

# Systematics and biogeography of the Asiatic cobra (*Naja naja*) species complex in the Philippine Islands

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**Abstract.** The population systematics of the cobras of the Philippines are investigated by canonical variate analysis and discussed with reference to recent work on the Indonesian populations. Three well differentiated taxa, the ranges of which correspond to those of the conventional subspecies of *Naja naja* in these islands, are shown to occur in the Archipelago: one form occurs on Luzon, Mindoro and Marinduque; the second on Samar, Leyte, Bohol, Mindanao and Camiguin; and the third on Palawan and Culion. The latter is considered to belong to the equatorial spitting cobra, *Naja sumatrana*. The other two form distinct taxa which probably deserve species status. The distribution of the three taxa can be related to Pleistocene sea levels. Each one occurs on a group of islands which were linked by land bridges during the middle and late Pleistocene.

**Key words.** *Naja*, population systematics, multivariate analysis, biogeography, South-east Asia, Philippines, Indonesia, Pleistocene, sea level changes.

## Introduction

The systematics of the Asiatic cobras of the genus *Naja* have, for many decades, been a subject of confusion and controversy. Most workers dealing with the subject have considered all Asiatic cobra populations to be part of a single species, the Indian cobra, *Naja naja*. A number of subspecies have been described from various parts of the range of the group, but most of these were ill-defined, and with disconnected and incoherent ranges. For approximately the last 30 years, most workers have used a "standard" classification which recognizes 10 subspecies of *Naja naja* (Klemmer 1963; Harding & Welch 1980). Again, many of these are ill-defined, with uncertain and sometimes disjointed ranges, so that there has been a tendency to follow this "standard" version out of convenience rather than conviction. Deraniyagala (1960, 1961) split the entire complex into 4 species, but his suggestions have not been followed by most later workers. Despite the medical importance of these snakes, no thorough review of the systematics of this group has been carried out until now.

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Peters, G. & R. Hutterer, eds.:  
Vertebrates in the tropics.  
Museum Alexander Koenig, Bonn 1990.

The situation regarding the distribution of the subspecies of *Naja naja* was particularly confused in the south-eastern part of the range of the group, i. e. in the Malayan Peninsula and Indonesia. Wüster & Thorpe (1987, 1989) investigated the population systematics of the group in that area, and found three highly distinct taxa:

- a northern form, ranging from north-east India through Burma and Thailand into northern Peninsular Malaysia. This is normally referred to as *Naja naja kaouthia* Lesson, 1831, although there is some evidence that it may occur sympatrically with *Naja naja naja* in Bengal, which would make it a full species.
- an equatorial form, which occurs in extreme southern Thailand, Peninsular Malaysia, on the islands of Sumatra, Borneo, Bangka and Belitung, and in the Riau Archipelago. Since this form occurs sympatrically with the northern form in southern Thailand and northern Peninsular Malaysia, it represents a separate species, for which the correct designation is *Naja sumatrana* Müller, 1890.
- a southern form, from Java and the Lesser Sunda Islands. Since it shows no particular affinity to either of the other forms, it should also be considered as a separate species, *Naja sputatrix* Boie, 1827.

These results were shown to be of considerable importance for the treatment of cobra bites in this region, since it has been shown that *N. n. kaouthia* and *N. sumatrana* require different antivenoms for the neutralization of their venoms (Warrell 1986). This is obviously of great relevance in the area of sympatry between the two forms, and illustrates the importance of a clear understanding of the systematics of a group of venomous snakes for the treatment of snake venom poisoning.

In the Philippines, the taxonomy of the local *Naja* populations has been reasonably stable since Taylor (1922) described *Naja naja philippinensis* from Luzon and Mindoro. The only debate concerned the question of whether the three subspecies of *Naja naja* recognized from the islands should be raised to the level of species, as was advocated by Taylor (1934). Leviton (1964) argued for their retention as subspecies of *Naja naja*, and this was followed by all later workers. The three subspecies are:

- *Naja naja miolepis* Boulenger, 1896, from Borneo and Palawan. The Borneo populations were included with *Naja sumatrana* by Wüster & Thorpe (1989).
- *Naja naja philippinensis* Taylor, 1922, from Luzon and Mindoro.
- *Naja naja samarensis* Peters, 1861, from Samar, Leyte, Bohol and Mindanao.

The aim of this study is to investigate the population systematics of the cobra populations of the Philippines, and their relationships with the cobras of Indonesia.

### Materials and Methods

Preserved specimens representing *Naja sputatrix*, *Naja sumatrana* and the Philippine populations were obtained from a number of museums in Europe and North America. A large number of characters relating to scalation, colour pattern, dentition, internal anatomy and body proportions were recorded in each specimen. In order to record the position of internal anatomy characters or scale reductions along the body or tail, the ventral scales were numbered from the head, and the subcaudal scales from the vent, and the position of

the character was recorded as the number of the ventral or subcaudal scale opposite which it is situated. This is then encoded as the percentage of the total ventral or subcaudal scale count (%VS or %CS). See Thorpe (1975) and Wüster & Thorpe (1989) for more details about characters and methods of encoding them for analysis. A total of 36 meristic characters relating to scalation, visceral topography, dentition and colour pattern were selected for multivariate analysis. These are listed in Appendix 1.

The specimens were grouped into Operational Taxonomic Units (OTUs) on the basis of collecting gaps. Due to the incidence of sexual dimorphism in most characters, only one sex could be used in any single analysis. Since far more male than female specimens were available for examination, only male specimens were used in this study. The OTUs used in this study are listed in Appendix 2. A total of 109 specimens was used in the multivariate analyses.

The multivariate technique selected in order to investigate the population systematics of these snakes in the Philippines and Indonesia is canonical variate analysis. This technique maximises the separation of the OTUs relative to the within-group variation, while taking into account the within-group correlation between the characters. This technique is widely used for the study of population systematics (Thorpe 1976, 1983), and has been used in snakes (Thorpe 1979, 1980). It is particularly useful in studies of this nature since it does not infer the cause of geographic variation (Thorpe 1987).

## Results

The first CVA clearly separates the OTUs from Luzon, Mindoro and Marinduque (*Naja naja philippinensis* in the "standard" classification) from the other populations (Fig. 1). Since the interrelationships between the taxa are hypermultivariate (Thorpe 1976), all remaining groups could not separate along the first two canonical variates. Consequently, a second CVA was performed, using the same characters, but not including the *philippinensis* populations (Fig. 2). The ordination of these populations along the first two canonical variates clearly separates *Naja sputatrix*, *Naja sumatrana* and the samples from Samar, Leyte, Bohol and Mindanao (*Naja naja samarensis* in the "standard" classification) from each other. The Palawan sample appears to be phenetically intermediate between *Naja sumatrana* and the *samarensis* samples.

## Discussion

### Population systematics

The first point to note in this analysis of the population systematics of the cobras of the Philippines is that the conventional subspecies of *Naja naja* actually constitute distinct, well differentiated forms, a situation which contrasts sharply with that found in Indonesia and the Malayan Peninsula by Wüster & Thorpe (1989), where the conventional subspecies completely failed to represent the pattern of geographic variation.

The populations from Luzon, Marinduque and Mindoro, conventionally referred to as *Naja naja philippinensis*, form a highly distinct group, with no obvious affinities to either *samarensis* or the two Indonesian species. In separate analyses not included in this study, these populations showed a comparable lack of similarity with any other cobra populations from anywhere within the range of the entire complex. We have examined specimens from Mindoro, Marinduque and several parts of Luzon.

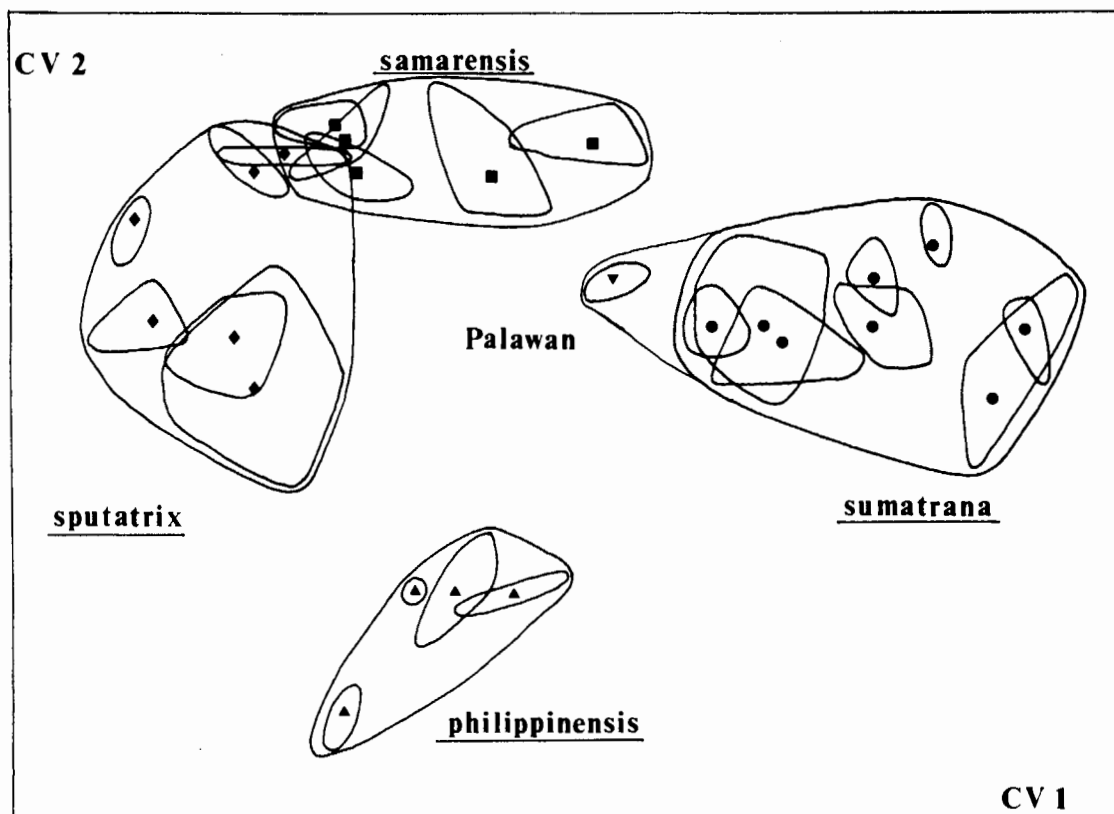


Fig. 1. Ordination of all Philippine populations, *Naja sumatrana* and *N. sputatrix* along the first two canonical variates.

The differences between *philippinensis* and other Asiatic cobra taxa also extend to the symptoms of bites in humans: whereas the bites of most Asiatic *Naja* result primarily in local tissue necrosis, with only a moderate percentage of the victims developing the neurotoxic symptoms usually associated with Elapid bites, bites by *philippinensis* result in the rapid onset of neurotoxic symptoms, but only minimal local tissue damage (Watt et al. 1988). It should also be mentioned that Vogtman (1950) found that Indian antivenom failed to neutralize the venom of *philippinensis*.

The populations from Mindanao, Samar, Leyte and Bohol, conventionally referred to as *Naja naja samarensis*, are also highly distinct from *Naja sputatrix* and the Indonesian and Malayan populations of *Naja sumatrana*. We have examined specimens from Samar, Leyte, Bohol, Mindanao and Camiguin (the island in the Bohol Sea, north of Mindanao, not its namesake in the Babuyan group, north of Luzon).

The population from Palawan presents something of a problem. In many ways, this population appears to be morphologically intermediate between *samarensis* and *Naja sumatrana*. From its conventional placement in the subspecies *N. n. miolepis*, one would have expected this population to group clearly with *Naja sumatrana*. However, as far as the colour pattern is concerned, the Palawan

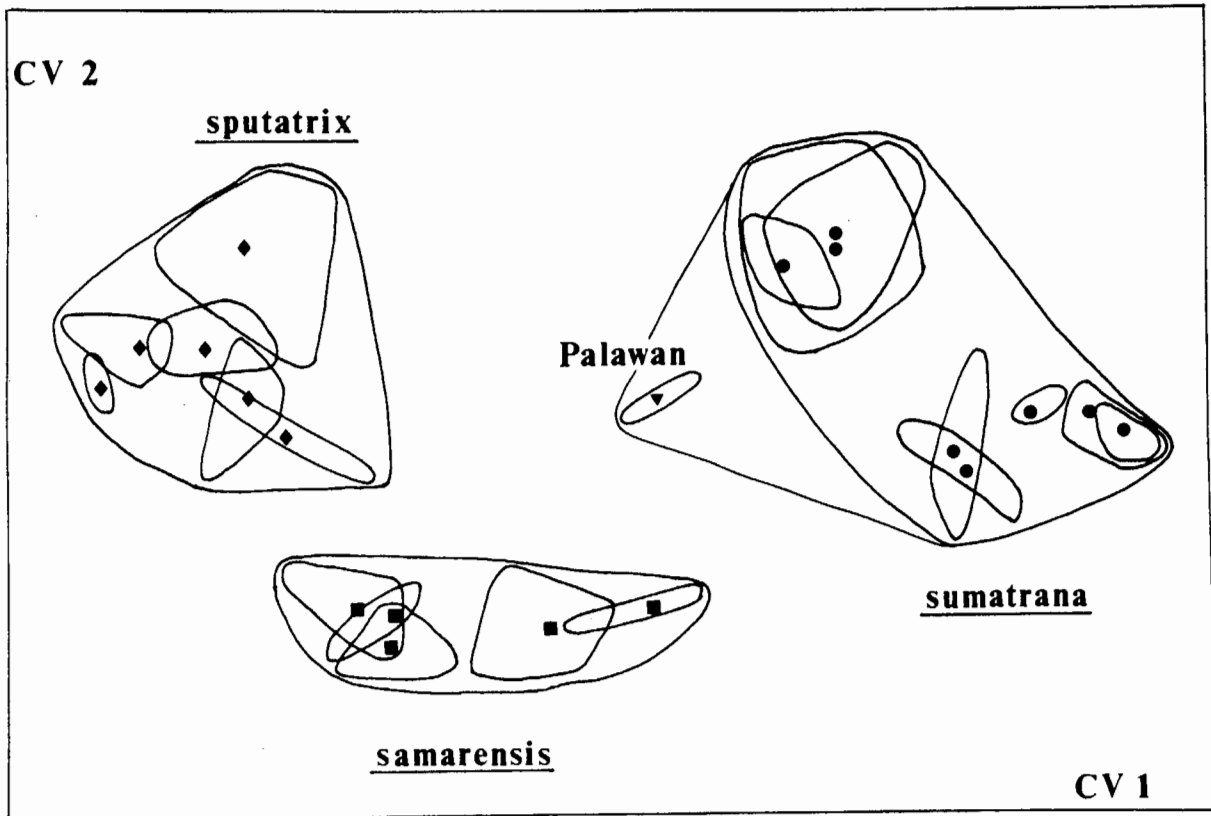


Fig. 2. Ordination of *Naja sumatrana*, *N. sputatrix* and the Philippine populations excluding *philippinensis* along the first two canonical variates.

population shares all the distinctive characteristics of the Borneo populations of *Naja sumatrana* (in juveniles, conspicuous light crossbands on a dark ground colour, which encircle the body, a rearward pointing chevron mark on the hood, and a conspicuous light throat area; in adults, an entirely black body, only the head remaining light), and none of the equally distinctive characteristics of *Naja samarensis* (single broad dark band across the throat, situated far forward, often fading gradually into a lighter belly colour; light ventrolateral line along the lower dorsal scale rows in the anterior quarter of the body; light reticulate markings on a dark dorsal ground colour, most prominent on the skin between the scales; only slight fading of light markings with age). There is no sign in the colour pattern that this population is in any way related to *samarensis*. For this reason, we consider the Palawan population to be a divergent peripheral population of *Naja sumatrana*. It should also be mentioned that the Palawan OTU used in this study was very small (2 specimens), so that individual variation may also have played a part in separating this population from the *Naja sumatrana* populations in the CVA. In any case, only a thorough analysis of the phylogeny and ecological adaptations of the entire Asiatic *Naja* complex can resolve this problem with certainty. We have examined specimens from Palawan, and a single specimen from Culion, an island of the Calamian group, north of Palawan.

The distribution of the three Philippine cobra taxa is shown in Fig. 3.

## Nomenclature

The taxonomic status of the Philippine forms is difficult to resolve. We have so far found no evidence of sympatry on any of the islands of the Archipelago, and we follow Leviton (1964) in rejecting Taylor's statements (1922, 1934) that *philippinensis* occurs sympatrically with the other two Philippine taxa.

Since the taxa involved are therefore allopatric, it is difficult to be certain of whether they represent separate species or subspecies of a single species. Since *philippinensis* shows no affinities to any of the other Indonesian or Philippine taxa, nor for that matter to any other Asiatic *Naja* populations, it seems highly likely that this taxon should be considered as a separate species.

The taxon *samarensis* is also highly distinct from all the other taxa, and may deserve specific status, but its relationship with *Naja sumatrana* deserves further study, especially due to the possible (albeit unlikely) intermediate position of the Palawan population.

Since the taxa *samarensis* and *philippinensis* represent two distinct, unambiguous and generally recognized taxa, it seems best to leave the question of their taxonomic rank until a full phylogenetic analysis of the entire Asiatic *Naja* complex has been carried out. What matters most, at the moment, is that the two taxa should be recognized as distinct, and not whether their scientific names happen to be binomials or trinomials.

The Palawan population may deserve subspecific status within *Naja sumatrana*, but our present sample is too small to permit any firm conclusions on this matter.

## Biogeography

In the case of the cobra populations of the Malayan Peninsula and Indonesia, two main factors affecting the distribution of the cobra taxa in the region were identified: current ecological conditions and Pleistocene sea level changes (Wüster & Thorpe 1989).

Current ecological conditions were found to correlate with the pattern of intra-specific variation in *Naja sputatrix*, which occurs in a wide variety of climatic zones on Java and the Lesser Sunda Islands. Climate is also thought to influence the northern distribution limit of *Naja sumatrana* in southern Thailand, together with competition from *N. n. kaouthia*.

By far the most important factor influencing the distribution of the Indonesian taxa was the pattern of Pleistocene sea level changes: lowered sea levels at times of glaciation at high latitudes allowed a free interchange of terrestrial faunal elements between the various parts of the Sunda shelf, which are now widely separated islands. Thus, *Naja sumatrana* was able to spread throughout the equatorial belt, from Sumatra to Borneo.

In the Philippines, the first thing to note is the very poor correlation between the distribution of the three cobra taxa and climate. Climatic differences within the Philippine islands are mainly between the western and eastern regions: eastern Mindanao, eastern Luzon and Samar have a more humid and less seasonal climate than the western parts of Luzon and Mindanao, and the other western

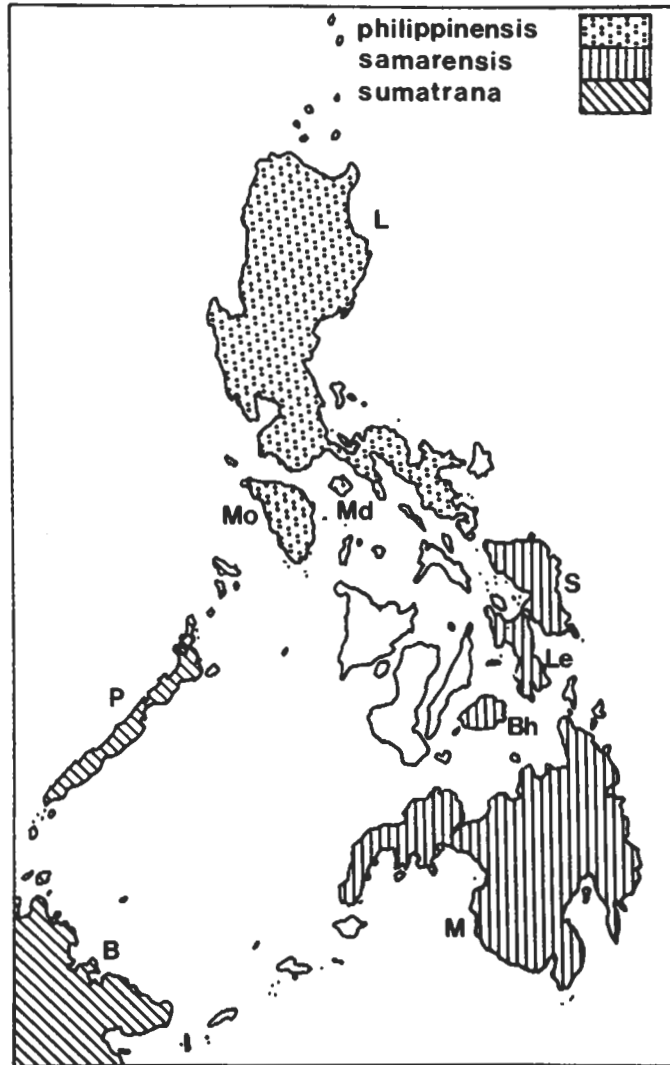


Fig. 3. Distribution of the three Philippine cobra taxa. Letters represent islands: B = Borneo, Bh = Bohol, L = Luzon, Le = Leyte, M = Mindanao, Md = Marinduque, Mo = Mindoro, P = Palawan, S = Samar.

islands in the Archipelago (Whitmore 1975). In fact, Palawan, the most westerly of the major Philippine islands, is notable for being one of the few places where *Naja sumatrana* occupies an area with a distinctly seasonal climate, a factor that may account for the differentiation of the local *Naja* population. This supports the hypothesis of Wüster & Thorpe (1989) that, in the absence of species better adapted to such climatic conditions, this species is able to exist in areas with a seasonal climate.

In the other islands, the distributional boundary between *philippinensis* and *samarensis* lies in an east-west direction, the former occurring in the northern, the latter in the southern islands. In each of these taxa, the distribution does not reflect climatic zones within the islands.

The middle and late Pleistocene geography and geology of the Philippines are now quite well understood (see Heaney 1985, 1986 for a summary). During the late Pleistocene, approximately 18,000 years B. P., when sea levels were approximately 120 metres below their present level, the Philippines were divided into four mega-islands: Greater Luzon, which included the present-day islands of Luzon, Polillo, Marinduque and Catanduanes; Greater Mindanao, which included Mindanao, Samar, Leyte, Bohol, Basilan, Dinagat and various other small islands; Negros-Panay, including present-day Negros, Panay, Cebu and Masbate; and greater Palawan, including Palawan and the Calamianes group. Mindoro was isolated from Luzon and the other islands. In the middle Pleistocene, approximately 160,000 years B. P., the sea level was 160 metres below the current sea level. As a result, Greater Palawan was then linked to northern Borneo by a broad land bridge, allowing faunal interchange. There is also the possibility that Greater Luzon and Greater Mindanao were linked, since the channel now separating Samar and Luzon is only 140 metres deep. However, southern Luzon lies in a tectonically highly active zone, and considerable uplift may have taken place in the last 160,000 years. Comparisons of the mammalian, reptile and amphibian faunas suggest that Greater Luzon and Greater Mindanao remained separate throughout the middle Pleistocene (Heaney 1985; Leviton 1963).

A comparison of the current distribution of the Philippine cobra taxa with the Pleistocene mega-islands reveals a striking degree of correspondence:

- the major islands of Greater Mindanao are occupied by *samarensis*.
- several of the islands of Greater Luzon are occupied by *philippinensis*.
- several islands of Greater Palawan are occupied by *Naja sumatrana*, which probably reached the islands during the middle Pleistocene. The time elapsed since the last land bridge between Borneo and Palawan may account in part for the degree of differentiation between the Palawan populations of this species and their Bornean counterparts.
- the Negros-Panay-Cebu-Masbate group does not have any *Naja* populations. This is despite the fact that the Bohol Strait, which separates Bohol from Cebu, is only 25 km wide; its depth of over 500 metres means that it remained below water during the middle and late Pleistocene, and *samarensis*, the cobra taxon found on Bohol, did not penetrate across this narrow channel. While it is conceivable that undetected populations of *Naja* may exist on some small, poorly-explored islands in the Philippines, it is highly improbable that they would have remained unknown in an entire island group such as this. Cobras tend to be conspicuous components of Asiatic reptile faunas, since they frequent agricultural areas and human settlements, and occasionally bite and kill some of the human inhabitants.

The distribution pattern of the genus *Naja* in the Philippines thus clearly reflects Pleistocene sea level changes. The distribution of the cobra taxa in the Archipelago is almost entirely limited to island groups linked by land bridges during the Pleistocene. There are two exceptions: Mindoro has *philippinensis*, despite the fact that it must have remained disconnected from Luzon throughout the middle and late Pleistocene, since it is separated from Luzon by a channel



more than 160 metres deep; and *samarensis* occurs on the small island of Camiguin, north of Central Mindanao, which would have remained separate from Mindanao.

Cobras have not yet been recorded from a number of islands on which they might be expected to occur from a biogeographical point of view. This may be due to a lack of collectors on these islands. Thus, *philippinensis* should be looked for on Catanduanes and Polillo, *samarensis* on Basilan, Dinagat and Siargao, and *sumatrana* on the other islands of the Calamianes and Balabac groups.

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### Appendix 1

List of characters used in this study.

1. No. of ventral scales.
2. No. of subcaudal scale pairs (undivided subcaudals count as one pair).
3. % of subcaudals undivided.
4. No. of cuneate scales.
5. No. of posterior temporal scales.
6. No. of temporal and nuchal scales contacting parietal scales.
7. No. of dorsal scale rows at level of 10th ventral scale.
8. No. of dorsal scale rows at 20 % VS length.
9. No. of dorsal scale rows at 40 % VS length.
10. No. of dorsal scale rows at 60 % VS length.
11. No. of dorsal scale rows at 80 % VS length.
12. No. of dorsal scale rows at 100 % VS length.
13. %CS of tail segments with 2 dorsal scale rows.
14. %CS position of reduction from 6 to 4 dorsal scale rows.
15. %CS position of reduction from 8 to 6 dorsal scale rows.
16. %CS position of reduction from 10 to 8 dorsal scale rows.
17. %VS position of anterior edge of thyroid.
18. %VS position of posterior tip of heart.
19. %VS position of systemic junction.
20. %VS position of anterior liver tip.
21. %VS position of posterior liver tip.
22. %VS position of anterior edge of pancreas.
23. %VS position of junction between cystic duct and intestine.
24. %VS length of cystic duct.
25. %VS position of anterior tip of right testis.
26. %VS position of posterior tip of right testis.
27. %VS position of anterior tip of left testis.
28. %VS position of posterior tip of left testis.
29. %VS position of anterior tip of right kidney.
30. %VS position of posterior tip of right kidney.
31. %VS position of anterior tip of left kidney.
32. %VS position of posterior tip of left kidney.
33. No. of palatine teeth.
34. No. of pterygoid teeth.
35. No. of dentary teeth.
36. No. of lateral spots on throat.

## Appendix 2

### List of Operational Taxonomic Units used in this study.

1. N. Malaysia & S. Thailand.
2. S. Malaysia.
3. Medan, N. Sumatra.
4. Padang, W. Sumatra.
5. Bengkulu, SW. Sumatra
6. Kuching, Sarawak, W. Borneo.
7. Sabah, N. Borneo.
8. SE. Borneo.
9. W. Java.
10. Central Java.
11. E. Java.
12. Sumbawa, Lesser Sunda Islands.
13. Komodo, Lesser Sunda Islands.
14. Flores, Lesser Sunda Islands.
15. Samar Island, Philippines.
16. Leyte Island, Philippines.
17. Davao Prov., Mindanao, Philippines.
18. Zamboanga Prov., Mindanao.
19. Bohol Island, Philippines.
20. Palawan Island, Philippines
21. Central Luzon, Philippines
22. Camarines Sur Prov., SE. Luzon.
23. Marinduque Island, Philippines.
24. Mindoro Island, Philippines.