Dietary notes and foraging ecology of south-east Asian water monitors (*Varanus salvator*) in Sabah, northern Borneo, Malaysia

JOSHUA P. TWINING[1*] & ANDRÉ KOCH[2]

[1]Queen's University, Belfast, School of Biological Sciences, MBC, 97 Lisburn Road, BT9 7 BL, Northern Ireland, UK
[2]Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, 53113 Bonn, Germany
[*]Corresponding Author Email: joshuaptwining@gmail.com

The South-east Asian water monitor (*Varanus salvator*) is one of the largest and most widely distributed lizard species in the world occurring from Sri Lanka to the Moluccas (Koch et al., 2007; Somaweera & Somaweera, 2009; Koch & Böhme, 2010). Despite its widespread distribution, and being considered an apex predator in many of the ecosystems it inhabits, particularly east of the Sunda shelf where large carnivorous mammals are generally absent (Sweet & Pianka, 2007), little is known about the functional ecology of water monitors. Typically regarded as generalist carnivores, they have been observed feeding on a huge variety of prey ranging from invertebrates, crustaceans and vertebrates including frogs, snakes, birds, fish, squirrels, deer, crocodiles, rats and tortoises (Gadow, 1901; Smith, 1932; Losos & Greene, 1988; Gaulke, 1991), to carrion, human refuse, fermented coconut and even human corpses (Uyeda, 2009; Guawardenam, 2016; Koch & Arida, 2017). From such records it can be deduced that water monitors provide integral ecosystem services through regulation of prey populations and carrion removal which is important in disease dynamics and nutrient cycling (Wilson & Wolkovich, 2011; Moleon et al., 2015; Twining et al., 2017). However, the effects of land-use change on ecological role of the species remains unclear, as wild-living water monitors are typically highly mobile and alert making direct observations difficult.

During a study of land-use change on vertebrate scavengers in Sabah, northern Borneo (Twining et al., 2017) water monitors were sampled using large cage traps (150 x 50 x 50 cm), baited with native fish, rodents, half domestic chickens and pig. Individuals were injected with a unique passive integrated transponder (PIT) tag in the thigh of the left hind leg, injecting it between muscle and skin pointing downwards (Ariefiandy et al., 2014; Twining et al., 2017). Due to the physiological stress response observed in water monitors in which they regurgitate their stomach contents when the trap is approached by the researcher some opportunistic observations were made on the diet of *V. salvator* macromaculatus in areas of varying land-use intensity. Typically, only the bait provided in traps was expelled, however, three observations of non-bait items were made from two individuals along riverine margins in oil palm plantation and selectively logged forest.

The first and second observations were on the 3rd May 2014, and 6th December 2014 from the same individual, a large female trapped along a riverine margin in an oil palm estate, which had ingested human refuse (in the form of instant noodle packets) on two separate occasions. This individual had a snout-vent length of 51.2 cm, a tail length of 88.5 cm and a mass of 1.39 kg. The third observation was made on the 18th December 2014, from a small adult male in selectively logged forest, with a snout-vent length of 39.8 cm, a tail length of 62.9 cm and a body mass of just 700 g. This lower body condition individual on its second capture regurgitated fourteen 3 - 4cm long, thick keratin coated quills, the internal organs, and upper cranium of a juvenile Malayan porcupine (*Hystrix brachyura*) Although having been reported to eat other rodents, to our best knowledge this is the first record of any varanid consuming a porcupine (Henry, 1912; Harrison, 1955; Sharma & Vazirani, 1977, Auffenberg & Ipe, 1983; Rao & Rao 1984; Losos & Greene, 1988; Gaulke, 1991; Traeholt, 1994; Uyeda et al., 2009; 2015). Even on recovery, the quills remain hard, and very sharp. The presence of such a number of quills, and the intact gastro-intestinal tract suggest the prey was consumed whole, a particularly tricky prey item to ingest in such a way. Such a prey item is indicative of an active hunting strategy, perhaps a greater necessity in order to meet high metabolic demands of varanids in lower intensity land use areas due to elevated competition for carrion with mammalian counterparts (Twining et al., 2017; Wearn et al., 2017).

Greater abundance and size of varanids in habitats with high anthropogenic presence have been linked to the utilisation of human trophic subsidies previously (Uyeda et al., 2009; Jessop et al., 2012). The female, which regurgitated human refuse on two occasions, had a high body condition, despite the presence of six buccal nematodes inside its mouth. This observation provides another record of water monitors adapting to human inhabitancy, which may be indicative of a switch to life history more dependent on scavenging of refuse (Uyeda et al., 2009; 2015). Such dependence on human refuse has also been observed in many small islands in the Indo-Malay Archipelago, including the Wakatobi Islands south-east of Sulawesi, the Gili Islands northwest of Lombok, Pulau Tiga and Pulau Gaya east of Sabah (JT, personal observation; H. Bernard, pers. comm., 2017). However, despite the presence of highly calorific food sources, and the low energy cost in attaining them, the benefits of this energy trade off, in conjunction with increased abundance resulting in increased sexual competition, biased sex ratios

and increased parasitism has been questioned previously (Uyeda et al., 2009; 2015; Jessop et al., 2012; Twining et al., 2017)

Although three observations are not sufficient to make any concrete conclusions from, when considered with the reported significant declines in biodiversity and abundance of typical prey items of varanids in oil palm estates, they may represent a shift in feeding ecology. Anurans, large and small mammals, fish and invertebrates were all reported to decline in the highest land-use intensity areas compared to forested sites within the same experimental landscape (Wilkinson et al., 2003; Konopik et al., 2015; Gray et al., 2016; Wearn et al., 2017). This decline in abundance and biodiversity of prey species, in conjunction with observed greater abundance, masses and body conditions of water monitors in oil palm estates (Twining et al., 2017), may be indicative of a distinct switch in foraging ecology observed in populations in forested sites compared to those in oil palm estates. Although observations were scarce, those made suggest an ecological switch from active hunting in natural environments to a scavenging life history in oil palm.

ACKNOWLEDMENTS

We would like to thank the Sabah Biodiversity Centre for providing research permits, the Sabah Foundation, Benta Wawasan, the Sabah Forestry Department and the South East Asia Rainforest Research Partnership for providing financial support. Ryan Gray, Denny Benasip and the SAFE Project team of Research Assistants kindly provided field assistance. Robert Ewers and Henry Bernard provided supervision of fieldwork. The SAFE project is funded by the Sime Darby Foundation.

REFERENCES

Ariefiandy A., Purwandana D., Seno A., Chrismiawati M., Jessop T.S. & Ciof C. (2014). Evaluation of three field monitoring-density estimation protocols and their relevance to Komodo dragon conservation. *Biodiversity Conservation* 23: 2473–2490.

Auffenberg, W. & Ipe, I.M. (1983). The food and feeding of juvenile Bengal monitor lizards (*Varanus bengalensis*). *Journal of the Bombay Natural History Society* 23: 119-124.

Gadow, H., (1901). *The Cambridge Natural History: Amphibians and Reptiles*. Macmillan: London. Pp. 668.

Gaulke, M. (1991). On the diet of the water monitor, *Varanus salvator* in the Philippines. In, Bohme, W. & Horn, H.G. (eds). Advances in Monitor Research. *Mertensiella* 2: 143 - 153.

Gunawardena, S.A. (2016). Forensic significance of monitor lizard scavenging activity on human corpses. *Biawak* 10: 45-47.

Gray C.L., B.I. Simmons, T.M. Fayle, D.J. Mann & E.M. Slade. (2016). Are riparian forest reserves sources of invertebrate biodiversity spillover and associated ecosystem functions in oil palm landscapes? *Biological Conservation* 194: 176-183.

Harrison, J. L. (1955). The age of a monitor lizard. *Malayan Nature Journal* 9: 126 -128.

Henry, G. M. (1912). Notes on the food of the jackal ("*Canis aureus*") and that of the talagoya ("*Varanus bengalensis*"). *Spolia Zeylanica* 8: 70.

Koch, A., M. Auliya, A. Schmitz, U. Kuch & W. Böhme. 2007. Morphological studies on the systematics of south east Asian water monitors (*Varanus salvator* Complex): nominotypic populations and taxonomic overview. In Horn, H.-G., W. Böhme and U. Krebs (eds.). Advances in Monitor Research III. Mertensiella 16. Pp. 109 – 189. Rheinbach.

Koch A, & Böhme W. (2010). Heading east: a new subspecies of *Varanus salvator* from Obi Island, Maluku Province, Indonesia, with a discussion about the easternmost natural occurrence of Southeast Asian water monitor lizards. *Russian Journal of Herpetology* 17: 299–309.

Koch A, & Arida E. (2017). A coconut-eating monitor lizard? On an unusual case of frugivory in the melanistic Sulawesi water monitor (*Varanus togianus*). *The Herpetological Bulletin* 139: 41-42.

Konopik, O., Steffan-Dewenter, I. & Grafe, T. U. (2015). Effects of logging and oil palm expansion on stream frog communities on Borneo, south-east Asia. *Biotropica* 47: 636–643.

Losos, J.B. & Greene, H.W. (1988). Ecological and evolutionary implications of diet in monitor lizards. *Biological Journal of the Linnean Society* 35: 379-407.

Moleón M., Sánchez-Zapata J. A., Selva N., Donázar J. A. & Owen-Smith N. (2014). Inter-specific interactions linking predation and scavenging in terrestrial vertebrate assemblages. *Biological Reviews* 89: 1042–1054.

Rao, M.V.S. & K.K. Rao. (1984). Feeding ecology of the Indian common monitor, *Varanus monitor*. Pp. 197-204. In: Marcellini, D. (Ed.), *6th Annual Reptile Symposium on Captive Propagation and Husbandry*. Reptile Symposium on Captive Propagation and Husbandry Zoological Consortium Inc., Thurmond, Maryland.

Smith, M. A. (1932). Sonic notes on the monitors. *Journal of the Bombay Natural History Society* 35: 615-619.

Somaweera, R. & Somaweera, N. 2009. *Lizards of Sri Lanka: A Colour Guide with Field Keys*. Edition Chimaira, Frankfurt am Main, Germany. Pp. 304.

Twining, J.P, Bernard, H., Ewers R.M. 2017. Increasing land-use intensity reverses the relative occupancy of two quadrupedal scavengers. *PLOS ONE*. DOI: 10.1371/journal.pone.0177143

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: 9-17.

Uyeda L.T., Iskandar E., Kyes R.C. & Wirsing A.J. (2015). Encounter rates, agnostic interactions and social hierarchy among garbage-feeding Water monitor lizards (*Varanus salvator bivittatus*) on Tinjil Island, Indonesia. *Herpetological Conservation and Biology* 10: 753–764.

Wilkinson, C. (2013). Composition and abundance of freshwater fish communities across a land use gradient in Sabah, Borneo. A Thesis submitted as fulfilment of Masters of Science. Imperial College London.

Wilson E. E., and Wolkovich E. M. (2011). Scavenging: how carnivores and carrion structure communities. *Trends in Ecology & Evolution* 26:129–135.

Wearn, O.R., Rowcliffe, M.J., Carbone, C., Pfieifer, M., Bernard H. & Ewers R.M. (2017). Mammalian species abundance across a gradient of tropical land-use intensity: A hierarchical multi-species modelling approach. *Biological Conservation* 212: 162-171.

Accepted: 10 January 2018