Venomous Terrestrial Snakes of Malaysia: Their Identity and Biology

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Indraneil Das, Norhayati Ahmed, and Lim Boo Liat

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Abstract

This article presents an overview of the identity and biology of the venomous terrestrial snakes of Malaysia, from Peninsular Malaysia and the Bornean states of Sabah and Sarawak. Two families account for a majority of venomous snakes that are of medical significance – the Elapidae (cobras, kraits, and coral snakes) and Viperidae (vipers and pit vipers). Certain members of the Colubridae are capable of giving life-threatening bites to humans (especially species of *Rhabdophis*), but little is known of the Malaysian species of the genus.

I. Das (✉)
Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia
e-mail: idas@ibec.unimas.my

N. Ahmed
School of Environment and Natural Resource Sciences, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia
e-mail: noryati@ukm.my; yati_68@yahoo.co.uk

L.B. Liat
Cheras, Selangor, Malaysia
e-mail: limbooliat@yahoo.co.uk

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A number of other species in the family have been implicated with human envenomation, although little objective evaluation appears to have been published. This article synthesizes data on the identification, distribution, and conservation of these snakes; provide colored images of every recognized species and subspecies of venomous terrestrial snakes of the families Elapidae and Viperidae known to occur in the country; and conclude with strategies to improve knowledge of the snakes of the country.

Introduction

The political unit that comprises modern-day Malaysia composes of the southern-most tip of the Southeast Asian continental landmass (referred to as Peninsular Malaysia); its smaller, offshore islands; as well as two large areas on the northern portion of the island of Borneo (namely, Sabah and Sarawak). The total land area is 328,657 sq km, and the extent of surface area underwater is 1,190 sq km. The country is bounded by southern Thailand to the north of the Peninsular, and across the Straits of Melaka lies the island state of Singapore. Malaysia's Bornean possessions share its southern and southeastern boundaries with several provinces of Kalimantan, belonging to the Republic of Indonesia. The independent Sultanate of Brunei Darussalam is wedged within the state of Sarawak, as two discontinuous land masses, both with coastlines. Affected by its location and position, the northern Peninsula shows weak but distinct seasonality, with a recognizable dry season, while on the island of Borneo, which straddles the equator, rainfall is more or less spread year-round, albeit with higher precipitation coinciding with the (winter) Northeast Monsoons.

Native vegetation of the region, at least prior to extensive habitat alteration for development of agroindustries, timber industry, and urbanization, comprised mostly of tropical forests. The vegetation range currently extant includes mangrove forests, peat swamps, heath forests, lowland and mixed dipterocarp forests, and various types of highland forests, climaxing in stunted, montane forests. It is therefore not difficult to understand why Malaysia ranks among the 17 megadiverse countries of the world. The vertebrate fauna, in particular, is rich, with many distinct lineages (or autochthonous elements), often linked to particular mountain systems or have ranges demarcated by river valleys or marine boundaries, in addition to elements from the Indo-Chinese and Indian subregions, plus widespread Indo-Malayan lineages.

The bulk of the venomous terrestrial snakes of Malaysia can be accommodated into two families, the Elapidae and the Viperidae. The obvious character that distinguishes members of the Elapidae from that of the harmless snakes of other families is the short and erect fangs set anteriorly, on the maxillary bone. Further, Asian species are smooth scaled, have forehead covered with large scales, show rounded pupils, and are oviparous. Members of the second major family, the Viperidae, are differentiated from those of the Elapidae and other snake families

Fig. 3.1 *Bungarus candidus* (Linnaeus 1758), Malayan krait (Photo: Norhayati Ahmed)

Fig. 3.2 *Calliophis bivirgatus flaviceps* (Cantor 1839), Malayan blue coral snake (Photo: Indraneil Das)

in having large triangular heads, retractile hollow fangs, as well as short, moveable maxillary bone adapted for deep penetration of prey. Additionally, vipers tend to be relatively stocky, have keeled scales, and typically show vertically elliptical pupils. While most species are ovoviviparous (or live-bearing), oviparity has risen independently in several lineages of vipers.

In Malaysia, the family Elapidae is represented by cobras, kraits, and coral snakes, the venom of which shows neurotoxic properties (Figs. 3.1, 3.2, and 3.3). Coral snakes are ground dwellers or even burrowing. Cobras and kraits, on the other hand, while being mostly terrestrial, are also accomplished swimmers, often venturing into forest streams and ponds to prey on amphibians, fish, and other snakes. All elapids are oviparous. Sea snakes are currently classified as Elapidae but are excluded from this discussion. All species have strong neurotoxic venom, which attacks the nervous system, but some possess other effects including swelling, necrosis, and even cardiotoxic effects.

The Viperidae is traditionally divided into two subfamilies, distinguished by the presence or absence of a loreal pit on each side of the head between the eye and

Fig. 3.3 *Naja sumatrana* (Müller 1890), Sumatran spitting cobra (from Borneo) (Photo: Indraneil Das)

Fig. 3.4 *Calloselasma rhodostoma* (Kuhl 1824), Malayan pit viper (Photo: Chan Kin Onn)

nostril and both possessing hemotoxic venom (Figs. 3.4, 3.5, and 3.6). All the Malaysian species are characterized by the presence of the loreal pit and are referred to as pit viper of the subfamily Crotalinae. The loreal pit is a thermosensitive organ, enabling the snake to detect its warm-blooded prey at night. All Malaysian species of pit vipers are ovoviviparous. The Russell's vipers (currently including two *Daboia* species, subfamily Viperinae) are large, pitless vipers found in South Asia, Myanmar, Thailand, and Cambodia and also in Java, Sumatra, the Lesser Sundas, and Eastern Asia (see Belt et al. 1997). It does not naturally occur in either Peninsular Malaysia or Borneo (perhaps owing to the year-round moist conditions in these areas). It is not unusual to occasionally find these species in suburban and rural areas in Malaysian states bordering Thailand, such as Perlis and Kedah, that are presumably escapees or released by animal dealers and hobbyists. Most of Malaysian pit vipers are arboreal, and a few strictly terrestrial. The abundance of proteases (protein-degrading enzymes) in vipers is associated with intense pain suffered as a result of its bite, in addition to local swelling, blood loss from disruption of the blood-clotting system, and necrosis, and death is typically caused by collapse in blood pressure and shock.

Fig. 3.5 *Garthius chaseni* (Smith 1931), Kinabalu brown pit viper (Photo: Indraneil Das)

Fig. 3.6 *Tropidolaemus wagleri* (Boie 1827), male, Wagler's pit viper (Photo: Indraneil Das)

A third group, the so-called back-fanged snakes (Colubridae of some authors, classified as Natricidae by Pyron et al. (2013), including the genus *Rhabdophis*, comprises certain members that are capable of giving life-threatening bites to humans (Weinstein et al. 2013a). Four species of the genus (*chrysargos, conspicillatus, murudensis*, and *subminiatus*) are known from Malaysia, although no records of envenomation from the bites of these species in the country are available. The bite of *R. subminiatus* is known to show signs of envenomation (see Nivattayakul 2001; Smeets et al. 1991). A highly venomous congeneric species from Eastern Asia, *R. tigrinus*, has been shown to sequester toxins from toads ingested (Hutchinson et al. 2007).

Other species of colubrids have been suggested to pose some danger to humans. Large-growing species of cat snakes, especially the mangrove cat snake (*Boiga dendrophila*), has been linked to mild envenomation (see Monk 1991), and a three-finger toxin (denmotoxin) isolated from the species has been shown to display potent postsynaptic neuromuscular activity (Lumsden et al. 2004; Pawlak et al. 2006). Within the Colubridae, neurotoxic activity has been demonstrated from secretions of two congeneric species (*Boiga blandingi* and *B. irregularis*;

see Weinstein and Kardong 1994). Several other species of Colubridae (such as *Macropisthodon rhodomelas*; see Subaraj 2008) have been linked to symptoms of envenomation, but many published records lack rigor in their documentation, including qualified clinical assessment and sound conclusion from objective information (further arguments in Weinstein et al. 2013b). For others (e.g., Ashton 1963), rapid nomenclatural changes and lack of voucher specimens or images render identification of species uncertain.

In the last two decades, improved analytical approaches such as multivariate morphometrics (Wüster and Thorpe 1992a) and the use of mtDNA sequences (Slowinski and Wüster 2000; Broadley and Wüster 2004) have been instrumental in both revealing cryptic species and refining understanding of higher-level systematics within the venomous snakes of the region. In the case of the venomous land snakes of Malaysia, the species numbers for both elapid snakes and vipers have increased, with more genera and species recognized at present, particularly that of the vipers. Venomous snakes and snake bite in adjacent Brunei Darussalam have been treated to a review in this volume by Das and Charles (2014).

The revised nomenclature of the venomous land snakes (Elapidae and Viperidae) is documented in a recent work for Southeast Asia by Das (2010). As every species of these families has been described, a dichotomous key to their identification is presented in Table 3.1 instead.

Elapidae

Within the Elapidae, the number of species has increased from 9 to 10 since 1983 (Table 3.2). The species added to the fauna is the monocled cobra (*Naja kaouthia*), which was formerly treated as a subspecies of the Indian cobra (*N. naja*) by Tweedie (1961). Studies carried out by Wüster and Thorpe (1989, 1992a, b) on the Asiatic *Naja* complex showed that *N. naja* is not found in Southeast Asia; rather, the species encountered is the equatorial spitting cobra (*Naja sumatrana*). Sometimes referred to as the golden or Sumatran spitting cobra, *N. sumatrana* is the most common elapid among the rest of the nine species known in Malaysia (Table 3.2). Its geographical distribution includes extreme southern Thailand, Peninsular Malaysia, Singapore, Indonesia (Sumatra, Kalimantan, Bangka, Belitung, Riau, and Lingga), East Malaysia (Sabah and Sarawak), and Brunei (Wüster and Thorpe 1989), as well as the southern Philippines. It preys on vertebrate animals, primarily rodents and frogs, and inhabits many habitat types, ranging from human surroundings, fields, and plantations to forests at low altitudes throughout the country. This cobra appears catholic in its diet.

The monocled cobra (*Naja kaouthia*), a non-spitting species, is distributed from eastern India to south to northern Peninsular Malaysia, while being abundant in southern Thailand. In Malaysia, this species is confined to the northern parts of the Peninsula and has a feeding habit similar to that of *N. sumatrana*. It inhabits more open environments, such as rice fields, plantations, and other human-modified environments, and also lowland forest habitats. Bites by both these species are

Table 3.1 Dichotomous identification key to the venomous terrestrial snakes of Malaysia

1.	Head broad and flat, covered with small irregularly arranged scales of which six or more lie along a line between eyes	
	Viperidae	11
	Head variously shaped, usually covered with symmetrically arranged shields, three lie in a line between eyes	
	Elapidae	2
2.	Third upper labial large, touching the eye and nostril	3
	Third upper labial normal, not touching the eye and nostril	5
3.	Paired occipitals contact with each other behind parietals	*Ophiophagus hannah*
	No occipital behind parietals	4
4.	Body uniformly black, belly bluish gray, white markings on throat	*Naja sumatrana*
	Body brown to grayish brown, belly paler, a white circle centrally on the back of hood	*Naja kaouthia*
5.	Subcaudals of underside of the tail single anteriorly and paired posteriorly or entirely single	6
	Subcaudals of underside of the tail paired throughout	8
6.	Subcaudals single behind vent, paired posteriorly, body bluish black with the head, neck, and tail bright red	*Bungarus flaviceps*
	Subcaudals single throughout	7
7.	Body banded with alternate black and white bands, black bands encircling body; tail with blunt end	*Bungarus fasciatus*
	Body is banded with alternate black and white bands, black bands confined to the back and sides; tail tapering to point	*Bungarus candidus*
8.	Anal paired	9
	Anal single	10
9.	Body brown, scales dark edged; narrow black vertebral stripe connects series of small black spots on each side; belly with alternate black and yellow; underside of the tail banded black and red	*Calliophis gracilis*
	Body brown above with small black spots longitudinally arranged along each side of the back or with black vertebral stripe and no spots, belly red, underside of the tail blue or gray	*Calliophis maculiceps*
10.	Body brown with red and orange stripes enclosed between two black lines and white stripes below each side. Belly banded with alternate black and white pattern and underside of the tail band black and red	*Calliophis intestinalis*
	Body dark blue or blue black; head, belly, and tail bright red	*Calliophis bivirgatus*
11.	Species confined to Peninsular Malaysia	12
	Species confined to Borneo and/or Peninsular Malaysia and Borneo	22
12.	Top of the head with shields systematically arranged; body reddish or purplish brown; throat, belly, and tail pinkish white	*Calloselasma rhodostoma*
	Top of the head scales small	13
13.	Body predominantly brown	14
	Body predominantly green	17

(*continued*)

Table 3.1 (continued)

14.	Snout flat and projected	*Trimeresurus wiroti*
	Snout rounded and not projecting	15
15.	Body brown with a series of large dark square spots along each side of the back	*Ovophis convictus*
	Body without square-shaped spots	16
16.	Body dull olive or bluish green in males and grass green in females, scales on body keeled rusty or dull brown, belly dull brown with dark edges	*Popeia venustus*
	Body blackish variegated with brown or olive, belly dark brown or grayish	*Cryptelytrops purpureomaculatus*
17.	Tail mainly reddish throughout length	18
	Green banded with brown	19
18.	Body greenish black with scales black bordered, green above and yellow on sides. Belly greenish white with irregular yellow patches, bordered with black or black spotted	*Tropidolaemus wagleri*
	Tail entirely pinkish of posterior half	20
19.	Body olive green to bluish, with spots arranged to form transverse maroon bands and brownish bands on tail	*Popeia buniana*
	Tail rusty or reddish brown	21
20.	Nasal usually in contact, body green with two rows of blackish spots and a white line along the lowest dorsals bordered with black or by a row of black spots	*Parias hageni*
	Nasal not in contact	
21.	Body green in both sexes, with irregular rusty or reddish brown crossbands; tail rusty or reddish brown, sometimes mottled	*Popeia fucata*
	Body green above, pale green below; juveniles green, white stripe, bordered below with red, along the lowest row of dorsals	*Popeia nebularis*
22.	Body brown	23
	Body green	24
23.	Body brown with black-edged saddles across the back and row of light spots low on the sides of tail and the nose formed into a leaflike projection	*Trimeresurus borneensis*
	Body brown with irregular dark blotches in paired rows down center of back, tail brown with dark blotches	*Garthius chaseni*
24.	Anal entire	25
	Anal divided	26
25.	Body with striking pattern of bright green dots on black background, tail with parallel red dots with dark green scales	*Parias malcolmi*
	Body green with dark crossbands at intervals of 4–5 scales along body, a white line running along the lowest two rows of dorsal with a green line below it	*Popeia sumatranus*
26.	Body bright green, flanks with white or red spots or stripes in males, white or yellow in female	*Popeia sabahi*
	Body green or greenish blue with white or red spots or stripes in males, bluish-green and red crossbands in females	*Tropidolaemus subannulatus*

Table 3.2 The elapid and viperid snakes of Malaysia (Peninsular Malaysia, Sabah and Sarawak, and Borneo)

No.	Species	Common name	Locality
	Elapidae		
1.	*Bungarus candidus* (Linnaeus 1758)	Malayan krait	PM-P-C
2.	*Bungarus fasciatus* (Schneider 1801)	Banded krait	PM-P-C, SW-P-C
3.	*Bungarus flaviceps* Reinhardt 1843	Red-headed krait	PM-P- NC, SW-P-NC
4.	*Calliophis bivirgatus* (Boie 1827)	Blue coral snake	PM-P-C, SW-P-C
5.	*Calliophis gracilis* Gray 1835	Spotted coral snake	PM-P-NC
6.	*Calliophis intestinalis* (Laurenti 1768)	Striped coral snake	PM-P-C, SW-P-C
7.	*Calliophis maculiceps* (Günther 1858)	Speckled coral snake	PM-P-NC
8.	*Naja kaouthia* Lesson 1831	Monocled cobra	PM-P-C
9.	*Naja sumatrana* Müller 1890	Sumatran spitting cobra	PM-P-C, SW-P-C
10.	*Ophiophagus hannah* (Cantor 1836)	King cobra	PM-P-C, SW-P-C
	Viperidae		
11.	*Calloselasma rhodostoma* (Kuhl 1824)	Malayan pit viper	PM, northern states-C
12.	*Cryptelytrops venustus* (Vogel 1991)	Beautiful pit viper	PM, northern states-NC
13.	*Cryptelytrops purpureomaculatus* (Gray 1832)	Mangrove pit viper	PM-C
14.	*Garthius chaseni* (Smith 1931)	Kinabalu brown pit viper	S-HA, endemic to Borneo
15.	*Ovophis convictus* (Günther 1864)	Malayan brown pit viper	PM-C
16.	*Parias hageni* (Lidth de Jeude 1886)	Hagen's green pit viper	PM-C
17.	*Parias malcolmi* (Loveridge 1938)	Kinabalu green pit viper	S-HA, endemic to Sabah
18.	*Parias sumatranus* (Raffles 1822)	Sumatran pit viper	PM-C, SW-C
19.	*Popeia buniana* (Grismer et al. 2006)	Pulau Tioman pit viper	PM, endemic to Pulau Tioman
20.	*Popeia fucata* (Vogel et al. 2004)	Thai Peninsular pit viper	PM-C
21.	*Popeia nebularis* (Vogel et al. 2004)	Cameron Highlands pit viper	PM-C, endemic
22.	*Popeia sabahi* (Regenass and Kramer 1981)	Sabah green pit viper	SW-HA, endemic to Borneo
23.	*Trimeresurus borneensis* (Peters 1872)	Bornean palm pit viper	SW-C, endemic to Borneo

(*continued*)

Table 3.2 (continued)

No.	Species	Common name	Locality
24.	*Trimeresurus wiroti* Trutnau 1981	Wirot's palm pit viper	PM-C
25.	*Tropidolaemus wagleri* (Boie 1827)	Wagler's pit viper	PM-C
26.	*Tropidolaemus subannulatus* (Gray 1842)	Bornean pit viper	SB-C

PM Peninsular Malaysia, *SW* Sarawak, *S* Sabah, *P* present, *C* common, *NC* not common, *HA* high altitude. Species showing neurotoxic venom, nos. 1–10; species showing hemotoxic venom, nos. 11–26

common due to its close association with humans. A recent medical report indicates that cobra bites at a hospital in Penang were significantly more likely to result in severe envenomation, compared to bites by other species (Chew et al. 2011). Unfortunately, no identities of species were provided in this study, and given that both species are present in the hinterland of Penang State, it would have been of interest to know the identities of species, as their venom constituents as well as effects on humans are different (Yap et al. 2011). The behavior of spitting is well documented in *N. sumatrana* (see Wüster and Thorpe 1992b), thereby introducing additional medical complications among emergency physicians of the country.

The king cobra (*Ophiophagus hannah*) is the most feared elapid because of its size, and when encountered, it could raise the forepart of its body to about 1.2–1.5 m high at "eye level" with its hood extended. Its distribution extends from India to Hong Kong, Indochina, Peninsular Malaysia, Singapore, Sumatra, the Philippines, Borneo, Java, Sulawesi, and Bali (Grismer 2011). The behavioral response presumably depends on the extent of provocation it receives, and a brooding female guarding its eggs or young in its nest is ready to aggressively defend when confronted. Although *O. hannah* is common in oil palm plantations and forested areas and around human habituated areas in urban and suburban areas, bites by this snake are rarely recorded. Human mortality from its bite has been documented for Sabah and Sarawak (Haile 1958, 1963; Sawai 1972).

The kraits in Malaysia are represented by a single genus (*Bungarus*), with three species (Table 3.2). They are of moderate size and are conspicuously marked and colored, two with alternating black and yellow or white bands and one with a red head, making them easily recognizable. They are sluggish in behavior upon encounter but need to be considered extremely dangerous, and bites cause fatalities in humans. Among them, the red-headed krait (*Bungarus flaviceps*) is the least common, occurring mostly in primary forests in the highlands (Grismer 2011), although on Borneo this species is also encountered in the lowlands and along the foothills (Das, pers. obs.). The Malayan krait (*Bungarus candidus*) is common and is more of a forest snake, although it is occasionally encountered within human habitation. The banded krait (*Bungarus fasciatus*), the largest of the three species, is also the most common. This snake inhabits many habitat types, ranging from light forests, swamps, and near villages, under 2,500 m above mean sea level, asl (Das 2012). Within human habitations, this species is frequently sighted near mangrove

forests and often found as roadkills in rural areas. Bites from this snake are rarely reported, but there were occasions when the Orang Asli were bitten while handling *B. flaviceps* and *B. candidus* in Gombak and Ulu Langat Forest Reserve, Selangor. According to them, they survived using herbal remedies from the forest.

The Asian coral snakes are represented by the genus *Calliophis*, with four local species, *C. gracilis*, *C. maculiceps*, *C. bivirgatus*, and *C. intestinalis*. The last two were, till recently allocated to *Maticora*, a genus synonymized under *Calliophis* by Slowinski et al. (2001). Coral snakes are small- to medium-sized snakes, slender, and brightly colored, with very small heads. Among them, the longest is *C. bivirgatus*, which reaches 185 cm (Das 2012). Both *C. intestinalis* and *C. bivirgatus* have been encountered from lowland to forest fringes, such as in agricultural areas, to submontane forests (<1,200 m asl). *C. gracilis* and *C. maculiceps* have been found in lowland forests but can also occur in submontane forests and plantations (<1,300 m asl). Bites by coral snakes are rare. Tweedie (1961) reported two isolated cases of coral snake bites in Java in Indonesia and Melaka in Peninsular Malaysia. The first case was an adult bitten by *C. intestinalis*, which survived after suffering severe pain and vomiting (Jacobson 1937). The second case was a 2-year-old child, who was bitten by *C. bivirgatus* and died two hours after envenomation (Harrison 1957).

Viperidae

Intense interest in the study of the Malaysian vipers in recent years by several independent (and often competing) investigators has generated an increase in species diversity to 16 species of eight genera, as opposed to nine species from three genera since the end of the twentieth century (Tweedie 1983; Stuebing and Inger 1999). The new additions include species described on the basis of new material, such as *Popeia buniana* from Pulau Tioman, Pahang, by Grismer et al. (2006); application of different species concepts and/or discovery of new characters, as in the case of *Parias malcolmi* (cf. Stuebing and Inger 1998); as well as recognition of cryptic diversity within larger complexes during the course of faunal revisions, such as *Popeia popeiorum* and *Trimeresurus puniceus* (see Vogel et al. 2004; David and Vogel 2006). After a prolonged period of retention of the large number of the so-called green pit vipers within the genus *Trimeresurus*, Malhotra and Thorpe (2004) suggested a new taxonomy, including the recognition of seven genera. David et al. (2011) discussed the new taxonomy, choosing to retain the names proposed at subgeneric, rather than generic, levels; throwing in a caveat that the allocation to genera or subgenera remains open to discussion; and advancing merits and demerits of both decisions. In this essay, these novel generic names are retained, as they reflect distinct evolutionary lineages, the placement of which into a single genus would obscure their relationships. The latter authors' philosophy that "...recognizing 'genera' that cannot be diagnosed morphologically is not helpful to practicing taxonomists, especially when they do not have access to molecular facilities" is not followed, as the role of systematics should not be

facilitation, but recovering evolutionary relationships. Certainly, combining morphological with molecular and ecological data (see example in Sanders et al. 2006) has greatly enriched our knowledge of these interesting species.

Among the vipers, the Malayan pit viper (*Calloselasma rhodostoma*) is the most common among the 16 species known. This species is confined to the northern states of Perlis and Kedah in Peninsular Malaysia. It is terrestrial, its diet comprising rats, birds, and, more occasionally, fish and frogs. Radiotelemetric studies on the species, one of few snake species to be thus studied in the region, show a relationship between ambient relative humidity (rather than temperature, precipitation, or lunar cycle) and local movement (Daltry et al. 1998).

The mangrove pit viper (*Cryptelytrops purpureomaculatus*) is another common species of pit viper. It primarily inhabits mangrove forests and has also been found in peat swamp forests throughout Peninsular Malaysia. It is semiarboreal, its diet similar to that of the aforementioned species.

The other Malaysian species of pit vipers are patchily distributed throughout the country. They primarily feed on warm-blooded prey species, such as rats and birds. Stomach contents of *Parias hageni* and *P. sumatranus* and *Ovophis convictus* have shown remnants of the slender tree squirrel (*Sundasciurus* sp.), as well as gekkonid lizards.

Apart from the venomous land snakes of the families Elapidae and Viperidae and a few species of the genus *Rhabdophis*, there are several species of nonvenomous land snakes of the family Colubridae that have been reported to be mildly venomous. These are the mangrove snake (*Boiga dendrophila*) and mock viper (*Psammodynastes pulverulentus*). According to the Orang Asli (introduction to these indigenous people of the Malay Peninsula in Knox et al. 1996) and local snake handlers, bites by these snakes have caused severe pain and, in some cases, are accompanied by vomiting and headaches. It is, thus, possible that there are other seemingly harmless snakes but are actually mildly venomous.

Distribution and Status

Among the elapids, *Naja sumatrana* and *N. kaouthia* are not habitat specific. The former species is widely distributed throughout Malaysia, while the latter species is restricted to the northern parts of Peninsular Malaysia. They appear adaptable to local environmental conditions and can persist in changed habitats, where prey species may be more easily assessable. In recent years, *N. kaouthia* has been found further south of the country, from urban, suburban, and rural areas in the west and east coasts of Peninsular Malaysia. However, this species is yet to be encountered in forest habitats of these areas. The dispersal of this northern inhabitant species is suspected to be due to escapees from the trade, which obtains the snake from either the northern parts of the country or from southern Thailand to be traded as food for the local and overseas market. With time, this species is likely to be established throughout the peninsular portion of the country.

The rest of the elapid species, *Ophiophagus hannah* as well as species of *Bungarus* and *Calliophis*, are more habitat specific, being primarily forest inhabitants. Although common and widely distributed throughout the country, the density of each of these species may fluctuate corresponding to deforestation.

Calloselasma rhodostoma is the most common viper in Malaysia. In the last 15 years, this northern species has been collected on Bukit Larut, in the state of Perak. In 1990, individuals were collected around human habitations in Cheras, Kuala Lumpur, and in secondary and disturbed patch of forest surrounding the headquarter building complex of the Department of Wildlife and National Parks (DWNP) (Jasmi and Lim 1991). In 2010, roadkills of four juveniles and two adults were collected along the road toward DWNP. Its presence in Kuala Lumpur could derive from dealers who transported this species from the northern states for sale as food, for transhipment overseas, and for breeding or sale to zoos. However, the finding of this snake in Kuala Lumpur, especially the juveniles, indicated that this species has probably established itself in the forested areas around the country's capital. Significantly, in the last 10 years, the density of this species has dwindled within its natural range, due to the many plots of rice fields being developed into monoculture plantations.

Another common species of viper, *Cryptelytrops purpureomaculatus*, is restricted to mangrove and peat swamp forest. The density of this viper appears to be affected by the harvest of mangrove forest trees for commercial purposes; on the other hand, its density may be higher in peat swamp forests that are protected from deforestation. This species has also been reported from many offshore islands, such as Pulau Sembilan (Norhayati pers. obs.), Pulau Jarak (Daicus pers. obs.), and Pulau Langkawi (Lim et al. 2010).

The other vipers are forest inhabitants, and some are associated with highlands, with endemics of specific areas, while others are more widely distributed throughout the country. Those species that are inhabitants of low and hill forest up to 800 m asl. may be threatened by transformation of habitat, caused by logging and urbanization.

Conservation

There might be some disagreement in some quarters where conservation of the snake fauna, particularly of venomous land snakes, is mentioned. This appears due to reputation of snakes themselves, perhaps derived from irrational fear and societal conditioning. However, if knowledge held by a few of the economic importance of snakes, as predators of crop pests and as essential parts of a working ecosystem, in addition to their great diversity, is disseminated more widely, perhaps the rationale for conserving these maligned animals would be better appreciated. Snakes also offer excellent examples as models to test ecological and evolutionary theories (see, for instance, Sanders et al. 2004).

The association between many snakes, venomous as well as harmless, and rats is well known. Among the venomous land snakes, 19 species (three members of the

Elapidae and 16 of the Viperidae), out of a total of 26 species, feed primarily on rodents. It must be borne in mind that this is more than economic importance (rodents destroy significant amount of standing and stored grains), since rodents of various species are dangerous reservoirs of diseases. The potential rate of increase of jungle and field rats exceeds that of most mammals, and if it were not for natural predators to help control their numbers, the rat problem would be much more severe. In turn, snakes themselves may be responsible for eliminating their own excessive numbers by feeding on one another, as do *Ophiophagus hannah*, as well as species of *Bungarus* and *Calliophis*. It is quite obvious that snakes (venomous and harmless snakes) do more good than harm in nature. Unfortunately, in spite of the valuable assistance they render and the small danger they constitute, they are widely perceived as dangerous and the good they do remains unknown. This ignorance can be overcome in large measure by producing programs on the natural history of snakes, emphasizing their great beauty and diversity, as well as integral role in many ecosystems, for school children in their natural history lessons. At the same time, the general public and medical doctors involved in the treatment of snake bite should be made aware of the differences between the venomous and harmless snakes.

Conclusion and Future Direction

Life-threatening bites to humans can be given by at least 26 species of terrestrial snakes, belonging to two families (the elapids and vipers) in Malaysia. Additionally, some members of an otherwise nonvenomous group (the natricids) may be dangerously venomous, particularly a few species of the genus *Rhabdophis*.

Bites by several species produce extremely serious and potentially fatal results in human beings. These are the three species each of the cobras (*Ophiophagus hannah*, *Naja kaouthia*, and *N. sumatrana*) and kraits (*Bungarus candidus*, *B. fasciatus*, and *B. flaviceps*) of the family Elapidae and one species of the viper (*Calloselasma rhodostoma*) of the family Viperidae. The four species of coral snakes (*Calliophis bivirgatus*, *C. gracilis*, *C. intestinalis*, and *C. maculiceps*) among the elapids, based on two cases of bites, one each of *C. bivirgatus* and *C. intestinalis*, are known also to be of importance for human health. Bites have resulted in death and excruciating discomfort, respectively.

Human mortality associated with the bite of most arboreal vipers (with the exception of the relatively toxic *Cryptelytrops purpureomaculatus* and *Tropidolaemus wagleri*) may be primarily due to clinical complication of individual cases during treatment. Little is known of the effects of envenomation by most local pit viper species or their potency.

With the widespread use of contemporary analytical approaches (such as multivariate morphometrics and their combined use with mtDNA sequences), it is envisaged that the systematics of cryptic species would be resolved further in the future, including the recognition of cryptic species and stability of higher classification among the venomous snakes of Peninsular Malaysia and of Sarawak and

Sabah. Parallel to such advanced approaches, it is equally important that basic research be augmented in fields as diverse as ecology, ethology, population biology, evolution, and many others.

In biological research, an elemental understanding of the subject is critical. In this case, the ecology of the snake necessitates the acquisition of masterful knowledge of functions, interactions, and relationship of the concerned organism with its natural environment, as well as awareness of the utility of such knowledge for human welfare. In this context, some suggestions on future direction for research have been made:

1. To increase the knowledge of species diversity, the curation of specimens from the field becomes essential. It is through the establishment of natural history museums and specimen acquisition that information on habitats, interaction with their prey, and their relative abundance, and many other topics can be gathered.
2. Venom should be extracted from live specimens for studies on toxicity and for other medical usage especially antivenom production.
3. Tissues from freshly euthanized specimens can provide material for systematic research and should be added to the protocol for all material being acquired. For instance, blood direct from the heart and tissues of specific organs can be used for studies of relationships within species (phylogeography), recognition of cryptic species or higher taxonomic relationships. All specimens used for research need to be preserved as permanent vouchers, with all relevant documentation.
4. The need of the day is the creation of an institute of toxicology, perhaps established as a regional center for Malaysia and including expertise for species occurring both in Peninsular Malaysia and in Sabah and Sarawak. Apart from the study of venom of vertebrate and invertebrate species, such a center can synergize with other existing institutes in the region and perhaps in the future produce vaccine for the treatment of noxious venomous animals, including Malaysia's venomous snakes.

Cross-References

► Venomous Snakes and Envenomation in Brunei

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