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New predation records of monitor lizards (genus *Varanus*) on scolopendrid centipedes and a house gecko, with a review of bark centipedes (Scolopendromorpha) in the diet of varanid lizards

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Monitor lizards are monotypic reptiles belonging to the family Varanidae, currently comprising 88 species (Uetz et al., 2024). They are carnivorous and generally large-bodied lizards that feed through scavenging and opportunistic predation of both invertebrate and vertebrate prey. Their diet consists of different invertebrates (e.g., annelids, insects, crustaceans) and vertebrates (mammals, fish, reptiles, amphibians, birds), including even cannibalism (Overton, 1987; Bennett, 1998; Losos and Greene, 1988; Pianka et al., 2004; Zdunek, 2023; Zdunek et al., 2024a, b). There is also a presence of centipedes (Arthropoda: Chilopoda) in their diets, though records of it are scarce.

Centipedes are one of the four major classes of myriapods, comprising over 3300 species (Bonato et al., 2016). Their body length falls within the range of 10–300 mm (Edgecombe and Giribet, 2007), with the largest extant centipedes belonging to one of five families of tropical or bark centipedes (order Scolopendromorpha; Edgecombe and Bonato, 2011; Bonato et al., 2016). These predatory invertebrates can be found on all continents, except Antarctica, with the greatest diversity harboured in the tropical and warm temperate regions (Edgecombe and Giribet, 2007). Bark centipedes are nocturnal, they dwell in various environments, ranging from xeric to mesic environments, in decaying wood, and matted vegetation, and a few species in the tropics are arboreal (Auffenberg, 1994; Lewis, 2006; Voigtländer, 2011). They are dietary generalists that actively hunt prey of various sizes but can also feed on carrion (Lewis et al., 2010; Chitty, 2011). Under specific conditions, they may supplement themselves with plant material (Lewis, 2006) and opportunistically scavenge anthropogenic sources of food (Manton and Harding, 1964; Doody et al., 2015a).

All centipedes are equipped with forcipules, modified front legs that serve as pincers, with which they inject their venom into their prey (Dugon and Arthur, 2012). Bark centipedes possess strong, biochemically diverse neurotoxic venoms with which they paralyze their prey (Stankiewicz et al., 1999; Dugon and Arthur, 2012; Yang et al., 2012), but the venoms also contain other properties (e.g., myotoxic and haemolytic toxins; Malta et al., 2008; Undheim and King, 2011). External digestion is also possible, given that their venom contains proteolytic enzymes (Undheim and King, 2011).

We here present five observations of direct predation on centipedes by monitor lizards. Two observations involve feeding by the Southeast Asian Water Monitor, *Varanus salvator macromaculatus* Deraniyagala, 1944 on members of the genus *Scolopendra* in Malaysia and Singapore, while the third is of a Clouded Monitor, *Varanus nebulosus* (Gray, 1831), feeding on *Cormocephalus dentipes* in Singapore. The fourth is of a Bengal Monitor, *Varanus bengalensis* (Daudin, 1802),

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feeding on *Scolopendra hardwickei* in Sri Lanka, while the last is of *Varanus albigularis microstictus* Boettger, 1893 devouring *Ethmostigmus trigonopodus* in Kenya. Additionally, a review on bark centipedes (Scolopendromorpha) in the diet of monitor lizards based on the literature is presented.

(1) *Varanus salvator macromaculatus* on Mantanani Island. *Varanus s. macromaculatus* is a semi-aquatic, mostly diurnal lizard and one of the most widely distributed varanids in Southeast Asia (Bennett, 1998; Pianka et al., 2004; Auliya and Koch, 2020). This species averages approximately 200 cm in total length and is globally the second-largest lizard species (Cota et al., 2009; Auliya and Koch, 2020). Previously, only one case of a centipede in the stomach contents of *V. salvator* has been reported, without providing the exact location or details to determine the lizard's subspecies, age, size, and even the size of the prey consumed (Losos and Greene, 1988).

On 5 January 2023 at 14:14 h on the beach of the northernmost bay on the western side of Mantanani Island in Malaysia (6.7148°N, 116.3442°E; elevation near sea level), a juvenile *V. s. macromaculatus* of approximately 25–35 cm total length was observed foraging on a Beach Sheoak (*Casuarina equisetifolia*). The weather conditions at the time were clear and there was almost no wind (approx. 26°C). Shortly thereafter, the same monitor fell from the tree as it wrestled with a bark centipede (genus *Scolopendra*, not identified to species; Zdunek Herp, 2024). We were able to photograph and record most of the interaction between the two animals.

The lizard deliberately tried to bite and control the centipede's head in an attempt to restrain and kill it. It seemed to instinctively know that the most dangerous region of the centipede was the head (Fig. 1A). While the centipede attempted several times to escape from the lizard, it was always recaptured after a few seconds. It was evident that the lizard was bitten by the centipede during the initial part of the encounter when the lizard clamped on the posterior region of the centipede, which left enough body flexibility for a counterattack. The centipede's head became increasingly injured from the monitor's bite attempts and started to detach from the body.

Figure 1. (A) A juvenile *Varanus salvator macromaculatus* attacks precisely the head of a bark centipede (genus *Scolopendra*) and thereby avoids being bitten by the forcipules. (B) Violent shaking of the prey prevents its escape. (C) The decapitated body of the centipede is almost the same length as the lizard's snout–vent length, which demonstrates the impressive size of the prey. (D) After over 30 min of interaction, the centipede was swallowed entirely. Photos by Frederik C. De Wint.

This was a lengthy process, however, the centipede continued to struggle. It attempted several tactics to free itself from the lizard's mouth, including flailing about, pulling away, and crawling along the lizard's body (Fig. 1B). After several minutes of intense struggle, the lizard decapitated the centipede and swallowed the head. While the centipede's headless body held itself upright, it was no longer trying to escape (Fig. 1C).

Subsequently, the lizard bit the anterior region of the decapitated body, causing the centipede's body to jerk backward. The monitor did not try to tear off pieces of the centipede's body, but it instead attempted to fit as much of it as possible in its mouth. The victim's body jerked in the opposite direction, with legs still well-coordinated. It was interesting to note how much strength and coordination remained in the centipede after its head had been removed. A few minutes later, the lizard managed to swallow the centipede's body entirely. This observation ended when the last segment of the centipede was in the mouth, with only the posterior legs still hanging out (Fig. 1D). The entire event lasted a total of 33 min from the time the combatants fell from the tree until the complete consumption of the centipede. This centipede can be assigned to either *S. subspinipes* or *S. dehanii* based on the available evidence. Nonetheless, we refrain from identifying it to a species level, given that this group of scolopendrids requires careful morphological analyses and that the area where this predation occurred is not well studied in terms of *Scolopendra* occurrences (Siriwut et al., 2016). The predation on the gecko presented below, as a side observation, confirms the ability of even juvenile varanids to swallow large amounts of food (Bennett, 1998; Pianka et al. 2004).

Prior to catching the *Scolopendra*, the same monitor was hunting a Common House Gecko (*Hemidactylus frenatus* Duméril & Bibron, 1836) in the branches of the tree from which it fell. It was observed on a branch 2 m above the ground. The monitor caught the gecko at midbody (Fig. 2A), only to swallow it whole a moment later, starting with the head (Fig. 2B). It is unknown if the gecko was already injured at that time (autotomized tail), or whether the monitor had encountered the individual prior to our observation.

(2) *Varanus salvator macromaculatus* in Singapore. On 13 October 2022 at 13:47 h in the Sungei Buloh Wetland Reserve in Singapore (1.4469°N, 103.7268°E; elevation 17 m), a subadult *V. s. macromaculatus* of approximately 65–75 cm total length, was observed with an adult *Scolopendra subspinipes* (ca. 15 cm total length) trying to free itself from the lizard's mouth. It was hot and humid, approximately 25–30°C. The monitor held the prey around its neck (Fig. 3A), shaking it violently and subsequently swallowing it whole within a few seconds (Fig. 3B). Following the predation, the monitor fled rapidly into the bushes.

(3) *Varanus nebulosus* in Singapore. *Varanus nebulosus* is a semi-arboreal species widely distributed throughout South and Southeast Asia (Bennett, 1998; Auliya and Koch, 2020). In the Singapore Botanic Gardens, the population of this species was first documented in 2013 and found to be dependent on the size of the environment and the number of potential refugia (Thomas, 2013; Zdunek and Chew, 2023). This monitor species is well adapted to living in a variety of terrestrial habitats, tending to avoid aquatic habitats and preferring an arboreal lifestyle, often actively foraging in the leaf litter (Eidenmüller, 2021).

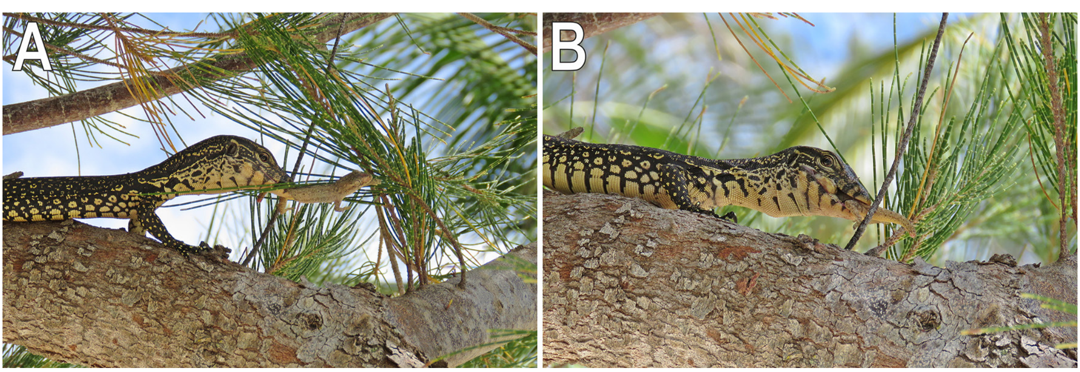

Figure 2. (A) A foraging juvenile *Varanus salvator macromaculatus* captures an adult *Hemidactylus frenatus*, identified by characteristic spines on its tail. (B) After capturing the prey, the monitor swallowed the gecko whole, starting with the head. Photos by Frederik C. De Wint.

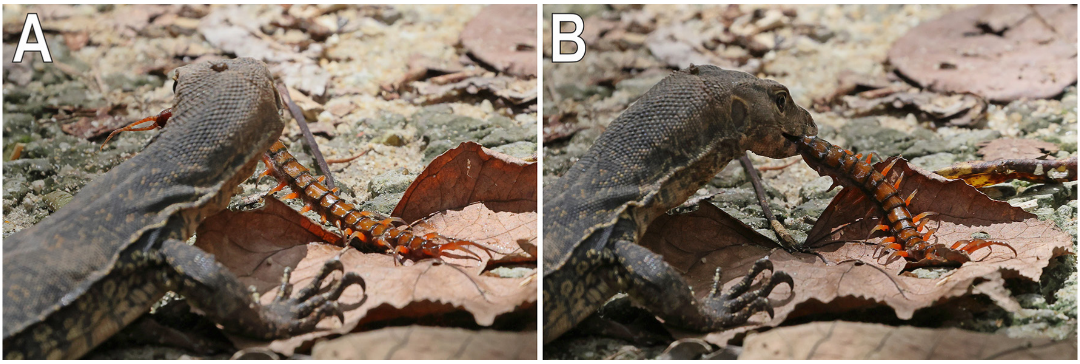

Figure 3. A subadult *Varanus salvator macromaculatus* holds firmly and precisely an adult *Scolopendra subspinipes* by its head region (A), violently shakes it until the prey appears to be dead, then swallows it completely beginning with the head (B). Photos by Ria Vogels.

So far, only a single observation of centipedes in the diet of this varanid species was published by Harrison (1955), who documented an unidentified species of *Scolopendra* among the stomach contents of an adult *V. nebulosus* in Malaysia (Lake Gardens area of Kuala Lumpur).

On 10 August 2023 at 14:13 h at Lakeside Garden in Singapore (1.3403°N, 103.7249°E; elevation 19 m), an adult *V. nebulosus* of approximately 100 cm total length, was observed foraging in leaf litter. Weather conditions at the time of observation were a partially cloudy sky with intense sunlight (approx. 28°C). After taking a series of photos, we were able to document the predation (Fig. 4).

Figure 4. An adult *Varanus nebulosus* swallows whole an adult *Cormocephalus dentipes*. Photo by Jkai Chan.

The monitor swallowed the *Cormocephalus dentipes* whole (approximately 4–5 cm), and subsequently continued foraging.

(4) *Varanus bengalensis* in Sri Lanka. *Varanus bengalensis* is a diurnal lizard, well adapted to living in various terrestrial habitats and usually avoids aquatic habitats, preferring an arboreal lifestyle (Auffenberg, 1984). Growing up to 175 cm in total length, this lizard has a diet not dissimilar to its conspecifics, richly documented to contain scolopendrid centipedes (Auffenberg and Ipe, 1983; Auffenberg, 1994; Karunarathna et al., 2017; Auliya and Koch, 2020). This is the second documented direct predation on *Scolopendra hardwickei*.

On 12 August 2024 at 17:05 h at Wilpattu National Park in Sri Lanka (8.3078°N, 80.1480°E; elevation 83 m) an adult *V. bengalensis*, approximately 100 cm in total length, was observed with a *S. hardwickei* already in its mouth, holding the prey at midbody (Fig. 5A). The centipede was about 10–12 cm in body length. The weather at the time of the observation was cool due to passing rainfall during the day, with little wind, and a late afternoon without sunshine. *Scolopendra hardwickei* unsuccessfully tried to defend itself, grabbing the predator's snout with its limbs. The centipede was later swallowed whole, starting with the head (Fig. 5B). The process lasted about 30 s. The incident occurred on the side of the road, where there was grass and forbs vegetation.

(5) *Varanus albigularis microstictus* in Kenya. *Varanus albigularis microstictus* is a large, mostly diurnal, mainly terrestrial lizard (Bennett, 1998; Spawls et al., 2018). The range of *V. a. microstictus* extends

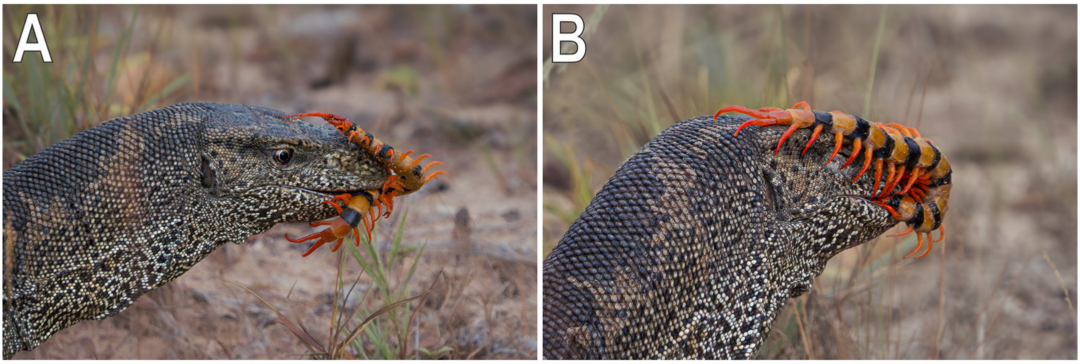

Figure 5. An adult *Varanus bengalensis* and a captured *Scolopendra hardwickei*. (A) The centipede is caught at midbody, which reduces its mobility. (B) The centipede tries to defend itself by firmly grasping onto the monitor's head but fails and is eaten soon after. Photos by Rajeev Abeysekara.

throughout much of eastern Africa, including Ethiopia, Somalia, Kenya, Tanzania, and Djibouti (Auliya and Koch, 2020; Eidenmüller, 2021). This varanid feeds on a wide variety of animal prey, including small mammals, birds, snakes, other lizards, eggs, frogs, toads, tortoises, snails, invertebrates, and even carrion (Bennett, 1998; Pianka et al., 2004; Cunningham and Cunningham, 2010; Conradie, 2012; Dalhuijsen et al., 2014; Branch et al., 2015; Spawls et al., 2018). To the best of our knowledge, direct observation of predation on centipedes in Kenya has not yet been documented for this species.

On 17 May 2010 at 15:36 h at Watamu in Kenya (3.3779°N, 39.9880°E; elevation 13 m), a subadult *V. a. microstictus*, approximately 60–70 cm in total length, was observed with a large centipede in its mouth. The incident occurred in a surrounding of shrubs/bushes near several occupied buildings with intensive human activity in the area. The weather was sunny. The lizard was found with an adult specimen of *E. trigonopodus* grabbed in the middle of its body. While being attacked by the monitor, the centipede initially tried to defend itself by biting its predator (Fig. 6A), but could not reach it with its forcipules. It was also unable to grasp onto the body of the lizard, as it was held by its midsection, which reduced its mobility (Fig. 6B). After a short while the monitor started swallowing the centipede, folding it in the middle in the shape of a 'C' (Fig. 6C), to later engulf it fully, while the prey was still alive (Fig. 6D).

Large bark centipedes can be regarded as dangerous prey due to their venomous forcipules. They are known to inflict precise bites on the head region of their prey, which enables the neurotoxic venom to work more swiftly (Bücherl, 1946; Shugg, 1961; Guizze et al., 2016). When hunting, bark centipedes will often utilize eight or more pairs of their front legs to grasp onto their prey, making them hard to dislodge (Molinari et al., 2005; Chiacchio et al., 2017). They can be so fierce and voracious, that they can still damage and even kill a predator after having themselves been ingested, both from mechanical and chemical injuries (Arsovski et al., 2014). All of these characteristics combined make bark centipedes potential threats to any similar-sized animal, including reptiles. There is ample documentation of bark centipedes preying on mammals (Shugg, 1961; Cloudsley-Thompson, 1968; Clark, 1979; Srbek-Araujo et al., 2012; Lindley et al., 2017), birds (Cumming, 1903; Menezes and Marini, 2017), amphibians (Carpenter and Gillingham, 1984; Folly et al., 2019; Pomeroy et al., 2021), and reptiles (Butler, 1970; Moura et al., 2015; van Buurt and Dilrosun, 2017; Koleska et al., 2023; for a review of snakes in this regard, see Pwa et al., 2023). However, in the available literature there have been no documented cases of centipedes feeding on monitor lizards. A possible explanation could be that many varanids are generally resistant to various types of toxins (Pettit et al., 2021; Chandrasekara et al., 2024), although this was not yet confirmed for scolopendrid venom.

Nonetheless, varanids have been documented to prey on other venomous and toxic animals, including scorpions (Pianka, 1994; Bennett, 1998), toads (Doody et al., 2015b; Pettit et al., 2021; Zdunek and Webb, 2023), and snakes (Shine, 1986; Dobson et al., 2024). Some animals possess specialised venoms, which target rather specific prey groups and may not affect different taxa in the same way.

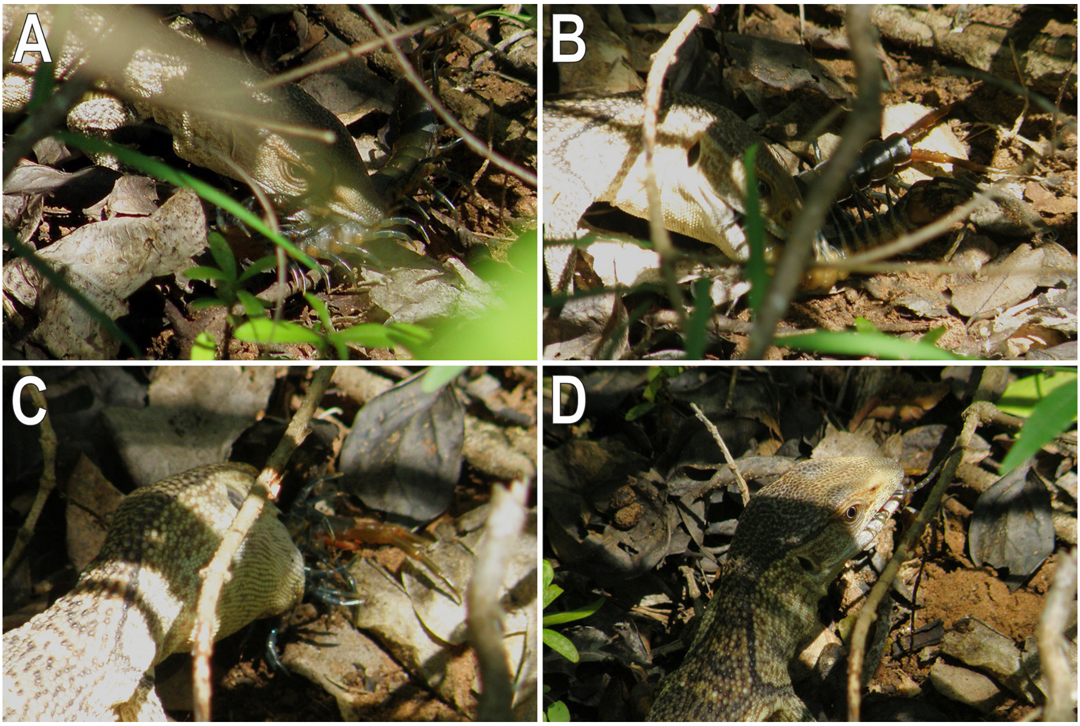

Figure 6. A subadult of *Varanus albigularis microstictus* capturing an *Ethmostigmus trigonopodus*. (A) The lizard catches the centipede at its midbody region. (B) The prey tries to bite its predator but fails and whirls around. (C) The monitor folds the centipede in half to be able to swallow it fully. (D) Soon after that, the lizard is seen with parts of the consumed centipede (i.e., antenna and legs) extending from its mouth. Photos by Ted Nanninga.

For example, the Transvaal Thicktail Scorpion, *Parabuthus transvaalicus*, kills mammalian prey with its venom, however, experimental venom injections into Green Anoles, *Anolis carolinensis* (Voigt, 1832), resulted only in inducing lethargy in the lizard (Inceoglu et al., 2001). It is also proven for scolopendrids that their venom is more specialised for killing invertebrates (Voigtländer, 2011). Nonetheless, it needs to be stated that monitor lizards are not completely immune to all kinds of toxins and venoms, as some observations have suggested (e.g., Pettit et al., 2020; Doody et al., 2015a; Harvey et al., 2022; Gilbert and Ping, 2023). Predation on such dangerous prey as scolopendrids could perhaps be beneficial for varanids. In addition to being an additional energy intake (especially with larger individuals; Fig. 1C), such dietary items could have positive effects on the predator. Recently, it has been shown that higher consumption of *Scolopendra* centipedes by juvenile Chinese Crocodile Lizards, *Shinisaurus crocodilurus* Ahl, 1930, promotes growth and maintenance of their gut microbiome homeostasis (Xie et al., 2024). Thus, predation on scolopendrids could also be potentially beneficial for monitor lizards in this or related matters, although further studies are required to be able to determine that conclusively. To the best of our knowledge, the records we have documented here are new to the issue of the interactions of these predators. Observations such as these, even as single events, can broaden the scope of information about the natural history and ecology of monitor lizards and their diet of chilopods. By summarizing records from literature with inclusion of our new observations (Table 1), we hope to facilitate future research on chilopods in the diet of monitor lizards.

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Table 1. Published records of bark centipedes in the diet of monitor lizards (genus *Varanus)*. Age is given for adults (A), subadults (S), and juveniles (J).

Monitor Taxon	Age	Centipede Taxon	Type of Observation	Location	Reference
albigularis microstictus	S	*Ethmostigmus trigonopodus*	Direct observation	Kenya	This study
bengalensis	-	*Cormocephalus pygmaeus*	Stomach contents, faeces	Sri Lanka	Auffenberg, 1994
bengalensis	-	*Otostigmus cavalcanti*[1]	Stomach contents, faeces	Sri Lanka	Auffenberg, 1994
bengalensis	A	*Rhysida* sp.	Direct observation	Sri Lanka	Karunarathna et al., 2017
bengalensis	-	*Rhysida longipes*	Stomach contents, faeces	Sri Lanka	Auffenberg, 1994
bengalensis	J	*Scolopendra* sp.	Stomach contents	India	Auffenberg and Ipe, 1983
bengalensis	A	*Scolopendra hardwickei*	Direct observation	Sri Lanka	Karunarathna et al., 2017; this study
bengalensis	-	*Scolopendra morsitans*[2]	Stomach contents, faeces	Sri Lanka	Auffenberg, 1994
bengalensis	-	*Scolopendra morsitans*	Stomach contents, faeces	Sri Lanka	Auffenberg, 1994
bengalensis	-	*Scolopendra subspinipes*[3]	Stomach contents, faeces	Sri Lanka	Auffenberg, 1994
brevicauda	-	Unidentified	Stomach contents	Australia	Pianka, 1994
caudolineatus	-	Unidentified	Stomach contents	Australia	Pianka, 1969
cerambonensis	J	Unidentified	Stomach contents	Indonesia	Philipp et al., 2007
caudolineatus	-	Unidentified	Stomach contents	Australia	Pianka, 1969
exanthematicus	J	Unidentified	Stomach contents, faeces	Senegal, Ghana	Losos and Greene, 1988; Bennett and Thakoordyal, 2003
eremius	-	Unidentified	Stomach contents	Australia	Pianka, 1982; 1994
giganteus	-	Unidentified	Stomach contents	Australia	Losos and Greene, 1988
glebopalma	-	Unidentified	Stomach contents	Australia	Losos and Greene, 1988
gouldii	-	Unidentified	Stomach contents	Australia	Pianka, 1982; 1994; Shine, 1986; Losos and Greene, 1988
griseus griseus	-	Unidentified	-	Africa	Bennett, 1998
indicus	A	Unidentified	Stomach contents	United States	Vogt, 2010
indicus complex		Unidentified	Stomach contents	New Guinea, Pacific Islands	Losos and Greene, 1988
nebulosus	-	*Scolopendra* sp.	Stomach contents	Malaysia	Harrison, 1955
nebulosus	A	*Cormocephalus dentipes*	Direct observation	Singapore	This study
mitchelli	-	Unidentified	Stomach contents	Australia	Shine, 1986
panoptes	-	Unidentified	Stomach contents	Australia	Shine, 1986
prasinus complex	A	Unidentified	Stomach contents	-	Greene, 1986
primordius	-	Unidentified	-	-	Pianka et al., 2004
rosenbergi	-	Unidentified	Stomach contents	Australia	King and Green, 1979
rudicolis	-	Unidentified	Stomach contents	Malaysia	Losos and Greene, 1988
salvadorii	-	Unidentified	Stomach contents	New Guinea	Losos and Greene, 1988
salvator	-	Unidentified	Stomach contents	Asia	Losos and Greene, 1988
salvator macromaculatus	J	*Scolopendra* sp.	Direct observation	Malaysia	This study
salvator macromaculatus	S	*Scolopendra subspinipes*	Direct observation	Singapore	This study
s. salvator	-	Unidentified	-	Sri Lanka	Deraniyagala, 1953
storri	-	Unidentified	Stomach contents	Australia	Losos and Greene, 1988
tristis	-	Unidentified	Stomach contents	Australia	Losos and Greene, 1988

[1] as *Otostigmus insularis*
[2] as *Scolopendra amazonica*
[3] as *Scolopendra subspinatus*. We believe that this was a typo in the text, because to the best of our knowledge, no *Scolopendra* taxon had ever been described with the specific name of "*subspinatus*"

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