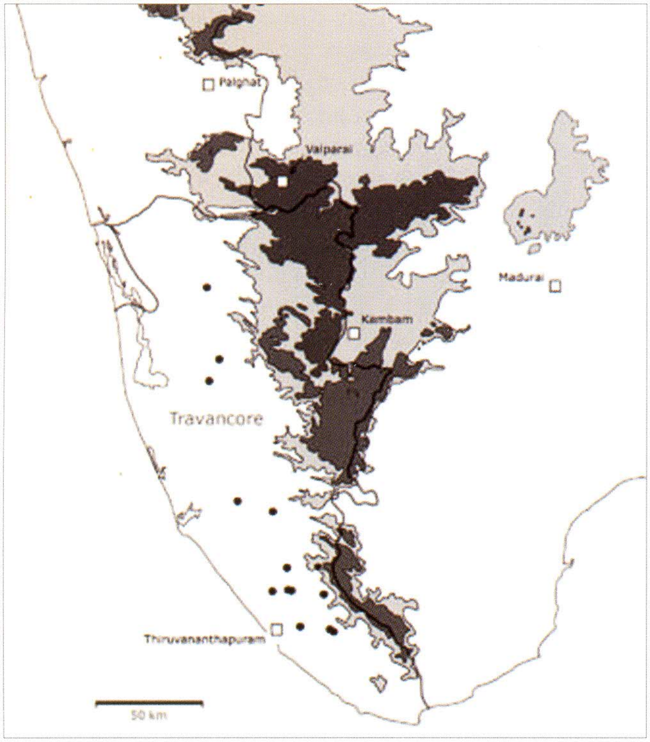

Figure 6. Map of south-western peninsular India (modified from Inger et al., 1984:fig. 1) showing position of localities for *Xylophis captaini* (black dots). Contours shown for 300 m and 1,000 m. The outline of the historical political region of Travancore is shown by a thick line. In the south, the border between the current states of Kerala and Tamil Nadu follow the eastern border of Travancore, but these depart from one another further north, near Valparai, where the Tamil Nadu – Kerala border continues northwards (shown by thinner line). Other than Travancore, the only known localities for *X. stenorhynchus* are in and close to the town of Valparai. The holotype of *X. indicus* is from ca. 1,600 m in the "Cumbum Valley", this is probably above the town of Kambam indicated on the map.

Ecology.– Almost nothing is known about the habitat or ecology (but see discussion of *Xylophis indicus*, below) of these species. Das (2002:49) reports "found in the leaf litter, in such places as buttresses of trees, within evergreen forests", and Whitaker and Captain (2004:274) state "probably a burrower. Found in leaf litter in wet forests. Probably eats earthworms", but some of this information may come from previous reports that have confused *X. stenorhynchus* and *X. captaini* (e.g., Inger et al., 1984).

Taxonomy.– Some previous conceptions of *Xylophis stenorhynchus* are based on material that includes specimens referable to at least two species. The type series of *X. stenorhynchus* represents a coherent species but by the time of Smith's (1943) work, reported ranges of variation include data for specimens that we now recognise as *X. captaini*. Subsequent works (e.g., Inger et al., 1984; Sharma, 2003; Whitaker and Captain, 2004) have followed Smith's taxonomy. Our analyses demonstrate that two main groups of specimens that can be detected based on numbers of ventral and subcaudal scales coincide with the same two groups circumscribed by the relative size of prefrontal/internasal scales as well as a host of other characters (Tables 1, 2). These two clearly diagnosed groups each include both male and female specimens, so that they can not be explained by sexual dimorphism, which nonetheless is pronounced. We conclude that material previously referred to *X. stenorhynchus* actually represents at least two species. In addition to recognising *X. captaini*, we believe a reassessment of X. *indicus* (treated as a junior synonym of *X. stenorhynchus* by Boulenger and subsequent workers) is warranted.

***Xylophis indicus* Beddome, 1878.–** *Xylophis indicus* Beddome was described on the basis of a single specimen (BMNH 78.8.2.1) that Beddome (1878:576) reported from "the dense heavy evergreen forests on the mountains at the south of the Cumbum Valley, Madura district; elevation 5000 feet. Under old logs with Uropeltidae." This locality (alternative spelling: Kambam) is now probably within the Teni District of Tamil Nadu, close to the state border with Kerala (Fig. 6). *X. indicus* was synonymised with *X. stenorhynchus* by Boulenger (1890:284), and this has been followed by subsequent workers (e.g., Smith, 1943). The type is superficially similar to *X. stenorhynchus* and *X. captaini* in being a small, brownish *Xylophis* with 15 dorsal scale rows. It is something of an outlier in being the longest *Xylophis* that has 15 dorsal scale rows, and in having a high number of subcaudals (29). Its teeth are

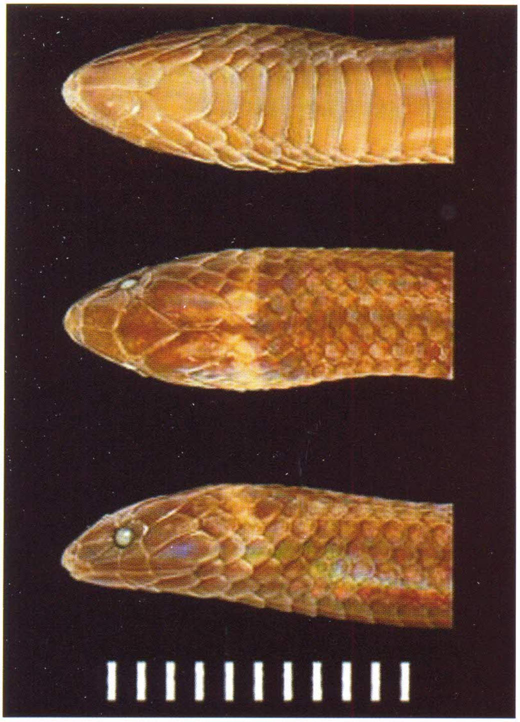

Figure 7. *Xylophis stenorhynchus*, head of one of three syntypes (BMNH 1946.1.14.14) in ventral, dorsal, and left lateral views. Scale bar in mm.

perhaps relatively larger, but this might be exaggerated by shrinkage of soft tissue in the mouth. The head might be longer and more pointed, but this is ambiguous because the snout of the holotype is notably squashed. The form of the prefrontals, internasals, and infralabials and the number of maxillary and dentary teeth are all close to those for the type series of *X. stenorhynchus*, and more similar to that species than to *X. captaini*. Beddome (1878) was correct in that subcaudals 3 and 4 are entire, but was wrong in reporting four supralabials (we observed five).

The type specimen of *Xylophis indicus* is a fairly uniform, pale brown in preservative. Although it seems to have retained some colour pattern (e.g., small darker spots on some dorsal scales, seen under magnification) there is no indication of a pale collar band or head blotches, or darker and paler, longitudinal body stripes. Interestingly, the two (CAS 17199, 17200) other specimens of *Xylophis* with 15 dorsal scale rows that are greatest in total length and have the longest tails (both relative to total length, and in terms of numbers of subcaudal scales) are also a uniform pale brown and lack a pale collar or any notable dorsal stripes (SP Loader, pers. comm.), and it might be that these pertain to *X. indicus* if this is a valid taxon. Finally, at least the holotype of *X. indicus* is even more slender than the types of *X. stenorhynchus*. We suggest that more material should be collected from the vicinity of the type locality of *X. indicus* and compared with a larger sample of *X. stenorhynchus*, so that the status of the former species can be reassessed in more detail. One of the specimens bearing greater superficial resemblance to the type of *X. indicus* than to those of *X. stenorhynchus* (CAS 17200) was the basis of Wallach's (1998) data on the lungs of *X. stenorhynchus*.

Although the taxonomic status of *Xylophis indicus* is in need of reassessment, it is currently only a question of whether or not this taxon is a junior synonym of *X. stenorhynchus*, because the type specimen of the former is distinguished easily from our new species, *X. captaini*. Thus, the questionable status of *X. indicus* does not challenge our hypothesis that *X. captaini* is a valid species.

Xylophis perroteti **(Duméril, Bibron and Duméril, 1854)**

Platypteryx perroteti Duméril, Bibron and Duméril, 1854:501

Rhabdosoma microcephalum Günther, 1858

Geophis microcephalus (Günther, 1858): Günther, 1864:200, pl. 18, fig. A; Theobald, 1868:43, 1876:142

Geophis perroteti (Duméril, Bibron and Duméril, 1854): Anderson, 1871:33

Xylophis perroteti (Duméril, Bibron and Duméril, 1854): Boulenger 1890:283, fig. 90

Xylophis perroteti is superficially the most distinctive species in the genus, having 13 as opposed to 15 scale rows and being much larger (Whitaker and Captain, 2004:272 report up to 630 mm, compared with the < 240 mm of the other species). *X. perroteti* is the best known *Xylophis* species in terms of numbers of specimens. Wall (1919:564, 583) summarised some morphological, ecological and reproductive data for a sample of 61 specimens from Wynaad in northern Kerala (beyond the northern limit of the map shown in Fig. 6), where it was reported to be common at altitudes above

c. 1,500 m. Wall (1923:398) provided some further data on five specimens from Shembaganur, near Kodaikanal, lying approximately between Valparai and Madurai at c. 2,000 m. Smith (1943:343) described the hemipenis of *X. perroteti* (see above). Wallach (1998) presented data on the lungs of *X. perroteti*. Specimens referred to *X. perroteti* vary notably in colour pattern, with animals having prominent dorsal longitudinal stripes on the body (pers. obs. of BMNH specimens) or being much more uniform (e.g., Whitaker and Captain, 2004:273). The taxonomy of *X. perroteti* was not reassessed for this study. Given that so little work has been done, that there is some notable variation in at least colour pattern, and that it seems to be an upland species occurring from both North and South of the Palghat Gap (e.g., BMNH catalogue), we suggest that a reassessment of the taxonomy of *X. perroteti* would be worthwhile.

Revised key to the species of *Xylophis*

1. Dorsal scales in 13 rows at midbody; supraoccular scale obviously larger than postocular scale; 6+ infralabial scales; one pair of genial scales between mental and first ventral . . . . *X. perroteti*
   Dorsal scales in 15 rows at midbody; supraoccular and postocular scales subequal; 5 infralabial scales; two pairs of genials, with anterior pair much the larger 2
2. Ventral scales 120–135; prefrontal scales much longer than internasals; second infralabial scale notably longer than first, the two together being about as long as the third infralabial. . . *X. stenorhynchus* (including its putative junior synonym *X. indicus*)
   Ventral scales 106–120+; prefrontal and internasal scales more or less subequal in midline length; second infralabial scale only marginally longer than first, the two together being shorter than the length of the third infralabial. . . . . *X. captaini*

DISCUSSION

Recognition of *Xylophis captaini* provides a compelling explanation for large ranges in the number of ventrals (c. 20% of total ventral count) and subcaudals in previous conceptions of *X. stenorhynchus* (Smith, 1943; Sharma, 2003; Whitaker and Captain, 2004), and Whitaker and Captain's (2004:274) pertinent observation of "internasals variable – very small or almost as long as prefrontals" in *X. stenorhynchus*. Some previously cited generic characters for *Xylophis*, including divided nasal scales (Smith, 1943) are possibly in error.

Hemipenial morphology of *Xylophis* matches that of better known, less equivocal xenodermatines, in terms of the deeply to very deeply forked form lacking spines, and the partially centrolineal (though tending to centripetal, rather than centrifugal) sulcus spermaticus (McDowell, 1987; Zaher, 1999). It is debatable whether there are convincing morphological characters diagnosing Xenodermatinae (Zaher, 1999:18–19; Dowling and Pinou, 2003) and there are few molecular data available to date (and none for *Xylophis*). Gans and Fetcho (1982) pointed out the superficial similarity between the Western Ghats *Xylophis* and Sri Lankan *Aspidura*, and we concur with Gans (1993) that in particular, *X. captaini* resembles *A. guentheri* in overall form, colour and habitus (DJG, pers. obs.). However, there are notable differences in scalation, and there are other superficially similar burrowing snakes of uncertain affinity in South Asia that should be considered (e.g., *Blythia, Haplocercus, Trachischium*, all of which are members, along with *Aspidura* and *Xylophis*, of Smith's, 1943 "Group 7"). Additionally, although *Xylophis* has been affiliated with the Xenodermatinae, *Aspidura* has been classified in the Natricinae by some recent workers (e.g., McDowell, 1987; Zaher, 1999; Lawson et al., 2005). Dowling and Pinou (2003) place *Aspidura* also in Xenodermatinae. Future work might explore the relationships of *Xylophis* and other small burrowing Asian caenophidians in more detail.

It is approaching 25 years since Gans and Fetcho (1982) argued that the taxonomy of Indian snakes as summarised by Smith (1943) is no more than a good platform from which much work remains to be done. We believe that for most species, this still remains the case. In particular, more attention might be paid to small, unassuming, burrowing snakes.

ACKNOWLEDGEMENTS

Many people collected valuable material, helped with fieldwork, provided facilities and support, and made useful observations for this project. Beyond the historical workers, special thanks go to S. D. Biju, J. George, R. Janardhanan, S. Mathew, G. J. Measey, Malan, O. V. Oommen, M. R. Sánchez-Villagra, S. Vishvambaran, M. Wilkinson, and many gardeners and farmers in Kerala and Tamil Nadu. For discussion, support, and help in working with the BNHS collections, we thank A. Captain and V. Giri. Fig. 2 was drawn by E. Wade, with skill and generosity. We are grateful to A. Resetar (FMNH), R. Drewes (CAS), and S. P. Loader (BMNH) for providing photographs and data for specimens out of our reach. DJG was able to visit BNHS, thanks to the NHM Zoology Research Fund, and a joint grant from The Royal Society and Indian Department of Science and Technology. V. Wallach provided constructive criticism on an earlier draft. Finally, DJG is thankful to the late G. Underwood for inspiration, and to him and M. Wilkinson for prompting an interest in *Xylophis*.

LITERATURE CITED

BEDDOME, R. H. 1878. Description of a new genus of snakes of the family *Calamaridae*, from southern India. Proceedings of the Zoological Society of London 1878:576.

BIJU, S. D. 2001. A synopsis to the frog fauna of the Western Ghats, India. Indian Society for Conservation Biology, Occasional Publication 1:1–24.

BOULENGER, G. A. 1890. The fauna of British India, including Ceylon and Burma. Reptilia and Batrachia. Taylor & Francis, London. 541 pp.

DAS, I. 1997. Checklist of the reptiles of India with English common names. Hamadryad 22:32–45.

_____. 2002. A photographic guide to the snakes and other reptiles of India. New Holland Publishers (UK) Ltd., London. 144 pp.

DOWLING, H. G. 1951. A proposed standard system of counting ventrals in snakes. British Journal of Herpetology 1:97–99.

_____ & T. PINOU. 2003. Xenodermatid snakes in America. Herpetological Review 34:20–23.

DUMÉRIL, A.-M.-C., G. BIBRON & A.-H.-A. DUMÉRIL. 1854. Erpétologie générale ou histoire naturelle complète des reptiles. Volume 7, part 1. Librairie Encyclopédique de Roret, Paris. xvi + 780 pp.

GANS, C. 1993. Fossorial amphibians and reptiles: their distributions as environmental indicators. In: Ecology and landscape management in Sri Lanka. pp:189–199. W. Erdelen, C. Preu, N. Ishwaran & C. M. Madduma Bandara (Eds). Magraf Scientific Books, Weikersheim.

_____ & J. R. FETCHO. 1982. The Sri Lankan genus *Aspidura* (Serpentes, Reptilia, Colubridae). Annals of Carnegie Museum 51:271–316.

GHARPUREY, K. G. 1933. The snakes of India. The Popular Book Depot, Bombay. 165 pp.

GOWER, D. J. 2003. Scale microornamentation in uropeltid snakes. Journal of Morphology 258:249–268.

_____ & J. D. ABLETT. 2006. Counting ventral scales in Asian anilioid snakes. Herpetological Journal. 16:259–263.

_____, M. S. DHARNE, G. BHAT, V. GIRI, R. VYAS, V. GOVINDAPPA, O. V. OOMMEN, J. GEORGE, Y. SHOUCHE & M. WILKINSON. IN PRESS. Remarkable genetic homogeneity in unstriped, long-tailed *Ichthyophis* (Amphibia: Gymnophiona: Ichthyophiidae) along 1500 km of the Western Ghats, India. Journal of Zoology.

GÜNTHER, A. 1875. Second report on collections of Indian reptiles obtained by the British Museum. Proceedings of the Zoological Society of London 1875:224–234.

INGER, R. F., H. B. SHAFFER, M. KOSHY & R. BAKDE. 1984. A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, South India. Journal of the Bombay Natural History Society 81:406–427, 551–570.

KELLY, C. M. R., N. P. BARKER & M. H. VILLET. 2003. Phylogenetics of advanced snakes (Caenophidia) based on four mitochondrial genes. Systematic Biology 52(4):439–459.

LAWSON, R., J. B. SLOWINSKI, B. I. CROTHER & F. T. BURBRINK. 2005. Phylogeny of the Colubroidea (Serpentes): new evidence from mitochondrial genes. Molecular Phylogenetics and Evolution 37:581–601.

McDOWELL, S. B. 1987. Systematics. In: Snakes: ecology and evolutionary biology. pp:3–50.

R. A. Seigel, J. T. Collins & S. S. Novak (Eds). Macmillan, New York.

MEASEY, G. J., D. J. GOWER, O. V. OOMMEN & M. WILKINSON. 2003. Quantitative surveying of limbless endogeic vertebrates- a case study of *Gegeneophis ramaswamii* (Amphibia: Gymnophiona) in southern India. Applied Soil Ecology 23:43–53.

MURTHY, T. S. N. 1990. Illustrated guide to the snakes of the Western Ghats, India. Records of the Zoological Survey of India, Occasional Paper 114:1–69.

SHARMA, R. C. 2003. Handbook Indian snakes. Zoological Survey of India, Kolkata. xx + 292 pp + 69 plates.

SMITH, M. A. 1943. The fauna of British India. Reptiles and Amphibia Vol. III: Serpentes. Taylor and Francis, London. 583 pp.

WALL, F. 1919. Notes on a collection of snakes made in the Nilgiri Hills and the adjacent Wynaad. Journal of the Bombay Natural History Society 26:552–584.

____. 1923. Notes on a collection of snakes from Shembaganur, Palnai Hills. Journal of the Bombay Natural History Society 29:388–398.

WALLACH, V. 1998. The lungs of snakes. In: Biology of the Reptilia. Volume 19 (Morphology G). pp:93–295. C. Gans & A. S. Gaunt (Eds). Society for the Study of Amphibians and Reptiles, Ithaca, New York.

WHITAKER, R. 1978. Common Indian snakes. A field guide. Macmillan India Ltd., Delhi. xiv + 154 pp.

____ & A. CAPTAIN. 2004. Snakes of India, the field guide. Draco Books, Chennai. xiv + 481 pp.

ZAHER, H. 1999. Hemipenial morphology of the South American xenodontine snakes, with a proposal for a monophyletic Xenodontinae and a reappraisal of colubroid hemipenes. Bulletin of the American Museum of Natural History 240:1–168.

____ & A. L. C. PRUDENTE. 2003. Hemipenes of *Siphlophis* (Serpentes, Xenodontinae) and techniques of hemipenial preparation in snakes: A response to Dowling. Herpetological Review 34:302–307.

Received: 15 July 2006.
Accepted: 30 October 2006.

SOURCES OF LARVAL IDENTITIES FOR AMPHIBIANS OF INDIA

Indraneil Das[1] and Sushil K. Dutta[2]

[1]Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300,
Kota Samarahan, Sarawak, Malaysia.
Email: idas@ibec.unimas.my

[2]Department of Zoology, North Orissa University, Takatpur, Baripada 757 003, Orissa, India.
Email: skdutta@yahoo.com

ABSTRACT.– **Status of knowledge of amphibian larvae occurring within the political limits of India is reviewed. Each description is ranked in order of completeness and the presence or absence of images. Of the 265 species of amphibians (representing three orders– Anura, Gymnophiona and Caudata), 118 have known tadpole stages. This represents 44.5% of the total fauna, significantly lower than those of at least two regional faunas. In addition, the quality of description of a vast majority of species are brief descriptions and basic anatomical sketches, and detailed descriptions and scanning electronic micrography have been rarely applied to the larvae of Indian amphibians.**

KEY WORDS.– **Amphibians, larva, tadpole, identification, India.**

INTRODUCTION

At present, 265 species of amphibians (composed of three orders– Anura, Gymnophiona and Caudata) are known from India (Table 1). This review provides an annotated list of Indian species of amphibians, along with details of larval forms in the literature. Nearly 90 years ago, Annandale and Rao (1918) presented a review of the subject, as well as a bibliography of Indian tadpoles, which included 28 citations. As many as 14 of these refer to material from extralimital areas, in addition to three general (monographic works of cosmopolitan nature), leaving just 11 papers based on researches made exclusively on Indian material. The most recent stock-taking of knowledge on tadpoles of Indian amphibians estimated that under 25% of the forms were known to science (Saidapur, 2001).

Because of extreme morphological decoupling of the larval stages of amphibians from that of adults, identification of tadpoles has been a challenge, particularly as species names are based exclusively on adult series and a short supply of specialists on tadpoles. Indeed, the larval stages have not been routinely collected during field sampling. When larval stages are described, voucher series are seldom preserved and identified as such in the published description, making subsequent investigations on their identities uncertain in many instances. Thus, species name allocations in many studies of Indian amphibians remain open to question. In some instances, the species concerned were left unidentified. For instance, one of Annandale's (1905) early papers described an advanced stage tadpole from north-eastern India that lacked hind limbs, representing an unnamed species. Other unnamed tadpoles found in the literature include those described by Rao (1938), that were purported to be of African affinities; Ramaswami's (1932), descriptions and line drawings of unnamed larval *Cacopus* (a junior synonym of *Uperodon*) and Chanda and Talukdar's (1973) description of the tadpoles of an unnamed rhacophorid from north-eastern India. The most recent treatments of the Indian amphibian fauna– those of Pillai and Ravichandran (1999) and Chanda (2002), covering Indian Gymnophiona and all amphibians, respectively, do not provide larval descriptions.

When larval descriptions of Indian amphibians are available, these may be in an abbreviated form, lacking images. A few tadpole descriptions in the literature comprise measurements only. Detailed investigations, including scanning electron micrographs and descriptions of internal oral morphology are few and far between. Currently, the staging system developed by Gosner (1960) is widely used in anuran tadpole descriptions. Many larval descriptions from India were made in the pre-Gosner era, and therefore, lack a standard for comparisons with other similar studies. The range of quality of description encountered in Indian amphibian studies is thus wide, with contemporary standards applied to only a small fraction of the fauna.

Species-level, as well as higher-level, taxonomy of amphibians have seen several recent proposed systems of classification (e.g., Dubois, 1986; 1992; Inger, 1996; Frost et al., 2006). Inclusion of a number of species of the genus Philautus that were described from Sri Lanka (and locally have restricted ranges; see Manamendra-Arachchi and Pethiyagoda, 2005) in the Indian fauna is on account of the existing status of knowledge of this group.

METHODS

In this work, the 'Tree of life' nomenclature was adopted (see Frost et al., 2006). In addition, for the problematic genus Philautus and species once referred to this genus, we followed Bossuyt and Dubois (2001). The quality of description of Indian amphibian larvae as found existing in the literature varies significantly, as noted by Das and Haas (2005) and Inger (1985) for Borneo and Leong (2002) for Peninsular Malaysia. In this treatment, we scored larval descriptions from 0–7, where:

0 = unknown;
1 = measurements; no description or images;
2 = no description, non-SEM image;
3 = abbreviated description, remarks or discussion; no figure;
4 = abbreviated description; with figure;
5 = extended description; no figure;
6 = extended description; with line drawing; and
7 = extended description and scanning electronic micrography (SEM) and/or images of internal oral morphology.

The respective references cited are in chronological order. Mention is made if descriptions are based on extralimital samples, and indicated with 'I', if drawn from India. Where not specified, these are from unspecified localities. Finally, this review deals with studies relevant to identification, taxonomy and systematics, and therefore, bypasses many fundamental researches done on tadpole ecology, growth and other biological aspects. Nonetheless, some works on developmental biology have been cited when these are relevant to systematics.

OBSERVATIONS

In total, 118 species of amphibians known from India now have known tadpoles, representing 44.5% of the 265 known Indian amphibian species. This compares unfavourably with the Bornean– 55.6% (Das and Haas, 2005) and Peninsular Malaysian– 76.1% (Leong, 2002) faunas, particularly since additional larval forms have been described or have been since recognised since these two reviews were published (e.g., Leong, 2004; Leong and Lim, 2003; Haas et al., 2006; Inger et al., 2006; Haas and Das, 2007). Additionally, the larvae of several species (including *Ingerophrynus macrotis*, *Fejervarya cancrivora*, *Limnonectes laticeps*, *Megophrys wuliangshanensis*, *Kaloula baleata*, *Microhyla fissipes* (population from India's Andaman Islands tentatively allocated to this nominal species), *Altirana parkeri*, *Amolops monticola*, *Hylarana erythraea*, *H. raniceps*, *Chiromantis doriae* and *C. vittatus*) have been described exclusively from adjacent regions (including China, Sri Lanka, Nepal and Pakistan) or extralimital areas (including Thailand, the Malay Peninsula, Java and the Philippine Archipelago). Given the systematic uncertainties with several lineages, it is unclear in a number of cases (e.g., *Kaloula baleata*, *K. pulchra*, *Fevervarya limnocharis*, *F. cancrivora*, *Limnonectes laticeps* and *Polypedates leucomystax*) whether the allocation would be relevant to Indian populations of the respective species.

Species with unknown or undescribed larval stages by family include: Bufonidae (10); Dicroglossidae (24), Megophryidae (five); Microhylidae (seven); Micrixalidae (10); Nyctibatrachidae (nine); Petropedetidae (five); Ranidae (nine); Rhacophoridae (50); Caeciliidae (eight); Ichthyophiidae (six); and Uraeotyphlidae (four). Apart from a single member (described by Smith, 1924a), an endemic family of Indian amphibians– the Micrixalidae– have unknown

Table 1. Checklist of amphibians of Republic of India (current: 16 November 2006), annotated with status information on larval descriptions and their sources. References: 0 = unknown; 1 = measurements; no description or images; 2 = no description, non-SEM image; 3 = abbreviated description, remarks or discussion; no figure; 4 = abbreviated description; with figure; 5 = extended description; no figure; 6 = extended description; with figure; and 7 = extended description and scanning electronic micrography (SEM) and/or images of internal oral morphology.

Species	Status of description
Bufonidae	
1. *Ansonia ornata* Günther, 1875	3 (Daniel, 2002:175: I)
2. *Ansonia rubigina* Pillai & Pattabiraman, 1981	0
3. *Bufo abatus* Ahl, 1925	0
4. *Bufo beddomii* Günther, 1875	0
5. *Bufo brevirostris* Rao, 1937	6 (Rao, 1937: I)
6. *Bufo hololius* Günther, 1876	0
7. *Bufo koynayensis* Soman, 1963	0
8. *Bufo parietalis* Boulenger, 1882	0
9. *Bufo scaber* Schneider, 1799	3 (Daniel, 2002:180: I; Daniels, 2005:113: I); 4 (Annandale and Rao, 1918: I, reprinted in Kirtisinghe, 1957:23–24 and Daniel, 1963a: as *Bufo fergusonii*)
10. *Bufo silentvalleyensis* Pillai, 1982	0
11. *Bufo stomaticus* Lütken, 1862	2 (Ray and Tilak, 1994: I; Khan, 1999); 3 (Daniel, 1963a: I; Daniel, 2002:180: I; Daniels, 2005:115: I); 4 (Nieden, 1923:86; Annandale and Rao, 1918: I, reprinted in Kirtisinghe, 1957:18; Khan, 1994: Pakistan; Deuti and Bharati Goswami, 1995: I; Anders, 2002:160–161: Nepal; Khan, 2006:19, 49: Pakistan); 6 (Khan, 1965: as *Bufo melanostictus*: Pakistan; Bhati, 1969: I; Ray, 1999: I; Khan, 2002: Pakistan; Khan, 2003d: Pakistan); 7 (Khan and Mufti, 1994b: Pakistan)
12. *Bufo stuarti* Smith, 1929	0
13. *Bufoides meghalayanus* (Yazdani & Chanda, 1971)	3 (Pillai and Yazdani, 1973: I)
14. *Duttaphrynus himalayanus* (Günther, 1864)	2 (Annandale, 1912: I); 3 (Annandale, 1906: I; Bhaduri, 1944c: I; Khan, 2001: Pakistan; Khan, 2006:42: Pakistan); 4 (Anders, 2002:148: Nepal; Fei et al., 2005:204: China); 6 (Ray, 1999: I)

15. *Duttaphrynus melanostictus* (Schneider, 1799)	2 (Pope, 1931: China; Iskandar, 1998: Java and Bali, Indonesia; Yang, 1998: Taiwan, Republic of China; Nutphand, 2001: Thailand); 3 (Boulenger, 1912; Bourret, 1942a: Indo-China; Daniel, 1963a: I; Inger, 1966: Borneo; Wu et al., 1987:54: China; Yang, 1991b:104: China; Ye et al., 1993:187: China; Karsen et al., 1998:52: Hong Kong, China; Khan, 2001: Pakistan; Daniel, 2002:178: I); 4 (Pope, 1931: Hainan, China, reprinted in Bourret, 1942b; Kirtisinghe, 1957:21–22: Sri Lanka; Nigam, 1984: I; Sahu, 1994: I; Tarkhnishvilli, 1994: Vietnam; Nutphand, 1988: Thailand; Ray and Tilak, 1994: I; Deuti and Bharati Goswami, 1995: I; Manthey and Grossmann, 1997: Borneo; Fei and Ye, 2001a:152: China; Fei and Ye, 2001b: China; Anders, 2002:156: Nepal; Fei et al., 2005:204: China; Inthara et al., 2005: Thailand; Khan, 2006:19, 44: Pakistan); 5 (Leong and Chou, 1999: Singapore); 6 (Ye et al., 1986: China; Chou and Lin, 1997:12–13: Taiwan, Republic of China; Ray, 1999: I)
16. *Duttaphrynus microtympanum* (Boulenger, 1882)	3 (Annandale and Rao, 1918: I; Daniels, 2005:108: I)
17. *Ingerophrynus macrotis* (Boulenger, 1890)	4 (Inthara et al., 2005: Thailand)
18. *Pedostibes kempi* (Boulenger, 1919)	0
19. *Pedostibes tuberculosus* Günther, 1875	0
20. *Pseudepidalea latastii* (Boulenger, 1882)	3 (Khan, 2006:43: Pakistan; Khan, 2006:46: Pakistan); 5 (Smith, 1924a: I)
Dicroglossidae	
21. *Euphlyctis cyanophlyctis* (Schneider, 1799)	2 (Ray and Tilak, 1994: I); 3 (Ferguson, 1904: I; Shrestha, 2001:81: Nepal; Daniel, 2002:198–199: I; Daniels, 2005:182: I); 4 (Annandale and Rao, 1918: I, reprinted in Bourret, 1942b; McCann, 1932: I; Kirtisinghe, 1957:31–32: Sri Lanka; Daniel, 1975: I; Sahu, 1994: I; Khan, 1994: Pakistan; Deuti and Bharati Goswami, 1995: I; Anders, 2002:227: Nepal; Khan, 2006:20; 57: Pakistan); 6 (Mohanty-Hejmadi and Dutta, 1979: I; Khan and Mufti, 1995: Pakistan; Khan, 1997: *E. c. microspinulata*: Pakistan; Ray, 1999: I; Khan, 2003b: Pakistan; Khan, 2003d: Pakistan); 7 (Das, 1994: I)
22. *Euphlyctis ghoshi* (Chanda, 1990)	0
23. *Euphlyctis hexadactylus* (Lesson, 1834)	3 (Boulenger, 1920a; Daniel, 1975: I; Shrestha, 2001:82: Nepal; Daniel, 2002:200: I; Daniels, 2005:184: I); 4 (Ferguson, 1904: I; Kirtisinghe, 1957:28–29: Sri Lanka; Annandale and Rao, 1918; Deuti and Bharati Goswami, 1995: I); 5 (Bhaduri, 1944b: I); 7 (Das, 1994: I)
24. *Fejervarya andamanensis* (Stoliczka, 1870)	0
25. *Fejervarya cancrivora* (Gravenhorst, 1829)	3 (Boulenger, 1920a; Smith, 1917: Thailand; Schijfsma, 1932: Java, Indonesia; Annandale, 1918, reprinted in Bourret, 1942a; 1943b; Alcala, 1962: Philippines; Inger, 1966: Borneo; Ye et al., 1993:248: China; Fei et al., 1999:182: China); 4 (Bourret, 1942b: Indo-China; Fei et al., 2005:216: China; Inthara et al., 2005: Thailand); 6 (Alcala, 1962: Negros, Philippines; Leong and Chou, 1999: Singapore; Leong, 2005:22–24; 174: Malaysia and Singapore)
26. *Fejervarya keralensis* (Dubois, 1980)	3 (Boulenger, 1920a: as *Rana verrucosa*; Daniel, 1975: I: as *Rana verrucosa*; Inger et al., 1984: I; Daniels, 1992: I; Daniels, 2005:207: I); 6 (Annandale, 1918: as *Rana verrucosa*: I)

27. *Fejervarya limnocharis* (Gravenhorst, 1829)	1 (Khongwir et al., 2003b: I); 2 (Ray and Tilak, 1994: I; Yang, 1998: Taiwan, Republic of China; Chan-ard, 2003:110: Thailand); 3 (Boulenger, 1920a; van Kampen, 1910: Java, Indonesia; Smith, 1916a; 1916b; 1917: Thailand; Schijfsma, 1932: Java, Indonesia; Bourret, 1942a; Inger, 1966: Borneo; Kiyasetuo & Khare, 1986: I; Wu et al., 1987:74: China; Yang, 1991b:132–133: China; Ye et al., 1993:111; 250: China; Karsen et al., 1998:59: Hong Kong, China; Shrestha, 2001:87: Nepal; Malkmus et al., 2002; Khan, 2006:59: Pakistan); 4 (Ferguson, 1904: I; Annandale, 1917b: India; Annandale and Rao, 1918: I; Pope, 1931: Hainan, China, reprinted in Bourret, 1942b; Liu, 1950:317–318: China; Kirtisinghe, 1957:39–40: I and Sri Lanka; Kripalani, 1961: Nepal; Wu and Sun, 1981: China; Dong, 1991a:98–99: China; Sahu, 1994: I; Tarkhnishvilli, 1994: Vietnam; Deuti and Bharati Goswami, 1995: I; Mohanty et al., 1996: I; Manthey and Grossmann, 1997: Peninsular Malaysia; Leong and Chou, 1999: Singapore; Fei et al., 1999:182–183: China; Fei and Ye, 2001a:179: China; Ziegler, 2002: Vietnam; Inthara et al., 2005: Thailand); 6 (Liu, 1940b: China; Chou and Lin, 1997:27–28: Taiwan, Republic of China; Sahu and Khare, 1980; Roy and Khare, 1978; Ray, 1999: I; Zhang and Lin, 1987: China; Fei and Ye, 2003:182–184: China; Daniels, 2005:I: 208–210; Khan, 2003d: description a composite of *F. limnocharis* and *F. syhadrensis*; Leong, 2005:26–27; 175: Malaysia) Note: Since *F. limnocharis* is now known to be a species complex, the tadpoles for this nominal species in the literature presumably belong to a number of species.
28. *Fejervarya murthii* (Pillai, 1979)	0
29. *Fejervarya nepalensis* (Dubois, 1975)	0
30. *Fejervarya nicobariensis* (Stoliczka, 1870)	3 (van Kampen, 1923:226: Java, Indonesia; allocation to parent species tentative; Smith, 1930; Bourret, 1942a: Indo-China; Inger, 1956; Iskandar, 1998: Java and Bali, Indonesia; Malkmus et al., 2002); 4 (Schijfsma, 1932: Java, Indonesia); 5 (van Kampen, 1923, reprinted in Bourret, 1942b); 6 (Leong, 2005:100–101; 198; 203: Malaysia)
31. *Fejervarya nilagiricus* (Jerdon, 1853)	3 (Annandale, 1917b: I)
32. *Fejervarya orissaensis* Dutta, 1997	3 (Deuti and Bharati Goswami, 1995: I: as *Rana keralensis;* Shrestha, 2001:85: Nepal: as *Rana keralensis*); 6 (Dutta, 1997: I)
33. *Fejervarya syhadrensis* (Annandale, 1919)	2 (Khan, 2006:21: Pakistan); 3 (Boulenger, 1920a); 4 (Khan, 1994: Pakistan; Anders, 2002:252: Nepal); 6 (Khan, 1996a: Pakistan; Khan, 2003c: Pakistan; Khan, 2003d: description a composite of *F. limnocharis* and *F. syhadrensis*: Pakistan)
34. *Fejervarya teraiensis* (Dubois, 1984)	0
35. *Hoplobatrachus crassus* (Jerdon, 1853	1 (Bhaduri, 1944a: 1); 2 (Ray and Tilak, 1994: I); 3 (Annandale and Rao, 1918: I; Shrestha, 2001:80: Nepal; Daniels, 2005:187: I); 4 (Kirtisinghe, 1957:34–35: Sri Lanka; Dutta et al., 1993: I; Deuti and Bharati Goswami, 1995: I; Anders, 2002:232–233: Nepal;); 6 (Dutta and Mohnanty-Hejmadi, 1984: I; Ray, 1999: I); 7 (Das, 1994: I)
36. *Hoplobatrachus tigerinus* (Daudin, 1803)	2 (Mohanty-Hejmadi and Dutta, 1981: I); 3 (Ferguson, 1904: possibly a composite of *H. tigerinus* and *H. crassus*: I; Annandale and Rao, 1918: I; Ray, 1999: I; Shrestha, 2001:79: Nepal); 4 (McCann, 1932: I; Chacko, 1965: I; Dutta and Mohanty-Hejmadi, 1976: I; Agarwal and Niazi, 1997: I; Nigam, 1978: I; Khan, 1994: Pakistan; Deuti and Bharati Goswami, 1995: I; Anders, 2002:240–241: Nepal; Daniels, 2005:189–191: I; Khan, 2006:21; 61: Pakistan); 6 (Annandale, 1917b: I; Bhati, 1969: I; Khan, 1969: Pakistan; Agarwal and Niazi, 1980: I; Khan, 2004b: Pakistan; Khan, 2003d: Pakistan); 7 (Khan, 1996b: Pakistan; Grosjean et al., 2004). Note: The tadpoles described by Boulenger (1920a) belong to *R. tigerinus rugulosa* (current name: *Hoplobatrachus chinensis*), according to Smith (1930:96)
37. *Limnonectes brevipalmatus* (Peters, 1871)	3 (Daniels, 2005:203: I); 4 (Annandale, 1917b: I)

38. *Limnonectes charlesdarwini* (Das, 1998)	6 (Das, 1998: I)
39. *Limnonectes hascheanus* (Stoliczka, 1870)	0 Notes: Remarks on tadpoles, mostly after Taylor (1962) in Leong (2005:39–40)
40. *Limnonectes khasianus* (Anderson, 1871)	0
41. *Limnonectes kuhlii* (Tschudi, 1838)	2 (Pope, 1931: China; Yang, 1998: Taiwan, Republic of China); 3 (Boulenger, 1920a; Smith, 1930: Thailand; Schijfsma, 1932: Java, Indonesia; Bourret, 1942a: Indo-China; Dring, 1979: Peninsular Malaysia; Matsui, 1979: Malaysia; Yang, 1991b:131: China; Karsen et al., 1998:57: Hong Kong, China; Leong and Chou, 1999: Singapore); 4 (Smith, 1917: Thailand; Pope, 1931: Hainan, China, both reprinted in Bourret, 1942b: Indo-China; Inger, 1966: Borneo; Manthey and Grossmann, 1997: Borneo; Fei et al., 1999:204–205: China; Malkmus et al., 2002: Borneo; Fei et al., 2005:214: China; Inthara et al., 2005: Thailand); 6 (Chou and Lin, 1997:25–26: Taiwan, Republic of China; Fei and Ye, 2003: China; Leong, 2005:41–43; 179: Malaysia); 4, 7 (Inger, 1985: Borneo)
42. *Limnonectes laticeps* (Boulenger, 1882)	3 (Inger, 1985: Borneo; association with parent species weak) Note: Leong's (2004; 2005:44–45; 179) description and illustrations of an endotrophic tadpole that was allocated to this species is considered doubtful by us)
43. *Limnonectes mawlindipi* (Chanda, 1990)	0
44. *Limnonectes mawphlangensis* (Pillai & Chanda, 1977)	0
45. *Limnonectes nepalensis* (Dubois, 1975)	0
46. *Limnonectes pierrei* (Dubois, 1975)	0
47. *Limnonectes sauriceps* (Rao, 1937)	0
48. *Limnonectes shompenorum* Das, 1996	0
49. *Nanorana annandalei* (Boulenger, 1920)	3 (Boulenger, 1920a, reprinted in Anders, 2002:264); 5 (Dubois, 1976:94: Nepal: reprinted in Anders, 2002:264); 6 (Bordoloi et al., 2001: I)
50. *Nanorana arnoldi* (Dubois, 1975)	0
51. *Nanorana barmoachensis* (Khan & Tasnim, 1989)	3 (Khan, 2006:62–63: Pakistan/I)
52. *Nanorana blanfordi* (Boulenger, 1882)	3 (Boulenger, 1920a; Dubois, 1976:111–112: Nepal; Fei et al., 1999:210: China); 4 (Anders, 2002:267: Nepal; Fei et al., 2005:220: China); 6 (Bhaduri, 1944c: Bhutan)
53. *Nanorana bourreti* (Dubois, 1987)	0
54. *Nanorana ercepeae* (Dubois, 1974)	0
55. *Nanorana hazarensis* (Dubois & Khan, 1979)	4 (Khan, 2006:20; 63–64: Pakistan); 5 (Dubois and Khan, 1979: Pakistan/I); 7 (Khan and Malik, 1987: Pakistan)

56. *Nanorana liebigii* (Günther, 1860)	3 (Annandale, 1906: I; Dubois, 1974; 1976:71–72: Nepal; Fei et al., 1999:214: China; Daniel, 2002:207: I); 4 (Anders, 2002:274–275: Nepal); 6 (Annandale, 1912: I)
57. *Nanorana minica* (Dubois, 1975)	3 (Dubois, 1976:155–156: Nepal; Anders, 2002:278: Nepal); 6 (Mehta, 1983: I; Tilak and Ray, 1985: I: as *Rana tuberculata*; Ray, 1999: I: as *Rana tuberculata*)
58. *Nanorana mokokchungensis* (Das & Chanda, 2000)	0
59. *Nanorana pleskei* Günther, 1896	3 (Annandale, 1908: I; Boulenger, 1920a; Ye et al., 1993:296: China; Fei et al., 1999:228: China); 4 (Annandale, 1917a: I; Liu, 1950:327–328: China; Fei and Ye, 2001a:181: China; Fei and Ye, 2001b: China; Fei et al., 2005:215: China); 6 (Liu, 1940b: China)
60. *Nanorana polunini* (Smith, 1951)	3 (Dubois, 1974; 1976:133: Nepal); 4 (Anders, 2002: Nepal)
61. *Nanorana rarica* (Dubois, Matsui & Ohler, 1983)	3 (Anders, 2002:285: Nepal); 5 (Dubois and Matsui, 1983: Nepal)
62. *Nanorana rostrandi* (Dubois, 1974)	3 (Dubois, 1974; 1976:172–173: Nepal); 4 (Anders, 2002:289: Nepal)
63. *Nanorana sternosignata* (Murray, 1885)	3 (Annandale and Rao, 1918: I; Boulenger, 1920a; Khan, 2004a: Pakistan; Khan, 2006:65: Pakistan)
64. *Nanorana vicina* (Stoliczka, 1872)	4 (Annandale, 1908: I; Khan, 2004a: Pakistan)
65. *Occidozyga borealis* (Annandale, 1912)	0
66. *Occidozyga lima* (Gravenhorst, 1829)	2 (Chan-ard, 2003:122: Thailand); 3 (Bourret, 1942a: Indo-China; Karsen et al., 1998:54: Hong Kong, China); 4 (Pope, 1931: China, reprinted in Bourret, 1942b; Tarkhnishvilli, 1994: Vietnam; Fei et al., 1999:246–247: China; Fei and Ye, 2003: China; Inthara et al., 2005: Thailand); 6 (Smith, 1916c: Thailand, reprinted in Annandale and Rao, 1918: I; Fei et al., 2005:207: China; Leong, 2005:64–65; 186: Java, Indonesia)
67. *Ombrana sikimensis* (Jerdon, 1870)	3 (Dubois, 1976:205–206: Nepal; Anders, 2002:219: Nepal)
68. *Sphaerotheca breviceps* (Schneider, 1799)	1 (Daniel, 1975: I); 2 (Ray and Tilak, 1994: I); 3 (Deuti and Bharati Goswami, 1995: I; Shrestha, 2001:89: Nepal); 4 (Ferguson, 1904: I; Kirtisinghe, 1957:44–45: Sri Lanka; Ray, 1999: I; Anders, 2002:305–306: Nepal; Daniels, 2005: I:242–244: I; Khan, 2006:20; 66: Pakistan); 6 (Rao, 1915a: I; Mohanty-Hejmadi et al., 1979: I)
69. *Sphaerotheca dobsonii* (Boulenger, 1882)	0
70. *Sphaerotheca leucorhynchus* (Rao, 1937)	0
71. *Sphaerotheca maskeyi* (Schleich & Anders, 1998)	0
72. *Sphaerotheca parambikulamana* (Rao, 1937)	0
73. *Sphaerotheca rolandae* (Dubois, 1983)	1 (Das and Dutta, 1996); 3 (Das, 1994: I; Das, 1996: I; Anders, 2002:312–313: Nepal); 6 (Kirtisinghe, 1957: Sri Lanka: as *Rana (Tomopterna) breviceps*)
74. *Sphaerotheca rufescens* (Jerdon, 1853)	0

75. *Sphaerotheca swani* (Myers & Leviton, 1956)	0
Hylidae	
76. *Hyla annectans* Jerdon, 1870	2 (Chan-ard, 2003:94: Thailand); 3 (Hu and Yang, 1960: China; Wu et al., 1987:56: China; Yang, 1991b:109: China; Ye et al., 1993:199: China); 4 (Liu, 1950:230–231: China; Fei et al., 1999:144–145: China; Ao and Bordoloi, 2001: I; Fei and Ye, 2003:144–146: China); 6 (Ao and Khare, 1986) Note: The tadpoles allocated to this species by Andersson (1938) are incertae sedis.
Megophryidae	
77. *Leptobrachium smithi* Matsui, Nabhitabhata & Panha, 1998	4 (Sahu, 1994: I: as *Leptobrachium hasselti*; Inthara et al., 2005: Thailand); 6 (Matsui et al., 1999: Thailand)
78. *Megophrys boettgeri* (Boulenger, 1899)	4 (Annandale, 1917b: as ? *Megalophrys boettgeri*: from Hong Kong, China; identity confirmed by Smith, 1924a; Pope, 1931: China; Liu, 1940a: China; Wang, 1991: China; Fei and Ye, 2001a:147: China; Fei and Ye, 2001b: China; Fei et al., 2005:199: China); 6 (Liu, 1940b: China)
79. *Megophrys glandulosa* (Boulenger, 1890)	0
80. *Megophrys kempii* (Annandale, 1912)	0
81. *Megophrys lateralis* (Anderson, 1871)	4 (Ziegler, 2002: Vietnam)
82. *Megophrys major* (Boulenger, 1908)	2 (Annandale, 1912: as *Megalophrys* (?) *major*: I, reprinted in Bourret, 1942a)
83. *Megophrys parva* (Boulenger, 1893)	2 (Annandale, 1912: I, reprinted in Bourret, 1942b); 3 (Annandale, 1906: as *Megalophrys montana*: I; Annandale and Hora, 1922: I; Bourret, 1942a: Indo-China; Daniel, 2002:172: I); 4 (Hora, 1922: I; Anders, 2002:142, 165–166: Nepal; Inthara et al., 2005: Thailand)
84. *Megophrys robusta* (Boulenger, 1908)	0
85. *Megophrys wuliangshanensis* Ye & Fe, 1995	4 (Fei et al., 2005:200: China)
86. *Scutiger boulengeri* (Bedriaga, 1898)	3 (Dubois, 1974: Nepal: as *Scutiger alticola*; Ye et al., 1993:135: China); 4 (Fei and Ye, 2001b: China; Anders, 2002:174: Nepal); 6 (Liu, 1943b: China: as *Scutiger alticola*?; Song and Feng, 1985: China; Song et al., 1990: China)
87. *Scutiger nepalensis* Dubois, 1974	0
88. *Scutiger nyingchiensis* Fei, 1977	2 (Fei, 1977: China); 3 (Ye et al., 1993:137: China; Khan, 2006:53: Pakistan); 4 (Fei et al., 1999:82–83: China; Anders, 2002:178: Nepal; Fei and Ye, 2003:82–83: China)
89. *Scutiger occidentalis* Dubois, 1978	0
90. *Scutiger sikimmensis* (Blyth, 1854)	3 (Myers and Leviton, 1962: Nepal; Dubois, 1974: Nepal, reprinted in Anders, 2002:188: Nepal); 4 (Liu, 1940a: China); 6 (Liu, 1940b; Liu, 1943b: China)

Microhylidae	
91. *Kalophrynus orangensis* Dutta, Ahmed & Das, 2000	0
92. *Kaloula assamensis* Das, Sengupta, Ahmed & Dutta, 2004	0
93. *Kaloula baleata* (Müller, 1836)	2 (Iskandar, 1998: Java and Bali, Indonesia); 3 (van Kampen, 1910: Java, Indonesia; Bourret, 1942a: Indo-China)
94. *Kaloula pulchra* Gray, 1831	2 (Nutphand, 2001: Thailand; Chan-ard, 2003:100: Thailand; Heyer, 1971: Thailand) 3 (Smith, 1930; Parker, 1934:85: Thailand; Bourret, 1942a: Indo-China; Inger, 1966: Thailand; Yang, 1991b:233: China; Ye et al., 1993: 349: China; Karsen et al., 1998:68: Hong Kong, China; Fei et al., 1999:300: China); 4 (Smith, 1916a: Thailand, reprinted in Bourret, 1942b; Annandale, 1917b: Singapore; Schmidt, 1978: Thailand; Manthey and Grossmann, 1997; Leong and Chou, 1999: Singapore; Malkmus et al., 2002; Fei et al., 2005:234: China; Inthara et al., 2005: Thailand); 6 (Smith, 1916: Thailand, reprinted in Bourret, 1942b)
95. *Kaloula taprobanica* Parker, 1934	3 (Daniels, 2005:121); 4 (Kirtisinghe, 1958: Sri Lanka; Deuti and Bharati Goswami, 1995: I: as *Kaloula pulchra*; Anders, 2002:185–186: Nepal)
96. *Melanobatrachus indicus* Beddome, 1878	0
97. *Microhyla berdmorei* (Blyth, 1856)	3 (Smith, 1930; Bourret, 1942a; Parker, 1934:128: Vietnam; Inger, 1966: Vietnam); 4 (Inthara et al., 2005: Thailand); 5 (Smith, 1924a: Vietnam, reprinted in Bourret, 1942b); 6 (Leong, 2004: Peninsular Malaysia)
98. *Microhyla fissipes* Boulenger, 1884	2 (Pope, 1931: China: as *Microhyla ornata*; Chan-ard, 2003:104: Thailand: as *Microhyla ornata*); 3 (Smith, 1917: Thailand: as *Microhyla ornata*; Bourret, 1942a: Indo-China: as *Microhyla ornata*; Wu et al., 1987:64–65: China: as *Microhyla ornata*; Karsen et al., 1998:70: Hong Kong, China: as *Microhyla ornata*); 4 (Flower, 1899: Thailand: as *Microhyla ornata*, reprinted in Nieden,1926:30, Bourret, 1942b and Kirtisinghe, 1957:90; Fei et al., 1999:294, 296–297: China: as *Microhyla ornata*; Fei and Ye, 2001a:224: China: as *Microhyla ornata*; Fei and Ye, 2001b: China: as *Microhyla ornata*; Fei and Ye, 2003:294; 296–297: China: as *Microhyla ornata*; Inthara et al., 2005: Thailand: as *Microhyla ornata*); 6 (Liu, 1940b: China: as *Microhyla ornata*; Chou and Lin, 1997:19–21: Taiwan, Republic of China: as *Microhyla ornata*; Fei et al., 2005:233: China: as *Microhyla ornata*)
99. *Microhyla heymonsi* Vogt, 1911	2 (Pope, 1931: China, reprinted in Bourret, 1942b; Ziegler, 2002: Vietnam; Chan-ard, 2003:104: Thailand); 3 (Smith, 1930: Thailand, reprinted in Bourret, 1942a; 1942b; Wu et al., 1987:68–69: China; Yang, 1991b:240: China; Ye et al., 1993: 343: China); 4 (Dong, 1991b:152: China; Fei and Ye, 2001a:220: China; Fei and Ye, 2001b: China; Fei et al., 2005:232: China; Inthara et al., 2005: Thailand); 6 (Chou and Lin, 1997:17–19: Taiwan, Republic of China)
100. *Microhyla ornata* Duméril & Bibron, 1841	1 (Dei et al., 1994: I; Dey and Gupta, 2002: I); 2 (Ray and Tilak, 1994: I); 3 (Daniel, 1963b: I; Khan et al., 1979: I; Ye et al., 1993: 345: China; Daniel, 2002:183: I; Daniels, 2005:126: I); 4 (Rao, 1917: India; Sahu, 1994: I; Khan, 1994: Pakistan; Deuti and Bharati Goswami, 1995: I; Anders, 2002:191–192: Nepal; Khan, 2006:20, 54: Pakistan); 6 (Padhye and Ghate, 1989: I; Ray, 1999: I; Khan, 2003a: Pakistan; Khan, 2003d: Pakistan; Mohanty-Hejmadi et al., 1980: I); 7 (Khan, 2000: Pakistan)
101. *Microhyla rubra* Jerdon, 1854	3 (Daniel, 1963b: I; Daniel, 2002:184: I; Daniels, 2005:129: I); 4 (Ferguson, 1904: I reprinted in Nieden,1926:20; Kirtisinghe, 1957:93–94: Sri Lanka); 6 (Rao, 1915a: I); 7 (Das, 1994: 1)
102. *Microhyla sholigari* Dutta & Ray, 2000	0

103. *Micryletta inornata* (Boulenger, 1890)	2 (Chan-ard, 2003:105: Thailand; Ziegler, 2002: Vietnam); 4 (Wang et al., 1989: Taiwan, Republic of China; Inthara et al., 2005: Thailand); 6 (Heyer, 1971: Thailand)
104. *Ramanella anamallaiensis* Rao, 1937	0
105. *Ramanella minor* Rao, 1937	0
106. *Ramanella montana* (Jerdon, 1854)	3 (Daniel, 1963b: I; Daniels, 2005:131: I)
107. *Ramanella mormorata* Rao, 1937	0
108. *Ramanella triangularis* (Günther, 1875)	3 (Daniel, 1963b: I; Daniels, 2005:132; 134: I); 4 (Rao, 1918: I); 5 (Inger et al., 1984: I)
109. *Ramanella variegata* (Stoliczka, 1872)	3 (Daniel, 1963b: I; Daniels, 2005:136: I); 4 (Rao, 1918: I, reprinted without figures by Kirtisinghe, 1957:84); 6 (Dutta et al., 1994: I)
110. *Uperodon globulosa* (Günther, 1864)	3 (Daniel, 1963b: I; Mallick, 1999: I; Shrestha, 2001:75: Nepal; Anders, 2002:197: Nepal; Daniel, 2002:186: I; Daniels, 2005:139: I); 4 (Deuti and Bharati Goswami, 1995: I); 6 (Bhaduri and Daniel, 1956: I)
111. *Uperodon systoma* (Schneider, 1799)	3 (Mallick et al., 1979: I; Khan, 2006:55: probably reprinted from descriptions of Indian populations); 4 (Ferguson, 1904: I, reprinted in Nieden,1926:20; Rao, 1933: I; Kirtisinghe, 1957:86–87: Sri Lanka; Anders, 2002:200: Nepal); 6 (Mohanty-Hejmadi et al., 1979: I; Ray, 1999: I)
Micrixalidae	
112. *Micrixalus elegans* (Rao, 1937)	0
113. *Micrixalus fuscus* (Boulenger, 1882)	0
114. *Micrixalus gadgili* Pillai & Pattabiraman, 1990	0
115. *Micrixalus kottigeharensis* (Rao, 1937)	0
116. *Micrixalus narainensis* (Rao, 1937)	0
117. *Micrixalus nudis* Pillai, 1978	0
118. *Micrixalus phyllophilus* (Jerdon, 1853)	6 (Smith, 1924a: as *Micrixalus opisthorhodus*: I)
119. *Micrixalus saxicolus* Jerdon, 1853	0
120. *Micrixalus silvaticus* (Boulenger, 1882)	0
121. *Micrixalus swamianus* (Rao, 1937)	0
122. *Micrixalus thampi* Pillai, 1981	0
Nyctibatrachidae	
123. *Nyctibatrachus aliciae* Inger, Shaffer, Koshy & Bakde, 1984	0

124. *Nyctibatrachus bedddomii* (Boulenger, 1882)	0
125. *Nyctibatrachus deccanensis* Dubois, 1984	0 Note: The report of *Nyctibatrachus pygmaeus* (synonymous with *N. deccanensis*) in Annandale (1918) was subsequently (Annandale, 1919) reidentified as pertaining to "*Ixalus variabilis*" (current name: *Philautus variabilis*). Since frogs of the genus *Philautus* do not have a free-swimming stage, the identity of the material dealt with by Annandale (1918) remains unknown
126. *Nyctibatrachus humayuni* Bhaduri & Kripalani, 1955	3 (Daniel, 2002:206: I); 4 (Daniels, 2005:223–224: I); 6 (Bhaduri and Kripalani, 1954: I)
127. *Nyctibatrachus hussaini* Krishnamurthy, Reddy & Gururaja, 2001	0 Note: A nomen nudum (fide Das and Kunte, 2005)
128. *Nyctibatrachus kempholeyensis* (Rao, 1937)	0
129. *Nyctibatrachus major* Boulenger, 1882	1 (Krishnamurthy, 1997: I); 3 (Inger et al., 1984: I); 4 (Daniels, 2005:227–228: I); 6 (Pillai, 1978: I)
130. *Nyctibatrachus minor* Inger, Shaffer, Koshy & Bakde, 1984	0
131. *Nyctibatrachus petraeus* Das & Kunte, 2005	0
132. *Nyctibatrachus sanctipalustris* Rao, 1920	6 (Rao, 1922: I)
133. *Nyctibatrachus sylvaticus* Rao, 1937	0
134. *Nyctibatrachus vasanthi* Ravichandran, 1997	0
Petropedetidae	
135. *Indirana beddomii* (Günther, 1875)	3 (Boulenger, 1920a; Inger et al., 1984: I; Daniel and Sekar, 1989: I; Daniel, 2002:203: I; Daniels, 2005:193: I); 6 (Annandale, 1918: I); 7 (Kuramoto and Joshy, 2002: I)
136. *Indirana brachytrasus* (Günther, 1875)	0
137. *Indirana diplosticta* (Günther, 1875)	0
138. *Indirana gundia* (Dubois, 1986)	3 (Dubois, 1985: I)
139. *Indirana leithii* (Boulenger, 1888)	2 (Kehimkar, 1982: I); 3 (Daniel and Sekar, 1989: I; Daniel, 2002:204: I; Daniels, 2005:199: I); 6 (Chari and Daniel, 1952: I; Sekar, 1992)
140. *Indirana leptodactyla* (Boulenger, 1882)	3 (Boulenger, 1920a; Daniel and Sekar, 1989: I); 6 (Annandale, 1918: I)
141. *Indirana longicrus* (Rao, 1937)	0
142. *Indirana phrynoderma* (Boulenger, 1882)	0
143. *Indirana semipalmata* (Boulenger, 1882)	3 (Boulenger, 1920a); 6 (Annandale, 1918: I)
144. *Indirana tenuilingua* (Rao, 1937)	0

Ranidae

145. *Altirana parkeri* Stejneger, 1927	3 (Ye et al., 1993:300: China; Fei et al., 1999:226: China); 4 (Anders, 2002:258: Nepal; Fei et al., 2005:215: China)
146. *Amolops chakrataensis* Ray, 1992	0
147. *Amolops gerbillus* (Annandale, 1912)	0
148. *Amolops formosus* (Günther, 1875)	0 Note: Although undescribed, the tadpoles of this species have been collected by Jha and Thapa (2002:83)
149. *Amolops jaunsari* Ray, 1992	0
150. *Amolops himalayanus* (Boulenger, 1888)	3 (Kripalani, 1952a: I); 4 (Kripalani, 1953b: I: as *Staurois himalayana*; Kripalani, 1961: Nepal: as *Staurois himalayana*)
151. *Amolops marmoratus* (Blyth, 1855)	2 (Annandale, 1912: I: as *Rana afghana*: I); 3 (Yang, 1991a: as *Amolops afghanus*; Yang, 1991b:174: China: as *Amolops afghanus;* Fei et al., 1999:238; 240: China: as *Amolops afghanus*); 4 (Kripalani, 1953b: I: as *Staurois afghana*; 1961: Nepal: as *Staurois afghanus*; Tilak and Mehta, 1983: I: as *Staurois afghana;* Sahu, 1994: I: as *Amolops afghanus*; Anders, 2002:210–211: Nepal); 6 (Bhaduri, 1935: I as *Rana afghana*; Hora, 1932: I: as *Rana afghana*; Ray, 1999: I: as *Amolops afghanus*)
152. *Amolops monticola* (Anderson, 1871)	3 (Yang, 1991a: China, reprinted in Anders, 2002:213); 4 (Fei and Ye, 2003:232;234–235: China)
153. *Amolops viridimaculatus* (Jiang, 1983)	3 (Yang, 1991a: China; Yang, 1991b:184: China)
154. *Clinotarsus curtipes* (Jerdon, 1853)	3 (Boulenger, 1920a; Daniel and Sekar, 1989: I; Daniel, 2002:210: I); 4 (Abdulali, 1962: I; Daniels, 2005:232–233: I); 6 (Rao, 1914: I; Lobo, 1961: I; Sekar, 1990b: I; Hiragond et al., 2001: I; James et al., 2000: I)
155. *Humerana humeralis* (Boulenger, 1887)	0
156. *Hylarana erythraea* (Schlegel, 1837)	1 (Manthey and Grossmann, 1997); 2 (Lim and Lim, 1992: Singapore); 3 (van Kampen, 1910: Java, Indonesia; Boulenger, 1920a; Smith, 1930; Bourret, 1942a; Bourret, 1942b: Indo-China; Inger, 1966: Borneo; Malkmus et al., 2002); 4 (Leong and Chou, 1999: Singapore; Inthara et al., 2005: Thailand); 6 (Leong, 2005:81–82; 191; 203: Thailand, Malaysia, Singapore and Philippines)
157. *Hylarana raniceps* (Peters, 1871)	3 (Boulenger, 1912: as *Rana labialis*; Bourret, 1942a: Indo-China: as *Rana chalconota;* Malkmus et al., 2002); 4 (Flower, 1896: Singapore: as *Rana chalconota*, reprinted in Bourret, 1942b: as *Rana chalconota*; Inger, 1966: Borneo: as *Rana chalconota*; Manthey and Grossmann, 1997: Peninsular Malaysia: as *Rana chalconota;* Leong and Chou, 1999: Singapore; Inthara et al., 2005: Thailand); 6 (Leong, 2005:78–79; 190: Malaysia, Singapore and Indonesia: as *Rana chalconota*); 4, 7 (Inger, 1985: as *Rana chalconota*)
158. *Hylarana tytleri* Theobald, 1868	3 (Deuti and Bharati Goswami, 1995: I: as *Rana erythraea*; Shrestha, 2001:84: Nepal: as *Rana erythraea*; Daniels, 2005:238: I); 4 (Annandale and Rao, 1918: I)
159. *Hydrophylax malabarica* (Tschudi, 1838)	3 (Annandale and Hora, 1922: I; Daniel, 1975: I; Daniel, 2002:209: I); 4 (Daniels, 2005:234–236: I); 6 (Chari, 1962: I). Note: According to Chari (1962), the description of larvae in Boulenger (1920a) is based on an incorrectly identified species.
160. *Minervarya sahyadris* Dubois, Ohler & Biju, 2001	3 (Dubois et al., 2001: I)

161. *Nasirana alticola* (Boulenger, 1882)	3 (Annandale and Hora, 1922: I; Boulenger, 1920a; Smith, 1930; Bourret, 1942a; Jha and Thapa (2002:86: I); 4 (Boulenger, 1882; Annandale, 1912: I, reprinted in Bourret, 1942b; Sahu, 1994: I); 6 (Sahu and Khare, 1983: I; Annandale, 1912: I; Leong, 2005:71–72; 188: Thailand and Malaysia); 7 (Grosjean et al., 2003: Thailand)
162. *Odorrana chloronota* (Günther, 1875)	3 (Ye et al., 1993:266: as *Rana livida*: China; Fei et al., 1999:188–189: as *Odorrana livida*: China; Fei and Ye, 2001a:196: China: as *Odorrana livida*); 5 (Smith, 1924a: as *Rana livida*: I)
163. *Pterorana khare* (Kiyasetuo & Khare, 1986)	0
164. *Sylvirana aurantiaca* (Boulenger, 1904)	3 (Daniels, 2005:229–230: I); 6 (Rao, 1937: I)
165. *Sylvirana danieli* (Pillai & Chanda, 1977)	6 (Khare and Sahu, 1994: I)
166. *Sylvirana garoensis* (Boulenger, 1920)	0
167. *Sylvirana intermedia* (Rao, 1937)	0
168. *Sylvirana leptoglossa* (Cope, 1868)	0
169. *Sylvirana nigrovittata* (Blyth, 1856)	3 (Smith, 1916a: Thailand, reprinted in Bourret, 1942a; 1943b; Smith, 1930: Thailand; Yang, 1991b:144: China); 4 (Liu, 1959: China; Anders, 2002:297: Nepal; Fei et al., 2005:224: China; Inthara et al., 2005: Thailand); 6 (Leong, 2005:103–104; 199; 203: Vietnam)
170. *Sylvirana temporalis* (Günther, 1864)	2 (Gupta, 1998); 3 (Daniel and Sekar, 1989: I; Daniel, 2002:211: I; Daniels, 2005:241: I); 4 (Kirtisinghe, 1957:47–48: Sri Lanka); 5 (Inger et al., "1984" 1985: I); 6 (Hiragond and Saidapur, 1999: I)
Rhacophoridae	
171. *Chiromantis cherrapunjiae* (Roonwal & Kripalani, 1961)	4 (Sahu, 1994: I); 6 (Roonwal and Kripalani, 1961: I) Note: The status of this species is uncertain, and is likely to be synonymous with a species of *Rhacophorus* (K. Deuti, pers. comm., 2006)
172. *Chiromantis doriae* (Boulenger, 1893)	3 (Bourret, 1942a: Indo-China; Yang, 1991b:197: China; Fei et al., 1999:262: China); 4 (Fei et al., 2005:228: China); 6 (Pope, 1931: China, reprinted in Bourret, 1942b)
173. *Chiromantis dudhwaensis* (Ray, 1992)	0
174. *Chiromantis shyamrupus* (Chanda & Ghosh, 1989)	0 Note: Allocated to *Chirixalus* by Bossuyt and Dubois (2001). Its placement within *Chiromantis* here is following the reallocation of all Indian *Chirixalus* to this genus, and require confirmation.
175. *Chiromantis simus* (Annandale, 1915)	0
176. *Chiromantis vittatus* (Boulenger, 1887)	2 (Heyer, 1971: Thailand); 3 (Yang, 1991b:199: China; Ye et al., 1993:323: China; Fei et al., 1999:264: China); 4 (Fei et al., 2005:228: China); 5 (Smith, 1924a: Thailand)
177. *Philautus andersonii* (Ahl, 1927)	0
178. *Philautus anili* Biju & Bossuyt, 2006	0

179. *Philautus annandalii* (Boulenger, 1906)	0 Note: Tadpoles purported to belong to this species in Ahl (1931) have been considered by Anders (2002:319) to be erroneously identified, as are those described as being free-living by Annandale (1913)
180. *Philautus beddomii* (Günther, 1876)	0
181. *Philautus bobingeri* Biju & Bossuyt, 2005	0
182. *Philautus bombayensis* (Annandale, 1919)	0
183. *Philautus chalazodes* (Günther, 1876)	0
184. *Philautus charius* Rao, 1937	0
185. *Philautus dubius* (Boulenger, 1882)	0
186. *Philautus dubois* Biju & Bossuyt, 2006	0
187. *Philautus femoralis* (Günther, 1864)	4 (Bahir et al., 2005: Sri Lanka)
188. *Philautus flaviventris* (Boulenger, 1882)	0
189. *Philautus garo* (Boulenger, 1919)	0
190. *Philautus glandulosus* (Jerdon, 1853)	6 (Rao, 1937: as *Philautus pulcher*: I) Note: See Bossuyt and Dubois (2001:46) for nomenclatural remarks on *Philautus pulcherrimus* Ahl, 1927
191. *Philautus jerdonii* (Günther, 1876)	0
192. *Philautus kempiae* (Boulenger, 1919)	0
193. *Philautus leucorhynus* (Lichtenstein & Martens, 1856)	2 (Gururaja and Ramachandra, 2006: as *Philautus* cf. *leucorhinus*: I); 6 (Rao, 1937: I)
194. *Philautus luteolus* Kuramoto & Joshy, 2003	0
195. *Philautus melanensis* Rao, 1937	0
196. *Philautus microdiscus* (Annandale, 1912)	0
197. *Philautus namdaphaensis* Sarkar & Sanyal, 1985	0
198. *Philautus nerostagona* Biju & Bossuyt, 2005	0
199. *Philautus ponmudi* Biju & Bossuyt, 2005	0
200. *Philautus sahai* Sarkar & Ray, 2006	0
201. *Philautus sanctisilvaticus* Das & Chanda, 1997	0
202. *Philautus shillongensis* Pillai & Chanda, 1973	0

203. *Philautus signatus* (Boulenger, 1882)	0
204. *Philautus temporalis* (Günther, 1864)	0
205. *Philautus terebrans* Das & Chanda, 1998	0
206. *Philautus tinniens* (Jerdon, 1853)	4 (Krishnamurthy et al., "2003" 2004: I: as *Philautus glandulosus*, K. V. Gururaja pers. comm. 2006)
207. *Philautus tuberohumerus* Kuramoto & Joshy, 2003	0
208. *Philautus travancoricus* (Boulenger, 1891)	0
209. *Philautus tuberculatus* (Anderson, 1879)	0
210. *Philautus variabilis* (Günther, 1859)	4 (Patil and Kanamadi, 1997)
211. *Philautus wynaadensis* (Jerdon, 1853)	0
212. *Polypedates insularis* Das, 1995	0
213. *Polypedates leucomystax* Gravenhorst, 1829	2 (Pope, 1931: China; Nutphand, 2001: Thailand); 3 (van Kampen, 1907: Sumatra, Indonesia; Boulenger, 1912; Smith, 1917: Thailand; Villadolid and Rosario, 1920: Luzon, Philippines; Bourret, 1942a: Indo-China; Alcala and Brown, 1956: Philippines; Inger, 1956: Borneo: as *Rhacophorus leucomystax linki*; Yang, 1991b:206–207: China; Ye et al., 1993:331: China; Shrestha, 2001:92: Nepal); 4 (Flower, 1899: Peninsular Malaysia and Singapore; Pope, 1931: Hainan, China, reprinted in Bourret, 1942b: Indo-China; Liu, 1940a: China; 1950:367–370: China; McCann, 1932: I; Sahu, 1994: I; Liang, 1991: China; Tarkhnishvilli, 1994: Vietnam; Matsui, 1979; Manthey and Grossmann, 1997: Pulau Bintan, off Sumatra, Indonesia; Iskandar, 1998: Java and Bali, Indonesia; Anders, 2002:324: Nepal; Malkmus et al., 2002: Pulau Bintan, Indonesia); 5 (Liu, 1943a: China); 6 (Ahl, 1931; Liu, 1940b: China; Ting, 1970: Singapore; Alcala, 1962: Negros, Philippines; Leong and Chou, 1999: Singapore; Ziegler, 2002: Vietnam; Iangrai et al., 2004)
214. *Polypedates maculatus* (Gray, 1834)	1 (Dutta et al., 2001); 2 (Ray and Tilak, 1994: I); 3 (Daniel and Sekar, 1989: I; Shrestha, 2001:94: Nepal; Daniel, 2002:193: I; Daniels, 2005:165–167: I); 4 (Ferguson, 1904: I; Kirtisinghe, 1957:56–57: as *Rhacophorus leucomystax maculatus*: I and Sri Lanka; Mohanty-Hejmadi and Dutta, "1988" 1989: I; Deuti and Bharati Goswami, 1995: I; Anders, 2002:328–329: Nepal); 6 (Annandale, 1912: I; Ray, 1999: I)
215. *Polypedates megacephalus* Hallowell, 1861	3 (Karsen et al., 1998:66: Hong Kong, China); 4 (Fei and Ye, 2001b: China; Fei and Ye, 2003:272; 273–274: China; Fei et al., 2005:231: China); 6 (Chou and Lin, 1997:12–13: Taiwan, Republic of China)
216. *Polypedates occidentalis* Das & Dutta, 2006	0
217. *Polypedates pseudocruciger* Das & Ravichandran, 1998	0
218. *Polypedates teraiensis* (Dubois, 1987)	0
219. *Rhacophorus appendiculatus* (Günther, 1859)	3 (Inger, 1966: Borneo; Malkmus et al., 2002: Borneo); 5 (Inger, 1985: Borneo); 6 (Leong, 2004: Peninsular Malaysia)
220. *Rhacophorus bipunctatus* Ahl, 1927	0

221. *Rhacophorus bisacculatus* Taylor, 1962	0
222. *Rhacophorus dubius* Boulenger, 1882	0
223. *Rhacophorus gongshanensis* (Yang & Su, 1984)	0
224. *Rhacophorus jerdoni* (Günther, 1875)	0
225. *Rhacophorus lateralis* Boulenger, 1883	0
226. *Rhacophorus longinasus* Ahl, 1931	0
227. *Rhacophorus malabaricus* Jerdon, 1870	1 (George et al., 1996: I); 3 (Inger et al., "1984" 1985: I; Daniel and Sekar, 1989: I; Daniel, 2002:195: I; Daniels, 2005:174: I); 4 (Ferguson, 1904: I); 6 (Sekar, 1990a: I)
228. *Rhacophorus maximus* Günther, 1858	1 (Khongwir et al., 2003: I); 4 (McCann, 1932: I; Anders, 2002:339: Nepal); 6 (Khongwir et al., 2003: I)
229. *Rhacophorus namdaphaensis* Sarkar & Sanyal, 1985	0
230. *Rhacophorus naso* Annandale, 1912	0
231. *Rhacophorus nigropalmatus* Boulenger, 1895	3 (Inger, 1966: Borneo; Malkmus et al., 2002: Borneo); 4 (Sahu, 1994: I); 5 (Inger, 1985: Borneo); 6 (Berry, 1972: Peninsular Malaysia)
232. *Rhacophorus pleurostictus* (Günther, 1864)	3 (Ramaswami, 1934: I), 6 (Rao, 1915b: I)
233. *Rhacophorus pseudomalabaricus* Vasudevan & Dutta, 2000	0
234. *Rhacophorus reinwardtii* (Schlegel, 1840)	2 (Siedlecki, 1909: Java, Indonesia); 3 (Manthey and Grossmann, 1997; Iskandar, 1998: Java and Bali, Indonesia). Note: The description in Boulenger (1882:89–90) probably refers to a species of *Amolops, Huia* or *Meristogenys*. The systematic status of Indian populations await study.
235. *Rhacophorus taeniatus* Boulenger, 1906	0
236. *Rhacophorus tuberculatus* (Anderson, 1871)	0
237. *Theloderma asperum* (Boulenger, 1886)	6 (Leong and Lim, 2003: Malaysia)
238. *Theloderma moloch* (Annandale, 1912)	3 (Fei et al., 1999:266–268: China); 4 (Fei et al., 2005:228: China); 6 (Annandale, 1912: I)
239. *Theloderma nagalandensis* Orlov, Dutta, Ghate & Kent, 2006	0
Sooglossidae	
240. *Nasikabatrachus sahyadrensis* Biju & Bossuyt, 2003	3 (Dutta et al., 2004: I); 6 (Annandale, 1918: I: as species incertae sedis, tentatively assigned to the family Cystignathidae)

Salamandridae	
241 *Tylototriton verrucosus* Anderson, 1871	1 (Daniel, 2002:168: I); 2 (Anders, 2002:139: Nepal); 3 (Boulenger, 1920b; Anders et al., 1998:18: Nepal); 4 (Shrestha, "1989" 1990: Nepal); 6 (Smith, 1924b: I and Thailand; Daniel, 1962: I; Ferrier, 1974; Dasgupta, 1988: I; Shrestha, 2001:67–69; 71: Nepal)
Caeciliidae	
242. *Gegeneophis carnosus* (Beddome, 1870)	3 (Daniel, 2002:169: I); 4 (Seshachar, 1942: I)
243. *Gegeneophis danieli* Giri, Wilkinson & Gower, 2003	0
244. *Gegeneophis fulleri* (Alcock, 1904)	0
245. *Gegeneophis krishni* Pillai & Ravichandran, 1999	0
246. *Gegeneophis madhavaorum* Bhatta & Srinivasa, 2004	0
247. *Gegeneophis nadkarnii* Bhatta and Prashanth, 2004	0
248. *Gegeneophis ramaswamii* Taylor, 1964	0
249. *Indotyphlus battersbyi* Taylor, 1960	0
250. *Indotyphlus maharashtraensis* Giri, Gower & Wilkinson, 2004	0
Ichthyophiidae	
251. *Ichthyophis beddomii* Peters, 1879	3 (Daniel, 2002:171: I ; Daniels, 2005:79: I); 7 (Exbrayat et al., 1999: I)
252. *Ichthyophis bombayensis* Taylor, 1960	0
253. *Ichthyophis garoensis* Pillai & Ravichandran, 1999	0
254. *Ichthyophis hussaini* Pillai & Ravichandran, 1999	0
255. *Ichthyophis longicephalus* Pillai, 1986	0
256. *Ichthyophis malabaricus* Taylor, 1960	3 (Taylor, 1968:103: I); 4 (Balakrishna et al., 1983: I)
257. *Ichthyophis peninsularis* Taylor, 1960	3 (Daniels, 2005:79: I); 4 (Ramaswami, 1947: I: as *Ichthyophis monochrous*; see Pillai and Ravichandran, 1999, for remarks on identification)
258. *Ichthyophis sikkimensis* Taylor, 1960	0

259. *Ichthyophis subterrestris* Taylor, 1960	0
260. *Ichthyophis tricolor* Annandale, 1909	3 (Daniels, 2005:79: I)
Uraeotyphlidae	
261. *Uraeotyphlus interruptus* Pillai & Ravichandran, 1999	0
262. *Uraeotyphlus malabaricus* (Beddome, 1870)	0
263. *Uraeotyphlus menoni* Annandale, 1913	0
264. *Uraeotyphlus narayani* Seshachar, 1939	0
265. *Uraeotyphlus oxyurus* (Duméril & Bibron, 1841)	6 (Wilkinson, 1992: I)

tadpoles (although tadpoles of an unspecified species of this family were reportedly collected by Malhotra et al., 1987). Not surprisingly, the highest level of description in the categories used here are those that are widely distributed /human commensal species (e.g., *Duttaphrynus melanostictus*, *Fejervarya limnocharis, Microhyla ornata* and *Polypedates leucomystax*). Tadpoles of species restricted to known hotspots, such as the Western Ghats and the Eastern Himalayas, remain poorly known, especially since spectacular discoveries have been made in the recent past from these regions (see, for instance, Biju and Bossuyt, 2003). Thus, rainforest amphibian larvae are poorly known relative to those from other habitats. Data on Indian amphibian eggs are even more sparse. Khan (1982b) provided a key to the identity of eggs of amphibian from the plains of Pakistan.

Larval stages of frogs being decoupled from adults (McDiarmid and Altig, 1999; Altig, 2006), reliable matching tadpoles to their parent species has been a challenge. Some workers have reared tadpoles to metamorphosis for species identification (although features used for identification of adults are not necessarily present in metamorphs). Others have assumed species identities of tadpoles on the basis of presence of adult frogs in syntopy at the time of collection, although parent species may not be present at the time of collection of their larval stages. Both techniques can thus lead to potentially misleading conclusions on larval identities. The introduction of PCR to mitochondrial DNA sequences (see Blaxter, 2004; amphibian examples in Vences et al., 2005) provides opportunities for unequivocal identification of tadpoles by matching gene sequences to those of adults. It is arguably the most accurate method available for reliable allocation of larval forms to their parent species. Additionally, good colour images and descriptions of the larval stages that capture diagnostic features need to be made, plus the permanent storage of a voucher series.

ACKNOWLEDGEMENTS

We dedicated this review to Nelson Annandale, founder of the Zoological Survey of India, and pioneering zoologist and limnologist in India, and C. R. Narayan Rao, Professor of Mysore

University, who conducted early researches on Indian tadpoles and prepared the first bibliography (Annandale and Rao, 1918). The Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak and North Orissa University supported our researches on the herpetology of Asia, and we thank Aaron Bauer, Kaushik Deuti, Genevieve V. A. Gee, Alexander Haas, Roopa Hooroo, Muhammad Sharif Khan, Sanjay Molur, Jiang Jiang-Pe, Tzi Ming Leong, Sanjay Molur and Olivier S. G. Pauwels, for literature, translations, information and comments.

LITERATURE CITED

ABDULALI, H. 1962. An account of a trip to the Barpede Cave, Talewadi, Belgaum District, Mysore State, with some notes on reptiles and amphibians. The Journal of the Bombay Natural History Society 59(1):228–237.

AGARWAL, S. K. & I. A. NIAZI. 1977. Normal table of developmental stages of the Indian bull frog *Rana tigrina* Daud. (Ranidae, Anura, Amphibia) The Proceedings of the National Academy of Sciences, India B2 47:79–92.

_____ & _____. 1980. Development of mouthparts in the tadpoles of *Rana tigrina* Daud. The Proceedings of the Indian Academy of Sciences (Animal Sciences) 89(2):127–132.

AHL, E. 1931. Anura III. Polypedatidae. Das Tierreich 55. Walter de Gruyter and Co., Berlin. XVI + 477 pp.

ALCALA, A. C. 1962. Breeding behavior and early development of frogs of Negros, Philippines Islands. Copeia 1962:679–726.

_____ & W. C. BROWN. 1956. Early history of two Philippine frogs with notes on deposition of eggs. Herpetologica 12:241–246.

ALTIG, R. 2006. Tadpoles evolved and frogs are the default. Herpetologica 62(1):1–10.

ANDERS, C. 2002. Class Amphibia (Amphibians). In: Amphibians and reptiles of Nepal. Biology, Systematics, Field guide. pp:133–348. H.-H. Schleich & W. Kästle (Eds). Koeltz Scientific Books, Koenigstein.

_____, H. H. SCHLEICH & K. B. SHAH. 1998. Studies on *Tylototriton verrucosus* (Amphibia: Urodela). Contributions to the biology of *Tylototriton verrucosus* Anderson, 1871 from East Nepal (Amphibia: Caudata, Salamandridae). In: Contributions to the herpetology of South Asia (Nepal, India). pp:1–26. H. H. Schleich & W. Kästle (Eds). Veröffentlichungen aus dem Fuhlrott-Museum, Volume 4. Wuppertal.

ANDERSSON, L. G. 1938. Batrachians from Burma collected by Dr. R. Malaise and from Bolivia and Ecuador collected by Dr. C. Hammarlund. Arkiv für Zoologi uitgivet av K. Svenska Vetenskapsakademien 30A(23):1–11.

ANNANDALE, N. 1905. On abnormal ranid larvae from north-eastern India. Proceedings of the Zoological Society of London 1:58–61; Pl. VI.

_____. 1906. Notes on the freshwater fauna of India. No. 8. Some Himalayan tadpoles. Journal of the Asiatic Society of Bengal, new series 2(7):289–292.

_____. 1908. Description of the tadpole of *Rana pleskii*, with notes on allied forms. Records of the Indian Museum 1(4):345–346.

_____. 1912. Batrachia. Zoological results of the Abor Expedition, 1911–12. Records of the Indian Museum 8(1):7–36; captions, Plates I–IV.

_____. 1913. Some new and interesting Batrachia and lizards from India, Ceylon and Borneo. Records of the Indian Museum 9:301–307; captions; Plate XV.

_____. 1917a. The occurrence of *Rana pleskii*, Günther, in Kashmir. Records of the Indian Museum 13(6):417–418.

_____. 1917b. Zoological results of a tour in the Far East. Batrachia. Memoirs of the Asiatic Society of Bengal 6:119–155; Pl. V–VI.

_____. 1918. Some undescribed tadpoles from the hills of southern India. Records of the Indian Museum 15(1):17–23; captions, Plate I; 1 pp. (erratum.)

_____. 1919. The tadpoles of *Nyctibatrachus pygmaeus* and *Ixalus variabilis*: a correction. Records of the Indian Museum 16(4):302.

_____ & S. L. HORA. 1922. Parallel evolution in the fish and tadpoles of mountain torrents. Records of the Indian Museum 24(4):505–510.

_____ & C. R. N. RAO. "1916": 1917. Indian tadpoles. Proceedings of the Asiatic Society of Bengal 1916: clxxxv, clxxxvi.

_____ & _____. 1918. The tadpoles of the families

Ranidae and Bufonidae found in the plains of India. Records of the Indian Museum 15(1):25–40; captions; Plate I.

AO, M. & S. BORDOLOI. 2001. Development of *Hyla annectans* Jerdon, 1870 from Nagaland, India. The Journal of the Bombay Natural History Society 98(2):169–178; Plates 1–4.

____ **& M. K. KHARE. 1986.** Diagnostic features of *Hyla annectans* Jerdon tadpoles (Anura: Hylidae). Asian Journal of Experimental Science 1:30–36.

BAHIR, M., M. MEEGASKUMBURA, K. MANAMENDRA-ARACHCHI, C. J. SCHNEIDER & R. PETHIYAGODA. 2005. Reproduction and terrestrial direct development in Sri Lankan shrub frogs (Ranidae: Rhacophorinae: *Philautus*). The Raffles Bulletin of Zoology Supplement 12:339–350.

BALAKRISHNA, T. A., K. R. GUNDAPPA & K. SHAKUNTALA. 1983. Observations on the eggs and embryo of *Ichthyophis malabarensis* (Taylor) (Apoda: Amphibia). Current Science 52(20):990–991.

BERRY, P. Y. 1972. Undescribed and little known tadpoles from West Malaysia. Herpetologica 28:338–346.

BHADURI, J. L. 1935. The anatomy of the adhesive apparatus in the tadpoles of *Rana afghana* Günther, with special reference to the adaptive modifications. Transactions of the Royal Society of Edinburgh 58(2):339–349; 1 pl.

____**. 1944a.** A note on *Rana crassa* Jerdon, with extension of its range. The Journal of the Bombay Natural History Society 44(3):481–484.

____**. 1944b.** Further locality records of *Rana hexadactyla* Lesson in Bengal, with brief notes on its tadpoles. The Journal of the Bombay Natural History Society 44(3):484–485.

____**. 1944c.** On two salientian tadpoles, *Rana blanfordii* Boulenger and *Bufo himalayanus* Günther, from the Ha Valley, Bhutan, Eastern Himalayas. The Journal of the Royal Asiatic Society of Bengal 10(6):53–57.

____ **& J. C. DANIEL. 1956.** The tadpoles of *Uperodon globulosum* (Günth.). The Journal of the Bombay Natural History Society 53(4):713–716.

____ **& M. B. KRIPALANI. 1954.** *Nyctibatrachus humayuni*, a new frog from the Western Ghats, Bombay. The Journal of the Bombay Natural History Society 52:852–859.

BHATI, D. P. S. 1969. Normal stages in the development of the larvae of *Rana tigrina,* Daud. and *Bufo andersonii* Bouleng. Agra University Journal of Research (Science) 18(1):1–13.

BIJU, S. D. & F. BOSSUYT. 2003. New frog family from India reveals an ancient biogeographical link with the Seychelles. Nature, London 425:711–714.

BLAXTER, M. L. 2004. The promise of a DNA taxonomy. Philosophical Transactions of the Royal Society of London B, 359:669–679.

BORDOLOI, S., M. M. BORAH, P. CHAKRAVORTY & B. SINHA. 2001. First record of the ranid frog *Paa annandalii* (Boulenger 1920) from north-eastern region (Arunachal Pradesh) of India with a note on its larval stages. Current Science 80(9):1219–1222.

BOSSUYT, F. & A. DUBOIS. 2001. A review of the frog genus *Philautus* Gistel, 1848 (Amphibia, Anura, Ranidae, Rhacophorinae). Zeylanica 6(1):1–112.

BOULENGER, G. A. 1882. Catalogue of the Batrachia Salientia s. Ecaudata in the collection of the British Museum. Taylor and Francis, London. xvi + 503 pp + PL. I–XXX.

____**. 1912.** A vertebrate fauna of the Malay Peninsula from the Isthmus of Kra to Singapore including the adjacent islands. Reptilia and Batrachia. Taylor and Francis, London. xiii + 294 pp.

____**. 1920a.** A monograph of the south Asian, Papuan, Melanesian and Australian frogs of the genus *Rana*. Records of the Indian Museum 20:1–226.

____**. 1920b.** Observations sur un batracien urodele d'Asie, *Tylototriton verrucosus* Anderson. Bulletin de la Societe Zoologique de France 45:98–99.

BOURRET, R. 1942a. Comment determiner un Batracien d'Indochine. Publications de l'Instruction Publique en Indochine. 56 pp.

____**. 1942b.** Les batraciens de l'Indochine. Mémoires de l'Institut Océanographique de l'Indochine, Hanoi. 547 pp; Pl. I–IV.

CHACKO, T. 1965. The development and metamorphosis of the hyobranchial skeleton in *Rana tigerina* the Indian bull frog. Acta Zoologica, Stockholm 46:311–328.

CHAN-ARD, T. 2003. A photographic guide to amphibians of Thailand. Kriangkrai Suwannapak, Bangkok. 176 pp.

CHANDA, S. K. 2002. Hand book. Indian amphibians. Zoological Survey of India, Kolkata. (vi) + 274 pp.; Pl. I–LXI.

_____ **& S. K. TALUKDAR. 1973.** Preliminary observations on the foam nest and early development of a frog of *Rhacophorus* sp. (Amphibia: Rhacophoridae). Journal of the Assam Science Society 16(2):208–209.

CHARI, V. K. 1962. A description of the hitherto undescribed tadpole of, and some field notes on the fungoid frog, *Rana malabarica* Bibron. The Journal of the Bombay Natural History Society 59(1):1 plate; 71–76.

_____ **& J. C. DANIEL. 1952.** The tadpole of *Rana leithii* Boulenger. The Journal of the Bombay Natural History Society 51:512–514; 1 pl.

CHOU, W.-H. & J.-Y. LIN. 1997. Tadpoles of Taiwan. Special Publication, National Museum of Taiwan (7):iv + 98 pp.

DANIEL, J. C. 1962. Notes on some amphibians of the Darjeeling area, West Bengal. The Journal of the Bombay Natural History Society 59(2):666–668; Plates I–IV.

_____. **1963a.** Field guide to the amphibians of Western Ghats. Part 1. The Journal of the Bombay Natural History Society 60:415–438.

_____. **1963b.** Field guide to the amphibians of Western Ghats. Part 2. The Journal of the Bombay Natural History Society 60:690–702.

_____. **1975.** Field guide to the amphibians of Western Ghats. Part 3. The Journal of the Bombay Natural History Society 72(2):506–522.

_____. **2002.** The book of Indian reptiles and amphibians. Bombay Natural History Society / Oxford University Press, Mumbai, Delhi, Calcutta and Chennai. viii + 238 pp.

_____ **& A. G. SEKAR. 1989.** Field guide to the amphibians of Western Ghats. Part 4. The Journal of the Bombay Natural History Society 86(2):194–202; Plates I–II.

DANIELS, R. J. R. 1992. Geographical range and ecology of the verrucose frog *Rana keralensis* (Dubois). The Journal of the Bombay Natural History Society 89(2):199–203.

_____. **2005.** India– a lifescape. Amphibians of Peninsular India. Indian Academy of Sciences, Universities Press, Hyderabad. xii + 268 pp.; 60 pl.

DAS, I. 1994. The internal oral morphology of some anuran larvae from south India: a scanning electron microscopic study. Amphibia–Reptilia 15:249–256.

_____. **1998.** A remarkable new species of ranid (Anura: Ranidae) with phytotelmonous larvae, from Mount Harriet, Andaman Islands. Hamadryad 23(1):41–49.

_____ **& A. HAAS. 2005.** Sources of larval identities for amphibians from Borneo. Herpetological Review 36(4):375–382.

_____ **& K. KUNTE. 2005.** New species of *Nyctibatrachus* (Anura: Ranidae) from Castle Rock, Karnataka State, Southwest India. Journal of Herpetology 39(3):465–470.

DAS, S. 1996. Morphometric, growth and development of *Tomopterna rolandae* (Anura: Ranidae). Zoos' Print 11(8):42–43.

_____ **& S. K. DUTTA. 1996.** Population dynamics and growth in captivity and natural population of *Tomopterna rolandae* (Anura: Ranidae). Zoos' Print 11(8):16–21.

DASGUPTA, R. 1988. The young of the Himalayan newt. Journal of the Bengal Natural History Society 7(1):3–18.

DEI, C., P. K. MISRA & M. C. DASH. 1994. Larval stages, growth and metamorphosis of *Microhyla ornata* (Dum. & Bibr.). Journal of Freshwater Biology 6(3):269–273.

DEUTI, K. & B. C. BHARATI GOSWAMI. 1995. A field-guide to the amphibians of West Bengal plains. World Wide Fund for Nature– India, Calcutta. (10 +) 53 pp.

DEY, M. & A. GUPTA. 2002. A note on morphometry of tadpole and adult of *Microhyla ornata* (Duméril & Bibron) (Anura: Microhylidae). Zoos' Print Journal 17(12):951–93.

DONG, Y.-W. 1991a. *Rana limnocharis* Boie. In: The amphibiam (sic) and reptilian fauna of Anhui. pp:97–102. B. Chen (Ed). Anhui Publishing House of Science and Technology, Hefei.

_____. **1991b.** *Microhyla heymonsi* Vogt. In: The amphibiam (sic) and reptilian fauna of Anhui. pp:150–153. B. Chen (Ed). Anhui Publishing House of Science and Technology, Hefei.

DRING, J. C. M. 1979. Amphibians and reptiles from northern Trengganu, Malaysia, with descriptions of two new geckos: *Cnemaspis* and *Cyrtodactylus*. Bulletin of the British Museum (Natural History) Zoological Series 34(5):181–241.

DUBOIS, A. 1974. Liste commentée d'Amphibiens récoltés au Népal. Bulletin du Muséum National d'Histoire Naturelle 3e série (213) Zoologie (143):341–411.

_____. **1976.** Les grenouilles du sous-genre *Paa* du Népal famille Ranidae, genre *Rana*. Cahiers Népalais Documents 6. Editions du Centre National de la Recherche Scientifique, Paris. vi + 275 pp.

_____. **1985.** Diagnose préliminaire d'un nouveau genre de Ranoidea (Amphibiens, Anoures) du sud de l'Inde. Alytes 4(3):113–118.

_____. **1986.** Miscellanea taxinomica batrachologica (I). Alytes 5:7–95.

_____. **1992.** Notes sur la classification des Ranidae (Amphibiens Anoures). Alytes 61(10):305–352.

_____ **& M. S. KHAN. 1979.** A new species of frog (genus *Rana*, subgenus *Paa*) from northern Pakistan (Amphibia, Anura). Journal of Herpetology 13(4):403–410.

_____ **& M. MATSUI. 1983.** A new species of frog (genus *Rana*, subgenus *Paa*) from western Nepal (Amphibia: Anura). Copeia 1983(4):895–901.

_____**, A. OHLER & S. D. BIJU. 2001.** A new genus and species of Ranidae (Amphibia, Anura) from south-western India. Alytes 19(2–4):53–79.

DUTTA, S. K. 1997. A new species of *Limnonectes* (Anura: Ranidae) from Orissa, India. Hamadryad 22(1):1–8.

_____**, S. JENA & P. MOHANTY-HEJMADI. 1994.** Breeding and development of *Ramanella variegata* (Anura: Microhylidae). The Journal of the Zoological Society of India 42–43:55–76.

_____**, S. MISHRA & S. RATH. 2001.** Breeding and development of *Polypedates maculatus* (Anura: Rhacophoridae). Pranikee, Journal of Zoological Society of Orissa Special Volume:121–134.

_____ **& P. M. MOHANTY-HEJMADI. 1976.** Breeding and life history of the Indian bull frog, *Rana tigrina* (Daudin). Prakruti, Utkal University Journal of Science 13(1&2):51–59.

_____ **&** _____. **1984.** Ontogeny of teeth row structure in *Rana tigrina* tadpole. The Journal of the Bombay Natural History Society 80(3):517–528.

DUTTA, S. K., P. MOHAPATRA & P. MOHANTY-HEJMADI. 1993. Breeding and development of *Rana crassa* (Anura: Ranidae). Herpeton 5&6:3–7.

_____**, K. VASUDEVAN, M. S. CHAITRA, K. SHANKAR & R. K. AGGARWAL. 2004.** Jurassic frogs and the evolution of amphibian endemism in the Western Ghats. Current Science 86(1):211–216.

EXBRAYAT, J.-M., G. BHATTA, J. ESTABEL & R. PALLOT. 1999. First observations on embryonic development of *Ichthyophis beddomei*, an oviparous gymnophionan Amphibia. In: Current studies in herpetology. Proceedings of the 9th Ordinary General Meeting of the Societas Europaea Herpetologica, 25–29 August 1998, Le Bourget du Lac, France. pp:113–120. C. Miaud & R. Guyetant (Eds). Societé Herpétologique de France, Le Bourget du Lac.

FEI, L. 1977. A survey of amphibians in Xizang (Tibet). Acta Zoologica Sinica 23(1):54–63; Plates I–II. (In Chinese and English.)

_____ **& C.-Y. YE. 2001a.** The colour handbook of the amphibians of Sichuan. Chengdu Institute of Biology, Chengdu. xvi + 263 pp.

_____ **&** _____. **2001b.** The colour handbook of the amphibians of China. Chengdu Institute of Biology, Chengdu. ii + 412 pp.

FEI, L., C.-Y. YE, Y.-Z. HUANG & M.-Y. LIU. (ED). 1999. Atlas of amphibians of China. China Wildlife Protection Association, Henan Publishing House of Science and Technology, Zhengzhou, Henan. (2) + 432 pp. [in Chinese.]

_____, _____**, J. JIANG & F. XIE. 2005.** An illustrated key to Chinese amphibians. Sichuan Publishing Group, Sichuan Publishing House of Science and Technology, Chengdu. 5 + 340 pp + Plates I–XII.

FERGUSON, H. S. 1904. A list of Travancore batrachians. The Journal of the Bombay Natural History Society 15:499–509.

FERRIER, V. 1974. Chronologie du développement de l'amphibien urodèle *Tylototriton verrucosus* Anderson (Salamandridae). Annals D.

Embryologie et de Morphogénèse 7:407–416.

FLOWER, S. S. 1899. Notes on a second collection of batrachians made in the Malay Peninsula and Siam, from November 1896 to September 1898, with a list of the species recorded from those countries. Proceedings of the Zoological Society of London 1899:885916; Pl. LIXLX.

FROST, D. R., T. GRANT, J. FAIVOVICH, R. H. BAIN, A. HAAS, C. F. B. HADDAD, R. O. DE SÁ, A. CHANNING, M. WILKINSON, S. C. DONNELLAN, C. J. RAXWORTHY, J. A. CAMPBELL, B. L. BLOTTO, P. MOLER, R. C. DREWES, R. A. NUSSBAUM, J. D. LYNCH, D. M. GREEN & W. C. WHEELER. 2006. The amphibian tree of life. Bulletin of the American Museum of Natural History (297):1–370.

GEORGE, S., K. HARI KRISHNAN, G. VARGHESE, S. SHYAM KUMAR, S. THOMAS & N. K. ARJUNAN. 1996. A note on the captive rearing of *Rhacophorus malabaricus*. Zoos' Print 11(8):36–37.

GOSNER, K. L. 1960. A simplified table for staging anuran embryos and larvae, with notes on identification. Herpetologica 16:183–190.

GROSJEAN, S., M. VENCES & A. DUBOIS. 2004. Evolutionary significance of oral morphology in the carnivorous tadpoles of tiger frogs, genus *Hoplobatrachus* (Ranidae). The Biological Journal of the Linnean Society 81:171–181.

____, M. PÉREZ & A. OHLER. 2003. Morphology and buccopharyngeal anatomy of the tadpole of *Rana* (*Nasirana*) *alticola* (Anura: Ranidae). The Raffles Bulletin of Zoology 51(1):101–107.

GUPTA, B. K. 1998. Captive care of common Indian frogs and toads. Coimbatore Zoological Park and Conservation Centre, Anaikatty. iv + 28 pp.

GURURAJA, K. V. & T. V. RAMACHANDRA. 2006. Developmental mode in white-nosed shrub frog *Philautus* cf. *leucorhinus*. Current Science 90(3):450–454.

HAAS, A. & I. DAS. 2007. Larval identities of *Ansonia hanitschi* Inger, 1960 (Amphibia: Bufonidae) and *Polypedates colletti* (Boulenger, 1890) (Amphibia: Rhacophoridae) from East Malaysia (Borneo). Salamandra. in press.

____, S. HERTWEG & I. DAS. 2006. Extreme tadpoles: the morphology of the fossorial megophryid larva, *Leptobrachella mjobergi*. Zoology 109(1):26–42.

HEYER, W. R. 1971. Descriptions of some tadpoles from Thailand. Fieldiana Zoology 58(7):83–91.

HIRAGOND, N. C. & S. K. SAIDAPUR. 1999. Description of tadpole of *Rana temporalis* from south India. Current Science 76(3):443–444.

____, B. A. SHANBHAG & S. K. SAIDAPUR. 2001. Description of the tadpole of a stream breeding frog, *Rana curtipes*. Journal of Herpetology 35(1):166–168.

HORA, S. L. 1922. Some observations on the oral apparatus of the tadpoles of *Megalophrys parva* Boulenger. Proceedings of the Asiatic Society of Bengal, new series 17(1):9–15.

____. 1932. Development and probable evolution of the suctorial disc in the tadpoles of *Rana afghana* Günther. Transactions of the Royal Society of Edinburgh, Part II 57:469–472.

HU, S.-C. & F.-H. YANG. 1960. Preliminary survey of amphibians in Mt. Jinfo, southern Sichuan. Chinese Journal of Zoology, Peking 4(6):256–263.

IANGRAI, A., R. N. K. HOOROO, B. B. P. GUPTA & K. CHATTERJEE. 2004. Changes in the teeth rows structure of the tadpoles of *Polypedates leucomystax* with reference to food and feeding habits. Uttar Pradesh Journal of Zoology 24(2):143–146.

INGER, R. F. 1956. Some amphibians from the lowlands of North Borneo. Fieldiana Zoology 34:389–424.

____. 1966. The systematics and zoogeography of the Amphibia of Borneo. Fieldiana Zoology 52:1–402.

____. 1985. Tadpoles of forested regions of Borneo. Fieldiana Zoology 26:1–89.

____. 1996. Commentary on a proposed classification of the family Ranidae. Herpetologica 52(2):241–246.

____, H. B. SHAFFER, M. KOSHY & R. BAKDE. 1984. A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, south India. The Journal of the Bombay Natural History Society 81(2):406–427; Plates I–III.

____, ____, ____ & ____. "1984" 1985. A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, south India. The Journal of the Bombay Natural History Society 81(3):551–570; Plates IV–VIII.

_____, **R. B. STUEBING & B. L. STUART. 2006.** The tadpole of *Rana glandulosa* Boulenger (Anura: Ranidae). The Raffles Bulletin of Zoology 54(2):465–467.

INTHARA, C., V. LAUHACHINDA, J. NABHITABHATA, Y. CHUAYNKERN & P. KUMTONG. 2005. Mouth part structures and distribution of some tadpoles from Thailand. The Thailand Natural History Museum Journal 1(1):55–78.

ISKANDAR, D. T. 1998. Amfibi Jawa dan Bali. Puslitbang Biologi– LIPI and GEF– Biodiversity Collections Project, Bogor. xviii + 117 pp; 26 pl. English edition, 1998. The amphibians of Java and Bali. Research and Development Centre for Biology– LIPI and GEF– Biodiversity Collections Project, Bogor. xix + 117 pp; 26 pl.

JAMES, J., T. V. VALAMPARAMPIL & O. V. OOMMEN. 2000. Studies on the development of the labial teeth row structure in *Rana curtipes* Jerdon tadpoles. The Journal of the Bombay Natural History Society 97(2):223–229; Plate 1.

JHA, A. & K. THAPA. 2002. Reptiles and amphibians of Sikkim. Mrs. Shila Jha, Raipur. (4) + 100 pp.

VAN KAMPEN, P. N. 1907. Amphibien des indischen Archipels. In: Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien, herausgegeben von Dr. Max Weber 4(2):383–417; Pl. 16. E. J. Brill, Leiden.

_____. **1910.** Beiträg zur Kenntnis der Amphibienlarven des Indischen Archipels. Natuurkundig Tijdschrift voor Nederlandsch Indie 69:25–48; Pl. II.

_____. **1923.** The Amphibia of the Indo-Australian Archipelago. E. J. Brill, Leiden. xii + 304 pp.

KARSEN, S. J., M. W.-N. LAU & A. BOGADEK. 1998. Hong Kong amphibians and reptiles. Provisional Urban Council, Hong Kong. (4) + 186 pp.

KEHIMKAR, I. 1982. The frogs. A closer look. Sanctuary Asia 2(4):350–359.

KHAN, I., S. K. DUTTA & P. MOHANTY-HEJMADI. 1979. The life history of the ornate frog, *Microhyla ornata*. Proceedings of the 6th Conference of the Orissa Advancement of Science:9–10.

KHAN, M. S. 1965. A normal table of *Bufo melanostictus*. Biologia, Lahore 11(1):1–39.

_____. **1969.** A normal table of *Rana tigrina* Daudin 1. Early development (Stages 1–27). Pakistan Journal of Science 21(1–2):36–50.

_____. **1982a.** Key for the identification of amphibian tadpoles from the plains of Pakistan. Pakistan Journal of Zoology 14:133–145.

_____. **1982b.** Collection, preservation and identification of amphibian eggs from the plains of Pakistan. Pakistan Journal of Zoology 14:241–243.

_____. **1991.** Morphoanatomical specialization of the buccopharyngeal region of the anuran larvae and its bearing on the mode of larval feeding. Unpublished Ph.D. dissertation, University of the Punjab, Lahore. 99 pp.

_____. **1996a.** Oropharyngeal morphology of tadpole of southern cricket frog *Rana syhadrensis* Annandale, 1919, and its ecological correlates. Pakistan Journal of Zoology 28(2):133–138.

_____. **1996b.** The oropharyngeal morphology and feeding habits of tadpole of tiger frog *Rana tigerina* Daudin. Russian Journal of Herpetology 3(2):163–171.

_____. **1997.** A new subspecies of common skittering frog *Euphlyctis cyanophlyctis* (Schneider, 1799) from Balochistan, Pakistan. Pakistan Journal of Zoology 29(2):107–112.

_____. **1999.** Food particle retrieval in amphibian tadpoles. Zoos' Print Journal 14(5):17–20.

_____. **2000.** Buccopharyngeal morphology and feeding ecology of *Microhyla ornata* tadpoles. Asiatic Herpetological Research 9:130–138.

_____. **2001.** Notes on cranial-ridged toads of Pakistan and description of a new subspecies (Amphibia: Bufonidae). Pakistan Journal of Zoology 33(4):293–298.

_____. **2002.** Riparian tadpoles of Punjab, Pakistan: *Bufo stomaticus* Lütken, 1862. Bulletin of the Chicago Herpetological Society 37(12):216–219.

_____. **2003a.** Morphology of the tadpole of *Microhyla ornata*, with notes on its feeding ecology and breeding habits. Bulletin of the Chicago Herpetological Society 38(3):40–51.

_____. **2003b.** Morphology of riparian tadpoles: *Euphlyctis cyanophlyctis* (Schneider, 1799). Bulletin of the Chicago Herpetological Society 38(5):95–98.

_____. **2003c.** Morphology of the *Limnonectes* tadpole, with notes on its feeding ecology and on the breeding habits of *Limnonectes* frogs in riparian Punjab. Bulletin of the Chicago Herpetological Society 38(9):177–179.

_____. **2003d.** The larval hyobranchial skeleton of five anuran species and its ecological correlates (Amphibia: Anura) / Das larvale Hyobranchialskelett von fünf Anurenarten und seine ökologischen Entsprechungen (Amphibia: Anura). Herpetozoa 16(3/4):133–140.

_____. **2004a.** Frogs of the genus *Paa* Dubois, 1992, of submontane regions of Pakistan. Bulletin of the Chicago Herpetological Society 39(3):45–47.

_____. **2004b.** Riparian tadpoles: *Hoplobatrachus tigerinus* (Daudin, 1802) with notes on breeding habits and feeding ecology. Bulletin of the Chicago Herpetological Society 39(6):101–104.

_____. **2006.** Amphibians and reptiles of Pakistan. Krieger Publishing Company, Malabar, Florida. xvi + 311 pp.

_____ **& S. A. MALIK. 1987.** Buccopharyngeal morphology of tadpole larva of *Rana hazarensis* Dubois and Khan, 1979, and its torrenticole adaptations. Biologia, Lahore 33(1):45–60

_____ **& S. A. MUFTI. 1994a.** Oral disc morphology of amphibian tadpole and its functional correlates. Pakistan Journal of Zoology 26:25–30.

_____ **& _____. 1994b.** Buccopharyngeal specializations of tadpole of *Bufo stomaticus* and its ecological correlates. Pakistan Journal of Zoology 26:285–292.

_____ **& _____. 1995.** Oropharyngeal morphology of detritivorous tadpole of *Rana cyanophlyctis* Schneider, and its ecological correlates. Pakistan Journal of Zoology 27(1):43–49.

KHARE, M. K. & A. K. SAHU. 1984. Diagnostic features of *Rana danieli* (Anura: Ranidae) tadpoles. Amphibia-Reptilia 5:275–280.

KHONGWIR, S., A. IANGRAI & R. N. K. HOOROO. 2003. Development of mouth parts and food choice in the tadpoles of *Rhacophorus maximus*. Uttar Pradesh Journal of Zoology 23(2):101–104.

_____**, D. MARNGAR, D. WANSWETT & R. N. K. HOOROO. 2003.** Effect of low temperature on the metamorphosis of two anuran species *Rhacophorus maximus* and *Limnonectes limnocharis*. Geobios 30:117–120.

KIRTISINGHE, P. 1957. The Amphibia of Ceylon. Privately published, Colombo. xiii + 112 pp.

_____. **1958.** Some hitherto undescribed anuran tadpoles. Ceylon Journal of Science (Biological Science) 1(2):171–176.

KIYASETUO & M. K. KHARE. 1986. Annual breeding cycle and development of *Rhacophorus leucomystax* (Kuhl). In: Studies in herpetology. Proceedings of the European Herpetological Meeting (3rd Ordinary General Meeting of the Societas Europaea Herpetologica, Prague. 1985. pp:417–422. Z. Rocek (Ed). Charles University, Prague.

KRIPALANI, M. 1953a. On two remarkable tadpoles from the Darjeeling District. Everyday Science, Hoshiarpur 2:57–61.

_____. **1953b.** On Indian tadpoles with a suctorial disc. Records of the Indian Museum 50:359–365; caption (1 page); Plate VIII.

_____. **1961.** Zoological results of the Indian Cho-Oyu Expedition (1958) in Nepal. Records of the Zoological Survey of India 59:241–244; captions (= 1 pp); Plate I.

KRISHNAMURTHY, S. V. 1997. Growth pattern in tadpoles of *Nyctibatrachus major* (Boulenger). Herpeton 7:12–13.

_____**, K. V. GURURAJA & A. H. MANJUNATHA REDDY. "2003" 2004.** Direct development in *Philautus glandulosus* (Anura: Rhacophoridae). Herpetological Natural History 9(1):97–102.

KURAMOTO, M. & S. H. JOSHY. 2002. Tadpoles of *Indirana beddomii* (Anura: Ranidae). Hamadryad 27(1):71–77.

LEONG, T.-M. 2002. Status of larval identities among the Peninsular Malaysian Anura. Herpetological Review 33(3):171–174.

_____. **2004.** Larval descriptions of some poorly known tadpoles from Peninsular Malaysia (Amphibia: Anura). The Raffles Bulletin of Zoology 52(2):609–620.

_____. **2005.** Larval systematics of the Peninsular Malaysian Ranidae (Amphibia: Anura). Unpublished Ph. D. dissertation, National University of Singapore, Singapore. ix + 203 pp.

_____ **& L. M. CHOU. 1999.** Larval diversity and development in the Singapore Anura (Amphibia). The Raffles Bulletin of Zoology 47(1):81–137.

_____ **& K. K. P. LIM. 2003.** Herpetofaunal records from Fraser's Hill, Peninsular Malaysia, with larval descriptions of *Limnonectes nitidus* and *Theloderma asperum* (Amphibia: Ranidae and Rhacophoridae). The Raffles Bulletin of Zoology 51(1):123–136.

LIANG, R. 1991. *Polypedates lencomystax* (sic) Gravenhorst. In: The amphibiam (sic) and reptilian fauna of Anhui. pp:145–148. B. Chen (Ed). Anhui Publishing House of Science and Technology, Hefei.

LIM, K. K. P. & F. L. K. LIM. 1992. A guide to the amphibians and reptiles of Singapore. Singapore Science Centre, Singapore. 160 pp.

LIU, C.-C. 1940a. Natural history studies of west China. Amphibia. 1. Adaptations in tadpoles and adults. Peking Natural History Bulletin 15(2):161–174; 2 plates.

____. 1940b. Tadpoles of west China Salientia. The Journal of the West China Border Research Society 12(B):7–62; 4 plates.

____. 1943a. Natural history studies of west China. Amphibia. VI1. Life history of *Rhacophorus leucomystax*. The Journal of the West China Border Research Society 14(B):43–50.

____. 1943b. Natural history studies of west China. Amphibia. VI1I. Life history of *Scutiger sikkimensis* with a discussion of its allied species in China. The Journal of the West China Border Research Society 14(B):51–78; 2 plates.

____. 1950. Amphibians of western China. Fieldiana Zoology 2:1–400; 10 pl.

____. 1959. Preliminary report of Amphibia from southern Yunnan. Acta Zoologica Sinica 11(4):509–533; 5 Plates. (in Chinese.)

LOBO, L. 1961. Some observations on the metamorphosis of the frog *Rana curtipes* Jerdon. Zoologica, New York 46:103–104; Plate I.

MALHOTRA, A., K. DAVIS, T. SCOONES & R. WOODROFFE. 1987. India 87. The final report of the Oxford University Herpetological Expedition to south India. July 1st – August 30th 1987. Privately printed, Oxford. 60 pp.

MALKMUS, R., U. MANTHEY, G. VOGEL, P. HOFFMANN & J. KOSUCH. 2002. Amphibians and reptiles of Mount Kinabalu (North Borneo). Koeltz Scientific Books, Königstein. 424 pp.

MALLICK, P. 1999. Chronology of morphogenesis of different structures of *Uperodon globulosum* Günther tadpoles. Transactions of the Zoological Society of Eastern India 3(2):7–8.

MALLICK, S., S. K. DUTTA & P. MOHANTY-HEJMADI. 1979. Life history of the marbled balloon frog, *Uperodon systoma*. Proceedings of the 6th Conference of the Orissa Association for the Advancement of Science:9(abstract.)

MANAMENDRA-ARACHCHI, K. & R. PETHIYAGODA. 2005. The Sri Lankan shrub-frogs of the genus *Philautus* Gistel, 1848 (Ranidae: Rhacophorinae), with description of 27 new species. The Raffles Bulletin of Zoology Supplement 12:163–303.

MANTHEY, U. & W. GROSSMANN. 1997. Amphibien und Reptilien Südostasiens. Natur und Tier Verlag, Münster. 512 pp.

MATSUI, M. 1979. Amphibians from Sabah I. Systematic and natural history notes. Contributions of the Biology Laboratory, Kyoto University 25(4):303–346.

____, J. NABHITABHATA & S. PANHA. 1999. On *Leptobrachium* from Thailand with a description of a new species (Anura: Pelobatidae). Japanese Journal of Herpetology 18(1):19–29.

McCANN, C. 1932. Notes on Indian batrachians. The Journal of the Bombay Natural History Society 36(1):152–180; Plates II–X.

McDIARMID, R. W. & R. ALTIG. 1999. Tadpoles. The biology of anuran larvae. University of Chicago Press, Chicago. 458 pp.

MEHTA, H. S. 1983. Some observations on the developmental stages of *Rana (Paa) minica* Dubois (Amphibia) at high altitude. In: Proceedings of the Workshop on High Altitude Entomology and Wildlife Ecology. pp:291–298. Zoological Survey of India, Calcutta.

MOHANTY, A. K., S. K. DUTTA & N. SINGH. 1996. Breeding, development and life history of *Limnonectes limnocharis* (Anura: Ranidae). Zoos' Print 11(8):8–14.

MOHANTY-HEJMADI, P. M. & S. K. DUTTA. 1979. Breeding and development of *Rana cyanophlyctis* Schneider. The Journal of the Bombay Natural History Society 76(2):291–296.

____ & ____. 1981. Inter and intraspecific predation by *Rana tigerina* tadpoles. Pranikee, Journal of Zoological Society of Orissa 2:51–55.

____ & ____. "1988" 1989. Life history of the common Indian tree frog *Polypedates maculatus* (Gray, 1834) (Anura: Rhacophoridae). The Journal of the Bombay Natural History Society 85(3):512–517.

_____, _____ **& I. KHAN. 1980.** Life history of Indian frogs III: the ornate frog *Microhyla ornata*. The Journal of the Zoological Society of India 32(1&2):43–47.

_____, _____ **& S. MULLICK. 1979.** Life history of the Indian frogs II. The marbled balloon frog, *Uperodon systoma* Schneider. The Journal of the Zoological Society of India 31(1–2):65–72.

_____, _____ **& S. PARIDA. 1979.** Life history of the Indian frogs I. The burrowing frog, *Rana breviceps* Schneider. The Journal of the Zoological Society of India 31(1&2):29–38.

MYERS, G. S. & A. E. LEVITON. 1962. Generic classification of the high-altitude pelobatid toads of Asia (*Scutiger*, *Aelurophryne*, and *Oreolalax*). Copeia 1962(2):287–291.

NIEDEN, F. 1923. Anura I. Subordo Aglossa und Phaneroglossa, Sectio 1 Arcifera. Das Tierreich 46. Walter de Gruyter and Co., Berlin. X–XII + 584 pp.

_____. **1926.** Anura II. Engystomatidae. Das Tierreich 49. Walter de Gruyter and Co., Berlin. XVI + 110 pp.

NIGAM, H. C. 1978. Lateral line system in the tadpole of the Indian frog *Rana tigrina* (Daud). Current Science 47(14):519–521.

_____. **1984.** The lateral line system in the tadpole of *Bufo melanostictus*. Current Science 53(20):1110–1111.

NUTPHAND, W. 1988. [Khang khok, khang khok, khanf kak, toads *Bufo*] Thai Zoological Magazine (25–36):139–155. (in Thai.)

_____. **2001.** Amphibians of Thailand. Amarin Printing and Publishing Public Co., Ltd., Bangkok. 192 pp.

PADHYE, A. D. & H. V. GHATE. 1989. Preliminary photographic record and description of various developmental stages of the frog *Microhyla ornata* (Duméril and Bibron). Herpeton 2(1):2–7.

PARKER, H. W. 1934. A monograph of the frogs of the family Microhylidae. British Museum (Natural History), London. vi + 208 pp.

PATIL, N. S. & R. D. KANAMADI. 1997. Direct development in the rhacophorid frog, *Philautus variabilis* (Günther). Current Science 73(8):697–701.

PILLAI, R. S. 1978. On *Nyctibatrachus major* Boul. (Ranidae) with a description of its tadpole. Bulletin of the Zoological Survey of India 1(2):135–140.

_____ **& M. S. RAVICHANDRAN. 1999.** Gymnophiona (Amphibia) fauna of India. A taxonomic study. Occasional Papers of the Zoological Survey of India (172):i–vi + 1–117.

_____ **& G. M. YAZDANI. 1973.** *Bufoides*, a new genus for the rock-toad, *Ansonia meghalayana* Yazdani & Chanda, with notes on its ecology and breeding habits. Journal of the Zoological Society of India 25(1&2):65–70.

POPE, C. H. 1931. Notes on amphibians from Fukien, Hainan, and other parts of China. Bulletin of the American Museum of Natural History 61(8):397–611.

RAMASWAMI, L. S. 1932. Some cranial characteristics of Indian Engystomatidae (Anura). Current Science 1(6):167–168.

_____. **1934.** Contributions to our knowledge of the cranial morphology of some ranid genera of frogs.– Part 1. Proceedings of the Indian Academy of Sciences 1B:80–95; Plates VII–XI.

_____. **1947.** Apodous Amphibia of the Eastern Ghats, south India. Current Science 16(1):8–10.

RAO, A. N. 1933. Engystomatid tadpoles. Current Science 1(9):275–276.

RAO, C. R. N. 1914. Larva of *Rana curtipes*, Boul. Records of the Indian Museum 10(4):265–267.

_____. **1915a.** Notes on some south Indian Batrachia. I. The larvae of *Microhyla rubra* and *Rana breviceps*. Records of the Indian Museum 11:31–38.

_____. **1915b.** The larva of *Rhacophorus pleurostictus*, Boul. Records of the Indian Museum 11(4):349–351.

_____. **1917.** On the occurrence of iridocytes in the larva of *Microhyla ornata* Boulenger. Records of the Indian Museum 13:281–292; Plate XI.

_____. **1918.** Notes on the tadpoles of Indian Engystomatidae. Records of the Indian Museum 15(1):41–45.

_____. **1922.** Notes on Batrachia. The Journal of the Bombay Natural History Society 28(1&2):439–447.

_____. **1937.** On some new forms of Batrachia from S. India. The Proceedings of the Indian Academy of Sciences 6(6):387–427.

_____. **1938.** Tadpoles of a genus not recorded from India. Current Science 6(9):455–456.

RAY, P. 1999. Systematic studies on the amphibian fauna of the district Dehradun, Uttar Pradesh, India. Memoirs of the Zoological Survey of India 18(3):(3) + 1–102.

_____ **& R. TILAK. 1994.** Amphibia. In: Fauna of conservation area 5: Rajaji National Park. pp:55–75. A. K. Ghosh (Ed). Zoological Survey of India, Calcutta.

ROONWAL, M. L. & M. B. KRIPALANI. 1961. A new frog, *Philautus cherrapunjiae* (Family: Ranidae) from Assam, India with field observations on its behaviour and metamorphosis. Records of the Indian Museum 59(1–2):325–333.

ROY, D. & M. K. KHARE. 1978. Normal table of development of *Rana limnocharis* Weigmann. The Proceedings of the National Academy of Sciences, India 48(B):5–16.

SAHU, A. K. 1994. Dichotomous key to the tadpoles of twelve anuran species from northeastern India. The Journal of the Bombay Natural History Society 91(3):412–419.

_____ **& M. K. KHARE. 1980.** Field key of the tadpoles of *Rana limnocharis* Wiegmann (Anura: Ranidae). The National Academy of Sciences Letters 3(5):161–164.

_____ **&** _____. **1983.** Field key of *Rana alticola* Annandale (Anura: Ranidae) tadpoles. The Journal of the Bombay Natural History Society 80:144–148.

SAIDAPUR, S. K. 2001. Behavioral ecology of anuran tadpoles: the Indian scenario. The Proceedings of the Indian National Science Academy B67(6):311–322.

SCHIJFSMA, K. 1932. Notes on some tadpoles, toads and frogs from Java. Treubia 14(1):43–72.

SCHMIDT, A. 1978. Erst-Nachzucht des Indischen Ochsenfrosches *Kaloula pulchra* (Amphibia: Salientia: Microhylidae). Salamandra 14(2):49–57.

SEKAR, A. G. 1990a. Observations on the developmental stages of the tadpoles of the Malabar gliding frog *Rhacophorus malabaricus* Jerdon, 1870 (Anura: Rhacophoridae). The Journal of the Bombay Natural History Society 87(2):223–226; Plates 1–3.

_____. **1990b.** Notes on morphometry, ecology, behaviour and food of tadpoles of *Rana curtipes* Jerdon, 1853. The Journal of the Bombay Natural History Society 87(2):312–313.

_____. **1992.** Morphometry, habitat, behaviour and food of the tadpoles of Leith's frog *Rana leithii.* The Journal of the Bombay Natural History Society 89(2):259–261.

SESHACHAR, B. R. 1942. The eggs and embryos of *Gegenophis carnosus* Bedd. Current Science 11(9):439–441.

SHRESTHA, T. K. "1989" 1990. Ecological aspects of the life-history of the Himalayan newt, *Tylototrion verrucosus* (Anderson) with reference to conservation and management. The Journal of the Bombay Natural History Society 86(3):332–338; Plates I–II.

_____. **2001.** Herpetology of Nepal. A study of amphibians and reptiles of trans-Himalayan region of Nepal, India, Pakistan and Bhutan. Bimala Shrestha, Kathmandu. (8) + 280 pp.; 32 pl.

SIEDLECKI, M. 1909. Zur Kenntnis des javanischen Flugfrosches. Biologie Centralblatt 29(22–23):704–737; Pl. VII–X.

SMITH, M. A. 1916a. Description of five tadpoles from Siam. The Journal of the Natural History Society of Siam 2:37–43.

_____. **1916b.** On a collection of reptiles and batrachians from Peninsular Siam. The Journal of the Natural History Society of Siam 2:148–171.

_____. **1916c.** On the frogs of the genus *Oxyglossis*. The Journal of the Natural History Society of Siam 2:172–175; 1 plate.

_____. **1917.** On tadpoles from Siam. The Journal of the Natural History Society of Siam 2(4):261–275; 2 pl.

_____. **1924a.** Descriptions of Indian and Indo-chinese tadpoles. Records of the Indian Museum 21(2):137–143; caption (1 pp); Plate VII.

_____. **1924b.** The tadpole of *Tylototriton verrucosus* Anderson. Records of the Indian Museum 26(4):309–310; caption (1 pp); Plate XX.

_____. **1930.** The Reptilia and Amphibia of the Malay Peninsula from the Isthmus of Kra to Singapore including the adjacent islands.

Bulletin of the Raffles Museum 3:(2) + xviii + 1–149.

SONG, Z.-M. & O. FENG. 1985. Early embryological development in *Scutiger boulengeri*. Acta Herpetologica Sinica, new series, 4(3):181–186. (In Chinese.)

_____, Z.-M., D.-M. HUANG & C. CHENG. 1990. On the development and population age structure of *Scutiger boulengeri* tadpoles. Acta Zoologica Sinica 36(2):187–193. (In Chinese.)

TARKHNISHIVILLI, D. N. 1994. Amphibian communities of the southern Viet Nam: preliminary data. The Journal of the Bengal Natural History Society 13(1):3–62.

TAYLOR, E. H. 1962. The amphibian fauna of Thailand. University of Kansas Science Bulletin 43(8):265–599.

_____. 1968. The caecilians of the world. A taxonomic review. University of Kansas, Lawrence. vii + 848 pp.

TILAK, R. & H. S. MEHTA. 1983. On a collection of amphibians of the Sirmour District (Himachal Pradesh). Research Bulletin (Science) of the Panjab University 34(3–4):157–166.

_____ & P. RAY. 1985. Description of a new species of the sub-genus *Rana* (*Paa*) Dubois from Chakrata Hills, District Dehra Dun, Uttar Pradesh, India (Ranidae, Anura). Zoologischer Anzeiger 215(3/4):231–239.

TING, M. C. 1970. Table of the early development of *Rhacophorus leucomystax* Boie. The Journal of the Singapore National Academy of Sciences 2(2):38–46.

VENCES, M., M. THOMAS, A. VAN DER MEIJDEN, Y. CHIARU & D. R. VIETES, 2005. Comparative performance of the 16S rRNA gene in DNA barcoding of amphibians. Frontiers in Zoology 2(5):1–3.

VILLADOLID, D. & N. DE ROSARIO. 1929. Studies on the development and feeding habits of *Polypedates leucomystax* (Gravenhorst), with a consideration of the ecology of the more common frogs of Los Banõs and vicinity. Philippine Agriculturalist 18:475–503.

WANG, C.-S., S.-H. WU & H.-T. YU. 1989. Notes on *Microhyla inornata* Boulenger (Anura: Microhylidae) in Taiwan. Journal of Herpetology 23(4):342–349.

WANG, Y-Q. 1991. Pelobatidae. In: The amphibiam (sic) and reptilian fauna of Anhui. pp:62–66. B. Chen (Ed). Anhui Publishing House of Science and Technology, Hefei.

WILKINSON, M. 1992. On the life history of the caecilian genus *Uraeotyphlus* (Amphibia: Gymnophiona). Herpetological Journal 2:121–124.

WU, L., Q. DONG & R.-H. XU. 1987. [Amphibian fauna of Guizhou.] Guizhou People's Press, Guiyang. (7) + 4 + 192 pp; 46 plates; 1 folding map. (in Chinese.)

WU, Y.-L. & Y.-C. SUN. 1981. Preliminary observations on early embryonic development of *Rana limnocharis*. Chinese Journal of Zoology, Peking 16(3):28–30; 1 Plate. (in Chinese.)

YANG, D.-T. 1991a. Phylogenetic systematics of the *Amolops* group of ranid frogs of southeast Asia and the Greater Sunda Islands. Fieldiana Zoology new series (63):i–iii + 1–42.

_____. (ED). 1991b. Amphibian-fauna of Yunnan. China Forestry Publ. House, Beijing. (1) + (1) + (3) + iv + 259 pp. (authors are: S.-M. Li, W.-Z. Liu, S.-Q. Lü, B.-L. Wu & D.-T. Yang.)

YANG, Y.-J. 1998. A field guide to the frogs and toads of Taiwan. Society of Nature and Ecological Photography, Taipeh. 143 pp.

YE, C., L. FEI & S.-Q. HU. 1993. Rare and economic amphibians of China. Sichuan Publishing House of Science and Technology, Chengdu. 412 pp.

YE, R.-Q., X.-F. HONG & X.-Z. CHEN. 1986. Early stages of the embryonic development in *Bufo melanostictus*. Acta Herpetologica Sinica, new series 5(3):185–188; 2 plates. (in Chinese.)

ZHANG, J. & D.-J. LIN. 1987. Studies on the embryonic development of *Rana limnocharis*. I. The early development and staging. Acta Herpetologica Sinica, new series 6(3):26–33; 3 Plates. (in Chinese.)

ZIEGLER, T. 2002. Die Amphibien und Reptilien eines Tieflandregenwaldschutzgebietes in Vietnam. Natur und Tier Verlag, Münster. 342 pp.

Received: 21 June 2006.
Accepted: 16 November 2006.

Hamadryad Vol. 31, No. 2, p. 359, 2007.

RECORD OF *RANA CHLORONOTA* (GÜNTHER, 1875) (ANURA: RANIDAE) FROM MIZORAM, NORTH-EASTERN INDIA

Rana chloronota was originally described from Darjeeling, eastern India as *Polypedates chloronotus* Günther, 1875, and previously reported from India (Darjeeling and Assam), China (including Hong Kong), Lao People's Democratic Republic, Myanmar, Thailand and Vietnam (Bain et. al., 2003).

This note reports the occurrence of *Rana chloronota* in a forested area of Mizoram State, north-eastern India. Four adults (two males and two females) of the species were collected from the stream Herhse (23° 58'N; 92° 41'E; ca. 310 m asl) at Kawnpui, Kolasib District, Mizoram. The climate of the area is highly variable: summer is hot (up to 36°C) and wet, with relative humidity of 94%, whereas winter is cold (down to 13°C) and dry (relative humidity 32%). The average air temperature during the time of collection in the months of September 2003 and April 2006 was 23°C. Morphometric measurements were taken using dial caliper and ruler (in mm), the data shown in Table 1. One of the specimens (a male) was deposited at the Zoological Survey of India, Eastern Regional Station, Shillong (V/A/ERS/706) to serve as voucher.

All specimens are green on the dorsum, with a row of large black spots on the middorsum. A prominent white streak is present on both sides of upper jaw. There is glandular fold originating from the posterior corner of eyes to the shoulder, which is followed by a glandule. Tympanum is brown with a clear whitish circular rim. Head is broader than long, much depressed; snout rounded in dorsal view and the interorbital width is close to the diameter of eyes. Limbs have prominent brownish cross bands and the ventral part of the skin is cream-white and smooth.

Table 1. Morphometric measurements (in mm) of adult *Rana chloronota* collected from Kolasib District, Mizoram State, north-eastern India.

Measurements	adult females		adult males	
	min	max	min	max
Snout-vent length	78.46	101.36	46.8	48.81
Head length	23.08	31.32	15.5	16.62
Head width	26.24	35.52	17.66	18.20
Snout length	12.51	18.48	7.28	8.32
Length of tibia	50.52	71.80	31.42	34.6

Fingers are free, their relative length II < I < IV < III. Hind limbs are long, tibiotarsal articulation reaching beyond tip of snout; heels are strongly overlapping when hind limbs are folded at right angles to body; tibia almost five times as long as broad, webbing of feet up to disks, weak lateral fringes on I and V to terminal phalanges, webbing brown. Disks on fingers and toes greatly enlarged with ventral circummarginal grooves. Subarticular tubercles and inner metatarsal tubercle distinct, conical: outer metatarsal tubercle absent; relative length of toes IV > V > III > II > 1.

HTL expresses his thanks to CSIR, New Delhi, for financial assistance. We also thank Raoul H. Bain, Biodiversity Specialist, Center for Biodiversity and Conservation, and Division of Zoology (Herpetology), American Museum of Natural History, for his help in the identification of the specimen.

LITERATURE CITED

BAIN, R. H., A. LATHROP, R. W. MURPHY, N. L. ORLOV & T. C. HO. 2003. Cryptic species of a cascade frog from Southeast Asia: taxonomic revisions and description of six new species. American Museum Novitates 3417:1-60.

GÜNTHER, A. 1875. Third report on the collections of Indian amphibians and reptiles obtained by the British Museum. Proceedings of the Zoological Society of London 1875:567–577; pls. 1xiii-1xvi.

H. T. Lalremsanga[1], Saipari Sailo and R. N. K. Hooroo

Department of Zoology, North Eastern Hill University, Shillong 793 022, Meghalaya, India.

[1] Email: kasto_h@yahoo.co.in

Received: 27 August 2004.
Accepted: 18 May 2006.

Hamadryad Vol. 31, No. 2, pp. 360 – 361, 2007.

DIET AND SIZE RECORDS FOR *CROCODYLUS CATAPHRACTUS* (CROCODYLIDAE) IN SOUTH-WESTERN GABON

In the course of a crocodile survey at Lake Divangui (01°56'28.4"S, 9°59'19.9"E), in the Gamba Complex of Protected Areas (GCPA), Ogooué-Maritime Province, south-western Gabon, in the last week of June 2003, 19 *Crocodylus cataphractus* Cuvier, 1825 were captured, sexed and measured to the nearest cm (Table 1). Tails were checked for the correct number of caudal scutes in order to ensure that they were not truncated (only that of crocodile no. 19 was). Crocodiles were detected at night by spotlight via their eyeshine and captured by pole-snare from a motor boat. No *C. cataphractus* specimen was kept as voucher, but some of these Divangui specimens were illustrated on the front cover of the Crocodile Specialist Group Newsletter 23(1) (Barr, 2004) and in Anonymous (2003).

Sex ratio in our sample was in favour of males (68%). Ratio of tail L/total L in our sample varied for females between 0.40 and 0.47 (mean = 0.44; n = 6) and for males between 0.42 and 0.49 (mean = 0.44; n = 12). Five specimens (# 3, 8, 9, 10 and 11) were randomly selected for stomach flushing using the hose-Heimlich method. Specimens were held no longer than two hours between capture and stomach flushing. Following stomach flushing, specimens were released in the lake. Stomach contents are presented in Table 2.

The frequency of occurrence by prey class are: 100% for Osteichthyes (5/5 stomachs) and 40% for Insecta (2/5 stomachs). Considering the five stomachs as a data set, eight fish specimens and two insect specimens were counted. Fish thus represent 80% of the total number of prey items recorded and insects represent only 0.3% of the total prey mass (see Table 2). Although two insect orders are presently recorded, fish is most likely this species' staple diet. Accidental ingestion of the insects cannot be excluded in any of the two cases (as well as secondary ingestion, via fish stomach contents). Lake Divangui is the only locality in Gabon for which dietry data for *C. cataphractus* were previously documented (Pauwels et al., 2003); only fishes, belonging to at least four species and four families were recorded.

Table 1. Measurements and mass data for 19 *Crocodylus cataphractus* from Lake Divangui, south-western Gabon. Within each sex, specimens are arranged by increasing snout-vent length (SVL).

Crocodile #	Sex	SVL (cm)	Tail L (cm)	Mass (kg)
1	F	20	18	Not recorded
2	F	37	30	0.4
3	F	73	56	6.2
4	F	106	82	17.6
5	F	126	101	35.1
6	F	136	89	37.8
7	M	18	17	Not recorded
8	M	52	41	1.8
9	M	58	46	2.7
10	M	71	58	5.0
11	M	75	60	6.4
12	M	101	79	17.1
13	M	104	79	13.1
14	M	112	91	21.2
15	M	113	87	24.8
16	M	116	91	23.0
17	M	117	84	19.8
18	M	120	97	28.4
19	M	127	>83	28.8

Another observation on the diet of *Crocodylus cataphractus* was made in the GCPA. On 14 June 2003 at about 2100 h, on the Echira River close to its confluence with the Ngové River (near Akaka village), Edward Truter (pers. com.) observed a juvenile specimen lying in shallow water, mouth open, waiting for small alestiid fish to swim into its jaws and then snap.

Table 2. Stomach contents from five *Crocodylus cataphractus* from Lake Divangui, south-western Gabon.

Crocodile #	Stomach contents and content mass (g)
3	Scales and bones of a large fish (5.6)
8	Two small headless fishes (0.1); 2 gastroliths (0.8 & 1.1)
9	Digested remains of two large fishes (17.5)
10	Elytra and remains of one aquatic Coleoptera (0.1); bones of a fish (0.4)
11	Wings and body parts of a dragonfly (Odonata) (< 0.1); digested remains of two large fishes (15.1); a tree leaf (< 0.1) and five gastroliths (< 0.1, 0.1, 0.4, 0.4, 0.5)

No parasitic worms were detected in our Divangui samples. All gastroliths were composed of limonite.

Maximal diameters of the gastroliths found in crocodile # 8 were 10.8 and 13.6 mm. In crocodile # 11, maximal diameter of smallest and largest gastroliths were respectively 5.1 and 11.4 mm. In these two crocodiles, gastroliths represented respectively 0.1% and 0.02% of the crocodile mass. The absence of gastroliths in 60% of our sample, and the extremely small mass of the gastroliths compared to the whole crocodile's mass, indicate that they are unlikely to serve a hydrostatic function.

Global knowledge on the diet of this crocodile species is still poor and was synthesized by Pauwels et al. (2003). Additional data were later added by Eaton and Barr (2005) who recorded catfish (Clariidae) spines, unidentified fish scales and palm nuts in a single specimen's stomach in northern Congo Republic. Although fish obviously represent the main part of its diet, as supported by our new data, Insecta, Crustacea, Amphibia, Reptilia (aquatic snakes), Mammalia and Aves (water fowls) were also occasionally recorded (Pauwels et al., 2003; Waitkuwait, 1985).

We thank E. Truter (Opération Loango) and W.-E. Waitkuwait (Libreville) for useful information. This research was partly supported by the National Geographic Channel, the Smithsonian Institution/Monitoring and Assessment of Biodiversity Program and grants from Shell Foundation and Shell Gabon. This publication is contribution 54 of the Gabon Biodiversity Program. We are grateful to M. E. Lee, F. Dallmeier and A. Alonso (SI/MAB), F. Bangole and F. Denelle (Shell Gabon), and D. Hamlin and B. Harvey (NGC) for working facilities. Research authorizations were kindly provided by A. Sambo (CENAREST, Libreville) and A. Noungou (Direction de la Faune et de la Chasse, Libreville).

LITERATURE CITED

ANONYMOUS. 2003. Croc Chronicles III. Episode 12. Forest Crocs. National Geographic Television & Film, Washington, D.C.

BARR, B. 2004. Brief population survey of *C. cataphractus* in Lake Divangui, southwest Gabon. Crocodile Specialist Group Newsletter 23(1):4–5.

EATON, M. & B. BARR. 2005. Africa. Republic of Congo. Crocodile Specialist Group Newsletter 24(3):18–20.

PAUWELS, O. S. G., V. MAMONEKENE, P. DUMONT, W. R. BRANCH, M. BURGER & S. LAVOUÉ. 2003. Diet records for *Crocodylus cataphractus* (Reptilia: Crocodylidae) at Lake Divangui, Ogooué-Maritime Province, south-western Gabon. Hamadryad 27(2):200–204.

WAITKUWAIT, W.-E. 1985. Contribution à l'étude des crocodiles en Afrique de l'ouest. Nature et Faune 1(1):13–29.

Olivier S. G. Pauwels[1,2], Brady Barr[3] and Mei Len Sanchez[4]

[1]Monitoring and Assessment of Biodiversity Program, National Zoological Park, Smithsonian Institution, Gamba, Gabon

[2]Mail address: Department of Recent Vertebrates, Institut Royal des Sciences Naturelles de Belgique, Rue Vautier 29, 1000 Brussels, Belgium; Email: osgpauwels@yahoo.fr

[3]National Geographic Channel, 1145 17th Street NW, Washington, DC 20036, U.S.A.; Email: bradybarr@aol.com

[4]National Aquarium in Baltimore, 501 E. Pratt Street, Baltimore, Maryland 21202, U.S.A.; Email: meilenS@aol.com

Received: 22 November 2005.
Accepted: 12 May 2006.

Hamadryad Vol. 31, No. 2, pp. 361 – 365, 2007.

HEAD SCALATION IN *NAJA SPUTATRIX* BOIE, 1827– DISCUSSION ON THE PRESENCE OF A SMALL ACCESSORY SCALE

(with seven text-figures)

Cephalic scalation provides helpful characters for snake identification. A small accessory scale separates the preocular from the internasal in *Naja sputatrix*. Typically, scalation of the head

No parasitic worms were detected in our Divangui samples. All gastroliths were composed of limonite.

Maximal diameters of the gastroliths found in crocodile # 8 were 10.8 and 13.6 mm. In crocodile # 11, maximal diameter of smallest and largest gastroliths were respectively 5.1 and 11.4 mm. In these two crocodiles, gastroliths represented respectively 0.1% and 0.02% of the crocodile mass. The absence of gastroliths in 60% of our sample, and the extremely small mass of the gastroliths compared to the whole crocodile's mass, indicate that they are unlikely to serve a hydrostatic function.

Global knowledge on the diet of this crocodile species is still poor and was synthesized by Pauwels et al. (2003). Additional data were later added by Eaton and Barr (2005) who recorded catfish (Clariidae) spines, unidentified fish scales and palm nuts in a single specimen's stomach in northern Congo Republic. Although fish obviously represent the main part of its diet, as supported by our new data, Insecta, Crustacea, Amphibia, Reptilia (aquatic snakes), Mammalia and Aves (water fowls) were also occasionally recorded (Pauwels et al., 2003; Waitkuwait, 1985).

We thank E. Truter (Opération Loango) and W.-E. Waitkuwait (Libreville) for useful information. This research was partly supported by the National Geographic Channel, the Smithsonian Institution/Monitoring and Assessment of Biodiversity Program and grants from Shell Foundation and Shell Gabon. This publication is contribution 54 of the Gabon Biodiversity Program. We are grateful to M. E. Lee, F. Dallmeier and A. Alonso (SI/MAB), F. Bangole and F. Denelle (Shell Gabon), and D. Hamlin and B. Harvey (NGC) for working facilities. Research authorizations were kindly provided by A. Sambo (CENAREST, Libreville) and A. Noungou (Direction de la Faune et de la Chasse, Libreville).

LITERATURE CITED

ANONYMOUS. 2003. Croc Chronicles III. Episode 12. Forest Crocs. National Geographic Television & Film, Washington, D.C.

BARR, B. 2004. Brief population survey of *C. cataphractus* in Lake Divangui, southwest Gabon. Crocodile Specialist Group Newsletter 23(1):4–5.

EATON, M. & B. BARR. 2005. Africa. Republic of Congo. Crocodile Specialist Group Newsletter 24(3):18–20.

PAUWELS, O. S. G., V. MAMONEKENE, P. DUMONT, W. R. BRANCH, M. BURGER & S. LAVOUÉ. 2003. Diet records for *Crocodylus cataphractus* (Reptilia: Crocodylidae) at Lake Divangui, Ogooué-Maritime Province, south-western Gabon. Hamadryad 27(2):200–204.

WAITKUWAIT, W.-E. 1985. Contribution à l'étude des crocodiles en Afrique de l'ouest. Nature et Faune 1(1):13–29.

Olivier S. G. Pauwels[1,2], Brady Barr[3] and Mei Len Sanchez[4]

[1]Monitoring and Assessment of Biodiversity Program, National Zoological Park, Smithsonian Institution, Gamba, Gabon

[2]Mail address: Department of Recent Vertebrates, Institut Royal des Sciences Naturelles de Belgique, Rue Vautier 29, 1000 Brussels, Belgium; Email: osgpauwels@yahoo.fr

[3]National Geographic Channel, 1145 17th Street NW, Washington, DC 20036, U.S.A.; Email: bradybarr@aol.com

[4]National Aquarium in Baltimore, 501 E. Pratt Street, Baltimore, Maryland 21202, U.S.A.; Email: meilenS@aol.com

Received: 22 November 2005.
Accepted: 12 May 2006.

Hamadryad Vol. 31, No. 2, pp. 361 – 365, 2007.

HEAD SCALATION IN *NAJA SPUTATRIX* BOIE, 1827– DISCUSSION ON THE PRESENCE OF A SMALL ACCESSORY SCALE

(with seven text-figures)

Cephalic scalation provides helpful characters for snake identification. A small accessory scale separates the preocular from the internasal in *Naja sputatrix*. Typically, scalation of the head

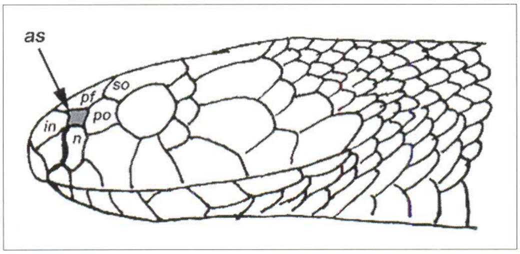

Figure 1. Head scalation of *Naja sputatrix* (MZB Oph 1853) from Sukabumi, West Java showing a small accessory scale (grey shading) directly adjacent to four other scales without touching supraocular (as = accessory scale, po = preocular, so = supraocular, n = nasal, in = internasal and pf = prefrontal)

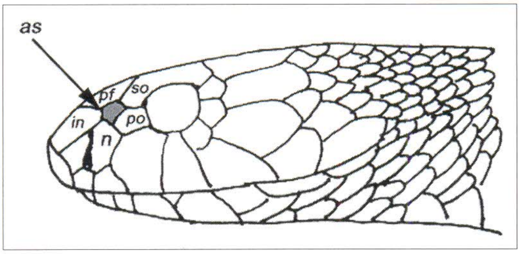

Figure 2. Head scalation of *Naja sputatrix*, showing a small accessory scale (grey shading) directly adjacent to five other scales (as = accessory scale, so = supraocular, po = preocular, n = nasal, in = internasal and pf = prefrontal), all specimens with this pattern are from West Java (e.g. specimen MZB Oph 392, also shows two preoculars on one side) and Sulawesi (MZB Oph 394).

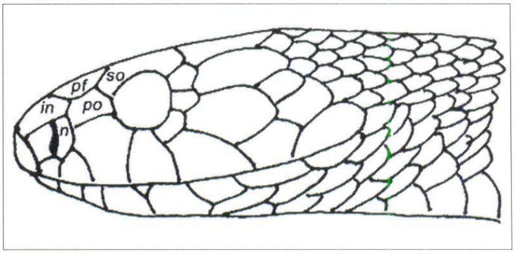

Figure 3. The common head scalation of *Naja sputatrix* from Java and the Lesser Sunda, without a small accessory scale showing separation of prefrontal from nasal caused by the preocular-internasal contact (so = supraocular, po = preocular, n = nasal, in = internasal and pf = prefrontal).

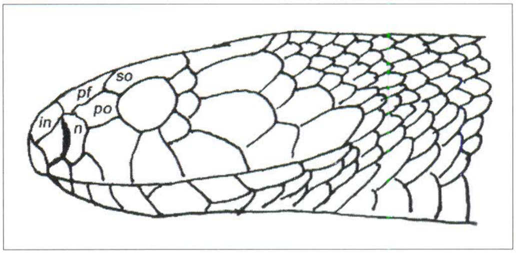

Figure 4. Head scalation of *Naja sputatrix*, showing direct contact of prefrontal and nasal and separation of preocular from internasal (in = internasal, pf = prefontal, po = preocular, so = supraocular).

in this species shows seven upper labials, the 3rd and 4th touching the eye, the 3rd being enlarged and also in contact with the posterior nasal, and lower labials 8, between 4th and 5th there is usually a small triangular scale, the cuneate, on the margins of the mouth (Tweedie, 1983).

Naja sputatrix is a species endemic to Indonesia, found in Java (de Haas, 1941), Bali, Lombok, Alor (Wüster and Thorpe, 1989), Sumbawa, Komodo, Flores (Auffenberg, 1980) and Sulawesi (Kopstein, 1936). Its occurrence in Sulawesi is not confirmed (Wüster, 1996; Wüster in: David and Ineich, 1999). A character of head scalation of *Naja sputatrix* that shows an uncommon condition in all other Asiatic *Naja*, is the lack of contact between the preocular and the internasal. It is caused either by the presence of a small accessory scale or prefrontal-nasal contact (Wüster, 1996).

On the basis of a single specimen of *Naja sputatrix* from Makale, Sulawesi (MZB Oph 394), Kopstein (1936) described a small accessory scale that is smaller than preocular, and located between the internasal, the preocular, the supraocular, the prefrontal and the nasal. The differences between MZB Oph 394 and the Javan *Naja sputatrix* is the fact that in the Sulawesi specimen the internasal is separated from the preocular by a small accessory scale, whereas in the Javan specimens, the two scales are in contact (Kopstein, 1936). On the other hand, Wüster (1996) cited that the lack of contact between these two scales is common in *Naja sputatrix*, both from Java and the Lesser Sunda Islands. In most Javan specimens, the preocular was separated from the internasal by the presence of a small accessory scale, whereas in the specimens from the Lesser Sunda Islands, the separation is more commonly due to a contact between the prefrontal and the nasal (Wüster, 1996).

I examined 54 specimens of *Naja sputatrix* in Museum Zoologicum Bogoriense (MZB), including a single specimen (MZB Oph 394) from Makale–Sulawesi, 38 specimens from Java (west Java = 24, central Java = 2, east Java = 12) and 15 specimens from the Lesser Sunda Islands. The results based on the pattern of head

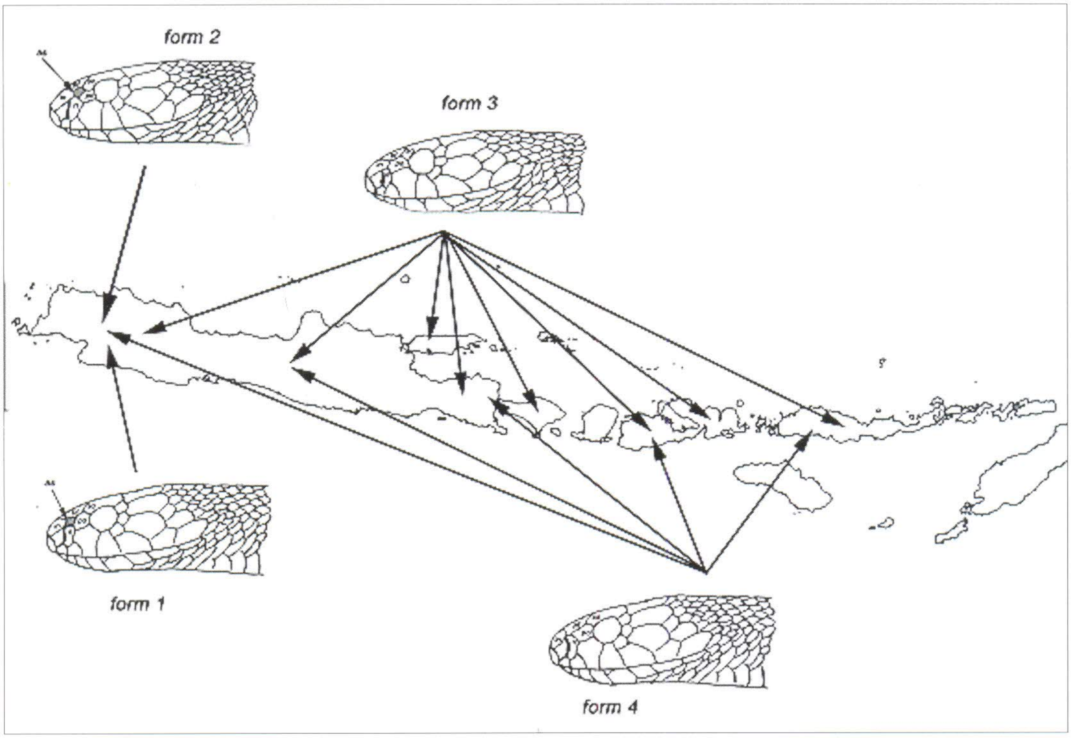

Figure 5. The four patterns of head scalation of *Naja sputatrix* and their distribution.

scalation with or without a small accessory scale revealed four different patterns of head scalation in *Naja sputatrix* that can be described as follows:

1) Pattern 1: a small accessory scale directly adjacent to four other scales (prefrontal, preocular, nasal and internasal).
2) Pattern 2: a small accessory scale directly adjacent to five other scales (supraocular, preocular, prefrontal, internasal and nasal)
3) Pattern 3: without a small accessory scale, the internasal and the preocular are in contact, thus separating prefrontal from nasal.
4) Pattern 4: without a small accessory scale, the internasal is separated from the preocular by a prefrontal-nasal contact.

Four patterns of head scalation in *Naja sputarix* are known, these distributed over many localities both in Java and the Lesser Sunda Islands (Fig. 5). The common characters in the head scalation of *Naja sputatrix* are the lack of a small accessory scale and a preocular-internasal contact (Pattern 3, Fig. 3). Based on the MZB specimens, pattern 3 was found in specimens from West Java, Central Java, East Java, Madura, Bali, Sumbawa, Flores and Rinca. This pattern was distributed in all population of *Naja sputatrix*, both from Java and the Lesser Sunda Islands. Wüster (1996) described Pattern 3 as common scalation of Asiatic cobras as shown in Fig. 6a.

The head scalation pattern (Fig. 6b) is often found in Javan *Naja sputatrix* (Wüster, 1996). The presence of a small accessory scale which, by its position separates the internasal from the preocular and is directly in contact with four other scales (preoccular, prefrontal, internasal and nasal), without contacting supraoccular (Fig. 1 and Fig. 6b) was hitherto unknown in *Naja sputatrix*. However, this pattern was found in a specimen (MZB Oph 1853) from Sukabumi, West Java.

Wüster (1996) considered the separation of the preocular from the internasal by a prefrontal-nasal contact (pattern 4) (Fig. 4) to be common in specimens from the Lesser Sunda, but I found it in only four of 15 specimens from the Lesser Sundas, so it is probably atypical. However, this type of scalation is also seen in specimens from West Java, Central Java and East Java.

A single specimen of *Naja sputatrix* from Makale, Sulawesi (MZB Oph 394) that was re-

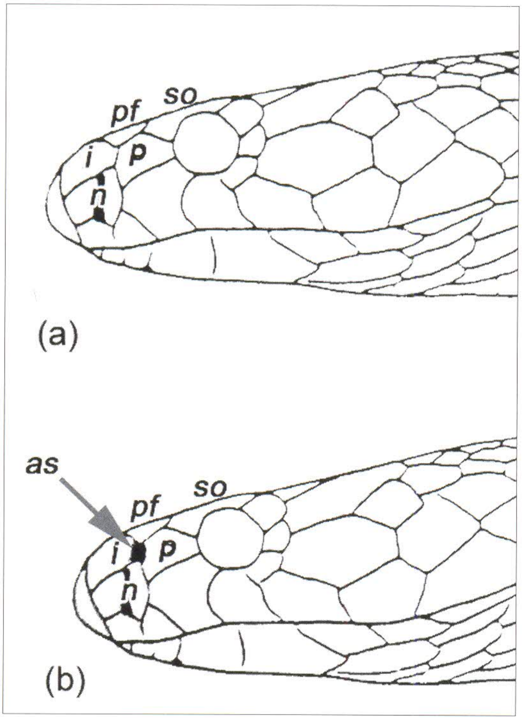

Figure 6. Head scalation of Asiatic cobras. (a) The most common scalation in Asiatic cobras, showing contact between preocular and internasal. (b) Situation often found in Javanese *Naja sputatrix*, preocular and internasal separated by a small accessory scale (in black). It shows position of a small accessory scale that is directly adjacent to four other scales (preocular, internasal, nasal and prefrontal, without contacting supraocular (as = accessory scale, p = preocular, n = nasal, i = internasal, pf = prefrontal, so = supraocular). Modified from Bogert (1943) in Wüster (1996).

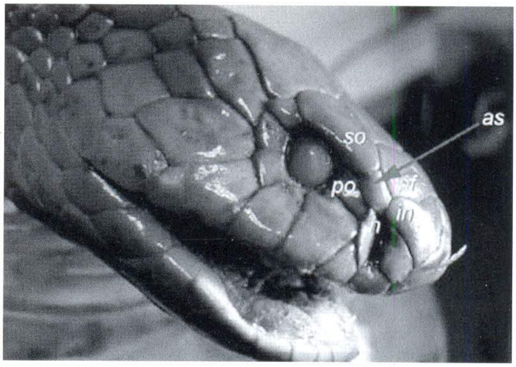

Figure 7. Head scalation of a single specimen of *Naja sputatrix* (MZB Oph 394) from Makale, Sulawesi, showing the position of a small accessory scale directly adjacent to five other scales (as = accessory scale, so = supraocular, po = preocular, n = nasal, in = internasal and pf = prefrontal).

ported by Kopstein (1936) and considered by Wüster (1996) to be indistinguishable from Java specimens, has a small accessory scale separating the internasal from the preocular. This scale is directly adjacent to four other scales (prefrontal, preocular, internasal and nasal) without touching supraocular (Fig. 6b). I reexamined the presence and position of this small accessory scale in this specimen, and it is directly adjacent to five other scales (supraocular, preocular, internasal, prefrontal and nasal), so this small accessory scale is in contact with the supraocular, as shown in Fig. 7.

The accessory scale may also be defined as a loreal scale. The traditional practical definition of a loreal scale is one of several scales between the orbit and the nostril. This term is usually applied to a plate(s) lying between the nasal(s) and preocular(s). In some snakes, a single plate lies between the eye and the nasal ("preocular", if higher than long and "loreal" if longer than high; Peters in: Savage, 1972). Savage (1972) defined loreal as a plate or plates posterior to the nasal or postnasal and anterior to the orbit or preocular that separates the prefrontal from contact with the supralabials; when the loreal is absent (i.e., the suture fails to develop between the loreal and the prefrontal, or they are "fused") the prefrontal contacts one or more supralabial. Preocular is a plate or plates anterior to and bordering the orbit, that separates the prefrontal and/or loreal from orbit. Based on the definition above, the accessory scale in *Naja sputatrix*, is doubtfully defined as a loreal because the preocular is present and directly contacts the postnasal and separates the prefrontal from the supralabials.

A small accessory scale has been recorded only in specimens from west Java (including localities: Bogor, Jakarta, Sukabumi, Salak) and Makale Sulawesi (MZB Oph 394). Based on the multivariate analysis from morphological character of *Naja sputatrix*, Wüster and Thorpe (1989) noted tree groups; 1) the West Java population, 2) The Central & East Java, Bali, Lombok, Sumbawa population, and 3) The Komodo and Flores population. Furthermore, in considering only the presence of the small accessory scale, population from West Java includes all the four patterns described above, while other localities such as Central Java, East Java and the Lesser Sunda Islands belongs to two patterns.

The character of head scalation due to the presence of a small accessory scale is indirectly related to the adaptation process. In contrast, the coloration might be one of the factors that result from adaptation processes. The population in West Java has dominantly a blackish colour, and occupies humid and thick rainforest. In East Java and the Lesser Sunda Islands, some population have brighter colouration (e.g., silvery or brown) and occupies relatively open monsoon forests. The habitat type difference among localities separated by distance suggests a possible process of ecogenesis as current natural selection for environmental condition (Wüster et al., 1995). The current ecological condition in West Java had caused population of *Naja sputarix* to be taxonomically isolated from other localities (Wüster and Thorpe, 1989).

Kopstein (1936) noticed that on the basis of ventral, subcaudal and dorsal scale counts, *Naja sputatrix* from Sulawesi (MZB Oph 394) is morphologically more similar to the *Naja* population of the Lesser Sunda Islands. However, Wüster (1996) reexamined this single specimen (MZB Oph 394) and on the basis of morphological characters, it is indistinguishable from Java specimens. Wüster (1996) suggested that it may not originate from Sulawesi but it is closest to Java population. In this study, based on the presence and position of a small accessory scale (directly adjacent with five other scales: supraoccular, preoccular, internasal, prefrontal and nasal), I concur with Wüster that MZB Oph 394 is morphologically similar with those from West Java.

The populations of *Naja sputatrix* distributed in different localities in Java and the Lesser Sunda have different morphological characters. This information could be the base of more advanced research on the species taxonomy.

I am most grateful to Mrs. Mumpuni, Herpetology Curator, Museum Zoologicum Bogoriense, who allowed me to examine all specimens, M. Irham and Evy Arida for reviewing this note, Wolfgang Wüster for discussions and Daniel L. Tobing for photography.

LITERATURE CITED

AUFFENBERG, W. 1980. The herpetofauna of Komodo, with notes on adjacent areas. Bulletin of the Florida State Museum, Biological Sciences 25(2):39–156.

BOGERT, C. M. 1943. Dentitional phenomena in cobras and other elapids with notes on the adaptive modifications of fangs. Bulletin of the American Museum of Natural History 81(3):285–360; Pl. XLVIII–LI.

DAVID, P. & I. INEICH. 1999. Les serpens venimeux du monde: systematique et repartition. Dumerilia (3):3–499.

DE HAAS, C. P. J. 1941. Some notes on the biology of snakes and their distribution in two districts of West Java. Treubia 18(2):327–375.

KOPSTEIN, F. 1936. Herpetologische Notizen XII–XV. Ein Beiträg zur Herpetofauna Celebes. Treubia 15:255–256.

PETERS, J. 1964. Dictionary of herpetology. A brief and meaningful definition of words and terms used in herpetology. Haffner Publishing Company, New York and London. xii + 392 pp.

SAVAGE, J. M. 1972. A revised terminology for plates in the loreal region of snakes. British Journal of Herpetology 5(1):360–362

TWEEDIE, M. W. F. 1983. The snakes of Malaya. Third edition. Singapore National Printers (Pte) Ltd., Singapore. (iv) + 167 pp.

WÜSTER, W. 1996. The status of the cobras of the genus *Naja* Laurenti, 1768 (Reptilia: Serpentes: Elapidae) on Sulawesi. The Snake 27:85–90.

____ & R. S. THORPE. 1989. Population affinities of Asiatic cobra (*Naja naja*) species complex in south-east Asia: reliability and random resampling. Biological Journal of Linnean Society 36:391–409.

_____, _____, M. J. COX, P. JINTAKUNE & J. NABHITABHATA. 1995. Population sytematics of the snake genus *Naja* (Reptilia: Serpentes: Elapidae) in Indochina: multivariate morphometrics and comparative mitochondrial DNA sequencing (cytochrome oxidase I). Journal of Evolutionary Biology 8:893–510.

Amir Hamidy

Section of Herpetology, Museum Zoologicum Bogoriense, Research Center for Biology, The Indonesian Institute of Sciences, Cibinong, Indonesia.
Email: ahamidy_mzb@yahoo.co.id

Received: 30 August 2005.
Accepted: 29 April 2006.

Hamadryad Vol. 31, No. 2, p. 366, 2007.

OBSERVATIONS ON EGG-LAYING BY *CALOTES ELLIOTI* (GÜNTHER, 1864)

Calotes ellioti Günther, 1864 is a lizard endemic to the southern ranges of the Western Ghats of India, distributed in semi-evergreen and evergreen forests (Smith, 1943; Das, 2002). Existing information on its reproductive biology is limited: between 3–5 eggs, measuring 5 x 12 mm are laid in April (Das, 2002). This short communication presents observations of egg-laying in *C. ellioti,* made in a privately owned vanilla plantation in Candurra Division, Murugalli Estate, Anamalai Hills, Tamil Nadu, bordering Vazhachal Reserve forest in Kerala.

On 9 May 2006 at 1444 h, a female *Calotes elliotti* (SVL 61.6 mm; TL 172.5 mm) was observed digging a pit on barren soil. The pit (2 x 2 cm) was under a tree, 5 m from a path, at 845 m above msl, under contiguous canopy cover. The understorey has been cleared for planting *Erythrina indica*, which supports the vanilla plants. The lizard used both fore- and hind limbs to throw mud out of the pit, which was conical, gently curving downwards and was excavated till 1500 h. Between 1500 and 1504 h, four ovoid eggs, within an interval of ca. 1 min was produced. They were white in colour, leathery and oval, measured 13.3 x 7.75 mm; 12.7 x 7.77 mm; 13.25 x 8.00 mm and 12.45 x 7.15 mm.

The lizard arranged the eggs in the pit, licked them and settled them firmly in place by pounding them with the head. This continued till 1514 h. The lizard positioned its midbody at the centre and covered the pit primarily using the forelimbs to push the soil back into the pit. The soil was rather dry and the eggs were packed together closely, by pounding the mud with the snout. The forelimbs were also used for packing the mud. Once the pit was covered, mud in the area immediately around the nest was packed by scraping and collecting the soil from around the nest, with the jaw. The packing of the nest and the soil around the nest, into a firm neat surface continued till about 1556 h, or over half an hour. The process of egg laying and covering the pit took about 56 min. This included several minutes of rest several times during the process and once it stopped to feed on a passing insect. While I observed pit digging for about 15 min, the exact time taken for digging the pit could not be determined.

Usage of the snout to pack the nest has been reported in *Calotes grandisquamis* by Vijaya (1984). This may be a common method used by agamids for nest packing. *C. calotes* were observed to nest during May–June in Anaikatty Hills (Rathinasabapathy and Gupta, 1997). *C. versicolor* has been observed nesting between April–May (Singh et al., 1984). In *C. ellioti*, nesting continues to the second week of May and some gravid individuals were observed till the end of May. Along with observations of other gravid females and juveniles, this observation also substantiates that the human modified, privately owned vanilla plantation in Anamalai hills support reproducing populations of *C. ellioti.*

These observations were made while working on a project documenting the diversity of reptiles in various plantation types in Anamalai hills, Western Ghats. I thank the management and staff of M/S Parry Agro Industries Limited, Murugalli Estate, for support and Venky Muthiah and Murugappa Trust for funding and other support provided.

LITERATURE CITED

DAS, I. 2002. A photographic guide to snakes and other reptiles of India. New Holland Publishers (UK) Ltd., London. 144 pp.

RATHINASABAPATHY, B. & B. K. GUPTA. 1997. A note on reproduction in *Calotes calotes* at Anaikatty, Western Ghats. Hamadryad 22(2):128–129.

SINGH, L. A. K., L. N. ACHARJYO & H. R. BUSTARD. 1984. Observations of the reproductive biology of the Indian chameleon, *Chamaeleo zeylanicus* (Laurenti). Journal of the Bombay Natural History Society 81:86–92.

SMITH, M. A. 1935. The fauna of British India, including Ceylon and Burma. Reptilia and Amphibia. Vol. II.– Sauria. Taylor and Francis, London. xiii + 440 pp + 1 pl.

VIJAYA, J. 1984. A *Calotes grandisquamis* nest. Hamadryad 9(2):19.

P. Dilip Venugopal

Group for Nature Preservation& Education
(GNAPE), 30, Block II, Gandhi Mandapam Road, Kotturpuram, Chennai 600 085,
India. Email: dilipvenugopal@yahoo.com

Received: 19 September 2006.
Accepted: 18 October 2006.

Hamadryad Vol. 31, No. 2, pp. 367 – 368, 2007.

WRESTLING FOR TERRITORIAL DEFENSE IN *PHILAUTUS ANNANDALII*

(with one text-figure)

Existence of territoriality is generally accepted when animals maintain some sort of spacing and in some manner exclude conspecifics from their immediate proximity (Bunnell, 1973). Spacing in anuran amphibians was first documented in *Rana clamitans* by Martof (1953) and territorial defense has been observed in *Rana catesbeiana* by Emlen (1968) and in the dendrobatid, *Prostherapsis trinitatis* by Sexton (1960). Whereas Emlen (1968) showed that territoriality in *R. catesbeiana* is associated with mating, Sexton (1960) presented evidence that in the dendrobatids, feeding was the primary basis for territoriality. Actual fighting which may be related to territorial defense has also been observed in other dendrobatid species, including *Dendrobates granuliferus* (see Goodman, 1971).

Territorial defense by frogs is accomplished through a continuum of behavioural patterns ranging from acoustic advertisements to overt aggression. Male *Eleutherodactylus coqui* call from exposed perches that are separated in space from their retreat sites. Aggressive behaviour exhibited by males in defense of nests includes calling, biting, blocking and wrestling (Townsend, 1989). Typical aggressive bouts consist of aggressive calling, followed by lunges toward the opponent with forward kicks of the legs and then by more bouts of aggressive calling. Persistent intruders are occasionally bitten during which time both frogs kicked each other with their rear legs (Stewart and Rand, 1991).

The agonistic behaviour exhibited by male *Dendrobates pumilio* in defense of territories was described by Duellman (1966) and Bunnell (1973). Typical interactions begin with distinctive aggressive calls and then escalate into prolonged display and wrestling matches. Display behaviour in this species includes orientation toward the opponent and elevation of the body in a „push up" posture (Duellman, 1966). Males distribute themselves uniformly at an inter-individual spacing of 2–3 m. They detect the intrusion of an aberrant call within at least 3 m of their calling site, as evidenced by changes in the rate and pattern of their own calling. As the distance of the intruding call crosses some threshold between 2–3 m, some degree of advance towards the source of the intruding call is initiated. The intensity of advance increases as the intruder approaches the calling site. The approach and modified calling may result in retreat of the intruder or less frequently result in fighting and wrestling bouts (Bunnell, 1973).

Casual observations were made while photographing *Philautus annandalii* at Mirik (26°53'146"N; 88°11'235"E; 1,408 m asl), Darjeeling District, northern West Bengal, eastern India. On 31 May 2006 at 2100 h, several males were found calling from a single site. One of the males approached another and soon both were entangled in a wrestling bout, which continued for 8 min, until the intruder left the occupant's calling area. About 35 min later, a female entered the occupant male's area and amplexus occurred. Fig. 1 shows aggressive calling and wrestling by two male *P. annandalii*. While fighting for territorial defense was previously known for Neotropical anurans, this appears to be the first record in an Oriental species of anuran amphibian.

LITERATURE CITED

BUNNELL, P. 1973. Vocalizations in the territorial behaviour of the frog, *Dendrobates pumilio.* Copeia 1973:277–284.

DUELLMAN, W. E. 1966. Aggressive behaviour in

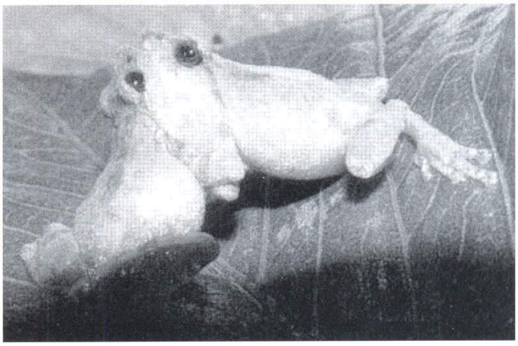

Figure 1. Wrestling for territorial defense in *Philautus annandalii* at Mirik (26°53'146"N; 88°11'235"E; 1,408 m asl), Darjeeling District, West Bengal, India.

dendrobatid frogs. Herpetologica 22:217–221.

EMLEN, S. T. 1968. Territoriality in the bullfrog *Rana catesbeiana*. Copeia 1968:240–243.

GOODMAN, D. 1971. Territorial behaviour in a Neotropical frog, *Dendrobates granuliferus*. Copeia 1971:365–370.

MARTOF, B. S. 1953. Territoriality in the green frog, *Rana clamitans*. Ecology 34:165–174.

SEXTON, O. J. 1960. Some aspects of the behaviour and of the territoriality of a dendrobatid frog, *Prostherapsis trinitatis*. Ecology 41:107–115.

STEWART, M. M. & A. S. RAND. 1991. Vocalizations and the defense of retreat sites by male and female frogs, *Eleutherodactylus coqui*. Copeia 1991:1013–1024.

TOWNSEND, D. S. 1989. The consequences of microhabitat choice for male reproductive success in a tropical frog (*Eleutherodactylus coqui*). Herpetologica 45:451–458.

Anjan Sarkar[1] and Kaushik Deuti[2]

[1] 29, Dr. Nilmoni Sarkar Street, Kolkata 700 090, India.
Email: drsarkar@rediffmail.com

[2] Zoological Survey of India, Nizam Palace, Kolkata 700 020, India.
Email: kaushikdeuti@rediffmail.com

Received: 2 August 2006.
Accepted: 20 October 2006.

SNAKES OF THE AMERICAS: CHECKLIST AND LEXICON

by Bob L. Tipton. 2005.
Krieger Publishing Company, Melbourne, Florida, U.S.A.
492 pp (+ CD ROM). ISBN 1-57524-215-X. Hardcover. Price: US$94.50.
Available from: Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

Krieger Publishing keeps coming out with good, meaty books on herpetology around the world and 'Snakes of the Americas' is no exception. It is a large tome, no illustrations and dry looking but contains a wealth of information, never compiled in one source book before. The Checklist part of the book is an important update of the 179 genera and 1197 species dealt with. The most amazing feature of the book is the lexicon of over 20,000 vernacular names for the snakes of the Americas which Tipton has painstakingly collected himself and via a host of distinguished colleagues mentioned in the Acknowledgements. Understanding how important this contribution is, author of the Foreword, Jonathan Campbell writes "In conversation such (vernacular) names are sometimes more important than scientific epithets. Most Guatemalans would have no idea what a *Bothrops asper* is, but mention the name 'Barba amarilla', and almost everyone will have a story to tell". Because of the size of this achievement, the author has wisely included a CD with the book for quick and easy access to the snake of your choice.

Let's say you are going to Guatemala to look for snakes. Well, though they speak almost the same Spanish you will hear in Mexico or Costa Rica, snake names vary tremendously. In our experience in India, snake names may differ even in a small geographic area which can get confusing. This book is the answer to those problems for the snake researcher/hunter in the Americas and such a compilation is way overdue in our part of the world.

'Snakes of the Americas' consists of Foreword, Preface, User's Guide to the CD, Introduction, Checklist Overview, an extensive Bibliography and the Index. The rest of the book, 340 pages of it, consists of the Checklist to the snakes of the eleven snake families found in North, Central and South America. This book is highly recommended for anyone carrying out field work on snakes in the Americas.

Romulus Whitaker
Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.
Email: serpentcatcher@yahoo.com

A FIELD GUIDE TO THE AMPHIBIANS AND REPTILES OF BALI

by J. Lindley McKay. 2006.
Krieger Publishing Company, Melbourne, Florida, U.S.A.
148 pp. ISBN 32902-9542. Hardcover. Price US$39.50.
Available from: Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

Bali is a 5,500 square kilometer island in the Indonesian archipelago and as expected, it combines the flora and fauna of several neighbouring islands. Typical of much of Indonesia, the

SNAKES OF THE AMERICAS: CHECKLIST AND LEXICON

by Bob L. Tipton. 2005.
Krieger Publishing Company, Melbourne, Florida, U.S.A.
492 pp (+ CD ROM). ISBN 1-57524-215-X. Hardcover. Price: US$94.50.
Available from: Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

Krieger Publishing keeps coming out with good, meaty books on herpetology around the world and 'Snakes of the Americas' is no exception. It is a large tome, no illustrations and dry looking but contains a wealth of information, never compiled in one source book before. The Checklist part of the book is an important update of the 179 genera and 1197 species dealt with. The most amazing feature of the book is the lexicon of over 20,000 vernacular names for the snakes of the Americas which Tipton has painstakingly collected himself and via a host of distinguished colleagues mentioned in the Acknowledgements. Understanding how important this contribution is, author of the Foreword, Jonathan Campbell writes "In conversation such (vernacular) names are sometimes more important than scientific epithets. Most Guatemalans would have no idea what a *Bothrops asper* is, but mention the name 'Barba amarilla', and almost everyone will have a story to tell". Because of the size of this achievement, the author has wisely included a CD with the book for quick and easy access to the snake of your choice.

Let's say you are going to Guatemala to look for snakes. Well, though they speak almost the same Spanish you will hear in Mexico or Costa Rica, snake names vary tremendously. In our experience in India, snake names may differ even in a small geographic area which can get confusing. This book is the answer to those problems for the snake researcher/hunter in the Americas and such a compilation is way overdue in our part of the world.

'Snakes of the Americas' consists of Foreword, Preface, User's Guide to the CD, Introduction, Checklist Overview, an extensive Bibliography and the Index. The rest of the book, 340 pages of it, consists of the Checklist to the snakes of the eleven snake families found in North, Central and South America. This book is highly recommended for anyone carrying out field work on snakes in the Americas.

Romulus Whitaker
Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.
Email: serpentcatcher@yahoo.com

A FIELD GUIDE TO THE AMPHIBIANS AND REPTILES OF BALI

by J. Lindley McKay. 2006.
Krieger Publishing Company, Melbourne, Florida, U.S.A.
148 pp. ISBN 32902-9542. Hardcover. Price US$39.50.
Available from: Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

Bali is a 5,500 square kilometer island in the Indonesian archipelago and as expected, it combines the flora and fauna of several neighbouring islands. Typical of much of Indonesia, the human population is dense and landuse has decimated much of the natural habitat. Nevertheless, many reptiles and amphibians have found a niche living in and around human habitation, farms and plantations, besides the surviving protected forests, and McKay has produced a good popular introduction to the 14 species of frogs and 57 land reptiles recorded from the island.

In most cases the colour photos (which include the majority of Bali's amphibians and reptiles) are adequate to identify the species but several of the pictures of smaller frogs and lizards are blurry. Detailed keys are provided, including to the tadpoles, generally tough to identify. An annotated checklist would have been a useful addition. Descriptions of species are simple and straight-forward; range maps would be helpful, especially for new-comers to the islands topography and vegetative cover. The chapter 'The Environment of Bali' is useful, with sub-sections on which herp taxa are likely to be found in the different habitats but it would be a luxury to have range maps to directly refer to when one is reading species descriptions.

Other chapters include one on using the keys, the turtle trade, snakebite, a glossary, reference list and index. There is an interesting appendix on "Species Not Yet Recorded on Bali" which describes species which "are found in nearby areas or are widespread throughout the region". This is an encouragement for local and visiting students of the flora and fauna to find and extend the range of these species.

There are a few glitches or conclusions which need confirmation or correction. Regarding Malayan krait venom, the author states that it is "less toxic than that of the cobras". In general, krait venom is much more toxic than cobra (and especially king cobra). Herpetologist Joe Slowinski was bitten by a small krait in Burma in 2001 and expired despite efforts to keep him alive over a 24 hour period and there are other cases of human fatalities from bites of even smaller kraits. The author also states that seasnakes are 'typically gentle', which is generally true for the sea kraits (*Laticauda laticaudata*), but there are other seasnakes like *Enhydrina schistosa* which can be downright snappy. Plate 130 is captioned *Ophiophagus hannah* but it is clearly a juvenile of the genus *Naja,* judging from the few bands and head shape.

These are minor quibbles for what is an extremely useful addition to the literature on the natural history of the region. Bali is a primary tourist destination in Asia and development has already limited much of the space where wildlife can still survive there. Up until 1999, when it was banned, the sea turtle trade badly hammered sea turtle populations in the Archipelago; hopefully this will help their recovery. The skin trade, which has wiped out many local populations of pythons, monitor lizards and other reptiles in Indonesia, fortunately never took hold in Bali.

It is important for this book to be published in Bahasa Indonesia (the keys are both in English and Bahasa) to educate and stimulate positive interest in herps in the people of Bali. Everyone interested in Asian herps should get a copy of 'A Field Guide to the Amphibians and Reptiles of Bali'.

Romulus Whitaker

Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.

Email: serpentcatcher@yahoo.com

AMPHIBIANS AND REPTILES OF PAKISTAN

by Muhammad Sharif Khan. 2006.
Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
311 pp. ISBN 32902-9542. Hardcover. Price: US$145.00.
Available from: Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

Following on the heels of his much appreciated 2002 book, 'A Guide to the Snakes of Pakistan', M.S. Khan has come out with a large-format book on all the herps of Pakistan. A much-needed book, there are some limitations, particularly with respect to the photos, some of which are faded, blurry and some are of preserved museum specimens. Many of these should simply have been left out as they add little in terms of being useful for identifying species. Using a fuzzy gharial photograph for the cover does not encourage the browser to expect too much of the photos inside, especially in this day and age of spectacular digital photography. While the photographer/artist is credited for many of the pictures and some of the drawings, there is a picture of a hawksbill turtle taken by this writer in the 1970s with no credit.

Having gotten through the picture criticisms of the book, some of the text glitches can be addressed. Most of the scientific nomenclature seems solid. But the designation of all the subspecies leaves the reader wondering where they all came from. Admittedly there are some reptile and amphibian complexes that are real cans of worms and need rigorous taxonomic examination; meanwhile however the listing of lots of subspecies may not be of much value since no one seems to be able to agree on designation of colour variation, race or subspecies at this point in time (though of course the author may have a good argument for incorporating them).

Unfortunately common names are often at variance with those of earlier authors. The Red Sand Boa (*Eryx johnii*) is called the Common Sand Boa and the snake generally called the Common Sand Boa (*Eryx* or *Gongylophis conicus*) is referred to in the book as the Chain Sand Boa. This may seem like a minor point but it does mix things up for the layman who may only rarely delve into scientific names. Or perhaps the mixups will encourage that same layman to become more exacting and learn those technical names. And by the way, both of these species look so different from the South India forms, plenty of work to be done!

Some statements in the text beg correction including this description of the mugger crocodile: "Mugger is bad-tempered; when it is disturbed it hisses loudly . . . etc". Hell, I have an uncle who is much more bad-tempered than any mugger. Hissing is done by frightened hatchling mugger and is a defensive rather than an aggressive expression. It's also written that the female mugger covers her eggs with vegetation, but being a hole-nester it is generally sand, earth or gravel. Also, the eggs take 8 to 10 weeks to hatch, not an incredibly brief 4 to 6 weeks.

A few discrepancies caught in Chapter 4, Chelonians are: the Indian Softshell Turtle (*Aspideretes gangeticus*) is reported by Khan to grow to 75 cm and 17 kg but in Indraneil Das' 'Colour Guide to the Turtles and Tortoises of the Indian Continent' the maximum size for the species is given as 94 cm and 67 kg. Similarly, the Narrow-headed Softshell Turtle (*Chitra indica*) is here said to reach 115 cm while Das reports 183 cm, possibly surpassing the biggest reported Giant Asian Softshell Turtle (*Pelochelys* sp). The trend continues- Flapshell (*Lissemys punctata*) – Khan says 28 cm, Das says 37 cm; Star Tortoise (*Geochelone elegans*) – Khan says 28 cm, Das says 38 cm). The problem with this kind of consistent inaccuracy is that it behooves the reader to go to the hassle of checking on the veracity of the rest of such data in the book. Sorry, I didn't have time for that.

Moving to lizards, the Garden lizard (*Calotes versicolor*) is described as having a prehensile tail which it most definitely doesn't. The agamids of India's northern neighbour are impressive, there are twelve of them in one interesting genus alone: *Laudakia*.

And on to snakes where there is a picture of the Spectacled Cobra which is captioned *Naja oxiana* (called Brown Cobra by Khan, Central Asian Cobra in Whitaker and Captain, 2004, Snakes of India-the Field Guide). The 'Spectacled Cobra' in Pakistan is actually a black snake with a barely or not discernible spectacle, as it is in much of Northwest India as well. Perhaps we should change the English name to 'Common Cobra' to encompass this distinct and widely distributed colour form. Or perhaps Wolfgang Wüster and his pals will have another look at these black ones' DNA and give us another species!? Another point of interest is the distribution of *Naja oxiana*; on the range map it shows records close to Pakistan's borders with the Indian States of Gujarat and Rajasthan where we should do some serious cobra observation to sort out whether this snake is ever found there. A good question would be whether the bite of this species would be helped using antivenom made from the Spectacled Cobra.

Other chapters in the book include 'Distribution and Affinities of Herpetofauna', 'Herpetology of Habitat Types' and 'Altitudinal Distribution of Amphibians and Reptiles', short but meaty chapters with much of interest about a region we know so little about. The book finishes up with a short section on snakebite, one on 'Threats to the Herpetofauna of Pakistan' (though some of us would wonder what the Asian Rat Snake and Checkered Keelback Watersnake are doing on a list of threatened species) and a good bibliography.

Criticisms aside (and wouldn't it have been great if more attention had been paid to editing and cross-checking facts), 'Amphibians and Reptiles of Pakistan' is an important contribution and update to our knowledge of the herps of the region. If this volume will help encourage more herpetological work in Pakistan from local and visiting biologists it will have more than fulfilled its usefulness.

Romulus Whitaker
Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.
Email: serpentcatcher@yahoo.com

SNAKE VENOMS AND ENVENOMATIONS

by Jean-Philippe Chippaux. 2006 (original French edition 2002).
Krieger Publishing Company, Melbourne, Florida, U.S.A.
282 pp. ISBN 1-57524-272-9. Hardcover. Price: US$58.50.
Available from Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

This is a remarkable compilation of recent work on venoms and snakebite by one of the world's acknowledged authorities. To jump right in to the criticisms, the translation from the French suffers by somewhat quaint sentence structure and word choice. For example under 'Folklore': "The flower of *Feretia apodanthera* would be an appreciated food of snakes..." and "...the action of certain plants gives relieve to patients presenting disorders as a consequence of the bite of a venomous animal". Added to this, the book is rife with typos. To start with, on the second page is the irony-tinged statement: "This publication is designed to provide accurqate (sic) and authoritative information..." and while we can believe the text to be accurate and authoritative, we wish that the publishers would engage a strict editor and meticulous proof-reader, especially for translations.

There are further discrepancies which could be partly explained by the author's bias toward African snakes and snakebite there. In Table VIII on page 127, it is stated that inflammation, edema and necrosis are rare in elapid sive, there are twelve of them in one interesting genus alone: *Laudakia*.

And on to snakes where there is a picture of the Spectacled Cobra which is captioned *Naja oxiana* (called Brown Cobra by Khan, Central Asian Cobra in Whitaker and Captain, 2004, Snakes of India-the Field Guide). The 'Spectacled Cobra' in Pakistan is actually a black snake with a barely or not discernible spectacle, as it is in much of Northwest India as well. Perhaps we should change the English name to 'Common Cobra' to encompass this distinct and widely distributed colour form. Or perhaps Wolfgang Wüster and his pals will have another look at these black ones' DNA and give us another species!? Another point of interest is the distribution of *Naja oxiana*; on the range map it shows records close to Pakistan's borders with the Indian States of Gujarat and Rajasthan where we should do some serious cobra observation to sort out whether this snake is ever found there. A good question would be whether the bite of this species would be helped using antivenom made from the Spectacled Cobra.

Other chapters in the book include 'Distribution and Affinities of Herpetofauna', 'Herpetology of Habitat Types' and 'Altitudinal Distribution of Amphibians and Reptiles', short but meaty chapters with much of interest about a region we know so little about. The book finishes up with a short section on snakebite, one on 'Threats to the Herpetofauna of Pakistan' (though some of us would wonder what the Asian Rat Snake and Checkered Keelback Watersnake are doing on a list of threatened species) and a good bibliography.

Criticisms aside (and wouldn't it have been great if more attention had been paid to editing and cross-checking facts), 'Amphibians and Reptiles of Pakistan' is an important contribution and update to our knowledge of the herps of the region. If this volume will help encourage more herpetological work in Pakistan from local and visiting biologists it will have more than fulfilled its usefulness.

Romulus Whitaker

Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.

Email: serpentcatcher@yahoo.com

SNAKE VENOMS AND ENVENOMATIONS

by Jean-Philippe Chippaux. 2006 (original French edition 2002).
Krieger Publishing Company, Melbourne, Florida, U.S.A.
282 pp. ISBN 1-57524-272-9. Hardcover. Price: US$58.50.
Available from Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

This is a remarkable compilation of recent work on venoms and snakebite by one of the world's acknowledged authorities. To jump right in to the criticisms, the translation from the French suffers by somewhat quaint sentence structure and word choice. For example under 'Folklore': "The flower of *Feretia apodanthera* would be an appreciated food of snakes…" and "…the action of certain plants gives relieve to patients presenting disorders as a consequence of the bite of a venomous animal". Added to this, the book is rife with typos. To start with, on the second page is the irony-tinged statement: "This publication is designed to provide accurqate (sic) and authoritative information…" and while we can believe the text to be accurate and authoritative, we wish that the publishers would engage a strict editor and meticulous proof-reader, especially for translations.

There are further discrepancies which could be partly explained by the author's bias toward African snakes and snakebite there. In Table VIII on page 127, it is stated that inflammation, edema and necrosis are rare in elapid bites, when actually the first two are common symptoms and necrosis is a by no means rare sequelae in bites of the Indian cobra. There are a number of 'throwaway' statements in the book which are not 'universal truths' like: "...venomous snakes are rare in pineapple plantations" when actually Russells vipers seem to like them in south-western India. Another is: "Snakes do not have a developed social behaviour", and then the author goes on to give us examples of interesting social behaviour that disprove this line. But perhaps the most serious criticism of this book is the lack of citations in the text after important facts are divulged, a standard for this kind of reference book, the lack of which detracts from its value.

The section on Traditional Medicine reveals a lot of what is known about plant 'antidotes' and their specific application to certain symptoms of snakebite. What remains unmentioned is that while many of these plants do have 'remedies' for some symptoms of snakebite, there is no way of getting them into the bloodstream fast enough to deal with the rapid invasion of a toxin, protein and enzyme cocktail that the snake injects.

The history of the discovery and development of antivenom serum (AVS) is fascinating. Sewall immunized pigeons in the USA way back in 1887 by injecting small doses of massasauga rattlesnake venom. Then in 1894, Phisalix refined the technique using European vipers. But it was Calmette, who in 1896, made the first cobra AVS in Saigon and brought this life saving drug into commercial use. By 1907, workers in Brazil, Australia, India, England, Japan, USA and South Africa had produced AVS for many species of snakes which were causing major mortality and revolutionized snakebite treatment with this most important discovery.

The author cites data showing that even late administration of AVS, many hours after a snakebite has occurred, can still effectively treat serious systemic symptoms. He points out the value of studies on snake occurrence, distribution in the habitat, population density, night/day and seasonal activity cycles and other habits of snakes in aiding the clinician and educating people to mitigate or minimize the occurrence of snakebite. He stresses the fact that in developing countries, snakebite is primarily associated with agricultural workers. However, in many areas where snakebite is prevalent, the problem is mainly that people are barefoot and don't use lights at night when they walk. The author writes that "Some snakes are ubiquitous, disquieting commensals of man" but doesn't finish the thought with the obvious answer: RATS! That plus the perennial water we tend to store, luring frogs and toads close to our homes and gardens, are all perfect snake food.

The country-by-country lineup of snakebite and mortality gives a neat perspective on the problem at a global level. How the statistics were arrived at and what references were used remains unknown but the estimates for Asia appear somewhat inflated. The figures given are: 4 million snakebites in Asia each year, 50% of which cause envenomation with over 100,000 deaths. Admittedly, we have no reliable statistics for incidence of snakebite and mortality for India (the country alleged to have the highest snakebite mortality worldwide) but 'informed' guesstimates have rarely exceeded 20,000 deaths. The author points out the panacea: availability of antivenom where it is needed in the countryside, adequate dosages of antivenom administered and the correct treatment protocol given in time. He notes that in developing countries, the cost of modern treatment for snakebite can be double the monthly income of a family, a major factor for the poor in deciding whether to go to hospital or not.

The book ends with a surprisingly brief bibliography, and several expected authors' names conspicuously absent. Nevertheless, 'Snake Venoms and Envenomations' is a useful compilation and update on the subject and while several chapters are technical and would make sense only to a toxicologist or medical practitioner, there is plenty to interest the layman and herpetologist.

Romulus Whitaker
Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.
Email: serpentcatcher@yahoo.com

RATTLESNAKE ADVENTURES– HUNTING WITH THE OLDTIMERS

By John W. Kemnitzer. 2006.
Krieger Publishing Company, Malabar, Florida, U.S.A. Hardbound.
236 pp. ISBN 1-57524-278-8. Price: $32.50.
Available from Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida, U.S.A.
Email: info@krieger-publishing.com

Most herp titles that appear today are either field guides or treatises on various aspects of reptile and amphibian biology; many are good reads for folks like us but only in dribs and drabs. "Rattlesnake Adventures" is a refreshing departure, it's like being pulled into a circle of story tellers who just happen to have had experiences with, and like to talk about, some of the most impressive snakes on the planet: the rattlers.

Names like Raymond L. Ditmars, who popularized snakes over several generations with his books "Snakes of the World" and "Thrills of a Naturalist's Quest" evoke strong memories. Like the letter I wrote to him in 1960 from school in South India. The reply came a month later (airmail was slower then) and read "I regret to advise you that Dr. Ditmars passed away in 1942". It was signed by Bronx Zoo Reptile Curator, James A. Oliver.

As a GI during the Viet Nam conflict, I was stationed for a time in El Paso, Texas. Every spare moment was spent hunting for Blacktails, Western Diamonbacks and sneaking over to 'Huachuca Heaven', Ajo Road, and other hotspots mentioned in Carl Kauffeld's magical book "Snake's and Snake Hunting". I was collecting snakes for zoos during my spare time and the Army was understandably peeved when I missed duty for 3 weeks due to a Prairie Rattler bite. At Kauffeld's request I hunted the Huachucas (now a protected area) and sent him a pair of Green Rock Rattlers and a stunning male Willard's for his collection at the Staten Island Zoo. I wrote to him about how much his book was appreciated and got back a poignant reply which went something like this: "If I had known what a flood of snake collectors would be unleashed on the wonderful places I so meticulously described in the book, I would have refrained from giving the details".

It's true, those of us who were 'commercial collectors' in the 1960s wreaked havoc on some of the pristine snake populations found by accident or revealed to us by our herp heroes of the day. In Miami in 1963, animal dealer Bill Chase was paying us $2 a foot for Indigos, 35 cents a foot for Yellow Ratsnakes and 50 cents a foot for Red Ratsnakes. Garters, Ribbons and Watersnakes were a quarter apiece. Bill Haast at the Miami Serpentarium, where I worked for 2 years, would give us a dollar and a half a foot for Eastern Diamonbacks and 50 cents a foot for Water Moccasins over 2 feet long (I can remember catching 40 Moccasins one memorable Saturday morning out on Loop Road during a drought, along with snake hunting legend Schubert Lee who later died of cobra bite).

But we were preceded by some pretty heavy zoo collectors such as some of the story-tellers in Kemnitzer's book. While entertaining to read "A Ledge" and "Do Snakes Die in the Sun", you can't help squirming at the thought of childhood hero Raymond Ditmars noosing Timbers by the dozen at the dens of the Northeast. The new generation, represented by the editor/author, only want to make sure these dens and their buzztail denizens remain unpublicized when possible and survive in a rapidly changing landscape. It makes a repentant collector feel good to know that these ultimate icons of the American wilderness have such staunch champions.

Floridians Dick Bartlett (whom we used to visit to learn the science side of snakes and listen to country music), and Frank Weed (who once hauled my badly stuck Olds out of a swampy pit near his place outside of Miami) both have yards and yards of good yarns to tell, and provide some short but sweet rattler tales in this book. Welcome too are the stories by people like Samuel Scoville, Jr., who writes about a famous New Jersey rattlesnake den, Mt. Misery, back in 1929. And then there's "The Last Rattlesnakes" by a fine nature writer, Ted Levin, whose story about Vermont's surviving Timber Rattlers comes alive.

Well, there's that old knuckle arthritis from carelessly handled hot snakes so I'll have to quit typing now. The crick in the right knee and shortness of breath on steep climbs all indicate this reviewer's impending status as an 'oldtimer'. It's a pleasure to be in such good company. Looking forward to more collections of good snake-hunting yarns!

Romulus Whitaker

Post Box 21, Chengalpattu 603 001, Tamil Nadu, India.

Email: serpentcatcher@yahoo.com

REVIEWERS FOR *HAMADRYAD*
VOL. 31, NO 2.

Kraig Adler, Ron Altig, Chris Austin, Aaron Bauer, William Branch, Ashok Captain, Patrick David, Sushil K. Dutta, Jack Frazier, L. Lee Grismer, Colin J. McCarthy, Peter Narins, Olivier S. G. Pauwels, Bryan Stuart, Harold Voris, Peter Paul van Dijk, Van Wallach and Addison Wynn.