Underestimated Diversity of Philippine Water Monitor Lizards (*Varanus salvator* Complex) Unraveled: a Contribution to the International Year of Biodiversity, 2010

The Philippine Archipelago comprises more than 7,000 tropical islands. This island nation is well known for its spectacular biological richness and high diversity of plants and animals. It is one of the biodiversity hotspots of our planet, a real megadiversity country. Despite this internationally recognized distinction, knowledge about the enormous natural heritage of the Philippines is still rudimentary and we are far from a complete species inventory of these islands. This is not only true for coral fishes or butterflies and other small insects, but also for the large predators in this region, the monitor lizards. Thus, many new species are described each year from the Philippines – and many more remain to be discovered in the future.

Traditionally, three water monitor lizard species are recognized from the Philippines. These are *Varanus cumingi* Martin, 1838, from the islands of the Greater Mindanao region in the southeast, *V. nuchalis* (Günther, 1872) from the central Philippine Greater Negros–Panay region, as well as *V. marmoratus* (Wiegmann, 1834), which has a disjunct distribution range including the islands of Greater Luzon, Mindoro, Greater Palawan, and Greater Sulu (see Fig. 1). In addition, two herbivorous monitor lizard species, *V. mabitang* and *V. olivaceus* from Panay and Luzon, respectively, inhabit the Philippine Islands. The former species was discovered only nine years ago (Gaulke and Curio, 2001) and the latter species was recently split into two distinct species (Welton *et al*., 2010).

Since Mertens' (1942) revision of the genus *Varanus*, the three Philippine taxa have been treated as subspecies of the wide-spread *V. salvator*. A recent study on the systematics and diversity of Southeast Asian water monitor lizards (Koch *et al*., 2007), however, showed that they actually represent distinct species that can be distinguished from each other and *V. salvator* by significant differences in color pattern and scalation features. These decisions are also partly corroborated by molecular genetic evidence (see Ast, 2001).

Now, in a recently published morphological revision,

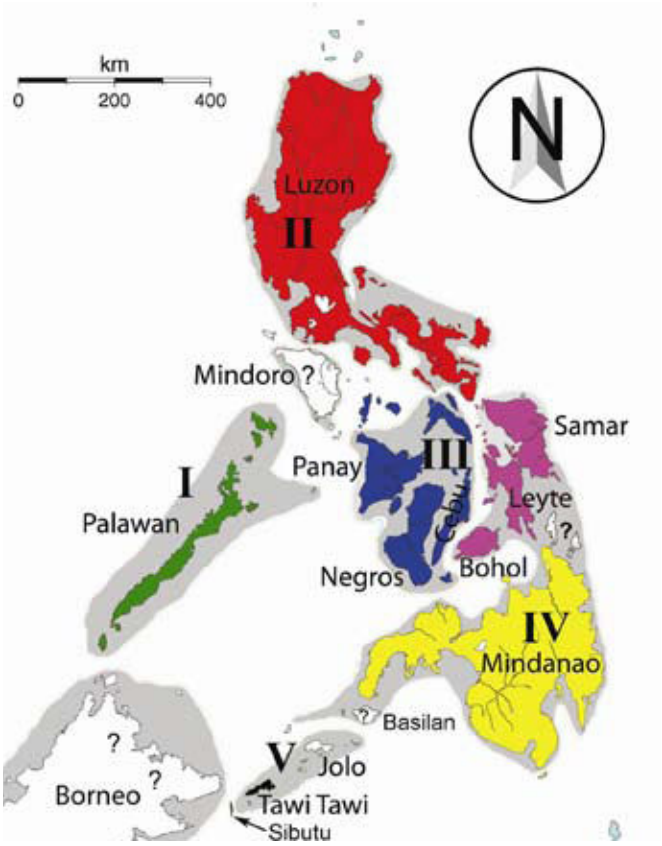

Fig. 1. Map of the Philippine Archipelago showing the distribution ranges of the six endemic water monitor lizard taxa: *Varanus marmoratus* = red; *V. nuchalis* = blue; *V. palawanensis* = green; *V. rasmusseni* = black; *V. c. cumingi* = yellow; and *V. cumingi samarensis* = purple. Question marks denote the water monitor populations from Mindoro, Basilan, and northern Borneo of unknown taxonomic status. The grey shaded areas indicate the extent of emerged land during global Pleistocene sea level low stands. Today, these former paleo-islands form five biogeographic subprovinces within the Philippines: I = Greater Palawan; II = Greater Luzon; III = Greater Negros–Panay; IV = Greater Mindanao; and V = Greater Sulu. Copyright **Maren Gaulke** & **André Koch.**

the Philippine members of the *V. salvator* complex were reinvestigated based on examination of numerous preserved voucher specimens in major European natural history museums, in combination with long-term studies in the field (Koch *et al*., 2010). As a consequence, three new taxa - two species and one subspecies- were identified as new to science. One main result was that the wide-spread *V. marmoratus*, with its disjunct island populations, actually represents a composite species, comprising at least three distinct taxa. Hence, the populations of Palawan, Balabac, the Calamian group and Sibutu, as well as those of Tawi–Tawi Island within the small Sulu Archipelago, were described as new species, viz. *V. palawanensis* (Fig. 2) and *V. rasmusseni* (Figs. 3A,B). The latter species is known from only two historical voucher specimens which were collected by the Danish Noona Dan Expedition in 1961. *Varanus rasmusseni* is considered endemic to the Sulu Archipelago, located between northern Borneo and Mindanao (Fig. 1). Due to its limited distribution range, the new species has to be treated as "vulnerable" according to the official criteria of the International Union for Conservation of Nature (IUCN 2001).

Although a large sample size of Philippine water monitor lizards was investigated, not all open questions could be answered. Thus, in the absence of voucher specimens, the taxonomic status of the monitor lizard population from Mindoro (Fig. 4) deserves further systematic investigations and has to be treated *incertae sedis* until new data are available. This is also true for the population of northern Borneo, which was hitherto allocated to the natural range of *V. s. macromaculatus* (Koch *et al*., 2007). However, the finding of *V. palawanensis* on the little island of Sibutu, belonging to the Sulu Archipelago off the coast of Sabah, northern Borneo (Fig. 1), suggests that this species might also occur on Borneo itself.

In addition, the morphological investigations revealed the colorful *V. cumingi* to be polytypic. The allopatric island populations from Samar, Leyte, and Bohol show diagnostic and geographically correlated color patterns distinct from the type locality Mindanao, warranting subspecific partition of this species. The new recognized subspecies was called *V. c. samarensis* after the island of Samar, from where the type specimens originated (Figs. 5 & 6). The nominotypic subspecies is restricted to Mindanao (Fig. 7), the second subregion of the Greater Mindanao subprovince (Fig. 1). In contrast, the various populations of *V. nuchalis* remain monotypic despite a considerable degree of polymorphism in color pattern ranging from individuals with large bright spots to nearly melanistic specimens. There is, however, no strict correlation between the different morphotypes of *V. nuchalis* and the islands inhabited. A summary of the respective distribution ranges and the most obvious distinguishing characters of the six Philippine members of the *V. salvator* complex are shown in Table 1.

Interestingly, the distribution ranges of the Philippine water monitor lizards reflect general biogeographic patterns of the Philippine Archipelago. Each species is endemic to one or few major modern-day islands constituting one of five faunistic subprovinces of the

Fig. 2. *Varanus palawanensis*, one of the new monitor lizard species from Palawan Island. Photograph by **Ingo Langlotz**.

Fig. 3. *Varanus rasmusseni* is only known from the two specimens of the type series. This endemic species is characterized by a dorsal color pattern of many small bright spots in juveniles (A, shown is the paratype specimen ZFMK 89391, formerly ZMUC R42153) and a melanistic coloration in adults (B, the holotype ZMUC R42151). Photographs by **André Koch**.

Philippines (Fig. 1), which formerly represented larger land masses of several interconnected islands during Pleistocene glacial periods of global sea level low stands. This circumstance is amazing given the good swimming ability of water monitor lizards. However, similar observations of distinct and endemic water monitor lizard taxa in close proximity, separated merely by narrow but deep ocean channels, have been made on Sulawesi and its satellite islands in Central Indonesia (Koch *et al*., unpubl. data). Obviously, strong sea currents impeded a faunal exchange and hybridization between neighboring island populations in the past, thus warranting an independent evolution in geographical isolation once these oceanic islands had been successfully colonized. The potential ability to reproduce parthenogenetically without males, as has been demonstrated for several other monitor lizard species (*e.g.*, Lenk *et al.*, 2005, Watts *et al*., 2006), might have facilitated the establishment of new founder populations.

Remarkably, the newly described monitor lizards virtually double the number of known Philippine water monitor lizard taxa. These important findings together with two other monitor lizard species described in the first months of 2010 (see Welton *et al.*, 2010; Weijola and Sweet, 2010), the International Year of Biodiversity (http://www.cbd.int/2010/welcome/), reveal again the underestimated diversity of these CITES-relevant giant lizards in insular Southeast Asia.

Fig. 4. The taxonomic status of the water monitor lizard population from Mindoro Island is still unsolved. This specimen shows enlarged nuchal scales as typical for *V. marmoratus* from Luzon. Photograph by **Maren Gaulke**.

Fig. 5. This adult specimen of *V. cumingi samarensis* from Leyte Island shows the distinctive and rich in contrast dorsal color pattern. Photograph by **Maren Gaulke**.

Fig. 6. A juvenile specimen of *V. cumingi samarensis*, the new subspecies of Cuming's water monitor from the islands of Samar, Leyte, and Bohol. Photograph by **Maren Gaulke**.

Table 1. Distribution ranges and most obvious distinguishing characters of the six Philippine members of the *V. salvator* complex. Data taken from Koch *et al*. (2010). Values in parentheses represent mean ± standard deviation; n = number of specimens examined.

	V. palawanensis	***V. rasmusseni***	***V. marmoratus***	***V. nuchalis***	***V. c. cumingi***	***V. c. samarensis***
Distribution range (see Fig. 1)	Palawan island group, Sibutu (North Borneo?)	Tawi-Tawi island group (Sulu Islands)	Luzon and off-shore islands (Mindoro?)	Negros, Panay, Cebu, Masbate, Ticao	Mindanao and off-shore islands	Samar, Leyte, Bohol
Scales around midbody	129–178 (141.93 ± 11.55; n = 14)	152–157 (154.50 ± 3.54; n = 2)	115–145 (133.60 ± 8.53; n = 15)	136–169 (151.45 ± 9.55; n = 29)	121–150 (138.70 ± 8.27; n = 10)	130–152 (140.38 ± 7.91; n = 8)
Ventral scales from tip of snout to insertion of hind legs	155–176 (169.50 ± 6.49; n = 14)	183–187 (185.00 ± 2.83; n = 2)	158–180 (169.00 ± 7.60; n = 15)	159–176 (167.64 ± 4.63; n = 28)	149–175 (161.10 ± 6.67; n = 10)	155–165 (160.63 ± 3.54; n = 8)
Dorsal scales from hind margin of ear to insertion of hind legs	116–145 (127.14 ± 8.29; n = 14)	135–138 (136.50 ± 2.12; n = 2)	101–123 (110.80 ± 6.13; n = 15)	94–138 (109.45 ± 9.99; n = 29)	114–136 (121.18 ± 7.08; n = 11)	114–127 (119.38 ± 4.90; n = 8)
Scales around neck anterior to gular fold	93–116 (101.15 ± 6.18; n = 13)	120–129 (124.50 ± 6.36; n = 2)	72–105 (98.71 ± 8.30; n = 14)	85–106 (97.21 ± 5.71; n = 29)	86–102 (96.60 ± 4.74; n = 10)	89–104 (98.00 ± 5.07; n = 8)
Color pattern of head	mostly dark, sometimes with whitish markings, a bright temporal streak more or less pronounced	juveniles: brown with 3 indistinctive dark crossbands on snout; adults: dark brown; a bright temporal streak only in juveniles	dark, with 1–2 indistinct bright crossbands on snout	dark, with or without white markings	predominantly yellow, sometimes brownish, with few dark markings	predominantly black, with yellow markings
Color pattern of back	mostly dark, mottled with light bordered scales; sometimes with up to eight transverse rows of spots	juveniles: brown with 12 transverse rows of small spots;adults: dark brown mottled with single bright scales	dark, with or without 4–6 transverse rows of more or less distinctive larger spots	dark, with or without 4 more or less reduced transverse rows of spots, sometimes with bright medium stripe	black, with 5–6 indistinctive yellow transverse rows, sometimes with medio–dorsal stripe	black, with 6–8 transverse rows of more or less distinctive yellow spots, ocelli or markings
Color pattern of belly	whitish, with 7–11 more or less distinctive dark crossbands	juveniles: whitish with ca. 11 dark cross bars; adults: dark with indistinctive bright median bars	whitish, with 6–11 more or less distinct dark pointed bars or cross bands	entirely dark or yellowish with dark reticulate markings or indistinctive dark bars	yellow, with 8–11 more or less distinctive dark bars or crossbands	yellow, with 9–15 more or less distinctive dark bars or crossbands

Fig. 7. The nominotypic subspecies of *V. cumingi* is restricted to Mindanao and some smaller offshore islands. Note the typical dorsal color pattern of indistinctive yellow transverse bands. Photograph by **Maren Gaulke**.

Finally, the recent revision of Philippine water monitor lizards is a convincing demonstration of the international importance of natural history museum collections as the archives of global biodiversity. Unfortunately, in times of limited public funding, necessary curatorial positions often remain unfilled once a scientist is retired. This gravely affects not only the relevant collections, but also the related field of study. Thus, one of the new monitor species, viz. *V. rasmusseni* (see Figs. 3A,B), which is known from only two specimens in the Zoological Museum of the University of Copenhagen (ZMUC), was named after the late Jens B. Rasmussen, former herpetologist in that museum, whose position was not reopened again. Thereby, the authors also want to call attention to the global taxonomy crisis.

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Contact:

ANDRÉ KOCH
Zoologisches Forschungsmuseum A. Koenig & Leibniz Institute for terrestrial Biodiversity
Department of Herpetology
Adenauerallee 160, D-53113 Bonn, Germany
E-mail: andrepascalkoch@web.de