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On the taxonomy and distribution of *Varanus salvator andamanensis* Deraniyagala, 1944 (Reptilia: Varanidae), including a redescription of the type specimens and a discussion about its allopatric co-occurrence with *V. s. macromaculatus* on the Nicobar Islands

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Abstract

We provide a detailed redescription of the two original type specimens of the little-known, endemic Andaman water monitor, *Varanus salvator andamanensis* Deraniyagala, 1944. Examination of further voucher specimens allows for an expanded morphological diagnosis of this island taxon and comparison with other currently recognized subspecies of the wide-spread Southeast Asian water monitor. Based on the specimens examined, *V. s andamanensis* is characterized by a homogenous black dorsal background colour, with five to seven, more or less distinctive transverse rows of small spots or ocelli, light yellowish dots arranged sporadically between transverse spot/ocelli rows on the body, light yellowish coloured spots distributed sporadically throughout both forelimbs and hind limbs; 17–18 prominent rows of light spots continuing from base of tail to its tip dorsally with sporadically arranged dots on lateral sides of tail; and higher scale counts in transverse dorsal scale rows. Based on photographic evidence and examination of museum specimens, *V. s. andamanensis* inhabits both the Andaman and southern Nicobar Islands, which politically belong to the Republic of India. In addition, we confirm the presence of *V. s. macromaculatus* in the northern and central Nicobar Islands, thus providing evidence for the allopatric co-occurrence of two different water monitor subspecies in these remote archipelagos.

Key words: *Water monitor lizards*, *Varanus salvator* complex*, Andaman and Nicobar Islands*, *India*, *South and Southeast Asia*

Introduction

Water monitors of the *Varanus salvator* complex have one of the widest distribution ranges of all varanids, occurring from Sri Lanka in the East through continental Southeast Asia to the Greater and Lesser Sunda Islands finally reaching Sulawesi, the Philippines and the Moluccas in the Indo-Australian Archipelago (Mertens 1942c; Koch *et al*. 2007; Koch & Böhme 2010). Since the monumental monograph by Mertens (1942a–c), water monitors were considered to consist of only one polytypic species with several subspecies. After a long period of neglect, however, Koch *et al*. (2007 & 2010) and Welton *et al*. (2014a) recently revised the taxonomy of these giant reptiles that are among the largest living squamates. At the same time they are heavily exploited for the international reptile leather trade and to a lesser extent for the pet trade (Shine *et al*. 1996; Koch *et al*. 2013). Koch *et al*. (2007) critically evalu-

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ated the taxonomic status of all recognized subspecies including *V. salvator andamanensis* Deraniyagala, 1944. However, this investigation was merely based on the very short description given by Deraniyagala (1944) since the type specimens and further material were not accessible to them. Therefore, the purpose of this contribution is to extend the current knowledge about taxonomy and distribution of the locally restricted *V. s. andamanensis*.

The populations of the Andaman Islands were considered taxonomically distinct by Deraniyagala (1944) due to differences in colour pattern, which consists of "(...) yellow dorsal body spots [that] are only represented by two feeble transverse rows". In addition, the author mentioned that "(…) the body scales are also finer than in other varieties where specimens of this size display strongly defined ocelli." However, since no other voucher specimens were available to Deraniyagala (1944), he could not give an extended diagnosis for his new taxon. Based on the available literature, the water monitor populations of the Andaman and Nicobar Islands are considered to belong to two different subspecies: *V. s. andamanensis,* which is restricted to the Andaman Islands, and the widespread *V. s. macromaculatus* Deraniyagala, 1944, which is found across East and Northeast India, Bangladesh, Myanmar and some Southeast Asian countries including Thailand, Cambodia, Vietnam, Singapore, Indonesia, Malaysia and many island groups such as the Nicobars (Deraniyagala 1944 & 1961; Mertens 1959; Koch *et al.* 2007; Cota *et al*. 2009). The latter island population was described by Deraniyagala (1947) as a distinct and endemic subspecies, viz. *V. s. nicobariensis*. Mertens (1959), however, synonymised *V. s. nicobariensis* with *V. s. salvator.* In the comprehensive review of the *V. salvator* species complex Koch *et al*. (2007) later synonymised the putative subspecies from Nicobar with *V. s. macromaculatus*.

Due to the scarcity of the data provided by Deraniyagala (1944) in the original description of *V. salvator andamanensis*, which lacks most of the important diagnostic characters, here, we provide a comprehensive redescription of the taxon based on the examination of its holotype with a comparison of the paratype and five additional voucher specimens.

Materials and methods

A total of 25 morphometric and meristic characters were assessed for each specimen. Terminology and definitions of characters selected are based on Brandenburg (1983), Böhme *et al*. (1994) and Koch *et al*. (2007). A SP 150 mm (±0.02mm) LCD Vernier Calliper was used to obtain measurements. The type specimens of *V. salvator andamanensis* and the other five voucher specimens were examined by DJSS. All specimens examined are deposited in the Zoological Survey of India, Kolkata (ZSI). In addition, data collected during field visits to the islands by Surendran Harikrishnan (SH) and Manish Chandi (MC) from 2008–2018 were used to assess the distribution and colour in life of *V. s. andamanensis*. Live specimens were not collected during field trips, but photographs recording locality data were taken. Other abbreviations: SMF—Naturmuseum Senckenberg, Frankfurt, Germany.

Morphometric measurements include: SVL, snout-vent length from tip of snout to cloaca; TaL, tail length from cloaca to tail tip; ToL, total length from tip of snout to tip of tail (=SVL+TaL); A, head length (distance between tip of snout to anterior margin of ear); B, head width (maximum width between eyes and ears); C, head height above the eye; G, eye to mid-nares length (distance between anterior most point of orbit to middle of nostril); H, snout to mid-nares (distance from middle of the nostril to tip of the snout); Index 1 (=TaL/SVL), relative tail length; Index 2 (=G/H), position of nostril between tip of snout and eye; Index 10 (=A/B), relative head length in relation to head width; Index 11 (=A/C), relative head length in relation to head height; P—scales from rictus to rictus across dorsum of head; Q—scales around tail base; R—scales around tail at approximately one third from base; S—scales around midbody; T—transverse ventral scale rows from gular fold to insertion of the hind legs (anterior margin); N—Gular scales from tip of snout to gular fold; TN—ventral scales from tip of snout to insertion of hind leg(=T+N); X—transverse dorsal scale rows from hind margin of tympanum to gular fold; Y—transverse dorsal scale rows from gular fold to insertion of hind legs; XY—dorsal scales from hind margin of tympanum to insertion of hind legs(=X+Y); c—supralabials exclusive the rostral scale; m—scales around neck anterior to gular fold; U—scales of differentiated (=enlarged) supraocular scales.

Other specimens examined (n=5). Andaman Islands: ZSI 20921, Station 2, Laitora, 10 miles north of Tokoibuea, Little Andaman Island; collection date 14.02.1961; SVL: 483 mm; male. ZSI 20922, Station 2, Bedeabdalu Forest, 12 miles south of Tokoibuea (present Totibue), Little Andaman Island; collection date 16.02.1961; SVL: 358 mm; sex undetermined. ZSI 20923, Station 3, 10 Miles West of Kwate-Tu-Kwage (Hut Bay); collection date 20.02.1961; SVL: 410 mm; sex undetermined. Nicobar Islands: ZSI 23424, Lakshman (present alternative Laxman)

beach, Great Nicobar Island; collection date: 26.03.1977; SVL: 194.35 mm; sex undetermined. Unknown locality: ZSI 21213, collection date: unknown; SVL: 299 mm; sex undetermined.

Results

Redescription of *Varanus salvator andamanensis* Deraniyagala, 1944

(Figure 1, Supplementary Table 1)

Synonymy. No synonyms for this subspecies are known (Böhme 2003; Koch *et al*. 2013).

Holotype. ZSI 2176, a juvenile specimen from Port Blair, Major Field, South Andaman Island, Andaman Islands, Bay of Bengal; collection date unknown; condition of specimen: all limbs intact, skin slightly shrivelled, undissected, some claws of left forelimb vaguely intact (Figure 1A & B).

Paratype. ZSI 2174, a juvenile specimen from Andaman Islands; collection date: October 1872; Condition of specimen: Good, but tail mutilated, all limbs intact, skin is slightly shrivelled, undissected (Figure 1C & D). Snout–vent length 136 mm, tail length 22.4 mm (mutilated).

FIGURE 1. A. Holotype (ZSI 2176) of *V. s. andamanensis*, dorsal (A) and ventral (B) aspects; B. Paratype (ZSI 2174) of *V. s. andamanensis*, dorsal (A) and ventral (B) aspects. Photos by Dinal Samarasinghe.

Extended Diagnosis. *V. s. andamanensis* is distinguished from all its congeners of the *V. salvator* complex by the following combination of characters: (1) in juveniles and subadults, a homogenous black dorsal background colour with five to seven distinctive transverse rows of small spots or ocelli; in specimens above ca. 600 mm (SVL) the dorsal body is black, transverse rows of feebly defined ocelli present, fading with age; (2) light yellowish dots arranged sporadically between transverse spot/ocelli rows on the body; (3) light yellowish coloured spots distributed sporadically throughout both forelimbs and hind limbs; (4) 17–18 prominent rows of spots continuing from base of tail to its tip dorsally with sporadically arranged dots on lateral side of tail; and (5) high average scale counts in characters X, Y, Q, R, N, and NT (see Supplementary Table 3).

Redescription of the Type Specimens (variations of the paratype are given within parentheses). Juvenile, SVL 216 mm. Head slender, Index 10=1.87 (2.24 in paratype), distinct from neck; nostril openings slit-like, oval, surrounded by an elevated protuberance, laterally orientated. Lateral side of snout slightly concave. Snout relatively shorter than head length (Index 12); anteriorly rounded; area between nostrils and eye concave dorsally; internasal area concave in dorsal profile. Rostral shield pentagonal, taller than wide, scales on snout smooth, slightly smaller than those of occipital region; supralabial scales 33/33 (33/33 in paratype); scales on interorbital area relatively enlarged, smooth, arranged somewhat linearly; supraocular area smooth, polygonal; enlarged supraoculars smooth, wider than length, polygonal. Scales around the eyes minute. Head scales: immediately surrounding pineal organ are polygonal, relatively small, but enlarged in adjoining, anteriorly and laterally larger than that of posteriorly arranged scales (polygonal in paratype). The scale covering the pineal ocellus has a whitish blotch. Scales of nape granular, more rounded than oval, granules oval, larger and broader than dorsal body scales. Mental large, box shaped (pentagonal, taller than wide in paratype). Chin scales smooth, irregularly shaped anteriorly, becoming more rectangular posteriorly towards the throat; Throat scales elongated, rectangular, smooth, and narrower than chin scales; reduced in size and rounded towards gular sac. Gular scales smooth, rounded, increasing in size towards gular fold. Scales around the gular fold are very small.

Body slender, dorsal scales at midbody equal, granulated, relatively elongated than scales of nape; scales on dorsum at midbody smaller than those of venter at same level; lateral body scales similar, relatively smaller than dorsals; 151 scales around midbody (146 in paratype); pectoral scales smooth, some hexagonal and some polygonal (some rounded and some polygonal in paratype), larger than gular scales but minute at gular fold and larger towards abdominal scales; abdominal scales enlarged, smooth, rectangular, arranged in regular transverse rows. Dorsal scales on upper arm slightly larger and rounder than dorsal body scales. Ventral scales on upper arm relatively smaller than on the dorsal surface, smooth, rounded; Dorsal scales on lower arm smaller than on upper arm; ventral scales on lower arm relatively smaller than dorsal surface, smooth, rounded; Scales on dorsal surface of thigh and shank relatively larger than dorsal body scales; ventral surface of thigh and shank relatively larger than the dorsal surface. Finger and toe scales are small somewhat rectangular ventrally and dorsally, arranged transversely.

Tail length 354 mm. Tail laterally compressed. The two median rows of dorsal tail scales form a double crest starting from the base. Caudal scales rectangular, above slightly keeled, below with prominent keels, ventral caudal scales much larger than dorsally (tail incomplete, mutilated, 22.40 mm present; laterally compressed, tail base swollen in paratype).

Colouration in preservative (Based on the type specimens). Lateral side of snout with three dark (brownish) cross-bands and three light yellow cross-bands in-between; head dorsally dark (brownish), eyelids and surrounding scales light yellow coloured. Nape dark brownish coloured, post-temporal stripe behind the eye absent. Ventrally light yellow coloured with brownish dark coloured irregular shaped markings present on neck and gular region. Dorsal body dark coloured (greyish brown) with four light yellow transverse dorsal rows of spots present. Irregularly arranged light yellow coloured dots present in between transvers rows. Ventrally light yellow coloured with thin brownish dark bands from sides present. One brownish dark coloured band or scale row continues between the forelimbs. Dorsal side of limbs: mainly dark coloured (brownish), with few small spots interspersed, similar to dorsal spots but much smaller. These dots are clearly visible on fingers and toes. Tail brownish; three feebly defined transverse rows similar to dorsal body rows present; the number of rows is not clear because of the bad condition of the specimen. However, clear light coloured bands are visible towards the end of the tail. Small light yellow coloured dots are arranged sporadically on the tail dorsally in between the transverse rows.

Variation. The longest alcohol preserved specimen examined (ZSI 20921) measures 1,213 mm (SVL=483 mm, TaL=730 mm). A descriptive summary on the variation of the type specimens and other specimens examined are depicted in Supplementary Table 1. Meristic characters: 11 to 14 enlarged supraoculars on both sides; 63–66 supralabials excluding the rostral. Some head scale counts of ZSI 20922 could not be counted since these parts

were damaged. All except two specimens were less than one meter in total length. With regards to the colouration, transverse rows of spots and ocelli become less distinctive in specimens above ca. 600 mm and the black dorsum with white/yellow spots/speckles are distributed throughout the dorsum. The post-temporal stripe is feebly present in ZSI 20923, ZSI 21213 & ZSI 23424.

Colouration in life. The snout colouration consists of three to four black vertical bands and two to three vertical light yellow bands on the snout (Figure 2B). However, specimens above ca. 0.5 m have much reduced bands on the snout (Figure 2A, C, D & E). Post-temporal stripe are present mostly in juveniles and less developed in mature specimens (Figure 2).

Dorsally black coloured, six to seven transverse rows of spots or ocelli present. In between, there are rows of dots present consisting of 6–7 scales. In specimens > 0.5 m, these spots and ocelli are enlarged and scattered, making rows less discernible. Light yellow dots are sporadically distributed between the prominent dorsal body rows and throughout both fore limbs and hind limbs. Dorsal side of tail possesses 17–18 prominent transverse rows/bands of yellow spots up to the tail tip. These rows are not visible in specimens > 0.5 m.

Comparison with neighbouring subspecies of *V. salvator*. *V. s. andamanensis* can be distinguished from *V. s. salvator* endemic to Sri Lanka by the following morphological characteristics: post-temporal stripes present vs. less developed or absent; six to seven, more or less distinctive transverse dorsal body rows comprised of small sized spots or weakly defined ocelli vs. five to six distinctive transverse dorsal body rows with well-defined spots or ocelli; sporadically arranged single scaled yellow dots between dorsal body rows vs. prominent rows of small yellow spots between dorsal body rows; well defined prominent transverse yellow bands around the tail with sporadically arranged dots on dorsal side of tail vs. well defined prominent transverse yellow bands around the tail. Meristic characters: *V. s. andamanensis* can be distinguished from *V. s. salvator* by having higher scale counts for characters X (38–53, x=45.42±5.38, n=7 vs. 26–36, x=32.40±3.16, n=15), Y (105–130, x=115.29±9.52, n=7 vs. 86–99, x=93.27±3.99, n=15) and XY (144–180, x=160.71±14.30, n=7 vs. 118–135, x=125.67±5.34, n=15). *V. s. andamanensis* also has on average higher scale counts in characters Q (82–125, x=111.57±14.3, n=7 vs. 92–108, x=98.73±4.65, n=15), R (65–78, x=71.2±5.54, n=7 vs. 55–67, x=62.13±3.50, n=15), N (81–103, x=88.43±7.25, n=7 vs. 75–85, x=78.85±2.30, n=13) and TN (171–194, x=178.14±7.78, n=7 vs. 164–172, x=168.69±2.59, n=13). Average lower mid-body scales (character S: 143–161, x=152.57±7.14, n=7 vs. 142–165, x=153.73±6.12, n=15) and scales around the neck (character m: 80–97, x=87.14 ± 6.82, n=7 vs. 94 –109, x=102.43±4.57, n=14). Nostril positioned relatively further away from tip of snout (index 2): 1.92–2.94, x=2.21±0.35, n=7 vs. 2.17–2.91, x=2.47±0.19, n=15 in *V. s. salvator*. In relation to head length: Index 10: 1.87–2.47, x=2.21±0.20, n=7 vs. 1.70–2.27, x=1.87±0.14, n=15; index 11: 2.47–3.29, x=2.83±0.30; n=7 vs. 2.31–3.09, x=2.69±0.17, n=15.

V. s. andamanensis can be distinguished from *V. s. macromaculatus* inhabiting continental Southeast Asia plus Borneo and Sumatra, among other islands, by the following morphological characteristics: post-temporal stripe behind the ear less distinctive vs. well developed; black body (brown when preserved) with six to seven more or less distinctive transverse dorsal body rows comprised of only small size spots or weakly defined ocelli vs. brown/greyish body with four to seven clearly distinctive transverse dorsal body rows with well-defined spots or ocelli; sporadically arranged single scaled light yellowish dots between dorsal body rows vs. mostly with light orange/yellow dots or marbling in between dorsal body rows; tail has 17–18 rows of thin bands vs. 10–12 transverse rows of light spots or ocelli. When meristic measurements are considered, *V. s. andamanensis* can be distinguished from *V. s. macromaculatus* by having higher average scale count in: character N (81–103, x=88.43±7.25, n=7 vs. 65–95, x=81.12±5.53, n=93), T (87–91, x=89.71±1.38, n=7 vs. 75–95, x=84.60±4.06, n=95) and R (65–78, x=71.2±5.54, n=5 vs. 41–82, x=60.84±6.42, n=94). Having lower average scale counts in character m (80–97, x=87.14±6.82, n=7 vs. 81–127, x=102.34±11.30, n=92). Nostril positioned relatively further away from tip of snout (index 2): 1.92–2.94, x=2.21 ± 0.35, n=7 vs. 1.82–3.46, x=2.30 ± 0.26, n=163 in *V. s. macromaculatus*.

Based on the available literature *V. s. macromaculatus* is also found in the Nicobar Islands, but not in the Andaman Islands. The holotype of *Varanus salvator nicobariensis* could not be located and was deemed lost, despite rigorous searches in ZSI by one of us (DJSS) and ZSI staff. However, we found two voucher specimens belonging to *V. s. macromaculatus* at the ZSI collection: ZSI 25965, Car Nicobar, Car Nicobar tehsil (Figure 3B) and ZSI 15038 with no specific description of the locality, but mentioning "Nicobars". In addition we examined a specimen of *V. s. macromaculatus* from SMF, Tillanchong Island, Nancowry, Nancowry tehsil (SMF 55423). Several live specimens from Kamorta Island, Nancowry tehsil, Nicobar Islands were also photographed (Figure 3A). Based on these specimens we provide a comparison of the morphometric and meristic data between the Nicobar populations of *V. s. macromaculatus* and those from the mainland in Supplementary Table 2.

FIGURE 2. *Varanus salvator andamanensis*: A. Adult specimen (South Andaman Island) in life (SH); B. Juvenile specimen (South Andaman Island) in life (SH); C. Juvenile specimen (ZSI 23424) from Laxman beach, Great Nicobar Island (DJSS); D. Subadult specimen from Galathea, Great Nicobar Island, Nicobar Islands in life (MC). E. Subadult/Juvenile specimen from Govind Nagar, Great Nicobar Island, Nicobar Islands, in life (SH). F. Juvenile from Little Nicobar Island (MC). See Figure 4 for location on distribution map.

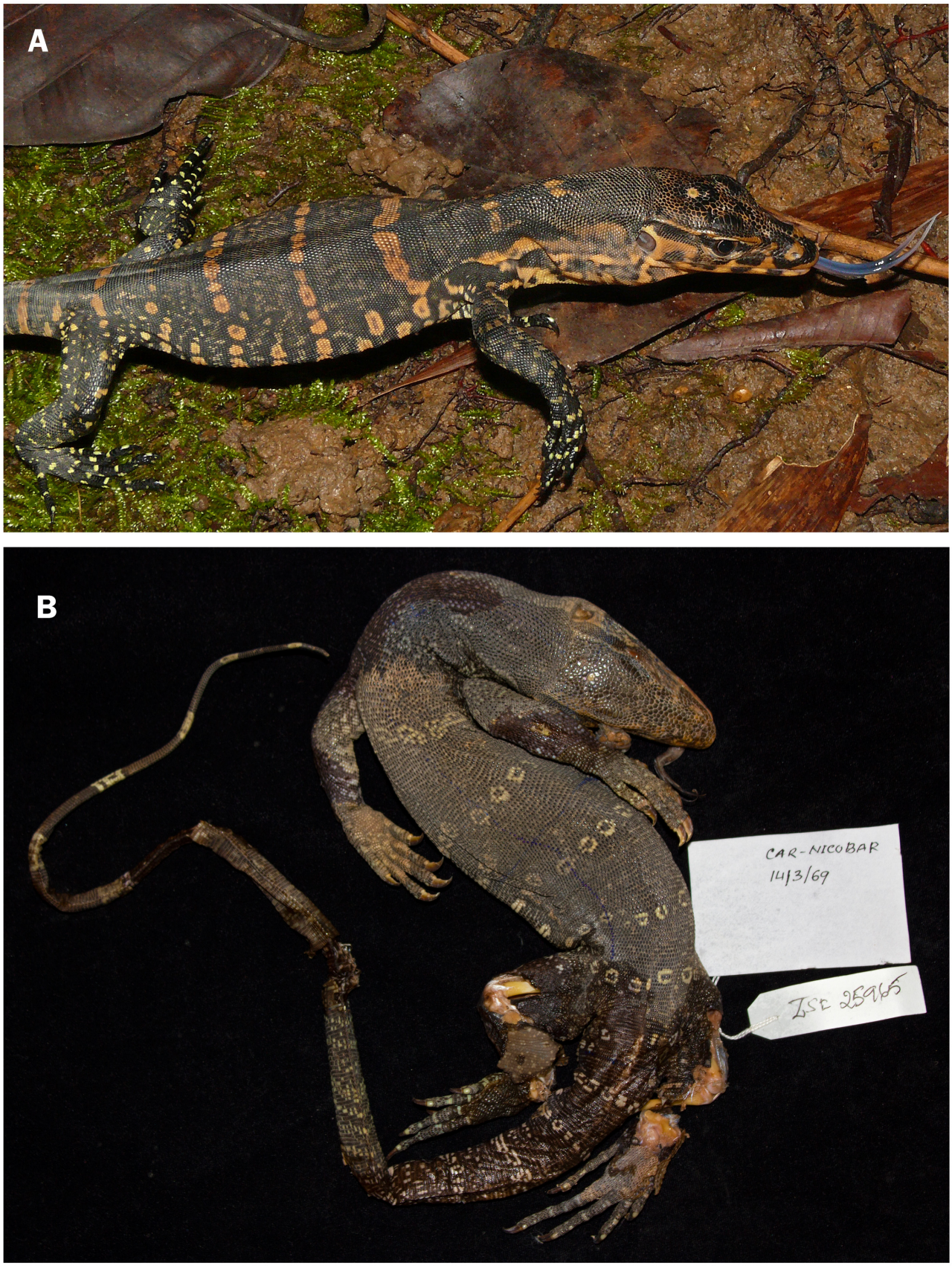

FIGURE 3. *Varanus salvator macromaculatus* from the Nicobar Islands: A. Juvenile specimen from Kamorta Island, Kamorta tehsil, Nicobar Islands (SH); B. ZSI 25965, subadult (total length 740 mm) from Car Nicobar, Car Nicobar tehsil, Nicobar Islands (DJSS).

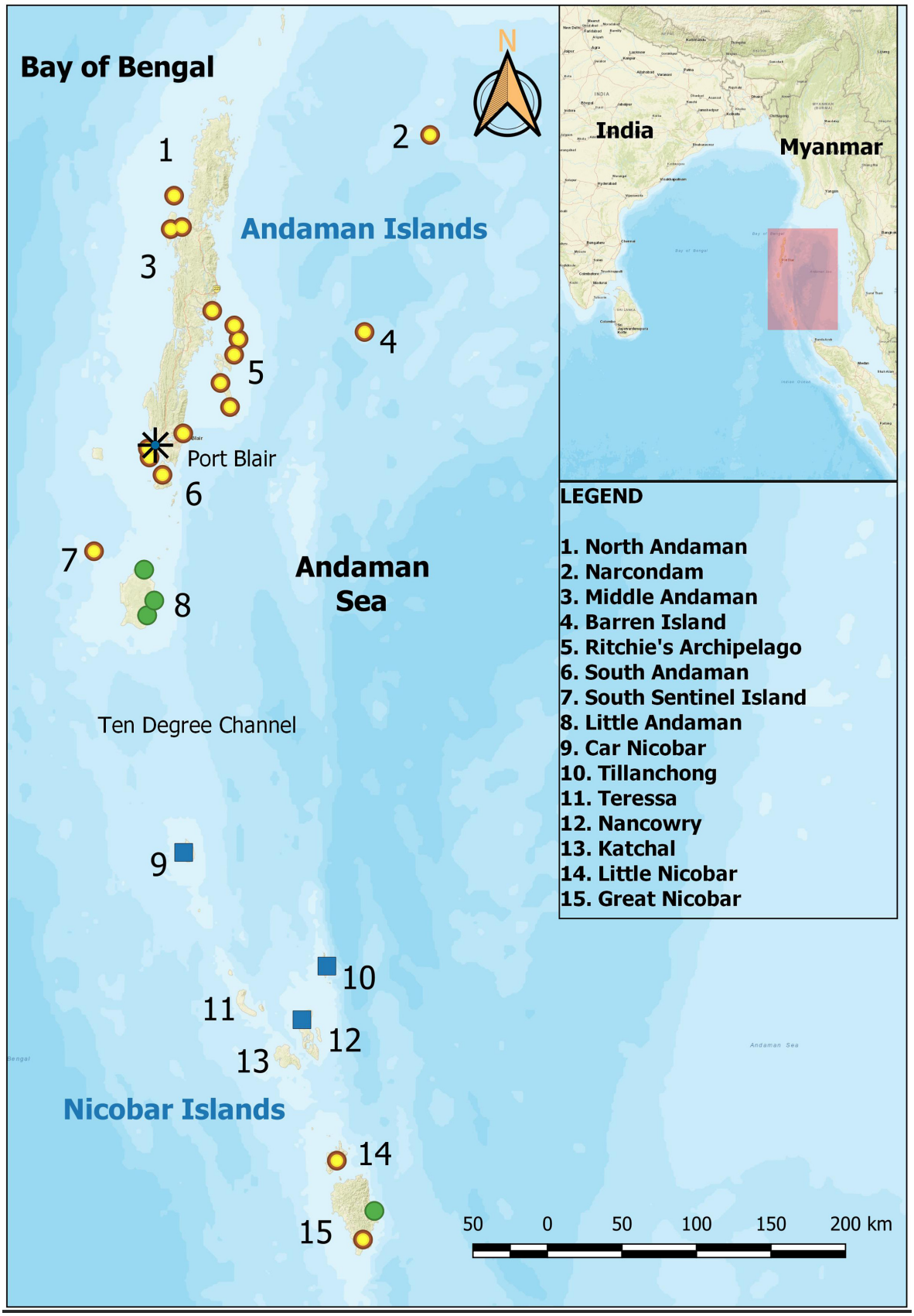

FIGURE 4. Distribution ranges of *V. s. andamanensis* and *V. s. macromaculatus* within the Andaman and Nicobar Islands, respectively. Black star: type locality of *V. s. andamanensis*; green circles: voucher specimens of *V. s. andamanensis*; yellow circles: distribution records of *V. s. andamanensis* based on photographs; blue squares: locality records of *V. s. macromaculatus*.

Distribution. Among the specimens examined, *V. s. andamanensis* is recorded from localities belonging to both the Andaman and Nicobar Islands. Andaman Islands: Port Blair, South Andaman Island; Laitora, Little Andaman Island; Bedeabdalu Forest, Little Andaman Island; Kwate-Tu-Kwage, Hut Bay, Little Andaman Island. Nicobar Islands: Laxman beach, Great Nicobar Island (Figure 4).

The following locations are based on published literature records, personal observations by the authors and photographs provided by colleagues. Raman *et al*. (2013) reports *V. s. andamanensis* from Narcondam Island, North and Middle Andaman District; the photograph provided in this study matches clearly with the description of *V. s. andamanensis*. In addition, this subspecies was also observed from several other islands from within this district: Long Island, North Reef Island, South Reef Island, Interview Island (Whitaker and Whitaker 1980), North Button Island and Barren Island. Individuals were also recorded from the following islands of the South Andaman District: Rutland, Outram, Tarmugli Island, Neil Island, Havelock Island, John Lawrence, Ross Island, Boat Island, South Sentinel Island and South Andaman Island. Field work carried out by MC and SH in the Andaman Archipelago revealed that water monitor lizards are spread across all islands (including the islands which belong to the territory of the Republic of the Union of Myanmar) in addition to the islands listed above. However, the identification of the subspecies present in these islands is yet to be determined. Nicobar Islands: Galathea Bay, Great Nicobar Island (Figure 2D); Little Nicobar Island (Figure 2F); Govind Nagar, Great Nicobar (Figure 2E).

Conservation status. *Varanus salvator* is assessed as "Least Concern" by the IUCN Red List considering its wide distribution range throughout South and Southeast Asia. However, it is recommended that the Red List authority recognises the individual subspecies and assesses their respective conservation statuses individually since, for instance, *V. s. andamanensis* inhabits a very small distribution range on the Andaman (6,400 km^2) and Nicobar (1,800 km^2) Islands. This would have positive implications for conservation of the entire species in the future.

Although *V. s. andamanensis* is currently found in a number of locations, recent research suggests that these populations are under threat due to poaching (Figure 2F) (Raman *et al*. 2013).

Discussion

Since its first description by Deraniyagala (1944), *V. s. andamanensis* was thought to be restricted to the Andaman Islands. However, our field observations together with the museum voucher specimens examined, indicate its presence also in the Nicobar Archipelago. Thus, it is now considered endemic to both the Andaman and Nicobar Archipelagos (Figure 4). Based on our available data, *V. s. andamanensis* is found throughout the Andaman Islands, while it is only found in the southern group of the Nicobar Islands, whereas *V. s. macromaculatus* is restricted to the central and northern island groups of the Nicobars (Figure 4). Our study indicates that the water monitors of the Andaman and Nicobar Archipelagos, specifically *V. s. andamanensis*, have a disjunct distribution which may have been a result of biogeographic events in the past and surface ocean current patterns. This suggests that the two subspecies may have entered the islands through different routes, colonization events, and/or at different time periods.

Similar distributions to that of *V. s. andamanensis* can be observed in some other reptiles of the Andaman Islands. For instance, the skink *Lipinia macrotympanum* (Stoliczka, 1873) was originally described from a single specimen from South Andaman by Stoliczka (1873). Das (1997) rediscovered this species from the Little Nicobar and Great Nicobar Islands, Southern Nicobars. Similarly, *Hemiphyllodactylus* cf. *typus* Bleeker, 1860 occurs in the Andaman Islands and in Great Nicobar, but has not been recorded from the central and northern groups of islands in the Nicobars.

As suggested by Das (1999), these species may have entered the Andaman Islands when they were connected with Arakan Yomas, the Rakhine Mountains in Myanmar, during periods of lowered global sea levels associated with the Pleistocene glaciations (ca. 2.58 to 0.011 million years ago (mya)) (Voris 2000; Amante & Eakins, 2009; Wilting *et al*. 2016) and may have then dispersed (via waif dispersal) to the Nicobar Islands. The Andaman and Nicobar Islands are separated by the Ten Degree Channel, which is approximately 1,000 m in depth, with 140 km of spatial separation between Little Andaman Island and Car Nicobar Island. This distance acts as a natural marine barrier for many faunal species. However, the distribution patterns of some reptile species, as explained above, suggest that there have been faunal exchanges between the two islands groups via ocean currents and waif dispersal (Das 1999).

Varanus salvator macromaculatus is the most widely distributed subspecies of the Asian water monitor. In Myanmar, it is currently only found in three locations in the northwestern and northern parts of the country. However, it is believed that the historical range may have been larger, and poaching may have caused the extirpation of

V. s. macromaculatus from the rest of its natural range (Smith 1935; Oo & Bates 2016; Platt *et al*. 2018). Welton *et al*. (2014b) shows that the Myanmar population diverged from the Southeast Asian clade of *V. s. macromaculatus* approximately 1.28 mya. On this backdrop, *V. s. macromaculatus* from Myanmar may have colonized the Andaman Islands during the Pleistocene period and an early dispersal event may have taken place for it to establish itself in the Southern Nicobar Island groups, similar to the evolution of *L. macrotympanum* as suggested by Das (1999). However, the absence of *V. s. andamanensis* from Northern and Central Nicobar island groups needs to be further investigated. *Varanus salvator macromaculatus* entering these islands through waif dispersal or with the help of humans via the Andaman Sea from Thailand seems to be the most plausible explanation. Water monitor lizards are known to swim across sea water and enter nearby island areas (Rawlinson *et al*. 1990; Borden 2007; Duengkae 2008). Borden (2007) reports an observation of *V. s. macromaculatus* swimming ca. 900 m in the open ocean in the Andaman Sea off the coast of South Thailand. And more recently Sieniawski & Somaweera (2019) reported instances of *Varanus salvator* deep diving in Bali, Indonesia. However, this question can be resolved only through further research on the phylogeography of water monitors.

In the light of the present information, it is important to further explore the distribution of the two subspecies in the archipelagos including the northern islands belonging to Myanmar. Scientists working in the islands should thoroughly understand the differences between the two subspecies and carry out work. Temporal activity, thermoregulatory strategies, habitat requirements and movement patterns which are key information are not known for the two subspecies living in the islands. Further investigations on these aspects as well as studies on reproduction ecology and behaviour should be carried out.

Furthermore, Welton *et al*. (2014b) underscores the need for a broader molecular phylogenetic study on the *Varanus salvator* species complex including water monitor samples from the Andaman and Nicobar Islands together with the Indian and Sri Lankan populations. This will be very useful to understand and stabilise the respective taxonomic status of each subspecies which will in turn be extremely useful to address conservation issues relating to the entire species.

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References

Amante, C. & Eakins, B.W. (2009) *ETOPO1 1 arc-minute global relief model: procedures, data sources and analysis. NOAA Technical Memorandum NESDIS, NGDC-24*. US Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Marine Geology and Geophysics Division, Boulder, Colorado, 19 pp.

Böhme, W., Horn, H.G. & Ziegler, T. (1994) Zur Taxonomie der Pazifikwarane (*Varanus indicus*-Komplex): Revalidierung von *Varanus doreanus* (A. B. Meyer, 1874) mit Beschreibung einer neuen Unterart. *Salamandra*, 30, 119–142.

Böhme, W. (2003) Checklist of the living monitor lizards of the world (family Varanidae). *Zoologische Verhandelingen*, 341, 1–43.

Brandenburg, T. (1983) *Monitors in the Indo-Australian Archipelago.* Unpubl. MSc. Thesis, University of Leiden, Leiden, 98 pp.

Borden, R. (2007) *Varanus salvator* (Asian Water Monitor) migration. *Biawak*, 1 (2), 84.

Chandi, M. (2006) The Use and Knowledge of Herpetofauna on Little Nicobar Island, India. *Conservation and Society*, 4, 155–165.

Cota, M. (2009) Study and conservation of varanids of Thailand: past achievements and future challenges. *Journal of Wildlife*

in Thailand, 16 (1), 11–12.
Das, I. (1999) Biogeography of the amphibians and reptiles of the Andaman and Nicobar Islands, India. *In*: Ota, H. (Ed.), *Tropical island herpetofauna: Origin, current diversity, and conservation*. Elsevier, Amsterdam, pp. 43–77.
Deraniyagala, P.E.P. (1944) Four new races of the 'Kabaragoya' lizard, *Varanus salvator*. *Spolia Zeylanica*, 24, 59–62.
Deraniyagala, P.E.P. (1947) The names of the Water monitors of Ceylon, the Nicobars and Malaya. *Proceedings of Third annual session of Ceylon Association of Science*, Section 2 (Abstract), 12.
Deraniyagala, P.E.P. (1961) The Water monitor of the Andaman Islands—a distinct subspecies. *Spolia Zeylanica*, 29 (2), 203–206.
Duengkae, P. (2008) Observation of *Varanus salvator* from Koh Tao Island in the Gulf of Thailand. *Biawak*, 2, 159–161.
Koch, A. & Böhme, W. (2010) Heading east: a new subspecies of *Varanus salvator* from Obi Island, Maluku Province, Indonesia, with a discussion about the easternmost natural occurrence of Southeast Asian water monitor lizards. *Russian Journal of Herpetology*, 17, 299–309.
Koch, A., Gaulke, M. & Böhme, W. (2010) Unravelling the underestimated diversity of Philippine water monitor lizards (Squamata: *Varanus salvator* complex), with the description of two new species and a new subspecies. *Zootaxa*, 2446 (1), 1–54.
https://doi.org/10.11646/zootaxa.2446.1.1
Koch, A., Auliya, M., Schmitz, A., Kuch, U. & Böhme, W. (2007) Morphological Studies on the Systematics of South East Asian Water Monitor (*Varanus salvator* Complex): Nominotypic Populations and Taxonomic Overview. *In*: Horn, H.-G., Böhme, W. & Krebs, U. (Eds.), Advances in Monitor Research III. *Mertensiella*, pp. 109–180.
Koch, A., Ziegler, T., Böhme, W., Arida, E. & Auliya, M. (2013) Pressing Problems: Distribution, Threats, and Conservation Status of the Monitor Lizards (Varanidae: *Varanus* ssp.) of Southeast Asia and the Indo-Australian Archipelago. *Herpetological Conservation and Biology*, Monograph 3, 8, 1–62.
Mertens, R. (1942a–c) Die Familie der Warane (Varanidae). *Abhandlungen der Senckenbergischen naturforschenden Gesellschaft*, 462, 465, 466, 1–391.
Mertens, R. (1959) Liste der Warane Asiens und der Indo-australischen Inselwelt, mitsystematischen Bemerkungen. *Senckenbergiana Biologica*, 40 (5/6), 221–240.
Platt, S.G., Win, M.M. & Rainwater, T.R. (2018) Additional field records provide further resolution of the distribution of the Water Monitor *Varanus salvator* (Squamata: Varanidae) in northwestern Myanmar. *Journal of Threatened Taxa*, 10 (10), 12425–12428.
https://doi.org/10.11609/jott.4425.10.10.12425-12428
Raman, T.R., Shankar, D.M., Khan, T., Mistry, U., Saxena, A., Varma, K., Ekka, N., Lenin, J. & Whitaker, R. (2013) An Expedition to Narcondam: Observations of Marine and Terrestrial Fauna including the Island-endemic Hornbill. *Current Science*, 105 (3), 346–60.
Rawlinson, P.A., Widjoya, A.H.T., Hutchinson, M.N. & Brown, G.W. (1990) The terrestrial vertebrates of Krakatau Islands, Sunda Strait, 1883–1986. *Philosophical Transaction Royal Society London B*, 328, 2–28.
https://doi.org/10.1098/rstb.1990.0107
Oo, S.S.L & Bates, P.J.J. (2016) The rediscovery of the Common Water Monitor Lizard *Varanus salvator* (Squamata: Varanidae) in northern Myanmar. *Journal of Threatened Taxa*, 8 (5), 8827–8828
https://doi.org/10.11609/jott.2746.8.5.8827-8828
Shine, R., Harlow, P.S., Keogh, J.S. & Boeadi (1996) Commercial harvesting of giant lizards: the biology of water monitors *Varanus salvator* in southern Sumatra. *Biological Conservation*, 77, 125–134.
https://doi.org/10.1016/0006-3207(96)00008-0
Sieniawski, K. & Somaweera, R. (2019) *Varanus salvator* (Asian water monitor). Deep Diving. *Herpetological Review*, 50 (2), 2019
Smith, M.A. (1935) *The Fauna of British India, including Ceylon and Burma. Reptilia and Amphibia. Vol. II. Sauria.* Taylor & Francis, London, 440 pp.
Stoliczka, F. (1873) Note on some Andamanese and Nicobarese reptiles, with the description of three new species of lizards. *Journal of the Asiatic Society of Bengal*, 92 (3), 162–169.
Voris, H. (2000) Maps of Pleistocene sea levels in Southeast Asia: shorelines, river systems and time durations. *Journal of Biogeography*, 27, 1153–1167.
https://doi.org/10.1046/j.1365-2699.2000.00489.x
Welton, L.J., Travers, S.L., Siler, C.D. & Brown, R.M. (2014a) Integrative taxonomy and phylogeny-based species delimitation of Philippine water monitor lizards (*Varanus salvator* Complex) with descriptions of two new cryptic species. *Zootaxa*, 3881 (3), 201–227.
https://doi.org/10.11646/zootaxa.3881.3.1
Welton, L.J., Wood, Jr. P.L., Oaks, J.R., Sile, C.D. & Brown, R.M. (2014b) Fossil-calibrated phylogeny and historical biogeography of Southeast Asian water monitors (*Varanus salvator* Complex). *Molecular Phylogenetics and Evolution*, 74, 29–37.
https://doi.org/10.1016/j.ympev.2014.01.016
Whitaker, R. & Whitaker, Z. (1980) Distribution and status of Varanus salvator in India and Sri Lanka. *Herpetological Review*, 11 (3), 81–82.
Wilting, A., Patel, R., Pfestorf, H., Kern, C., Sultan, K., Ario, A., Penaloza, F., Kramer-Schadt, S., Radchuk, V., Foerste, D.W. & Fickle, J. (2016) Evolutionary history and conservation significance of the Javan leopard *Panthera pardus melas*. *Journal of Zoology*, 299, 239–250
https://doi.org/10.1111/jzo.12348

SUPPLEMENTARY TABLE 1. Descriptive statistics of main morphometric and meristic characters of the type specimens of *V. s andamanensis* together with other specimens examined. Provided for each character are range (min–max), mean (x) ± standard deviation (SD), and number (n) of specimens examined. *Tail mutilated in ZSI 20922; N/A—Not available.

Character	Holotype ZSI 2176	Paratype ZSI 2174	ZSI 20921	ZSI 20922	ZSI 20923	ZSI 21213	ZSI 23424	Range (mean±SD)
A (mm)	46.83	42.02	100.89	98.78	93.17	60.77	48.82	42.02–100.89 x = 2.21 ± 0.35
B (mm)	25.10	18.77	47.08	39.92	44.2	27.59	20.26	18.77–47.08 x = 31.85 ± 11.68
Index 1	1.64	N/A	1.51	N/A	1.78	1.67	1.75	1.51–1.78 x = 1.67 ± 0.11*
Index 2	1.92	1.95	2.12	2.22	2.94	2.31	1.99	1.92–2.94 x = 2.21 ± 0.35
Index 10	1.87	2.24	2.14	2.47	2.11	2.2	2.41	1.87–2.47 x = 2.21 ± 0.20
Index 11	2.55	3.01	2.47	2.62	2.79	3.06	3.29	2.47–3.29 x = 2.83 ± 0.30
P	50	50	54	50	55	53	48	48–55 x = 51.43 ± 2.57
Q	125	108	117	114	123	112	82	82–125 x = 111.57 ± 14.3
R	74	N/A	73	N/A	78	66	65	65–78 x = 71.2 ± 5.54*
S	151	146	158	161	160	149	143	143–161 x = 152.57 ± 7.14
T	90	87	89	90	90	91	91	87–91 x = 89.71 ± 1.38
N	87	87	82	90	89	103	81	81–103 x =88.43 ± 7.25
TN	177	174	171	180	179	194	172	171–194 x = 178.14 ± 7.78
X	43	44	50	41	38	53	49	38–53 x = 45.42 ± 5.38
Y	115	108	130	105	106	120	123	105–130 x =115.29 ± 9.52
XY	158	152	180	146	144	173	172	144–180 x = 160.71 ± 14.30
m	82	81	97	85	94	91	80	80–97 x = 87.14 ± 6.82

Character definitions: A, head length (distance between tip of snout to anterior margin of ear); B, head width (maximum width between eyes and ears); Index 1 (= TaL/SVL) relative tail length; Index 2 (= G/H) position of nostril between tip of snout and eye; Index 10 (= A/B) relative head length in relation to head width; Index 11 (= A/C) relative head length in relation to head height; P—scales from rictus to rictus across dorsum of head; Q—scales around tail base; R—scales around tail at approximately one third from base; S—scales around midbody; T-transverse ventral scale rows from gular fold to insertion of the hind legs (anterior margin); N—Gular scales from tip of snout to gular fold; TN—ventral scales from tip of snout to insertion of hind leg(= T+N); X—transverse dorsal scale rows from hind margin of tympanum to gular fold; Y—transverse dorsal scale rows from gular fold to insertion of hind legs; XY—dorsal scales from hind margin of tympanum to insertion of hind legs(= X+Y); m—scales around neck anterior to gular fold.

SUPPLEMENTARY TABLE 2. Comparison between the *V. s. macromaculatus* from the Nicobar Islands and the remaining population. Data for specimens from mainland, Sumatra and Borneo are derived from Koch *et al*. (2007).

Character	*V. s. macromaculatus* (Car Nicbar) ZSI 25965	*V. s. macromaculatus* (Tillangchang) ZSI 2174	*V. s. macromaculatus* Mainland Southeast Asia, Sumatra, and Borneo (n = 92–163)
Index 2	1.91	2.31	1.82–3.46 (x = 2.30 ± 0.26)
P	58	60	49–65 (x = 57.43 ± 3.34)
Q	104	99	88–126 (x = 103.68 ± 7.40)
R	51	60	41–82 (x = 60.84 ± 6.42)
S	153	150	135–178 (x = 151.24 ± 9.05)
T	90	89	75–95 (x = 84.60 ± 4.06)
N	90	81	69–95 (x = 81.12 ± 5.53)
TN	180	170	152–187 (x = 165.71 ± 8.51)
X	38	39	29–50 (x = 37.75 ± 4.66)
Y	112	118	80–135 (x = 112.34 ± 10.22)
XY	150	157	116–182 (x = 150.20 ± 13.07)
m	105	113	81–27 (x = 102.34 ± 11.30)

Character definition: Index 2 (= G/H) position of nostril between tip of snout and eye; P—scales from rictus to rictus across dorsum of head; Q—scales around tail base; R—scales around tail at approximately one third from base; S—scales around midbody; T-transverse ventral scale rows from gular fold to insertion of the hind legs (anterior margin); N—Gular scales from tip of snout to gular fold; TN—ventral scales from tip of snout to insertion of hind leg(= T+N); X—transverse dorsal scale rows from hind margin of tympanum to gular fold; Y—transverse dorsal scale rows from gular fold to insertion of hind legs; XY—dorsal scales from hind margin of tympanum to insertion of hind legs(= X+Y); m—scales around neck anterior to gular fold.

SUPPLEMENTARY TABLE 3. Descriptive statistics of main morphometric and meristic characters of all individuals of the *Varanus salvator* species complex. Provided for each character are range (min–max), mean (x) ± standard deviation (SD), and number (n) of specimens examined. *Tail mutilated in ZSI 20922; N/A—Not available.

Character	*V. s. andamanensis*	*V. s. macromaculatus*	*V. s. salvator*	*V. s. bivittatus*	*V. s. celebensis*
n	7	92–163	13–15	63–65	17–18
Distribution	Andaman and Nicobar, India	Mainland Southeast Asia, Sumatra, and Borneo	Sri Lanka	Java and Lesser Sunda Islands, Indonesia.	North Sulawesi
Index 2	1.92–2.94	1.82–3.46	2.17–2.91	1.67–2.88	1.90–2.64
	x = 2.21 ± 0.35	x = 2.30 ± 0.26	x = 2.47 ± 0.19	x = 2.21 ± 0.25	x = 2.17 ± 0.2
P	48–55	49–65	48–56	47–63	50–68
	x = 51.43 ± 2.57	x = 57.43 ± 3.34	x = 51.93 ± 2.10	x = 55.75 ± 3.12	x = 57.33 ± 4.10
Q	82–125	88–126	92–108	79–128	83–107
	x = 111.57 ± 14.3	x = 103.68 ± 7.40	x = 98.73 ± 4.65	x = 102.70 ± 7.93	x = 97.29 ± 6.42
R	65–78	41–82	55–67	51–71	51–68
	x = 71.2 ± 5.54*	x = 60.84 ± 6.42	x = 62.13 ± 3.50	x = 59.60 ± 4.66	x = 59.61 ± 4.89
S	143–161	135–178	142–165	101–175	116–162
	x = 152.57 ± 7.14	x = 151.24 ± 9.05	x = 153.73 ± 6.12	x = 150.58 ± 10.62	x = 143.12 ± 10.92
T	87–91	75–95	86–93	75–97	77–89
	x = 89.71 ± 1.38	x = 84.60 ± 4.06	x = 89.85 ± 2.23	x = 84.78 ± 4.19	x = 82.65 ± 3.30
N	81–103	69–95	75–85	70–91	N/A
	x = 88.43 ± 7.25	x = 81.12 ± 5.53	x = 78.85 ± 2.30	x = 80.00 ± 5.08	
TN	171–194	152–187	164–172	145–183	149–172
	x = 178.14 ± 7.78	x = 165.71 ± 8.51	x = 168.69 ± 2.59	x = 164.56 ± 7.14	x = 160.76 ± 6.73
X	38–53	29–50	26–36	28–52	30–47
	x = 45.42 ± 5.38	x = 37.75 ± 4.66	x = 32.40 ± 3.16	x = 38.59 ± 5.02	x = 37.28 ± 4.78
Y	105–130	80–135	86–99	91–138	N/A
	x = 115.29 ± 9.52	x = 112.34 ± 10.22	x = 93.27 ± 3.99	x = 111.78 ± 9.96	
XY	144–180	116–182	118–135	123–189	127–171
	x = 160.71 ± 14.30	x = 150.20 ± 13.07	x = 125.67 ± 5.34	x = 150.41 ± 13.40	x = 144.76 ± 11.20
m	80–97	81–127	94–109	82–122	73–115
	x = 87.14 ± 6.82	x = 102.34 ± 11.30	x = 102.43 ± 4.57	x = 101.40 ± 9.22	x = 96.82 ± 10.71

Character definitions: A, head length (distance between tip of snout to anterior margin of ear); B, head width (maximum width between eyes and ears); Index 1 (= TaL/SVL) relative tail length; Index 2 (= G/H) position of nostril between tip of snout and eye; Index 10 (= A/B) relative head length in relation to head width; Index 11 (= A/C) relative head length in relation to head height; P—scales from rictus to rictus across dorsum of head; Q—scales around tail base; R—scales around tail at approximately one third from base; S—scales around midbody; T-transverse ventral scale rows from gular fold to insertion of the hind legs (anterior margin); N—Gular scales from tip of snout to gular fold; TN—ventral scales from tip of snout to insertion of hind leg(= T+N); X—transverse dorsal scale rows from hind margin of tympanum to gular fold; Y—transverse dorsal scale rows from gular fold to insertion of hind legs; XY—dorsal scales from hind margin of tympanum to insertion of hind legs(= X+Y); m—scales around neck anterior to gular fold.