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Redescription of *Naja siamensis* (Serpentes: Elapidae), a widely overlooked spitting cobra from S.E. Asia: geographic variation, medical importance and designation of a neotype

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(With 4 plates and 2 figures in the text)

The Indochinese spitting cobra, *Naja siamensis* Laurenti, 1768, is redescribed. In order to avoid future confusion with other Asiatic *Naja* species, and to fix this scientific name irrefutably, we designate a neotype for this species, and designate the same specimen as neotype for the junior synonym *Naja naja isanensis* Nutaphand, 1982. The pattern of geographic variation in this species is investigated by means of multivariate analysis of morphological characters. We summarize the literature concerning this species, with particular emphasis on separating information concerning *N. siamensis* from that relating to other Asiatic cobra species. This species is of considerable medical importance, and we present case histories of local envenoming and snake venom ophthalmia.

Introduction

The systematics of the Asiatic species of *Naja* have a history of extreme confusion. Nowhere is this more so than in Indochina (for the purposes of this paper, taken to mean Thailand, Cambodia, Laos and Vietnam). The cobras of this region comprise an astonishing array of colour 'forms', which may or may not correspond to variation in other character suites, such as scalation, body proportions, or the occurrence of spitting behaviour. Various authors have applied a number of specific and subspecific epithets to the cobra populations of this area, but no consistent picture of the systematics of these snakes has emerged until now.

Until recently, most authors (e.g. Smith, 1943; Klemmer, 1963; Taylor, 1965; Harding & Welch, 1980; Golay, 1985; Welch, 1988) listed all cobras of this region as belonging to the single taxon *Naja naja kaouthia*. More recently, others noted the sympatric occurrence of several cobra taxa in parts of Indochina, in particular Thailand (Nootpand, 1971; Nutaphand, in Tumwipat & Nutaphand, 1982; Warrell, 1986; Lingenhöle & Trutnau, 1989). However, owing to the enormous variation in many characters, especially colour pattern, much confusion over the affinities and classification of these forms persisted.

Multivariate analysis of morphological characters (Wüster, 1990; Wüster & Thorpe, 1991)

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demonstrated that two species are found in broad sympatry in much of Indochina: the monocellate cobra (*Naja kaouthia* Lesson, 1831), and a previously largely overlooked, superficially highly variable spitting cobra, which was referred to as the "Indochinese spitting cobra". This form includes a number of distinctive colour varieties, including brown, black, greenish-olive and contrastingly black and white specimens. The species was better defined by means of comparative mtDNA sequencing (Wüster & Thorpe, 1994; Wüster *et al.*, 1995) and assigned the scientific name *Naja siamensis* Laurenti, 1768 by Wüster & Thorpe (1994).

The name assignation was based on the description by Laurenti (1768) of a cobra from "Siam" (Thailand), with spectacle marks, as *Naja siamensis*. Laurenti's full description is as follows: "Perspicillo uncinulum referente; corpore cinereo-gryseo; summo dorso ruffo. Habitat in Imperio Siam, & Insulis Ternateis". This description was based on engravings of two cobras with a spectacle marking on Plate 89 of Volume II of *Seba's Thesaurus* (Seba, 1735) (Plate I), the first specimen originating from "Siam", the second from Ternate Island, Moluccas, present-day Indonesia. The specimens depicted by Seba are not known to exist at the present time. There are no records of cobras from the Moluccas, and, in view of this and the name given to the species, it is clear that "Siam" is the intended type locality of the species. Of the cobras found in Thailand, only the Indochinese spitting cobra normally has a spectacle-shaped hood mark, and the name *Naja siamensis* can therefore be

PLATE I. First depiction of *Naja siamensis*, in plate 89 of Vol. II of Seba (1735). The specimen illustrated served as one of two types for Laurenti's (1768) description of *Naja siamensis*, the only cobra found in Thailand which regularly features a spectacle-shaped hood marking.

firmly linked to this species. *Naja kaouthia* normally has a circular (monocellate) hood mark, spectacles being highly exceptional (see Cox, 1991, for hood mark illustrations), and *N. sumatrana* always lacks any kind of hood mark. Although *N. siamensis* with spectacle markings are common in parts of Thailand, practically all previous workers only noted spectacle marks in cobras from the Indian subcontinent. As a result, *N. siamensis* has generally been regarded as a synonym of the Indian *N. naja*.

Wüster (1992) proposed the vernacular name "Indochinese spitting cobra" for this species as a whole (several other vernacular names have been used for the various colour phases of this species, especially among herpetoculturists). In the following paragraphs, we will use this term to refer to the animal itself, in contradistinction to the various proposed scientific names.

Those recent workers who noted the distinct nature of the spitting cobras of Indochina were often led by the very considerable geographic variation in the colour pattern of this species to assign different populations to different taxa. Most of these names are clearly not available for this species, since they refer unambiguously to other Asiatic *Naja* species. The only name other than *Naja siamensis* Laurenti which is available for the Indochinese spitting cobra is *Naja naja isanensis* Nutaphand, in Tumwipat & Nutaphand (1982). The distribution of the subspecies was stated to include the Thai provinces of Khon Kaen, Mahasarakam, Kalasin, Roiet, Sisaket and Chaiyaphum, all in north-eastern Thailand. No type locality or type were designated, but a photograph labelled "*Naja naja isanensis*", showing a cobra with an indistinct spectacle mark on the hood, clearly depicts an Indochinese spitting cobra. The specimens used for the definition of the form were not preserved and do not exist today (Wirot Nutaphand, pers. comm.).

The combination of two names which are, or appear to be, available for the Indochinese spitting cobra, and the lack of type specimens for either, result in a potential for considerable nomenclatural instability. *Naja siamensis* Laurenti, 1768 is clearly the oldest potentially available name, but can only be definitely applied to the Indochinese spitting cobra on the basis of the combination of spectacle-shaped hood mark and its purported origin from Siam/Thailand. On the other hand, the continued existence of the name *Naja siamensis* Laurenti, 1768 as a *nomen dubium* would threaten the stability of *N. n. isanensis* Nutaphand, 1982, if the latter were to be adopted. Since the name *N. n. isanensis* Nutaphand, 1982, has had minimal impact in the scientific literature, it is our opinion that the interests of nomenclatural stability are best served by using the oldest potentially available name, *N. siamensis* Laurenti, 1768, and irrefutably fixing its status by designating a suitable neotype, as provided by Article 75, and particularly Recommendation 75E, of the International Code on Zoological Nomenclature (International Commission of Zoological Nomenclature, 1985). For the further stabilization of the nomenclature, it is desirable to ensure that all later names be made unambiguous synonyms of the older name. In the absence of a holotype for the junior name, this can be achieved by designating the neotype of *N. siamensis* Laurenti, 1768 as neotype of *N. n. isanensis* Nutaphand, 1982 as well. This requires that description and locality correspond to those of the junior names (Article 72(d) of the Code). This then reduces the junior synonym to objective synonymy of the senior synonym, thus settling the question.

In this paper, the species *N. siamensis* Laurenti, 1768 is redescribed, and a neotype is designated for the purposes of stabilizing the name of this form. The same specimen is also designated as neotype for *N. n. isanensis* Nutaphand, 1982, reducing this name to objective synonymy of *N. siamensis*. In addition, we investigate the pattern of geographic variation found in this extremely variable species, using multivariate analysis of morphological characters.

Since the presence of a previously unrecognized or misidentified species occurring in sympatry with *N. kaouthia* has considerable implications for toxinology and the treatment of snakebite patients in South East Asia, we summarize existing information on the medical importance of *N. siamensis*,

present case histories of a bite and a case of snake venom ophthalmia, and discuss the implications of the recognition of this species for toxinological research.

Materials and methods

Materials and character choice

Specimens of *Naja siamensis* were obtained from a number of museums in the United States and Europe, as well as from private sources in Thailand. A list of specimens examined was published in Wüster *et al.* (1995). Thirty-five morphological characters relating to scalation, colour pattern, internal anatomy and body proportions were recorded from each specimen. These correspond to characters 1–33 in Table I in Wüster *et al.* (1995), and additionally include the following 2 characters: the %VS position of the last ventral of the light throat area of each specimen, and the %VS width of the dark ventral band behind the light throat area. In addition, for descriptive purposes only, the neck region of some specimens was X-rayed, and the rearward extension of the 10th rib was estimated in units of cervical vertebrae (to the nearest 0.5 vertebra), the mean of both sides being used.

Multivariate methods

In order to investigate the pattern of geographic variation in meristic characters in *N. siamensis*, a principal components analysis (PCA) was run on the characters recorded from available specimens. Male and female specimens were analysed separately, in order to avoid problems due to sexual dimorphism.

PCA 1 was run on the male specimens of *N. siamensis*, using characters 1–33 of Wüster *et al.* (1995). PCA 2 was run on female specimens, using characters 1–16 and 33 of Wüster *et al.* (1995) and the 2 new characters introduced earlier. The lower number of characters used in PCA 2 is because the only 2 specimens from north-eastern Thailand had their internal organs removed before preservation.

Results

PCA 1 shows a clear pattern of geographic variation in male *N. siamensis* (Fig. 1): specimens from the Central Plain of Thailand are to a large extent distinct from specimens from the north and north-east of the country; specimens from Khok Samrong, at the eastern edge of the Central Plain, are phenetically intermediate between other Central Plain specimens and those from the north-eastern parts of the country, as are those from south-eastern Thailand and Vietnam. PCA 2 reveals essentially the same pattern (Fig. 1). Note the relatively tight clustering of specimens from the eastern parts of the range, i.e. southern Vietnam and Cambodia.

Despite the relatively clear pattern of geographic differentiation in morphology revealed by these PCAs, there is no geographic variation in cytochrome oxidase I sequence (mtDNA) between the different populations of this species (Wüster *et al.*, 1995). This suggests that the strong pattern of geographic variation in morphology cannot be attributed to separate ancestry (phylogenesis) of the various 'forms'. There is no evidence of a separate evolutionary history for the different varieties found within this species. This strongly suggests that these superficially very different varieties, classified as different taxa by a number of previous workers, in reality comprise one single species. We similarly feel that it would be inappropriate to recognize any subspecies of *N. siamensis*.

Redescription of ***Naja siamensis***

Naja siamensis Laurenti, 1768: 91. Based upon Seba, 1735: 95, pl. 89, figs 1–2.

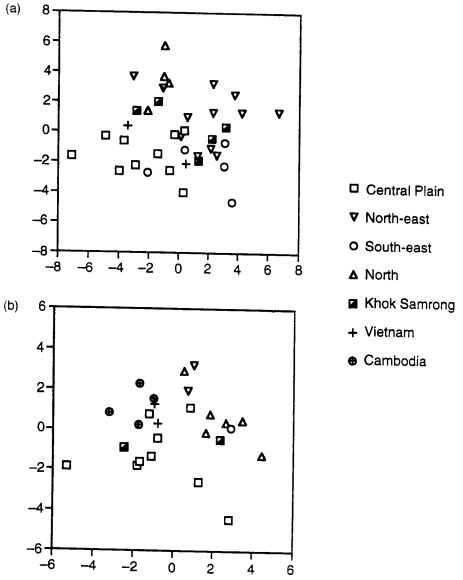

FIG. 1. Ordination of the component scores of (a) male and (b) female specimens of *Naja siamensis* along the first two principal components of PCAs 1 and 2.

Naja naja kaouthia (variety C) Taylor, 1965: 954.
Naja tripudians Nootpand, 1971: 21.
Naja oxiana Nootpand, 1971: 21.
Naja naja sputatrix Nutaphand, in Tumwipat & Nutaphand, 1982: 65.
Naja naja isanensis Nutaphand, in Tumwipat & Nutaphand, 1982: 67. (Type locality: provinces of Khon Kaen, Mahasarakham, Kalasin, Roiet, Sisaket and Chaiyaphum, Thailand; here restricted to Ban Phai District, Khon Kaen Province, Thailand, by neotype selection).
Naja isanensis Nutaphand, 1986 (unpaginated).
Naja sputatrix atra Lingenhöle & Trutnau, 1989: 9.
Naja sputatrix isanensis Lingenhöle & Trutnau, 1989: 9.
Naja sputatrix Jintakune *et al.*, 1990: 557.
Naja atra Wüster & Thorpe, 1991: 205.

Naja cf. *atra* Wüster & Thorpe, 1992*b*: 425.
Naja sp. Golay *et al.*, 1993: 192.
Naja siamensis Wüster & Thorpe, 1994: 75.
Neotype: BMNH 1987.678, an adult female, collected by D. A. Warrell (Plate II). The snake was brought to Ban Phai district hospital by a patient bitten by the specimen.
Type locality: "Imperio Siam & Insulis Ternateis", *fide* Laurenti, 1768: 91. Here restricted to Ban Phai District, Khon Kaen Province, Thailand, by neotype selection.

The same specimen is hereby designated as neotype of *Naja naja isanensis* Nutaphand, 1982. The specimen fulfils the requirements of having a spectacle-shaped hood mark, thus conforming to the descriptions of Laurenti (1768) and Nutaphand (in Tumwipat & Nutaphand, 1982), and of originating from a locality compatible with the original descriptions of both forms.
Dimensions: snout-vent length 795 mm, tail length 141 mm.
Scalation: 168 ventrals, 49/50 subcaudals, all divided; anal entire.
Dorsal scale row reduction formula: 27 7+8(12/14) 25 7+8(16/17) 23 6+7(20/20) 21 5+6(84/91) 19 5+6(109/112) 17 4+5(119/121) 15 4+5/5+6(141/145) 13 +4(165/163) 15.
Caudal scale row reduction formula: 12 1+2(2) 11 1+2(3/3) 9 5+6(3) 8 4+5(6) 7 3+4(9) 6 2+3(20/21) 4 1+2(48/49) 2.
Head scalation: 7/7 supralabials, third and fourth enter orbit, third contacts both nasal and orbit; 8/8 infralabials (excluding cuneates); one small cuneate inserted between the mouth edge and infralabials 4 and 5 on each side; nasal almost completely divided by nostril, which is large and in the shape of a vertical slit; one preocular, three postoculars; preocular in contact with nasal and internasal; prefrontals of approximately the same size as the internasals; frontal longer than broad (7.2 × 5.0 mm), slightly

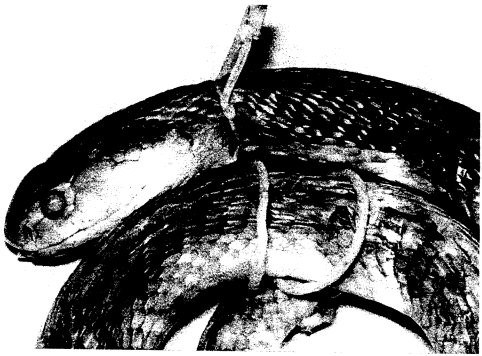

PLATE II. Neotype of *Naja siamensis* Laurenti, 1768 and *Naja naja isanensis* Nutaphand, 1982. Female specimen from Ban Phai District, Khon Kaen Province, north-eastern Thailand (BMNH 1987.678). The anterior part of the spectacle-shaped hood mark is visible on the right, albeit indistinctly.

shorter than its distance from the rostral (7.5 mm) or the interparietal suture (7.6 mm); 2/2 anterior temporals, the lower larger and approaching mouth edge; 4/4 posterior temporals; 10 temporals and nuchals contact the posterior and lateral edges of the parietals; anterior chin shields contact first four infralabials; posterior chin shields slightly longer but narrower than anterior.

Dorsal pattern (after preservation; live specimens from north-east Thailand are similar): head khaki, sides lighter than upper surface, otherwise uniform except for indistinct darker edge on upper posterior edges of third and fourth supralabials; ground colour of dorsal side of body greyer than head; interstitial skin darker than scales, except in areas comprised of lighter markings; dorsal side of body with faint lighter variegations having a tendency to form backward-pointing double chevron bands.

Throat and ventral pattern: first 16 ventrals mostly cream-coloured; ventrals 17–20 totally covered in dark pigment, ventral 21 largely so, forming a conspicuous band across the throat; remainder of venter largely cream-coloured, with indistinct darker marbling; outer tenth to sixth of most ventrals of same colour as dorsal side of the animal; in the light throat area, the cream coloured area encroaches on the first three dorsal scale rows on each side of the animal; it is separated from the dorsal ground colour by a blackish-grey line 2–3 dorsal scales wide; the outer edges of the 10th–12th ventrals and the lower two-thirds of the adjoining lowest dorsal scale row are covered in blackish-grey pigment, forming an elongate lateral spot on each side of the throat.

Hood mark: the hood mark is in the classical spectacle shape, consisting of two light ocelli with dark centres, whose posterior edges are linked by a posteriorly convex light chevron; the lowest scale row involved on each side is the eighth, the maximum width of the hood mark is 11 scale rows; the hood mark extends from the level of the 13th to the 20th ventral scale.

Dentition: 7 palatine teeth, 18 pterygoid teeth, 15 dentary teeth; one solid maxillary tooth behind the fang (data from one side only). Fang length: 4.09 mm; fang discharge orifice length: 0.46 mm.

Diagnosis

Only one species, the monocellate cobra (*N. kaouthia*), is known to occur sympatrically over much of the range of *N. siamensis*. *N. siamensis* differs from *N. kaouthia* in having a lower number of ventral scales (153–174 vs. 170–197), a different hood mark (spectacle- U-, V- or H-shaped vs. monocellate or mask-shaped), a differently-shaped frontal scale (elongated, posterior end forms acute angle vs. squarish, posterior end forms obtuse angle), fewer cuneate scales (usually one on each side vs. often two or three on each side), a smaller average size (about 90–130 cm vs. 120–150 cm) and in the frequency of spitting behaviour (very common vs. practically unknown) (Wüster & Thorpe, 1992*b*, 1994). *Naja siamensis* is an extremely variable species, especially in its pattern, and this can make some specimens difficult to separate from some of the other cobra species of S.E. Asia.

Many of the other species of Asiatic *Naja* can be distinguished from *N. siamensis* with relative ease: (i) *N. naja* can be superficially similar to brown specimens on account of its spectacle-shaped hood mark, but has almost consistently higher ventral (>170) and subcaudal (>52 in males, >49 in females) scale counts and does not spit; (ii) *N. oxiana* also has consistently higher ventral (>190) and subcaudal (>57) scale counts, always lacks a hood mark and does not spit; (iii) *N. sumatrana* has consistently higher ventral scale counts (>178) and always lacks a hood mark; (iv) *N. samarensis* has a very distinct colour pattern consisting of fine yellow reticulations on the interstitial skin, a very broad throat band starting within the first 10 ventrals, and only 17–23 dorsal scale rows at the level of the 10th ventral; (v) *N. philippinensis* always has more than 180 ventral scales, and lacks a distinct pattern; (vi) *N. sagittifera* has higher subcaudal scale counts (>59), a distinct pattern consisting of chevron

markings along the flanks (at least in juveniles), and a monocellate hood mark, rather than the spectacle or chevron mark seen in *N. siamensis*.

The most difficult cobras to distinguish from *N. siamensis* are the Javan populations of *N. sputatrix* and some specimens of the Chinese cobra (*N. atra*). Javan *N. sputatrix* tend to have higher ventral scale counts (often over 170) and lower dorsal scale row counts around the neck at the level of the 10th ventral scale (often 25 or fewer in *N. sputatrix*; usually 27 or more in *N. siamensis*). Javan *N. sputatrix* measuring over about 550 mm in total length normally lack a hood mark. In most adult specimens of *N. sputatrix*, there is no clearly defined light throat area; even if there is, it is generally very dusky and indistinct, and the dark spots at the outer edges of the ventrals and the lower dorsal scale rows are often missing in *N. sputatrix*. *Naja siamensis* often has several dark bands crossing the ventral side, whereas *N. sputatrix* has at most one. In Javan *N. sputatrix*, the posterior portion of the ventral side is of approximately the same hue as the dorsum, whereas in most *N. siamensis*, it is lighter than the dorsum. *Naja sputatrix* never has any light crossbands on the dorsal side (except, on rare occasions, a light band behind the hood), *N. siamensis* often shows cross-banding or reticulations.

Naja atra can also present some identification problems, as it overlaps with *N. siamensis* in most scale counts. In *N. atra*, the hood mark is usually present and obvious (frequently absent or very indistinct in *N. siamensis*), and is frequently connected to the light throat area through a light lateral extension to the anterior or central part of the hood mark on one or both sides; in *N. siamensis*, the only examples of hood marks linked to the throat occur in black and white specimens with an H-shaped hood mark, where the posterior end of the mark can occasionally form a link to the light throat or ventral colour. The hood mark of *N. atra* is generally situated in a more anterior position than in *N. siamensis*, having its anterior edge situated at the level of ventrals 4–9 (7–13 in *N. siamensis*) and its posterior edge at the level of ventrals 10–16 (14–21 in *N. siamensis*). *Naja siamensis* never has a mask or monocle-shaped hood mark, unlike many *N. atra*. The typical throat pattern, consisting of a light throat area with a lateral spot on each side, and a dark band several ventrals wide at the end of the throat area is generally present in *N. atra*, but may be absent or ill-defined in *N. siamensis*. *Naja atra* is also a more heavily built snake, with a narrower hood than *N. siamensis*, and rarely spits (see Wüster & Thorpe, 1992*b* and references therein).

Variation

Naja siamensis displays considerable geographic and individual variation in many characters. The total range of variation in a number of quantitative characters is summarized in Table I. Geographic variation in qualitative characters, especially colour pattern, is discussed in the following paragraphs.
Size: most adult specimens measure 90–130 cm in total length. The longest specimen recorded appears to be a male measuring 1600 mm in total length, reported from Trapeang Chan, Cambodia, by Saint Girons (1972*a*).
Colour pattern: *Naja siamensis* displays a bewildering array of colour morphs, with a considerable geographic component to their occurrence.

In many localities of the Central Plain of Thailand, this species features a brightly contrasting black and white pattern. In these populations, the ventral surface is mostly white, with or without black or dark brown bars across the ventral surface. The back of adults is usually predominantly black in this colour phase. However, Cox (1991) noted that at least some juveniles were predominantly white, and acquired more black pigmentation as they grew. We have also seen other specimens with a dorsal pattern consisting of black (or dark grey) and white speckling. In other specimens, the dark dorsal colour is interrupted by a number of light cross bars (Plate III). In specimens without such a pattern, the

TABLE I

Range of variation of selected quantitative characters in ***Naja siamensis***

	♂♂	♀♀
Ventrals	153–174	162–173
Subcaudals	47–54	41–51
Cuneates	Usually one each side	
Nuchals + temporals contacting parietals	7–13	6–11
Dorsal rows at 10th ventral	25–31	26–29
Dorsal rows at 20% VS length	19–21	
Dorsal rows at 40% VS length	19–22	
Dorsal rows at 80% VS length	13–15	
Palatine teeth	6–9	
Pterygoid teeth	14–18	
Dentary teeth	12–16 (usually 14)	
Last ventral of light throat area	12–17	
No. of ventrals in first throat band	3–9	
Ventral scale position of anterior hood mark edge	7–13	
Ventral scale position of posterior hood mark edge	14–21	
Ventral scale position of lateral throat spots	7–12	
Posterior extension of 10th cervical rib	5.5–7 vertebrae	

VS: ventral scale

lower 1–2 dorsal scale rows are often of the same light colour as the ventral surface, and the ventral surface may be entirely white. Some specimens show a dorsal coloration consisting of irregular black and white spots. A hood mark is absent in most of these specimens, or it may be spectacle-, U-, V- or H-shaped. The typical cobra throat pattern, consisting of a light throat area with a lateral spot on each side of the throat, terminated by a dark band across the throat, is often absent in black and white specimens. In many individuals, the middle of the ventral scales under the throat may have a dark spot, giving the impression of a somewhat ragged, elongated, median black spot under the throat. The level of contrast of the pattern is highly variable. Specimens of this black and white colour form have been recorded from the Thai provinces of Samut Prakan, Suphan Buri, Nakhon Sawan, Chainat, Kamphaeng Phet, Uthai Thani and Phitsanulok, and they are likely to be found in many adjoining provinces.

Other specimens from the central plain and surrounding areas may exhibit a less contrasting version of the pattern described above (Plate III), or may be uniformly brown, with or without a hood mark). In the north and north-east of Thailand, most specimens are some shade of medium or light brown or olive, or even greenish-olive (Smith, 1943). Most specimens of this morph have a more or less conspicuous U-, V- or spectacle-marking on the back of the hood, and have the typical cobra throat pattern, although this may appear rather washed-out or indistinct. This description also applies to most specimens of this species in Vietnam and Cambodia.

Specimens from south-eastern and western Thailand are often rather dark, with or without a spectacle-shaped hood mark (Plate III). Some are uniformly blackish-brown (south-eastern Thailand—provinces of Chon Buri, Chanthaburi and Rayong) or black (western Thailand—provinces of Phetchaburi, Ratchaburi and Kanchanaburi). These black specimens often appear glossier than specimens from other parts of the range.

The shape of the hood mark is variable, but by far the most frequently encountered shape is that of a spectacle marking (defined as two light ocelli linked by a posteriorly convex light U- or V-shaped mark (Plate III). However, V-, U- or H-shaped marks also occur (Plate III). The hood mark may be vestigial, reduced to a few white flecks or absent altogether.

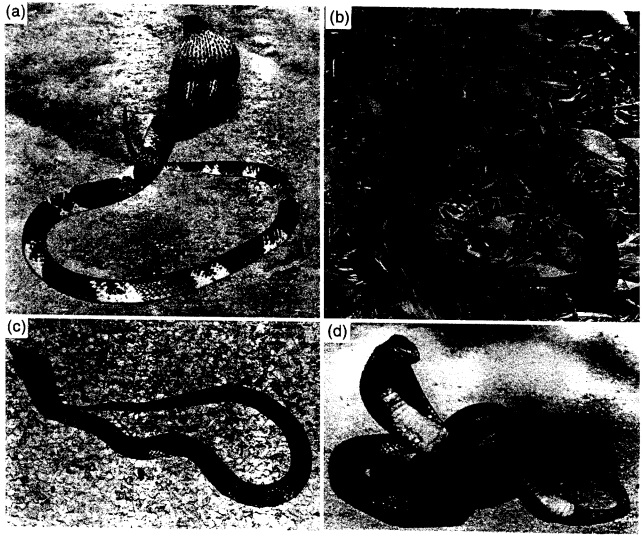

PLATE III. Variation in the pattern of *Naja siamensis*. (a) Specimen from Ta Khli District, Nakhon Sawan Province, central Thailand, illustrating the black and white pattern commonly found in the central plain of Thailand. The light bands across the body are absent in many specimens of this phase. Note also the U-shaped spectacle mark, which is absent in many specimens of this colour phase (photograph W. Wüster). (b) Specimen from Hang Chat District, Lampang Province, northern Thailand. Note light dorsal colour and the spectacle-shaped hood mark (photograph W. Wüster). (c) Specimen from Si Thep District, Phetchabun Province, north-eastern Thailand. Note U-shaped hood mark (photograph W. Wüster). (d) Specimen of the black colour phase (locality unknown, probably western Thailand) (photograph M. J. Cox).

Scalation: there is a general tendency for specimens from the north-eastern part of the range to have lower ventral scale counts, and more scale rows around the hood. Specimens from the central plain and the south-western part of the range tend to have fewer dorsal scale rows, more ventrals, and a stronger tendency to have a few undivided subcaudals near the base of the tail.

Distribution

Naja siamensis has a wide distribution in Indochina (Fig. 2). In Thailand, it is found in most parts of the country, with the exception of the provinces situated on the Malayan Peninsula (Cox, 1991, pers. obs.; Viravan *et al.*, 1992). The most southerly records are from Phetchaburi Province (Cox, 1991;

Viravan *et al.*, 1992). It occurs throughout the north-eastern and northern parts of the country, and in many parts of the Central Plain, where it seems to be mostly restricted to slightly higher lying areas. It is also found in the south-east and in the western parts of the country. In general, it appears to occupy slightly higher and drier areas than *N. kaouthia* where the two species are sympatric. In Cambodia, it has been recorded from Trapeang Chan, in central Cambodia, near the Great Lake or Tonlé Sap (Saint Girons, 1972*a*). In Vietnam, it has been recorded from Can Ranh Bay (reference to spitting cobras: Campden-Main, 1970), and is apparently common in Phan Tiet Province (Trinh Xuan Kiem, pers. comm.). It appears to be rare or absent in the Mekong Delta and to the south thereof. However, two specimens reported by Saint Girons (1972*b*) from Ha Tien, extreme south-western Vietnam, near the Cambodian border, have ventral scale counts more compatible with *N. siamensis* than with *N. kaouthia*. The northern extent of its range in Vietnam unknown, due to the lack of collections from this area. There are no verified records from Laos, but the species almost certainly occurs at least in the lowlands of the Mekong drainage, along the Thai border. Similarly, it may well occur in eastern Burma along the Thai border, and possibly further inside the country. Wall & Evans (1900) reported a spectacled cobra from Myaungmya, Irrawaddy State, Lower Burma, and as this hood mark shape is exceptional in *N. kaouthia*, the specimen may well have been *N. siamensis*. Without scale counts, this is impossible to verify. Wüster & Thorpe (1992*a*, *b*) discussed some problematical specimens from north-eastern India and Burma, which may eventually turn out to be conspecific with *N. siamensis*.

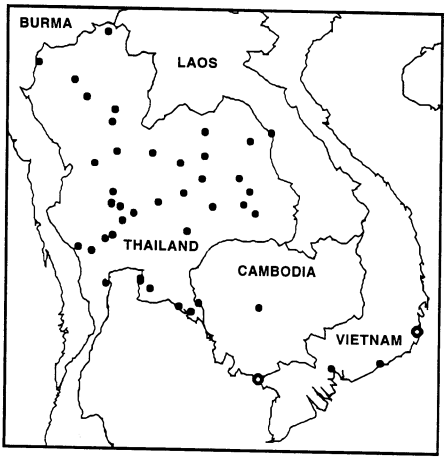

FIG. 2. Distribution of *Naja siamensis*. Solid symbols indicate localities from where the authors have seen specimens, hollow symbols indicate literature records deemed reliable. Although we have seen no specimens from Laos and Burma, the species is very likely to occur there.

Older literature data

Although *Naja siamensis* has remained largely unrecognized until recently, there is a considerable amount of published information available on this species, but it is often difficult to discriminate between data pertaining to this species and to the sympatric *N. kaouthia*. It is in fact remarkable how many herpetologists came into contact with *N. siamensis* during fieldwork in Thailand or elsewhere in Indochina, but did not note its identity as a distinct species. It is also remarkable how few specimens of this species were deposited in European and North American natural history collections, compared with *N. kaouthia*. No less than 65% of the specimens currently held in these museums were collected during a recent epidemiological survey in Thailand (Viravan *et al.*, 1992). This is despite the fact that this cobra is one of the commonest venomous snakes in Thailand, at least judging by its contribution to snakebite statistics (Viravan *et al.*, 1992), and the large numbers of specimens sold by animal dealers in Thailand. It also demonstrates the contribution clinicians can make to the development of herpetological systematics by collecting and preserving dead snakes brought by patients.

In the following paragraphs, we briefly survey some of the literature references to *N. siamensis*, with the aim of separating information on this species from that concerning other species. In the literature, *Naja siamensis* can be separated from *N. kaouthia* by its lower ventral scale counts, the shape of the hood mark, and the occurrence of spitting behaviour. However, reports of spitting need to be interpreted with caution: many authors writing about the cobras of a specific region mention spitting, but may be referring to the occurrence of spitting in Asiatic cobras in general rather than in the populations occurring in their specific region (see Wüster & Thorpe [1992*b*] for examples).

Smith (1943) assigned all cobras from Indochina and China to *N. n. kaouthia*; however, his specimen from Den Chai (BM 1938.8.7.61) is assignable to *N. siamensis*. Taylor's (1965) "*Naja naja kaouthia* variety C" is *N. siamensis* (var. A is *N. sumatrana*, the others *N. kaouthia*). Saint Girons' (1972*a*) "*N. n. kaouthia*" from Trapeang Chan, Cambodia, are *N. siamensis*; specimen IPC VIII is a *N. kaouthia*. Saint Girons & Pfeffer (1971, 1972) provide reproductive and ecological data on *N. siamensis*. Cox (1991) discussed *N. siamensis* as *Naja* sp.; the ventral scale counts given for the "Isan spitting cobra" are erroneous—north-eastern specimens have fewer than 170 ventrals.

Other references to *N. siamensis* include Gyldenstolpe (1916) (specimen from Chieng Hai); Taylor (1934) (specimen from Chiang Mai area); Campden-Main (1970) (spitting specimens from Cam Ranh Bay); Saint Girons (1972*b*) (specimens 1006 and 1007, from Ha Tien); Warrell (1986) (as *N. n. sputatrix*—only for specimens from Thailand; Malaysian "*sputatrix*" are assignable to *N. sumatrana*); Lingenhöle & Trutnau (1989) and Trutnau (1990) (as *N. sputatrix isanensis* and *N. sputatrix atra*); Jintakune *et al.* (1990) and Pochanugool *et al.* (1990) (as *N. sputatrix*); Golay *et al.* (1993) (as *Naja* sp.)

Naja siamensis *in toxinology and clinical science*

Until recently, physicians treating cases of snake bite in Thailand did not distinguish between the different colour forms or species of cobra responsible for bites in different parts of the country. However, experienced snake catchers and handlers working on snake farms around Bangkok associated the ability to 'spit' venom with the complete absence of nuchal markings or with a complete or partial 'spectacle' pattern, but not with the monocellate pattern of *N. kaouthia* (Warrell, 1986). In his book on venomous animals and the treatment of animal poisoning, Trishnananda (1979) illustrated a typical brown *N. siamensis* with partial spectacle marking ('ngoo how pon pit') and described the effects of venom 'spat' into the eyes, assuming them to be the same as reported for *N. nigricollis* in Africa (Warrell & Ormerod, 1976). However, it seems likely that effects of

N. siamensis venom are less severe than those of *N. nigricollis* as corneal abrasion, hypopyon and anterior uveitis have never been reported in Thai patients. In a national hospital-based survey of snakes responsible for bites in Thailand, carried out in the 1980s, 114 (10%) of 1,145 dead snakes brought to hospitals with the people they had bitten were identified as *N. siamensis* (referred to as *'N. atra'*, northern spitting cobra), compared to only 83 (7.2%) identified as *N. kaouthia* (Viravan *et al.*, 1992). Bites by *N. siamensis* occurred from Phetchaburi northwards and were recorded at 62.5% of all collaborating hospitals throughout the country, compared to only 25% for *N. kaouthia*. The total length of the specimens responsible for bites ranged from 210–1330 mm (mean = 852) and the male:female sex ratio was 1.8:1. Neurotoxic signs of envenoming recorded on the hospital questionnaires (ptosis and difficulty in breathing) were observed in 10.5% of *N. siamensis* bites, compared to 8.4% of *N. kaouthia* bites. Local swelling and necrosis (Plate IVa–c) were common after bites by both species, but many of the patients were followed up for too short a time to allow a precise assessment of the incidence of these effects. No human fatalities due to *N. siamensis* bites have been reliably recorded, whereas *N. kaouthia* is an important cause of snakebite death in Thailand (Looareesuwan, Viravan & Warrell, 1988; Viravan *et al.*, 1986). However, fatal bites by *N. siamensis* are certainly a possibility.

Case report 1: local envenoming from ***Naja siamensis*** *bite in Thailand*

A 13-year-old girl was bitten on the medial surface of her right calf while cleaning out a cupboard in her house in Amphoe Muang, Kanchanaburi (west central Thailand). The snake responsible was a 1,300 mm long male *N. siamensis*. She noticed immediate pain and early swelling. On admission to Pohonponpayuhasena Hospital, Kanchanaburi, 2½ hours after the bite, she had tenderness and swelling of the lower leg and a darkened area of skin at the site of the single fang mark. There were no neurological signs. She was treated with 10 vials (100 ml) of Thai Red Cross 'cobra' antivenom infused over 20 minutes, starting 5 hours after the bite. She developed an urticarial rash and chills 25 minutes after starting the antivenom and was treated with adrenaline and chlorpheniramine. On the next day, 18 hours after the bite, she was feverish, with a temperature of 38.3 °C; there was an enlarged darkened area of early necrosis and extension of swelling up to the knee. The total peripheral leucocyte count was $11.2 \times 10^9/l$ (92% neutrophils). To prevent infection, she was treated with penicillin and gentamicin and given a dose of tetanus toxoid. Two days after the bite the peripheral leucocyte count rose to $19.95 \times 10^9/l$ (neutrophils 95%) and blistering first appeared at the site of the bite. Four days after the bite, there was a continuous ring of blisters demarcating the necrotic skin (Plate IVb).

Case report 2: venom ophthalmia from ***Naja siamensis*** *'spit'*

A 29-year-old woman was collecting latex from a rubber tree at Amphoe Tamai, near Chanthaburi (eastern Thailand), when she disturbed what she described as a uniformly black cobra and was spat at from a distance of about one metre. Venom entered both her eyes but she washed it out almost immediately with water. There was immediate sharp pain, stinging and irritation in both eyes. When seen at Prapoklao Hospital, Chanthaburi, one hour after the accident, there was injection of the conjunctivae of both eyes, left more than right, with bilateral epiphora and leucorrhea and swelling of the left eyelid (Plate IVd). Visual acuity was normal. Slit lamp examination revealed conjunctival injection and superficial corneal opacities but no corneal abrasion and no abnormality of the anterior chamber. Chloramphenicol eye drops and ointment were prescribed and she made an uneventful recovery.

Bites by *N. siamensis* may occur even in western countries, as this is one of the Asian cobras which is commonly imported for herpetoculturists. For example, a 31-year-old man was recently bitten on the hand by a 25 cm long 'Indian spitting cobra' which he was keeping in his bedroom in London. This


(a)
(b)
(c)
(d)

juvenile snake was speckled with grey and white, with white ventrals, a black hood with a faint U-shaped mark, and two black throat bands. It was eventually identified as *N. siamensis* while the patient developed symptoms of local and systemic envenoming. The misleading information about the geographical origin added to the difficulties of identification and to the selection of appropriate antivenom treatment.

No specific antivenom is produced for the treatment of envenoming by *N. siamensis*, although paraspecific activity against '*N. sputatrix*' (= *N. siamensis*) is claimed for Thai Red Cross cobra antivenom (Theakston & Warrell, 1991); however, this was not confirmed by the studies in rodents referred to above (R. D. G. Theakston, pers. comm.). In the absence of any more specific antivenom, in a case of life-threatening neurotoxic envenoming by *N. siamensis*, it would be worth trying this Thai Red Cross cobra antivenom in an initial dose of 5–10 ampoules. Treatment with anticholinesterase might well improve neuromuscular transmission and, if bulbar/respiratory muscle paralysis developed, endotracheal intubation and mechanical ventilation would be essential to save the patient's life (Warrell, 1995).

No studies have been carried out on venom reliably attributed to *N. siamensis*. However, in the toxinological literature, there are numerous misleading references to the venom of '*Naja naja siamensis*', for example as the source of short- and long-chain post-synaptic toxins (Karlsson, Arnberg & Eaker, 1971). Since venom suppliers have not distinguished between different species of cobra in Thailand, the precise origin of '*Naja n. siamensis*' venom will remain obscure, but is more likely to have been *N. kaouthia* than *N. siamensis* because the former species is the more commonly collected. This has caused considerable confusion in the literature (e.g. Ohkura *et al.*, 1988; Namiranian & Hider, 1992). Research on the composition, toxins and neutralization of *N. siamensis* venom is needed, as are comparisons with the venoms of other Asian *Naja* species.

We particularly wish to emphasize that the designation *Naja naja siamensis* in the catalogues of venom and chemical suppliers should on no account be relied upon: the venom is far more likely to be from *N. kaouthia*, and may even represent a mixture of venoms from more than one species. We strongly recommend that clinical and toxinological researchers ensure that the snakes they are dealing with are identified by experts, and deposited in major natural history collections, so that their identification can be verified later and/or revised (Wüster & Thorpe, 1991; Warrell & Harvey, 1995; Wüster, 1996; Wüster & McCarthy, 1996). We also urge researchers in clinical medicine and toxinology, as well as suppliers of snake venoms, to collaborate with venomous snake taxonomists from the early stages of any project. This would ensure the purity and identification of the venoms from the very beginning of a study, avoiding the need to sort out a confused situation later. These recommendations apply to any complex group of venomous snakes, not just the Asiatic cobras.

Conservation status

Naja siamensis has a wide range, within which it appears to be relatively common in many areas, at

PLATE IV. Clinical effects of envenoming and snake venom ophthalmia by *Naja siamensis*. (a) Local swelling eight hours after a bite on the dorsum of the foot by a uniformly black-coloured specimen of *N. siamensis* near Kanchanaburi, Thailand (photograph Sornchai Looareesuwan). (b) Case 1. Ring of confluent blisters surrounding a blackened necrotic area (8 × 5 cm) four days after the bite (photograph R. E. Phillips). (c) Extensive necrosis of skin and subcutaneous tissue two weeks after a bite on the back of the hand by a specimen of *N. siamensis* near Ubon Ratchathani, north-eastern Thailand (photograph Sornchai Looareesuwan). (d) Acute bilateral conjunctivitis one hour after 'spit' by *N. siamensis* near Chanthaburi, south-eastern Thailand (photograph D. A. Warrell).

least judging by its importance in snakebite statistics (Viravan *et al.*, 1992). Furthermore, it survives well in agricultural areas, such as in rice fields, and in or near human settlements. Its survival as a species is therefore unlikely to be seriously threatened. However, it is subject to severe human predation, both as a result of being killed on sight by many agricultural workers reluctant to share their fields with spitting cobras, and also for the very substantial 'jungle food' and traditional medicine trade. Since rice fields and similar habitats can be efficiently searched for snakes, many local populations are likely to have gone extinct, or will do so in the near future. The colour pattern variation exhibited by this species in Thailand is a fascinating phenomenon, and its causation and genetics deserve much further study. This will be impossible if much of this variation is lost through excessive capture and killing of these cobras. The authors therefore feel that this species should be protected from further exploitation for what is, after all, a non-essential luxury trade.

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