

# BIAWAK

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# On the Cover: *Varanus douarrha*

The individuals depicted on the cover and inset of this issue represent a recently redescribed species of monitor lizard, *Varanus douarrha* (Lesson, 1830), which originates from New Ireland, in the Bismark Archipelago of Papua New Guinea. Although originally discovered and described by René Lesson in 1830, the holotype was lost on its way to France when the ship it was traveling on became shipwrecked at the Cape of Good Hope. Since then, without a holotype for comparative studies, it has been assumed that the monitors on New Ireland represented *V. indicus* or *V. finschi*. Recent field investigations by Valter Weijola in New Ireland and the Bismark Archipelago and phylogenetic analyses of recently collected specimens have reaffirmed Lesson's original classification of this animal as a distinct species.

The *V. douarrha* depicted here were photographed by **Valter Weijola** on 17 July and 9 August 2012 near Fissoa on the northern coast of New Ireland. Both individuals were found basking in coconut groves close to the beach.

**Reference:** Weijola, V., F. Kraus, V. Vahtera, C. Lindqvist & S.C. Donnellan. 2017. Reinstatement of *Varanus douarrha* Lesson, 1830 as a valid species with comments on the zoogeography of monitor lizards (Squamata: Varanidae) in the Bismarck Archipelago, Papua New Guinea. *Australian Journal of Zoology* 64(6): 434–451.



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# BIAWAK

*Journal of Varanid Biology and Husbandry*

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**INTERNATIONAL VARANID INTEREST GROUP**  
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The International Varanid Interest Group is a volunteer-based organization established to advance varanid research, conservation, and husbandry, and to promote scientific literacy among varanid enthusiasts. Membership to the IVIG is free, and open to anyone with an interest in monitor lizards and the advancement of varanid research. Membership includes subscription to *Biawak*, an international research journal of varanid biology and husbandry, and is available online through the IVIG website.



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*Varanus glauerti*. Kununurra, Western Australia. Photograph by **Chris Applin**.

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# ORGANIZATIONAL NEWS

## Continued Growth

*Biawak* continues to grow in terms of its global reach and readership. The period between June 2016 and July 2017 saw the addition of 78 new members, bringing IVIG membership to a total of 1,125 individuals from 60 countries. In addition to the informational resources available through the IVIG's website, <http://varanidae.org>, the discussion group entitled "*Biawak - International Journal of Varanid Biology and Husbandry*" on the popular social media website Facebook.com continues to grow and promote the exchange of ideas, news, and information relating to the biology and husbandry of varanid lizards. All IVIG members are encouraged to join and participate in this open forum. Current participants of this discussion group number 2,752.

## New Editorial Board Members

The International Varanid Interest Group welcomes several new individuals to the editorial board of *Biawak*. David S. Kirshner (Sydney, Australia), Laurence Paul (San Antonio Zoo, United States), Samuel S. Sweet (University of California, Santa Barbara, United States), Valter Weijola (University of Turku, Finland), and Thomas Ziegler (Cologne Zoo, Germany) join the board as members of the editorial review team. Collectively, their research backgrounds span such diverse fields as ecology, evolution, taxonomy and systematics, conservation and captive management, and bring decades of further expertise to the editorial board.

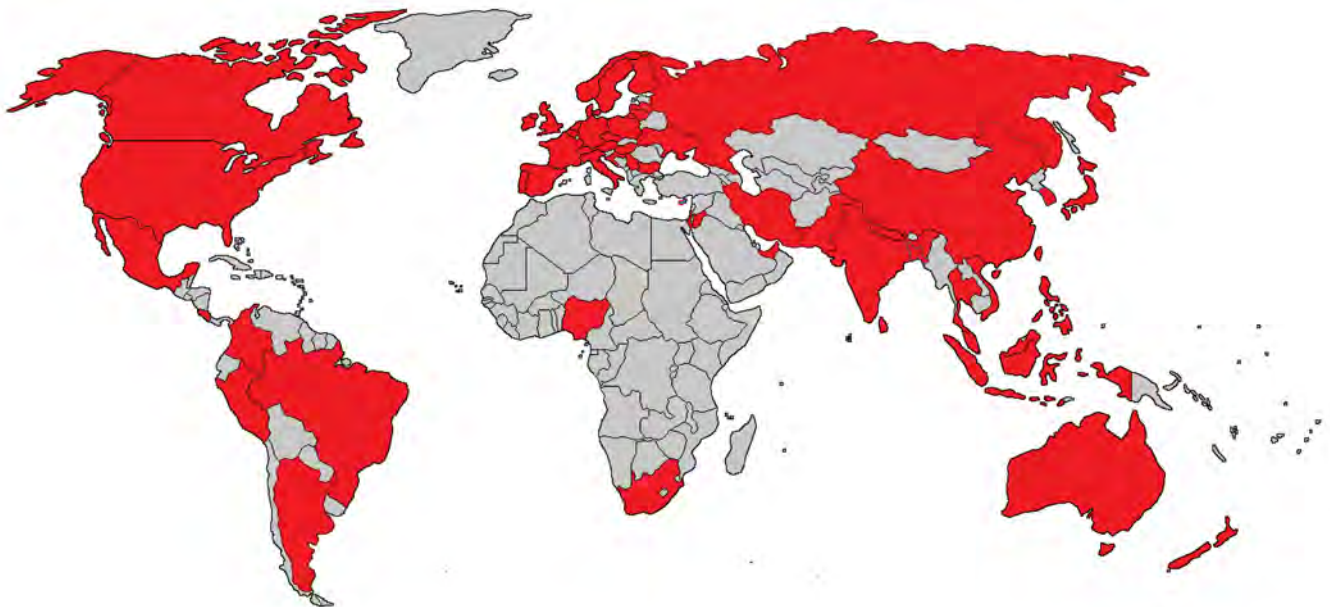


Fig. 1. Current global distribution of IVIG membership.

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# NEWS NOTES

## Bengal Monitor Population Declining in Seshachalam Hills, India

Bengal monitors (*Varanus bengalensis*) are reported to be in serious decline in the Seshachalam Hills area of the Eastern Ghats in Andhra Pradesh, India due to poaching. Parts from the lizards are claimed to be aphrodisiacs, with the tongue and liver being especially prized. Villagers who capture them may sell a single specimen for as much as Rs 5,000 (~ \$78 US). Although the species is protected, such protections are poorly known in areas occupied by the species and are widely ignored. Habitat loss has also played a role in the animal's disappearance from the region, which started a decade ago.

Source: *The Hindu*, 18 January 2017

## Trade in Bengal Monitor Sexual Organs Revealed

Indian wildlife officials have announced the discovery of an online-based trade in wildlife including the dried hemipenes of Bengal monitors (*Varanus bengalensis*), a protected species. The discovery was made following a raid on a house in Brahmeswarpatna in Odisha (formerly Orissa), India in which the organs from more than two hundred monitors were seized. The dried hemipenes were allegedly being sold as plant roots with magical, curative properties. Monitors are in high demand both in



*Varanus mertensi*. Litchfield NP, Northern Territory. Photograph by **Chris Applin**.

India and throughout Asia both for their meat as well as for their fat and oil which are claimed (without evidence) to cure various ailments including bone fractures and chronic pain. Authorities are now trying to determine this the source of the specimens.

Sources: *The Times of India*, 30 May 2017; *Hindustan Times*, 21 June 2017

## Komodo Dragon Dies at Louisville Zoo

A male Komodo dragon (*Varanus komodoensis*), the facility's only specimen, has been euthanized at the Louisville Zoo (USA). The twenty-three year old animal, nicknamed "Big Man", first arrived at the facility in 1994 from the Cincinnati Zoo. At the time of its death, it was the second oldest dragon in the United States. Zoo staff first noted that the dragon showed difficulty moving in April 2016. The cause was believed to be a compressive spinal cord lesion high in the neck (a problem that has been seen before in captive dragons). Initial steroid treatment was successful, but the dragon eventually stopped responding. After surgery was ruled out, zoo staff made the decision of euthanasia. A zoo spokesman said they hope to find a replacement specimen soon.

Source: *Courier-Journal*, 22 February 2017

## Bengal Monitor Stows Away in Tourist's Suitcase

A juvenile clouded monitor (*Varanus bengalensis nebulosus*) stowed away in the luggage of a British tourist returning from a trip to Thailand. The ca. 16 cm long lizard was discovered in a suitcase containing diving equipment after the owner had returned to his home in Derbyshire. Authorities were notified, who then retrieved the lizard and took it to a specialist exotics center where it was determined to be in good health. Officials are now seeking permission from Thai officials to place the lizard in a zoo.

Source: *www.upi.com*, 10 April 2017



## Virginia Aquarium Announces Genders of Juvenile Komodo Dragons

The Virginia Aquarium & Marine Science Center (USA) has announced that the two Komodo dragons (*Varanus komodoensis*) hatched at the facility in August 2016 are both males. The two are the offspring of Teman and Jude, a male and female pair who were on loan from the Denver and San Antonio Zoos, respectively. Jude developed egg-yolk coelomitis and was euthanized in 2016 following complications after surgery. However, prior to her passing, Jude had dug a nest and laid eighteen eggs which managed to escape the attention of zoo staff for seven months until two hatchlings were observed during routine exhibit cleaning. Of the clutch, only two eggs hatched. The offspring are now one meter in length and were considered large enough for blood to be drawn for DNA testing to determine their genders. Aquarium officials hope to place the two on public display sometime this summer, although one will eventually go to San Antonio Zoo.

Source: *The Virginian-Pilot*, 13 April 2017

## Tourist Bitten by Komodo Dragon

A Singaporean tourist was bitten and severely injured by a wild Komodo dragon (*Varanus komodoensis*) while watching the animals feed. According to Komodo National Park officials, the victim, a 50-year-old man, was watching several dragons feed on livestock belonging to villagers. Ignoring warnings, he approached the animals to take photographs and was then bitten on his left leg. Locals immediately pulled him away and took him to a nearby medical center in Labuan Bajo, Flores for first aid. He was later taken to Siloam General Hospital on Java. Although the specific site (and island) where the attack took place was not mentioned, park officials stated that the tourist had been staying with locals and that the attack occurred outside of designated dragon viewing areas. This represents the first incident of a human being bitten by a wild Komodo dragon in the past five years.

Sources: *The Jakarta Post*, 3 May 2017; [www.bbc.com](http://www.bbc.com),

4 May 2017; *The Telegraph*, 4 May 2017

## Questionable Practices Surrounding Monitor Lizard Deaths at Delhi Zoo

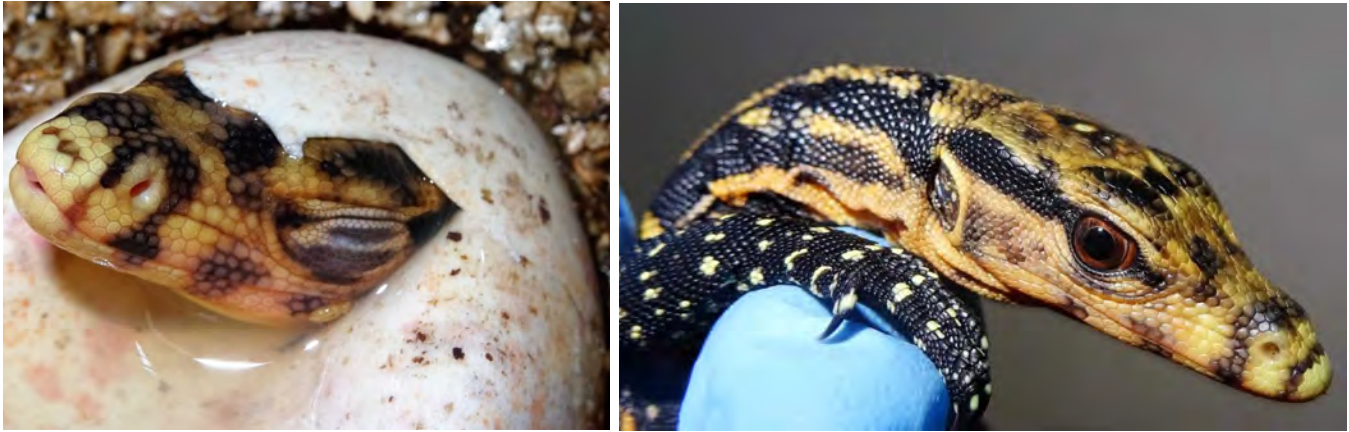
A recent investigation into several monitor lizard deaths at the National Zoological Park, or Delhi Zoo (India) has uncovered questionable record keeping practices that appear to attempt to hide the deaths and replacement of these individuals (species not identified, but likely *Varanus bengalensis*). Five monitor lizards allegedly died at the zoo between November 2016 and early January 2017, and were secretly replaced with another four individuals in January. These four replacement animals reportedly died shortly after their arrival in early February, allegedly due to shock associated with being “disturbed from hibernation.” Two of these animals reportedly died the same day as their “disturbance”, whereas the other two perished a few days later.

Inconsistencies in the zoo’s collection records of how many individuals were on hand, and questionable dietary records documenting food rations for the monitor lizards during January 2016 suggest foul play. All animal deaths are required to be reported to the Central Zoo Authority; however, the Delhi Zoo’s ranger alleges that the keeper and head keeper were instructed to hide the transfer of the replacement monitor lizards. This investigation is ongoing.

Source: *The Indian Express*, 25 February 2017



*Varanus baritji*. Adelaide River, Northern Territory. Photograph by **Chris Applin**.



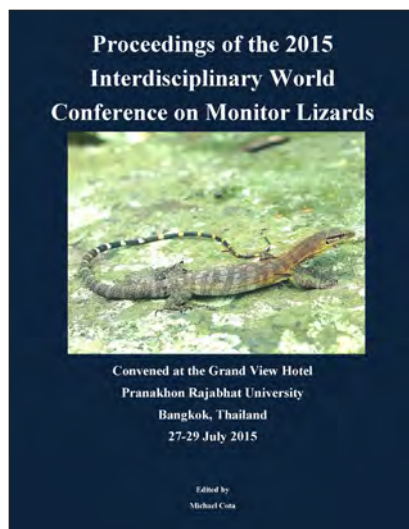
Successful captive breeding of *Varanus cumingi* at Cologne Zoo. Photographs courtesy of **Thomas Ziegler**.

## *Varanus cumingi* Hatch at Cologne Zoo

A total of five *Varanus cumingi* recently hatched at the Cologne Zoo (DE). The zoo acquired the species as a confiscation in 2010 and these animals were integrated into the zoo's Philippines exhibit, next to its Philippine crocodile enclosure; additional specimens were maintained in off-exhibit areas. From this initial group, all individuals proved to be male. To acquire specimens of both sexes, some individuals were exchanged for *V. cumingi* from Augsburg Zoo (DE) in March 2016.

Mating occurred in mid-October 2016, with eggs laid on 16 November 2016. The eggs were incubated at temperatures ranging from 29–31.5 °C, with hatching taking place between 22 and 27 May 2017. The five hatchlings ranged from 12.1–13.4 cm in snout-to-vent length and 30.1–32.4 cm in total length, and weighed between 31 and 36 g. Further mating occurred in April 2017, with a clutch of nine eggs laid on 14 May which are currently incubating. Officials plan to eventually display some of the offspring at the zoo.

*Source: Thomas Ziegler and Anna Rauhaus, Cologne Zoo*



## Proceedings of the 2015 Interdisciplinary World Conference on Monitor Lizards

The published proceedings of the Interdisciplinary World Conference on Monitor Lizards held in Bangkok, Thailand from 27-29 July 2015 is now available for purchase. The price is \$35.00 US plus shipping from Thailand. Due to a limited print run, only a limited number of copies are available.

Please contact **Michael Cota** at [Herpetologe@gmail.com](mailto:Herpetologe@gmail.com) to order and for further information.



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# ARTICLES

Biawak, 11(1), pp. 8–14

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## Notes on the Natural History of Blue-tailed Monitors (*Varanus doreanus*) in Australia

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**Abstract - The blue-tailed monitor (*Varanus doreanus*) is a large but poorly known lizard described from New Guinea and adjacent islands. Recently, *V. doreanus* was recorded from mainland Australia, but its extent of occurrence there and aspects of its natural history remain unknown. We provide basic notes on the habitat associations, morphometrics, male combat, diet, predation and relative abundance of *V. doreanus*, based on observations of 12 specimens from the northern tip of Cape York Peninsula, Australia. We conclude by providing an assessment of the distribution range and conservation status of *V. doreanus* in Australia.**

### Introduction

The blue-tailed monitor (*Varanus doreanus* [Meyer 1874]) is a large monitor lizard (< 1.6 m) described from New Guinea and surrounding islands (Böhme *et al.*, 1994; Ziegler *et al.*, 2007). In the 1990s, examination of specimens held in European museum collections suggested that *V. doreanus* also occurred on the Australian mainland (Ziegler *et al.*, 1999; Ziegler *et al.*, 2001). However, the specimens' locality data were vague (referring only to "Queensland, Australia") and herpetologists did not recognize the species' occurrence in the country until recently (Cogger, 2014; Wilson, 2015). Since then, several photographs of specimens resembling *V. doreanus* were taken in the Iron Range area of Cape York Peninsula, Australia. Finally, detailed examination of *V. indicus* specimens held in the collections of the Queensland Museum revealed they were in fact *V. doreanus* (Weijola *et al.* 2016; Weijola,

pers. comm. 2017). The species' remote distribution and superficial similarity to the mangrove monitor (*V. indicus*) are the primary reasons for it remaining unrecorded for so long (Ziegler *et al.*, 1999).

Few field studies have been conducted on *V. doreanus* in its native range (but see Phillip, 1999), and they remain one of the rarest monitor lizards in zoological gardens worldwide (< 10 specimens; Ziegler *et al.*, 2016; although they are moderately common in the pet trade, S. Sweet, pers. comm. 2017). Hence, basic information on the natural history of the species is lacking. In 2013, we began a field study on the ecology of tropical snakes in the vicinity of the Lockerbie Scrub, near the town of Bamaga at the northern tip of Cape York Peninsula, Australia (*e.g.*, see Natusch *et al.*, 2016). While undertaking fieldwork we made observations of 12 specimens of *V. doreanus*. Here, we use those observations to describe aspects of the species' natural history, and discuss its conservation status in Australia.

## Materials and Methods

### Data collection

While conducting fieldwork in New Guinea from 2009 to 2011, we observed 70 live specimens of *V. doreanus* at wildlife traders' premises (to be sold as pets) and in the wild (Natusch & Lyons, 2012). In addition, we observed 68 specimens of *V. indicus* and three specimens of *V. jobiensis*, against which comparisons could be made. Based on this experience, we are confident in our ability to correctly identify specimens of *V. doreanus*. We did observe many more than 12 monitor lizards while conducting fieldwork in the Lockerbie Scrub, some of which were undoubtedly *V. doreanus*. However, many of those sightings were only fleeting glances of fast-moving lizards in dense undergrowth, and so we have only recorded observations where we are certain the specimen was *V. doreanus*.

### Study site and habitat associations

The observations reported in this paper all occurred in the Lockerbie Scrub, at the extreme northern tip of

Cape York Peninsula, Queensland (Fig. 1). The climate there is hot year-round (27 to 33 °C) with an average annual rainfall of 1,744 mm (range = 1,268 to 3,184 mm), most of which falls during the summer monsoon (December to April; Bureau of Meteorology, 2016). The rest of the year remains relatively dry with frequent fires (at least in woodland vegetation). The Lockerbie Scrub is characterized by semi-deciduous notophyll vine forest (hereafter referred to as "rainforest"), interspersed and surrounded by tropical woodlands dominated by *Corymbia tessellaris*, *C. clarksoniana* and/or *Eucalyptus brassiana* (Nelder & Clarkson, 1995; Stanton & Fell, 2005).

Most observations of *V. doreanus* occurred deep within the rainforest (Fig. 2). The exceptions were four specimens collected or observed on roads transecting tropical woodlands. On all occasions, rainforest habitat was < 50 m away. We never observed a monitor lizard resembling *V. doreanus* in tropical woodland away from rainforest. It is therefore reasonable to assume that this species is closely associated with rainforests in Australia. By contrast, we never observed the closely related *V. indicus* within the inland rainforest of the Lockerbie Scrub. All specimens of that species were

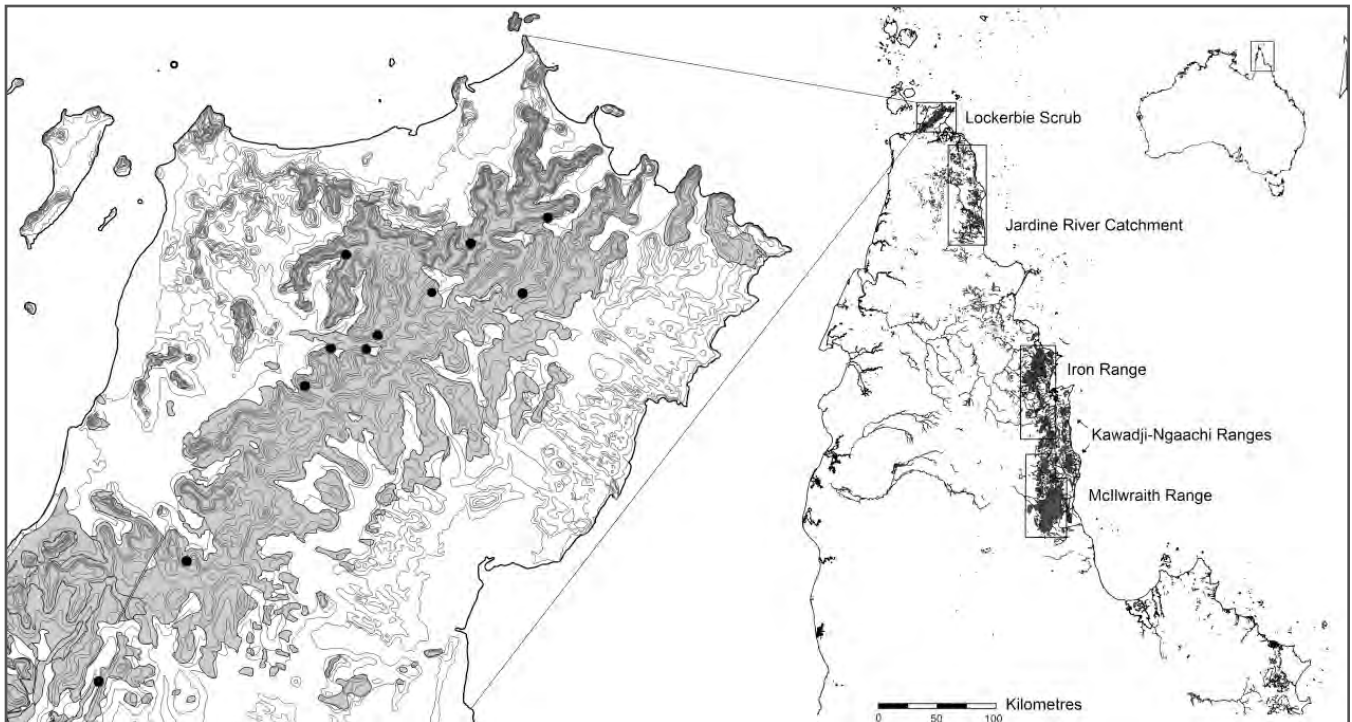


Fig. 1. The Lockerbie Scrub at the northern tip of Cape York Peninsula, Australia, where *Varanus doreanus* were observed (black dots) in relation to semi-deciduous notophyll vine forest (grey shading). The map also shows the Lockerbie Scrub in relation to other major rainforest habitats on Cape York Peninsula (based on regional ecosystem mapping for Queensland; Neldner & Clarkson, 1995; Sattler & Williams, 1999). *Varanus doreanus* has also been recorded from the Iron, McIlwraith and Kawadji-Ngaachi ranges, but is yet to be recorded from the Jardine River Catchment.





Fig. 2. Typical rainforest habitat of *V. doreanus* in the Lockerbie Scrub, at the northern tip of Cape York Peninsula, Australia. Photograph by **Daniel Natusch**.

observed in mangroves or in rainforest near the coast. That being said, DJDN has observed true *V. indicus* at 400 m a.s.l in the McIlwraith Range (Fig. 2; D. Natusch unpubl. data, 2008), suggesting the species may be more broadly distributed in the Lockerbie Scrub but simply not recorded by us.

## Results

### *Morphometrics*

On 16 August 2013 and 9 March 2016 we encountered two specimens of *V. doreanus* killed on a dirt road in the vicinity of the Lockerbie Scrub. The first specimen was a sexually mature male (assumed by its size), measuring 630 mm from snout-to-vent (SVL) and 910 mm from vent to tail tip. This specimen therefore represents a maximal size record for this species (Fig. 3b). The second specimen was a female, measuring 310 mm SVL and 500 mm from vent to tail (Fig. 3a). Dissection of the female specimen revealed that she had not undergone a reproductive event (determined by the absence of vitellogenic follicles, thickened oviducts and corpora albicantia indicative of ovulation) and was thus likely to be physiologically immature. Both specimens contained ectoparasites (ticks) common to snakes and other monitors in the area (D. Natusch, unpubl. data).

### *Diet*

While surveying a colony of metallic starlings

(*Aplonis metallica*) we observed a small (estimated 300 mm SVL) *V. doreanus* approximately 10 m up the trunk of the colony's host tree. We did not observe the specimen entering starling nests, but speculate that it was preying upon starling eggs or chicks. In keeping with this, Phillip *et al.* (2007) recorded a bird in the stomach of the closely related *V. semotus* from Mussau Island (Weijola *et al.*, 2016). Finally, dissection of the small female specimen (SVL 310 mm, see above) found dead on the road revealed its stomach to contain few content except for the remains of unidentified coleopterans (as has been shown previously; Phillip *et al.*, 2007).

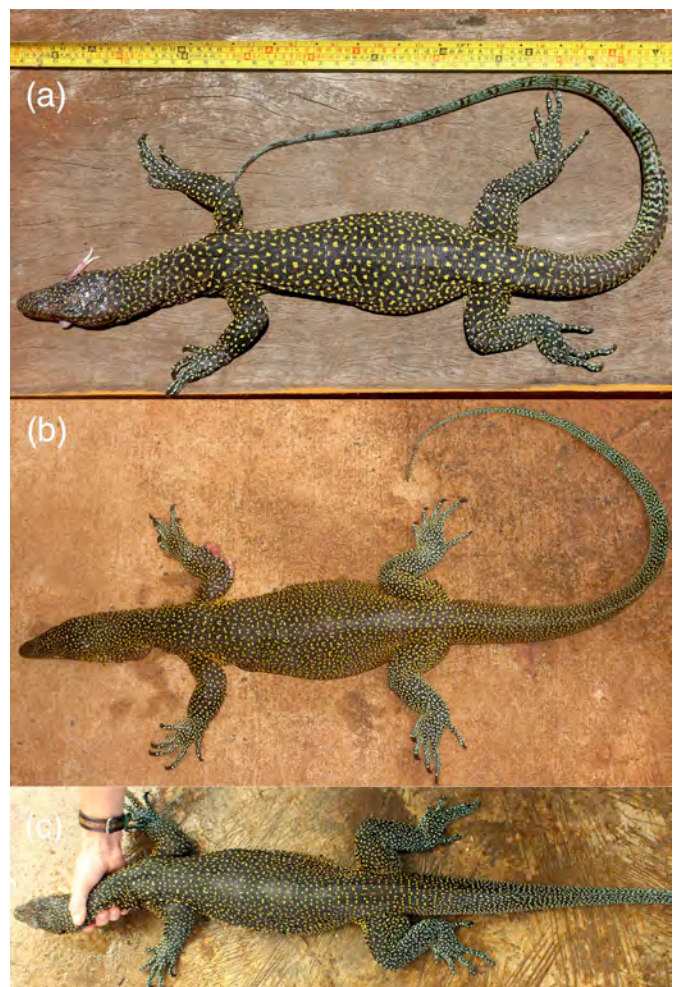


Fig. 3. Comparison of *V. doreanus* dorsal pattern between (a) a female specimen (310 mm SVL) from the Lockerbie Scrub, Cape York Peninsula, Australia, (b) a male specimen from the Lockerbie Scrub (630 mm SVL), and (c) a male specimen (not measured) from Muting, southern Papua, Indonesia. Note the ontogenetic change in colour pattern between (a) smaller and (b, c) larger specimens. Photographs by **Daniel Natusch**.

**Male combat**

On 8 December 2013, DJDN observed two large male (> 500 mm SVL) *V. doreanus* engaged in ritualized combat next to a dirt road in the vicinity of the Lockerbie Scrub. The specimens were in tropical woodland habitat, but closed rainforest was approximately 20 m away. The specimens were on their hind-legs, engaged in combat typical of other varanids. The combat ritual was observed for fewer than 10 seconds before the lizards disengaged and fled into the surrounding rainforest.

**Predation**

On 20 May 2015, a male black-headed python (*Aspidites melanocephalus*) measuring 1700 mm SVL with a mass of 1068 g (measured without stomach contents) regurgitated a female (approximately 200 mm SVL) *V. doreanus*. The specimen was partly digested, but identifiable by its bright blue-banded tail. The python was captured in tropical woodland, but only 20 m from rainforest. Black-headed pythons frequently consumed monitor lizards at our study site (usually *V. panoptes* and *V. scalaris*), and may represent a common predator for *V. doreanus* (D. Natusch, unpubl. data).

**Discussion****Distribution within Australia**

In addition to occurring in the Lockerbie Scrub, *V. doreanus* has also been recorded from semi-deciduous mesophyll vine forests in the vicinity of Lockhart River (Iron Range), 230 km to the south (Fig. 4). It also occurs in the nearby McIlwraith Range, as well as the Kawadji-Ngaachi Ranges (V. Weijola, pers. comm. 2017; Fig. 1).

The occurrence of *V. doreanus* in the Lockerbie Scrub strongly suggests that this species is not confined

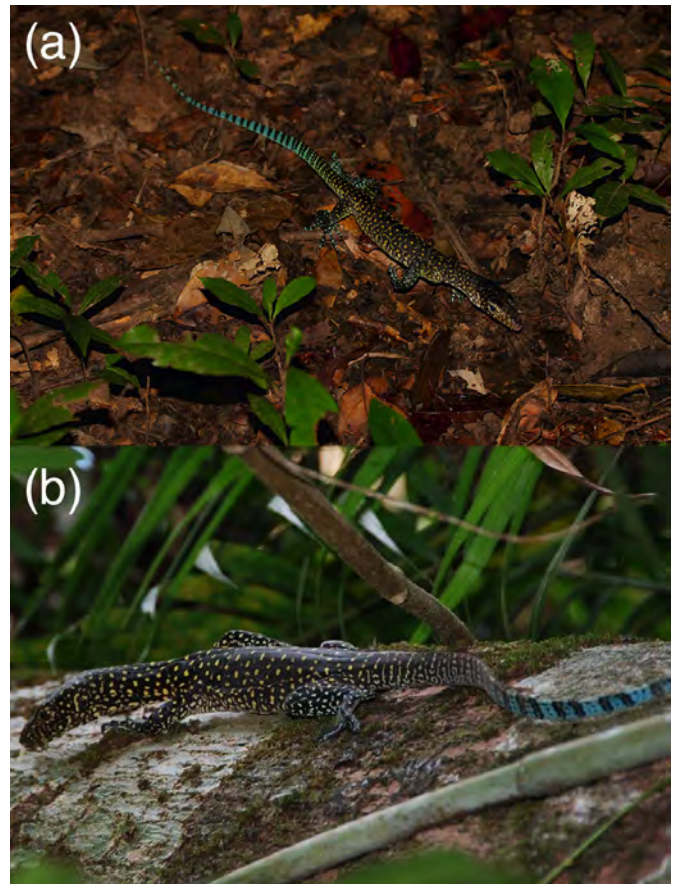


Fig. 4. Two young *V. doreanus* from the Iron Range area, Cape York Peninsula, Australia (approximately 230 km south of the Lockerbie Scrub). Photographs by (a) **Ricky Mackenzie** and (b) **David Newman**.

to well-developed rainforest. Unlike other obligate rainforest species (*e.g.*, the eclectus parrot [*Eclectus roratus macgillivrayi*] and the green python [*Morelia viridis*]; Legge *et al.*, 2004; Natusch & Natusch, 2011), *V. doreanus* must have persisted in the Lockerbie Scrub

Table 1. Extent of closed forest on Cape York Peninsula suitable for *Varanus doreanus*. Values from Neldner & Clarkson (1995) and adapted from Natusch & Natusch (2011). All values in km<sup>2</sup>.

Rainforest site	Extent of rainforest habitat	Percent in protected areas
Lockerbie Scrub	87	0%
Jardine River Catchment	241	100%
Iron Range	532	73%
McIlwraith Range	1,512	62%
Total	2,372	58%





Fig. 5. A *Varanus doreanus* from the Lockerbie Scrub, Cape York Peninsula, Australia, escapes up a nearby tree. Photograph by **Anders Zimny**.

during periods of glaciation and continental drying. At those times, the extent of rainforest vegetation on Cape York diminished considerably, and probably disappeared almost completely from the Lockerbie Scrub (Nix & Kalma, 1972; Kikkawa *et al.*, 1981; Rowe, 2007).

This ability to persist in drier vine thickets indicates that *V. doreanus* probably also occurs in the rainforests

of the Jardine River Catchment (Fig. 1). In terms of southern distribution, *V. doreanus* is unlikely to occur south of the Princess Charlotte Bay dry corridor in southern Cape York (in keeping with many other species of Papuan origin; *e.g.*, see Natusch & Natusch, 2011). Therefore, assuming an almost continuous distribution within suitable habitat in the major rainforests of Cape York Peninsula, we estimate that *V. doreanus* has an Australian range of 2,372 km<sup>2</sup> (Table 1).

#### *Abundance and conservation status of Varanus doreanus in Australia*

We do not consider *V. doreanus* to be rare in the Lockerbie Scrub. That being said, we conducted fieldwork in rainforest habitat almost daily for four years but only recorded 12 specimens. A possible explanation for this is that, in contrast with several other Australian monitors, *V. doreanus* is extraordinarily elusive (Fig. 5). This is undoubtedly a major factor contributing to it remaining undetected in Australia, and we suspect the species is more abundant than it appears (Fig. 6). We consider *V. doreanus* to be the most common rainforest monitor in the Lockerbie Scrub rainforest. In comparison, Phillip *et al.* (1999) recorded remarkably high densities of this species within a riverbed in West Papua, Indonesia (13 specimens within 600 m<sup>2</sup>). A similar situation occurs in the Lockerbie Scrub. Four individuals (adults and juveniles) were seen congregating around a pool of water in the bed of a rainforest stream in the late dry season (L. McIntyre, pers. comm. 2016).

*Varanus doreanus* in Australia is subject to few threatening processes. Introduced cane toads (*Rhinella marina*) severely impacted populations of monitor lizards in other parts of Australia (Shine, 2010), and



Fig. 6. A camera trap photograph of a young *V. doreanus* in the Lockerbie Scrub, Cape York Peninsula, Australia. Interestingly, we recorded only two photographs of monitor lizards from > 20,000 photographs of > 100,000 animals in the Lockerbie Scrub – both were *V. doreanus* (Natusch *et al.*, 2016).

probably impacted *V. doreanus* in a similar way when they first reached Cape York Peninsula. Despite this, and despite a continually high abundance of cane toads in the Lockerbie Scrub, the *V. doreanus* population there has likely stabilized. In conclusion, based on the species' estimated area of occupancy (2,372 km<sup>2</sup>), lack of known threats, and extremely remote distribution (much of which occurs in protected areas), we consider the conservation status of *V. doreanus* in Australia to be of least concern (IUCN, 2001).

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## References

- Böhme, W., H.G. Horn & T. Ziegler. 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.
- Bureau of Meteorology 1887–1955. Monthly climate statistics. 2016. Available: [http://www.bom.gov.au/climate/averages/tables/cw\\_027004.shtml](http://www.bom.gov.au/climate/averages/tables/cw_027004.shtml).
- Cogger, H. 2014. *The Reptiles and Amphibians of Australia*. Reed Books, Sydney. 1033 pp.
- IUCN. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland/Cambridge, UK.
- Kikkawa, J., G. Monteith, & G.J. Ingram. 1981. Cape York Peninsula: Major region of faunal interchange. Pp. 1695–1742. *In*: Keast, A. (ed.), *Ecological Biogeography of Australia*. Dr. W. Junk, The Hague.
- Legge, S., R. Heinsohn & S. Garnett. 2004. Availability of nest hollows and breeding population size of eclectus parrots, *Eclectus roratus*, on Cape York Peninsula. *Wildlife Research* 31: 149–161.
- Natusch, D.J.D. & D.F.S. Natusch. 2011. Distribution, abundance and demography of green pythons (*Morelia viridis*) in Cape York Peninsula, Australia. *Australian Journal of Zoology* 59: 145–155.
- Natusch, D.J.D. & J.A. Lyons. 2012. Exploited for pets: The harvest and trade of amphibians and reptiles from Indonesian New Guinea. *Biodiversity and Conservation* 21: 2899–2911.
- Natusch, D.J.D., J.A. Lyons, G.P. Brown & R. Shine. 2016. Communally breeding birds create ecological hotspots in tropical Australia. *PLoS ONE* 11(10): e0162651.
- Neldner, V. J. & J.R. Clarkson. 1995. *Vegetation of Cape York Peninsula*. Department of Environment and Heritage, Brisbane. 141 pp.
- Nix, H. A. & J.D. Kalma. 1972. Climate as a dominant control in the biogeography of northern Australia and New Guinea. Pp. 61–91. *In*: Walker, D. (ed.), *Bridge and Barrier: The Natural and Cultural History of Torres Strait*. Research School of Pacific Studies, ANU, Canberra.
- Phillip, K.M. 1999. Niche partitioning of *Varanus doreanus*, *V. indicus* and *V. jobiensis* in Irian Jaya: Preliminary results. Pp. 307–316. *In*: Horn, H.-G. & W. Böhme (eds.), *Advances in Monitor Research II*, Mertensiella 11. Deutsche Gesellschaft für Herpetologie und Terrarienkunde, Rheinbach.
- Phillip K.M., T. Ziegler & W. Böhme. 2007. Preliminary investigations of the natural diet of six monitor lizard species of the *Varanus (Euprepiosaurus) indicus* group. Pp. 336–345. *In*: Horn, H.-G. & W. Böhme (eds.), *Advances in Monitor Research III*, Mertensiella 16. Deutsche Gesellschaft für Herpetologie und Terrarienkunde, Rheinbach.
- Rowe, C. 2007. A palynological investigation of Holocene vegetation change in Torres Strait, seasonal tropics of northern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 251: 83–103.
- Sattler, P. & R. Williams. 1999. *The Conservation of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane. 625 pp.
- Shine, R. 2010. The ecological impact of invasive cane toads (*Bufo marinus*) in Australia. *Quarterly Review of Biology* 85: 253–291.
- Stanton, P. & D. Fell. 2005. *The Rainforests of Cape York Peninsula*. Cooperative Research Centre for



- Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns. 204 pp.
- Weijola, V., S.C. Donnellan & C. Lindqvist. 2016. A new blue-tailed monitor lizard (Reptilia, Squamata, *Varanus*) of the *Varanus indicus* group from Mussau Island, Papua New Guinea. *ZooKeys* 568: 129–154.
- Wilson, S. 2015. A Field Guide to Reptiles of Queensland. New Holland, Chatswood. 304 pp.
- Ziegler, T., K.M. Philipp & W. Böhme. 1999. Zum Artstatus und zur Genitalmorphologie von *Varanus finschi* Böhme, Horn et Ziegler, 1994, mit neuen Verbreitungsangaben für *V. finschi* und *V. doreanus* (Meyer, 1874) (Reptilia: Squamata: Varanidae). *Zoologische Abhandlungen, Staatliches Museum für Tierkunde, Dresden* 50: 267–279.
- Ziegler, T., W. Böhme, B. Eidenmüller & K.M. Philipp. 2001. A note on the coexistence of three species of Pacific monitor lizards in Australia (Sauria, Varanidae, *Varanus indicus* group). *Bonner Zoologische Beiträge, Bonn* 50:27–30.
- Ziegler T., A. Schmitz, A. Koch & W. Böhme. 2007. A review of the subgenus *Euprepiosaurus* of *Varanus* (Squamata: Varanidae): Morphological and molecular phylogeny, distribution and zoogeography, with an identification key for the members of the *V. indicus* and the *V. prasinus* species groups. *Zootaxa* 1472: 1–28.
- Ziegler, T., A. Rauhaus & I. Gill. 2016. A preliminary review of monitor lizards in zoological gardens. *Biawak* 10(1): 26–35.

## Record of a Water Monitor with a Foreign Bone Protruding from its Tympanum

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**Abstract - Records of injured monitor lizards and how they cope with their injuries in the wild are limited. This report documents observations made in Sumatra, Indonesia over the course of 28 months of an Asian water monitor (*Varanus salvator*) afflicted by a foreign bone protruding from its tympanum. The monitor's body condition, feeding behavior, nocturnal activity, social status, and ritualized combat are noted.**

### Introduction

The Asian water monitor, *Varanus salvator*, is a large (ca. 2 m total length) predator and scavenger, with a wide distribution throughout southern and southeastern Asia (Bennett *et al.*, 2010; Das, 2010). This species is semi-aquatic and diurnal, and occurs in many different habitats including mangrove swamps, along riverbanks, dipterocarp forests, and urban areas (Bennett, 1995; Bennet *et al.*, 2010; de Lisle, 2007; Uyeda, 2015). The diet of *V. salvator* is comprised of large invertebrates and small vertebrates such as insects, crabs, fishes, lizards, turtles, birds, and rats (Das, 2010; Traeholt, 1993, 1994), with carrion, including large mammal carcasses such as wild pigs and deer (Gaulke, 1991), also known to be a significant part of its diet. *Varanus salvator* often habituates to human presence and can be found in areas of anthropogenic disturbance such as human settlements and garbage areas (Bennet *et al.*, 2010; Das, 2010; Uyeda *et al.*, 2015).

In Sumatra, Indonesia, *V. salvator* is often found in lowland tropical rainforest (Teynie *et al.*, 2010). The Way Canguk Research Station is a tropical

ecosystem research station established in 1997 by the Wildlife Conservation Society Indonesia Program in collaboration with The Indonesian Ministry of Environment and Forestry (WCS-IP, 2001). It is located in Bukit Barisan Selatan National Park, the largest protected area in southern Sumatra (5° 39' 32" S; 104° 24' 21" E). The station's study area encompasses a 900 ha mosaic of primary and burned rainforest bisected by the Canguk River (WCS-IP, 2001). Approximately three months after the establishment of the Way Canguk Research Station, several *V. salvator* began visiting the station, frequently foraging on human food leftovers such as bones and meat from the kitchen. The average number of *V. salvator* typically seen around the camp on a daily basis has been five, but as many as 11 individuals have been recorded. All age classes are represented, from juveniles to adults.

Among the *V. salvator* present at Way Canguk, one individual was observed over the course of 28 months from March 2014 to June 2016 with a large bone protruding through its tympanum. As there is limited information on the biology of injured monitor lizards in the wild, here we report observations on the body





Fig. 1. The “tusked” monitor of Way Canguk Research Station, with approximately 20 cm of foreign bone protruding from its tympanum.

condition, feeding behavior, nocturnal activity, social status, and ritualized combat of this “tusked” monitor in a tropical rainforest of Sumatra.

### Observations

Research staff first observed an adult *V. salvator* (ca. 2 m total length) foraging around the station in March 2014 with a foreign bone protruding from the tympanum on the side of its head (Fig. 1). This particular individual had been visiting the station daily to forage for food leftovers before it was observed with the bone protruding. It is presumed that the monitor attempted to swallow part of an extremity bone from a primate carcass, possibly a Siamang (*Symphalangus syndactylus*) or Sumatran surili (*Presbytis melalophos*). Although there was no direct observation of the bone’s ingestion, one possible scenario is that the long bone

became stuck inside the throat and when the monitor attempted to regurgitate it through vicious shaking, and the sharp, broken tip of the bone pierced through its tympanum.

In April 2014, research staff captured the “tusked” individual and attempted to remove the bone by pulling it from the side of the monitor’s head. However, there was a possibility that the tip of the bone inside the throat was stuck, and attempts to remove the bone were immediately discontinued upon observation of blood dripping from the tympanum.

During 2014, the monitor was observed in an emaciated state, and the injury to the tympanum area was still fresh and appeared to be impairing the monitor’s ability to ingest food. By January 2015, eleven months after the first observation of the protruding bone, the injury had healed and showed no overt signs of disease (Fig. 2). Once again able to ingest food without complication, it began to gain weight and was able to return to a normal body condition.

Since monitors are generally diurnal, nocturnal activity has rarely been reported (*e.g.*, Milenkaya & McKay, 2016; Uyeda *et al.*, 2013). Uyeda *et al.* (2013) documented 16 observations of nocturnal activity by a single *V. salvator* on Tinjil Island, Indonesia between 0128 and 0530 h. In Way Canguk, nocturnal activity by the “tusked” monitor was observed on more than three occasions in which it was seen feeding on food leftovers in the garbage area of the station (Fig. 3).

Following the suspected death of the station’s dominant *V. salvator* in April 2016 (this individual was observed with severe swelling to the left hind leg in January 2016 and had not been seen around the station since April 2016), the “tusked” monitor appears to have



Fig. 2. Close-up of the “tusked” monitor taken on 11 November 2016, two and a half years after it was first seen with the protruding bone. The injury to the tympanum area had healed and the monitor’s body condition had dramatically improved since 2014.



Fig. 3. The “tusked” monitor ingesting a leftover fried catfish head in the garbage area at night (2345 h) on 29 June 2016.

become the dominant individual around the station. Although there are two other individuals of similar body size in the area, the “tusked” monitor frequently elicits greater agonistic interactions by displacing and briefly pursuing other monitors, including smaller individuals. In order to become dominant, the monitor would have had to prevail in a greater number of interactions with rivals (Uyeda *et al.*, 2015). Opportunistic observations have shown that other monitors around the station tend to avoid the “tusked” individual when encountered, suggesting its dominance (Fig. 4).

At 1423 h on 9 August 2016, the “tusked” monitor was observed engaged in ritualized combat with another individual of similar body size in the Way Canguk River that lasted about 10 minutes (Fig. 5). Such combat is needed to establish or maintain the dominance hierarchy



Fig. 4. Another *V. salvator* slowly approached the “tusked” monitor as both were searching for a basking site near the station, but then avoided the latter, even though it did not exhibit any aggression.

which may yield greater access to food and females (Horn *et al.*, 1994). However, we were unable to identify the winner of the combat as the monitors followed the current of the river and were too far away to be seen once the combat concluded.

## Discussion

Monitor lizards typically ingest their food whole, which can occasionally lead to health issues. This account documents a *V. salvator* that ingested a long and sharp bone, likely as part of a scavenged food item. Previous records of similar cases include a *V. varius* found with a sharp bone from a T-bone steak protruding from its throat (Fillett & Jackson, 2010) and a deceased *V. komodoensis* found with a deer antler piercing through its abdomen (A. Ariefiandy, pers. comm.). In the case of the *V. varius*, surgery was performed to successfully remove the bone from the monitor (Fillett & Jackson, 2010).

Fortunately for the *V. salvator* in the present account, it was able to recover from its injury on its own. In the Phillipines, Auffenberg (1988) found that there was a higher percentage of water monitors (*V. salvator* complex) encountered with scars (62%) when compared to *V. olivaceus* (52%), which may suggest that water monitors are more resilient and capable of withstanding injuries than other species. Observations on its current feeding behavior, dominance over other individuals, and ritualized combat illustrate the monitor’s ability to recover from the detrimental effects of such a highly invasive foreign bone protrusion.



Fig. 5. A video screen shot of ritualized combat observed between the “tusked” monitor and a rival male in the Way Canguk River.



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## References

- Auffenberg, W. 1988. Gray’s monitor lizard. University Presses of Florida. Gainesville. 419 pp.
- Bennett, D. 1995. A Little Book of Monitor Lizards. Viper Press. Aberdeen. 208 pp.
- Bennett, D., M. Gaulke, E.R. Pianka, R. Somaweera & S.S. Sweet. 2010. *Varanus salvator*. The IUCN Red List of Threatened Species 2010: e.T178214A7499172.
- Das, I. 2010. A Field Guide to the Reptiles of South-East Asia. New Holland Publishers. London. 376 pp.
- de Lisle, H.F. 2007. Observations on *Varanus s. salvator* in North Sulawesi. *Biawak* 1(2): 59–66.
- Fillett, A. & R. Jackson. 2010. Human food scrap ingestion in two wild lace monitors *Varanus varius*. *Biawak* 4(3): 99–102.
- Gaulke, M., 1991. On the diet of water monitor, *Varanus salvator*, in the Philippines. Pp. 143–153. In: Böhme, W. & H.-G. Horn (eds.), *Advances in Monitor Research, Mertensiella* 2. Deutsche Gesellschaft für Herpetologie und Terrarienkunde, Rheinbach.
- Horn, H.-G., M. Gaulke and W. Böhme. 1994. New data on ritualized combats in monitor lizards (Sauria: Varanidae) with remarks on their function and phylogenetic implications. *Der Zoologische Garten* 64: 265–280.
- Milenkaya, O. & McKay, J.L. 2016. Observation in the wild of the poorly-known *Varanus yuwonoi*. *Biawak* 10(1): 13–17.
- Teynie, A., P. David & A. Ohler. 2010. Note on a collection of amphibians and reptiles from Western Sumatra (Indonesia), with the description of a new species of the genus *Bufo*. *Zootaxa* 2416: 1–43.
- Traeholt, C. 1994. Food and feeding behavior of the water monitor, *Varanus salvator*, in Malaysia. *Malayan Nature Journal* 447: 331–343.
- Traeholt, C. 1993. Notes on the feeding behavior of the water monitor, *Varanus salvator*. *Malayan Nature Journal* 46: 229–241.
- Uyeda, L.T., E. Iskandar, R.C. Kyes & A.J. Wirsing. 2015. Encounter rates, agonistic interactions, and social hierarchy among garbage-feeding water monitor lizards (*Varanus salvator bivittatus*) on Tinil Island, Indonesia. *Herpetological Conservation and Biology* 10(2): 753–764.
- Uyeda, L.T., E. Iskandar, A.J. Wirsing & R.C. Kyes. 2013. Nocturnal activity of *Varanus salvator* on Tinjil Island, Indonesia. *Biawak* 7(1): 25–30.
- Uyeda, L.T. 2015. The water monitor lizard *Varanus salvator*: Behavior, ecology, and human dimensions in Banten, Indonesia. Unpublished dissertation, University of Washington.
- WCS-IP. 2001. Taman Nasional Bukit Barisan Selatan dalam ruang dan waktu: laporan penelitian 2000-2001 (Bukit Barisan Selatan National Park in space and time: research report 2000-2001). WCS-IP/PHKA. Bogor: Indonesia.

# First Breeding Report of the Pilbara Rock Monitor (*Varanus pilbarensis* Storr, 1980) in Spain with Taxonomic Comments on the Recently Described *V. hamersleyensis* Maryan *et al.*, 2014

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**Abstract** – The Pilbara rock monitor (*Varanus pilbarensis*) is an attractive Australian dwarf monitor lizard species which, due to its reddish-orange coloration and small body size, is a focal species for monitor keeping enthusiasts worldwide. However, very few published articles describing the captive husbandry and breeding of *V. pilbarensis* exist, even though it is clear from various photographs of these dwarf monitors on the internet, that private keepers are regularly breeding this species. This article describes the successful breeding of *V. pilbarensis* for the first time in a private collection in Spain. In addition, we make some taxonomic comments about the recently split-off *V. hamersleyensis* since intermediate phenotypes and hybrid crossings with *V. pilbarensis* are known to exist in captivity.

## Introduction

The Pilbara rock monitor, *Varanus pilbarensis*, is a small monitor lizard that inhabits rocky outcrops in the arid Pilbara region of Western Australia (Storr, 1980). They are predominantly reddish-brown to orange in coloration, anteriorly turning dark brown or blackish on the second half of the body, and have a long rounded tail with black and cream-colored banding distally (Fig. 1). The dorsal coloration is pale to dark reddish-brown and/or orange, occasionally with irregular cross-bands on the head and neck. The dorsum is covered with deep brown ocelli featuring dark central spots. The black legs are mottled with cream-colored spots, and the throat and venter are greyish-white, irregularly spotted, and reticulated with grey markings (King, 2004). Total length (TL) can reach 50–55 cm, but only males reach this maximum size, with females growing only to 40–

45 cm TL. Apart from the larger body size, males have larger and more robust heads, as is often the case in dwarf monitor lizards of the subgenus *Odatria* (Aplin *et al.*, 2006).



Fig. 1. A specimen of *Varanus pilbarensis* from Port Hedland, Western Australia. Photograph courtesy of Gunther Schmida.



Today, *V. pilbarensis* is popular in North American, European, and Australian collections, where it is occasionally bred in captivity and commands high prices in the international pet trade. Within the European Union, *V. pilbarensis* is protected under EU Directive 338/97 (European Union, 1997), the EU-wide implementation of the international regulations of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2017), where the species is listed under Appendix II along with most other monitor lizards. Australia banned the export of life native reptiles, amphibians, birds and mammals more than 50 years ago under the Environment Protection and Biodiversity Conservation Act (EPBC, 1999). According to a CITES trade database survey by Pernetta (2009), only 17 live specimens of *V. pilbarensis* have been legally exported out of Australia between 1975 and 2005. Our own analysis of the CITES trade database (2016), however, revealed that no *V. pilbarensis* specimens were ever exported. Therefore, most, if not all of the captive-bred specimens in private collections outside of Australia today have likely originated from illegally exported individuals.

Due to its colorful appearance and small body size, *V. pilbarensis* is a focal species for monitor keeping enthusiasts worldwide (Figs. 2 & 3). However, few reports describing its husbandry and breeding in captivity have been published (Eidenmüller & Langner, 1998; Retes & Bennett, 2001; Hörenberg, 2013), even though it is clear from various photographs on the internet that private

keepers are regularly breeding this species in captivity. This article describes the first successful breeding of *V. pilbarensis* in a private collection in Spain and provides some taxonomic comments about the recently split-off *V. hamersleyensis* since intermediate phenotypes and hybrid crossings with *V. pilbarensis* are known to exist in captivity.

### Breeding Group

In March 2014, a subadult male *V. pilbarensis* (30 cm TL) was acquired from a reptile show in Madrid, Spain (Fig. 4). A few months later, two females were acquired from a British keeper. Both were mature individuals measuring 35 and 40 cm TL, respectively (see Fig. 5). Both females have the same color pattern, but differ slightly in appearance from the male. They exhibit a banded dorsal pattern of large light spots in contrast to the male that features black-bordered ocelli with black centers. Sexual dimorphism was evident by the wider and thicker head and neck of the male, as well as its enlarged paracloacal spur clusters (see Figs. 6-8). In December 2015, a third, noticeably older female was acquired from a private keeper. It was put under daily veterinary observation due to its poor physical condition, but died a few weeks later (see Camina Vega & Wefer, 2016).

### Husbandry

The male was housed in its own terrarium measuring 100 x 60 x 60 cm (L x W x H), while the two younger females were kept together in a slightly larger enclosure measuring 120 x 60 x 60 cm. Each enclosure was divided into two sections with different microclimates including a basking area with a large pile of rocks, and a “shaded” area with a mix of cork tubes, cork walls and branches. Dried branches of the shrub *Retama sphaerocarpa* and rosemary (*Rosmarinus officinalis*)



Figs. 2 & 3. A European captive specimen of *V. cf. pilbarensis*. Photographs courtesy of **Edgar Wefer**.





Fig. 4. *Varanus pilbarensis* is an attractive Australian monitor lizard due to its colourful appearance and small body size. The adult male of the breeding group is pictured. Photograph by A. Camina Vega.



Fig. 5. The two female *V. pilbarensis*. Photograph by A. Camina Vega.



Figs. 6, 7 & 8. Differences in paraoccal spur clusters between the female (top) and male (bottom) *V. pilbarensis*. Note the broader tail base of the male due to the hemipenial pockets. Photographs by A. Camina Vega.



were used as decorative elements. *Varanus pilbarensis* can be very shy, so it was important to provide them with an abundance of hiding places such as large cork tubes, artificial caves and tree roots. The substrate consisted of a mixture of sand and sandy loam that measured 30–40 cm deep. Refuge sites were moistened twice per week. A water bowl was always available, but they seemed to prefer to drink when sprayed with water once to seven days per week, depending on the season.

Initially, the terrarium was equipped with a Solar Raptor lamp (Econlux GmbH, Köln, DE), but in order to improve ultraviolet radiation, UVB light was provided by an Arcadia (Arcadia Products, Redhill, UK) T5 desert reptile lamp (39W) covering Ferguson zones 3–4, depending on the distance (Baines *et al.*, 2016). One halogen spot lamp (35–50 W) and a white light (6500k) LED system were added to supply the correct visible light spectrum and create the basking spot. The temperature gradient remained virtually the same throughout the year (25–35 °C), with the highest temperatures of 40–45 °C recorded directly under the basking spot. Photoperiod was approximately 12:12 h (light:dark) during autumn and winter, and 14:10 h during spring and summer. The *V. pilbarensis* are most active between 1000 and 1300 h, and 1600 and 1800 h, but remain mostly hidden and become less active during winter.

For the first year, two different nesting boxes constructed of plastic and wood (each measuring 30 x 30 x 30 cm) were located in one corner of the shaded area of the enclosure and filled with a humid mix of sand and coir fiber, with vermiculite.

The group was predominantly fed live insects such as locusts and cockroaches and dusted with calcium and/or vitamin supplementation (Arcadia Earthpro-A) two times a week during the colder months and up to 4–5 times weekly during the warmer months. Prior to their introduction to one another, the animals were also offered dead baby mice.

### Captive Reproduction

Although some private *V. pilbarensis* breeders keep their groups together year-round (A. Camina Vega, pers. obs.), it was decided to house the adults separately since it can be important to prepare females for the mating season by allowing them to feed and rest without interference from the male. During the mating season (May–September), the humidity of the terrarium was increased, spraying heavily by hand 1–2 times a day.

In early May 2015, both females exhibited



Fig. 9. The *V. pilbarensis* breeding group together. Photograph by A. Camina Vega.

distended abdomens as a result of what appeared to be vitellogenesis. It was therefore deemed a good time to either introduce the male to the two females (Fig. 9), or introduce each female to the male's enclosure separately.

When the male was introduced to the females (introductions 1, 2 and 5), it immediately began rubbing its cloaca on different elements of the terrarium, in what appeared to be territorial marking. He then approached each female multiple times while frequently moving the head from side to side and tongue-flicking at the females' bodies. Normally, the female being pursued would try to escape and hide from the male, so the male would redirect its focus to the other female. Although the females were not receptive to the male's courtship behaviors during the first day, the male persistently followed the females around the enclosure until one of them was finally trapped or consented to copulation (Fig 10). The male sometimes grabbed the females' heads and necks with its mouth during copulation. Copulation occurred several times over the course of 2–5 days. The male was separated 7–14 days later (depending on his interest), leaving the females alone in their enclosure.

On later occasions (introductions 3 and 4), each female was carefully and individually transferred to the male's terrarium. Initially upon each of their introductions, both females seemed very nervous and attempted to find shelter, but then settled down after a few minutes. Since *V. pilbarensis* is a species that can very easily be stressed, and since the females seemed to be more sensitive than the male in this regard (A. Camina Vega, pers. obs.), handling was kept to a minimum. The male's courtship behavior and copulation during these individual introductions were similar to those described



Fig. 10. Copulation. Photograph by A. Camina Vega.



Fig. 11. Hatchling *V. pilbarensis* emerging from its egg. Photograph by A. Camina Vega.

above. Females were separated 4–6 days after their introduction, based on their behavioral interactions with the male. After a 2–3 day break, the same procedure was repeated with the other female; this process was repeated until both females began to show clear signs of gravidity.

Two to three weeks after copulations had ceased, the females could be seen basking for extended periods of time throughout the day. They frequently refused food around one week prior to oviposition, and spent considerable time digging test holes in the substrate in the last few days before oviposition. Gestation, measured as the timespan between the last observed copulation and oviposition, was 4–6 weeks. Locating the eggs once laid proved to be difficult as both females ignored the nest boxes provided. When an abundance of holes were noticed in the substrate, their physical appearances were monitored several times a day. Eggs were usually buried under the pile of rocks in the corner of the enclosure. Following oviposition, it was important to wait at least 3–4 weeks for the females to recuperate and return to their original body weights before the male was introduced again. A total of two and three different clutches were collected from each female

between June and October 2015, respectively (Table 1). The clutches produced in June and July proved not to be viable and were discarded since the eggs developed mold and had soft and dry, mottled eggshells. Based on our experiences with other reptile species, the first clutch produced by an inexperienced female could be infertile (A. Camina Vega, pers. obs.).

All eggs were removed from the terrarium, buried in a plastic container filled with a mixture of vermiculite and water to an approximate ratio of 1:1 by weight, and placed inside an incubator constructed from a modified refrigerator. Non-viable eggs were discarded throughout incubation. The eggs were incubated at temperatures ranging from 27.5–28.5 °C and began to hatch after 91–105 days of incubation (see Fig. 11). Other successful breeders have experienced similar incubation periods, such as Eidenmüller & Langner (1998; incubated at 27±1°C for 99–136 days) and Hörenberg (2013; at 29.2 °C for 102 days). One egg was found with a fully developed, but deceased hatchling inside.

During their first few days, the hatchlings (see Figs. 12 & 13), which measured 13–14 cm TL, were housed separately in small terrariums (30 x 30 x 45 cm), each equipped with a basking spot and UV-B lamp

Table 1. Reproductive data for five clutches of *V. pilbarensis* eggs produced in 2015.

Clutch No.	Female	Date of oviposition	Clutch size	No. Fertile Eggs	Incubation temperature	Incubation period	No. Live hatchlings
1	1	22/6/2015	4	0	-	-	0
2	2	1/7/2015	3	0	-	-	0
3	1	2/8/2015	2	1	27.5-28.5 °C	-	0
4	2	27/8/2015	4	4	27.5-28 °C	91-100 days	2
5	1	2/10/2015	3	2	27.5-28.5 °C	105 days	1





Figs. 12 & 13. Basking one-week-old juvenile *V. pilbarensis*. Photographs by **A. Camina Vega**.

which provided the same environmental conditions as those offered to the parents. It may be necessary to house juvenile monitor lizards individually until they reach a larger size, due to concerns of cannibalism as observed in other *Varanus* species (e.g., *V. storri*; Eidenmüller, 2007); it is also easier to control food intake and monitor the fecal output of each specimen when housed individually. With the exception of one individual that died five days after hatching, probably due to a minor spinal deformity, the hatchlings began feeding after 10–12 days. They fed primarily on small crickets, cockroaches and isopods which were always supplemented with calcium. *Drosophila* sp. was also offered as enrichment.

#### **Taxonomic Comments on the *V. pilbarensis* Species Group as Defined by Maryan *et al.* (2014)**

Since the recent description of the new parapatric *V. hamersleyensis* that was taxonomically split-off from the southern distribution range of *V. pilbarensis* by Maryan *et al.* (2014), some experienced keepers have expressed doubts regarding the true identity of the first specimens of “*V. pilbarensis*” that were available outside of Australia because specimens with intermediate character states in coloration and pattern are known (Figs. 2 & 3). Additionally, successful keepers have informed us that the two different forms of *V. pilbarensis* as defined by Maryan *et al.* (2014) have



successfully interbred in European private collections (B. Eidenmüller & T. Hörenberg, pers. comm.). Thus, it seems plausible that some of the individuals that are presently traded on the international market or kept in zoos and private collections are (1) either pure *V. pilbarensis* and/or *V. hamersleyensis*, (2) hybrids between both taxa, or (3) hybrids between either of them and other taxa phenotypically similar to *V. pilbarensis* that have not yet been formally described (Figs. 14–16).

Hints for further taxonomic differentiation within *V. pilbarensis* seem to be evident from the phylogeny provided by Maryan *et al.* (2014), with an uncorrected sequence divergence of up to 6.6% from east to west of the species’ distribution range. There is, however, a sampling gap of nearly 200 km between these two alleged lineages. By comparison, the mean uncorrected divergence between samples of *V. pilbarensis* and *V. hamersleyensis* north and south of the Fortescue River Basin, respectively, is 10.2%. Thus, the taxonomic conclusions drawn by Maryan *et al.* (2014) from the phylogenetic data seem reasonable. However, the sample size is somewhat limited with only seven specimens each of *V. pilbarensis* and *V. hamersleyensis*,





Fig. 14. Pair of male (left) and female (right) *V. hamersleyensis*. Note the larger head of the male specimen. Photograph courtesy of Úrsula Burdon.

where an extended sampling could reveal genetically less-differentiated populations.

Morphologically, the distinction between *V. pilbarensis* and *V. hamersleyensis* seems less clear since the holotype of *V. pilbarensis* (as illustrated by Maryan *et al.*, 2014) lacks the dorsal ocelli that are often thought to be characteristic of this taxon (Storr, 1980), and instead shows small dark spots that tend to form short transverse rows on a light brown background coloration. This may, however, be the result of the alcohol preservation, since the live specimen depicted by Storr (1980) shows clear ocelli dorsally. In this regard, it is interesting to note that the color pattern of the offspring produced within the same clutch from a mixed pair of *V. "pilbarensis"* (*i.e.*,



Fig. 15. *Varanus hamersleyensis* hatchlings. Photograph courtesy of Úrsula Burdon.



Fig. 16. Comparison between *V. pilbarensis* (right) and *V. hamersleyensis* (left). Note the differences in coloration and pattern. Photograph courtesy of Úrsula Burdon.

one specimen of the *pilbarensis* sensu stricto phenotype and the other of the *hamersleyensis* color pattern) can vary greatly in captivity (see Eidenmüller & Langner, 1998), with bright red specimens exhibiting distinct ocelli hatching next to dark red individuals lacking nearly all dorsal markings (B. Eidenmüller, pers. comm.).

Noteworthy, Storr (1980) included into the type series of *V. pilbarensis* a specimen (WAM R13082, unsexed, from Woodstock Station, 21° 37' S; 118° 57' E) that was later identified as belonging to the *hamersleyensis* phenotype by Maryan *et al.* (2014). Moreover, Maryan *et al.* (2014) mentioned a record of a true *V. pilbarensis* (R110941) from south of the



Fortescue River Basin, from the north-western margin of the range of the newly described *V. hamersleyensis*. Therefore, it remains unclear if the ephemeral Fortescue River actually provides such a strong dispersal barrier for a spatial exchange and whether it effectively prevents gene flow and interbreeding between the monitor lizard populations north and south of it given the fact that it does not carry water all year-round (B. Eidenmüller, pers. comm.).

The fact that successful crossings have occurred between different forms of *V. pilbarensis* in captivity (and seems well possible in nature as is evident from the geographical information discussed above), raises doubts that two reproductively isolated populations (*i.e.*, two biological species according to Ernst Mayr's [1942] species concept) are involved, but rather two mostly allopatric subpopulations (*i.e.*, subspecies) that are separated by a valley and a temporary river crossing the distribution range of a species. Following the biological species concept, the sympatric occurrence of both forms throughout the Pilbara region with only little or no evidence of hybridization (as is the case with *V. pilbarensis* and several other monitor lizard species of the area such as *V. eremius* and *V. giganteus*) would strongly support their status as two phylogenetically (and morphologically) distinct species.

Nowadays, however, the biological species concept is often replaced by the evolutionary (Wiley, 1978) or phylogenetic (Cracraft, 1983) species concepts (Torstrom *et al.*, 2014), which more or less state that species are independently evolving and diagnosably distinct lineages. This rather simplified definition of species may, however, overestimate the diversity of organisms and does not distinguish between inter- and intraspecific differences, which is the variation observed between distinct species and within a given species. For the latter, the subspecies category (formerly called "variation" or "race") had been erected in biological systematics in the mid-19th century (Mayr, 1942; Wilson & Brown, 1953).

Today, however, the recognition of subspecies in taxonomy is not as popular as it once was, particularly in English-speaking countries. In contrast, for some authors (*e.g.*, Mulcahy, 2008; Koch *et al.*, 2010; Braby *et al.*, 2012), this taxonomic category still has its eligibility since the evolution of two daughter species from a single ancestral species (*i.e.*, the formation of new species by the divergence of populations) is a steady process of accumulating unique properties (so called "apomorphies"). The taxonomic challenge in this context is to define the point when two sister populations

have achieved the level of two distinct species. This is also known as the "species problem" (de Queiroz, 2005). Here, Torstrom *et al.* (2014), for instance, recommended using an integrative taxonomic approach (Dayrat, 2005) in order to objectively decide if populations represent different species or subspecies (see *e.g.*, Miralles, 2011).

In conclusion, we criticise that Maryan *et al.* (2014) did not explain their decision or how they taxonomically interpreted the differences they revealed in *V. pilbarensis*, and overlooked the possibility of applying the subspecies category to the southern population of the Hamersley Range. For future taxonomic studies on monitor lizards (and reptiles and amphibians in general), we therefore encourage herpetologists to act with more objectivity when allocating taxonomic categories to populations.

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## References

- Aplin, K.P., A.J. Fitch & D.J. King 2006. A new species of *Varanus* Merrem (Squamata: Varanidae) from the Pilbara region of Western Australia, with observations on sexual dimorphism in closely related species. *Zootaxa* 1313: 1–38.
- Braby, M.F., R. Eastwood & N. Murray 2012. The subspecies concept in butterflies: has its application in taxonomy and conservation biology outlived its usefulness? *Biological Journal of the Linnean Society* 106: 699–716.
- Camina Vega, A., & E. Wefer 2016. Remarks on a case of deformities in a female *Varanus pilbarensis* *Biawak* 10: 51–53.
- CITES. 2016. CITES Trade Database. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Available at: <https://trade.cites.org>. Last accessed: 30 November 2016.
- CITES. 2017. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Available at: <https://www.cites.org>. Last accessed: 19 June 2017.

- Cracraft, J., 1983. Species concepts and speciation analysis. *Current Ornithology* 1: 159–187.
- Dayrat, B. 2005. Towards integrative taxonomy. *Biological Journal of the Linnean Society* 85: 407–415.
- de Queiroz, K. 2005. Different species problems and their resolution. *BioEssays* 27: 1263–1269.
- Eidenmüller, B. 2007. Monitor lizards. Natural history, Captive Care and Breeding. Edition Chimaira, Frankfurt, 176 pp.
- Eidenmüller, B. & C. Langner 1998. Bemerkungen zu Haltung und Zucht des Pilbara-Felsenwarans (*Varanus pilbarensis* Storr 1980). *Herpetofauna* 20(117): 5–10.
- EPBC. 1999. Environment Protection and Biodiversity Conservation Act. Available at: <http://www.environment.gov.au/epbc>. Last accessed: 21 June 2017.
- European Union. 1997. Council Regulation (EC) No. 338/97 of 9 December 1996 on the protection of species of wild fauna and flora by regulating trade therein. *Official Journal of the European Communities* L61: 1–69.
- Hörenberg, T. 2013. Der Pilbara-Waran, *Varanus pilbarensis* - Haltung und Nachzucht. *Draco* 53: 31–36.
- King, D.R. 2004. *Varanus pilbarensis*. Pp. 208–211. In: E.R. Pianka, D.R. King & R.A. King (eds.), *Varanoid Lizards of the World*, Indiana University Press. Bloomington, Indiana.
- Koch, A., M. Gaulke & W. Böhme 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: 1–54.
- Maryan, B., P.M. Oliver, A.J. Fitch & M. O’Connell 2014. Molecular and morphological assessment of *Varanus pilbarensis* (Squamata: Varanidae), with a description of a new species from the southern Pilbara, Western Australia. *Zootaxa* 3768: 139–158.
- Mayr, E. 1942. *Systematics and the Origin of Species*. Columbia University Press, New York. 334 pp.
- Miralles, A., R. Vasconcelos, A. Perera, D.J. Harris & S. Carranza. 2011. An integrative taxonomic revision of the Cape Verdean skinks (Squamata, Scincidae). *Zoologica Scripta* 40: 16–44.
- Mulcahy, D.G. 2008. Phylogeography and species boundaries of the western North American nightsnake (*Hypsiglena torquata*): Revisiting the subspecies concept. *Molecular Phylogenetics and Evolution* 46: 1095–1115.
- Pernetta, A.P. 2009. Monitoring the trade: Using the CITES database to examine the global trade in live monitor lizards (*Varanus* spp.). *Biawak* 3: 37–45.
- Retes, F. & D. Bennett 2001. Multiple generations, multiple clutches, and early maturity in four species of monitor lizards (Varanidae) bred in captivity. *Herpetological Review* 32: 244.
- Storr, G.M. 1980. The monitor lizards of Western Australia. *Records of the Western Australian Museum* 8: 237–293.
- Torstrom, S.M., K.L. Pangle & B.J. Swanson 2014. Shedding subspecies: The influence of genetics on reptile subspecies taxonomy. *Molecular Phylogenetics and Evolution* 76: 134–143.
- Wilson, E.O. & W.L. Brown Jr. 1953. The subspecies concept and its taxonomic application. *Systematic Zoology* 2: 97–111.



## Dietary Habits and the Predators of the Bengal Monitor *Varanus bengalensis* in Sri Lanka

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**Abstract** - The Bengal monitor (*Varanus bengalensis*) is the second largest lizard species in Sri Lanka, and is well adapted to living in a variety of terrestrial habitats. *Varanus bengalensis* is a diurnal generalist predator, but sometimes function as a scavenger. Given the ecological plasticity and generalist foraging strategy of *V. bengalensis*, its feeding ecology and role in trophic networks could vary among different environments. Thus, in this study we documented the prey and natural predators of *V. bengalensis* across different landscapes along the urban-rural gradient and geo-climatic zones of Sri Lanka through field observations, literature surveys, and personal communications with other biologists. We documented 82 species of vertebrate prey in the diet of *V. bengalensis*, which included 20 mammals, 21 birds, 20 reptiles, 14 amphibians, and seven fishes. Although numerous invertebrates were recorded, their identification to species level was challenging. *Varanus bengalensis* also fed on road-killed animals and organic waste, such as rotting fruits and vegetables. Although *V. bengalensis* is largely terrestrial, our dietary analyses revealed that it also preys on aquatic prey; their predation on introduced species as well as threatened species was also remarkable. Our study confirmed that *V. bengalensis* has a greater dietary selection than *V. salvator* in Sri Lanka, which remained consistent across a diverse array of habitats. Our study also noted that *V. bengalensis* is predated by 24 species of vertebrates, including nine mammals, 10 birds, and five reptiles, which largely targeted juveniles. Neither the predator nor prey communities of *V. bengalensis* varied across the urban-rural gradient or across different geo-climatic zones of Sri Lanka.

## Introduction

Varanid lizards, or monitors, are a highly diverse reptilian group that is broadly distributed throughout Africa, South and Southeast Asia, and Australasia (Pianka *et al.*, 2004). In general, varanids have a highly conservative body plan, but vary greatly in size, and have successfully colonized a wide range of habitats in various geo-climatic zones (Pianka & King, 2004). Their ecological success has frequently been attributed to elevated seasonal and daily activity levels, high stamina and metabolic rates, cardiovascular efficiency, respiratory efficiency due to gular pumping, and greater chemosensory perception (Pianka *et al.*, 2004).

With a few exceptions (*e.g.*, *Varanus bitatawa*, *V. olivaceus*, *V. indicus*), most varanids are highly-adaptive habitat generalists and opportunistic carnivores (Shine, 1986; Losos & Greene, 1988; Molnar, 2004). Certain species, such as, the Bengal monitor, *V. bengalensis*, have successfully established themselves in highly altered anthropogenic habitats, and also occur in a variety of natural landscapes including dense forests, sparse woodlands, grasslands, and thorny scrublands (Pianka, 2004). The geographic distribution of *V. bengalensis* extends from southeastern Iran through much of southern Asia, into the Malay Archipelago (Pianka, 2004). As in many wide-ranging varanids, the ecology and natural history of *V. bengalensis* vary remarkably throughout its range in response to the different habitats and geo-climatic zones they inhabit (Losos & Greene, 1988; Auffenberg, 1994; Pianka, 1995). In this study, we focused on the trophic ecology of *V. bengalensis* in Sri Lanka, an Indian oceanic island where varanid ecology still remains largely unexplored.

Two species of monitor lizard (genus *Varanus*) occur on Sri Lanka - *V. bengalensis* and *V. salvator* (de Silva, 2006). *Varanus bengalensis* has been recorded throughout Sri Lanka up to 500 m in elevation and across all geo-climatic zones (Das & de Silva, 2005). *Varanus bengalensis* is diurnal, and in Sri Lanka, due to year-round uniformly high temperatures, is active throughout the year. Daily activity is mostly limited to mid-day (1000 to 1400 h), and *V. bengalensis* is rarely observed during early mornings or late evenings (Deraniyagala, 1953; Wikramanayake & Dryden, 1993; Karunarathna *et al.*, 2012). Being a moderately large (average total length [TL] 100 cm) varanid, *V. bengalensis* is the second largest lizard species in Sri Lanka (Auffenberg, 1994), with the longest individual recorded measuring 174 cm TL at Hambegamuwa, a rural village in southern Sri Lanka (S. Karunarathna, pers. obs., 2013). *Varanus*

*bengalensis* is well adapted to occupy a variety of terrestrial habitats, and can also climb vertical surfaces and trees if necessary (Auffenberg, 1994). Although the species is found in floodplain woodlands, it tends to avoid aquatic habitats and is inept at swimming or diving (Pianka, 2004). In Sri Lanka, the thermoregulatory behavior, microhabitat use, metabolism (with respect to osmotic balance and energy), and behavioral aspects (particularly conspecific agnostic interactions) of *V. bengalensis* have been investigated (Wikramanayake & Green, 1989; Dryden *et al.*, 1992; Wikramanayake and Dryden, 1993); however, their trophic interactions remain largely unexplored. *Varanus bengalensis* are active generalist predators, feeding mostly on small invertebrate prey (Deraniyagala, 1953). They are also human commensals, and thrive in anthropogenic habitats such as home gardens and homesteads, and can even occupy households and built-up urban environments (Koch *et al.*, 2013).

Resource and microhabitat availability and environmental complexity differs remarkably across urban-rural gradients as well as geo-climatic gradients (Faeth *et al.*, 2005). Given the ecological plasticity and generalist foraging strategy of *V. bengalensis*, its feeding ecology and role in trophic networks could vary in different environments. Thus, documenting the diet and natural predators of *V. bengalensis* across different landscapes and geo-climatic zones are salient elements of ecological theory. In this paper, we studied the prey and predators of *V. bengalensis* in Sri Lanka.

## Methods

### Study Area

Sri Lanka is a tropical island (area: 65,610 km<sup>2</sup>) located in the Indian Ocean off the southern tip of peninsular India (5° 55' 0.12" – 9° 50' 60" N; 79° 40' 59.88" E – 81° 54' 0" E). The island consists of three elevation-based geographic zones (lowlands: < 300 m, uplands: 300-900 m, and highlands: > 900 m) and three major climatic zones based on average annual precipitation (dry zone: < 1900 mm, wet zone: > 2500 mm, and intermediate zone: 1900-2500 mm) (Survey Department of Sri Lanka, 2012).

### Data collection

We collected data on the prey and predators of *V. bengalensis* using various methods. Primarily, we made extensive field observations through opportunistic field



excursions conducted over a six-year (2010-2016) period in various regions of Sri Lanka representing different geo-climatic zones as well as habitats along the urban-rural gradient. Our field observations were made at distances of 2 to 20 m from the animals using 8×40 binoculars. Our field surveys were limited to periods of activity for *V. bengalensis*, between 0600 and 1800 h (Wikramanayake & Green, 1989; Wikramanayake & Dryden, 1993). We dissected ~12 fresh road-killed *V. bengalensis* from various parts of Sri Lanka and identified their stomach contents. Our direct feeding observations also included *V. bengalensis* feeding on road kills. During our field excursions, we also interviewed residents of local communities (~200 local residents) regarding their random observations on the trophic roles of *V. bengalensis*.

Additionally, we consulted veteran herpetologists and field biologists (a total of ~25) who have conducted field research in Sri Lanka in recent decades (1990-2016) on their experiences with *V. bengalensis* through in-person communication and social media. Whenever possible, we requested photographic evidence to validate their observations.

Finally, we conducted a comprehensive literature review utilizing online databases and scholarly search engines (Google Scholar, MEDLINE, Science Direct, Biological Sciences Collection, Academic Search Premier, EBSCOhost, JSTOR, and PubMed). We used a combination of the following keywords in the literature review: “*Varanus bengalensis*”, “Bengal monitor”, “Clouded monitor”, “Common Indian monitor”, “feeding”, “foraging”, “prey”, “predator”, “trophic”, “diet”, “Sri Lanka”, and “Ceylon”. We categorized the prey and predators based on their IUCN conservation status (Vulnerable, Endangered, and Critically Endangered) and residential status (endemic, residential, and non-native).

## Results

### Prey species

Our field-based observations, interviews with professional biologists, and review of the literature revealed a diverse array of prey consumed by *V. bengalensis* which included vertebrates, invertebrates, as well as dead organic matter including road-killed animals and household garbage and urban trash (Table 1; Fig. 1). We noted that the vertebrate prey of *V. bengalensis* was remarkably high in diversity: 20 mammals, 21 birds, 20 reptiles, 14 amphibians, and

7 freshwater fishes (a total of 82 species; Table 1). Among invertebrate prey, species-level identification was limited. Most of the invertebrate taxa preyed by *V. bengalensis* were arthropods. Live prey included different life-history stages (eggs, larvae, juveniles, and adults). *Varanus bengalensis* appeared to consume animal carcasses of different stages of decomposition ranging from fresh carcasses (such as road-kills) to carrion (rotting animal flesh). Among live prey, these monitors consumed both endemic species (Sri Lankan toque monkey [*Macaca sinica*] and Sri Lankan yellow-fronted barbet [*Megalaima flavifrons*]) and non-native species including invasive species (1 species) as well as domesticated species (2 species). Moreover, 10 endemics and a total of 5 IUCN Red Listed species (2 critically endangered, 2 endangered, and 1 vulnerable) were also documented in our survey.

### Predators

Our study revealed that *V. bengalensis* has several natural predators, including 9 mammals, 10 birds, and 5 reptiles (Table 2; Fig. 2). Among these predators, we found one endemic species (Sri Lankan grey hornbill [*Ocyrceros gingalensis*]) and one non-native species (domestic cat [*Felis catus*]). Of the 24 total records of predation we documented, juveniles were the victims in 14 (58.3%) instances, suggesting that juveniles are the most susceptible life-history stage (Table 2). In five instances, consumers of *V. bengalensis* were carrion feeders scavenging on road-killed individuals (jackal [*Canis aureus*], wild boar [*Sus scrofa*], and jungle crow [*Corvus leuallantii*]). Live, adult *V. bengalensis* suffered direct predation in a handful of instances (by five species). Most *V. bengalensis* predators were visually-oriented, active foragers (domestic cats, domestic dogs [*Canis familiaris*], leopards [*Panthera pardus*], mongoose [*Herpestes brachyurus*], birds of prey [*e.g.*, *Spilornis cheela*], Indian cobra [*Naja naja*], and rat snakes [*Ptyas mucosa*]), while a few were sit-and-wait foragers (mugger crocodile [*Crocodylus palustris*], stork-billed kingfisher [*Pelargopsis capensis*], and lesser adjutant [*Leptoptilos javanicus*]). Moreover, one predator is a threatened species listed in the IUCN Red List (leopard, *Panthera pardus*) while another (Sri Lankan grey hornbill, *Ocyrceros gingalensis*) is an endemic species. Humans are also considered a key predator of *V. bengalensis*, and harvest these monitors from the wild for their flesh, hide, and fat. Neither the natural predators nor prey of *V. bengalensis* were restricted or specific to a particular geo-climatic zone of



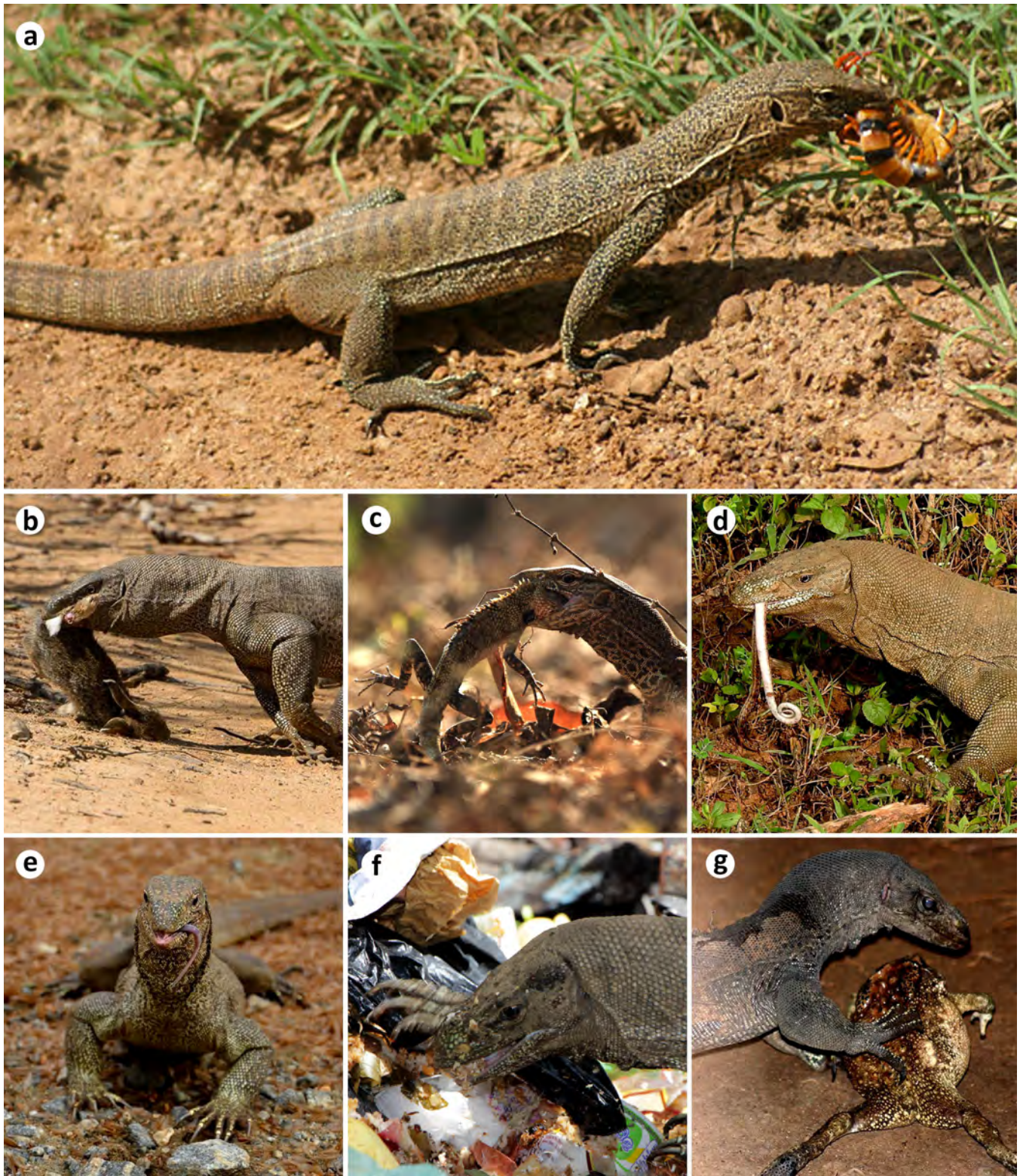


Fig. 1. *Varanus bengalensis* preying on an (a) Indian tiger centipede (*Scolopendra hardwickei*), (b) juvenile black-napped hare (*Lepus nigricollis*), (c) adult common garden lizard (*Calotes versicolor*), (d) adult variegated kukri snake (*Oligodon taeniolata*), (e) flying termites, (f) household trash, and (g) adult Asian common toad (*Duttaphrynus melanostictus*). Photographs by **Craig Moore**, **Mevan Piyasena**, **Senehas Karunarathna**, **Nilupul Rangana**, and **Bushana Kalhara**.



Table 1. Currently known prey items of *Varanus bengalensis* in Sri Lanka and their current status in Sri Lanka in terms of IUCN national conservation status, endemism, and residential (native vs introduced) status. Abbreviations used: E = Endemic; NA = not applicable; NV = native; NN = non-native; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. Non-native species include domesticated species (domestic cats and dogs), naturalized alien species, and invasive species.

Prey Class	Prey taxon	Common name	Species Status	Description of Prey	Geo-climatic Zone	Location (Habitat)	References
Mammalia	<i>Bandicota bengalensis</i>	Mole rat	NV	Freshly killed by home owner	Lowland wet zone	Ratmalana (Urban)	This study
	<i>Bandicota indica</i>	Malabar bandicoot	NV	Road kill	Lowland wet zone	Kelaniya (Residential)	This study
	<i>Bubalus bubalis</i>	Buffalo	NV	Scavenged from slaughter houses and carcasses	Lowland wet zone	Aluthgama (Residential)	M. Wickramasinghe, pers. comm.
	<i>Canis familiaris</i>	Domestic dog	NN	Road kill	Lowland wet zone, Lowland arid zone	Beruwala (Urban), Hambantota (Forest)	M. Wickramasinghe, pers. comm.
	<i>Crocidura sp.</i>	Shrew sp.	NV	Live adult	Lowland wet zone	Kudawa (Residential)	This study
	<i>Felis catus</i>	Domestic cat	NN	Live juveniles, road-killed carcass	Lowland wet zone	Kalutara (Forest)	M. Wickramasinghe, pers. comm.
	<i>Funambulus palmarum</i>	Palm squirrel	NV	Juveniles hunted from the nest, road kill	Lowland intermediate zone, Lowland dry zone, Upland wet zone	Hambegamuwa (Residential), Yala (Forest), Thammimalai (Residential)	S. Kumara, M. Karunarathna & T. Kusuminda, pers. comm.
	<i>Kerivoula picta</i>	Painted bat	NV	Road kill	Lowland dry zone	Polonnaruwa (Residential)	This study
	<i>Lepus nigricollis</i>	Black-napped hare	NV	Live subadult	Lowland dry zone	Yala (Forest)	M. Pyasena, pers. comm.
	<i>Macaaca sinica</i>	Sri Lankan toque monkey	E	Juvenile carcass	Lowland wet zone	Dombagaskanda (Forest)	This study
<i>Manis crassicaudata</i>	Pangolin	NV	Adult carcass	Lowland dry zone	Gaioya (Forest)	D. Kulathunga, pers. comm.	
<i>Mus booduga</i>	Field mouse	NV	Freshly killed by homeowner	Lowland intermediate zone	Tanamalwila (Residential)	S. Kumara, pers. comm.	
<i>Mus musculus</i>	Indian house mouse	NV	Freshly killed by homeowner	Lowland wet zone	Ambalangoda (Urban)	This study	
<i>Pteropus giganteus</i>	Flying fox	NV	Electrocuted carcass	Lowland wet zone	Piliyandala (Urban)	This study	
<i>Rattus rattus</i>	Black rat	NN	Freshly killed by homeowner	Lowland wet zone	Ratmalana (Urban)	This study	
<i>Rusa unicolor</i>	Sambar deer	NV	Adult carcass	Lowland wet zone	Sinharaja (Forest)	This study	
<i>Semnopithecus priam</i>	Grey langur	NV	Adult carcass	Lowland dry zone	Wilpattu (Forest)	D. Ramasinghe, pers. comm.	
<i>Semnopithecus vetulus</i>	Sri Lankan Purple-faced langur	E/EN	Electrocuted carcass	Lowland wet zone	Awissawella (Urban)	S. Kolambage, pers. comm.	
<i>Suncus murinus</i>	Common musk shrew	NV	Adult carcass	Lowland wet zone	Ganemulla (Urban)	This study	
<i>Vandeleuria oleracea</i>	Long-tailed tree mouse	VU	Live adult	Lowland dry zone	Karawalagaswewa (Forest)	This study	
Aves	<i>Acridotheres tristis</i>	Common myna	NV	Nestlings	Lowland wet zone	Ganemulla (Urban)	This study
	<i>Amaurornis phoeniceus</i>	White-breasted waterhen	NV	Road kill	Lowland dry zone	Tissamaharamaya (Residential)	This study
	<i>Chalcophaps indica</i>	Emerald dove	NV	Adult carcass	Lowland wet zone	Aluthgama (Residential)	This study
	<i>Columba livia</i>	Rock pigeon	NV	Adult carcass	Lowland wet zone	Ratmalana (Urban)	This study
	<i>Copsychus saularis</i>	Oriental magpie robin	NV	Eggs	Lowland intermediate zone	Bibila (Residential)	This study
	<i>Dinopium benghalense</i>	Black-rumped flameback	NV	Hatchlings from the nest	Lowland dry zone	Polonnaruwa (Residential)	L. Dayaratne, pers. comm.
	<i>Eudynamis scolopacea</i>	Asian koel	NV	Juvenile carcass	Lowland wet zone	Kadawatha (Urban)	R. Saranga, pers. comm.
	<i>Francolinus pictus</i>	Painted francolin	CR	Leftover meat discarded by hunters	Lowland intermediate zone	Nilgala (Forest)	D. Kulathunga, pers. comm.
	<i>Halcyon smyrnensis</i>	White-throated kingfisher	NV	Hatchlings from the nest	Lowland wet zone	Galle (Residential)	M. Dahanayake, pers. comm.
	<i>Megalaima flavifrons</i>	Sri Lankan yellow-fronted barbet	E	Live chicks from the nest	Lowland wet zone	Dombagaskanda (Forest)	This study
	<i>Megalaima zeylanica</i>	Brown-headed barbet	NV	Live chicks from the nest	Lowland dry zone	Polonnaruwa (Forest)	L. Dayaratne, pers. comm.
	<i>Perdicula asiatica</i>	Jungle bush-quail	CR	Trash body parts discarded by hunters	Lowland intermediate zone	Mahiyanganaya (Forest)	D. Kulathunga, pers. comm.
	<i>Psittacula calthropae</i>	Sri Lankan emerald collared parakeet	E	Dislodged live hatchlings and eggs	Lowland wet zone	Deraniyagala (Forest)	M. Wickramasinghe, pers. comm.
	<i>Psittacula krameri</i>	Rose-ringed parakeet	NV	Dislodged live hatchlings and eggs	Lowland wet zone	Mideripitiya (Forest)	M. Wickramasinghe, pers. comm.
	<i>Pycnonotus cafer</i>	Red vented bulbul	NV	Dislodged hatchlings	Lowland wet zone	Matara (Residential)	N. Rangana, pers. comm.
	<i>Pycnonotus luteolus</i>	White browed bulbul	NV	Road kill carcass	Lowland wet zone	Ingiriya (Residential)	This study
	<i>Saxicoloides fulvicaus</i>	Indian robin	NV	Eggs and hatchlings	Lowland dry zone	Rajanganaya (Forest)	D. Ramasinghe, pers. comm.
	<i>Stigmatopelia chinensis</i>	Spotted dove	NV	Adult carcass	Lowland dry zone	Chilaw (Urban)	A. Kumasinghe, pers. comm.
	<i>Turdoides affinis</i>	Yellow billed babbler	NV	Injured adult	Lowland wet zone	Panadura (Urban)	This study
	<i>Turdix suscitator</i>	Barred buttonquail	NV	Trash body parts discarded by hunters	Lowland dry zone	Giradurukotte (Forest)	D. Kulathunga, pers. comm.
	<i>Vanellus indicus</i>	Red-wattled lapwing	Live fledglings and eggs from the nest	Lowland wet zone	Seenigama (Residential)	S. de Soya, pers. comm.	

Table 1 (continued).

Prey Class	Prey taxon	Common name	Species Status	Description of Prey	Geo-climatic Zone	Location (Habitat)	References	
Reptilia	<i>Amphiesma stolatum</i>	Buff striped keelback	NV	Live adult, Road kill	Lowland intermediate zone, Lowland dry intermediate zone, Lowland wet zone	Thanamalwila (Residential), Kumana (Forest), Waga (Residential)	This study, G. Jayantha & M. Wickramasinghe, pers. comm.	
		Green garden lizard	NV	Live adults	Lowland dry zone, Lowland wet zone	Anuradapura (Residential), Maharagama (Urban)	This study	
	<i>Calotes calotes</i>	Common garden lizard	NV	Live adult, road-killed specimen	Lowland dry zone, Lowland arid zone	Mihintale (Forest), Yala (Forest)	This study, S. Karunarathna, pers. comm.	
		Sri Lankan chameleon	EN	Live adults	Lowland dry zone	Vanatavilluwa (Residential)	Karunarathna et al., 2009	
		Mugger crocodile	NV	Carcass	Lowland dry zone	Kanadara (Residential)	This study	
		Russell's viper	NV	Live juvenile	Lowland intermediate zone	Udawalawe (Forest)	S. Kumara, pers. comm.	
		Common skink	NV	Live adults	Lowland intermediate zone	Hambugamuwa (Residential)	This study	
		Star tortoise	NV	Live juvenile	Lowland dry zone	Eluwankulam (Residential)	D. Ramasinghe, pers. comm.	
		Common house-gecko	NV	Live adults	Lowland wet zone	Ganemulla (Residential)	This study, M. Wickramasinghe, pers. comm.	
		<i>Hemidactylus parimaculatus</i>	Spotted housegecko	NV	Live adults	Lowland wet zone	Ganemulla (Residential)	This study
			Merrem's hump nose viper	NV	Killed by villagers	Lowland wet zone	Niitambuwu (Residential)	This study
			Blind snake species	NV	Live adults	Lowland wet zone	Ganemulla (Residential)	This study
	Wolf snake		NV	Live adults	Lowland dry zone	Gampaha (Urban)	This study	
	Black turtle		NV	Live juvenile	Lowland wet zone	Maharagama (Urban)	This study	
	Common kukri snake		NV	Road kill	Lowland dry zone	Padaviya (Forest)	This study	
	Variiegated kukri snake		NV	Live adults	Lowland dry zone	Yala (Forest)	This study	
	Black spotted kangaroo lizard		E	Live adults	Lowland intermediate zone	Niigala (Forest)	This study	
	Rat snake		NV	Live juvenile	Lowland wet zone	Ragama (Urban)	This study	
	Devaka's fanthroat lizard		E	Live adults	Lowland dry zone	Vanatavilluwa (Residential)	This study	
	Amphibia	<i>Xenochrophis piscator</i>	Checked keelback	NV	Live adults	Lowland wet zone	Dediya (Forest)	M. Wickramasinghe, pers. comm.
			Aukoral's toad	E	Live adults	Lowland wet zone	Matarra (Residential)	This study
		<i>Duttaphrynus melanostictus</i>	Common house toad	NV	Live adult, road kill	Lowland wet zone	Kalutara (Residential), Polgasovita (Urban)	This study, B. Kalhara & T. Ramasinghe, pers. comm.
			Schneider's toad	NV	Live adults	Lowland dry zone	Jaffna (Residential)	This study
			Indian skipper frog	NV	Live adults	Lowland intermediate zone	Hambugamuwa (Forest)	This study
			Indian green frog	NV	Live adults	Lowland intermediate zone	Hambugamuwa (Residential)	This study
			Common paddy field frog	NV	Live adults	Lowland intermediate zone	Hettipola (Residential)	Jolley & Meek, 2006
			Jurdon's bullfrog	NV	Live adults	Lowland dry zone	Yala (Forest)	S. Roelofs, pers. comm.
Sri Lankan bullfrog			NV	Live adult, road kill	Lowland dry zone, Lowland wet zone	Puttalam (Urban), Dambulla (Residential), Matugama (Forest)	This study, M. Wickramasinghe, pers. comm.	
<i>Polypedates maculatus</i>			Spotted tree frog	NV	Live adults, road kill	Lowland intermediate zone, Lowland arid zone	Monaragala (Forest), Hambantota (Residential)	This study, M. Wickramasinghe, pers. comm.
	Common shrub frog		E	Live adults	Lowland wet zone	Ganemulla (Urban)	This study	
<i>Pseudophilautus popularius</i>	Variiegated ramanella		NV	Live adults	Lowland arid zone	Hambantota (Residential)	M. Wickramasinghe, pers. comm.	
	Short-headed burrowing frog	NV	Live adults	Lowland dry zone	Yala (Forest), Puttalam (Urban), Hambantota (Residential)	This study, M. Wickramasinghe, pers. comm.		
<i>Sphaerotheca breviceps</i>	Roland's burrowing frog	NV	Live adults	Lowland dry zone, Lowland arid zone	Karawalagasweva (Forest), Mannar (Urban)	This study, M. Wickramasinghe, pers. comm.		
	Marbled balloon frog	NV	Live adults	Lowland dry zone	Yala (Forest), Anuradapura (Residential), Wilpattu (Forest)	This study, M. Wickramasinghe, pers. comm.		
Pisces	<i>Sphaerotheca rolandae</i>	Sri Lankan filament Barb	E	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		Giant danio	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		Sri Lankan flying barb	E	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		Green chromide	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		Tilapia	NN	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		Long-snouted barb	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		Broad line Strip rasbora	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.	
		<i>Davkinsia singhala</i>	Sri Lankan filament Barb	E	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.
			Giant danio	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.
		<i>Devario malabaricus</i>	Sri Lankan flying barb	E	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.
Green chromide	NV		Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.		
<i>Esomus thermoicos</i>	Tilapia	NN	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.		
	Long-snouted barb	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.		
<i>Epiplatys suratiensis</i>	Broad line Strip rasbora	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.		
	Rashora dandiya	NV	Live specimens trapped in small pools	Lowland dry zone	Udawalawe (Forest)	S. Atapattu, pers. comm.		



Table 1 (continued).

Prey Class	Prey taxon	Common name	Species Status	Description of Prey	Geo-climatic Zone	Location (Habitat)	References
Arachnida	<i>Buthoscorpio sarasinorum</i>	Scorpion	NV	Live adults	Lowland dry zone	Eluwankulam (Residential)	A. Kumara, pers. comm.
	<i>Heterometrus gravimanus</i>	Scorpion	NV	Live adults	Lowland wet zone	Ambalangoda (Residential), Akuressa (Residential)	This study, S. Karunaratna, pers. comm.
Chilopoda	<i>Heterometrus serratus</i>	Scorpion	NV	Live adults and juveniles	Lowland intermediate zone	Nilgala (Forest)	This study
	<i>Reddyanus jayaratnani</i>	Scorpion	NV	Live adults	Lowland wet zone	Kanneliya (Forest)	S. Akmeemana, pers. comm.
	<i>Reddyanus loebli</i>	Scorpion	NV	Live adults	Lowland dry zone	Sangamankande (Residential)	This study
	<i>Rhyssida</i> sp.	Common centipede	NV	Live adults	Lowland dry zone	Bibila (Urban)	This study
	<i>Scelopendra hardwickii</i>	Indian tiger centipede	NV	Live adults	Lowland dry zone	Yala (Forest)	C. Moore, pers. comm.
Gastropoda	<i>Cryptozona bisridalis</i>	Common translucent snail	NV	Live adults	Lowland wet zone	Ganemulla (Urban)	This study
	<i>Lissachatina fulica</i>	Giant African snail	NN	Live adults	Lowland wet zone	Ganemulla (Urban), Gampaha (Urban)	This study, T. Ramasinghe, pers. comm.
Malacostraca	<i>Oziohelphusa</i> sp.	Freshwater crab	E	Live adults	Lowland dry zone	Mihintale (Forest)	This study
	<i>Oziohelphusa hippocastanum</i>	Freshwater crab	E/EN	Live adults, road kill	Lowland dry zone	Jaffna (Residential)	This study
	<i>Perbrinckia</i> sp.	Freshwater crab	E	Live adults	Lowland intermediate zone	Nilgala (Forest), Pokunnetenna (Forest)	This study, M. Wickramasinghe, pers. comm.
Insecta	Suborder: Caelifera	Grasshoppers	NV	Live adults	Lowland intermediate zone, Upland wet zone	Sigiriya (Residential), Peradeniya (Urban)	This study
	Family: Scarabaeidae	Dung beetles	NV	Live adults	Lowland dry zone	Mihintale (Forest), Udawalawe (Forest)	This study, M. Wickramasinghe, pers. comm.
	Infraorder: Isoptera	Termites	NV	Live adults, flying and larvae	Lowland dry zone, Lowland dry zone	Mihintale (Forest), Suriyawewa (Residential), Sigiriya (Residential), Dambulla (Forest)	N. Rangana & M. Rathnayake, pers. comm.
	Subfamily: Formicinae Order: Coleoptera	Black ants Beetle species	NV NV	Live adults	Lowland dry zone	Mihintale (Forest)	This study
Oligochaeta	Family: Gryllidae	Crickets species	NV	Live adults and juveniles	Lowland wet zone, Lowland dry zone	Moratuwu (Urban), Yala (Forest)	A. Godahewa & M. Wickramasinghe, pers. comm.
	Suborder: Oniscidea	Doodlebug	NV	Live adults and larvae	Lowland wet zone, Lowland wet zone	Ganemulla (Urban), Hambegamuwa (Residential)	This study
	Order: Blattodea	Wild cockroaches	NV	Live specimens	Lowland wet zone	Habarana (Residential), Galle (Residential)	This study, T. Ramasinghe, pers. comm.
	<i>Heteropoda venatoria</i> <i>Gryllotalpa</i> sp.	Huntsman spider Mole cricket	NV NV	Live specimens Live specimens	Lowland wet zone Lowland intermediate zone, Lowland dry zone	Aluthigama (Urban), Nittambuwa (Residential)	This study
	Suborder Megadriacea	Earthworm	NV	Live specimens	Lowland wet zone	Elpitiya (Forest)	This study
Garbage	n/a	Cooked anchovy	NA	Household trash	Lowland dry zone	Nilgala (Forest), Ampara (Urban)	D. Kulathunga, pers. comm.
	n/a	Cooked chicken	NA	Household trash	Lowland wet zone	Homagama (Urban), Ratmalana (Urban)	This study
	n/a	Cooked shrimps	NA	Household trash	Lowland dry zone	Higurakgoda (Residential)	This study
	n/a	Fruits	NA	Road-killed specimen (from inside the stomach)	Lowland dry zone	Kuruwita (Forest)	This study
						Yala (Forest)	C. Amarasinghe, pers. comm.
					Trincomalee (Urban)	M. Rathnayake, pers. comm.	

Table 2. Currently known predators of *V. bengalensis*, in Sri Lanka. Abbreviations used: E = Endemic; NV = native; NN = non-native; EN = non-native; EN = Endangered.

Predatory Class	Predator Taxon	Common name	Species Status	Prey Description	Location	References
Mammalia	<i>Homo sapiens</i>	Human	NV	Hunting on juveniles subadult, and adult stages, cats tongue and heart, skin use for drums, fat to make an oil	Lowland wet zone: Galle; Lowland intermediate zone: Kurunegala, Nilgala; Lowland dry zone: Jaffna	This study; Deraniyagala (1953), de Silva (1996)
Aves	<i>Panthera pardus</i>	Leopard	EN	Live subadult	Lowland dry zone: Yala, Wilpattu	D. Ramasinghe & M. Piyasena, pers. comm.
	<i>Canis familiaris</i>	Domestic dog	NN	Live adult	Lowland wet zone: Raddolugama, Ambalangoda	This study; S. Atapattu pers. com.
	<i>Felis catus</i>	Domestic cat	NN	Live juvenile	Lowland wet zone: Rambukkana	This study
	<i>Canis aureus</i>	Jackal	NV	Carcass	Lowland intermediate zone: Illukkumbura; Lowland wet zone: Mirrigama	This study
	<i>Herpestes brachyurus</i>	Brown mongoose	NV	Live juvenile	Lowland wet zone: Galle	M. Dahanayake, pers. comm.
	<i>Herpestes edwardsii</i>	Grey mongoose	NV	Live juveniles	Lowland wet zone: Ganemulla	This study
	<i>Herpestes smithii</i>	Ruddy mongoose	NV	Live juveniles	Lowland dry zone: Yala	M. Piyasena & S. Karunaratna, pers. comm.
	<i>Sus scrofa</i>	Wild boar	NV	Road kill	Lowland dry zone: Wilpattu, Galoya	This study; D. Kulathunga, pers. comm.
	<i>Ocyerops gingalensis</i>	Sri Lankan grey hornbill	E	Live juveniles	Lowland dry zone: Mahiyangamaya	D. Kulathunga, pers. comm.
	<i>Pelargopsis capensis</i>	Stork-billed kingfisher	NV	Live juveniles	Lowland dry zone: Chilaw	A. Kumarasinghe, pers. comm.
	<i>Centropus sinensis</i>	Greater coucal	NV	Live juveniles	Lowland dry zone: Pannala	This study
	<i>Spilornis cheela</i>	Crested serpent-eagle	NV	Live juveniles	Lowland dry zone: Yala, Giritale; Lowland intermediate zone: Udawalawe	This study; C. Amarasinghe, pers. comm.
	<i>Accipiter badius</i>	Shikra	NV	Live juveniles	Lowland wet zone: Panaadura, Kaluara	S. Dayananda, pers. comm.
	<i>Spizaetus cirrhatus</i>	Changeable hawk-eagle	NV	Live adult	Lowland dry zone: Yala	S. Karunaratna, pers. comm.
	<i>Mycteria leucocephala</i>	Painted stork	NV	Live juvenile	Lowland wet zone: Maharagama	K. Buddika pers. comm.
	<i>Leptoptilos javanicus</i>	Lesser adjutant	NV	Live juvenile	Lowland dry zone: Pokunutenna	N. Perera, pers. comm.
	<i>Corvus splendens</i>	House Crow	NV	Road kill	Lowland intermediate zone: Nilgala, Thanamalwila; Lowland dry zone: Eluwankulam	This study
<i>Corvus levaillantii</i>	Jungle crow	NV	Road kill	Lowland intermediate zone: Thanamalwila; Lowland dry zone: Nilgala	This study	
Reptilia	<i>Crocodylus palustris</i>	Mugger crocodile	NV	Live adult	Lowland dry zone: Wilpattu; Lowland dry zone: Yala	D. Ramasinghe & N. Kamalgoda, pers. com.
	<i>Ptyas mucosa</i>	Rat snake	NV	Live juveniles	Lowland intermediate zone: Nilgala, Hambegamuwa	This study, S. Kumara, pers. comm.
	<i>Python molurus</i>	Indian python	NV	Live adult	Lowland intermediate zone: Udawalawe; Lowland dry zone: Yala, Wilpattu; Upland wet zone: Kundsale	D. Jayantha, N. Kamalgoda & S. Karunaratna, pers. comm.
	<i>Naja naja</i>	Indian cobra	NV	Live juveniles	Lowland intermediate zone: Bulupitiya; Lowland dry zone: Polonnaruwa	This study; D. Kulathunga, pers. comm.
	<i>Varanus salvator</i>	Water monitor	NV	Road kill	Lowland wet zone: Kandana	This study



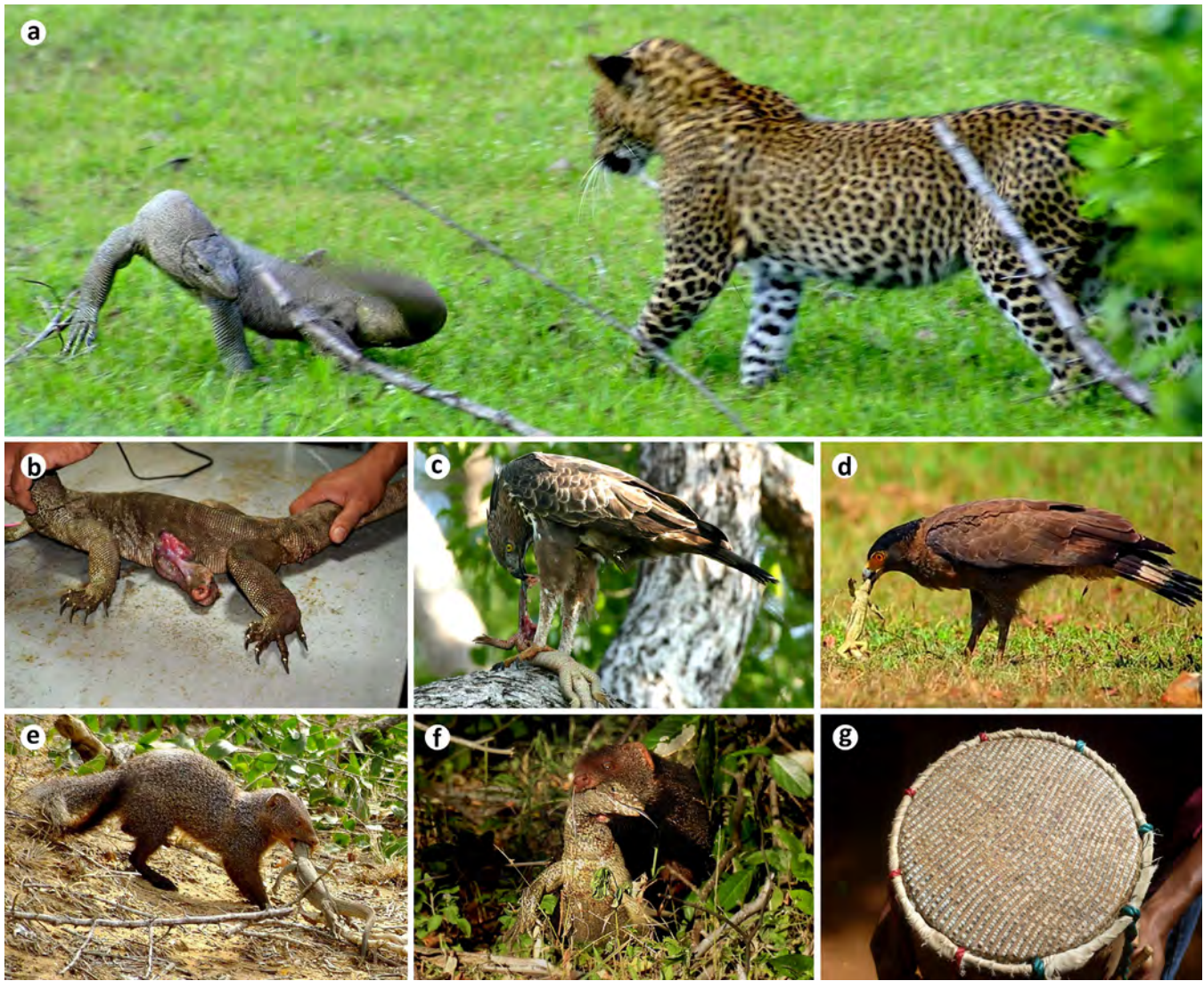


Fig. 2. Predators of *V. bengalensis*: (a) Sri Lankan leopard (*Panthera pardus*), (b) domestic dog attack (*Canis familiaris*), (c) changeable hawk-eagle (*Spizaetus cirrhatus*), (d) crested serpent-eagle (*Spilornis cheela*), (e & f) grey mongoose (*Herpestes edwardsii*), (g) local drum using the skin of *V. bengalensis*. Photographs by Mevan Piyasena, Sanjaya Atapattu, Mendis Wickramasinghe, and Dinesh Silva.

Sri Lanka or habitat type.

## Discussion

Our study confirmed that *V. bengalensis* is a widely-foraging generalist predator that can also function as an opportunistic scavenger (Auffenberg, 1994; Pianka, 2004). Broad dietary niches have been reported for several other varanids throughout the Indo-Malayan and Australasian realms (Sutherland, 2011). In Sri Lanka, *V. bengalensis* seems to forage mostly as an active predator, and most of its prey are vertebrates. In

contrast, studies conducted elsewhere have suggested that invertebrates (flying insects, annelids, arachnids, mollusks, and crustaceans) comprised the primary diet, while vertebrates were an alternative prey depending on their availability (Auffenberg, 1994; Pianka, 2004). The dietary bias we noted in our study can be an artifact of biased sampling and detectability since predation on vertebrates is more noticeable to an opportunistic observer. *Varanus bengalensis* is also considered an egg predator of both reptiles and birds (Deraniyagala, 1953; Somaweera & Somaweera, 2009); however, our study only confirmed *V. bengalensis* predation of bird

eggs in Sri Lanka. Dietary studies on varanids have suggested a strong positive correlation between prey size and the monitor's body size, with large-bodied monitors foraging predominantly on vertebrate prey such as mammals while smaller-sized monitors practice insectivory (Arbuckle, 2009). Gut content analyses of *V. bengalensis* have supported this notion, where juvenile monitors feed nearly exclusively on insects such as orthopterans and coleopterans (Auffenberg & Ipe, 1983). However, vertebrate prey may account for a greater caloric (energetic) intake by monitors irrespective of the relative proportion of vertebrates in monitor diets (Arbuckle, 2009).

Plasticity in food selection and the catholic dietary habits of *V. bengalensis* have previously been documented from southeastern and southern Asian mainland, Indo-Malayan island, and Indian oceanic island populations (Jolley & Meek, 2006). Although predominantly terrestrial, a minor proportion of the diet of *V. bengalensis* consists of both aquatic and semi-aquatic prey (freshwater fish, amphibians, waterfowl, crocodiles, and freshwater crabs) in aquatic and riparian environments (S. Karunarathna, pers. obs.). Therefore, *V. bengalensis*, like many other varanids, may even shift its prey choice in response to seasonal and spatial variation in food availability, ontogeny, and intensity of competitive interactions (Shine, 1986; Losos & Greene, 1988; Sutherland, 2011). In Sri Lanka, the diversity of large lizards (only two species of *Varanus*) is lower than other regions within the natural range of varanids such as the Indo-Malayan region; thus, inter-specific competition is lower, which may have enabled *V. bengalensis* to retain a generalist diet. The other extant Sri Lankan monitor species, *V. salvator*, is predominantly aquatic, which further minimizes niche overlap with *V. bengalensis* (Karunarathna *et al.*, 2012).

Although *V. bengalensis* is mostly terrestrial, we have documented that the species can forage in arboreal habitats, where individuals feed on birds (common myna [*Acridotheres tristis*]; Jolley & Meek, 2006). Sometimes, *V. bengalensis* forages in vegetation alongside river banks or at the land-water interphase of rivers, lakes, and wetlands. When feeding on larger vertebrate prey, these monitors are known to kill their prey by violently shaking it or slamming it against hard substrates, then swallow the prey head first by pushing the prey against the ground and then using inertial movements until ingestion is complete (Loop, 1974; Jolley & Meek, 2006; Rahman *et al.*, 2015). When handling or capturing larger prey, these monitors can dismember their prey by holding them with forelimbs;

they are also known to dig in search of prey with their forelimbs and jaws (Auffenberg & Ipe, 1983; Rahman *et al.*, 2015). Moreover, when feeding on invertebrates with hard exoskeletons, the monitors masticate the shells first prior to ingestion (Jolley & Meek, 2006). We noted that *V. bengalensis* forages in multiple habitat types, including forests and woodlands with trees of variable trunk densities, home gardens and homesteads, urban and suburban environments, lotic and lentic aquatic habitats of both natural and anthropogenic origins, and brackish water habitats.

Our study indicates that *V. bengalensis* is capable of feeding on live prey as well as dead organic matter, including both native and introduced species. Carrion feeding has been observed throughout its range (Karunarathna *et al.*, 2012). Populations inhabiting homestead environments are known to spend nearly 50% of their activity budget on scavenging among household garbage, particularly kitchen trash where they feed on cooked and uncooked vegetables, grains, and fruits (Rahman *et al.*, 2015). The ability of several varanid species to scavenge human-generated trash is a remarkable feature which has enabled them to successfully exploit built-up environments and as a human commensal (Uyeda, 2009). Human-assisted food subsidies for varanids could have profound ecological effects on wild populations, such as increased abundance, altered community and intraspecific interactions, modified social hierarchies, and aggravated human-wildlife conflicts. Dramatic changes in wildlife behavior and community structure have been recognized among many other human commensals such as coyotes, crows, raccoons, mongoose, and gulls upon "supplementary feeding" (O'Connor, 2013).

Our study also established the fact that *V. bengalensis* may not be a top predator in Sri Lanka's ecosystems, although we only documented a few predators of *V. bengalensis*. Throughout its biogeographic range, a number of predators including pythons and other large snakes, eagles, mongooses, wild and domesticated dogs, feral cats, humans, and other varanids are known to predate on *V. bengalensis* (Auffenberg, 1994; Pianka, 2004). Similar to our findings in Sri Lanka, predation mostly occurs in early life-history stages (eggs, hatchlings, and juveniles), with only a small portion of predation involving fully-grown adults (Auffenberg, 1994; Pianka, 2004). Although cannibalism has been cited elsewhere, we do not have any evidence for active intraspecific predation of *V. bengalensis* in Sri Lanka (Auffenberg, 1994; Pianka, 2004).

Humans' role as a predator of *V. bengalensis* in



Sri Lanka is noteworthy. The human exploitation of *V. bengalensis* for food in Sri Lanka has historically been recorded as far back as 800 BC - 200 AD, and continues today to a greater extent and includes both consumption and trade (Abayaratna & Mahaulpatha, 2006; de Silva, 2006). Human exploitation of *V. bengalensis* has also been reported from South and Southeast Asia (Koch *et al.*, 2013). The hunting pressure on *V. bengalensis* in Sri Lanka as well as in some other parts of its range have led to localized population declines and reductions in their former ranges and habitats (Amarasinghe *et al.*, 2009; Koch *et al.*, 2013). In some rural parts of Sri Lanka such as Hambegamuwa (southeastern Sri Lanka), local inhabitants use the hides of *V. bengalensis* for making drums (Fig. 2).

Given its broad dietary preferences, which include many insects and rats, *V. bengalensis* can be considered a biological pest control agent (Karunarathna *et al.*, 2008; Karunarathna *et al.*, 2012). Moreover, as scavengers, these monitors contribute to organic matter cycling and the removal of carrion (Somaweera & Somaweera, 2009; Karunarathna *et al.*, 2012). Their role as a mesopredator provisions many ecosystem services which involves regulating populations in lower trophic levels while also serving as prey for top predators. Behavioral studies have suggested that *V. bengalensis* allocate a greater portion of their daily activity budgets to foraging, where they roam extensively over great distances exploring profitable foraging grounds (Losos & Greene, 1988; Sweet & Pianka, 2007). Thus, their contribution to energy flow and nutrient cycling is salient for proper ecosystem functioning. Quantifying their role in food webs based on gut content surveys and carbon isotope analyses using network theory (carbon and energy flow across different trophic nodes) may provide considerable insight on their ecological role. Moreover, our study has indicated that *V. bengalensis* feeds on non-native species; therefore, these monitors could have some impacts on controlling invasive species. This potential requires further investigation.

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## References

- Abayaratna, M.G.T.H. & W.A.D. Mahaulpatha. 2006. Activity budgets and habitat preference of land monitor, thalagoya *Varanus bengalensis* in a residential area. *Vidyodaya Journal of Science* 13: 127–138.
- Amarasinghe, A.A.T., G. Chathuranga & D.M.S.S. Karunarathna. 2009. *Varanus salvator* (Laurenti, 1768) in Rathgama lagoon in Galle District, Sri Lanka. *Biawak* 3(3): 81–84.
- Arbuckle, K. 2009. Ecological function of venom in *Varanus*, with a compilation of dietary records from the literature. *Biawak* 3(2): 46–56.
- Auffenberg, W. 1994. *The Bengal monitor*. University Press of Florida, Gainesville. 590 pp.
- Auffenberg, W. & I. Ipe. 1983. The food and feeding of juvenile Bengal monitor lizards (*Varanus bengalensis*). *Journal of the Bombay Natural History Society* 80(1): 119–124.
- Das, I. & A. de Silva 2005. *A Photographic Guide to Snakes and Other Reptiles of Sri Lanka*. New Holland Publishers, London. 144 pp.
- de Silva, A. 2006. Current status of the reptiles of Sri Lanka. Pp. 134–163 *In*: Bambaradeniya, C.N.B. (ed.), *Fauna of Sri Lanka: Status of Taxonomy, Research and Conservation*. The World Conservation Union and Government of Sri Lanka, Colombo, Sri Lanka.
- Deraniyagala, P. 1953. *A Coloured Atlas of Some Vertebrates from Ceylon*. Tetrapod Reptilia, Volume 2, National Museums of Sri Lanka. The Ceylon Government Press, Colombo. 102 pp.
- Dryden, G., B. Green, E.D. Wikramanayake & K. Dryden. 1992. Energy and water turnover in two tropical varanid lizards, *Varanus bengalensis* and *V. salvator*. *Copeia* 1992: 102–107.
- Faeth, S.H., P.S. Warren, E. Shochat & W.A. Marussich. 2005. Trophic dynamics in urban communities. *Bioscience* 55(5): 399–407.
- Jolley, E. & R. Meek. 2006. *Varanus bengalensis* (Bengal monitor): Unusual behaviour and feeding. *Herpetological Bulletin* 95: 31–32.
- Karunarathna, D.M.S.S, A.A.T. Amarasinghe &

- A. De Vos. 2008. Preliminary notes on the monitor lizards (Family: Varanidae) within the National Zoological Gardens (NZG) Dehiwala, Colombo District, Sri Lanka. *Biawak* 2(3): 109–118.
- Karunaratna, D.M.S.S., A.A.T. Amarasinghe, B.M. Majintha & H.K.D. Kandambi. 2012. Population status of two *Varanus* species (Reptilia: Sauria: Varanidae) in Sri Lanka's Puttalam lagoon system, with notes on their diet and conservation status. *Biawak* 6(1): 22–33.
- Karunaratna, D.M.S.S., T.D. Surasinghe, M.C. De Silva, M.B. Madawala, D.E. Gabadage & W.M.S. Botejue, 2015. Dietary habits of *Varanus salvator salvator* in Sri Lanka with a new record of predation on an introduced clown knifefish, *Chitala ornata*. *Herpetological Bulletin* 133: 23–28.
- Koch, A., T. Ziegler, W. Boehme, E. Arida & M. Auliya. 2013. Pressing problems: Distribution, threats, and conservation status of the monitor lizards (Varanidae: *Varanus* spp.) of Southeast Asia and the Indo-Australian Archipelago. *Herpetological Conservation and Biology* 8(3): 1–62.
- Loop, M.S. 1974. The effect of relative prey size on the ingestion behavior of the Bengal monitor, *Varanus bengalensis* (Sauria: Varanidae). *Herpetologica* 30(2): 123–127.
- Losos, J.B. and H.W. Greene. 1988. Ecological and evolutionary implications of diet in monitor lizards. *Biological Journal of the Linnean Society* 35(4): 379–407.
- Molnar, R.E. 2004. The long and honorable history of monitors and their kin. Pp. 10–67. *In*: Pianka, E.R., D.R. King & R.A. King (eds.), *Varanoid Lizards of the World*. Indiana University Press, Bloomington.
- O'Connor, T. 2013. *Animals as Neighbors: The Past and Present of Commensal Animals*. Michigan State University Press, Lansing. 184 pp.
- Pianka, E.R. 1995. Evolution of body size: Varanid lizards as a model system. *The American Naturalist* 146(3): 398–414.
- Pianka, E.R. 2004. *Varanus bengalensis*. Pp. 157–160. *In*: Pianka, E.R., D.R. King & R.A. King (eds.), *Varanoid Lizards of the World*. Indiana University Press, Bloomington.
- Pianka, E.R., D. King & R.A. King. 2004. *Varanoid Lizards of the World*. Indiana University Press, Bloomington. 608 pp.
- Pianka, E.R. and D.R. King. 2004. Introduction. Pp. 3–9. *In*: Pianka, E.R., D.R. King & R.A. King (eds.), *Varanoid Lizards of the World*. Indiana University Press, Bloomington.
- Rahman, K.M., M. Khan & I. Rakhimov. 2015. Scavenging behavior of the bengal monitor (*Varanus bengalensis*) in Jahangirnagar University campus, Bangladesh. *Journal of Scientific Research and Reports* 7(7): 539–550.
- Shine, R. 1986. Food habits, habitats and reproductive biology of four sympatric species of varanid lizards in tropical Australia. *Herpetologica* 42(3): 346–360.
- Survey Department of Sri Lanka. 2012. *The National Atlas of Sri Lanka*. 2nd Edition. Survey Department of Sri Lanka, Colombo, Sri Lanka.
- Sutherland, D.R. 2011. Dietary niche overlap and size partitioning in sympatric varanid lizards. *Herpetologica* 67(2): 146–153.
- Sweet, S.S. & E.R. Pianka. 2007. Monitors, mammals, and wallace's line. Pp. 79–99. *In*: Horn, H.-G., W. Böhme & U. Krebs (eds.), *Advances in Monitor Research III*, Mertensiella 16. Deutsche Gesellschaft für Herpetologie und Terrarienkunde, e.V., Rheinbach.
- Uyeda, L. 2009. Garbage appeal: Relative abundance of water monitor lizards (*Varanus salvator*) correlates with presence of human food leftovers on Tinjil Island, Indonesia. *Biawak* 3(1): 9–17.
- Wikramanayake, E.D. & G.L. Dryden. 1993. Thermal ecology of habitat and microhabitat use by sympatric *Varanus bengalensis* and *V. Salvator* in Sri Lanka. *Copeia* 1993: 709–714.
- Wikramanayake, E.D. & B. Green. 1989. Thermoregulatory influences on the ecology of two sympatric varanids in Sri Lanka. *Biotropica* 21(1): 74–79.



# An Annotated Bibliography of Captive Reproduction in Monitor Lizards (Varanidae: *Varanus*). Part II. *Empagusia* and *Philippinosaurus*

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**Abstract:** Popular in zoos and private collections, monitor lizards have been maintained in captivity for nearly two centuries. During this time, but especially over the past three decades, a voluminous body of publications has brought to light important details and perspectives that have helped advance their captive husbandry and reproductive management. This bibliography presents an annotated compilation of publications pertaining strictly to the captive reproduction of monitor lizards belonging to the *Varanus* subgenera *Empagusia* and *Philippinosaurus*. It is intended to serve as a guide for zoos and private herpetoculturists looking to expand their knowledge and familiarity with this group and introduce readers to different perspectives on their management and reproduction in captivity.

## Introduction

Monitor lizards have a long and fascinating history of being maintained in captivity that dates back to at least the early 19th Century. Some of the earliest published accounts of monitor lizards in captive collections reference animals held in European menageries and zoological gardens (Cox, 1831; Knight, 1867; Mitchell, 1852; Sclater, 1877), although private keepers also maintained representatives of this group during this period (Bateman, 1897; Lachman, 1899; von Fischer, 1884). Alfred “Gogga” Brown was probably the first individual to genuinely attempt to reproduce monitor lizards in captivity in the late 1800s (Branch, 1991). Although he received hundreds of eggs (from 33 clutches) from a large group of more than 40 captive *Varanus albigularis* he maintained outdoors in South Africa, he was unsuccessful in hatching any live offspring (Branch,

1991). Eggs had also been received but not hatched by other keepers around this time (*e.g.*, Thilenius, 1898); these eggs were usually scattered by the females who clearly did not have appropriate conditions available for nesting (Branch, 1992; Thilenius, 1898). A poor understanding of monitor lizard biology and husbandry and reptile egg incubation undoubtedly prohibited successful captive breeding from taking place for many decades. This was especially apparent in a 1967 report by Osman (1967), who, while discussing a clutch of *V. komodoensis* eggs that were scattered across the ground of the enclosure rather than buried, suspected that the eggs were to be later buried in the sand by the female after they had been left out in the sun for the shells to harden.

The first documented record of successful captive breeding of a monitor lizard occurred with *V. komodoensis* in 1941 (de Jong, 1944). Unknown to their caretakers, a

pair of adults maintained at the Batavia Zoo since 1938 secretly nested a clutch of eggs in their exhibit which unexpectedly hatched several months later, much to the zoo's surprise. The next documented case of successful captive reproduction in monitor lizards did not occur until 1962, when a wild-caught gravid *V. albigularis* produced a clutch of eggs shortly after arriving at the San Diego Zoo, which resulted in a single hatchling. Several additional species were successfully bred for the first time in the 1970s (Horn, 1978; Horn & Visser, 1989), with more species hatched in the 1980s (e.g., Bredl & Horn, 1987; Bröer & Horn, 1985; Eidenmüller, 1986; Eidenmüller & Horn, 1985; Horn & Petters, 1982; Horn & Visser, 1989; Irwin, 1996; Stirnberg & Horn, 1981). From the 1990s onward, monitor lizard husbandry continued to advance rapidly, to the point where at least 53 species have now been successfully reproduced in captivity (Horn & Visser, 1997; Eidenmüller, 2007; Husband & Bonnett, 2009; Brown, 2012).

In a previous bibliographic installment (Mendyk, 2016), I focused on the predominately Australian *Varanus* subgenus *Odatria*, a group that is well-represented in zoos and private collections. Here, the focus is shifted to South and Southeast Asia and its offshore islands, which are home to several endemic subgenera that are also maintained in captive collections, albeit not as frequently or abundantly as *Odatria*. Two subgenera which will be focused on in this installment are *Empagusia*, a group comprised of four species (*V. bengalensis*, *V. dumerilii*, *V. flavescens* and *V. rudicollis*) occurring throughout southern and southeastern Asia and the Malay Archipelago, and *Philippinosaurus*, a group comprised of three frugivorous species endemic to the Philippines (of which only one species has been kept and bred in captivity – *V. olivaceus*). Unlike *Odatria*, for which virtually all specimens presently maintained in captivity are captive-bred in origin, most captive individuals belonging to *Empagusia* and *Philippinosaurus* are of wild-caught origin, denoting the rarity of captive breeding among these two groups.

The following bibliography, which represents a continuation of what will be several installments on the captive breeding of monitor lizards, focuses chiefly on the subgenera *Empagusia* and *Philippinosaurus*. Similar works that address other subgenera are forthcoming.

### Using this Bibliography

This bibliography covers all aspects of captive reproduction including both successful and unsuccessful attempts. It is largely intended to serve as a resource

for zoo professionals and private herpetoculturists working with these species in captivity, but may also prove valuable to conservation biologists, ecologists, veterinarians and general enthusiasts seeking to gain familiarity with existing literature on the reproductive biology of monitor lizards. Species covered in this bibliography are organized alphabetically, with annotations describing the nature and content of each work appearing inside brackets after each reference.

It should be noted that there still remains disagreement within the scientific community regarding the taxonomy of *V. bengalensis nebulosus*, particularly whether it constitutes a distinct species as proposed by Böhme & Ziegler (1997). For this bibliography, I follow the taxonomy proposed by Mertens (1942) and identify the taxon at the subspecies level. Given this taxonomic flux and the associated confusion it has created, it is possible, and perhaps inevitable, that the true taxonomic identities of taxa reported on in older publications may be unclear – whether *V. b. bengalensis* or *V. bengalensis nebulosus*. Nevertheless, the biological similarities between both subspecies suggest that reproductive data and information presented for one should be just as relevant and applicable to the other.

While best efforts were made to document all known publications relevant to the reproduction of these species in captivity, I recognize the possibility and likelihood that some publications may have been missed. Given that bibliographies are perpetual works in progress, I welcome and encourage feedback on publications missing from this bibliography and new accounts as they are published so that they can be added to an updated version of this document in the future.

**Acknowledgments** – This bibliographic series is dedicated to the late Mark K. Bayless, whose many contributions to the study of monitor lizards have helped advance the fields of monitor lizard biology and captive husbandry, inspire a new generation of enthusiasts, and stimulate new research on this group, including the present bibliography. I am indebted to Kristen Bullard, Richard Green, Michael Hardy, and Polly Lasker of the Smithsonian Institution Libraries for their assistance with sourcing obscure literature, and would also like to thank Ben Aller for allowing access to Mark Bayless's former library of monitor literature.

### References

Bateman, G.C. 1897. The Vivarium: Being a Practical Guide to the Construction, Arrangement, and



- Management of Vivaria. L. Upcott Gill, London. 424 pp.
- Böhme, W. & T. Ziegler. 1997. On the synonymy and taxonomy of the Bengal monitor lizard, *Varanus bengalensis* (Daudin, 1802) complex (Sauria: Varanidae). *Amphibia-Reptilia* 18(2): 207–211.
- Branch, W.R. 1991. The Regenia Registers of 'Gogga' Brown (1869-1909) "Memoranda on a species of monitor or varan". Pp. 57–110. *In*: Horn, H.-G. & W. Böhme (eds.), *Advances in Monitor Research, Mertensiella* 2. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e.V., Rheinbach.
- Bredl, J. & H.-G. Horn. 1987. Über die Nachzucht des australischen Riesenwarans *Varanus giganteus*. *Salamandra* 23(2/3): 90–96.
- Bröer, W. & H.-G. Horn. 1985. Erfahrungen bei der Verwendung eines Motorbruters zur Zeitung von Reptilieneiern. *Salamandra* 21(4): 304–310.
- Brown, D. 2012. *A Guide to Australian Monitors in Captivity*. Reptile Publications, Burleigh. 263 pp.
- de Jong, J.K. 1944. Newly hatched *Varanus komodoensis*. *Treubia* 18: 143–145.
- Eidenmüller, B. 1986. Beobachtungen bei der Pflege und Nachzucht von *Varanus (Odatria) t. timorensis* (Gray, 1831). *Salamandra* 22(2/3): 157–161.
- Eidenmüller, B. 2007. *Monitor Lizards: Natural History, Captive Care & Breeding*. Edition Chimaira, Frankfurt am Main, 176 pp.
- Eidenmüller, B. & H.-G. Horn. 1985. Eigene Nachzuchten und der gegenwertige Stand der Nachzucht von *Varanus (Odatria) storri* Mertens, 1966. *Salamandra* 21(1): 55–61.
- Stirnberg, G.E. & H.-G. Horn. 1981. Eine unerwartete Nachzucht im Terrarium: *Varanus (Odatria) storri*. *Salamandra* 17(1/2):55–62.
- Horn, H.-G. 1978. Nachzucht von *Varanus gilleni* (Reptilia: Sauria: Varanidae). *Salamandra* 14(1): 29–32.
- Horn, H.-G. & G. Petters. 1982. Beiträge zur Biologie des Rauh nackenwarans, *Varanus (Dendrovaranus) rudicollis* Gray. *Salamandra* 18(1/2): 29–40.
- Horn, H.-G. & G.J. Visser. 1989. Review of reproduction of monitor lizards *Varanus* spp. in captivity. *International Zoo Yearbook* 28: 140–150.
- Horn, H.-G. & G.J. Visser. 1997. Review of reproduction of monitor lizards *Varanus* spp. in captivity II. *International Zoo Yearbook* 35: 227–246.
- Husband, G. & M. Bonnett. 2009. Monitors. Pp. 484–583. *In*: Swan, M. (ed.), *Keeping and Breeding Australian Lizards*. Mike Swan Herp Books, Lilydale.
- Irwin, S. 1996. An innovative strategy for the detection of egg-deposition in captive varanid reptiles. *Herpetofauna (Sydney)* 26(1): 31–32.
- Knight, C. 1867. Monitoridae or Monitors. Pp. 879–882. *In*: *Natural History: Or, Second Division of The English Encyclopedia*. Volume 3. Scribner, Welford & Co., London.
- Lachmann, S. 1889. Die Bewohner meiner Terrarien. *Isis: Zeitschrift für alle naturwissenschaftlichen Liebhabereien* 14(23): 181–182.
- Mendyk, R.W. 2016. An annotated bibliography of captive reproduction in monitor lizards (Varanidae: *Varanus*). Part 1. *Odatria*. *Biawak* 10(2): 54–71.
- Mertens, R. Die Familie der Warane. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* 462: 1–116; 465: 117–234; 466: 235–391.
- Mitchell, D.W. 1852. *A Popular Guide to the Gardens of the Zoological Society of London*. D.W. Mitchell, London. 62 pp.
- Osman, H. 1967. A note on the breeding behaviour of the Komodo dragons *Varanus komodoensis* at Jogjakarta Zoo. *International Zoo Yearbook* 7: 181.
- Sclater, P.L. 1877. Family: Monitoridae. Pp. 448–449. *In*: *List of the Vertebrated Animals Now or Lately Living in the Gardens of the Zoological Society of London*. Zoological Society of London, London.
- Staedeli, J.H. 1962. Our very own monitors. *Zoonooz* 35(7): 10–15.
- Thilenius, G. 1898. Herpetologische Notizen aus Süd-Tunis. *Zoologische Jahrbücher* 1898(3): 219–237.
- von Fischer, J. 1884. *Das Terrarium, seine Bepflanzung und Bevölkerung: ein Handbuch für Terrarienbesitzer und Tierhändler*. Mahlau & Waldschmidt, Frankfurt a.M.. 384 pp.

## Subgenus: *Empagusia*

### *Varanus bengalensis*

- Ahsan, M.F. & M.A. Saeed. 2004. Some aspects of breeding biology of the Bengal lizard (*Varanus bengalensis*) in Bangladesh. *Asiatic Herpetological Research* 10: 236–240. [describes efforts to farm the species in Bangladesh and presents breeding info and reproductive data]
- Anonymous. 1981. Common monitor hatching at Madras Snake Park. *Hamadryad* 6(3): 10. [briefly documents successful reproduction]
- \_\_\_\_\_. 1982. Species of wild animals bred in captivity during 1980 and multiple generation captive births. *Reptiles. International Zoo Yearbook* 22: 367–371. [documents successful reproduction]
- \_\_\_\_\_. 1983. Species of wild animals bred in captivity during 1981 and multiple generation captive births. *reptiles. International Zoo Yearbook* 23: 267–272. [documents successful reproduction]
- \_\_\_\_\_. 1990. Huevos *bengalensis*. *Varanews* 1(1): 5. [documents egg laying]
- \_\_\_\_\_. 1991. Huevos *bengalensis* revisited. *Varanews* 1(4): 8. [documents inviable eggs]
- Bayless, M.K. 1997. Increases in breeding. *Varanids* 1(1): 3. [documents successful cases of reproduction]
- Bennett, D. 1997. *Varanus bengalensis*, the Bengal or clouded monitor. *Reptilian* 5(1): 47–56. [briefly mentions captive breeding at Honolulu Zoo]
- \_\_\_\_\_. 1998. *Monitor Lizards: Natural History, Biology and Husbandry*. Edition Chimaira, Frankfurt am Main. 352 pp. [provides general breeding information and documents successful cases of reproduction]
- D'Abreu, E.A. 1932. Notes on monitor lizards. *Journal of the Bombay Natural History Society* 36(1): 269–270. [documents egg laying taking place over several days, unsuccessful hatching]
- Deraniyagala, P.E.P. 1958. Reproduction in the monitor lizard *Varanus bengalensis* (Daudin). *Spoila Zeylanica* 28: 161–166. [describes hatching and artificial incubation of eggs collected from the wild]
- Gorman, D. 1993. Breeding the Bengal monitor in captivity. *Varanews* 3(4): 2. [describes successful captive reproduction]
- \_\_\_\_\_. 1997. Reproduction of the Bengal monitor lizard, *Varanus bengalensis*, in captivity. *Varanids* 1(2): 8–12. [describes successful captive reproduction]
- Horn, H.-G. & G.J. Visser. 1989. Review of reproduction of monitor lizards *Varanus* spp. in captivity. *International Zoo Yearbook* 28: 140–150. [presents reproductive data]
- \_\_\_\_\_ & \_\_\_\_\_. 1997. Review of reproduction of monitor lizards *Varanus* spp. in captivity II. *International Zoo Yearbook* 35: 227–246. [presents reproductive data]
- Huff, T.A. 1986. Monitor madness chapter 2: Murder and mayhem. *The Herpetoculturist* 1(2): 15–19.



Fig. 1. - Illustration of “*Tupinambis cepedien*” (= *Varanus bengalensis*). From: Daudin, F.M. 1802. *Histoire Naturelle, Générale et Particulière des Reptiles. Tome Troisième*. De l’Imprimerie de F. Dufart, Paris.



- [describes receiving eggs, but consumed by adults]  
 Kellough, R. 1990. Finally, Bengal monitor eggs! Scales and Tales 4(4): 1. [documents egg laying in captivity]  
 Klag, K. & H. Kantz. 1988. Bemerkungen zur Haltung und Fortpflanzung von *Varanus bengalensis bengalensis* im der Terrarium. Herpetofauna (Weinstadt) 10(52): 21–24. [describes successful captive reproduction]  
 Latyshev, V.A. 1996. Some data on the reproduction of the Bengal monitor lizard *Varanus bengalensis* (Daudin) in the Moscow Zoo. Scientific Research in Zoological Parks 6: 51–54. [describes successful captive reproduction (*In Russian*)]  
 Mendyk, R.W. 2012. Reproduction of varanid lizards (Reptilia: Squamata: Varanidae) at the Bronx Zoo. Zoo Biology 31(3): 374–389. [presents reproductive data]  
 Misra, P.L. 1960. A note on the common monitor, *Varanus monitor* Linn. Journal of the Bombay



Fig. 2. Illustration of “*Monitor dumerilii*” (= *V. dumerilii*). From: Müller, S. & H. Schlegel. 1839-1844. Reptilia. 72 pp. + 10 pl. In: Temminck, C.J. (ed.), Verhandelingen over de Natuurlijke Geschiedenis der Nederlandsche overzeesche bezittingen Lithogr. Instituut van A. Arnz & Co., Leiden.

- Natural History Society 57(3): 669–670. [documents egg laying, but unsuccessful hatching]  
 Petzold, H.-G. 2008. The Life of Captive Reptiles. Contributions to Herpetology, Volume 22. Society for the Study of Amphibians and Reptiles, Ithaca. 275 pp. [briefly mentions nesting behavior]  
 Rehák, I. 1991. Herpetology and herpetoculture in Czechoslovakia. Pp. 74–84. In: Zulich, A.W. (ed.), Proceedings of the 14th International Symposium on Captive Propagation & Husbandry. International Herpetological Symposium, Dallas and Fort Worth. [briefly documents successful reproduction]  
 Sprackland, R.G. 1989. Mating and waiting: a status report on reproduction in captive monitor lizards (Sauria:Varanidae). Pp. 57–63. In: Gowen, R.L. (ed.), Captive Propagation and Husbandry of Reptiles and Amphibians. Special Publication #5. Northern California Herpetological Society. [presents reproductive data]  
 van der Koore, J. 1989. Kweek met varanen van 1966-1987. Lacerta 47(4): 106–107. [briefly mentions successful reproduction at Honolulu Zoo]  
 Wonosasmito, B. 2009. *Varanus nebulosus* (Gray, 1831). Bulletin de liason du G.E.V. 1(1): 21. [describes successful captive reproduction]  
 Zheng-qiangl, X., Y. Yao-hual, C. Zhi-bingl, Z. Weil, C. Junl, W. Wei-chunl & S. Yi-xuan. 2010. Some reproductive characteristics of *Varanus bengalensis* in captivity. Sichuan Journal of Zoology 29(1): 70–72. [presents reproductive data]

### *Varanus dumerilii*

- Aller, B. 2014. On the cover: *Varanus dumerilii*. Biawak 8(1): 1–2. [photographic documentation of successful reproduction]  
 — & M. Manago. 2009. Breeding and reproduction of *Varanus dumerilii*. Pp. 264–265. In: Sprackland, R.G., Giant Lizards. 2nd Ed. TFH Publications, Neptune. [describes successful reproduction in a private collection]  
 Anonymous. 1997. Species of wild animals bred in captivity during 1994 and multiple generation captive birds. Reptiles. International Zoo Yearbook 35(1): 354–362. [documents successful reproduction at Birmingham Zoo]  
 Balsai, M.J. 1996. Natural history and captive husbandry of selected monitor species. Reptiles USA Annual 1996: 136–153. [documents

- successful reproduction at Zoo Atlanta]
- Bayless, M.K. 1995. Dumeril's monitor lizard: A look at an uncommon monitor lizard (*Varanus dumerilii* Schlegel, 1839). Iowa Herpetological Society Newsletter, January: 3–4. [provides general breeding information]
- \_\_\_\_ & B. Aller. 2004. Dumeril's monitor lizard (*Varanus dumerilii*). Reptiles 12(3): 42–46. [describes successful captive reproduction]
- Bennett, D. 1995. Dumeril's monitor lizard (*Varanus dumerilii*). Reptilian 3(3): 35–37. [reviews general breeding information]
- \_\_\_\_. 1998. Monitor Lizards: Natural History, Biology and Husbandry. Edition Chimaira, Frankfurt am Main. 352 pp. [reviews general breeding information]
- Card, W.C. 1995. North American Regional Asian Forest Monitor Studbook. Dallas Zoo, Dallas. 79 pp. [documents successful captive reproduction in North American zoos]
- Conners, S. 1994. Dumeril's monitor hatches at Birmingham Zoo. AZA Communique, December: 24. [briefly describes successful reproduction at Birmingham Zoo]
- Eidenmüller, B. 2007. Monitor Lizards: Natural History, Captive Care & Breeding. Edition Chimaira, Frankfurt am Main, 176 pp. [provides general breeding information]
- Fost, M. 1995. Dumeril's monitors hatched at Zoo Atlanta. AZA Communique, July: 26. [briefly describes successful reproduction at Zoo Atlanta]
- \_\_\_\_. 1997. Parting shot: Captive bred Dumeril's monitors, *V. dumerilii*, hatching in Atlanta. Dragon News 1(1): 12. [photographic documentation of successful reproduction at Zoo Atlanta]
- \_\_\_\_, S. Frankel & B. Johnson. 1996. Taxon management account: Dumeril's monitor *Varanus dumerilii*. 20 pp. In: Hammack, S.H. (ed.), American Zoo and Aquarium Association Lizard Advisory Group, Taxon Management Accounts. Fort Worth Zoological Park, Fort Worth. [provides general breeding information and documents successful reproduction in North American zoos]
- \_\_\_\_, S. Frankel & B. Johnson. 2000. Taxon management account: Dumeril's monitor *Varanus dumerillii*. Pp. 14–22. In: Hartdegen, R.W. (ed.), 1999 Asian Forest Monitor North American Regional Studbook. Dallas Zoo, Dallas. [provides general breeding information and documents successful reproduction]
- Hartdegen, R.W. 2000. 1999 Asian Forest Monitor North American Regional Studbook. Dallas Zoo, Dallas. 144 pp. [documents successful captive reproduction in North American zoos]
- \_\_\_\_. 2002. 2002 Asian Forest Monitor North American Regional Studbook. Dallas Zoo, Dallas. 123 pp. [documents successful captive reproduction in North American zoos]
- Hauschild, A. 1998. Haltung und Nachzucht des Dumeril-Warans, *Varanus dumerilii* (Schlegel, 1839). Herpetofauna (Weinstadt) 20(115): 27–34. [describes successful reproduction]
- \_\_\_\_. 2001. Kenntnisse, Beobachtungen und Nachzucht des Dumeril-Warans, *Varanus dumerilii* (Schlegel, 1839). Draco 7: 75–80. [describes successful reproduction]
- Horn, H.-G. & G.J. Visser. 1997. Review of reproduction of monitor lizards *Varanus* spp. in captivity II. International Zoo Yearbook 35: 227–246. [presents reproductive data]
- Kirschner, A., T. Müller & H. Seuffer. 1996. Faszination Warane. Kirschner & Seuffer Verlag, Keltern-Weiler. 254 pp. [provides general breeding information]
- Paine, F., S. Connaughton & L. Radford. 1988. Venezuelan sliders and Dumeril's monitors hatched at Buffalo Zoo. AAZPA Newsletter 29(7): 23. [documents successful reproduction at Buffalo Zoo]
- Radford, L. 1995. Life with Dumeril's monitor. Zoolog (Zoological Society of Buffalo), Fall: 7. [describes successful reproduction at Buffalo Zoo]
- \_\_\_\_ & F.L. Paine. 1989. The reproduction and management of the Dumeril's monitor *Varanus dumerilii* at the Buffalo Zoo. International Zoo Yearbook 28: 153–155. [describes successful reproduction at Buffalo Zoo]
- Spitsin, V.V. (ed.). 2012. Breeding of wild and some domestic animals at regional zoological institutions. Information on the Zoological Collections 2012. Informational Issue of the Eurasian Regional Association of Zoos & Aquariums 31: 40–41, 261–264. [documents successful reproduction at Leningrad Zoo (In Russian)]
- Sprackland, R.G. 1989. Mating and waiting: a status report on reproduction in captive monitor lizards (Sauria:Varanidae). Pp. 57–63. In: Gowen, R.L. (ed.), Captive Propagation and Husbandry of Reptiles and Amphibians. Special Publication #5. Northern California Herpetological Society. [briefly documents successful reproduction at zoos]



\_\_\_\_\_. 1995. Dumeril's monitor lizard. *Reptiles* 3(7): 56–69. [briefly mentions successful reproduction in zoos and private collections]

*Varanus flavescens*

Berker, M. 1992. Translation of: Visser, G.J. 1985. Notes on the breeding biology of the yellow monitor *Varanus (Empagusia) flavescens* (Hardwicke & Gray, 1827) in the Rotterdam Zoo (Sauria: Varanidae). *Salamandra* 21(2/3): 161–168. *Varanews* 2(3): 2–5. [describes successful reproduction at Rotterdam Zoo]

Horn, H.-G. & G.J. Visser. 1989. Review of reproduction of monitor lizards *Varanus* spp. in captivity. *International Zoo Yearbook* 28: 140–150. [presents reproductive data]

\_\_\_\_ & \_\_\_\_ 1991. Basic data on the biology of monitors. Pp. 176–187. *In*: Böhme, W. & H.-G. Horn (eds.), *Advances in Monitor Research*, *Mertensiella* 2. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e.V., Rheinbach. [presents reproductive data]

van der Koore, J. 1988. De kweek van varanen in gevangenschap. *Lacerta* 47(2): 35–39. [discusses successful captive reproduction at Rotterdam Zoo]

Visser, G.J. 1992. Notes on the breeding biology of the yellow monitor *Varanus (Empagusia) flavescens* (Hardwicke & Gray, 1827) in the Rotterdam Zoo (Sauria: Varanidae). *Varanews*

2(3): 2–5. [an English translation of Visser, 1985 describing successful reproduction at Rotterdam Zoo]

\_\_\_\_\_. 1996. Waranhaltung und Zucht im Zoo Rotterdam/Niederlande. *Monitor* 4(2): 27–31. [briefly mentions successful reproduction at Rotterdam Zoo]

\_\_\_\_\_. 2003. Herpetology at the Rotterdam Zoo. *Herpetological Review* 34(1): 11–16. [briefly mentions successful reproduction at Rotterdam Zoo]

\_\_\_\_\_. 1985. Notizen zur Brutbiologie des Gelbwarans *Varanus (Empagusia) flavescens* (Hardwicke & Gray, 1827) im Zoo Rotterdam. *Salamandra* 21(2/3): 161–168. [describes successful reproduction at Rotterdam Zoo]

*Varanus rudicollis*

Anonymous. 1990. Species of wild animals bred in captivity during 1988/1989 and multiple generation births. *Reptiles*. *International Zoo Yearbook* 30: 326–342. [documents successful reproduction in zoos]

\_\_\_\_\_. 1991. Reptiles bred in captivity and multiple generation births. *International Zoo Yearbook* 30: 326–342. [documents successful reproduction at Fort Worth Zoo]

Bayless, M. K. 1993. Reproductive notes on the black roughneck monitor lizard (*Varanus rudicollis* Gray, 1845). *Varanews* 3(2): 3. [discusses egg laying at Fort Worth Zoo]

\_\_\_\_\_. 1997. The rough-neck monitor lizard (*Varanus rudicollis*). *Bulletin of the Chicago Herpetological Society* 32(12): 250–252. [documents cases of successful reproduction]

\_\_\_\_\_. 2001. The black roughneck monitor: Malaysia's tree lizard. *Reptile and Amphibian Hobbyist* 6(9): 8–16. [documents cases of successful reproduction]



Fig. 3. Illustration of “*Monitor flavescens*” (= *V. flavescens*). From: Gray, J.E. 1833-134. *Illustrations of Indian Zoology*. Volume II. Adolphus Richter and Co., London.

- Bennett, D. 1993. A review of some literature concerning the rough-necked monitor lizard *Varanus rudicollis*. *Reptilian* 1(9): 7–10. [reviews captive breeding information]
- \_\_\_\_\_. 1998. *Monitor Lizards: Natural History, Biology and Husbandry*. Edition Chimaira, Frankfurt am Main. 352 pp. [reviews captive breeding information]
- \_\_\_\_\_. 2004. *Varanus rudicollis*. Pp. 230–233. *In*: Pianka, E.R., D.R. King & R.A. King (eds.), *Varanoid Lizards of the World*. Indiana University Press, Bloomington. [presents reproductive data]
- Card, W. 1995. Monitor lizard husbandry. *Bulletin of the Association of Reptilian and Amphibian Veterinarians* 5(3): 9–17. [provides general breeding information]
- \_\_\_\_\_. 1995. *North American Regional Asian Forest Monitor Studbook*. Dallas Zoo, Dallas. 79 pp. [documents successful reproduction in North American zoos]
- Eidenmüller, B. 2007. *Monitor Lizards: Natural History, Captive Care & Breeding*. Edition Chimaira, Frankfurt am Main, 176 pp. [provides general breeding information]
- Hartdegen, R. 1998. Black rough-necked monitors (*Varanus rudicollis*). *Reptiles* 6(10): 68–75. [provides general breeding information]
- \_\_\_\_\_. 2000. *1999 Asian Forest Monitor North American Regional Studbook*. Dallas Zoo, Dallas. 144 pp. [documents successful reproduction in North American Zoos]
- \_\_\_\_\_. 2002. *2002 Asian Forest Monitor North American Regional Studbook*. Dallas Zoo, Dallas. 123 pp. [documents successful reproduction in North American Zoos]
- Horn, H.-G. & G. Petters. 1982. Beitrage zur Biologie des Rauh nackenwarans, *Varanus (Dendrovaranus) rudicollis* Gray. *Salamandra* 18(1/2): 29–40. [describes successful reproduction]
- \_\_\_\_\_ & G.J. Visser. 1989. Review of reproduction of monitor lizards *Varanus* spp. in captivity. *International Zoo Yearbook* 28: 140–150. [presents reproductive data]
- \_\_\_\_\_ & \_\_\_\_\_. 1991. Basic data on the biology of monitors. Pp. 176–187. *In*: Böhme, W. & H.-G. Horn (eds.), *Advances in Monitor Research*, *Mertensiella* 2. Deutsche Gesellschaft für Herpetologie und Terrarienkunde e.V., Rheinbach. [presents reproductive data]
- \_\_\_\_\_ & \_\_\_\_\_. 1997. Review of reproduction of monitor lizards *Varanus* spp. in captivity II. *International Zoo Yearbook* 35: 227–246. [presents reproductive data]
- Hudson, R., A. Alberts, S. Ellis & O. Byers. 1994. *Conservation Assessment and Management Plan for Iguanidae and Varanidae*. Aza Lizard Taxon Advisory Group & IUCN/SSC Conservation Breeding Specialist Group, Apple Valley. 247 pp. [briefly documents cases of successful reproduction]
- Kirschner, A., T. Müller & H. Seufer. 1996. *Faszination Warane*. Kirschner & Seufer Verlag, Keltern-Weiler. 254 pp. [provides general breeding information]
- McGinnity, D. 1993. Captive notes on three *Varanus rudicollis* at Nashville Zoo. *Varanews* 3(6): 2. [provides information and documents successful reproduction]
- Mehaffey, D. & D. McGinnity. 1996. Taxon management account: Black roughneck monitor *Varanus rudicollis*. 8 pp. *In*: Hammack, S.H. (ed.), *American Zoo and Aquarium Association Lizard Advisory Group, Taxon Management Accounts*. Fort Worth Zoological Park, Fort Worth. [provides breeding information and documents successful cases of reproduction]
- \_\_\_\_\_ & \_\_\_\_\_. 2000. Taxon management account: Black roughneck monitor *Varanus rudicollis*. Pp. 30–35. *In*: Hartdegen, R.W. (ed.), *1999 Asian Forest Monitor North American Regional Studbook*. Dallas Zoo, Dallas. [provides breeding information and documents successful cases of reproduction]
- Peavy, B. 2010. *Asian Forest Monitor 2010 North American Regional Studbook*, 4th Edition. Dallas Zoo, Dallas. 106 pp. [documents successful cases of reproduction in North American Zoos]
- Schmicking, T. & C. Schirmer. 1999. Nachzucht des Rauh nackenwarans (*Varanus rudicollis*). *Monitor* 8(1): 6–8. [describes successful reproduction]
- Zimmermann, E. 1986. *Breeding Terrarium Animals*. TFH Publications, Neptune. 384 pp. [provides general breeding information]



**Subgenus: *Philippinosaurus****Varanus olivaceus*

- Anonymous. 2015. L.A. Zoo successfully hatches *Varanus olivaceus*. Biawak 9(1): 9–10. [documents successful reproduction at the Los Angeles Zoo]
- Aucune, B., V. Hornyak, S. Foley, D. Barber, K. Murphy, J. Johnson, J. Krebs, J. Kinkaid, R. Hartdegen & C. Peeling. 2007. Lizard Advisory Group (LAG) Regional Collection Plan. Association of Zoos and Aquariums. 73 pp. [claims that two Philippine zoos successful reproduced species, but no further details provided]
- Bennett, D. 2014. A dubious account of breeding *Varanus olivaceus* in captivity at the Paradise Reptile Zoo in Mindoro, Philippines. Biawak 8(1): 12–14. [calls an earlier breeding report by Lutz, 2006 into question regarding its authenticity]
- Card, W. 1993. Significant monitor hatchings at Dallas Zoo. AZA Communique. April: 16. [documents successful hatching at the Dallas Zoo]
- \_\_\_\_\_. 1994. A reproductive history of monitors at the Dallas Zoo. The Vivarium 6(1): 26–29, 44–47. [mentions successful reproduction at Dallas Zoo]
- \_\_\_\_\_. 1994. Double-clutching Gould's monitors (*Varanus gouldii*) and Gray's monitors (*V. olivaceus*) at the Dallas Zoo. Herpetological Review 25(3): 111–114. [describes successful reproduction at Dallas Zoo]
- \_\_\_\_\_. 1995. Gray's monitor lizard (*Varanus olivaceus*) at the Dallas Zoo. Reptiles. 3(9): 78–85. [describes successful reproduction at Dallas Zoo]
- \_\_\_\_\_. 1995. Monitor lizards: this man's best friends. Tropical Fish Hobbyist 44(1): 148–163. [briefly mentions successful reproduction at Dallas Zoo]
- \_\_\_\_\_. 1995. North American Regional Asian Forest Monitor Studbook. Dallas Zoo, Dallas. 79 pp. [documents successful reproduction at Dallas Zoo]
- \_\_\_\_\_. 1996. Taxon management account- Gray's monitor or Butaan *Varanus olivaceus*. 4 pp. In: Hammack, S.H. (ed.), American Zoo and Aquarium Association Lizard Advisory Group, Taxon Management Accounts. Fort Worth Zoological Park, Fort Worth. [provides breeding information and reproductive data]
- de Rooter, M. 1993. Erste Nachzucht des Gray-Warans. Die Aquarien- und Terrarien Zeitschrift 46(10): 619. [documents successful reproduction at Dallas Zoo]
- Gaulke, M. 2008. International terrarium exhibits- the Avilon Montalban Zoological Park, Philippines. Reptilia 59: 55–59. [mentions successful reproduction at the Avilon Montalban Zoo]
- Hartdegen, R.W. 2000. 1999 Asian Forest Monitor North American Regional Studbook. Dallas Zoo, Dallas. 144 pp. [documents successful reproduction in North American zoos]
- \_\_\_\_\_. 2002. 2002 Asian Forest Monitor North American Regional Studbook. Dallas Zoo, Dallas. 123 pp. [documents successful reproduction in North American zoos]
- Horn, H.-G. & G.J. Visser. 1997. Review of reproduction of monitor lizards *Varanus* spp. in captivity II. International Zoo Yearbook 35: 227–246. [presents reproductive data]
- Hudson, R., A. Alberts, S. Ellis & O. Byers. 1994. Conservation Assessment and Management Plan for Iguanidae and Varanidae. Aza Lizard Taxon Advisory Group & IUCN/SSC Conservation Breeding Specialist Group, Apple Valley. 247 pp. [mentions eggs being laid at Dallas and Riverbanks Zoos]
- Lutz, M. 2006. Der Butaan (*Varanus olivaceus*), Hallowell, 1856, Haltung und erste erfolgreiche Nachzucht im Terrarium. Sauria 28: 5–13. [describes a potentially fictitious case of reproduction; see Bennett, 2014]
- Mendyk, R.W. 2012. Reproduction of varanid lizards (Reptilia: Squamata: Varanidae) at the Bronx Zoo. Zoo Biology 31(3): 374–389. [presents reproductive data]
- Recchio, I. 2015. Reproduction of the rare, frugivorous monitor, *Varanus olivaceus* Hallowell (1857) at the Los Angeles Zoo (abstract). Biawak 9(1): 16. [documents successful reproduction at the Los Angeles Zoo]
- \_\_\_\_\_. Reproduction of the rare frugivorous monitor lizard *Varanus olivaceus* (Hallowell, 1857), at the Los Angeles Zoo and Botanical Gardens. Pp. 93–103. In: Cota, M. (ed.), Proceedings of the 2015 Interdisciplinary World Conference on Monitor

- Lizards. Suan Sunandha Rajabhat University, Bangkok. [describes successful reproduction at the Los Angeles Zoo]
- Yuyek, M.D. 2004. Only in the Philippines: The natural history and reproductive husbandry of the Gray's monitor, *Varanus olivaceus*, with emphasis on the world's first successful rearing of a neonate bred at Avilon Zoo (Part One). *Animal Scene* 4(5): 80–82. [describes successful reproduction at Avilon Zoo]
- \_\_\_\_\_. 2004. Only in the Philippines: The natural history and reproductive husbandry of the Gray's monitor, *Varanus olivaceus*, with emphasis on the world's first successful rearing of a neonate bred at Avilon Zoo (Part Two). *Animal Scene* 4(6): 78–81. [describes successful reproduction at Avilon Zoo]
- \_\_\_\_\_. 2006. Incubating reptile eggs under the Philippine climatic condition. *Animal Scene* 5(12): 81–84. [describes incubation of eggs at Avilon Zoo]
- \_\_\_\_\_. 2012. Husbandry and reproduction of *Varanus olivaceus* Hallowell (Sauria: Varanidae) at the Avilon Montalban Zoological Park. *Biawak* 6(1): 39–53. [describes successful reproduction at Avilon Zoo]



# RECENT PUBLICATIONS

- Barabanov, A. & K. Milto. 2017. An annotated type catalogue of the anguid, dibamid, scincid and varanid lizards in the Department of Herpetology, Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia (Reptilia: Sauria: Anguidae, Dibamidae, Scincidae and Varanidae). *Zootaxa* 4244(1): 065–078.
- Baumer, M. & T. Carrillo. 2017. Utilizing fire hose beds for juvenile Komodo monitors (*Varanus komodoensis*). *Animal Keepers' Forum* 44(6): 184–185.
- Bennett, D. 2017. Comment (Case 3676) – On the proposed conservation of *Tupinambus indicus* Daudin, 1802 by replacement of the neotype (See BZN 72(2): 134–141 [Case]; 73(1): 55–58; 73(2–4): 119–120). *Bulletin of Zoological Nomenclature* 73(2–4): 116–118.
- Bhattarai, S. C.P. Pokheral, B. Lamichhane & N. Subedi. 2017. Herpetofauna of a Ramsar site Beeshazar and associated lakes, Chitwan National Park, Nepal. *IRCF Reptiles & Amphibians* 24(1): 17–29.
- Bishop, B.M., M.L. Juba, P.S. Russo, M. Devine, S.M. Barksdale, S. Scott, R. Settlege, P. Michalak, K. Gupta, K. Vliet, J.M. Schnur & M.L. van Hoek. 2017. Discovery of novel antimicrobial peptides from *Varanus komodoensis* (Komodo dragon) by large-scale analyses and de-novo-assisted sequencing using electron-transfer dissociation mass spectrometry. *Journal of Proteome Research* 16(4): 1470–1482.
- Chowdhury, S., J. Maji A. Chaudhuri, S. Dwari & A.K. Mondal. 2017. *Ahaetulla nasuta* (Green vine snake). Diet. *Herpetological Review* 48(2): 444.
- Dey, S.K. 2017. Population, breeding and conservation of Bengal monitor, *Varanus bengalensis* in Bangladesh. Unpublished Dissertation. University of Dhaka, Bangladesh. 197 pp.
- Dick, T.J.M. & C.J. Clemente. 2017. Where have all the giants gone? How animals deal with the problem of size. *PLoS Biology* 15(1): e2000473.
- Doody, J.S. S. Clulow, C. McHenry, M. Brown, G. Vas & G. Canning. 2017. *Varanus acanthurus* (Spiny-tailed monitor lizard). Communal nesting, reproduction, and commensalism. *Herpetological Review* 48(1): 203.
- Eckles, J.K., F. Mazzotti, D. Giardina, D. Hazelton & H.L. Rodgers. 2016. First evidence for reproduction of Nile monitors (*Varanus niloticus*) in Palm Beach County. *Southeastern Naturalist* 15(sp8): 114–119.
- Eustace, R., M.M. Garner, K. Cook, C. Miller & M. Kiupel. 2017. Multihormonal islet cell carcinomas in three Komodo dragons (*Varanus komodoensis*). *Journal of Zoo and Wildlife Medicine* 48(1): 241–244.
- Fajri, F., M. Adam & N. Asmilia. 2017. Difensial leukosit biawak air (*Varanus salvator*) yang telah didomestikasi dan biawak air liar. *Jurnal Ilmiah Mahasiswa Veteriner* 1(3): 404–408.
- Georgalis, G.L., A. Villa & M. Delfino. 2017. The last European varanid: Demise and extinction of monitor lizards (Squamata, Varanidae) from Europe. *Journal of Vertebrate Paleontology*: e1301946.
- Koch, A. & E. Arida. 2017. A coconut-eating monitor lizard? On an unusual case of frugivory in the melanistic Sulawesi water monitor (*Varanus togianus*). *Herpetological Bulletin* 139: 41–42.
- Langner, C. 2017. Hidden in the heart of Borneo – Shedding light on some mysteries of an enigmatic lizard: First records of habitat use, behavior, and foot items of *Lanthanotus borneensis* Steindachner, 1978 in its natural habitat. *Russian Journal of Herpetology* 24(1): 1–10.
- McFadden, M.S. & S. Kozłowski. 2017. *Varanus komodoensis* (Komodo dragon). *Longevity. Herpetological Review* 48(2): 376.
- Qiaoyun, W., Z. Fuhua, W. Shibao, Z. Cuiyun & Z. Li. 2017. Does water monitor (*Varanus salvator*) inhabit Guangdong? *Chinese Journal of Wildlife* 38(2): 285–290. (in Chinese)
- Patawang, I., A. Tanomtong, N. Getlekha, S. Phimphan, K. Pinthong & L. Neeratanaphan. 2017. Standardized karyotype and idiogram of Bengal monitor lizard, *Varanus bengalensis* (Squamata, Varanidae). *Cytologia* 82(1): 75–82.
- Pianka, E.R. 2017. Challenges facing today's lizard ecologists. *Journal of Herpetology* 51(1): 2–11.
- Recchio, I. & S. Kasielke. 2017. Successful blood collection technique for sex determination of incubating Komodo dragon (*Varanus komodoensis*) eggs at the Los Angeles Zoo. *Herpetological Review* 48(2): 366–368.

- Sweet, S.S. & V. Weijola. 2017. Comment (Case 3676) – Response to a comment on the proposed conservation of *Tupinambus indicus* Daudin, 1802 by replacement of the neotype: (See BZN 72(2): 134–141 [Case]; 73(1): 55–58; 73(2–4): 116–118). *Bulletin of Zoological Nomenclature* 73(2–4): 119–120.
- Twining, J.P., H. Bernard & R.M. Ewers. 2017. Increasing land-use intensity reverses the relative occupancy of two quadrupedal scavengers. *PLoS ONE* 12(5): e0177143.
- Ward-Fear, G., J. Thomas, J.K. Webb, D.J. Pearson & R. Shine. 2017. Eliciting conditioned taste aversion in lizards: Live toxic prey are more effective than scent and taste cues alone. *Integrative Zoology* 12(2): 112–120.
- Weijola, V., F. Kraus, V. Vahtera, C. Lindqvist & S.C. Donnellan. 2017. Reinstatement of *Varanus douarrha* Lesson, 1830 as a valid species with comments on the zoogeography of monitor lizards (Squamata: Varanidae) in the Bismarck Archipelago, Papua New Guinea. *Australian Journal of Zoology* 64(6): 434–451.
- Wilken, A.T., K.M. Middleton, K.C. Sellers, I.N. Cost, J.L. Davis & C.M. Holiday. 2017. Modeling complex cranial joints in *Varanus exanthematicus*. *FASEB Journal* 31(1) Supplement 577.5.





A nest-guarding female *Varanus rosenbergi* examines her nest burrow in a termite mound. Skin folds on her sides indicate her post-laying condition. Sydney, NSW. Photograph by **David Kirshner**.