

Gastrointestinal helminths of nine species of *Cnemaspis* (Squamata: Gekkonidae) from Peninsular Malaysia, one species from Cambodia and Thailand and two species from Vietnam

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A total of 12 species of *Cnemaspis* (N = 104) from Southeast Asia were examined for gastrointestinal helminths. Samples consisted of nine species (n = 86) from Peninsular Malaysia: *Cnemaspis affinis* (n = 4); *Cnemaspis baueri* (n = 17); *Cnemaspis biocellata* (n = 12); *Cnemaspis grimeri* (n = 8); *Cnemaspis kumpoli* (n = 11); *Cnemaspis limi* (n = 9); *Cnemaspis monachorum* (n = 7); *Cnemaspis pemanggilensis* (n = 10); *Cnemaspis peninsularis* (n = 8); one species (n = 5) from Cambodia and Thailand, *Cnemaspis chanthaburiensis* (n = 5); and two species (n = 13) from Vietnam: *Cnemaspis nuicamensis* (n = 6) and *Cnemaspis tuidupensis* (n = 7). The aggregate helminth community consisted of one species of Cestoda, *Cylindrotaenia malayi* and nine species of Nematoda: *Bakeria schadi*, *Meteterakis singaporensis*, *Parapharyngodon maplestoni*, *Maxvachonia* sp., *Physalopteroides* sp., *Physalopteridae* gen. sp., *Reticulariidae* gen. sp., *Seuratoidea* gen. sp., *Ascaridoidea* gen. sp. *Meteterakis singaporensis* had the largest number of individuals (457) and greatest prevalence (24%). Twenty-eight new host records are reported.

Keywords: Gastrointestinal helminths; geckos; *Cnemaspis*; Gekkonidae; Cambodia; Thailand; Peninsular Malaysia; Vietnam

Introduction

There are currently 50 species of *Cnemaspis*, rock geckos (*sensu* Grismer et al. 2014), known from Southeast Asia, with disjunct distributions extending from southern Vietnam, Laos, southwestern Cambodia and Thailand southward through the Malay Peninsula (Grismer et al. 2014). In this paper, we examined the following species of *Cnemaspis* for helminths: *Cnemaspis affinis* (Stoliczka, 1870) is known only from Peninsular Malaysia, Pulau Pinang Penang (Grismer, Grismer, et al. 2008). *Cnemaspis baueri* Das and Grismer, 2003 is known only from Peninsular Malaysia: Pulau Aur, Johor (Das and Grismer 2003) and the rocky island of Dayang (Grismer et al. 2006b). *Cnemaspis biocellata* Grismer, Chan, et al. 2008 is known only from Peninsular Malaysia where it extends at least 40 km through the karst system of the Banjaran Nakawan from Thale Ban National Park, Satun (Grismer et al. 2014) southward through Wang Kelian and Perlis State Park (Grismer, Chan,

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et al. 2008). *Cnemaspis grimeri* Wood, et al. 2013 is known only from Peninsular Malaysia, Gua Asar, Bukit Kepala Gajah limestone massif, Lenggong, Perak, Malaysia (Wood et al. 2013). *Cnemaspis kumpoli* Taylor, 1963 ranges from southern Thailand south to the Isthmus of Kra (Taylor 1963) to extreme northern Malaysia (Chan and Grismer 2008). *Cnemaspis limi* Das and Grismer, 2003 is known only from Peninsular Malaysia: Pulau Tioman and Pulau Tioman of the Seribu Archipelago (Grismer et al. 2014). *Cnemaspis monachorum* Grismer et al. 2009 is known only from the karst formations Pulau Langkawi and Pulau Langgong, Kedah, Peninsular Malaysia (Grismer et al. 2014). *Cnemaspis peninsularis* Grismer et al. 2014 ranges from central Peninsular Malaysia to Singapore (Grismer et al. 2014). *Cnemaspis pemanggilensis* Grismer and Das, 2006 is known only from Peninsular Malaysia, Pulau Pemanggil, Johor (Grismer et al. 2014). Also studied was one species *Cnemaspis chanthaburiensis* Bauer and Das, 1988 from southeast Thailand (Chantuburi Chon Buri), and Cambodia (NW Cardamon Mts) (Grismer et al. 2014) and two species from Vietnam, *Cnemaspis nuicamensis* Grismer and Van Tri, 2007 known from the type locality Nui Cam Hill, Tinh Bien District, An Giang Province, Vietnam (Grismer and Van Tri 2007) and *Cnemaspis tuidupensis* Grismer and Van Tri, 2007 also known from the type locality Tuc Dup Hill, Tri Ton District, An Giang Province, Vietnam (Grismer and Van Tri 2007). In this paper, we list helminths of nine species of *Cnemaspis* from Peninsular Malaysia, one species from Cambodia and Thailand and two from Vietnam as part of an ongoing survey of amphibians and reptiles from Peninsular Malaysia. We establish the initial helminth list for all species of *Cnemaspis* examined in this paper.

Materials and methods

We examined the following samples of *Cnemaspis* for helminths (N = 104): *Cnemaspis affinis* (n = 4) mean snout–vent length, SVL = 45.8 mm ± 2.1 standard deviation (SD), range = 43–48 mm; *Cnemaspis baueri* (n = 17) mean SVL = 63.0 mm ± 2.6 SD, range = 57–68 mm; *Cnemaspis biocellata* (n = 12) mean SVL = 36.1 mm ± 1.8 SD, range = 33–39 mm; *Cnemaspis chanthaburiensis* (n = 5) mean SVL = 37.6 mm ± 1.3 SD, range = 35–42 mm; *Cnemaspis grimeri* (n = 8) mean SVL = 47.0 mm ± 2.1 SD, range = 44–50 mm; *Cnemaspis kumpoli* (n = 11) mean SVL = 51.9 mm ± 10.8 SD, range = 28–61 mm; *Cnemaspis limi* (n = 9) mean SVL = 76.7 mm ± 6.1 SD, range = 64–86 mm; *Cnemaspis monachorum* (n = 7) mean SVL = 32.2 mm ± 1.8 SD, range = 29–34 mm; *Cnemaspis nuicamensis* (n = 6) mean SVL = 46.2 mm ± 3.0 SD, range = 41–48 mm; *Cnemaspis pemanggilensis* (n = 10) mean SVL = 66.4 mm ± 10.2 SD, range = 39–73 mm; *Cnemaspis peninsularis* (n = 8) mean SVL = 54.3 mm ± 3.0 SD, range = 49–58 mm; and *Cnemaspis tuidupensis* (n = 7) mean SVL = 46.2 mm ± 2.5 SD, range = 41–49 mm. Hosts were deposited in the herpetology collection of LaSierra University (LSUHC), Riverside, California, USA (Appendix 1).

The body cavity was opened with a longitudinal incision and the gastrointestinal tract was removed by cutting across the oesophagus and rectum. The oesophagus, stomach, small intestine and body cavity were examined separately for helminths. Nematodes were cleared in lactophenol; cestodes were stained in haematoxylin and mounted in Canada balsam. All were examined under a compound microscope and identified. Helminths were deposited in the Harold W. Manter Laboratory (HWML),

University of Nebraska, Lincoln, USA (Appendix 2). Parasite terminology is in accordance with Bush et al. (1997).

Results

Lizard sample size, helminth number, prevalence, mean intensity of infection \pm SD and range are presented in Table 1. Twenty-eight new host records are reported.

Discussion

Cestoda

Nematotaeniidae

Cylindrotaenia malayi was originally described from the frog *Polypedates leucomystax* (Rhacophoridae) collected in Penang, Malaysia (Jones 1987). *Cnemaspis tuidupensis* represents the second host reported for *Cylindrotaenia malayi* and is a new host record.

Nematoda

Molineidae

Bakeria schadi was recently described from *Cnemaspis mcguirei* from Peninsular Malaysia (Burse et al. 2014). *Bakeria schadi* in *C. affinis*, *C. biocellata*, *C. grimeri*, *C. limi*, *C. monarchum* and *C. pemanggilensis* are new host records.

Heterakidae

Meteterakis singaporensis was described from *Duttaphrynus* (as *Bufo*) *melanostictus* from Singapore by Inglis (1958), and was also found in *C. mcguirei* from Peninsular Malaysia by Bursey et al. (2014). Congeners of *Meteterakis* are mainly restricted to Southeast Asia and the Philippines (Baker 1987) and also occur in Papua New Guinea (Goldberg et al. 2010). *Meteterakis singaporensis* had the largest number of individuals (457) and greatest prevalence (24%). *Meteterakis singaporensis* in *C. affinis*, *C. baueri*, *C. biocellata*, *C. grimeri*, *C. kumpoli*, *C. nuicamensis* and *C. pemanggilensis* are new host records.

Pharyngodonidae

Parapharyngodon maplestoni, described by Chatterji (1933) from the lizard *Calotes versicolor* (Agamidae) from Burma (currently Myanmar), has a wide distribution pattern including Thailand of Southeast Asia (Goldberg and Bursey 2001). Members of the Pharyngodonidae, such as *P. maplestoni*, have direct (monoxenous) life cycles and infection most likely occurs when contaminated substrate is ingested as lizards forage for food; a colonising *P. maplestoni* needs only to find suitable habitat occupied by other lizards. This lack of dependence on an intermediate host is likely to increase the efficiency of *P. maplestoni* in infecting additional lizards, probably contributes to the broad distribution of this species and may be partly responsible for its success in establishing in two species of geckos, *Nactus multicaudatus* and *N. pelagicus*, on various islands in Vanuatu, Oceania (Goldberg et al. 2011). *Parapharyngodon maplestoni* in *C. baueri* and *C. pemanggilensis* are new host records.

Cosmocercidae

Species of *Maxvachonia* are known to occur in the digestive tracts of amphibians and reptiles from Australia, Madagascar and New Guinea (Baker 1987). *Maxvachonia* sp. in *C. chanthaburiensis* is a new host record.

Table 1. Number of helminths (N), prevalence (P, as percentage) mean intensity (MI) \pm 1 standard deviation (SD) and range (R) for 12 species of *Cnemaspis*. All are new host records.

	<i>C. affinis</i> (N = 4)	<i>C. baueri</i> (N = 17)	<i>C. biocellata</i> (N = 12)	<i>C. chanthaburiensis</i> (N = 5)
<i>Cnemaspis</i> spp.	N P MI \pm SD (R)	N P MI \pm SD (R)	N P MI \pm SD (R)	N P MI \pm SD (R)
Cestoda				
<i>Cylindrotaenia malayi</i>	-	-	-	-
Nematoda				
<i>Bakeria schadi</i>	1 25 1 (-)	-	2 8 2 (-)	-
<i>Meteterakis singaporensis</i>	19 50 9.5 \pm 10.5 (-)	144 53 14.4 \pm 32.6 (1-107)	2 8 2 (-)	-
<i>Parapharyngodon maplestoni</i>	-	8 24 2.0 \pm 1.4 (1-4)	-	-
<i>Maxvachonia</i> sp. (female)	-	-	-	4 40 2.0 \pm 1.4 (1-3)
<i>Physalopteroides</i> sp. (female)	-	-	-	-
Ascaridoidea gen sp. (larvae)	-	2 12 1 (-)	-	-
Physalopteridae gen. sp. (larvae)	-	-	-	-
Riticulariidae gen sp. (larvae)	-	-	-	-
Seuratoidea gen sp. (larvae)	-	-	3 8 3 (-)	-
<i>Cnemaspis</i> spp.	<i>C. grismeri</i> (N = 8)	<i>C. kumpoli</i> (N = 11)	<i>C. limi</i> (N = 9)	<i>C. monachorum</i> (N = 7)
	N P MI \pm SD (R)	N P MI \pm SD (R)	N P MI \pm SD (R)	N P MI \pm SD (R)
Cestoda				
<i>Cylindrotaenia malayi</i>	-	-	-	-
Nematoda				
<i>Bakeria schadi</i>	14 50 3.5 \pm 2.7 (1-7)	-	8 33 2.7 \pm 2.9 (1-6)	14 57 3.5 \pm 3.8 (1-9)
<i>Meteterakis singaporensis</i>	210 100 26.2 \pm 24.9 (2-76)	11 36 2 (-)	-	-
<i>Parapharyngodon maplestoni</i>	-	-	-	-
<i>Maxvachonia</i> sp. (female)	-	-	-	-
<i>Physalopteroides</i> sp. (female)	-	-	-	-

(Continued)

Table 1. (Continued).

Ascaridoidea gen sp. (larvae)	–	–	–	4 11 4 (–)	–
Physalopteridae gen. sp. (larvae)	–	–	–	8 22 4.0 ± 1.5 (3–5)	–
Riticulariidae gen sp. (larvae)	1 13 1 (–)	–	–	–	–
Seuratoidea gen sp. (larvae)	13 63 2.6 ± 3.6 (1–9)	–	–	–	–
<i>Cnemaspis</i> spp.					
	<i>C. nuicamensis</i> (N = 6)	<i>C. pemanggilensis</i> (N = 10)	<i>C. peninsularis</i> (N = 8)	<i>C. tuadupensis</i> (N = 7)	
	N P MI ± SD (R)	N P MI ± SD (R)	N P MI ± SD (R)	N P MI ± SD (R)	
<i>Cylindrotaenia malayi</i>	–	–	–	–	1 14 1 (–)
Nematoda					
<i>Bakeria schadi</i>	–	–	–	–	–
<i>Meteterakis singaporensis</i>	1 17 1 (–)	3 20 1.5 ± 0.7 (1–2)	–	–	–
<i>Parapharyngodon maplestoni</i>	–	70 40 17.5 ± 19.9 (5–47)	–	–	–
<i>Maxvachonia</i> sp. (female)	–	11 40 2.8 ± 0.9 (2–4)	–	–	–
<i>Physalopteroides</i> sp. (female)	–	–	–	–	–
Ascaridoidea gen sp. (larvae)	9 17 9 (–)	–	–	2 23 2.7 ± 1.5 (2–5)	–
Physalopteridae gen. sp. (larvae)	1 17 1 (–)	7 20 3.0 ± 0.7 (3–4)	–	–	–
Riticulariidae gen sp. (larvae)	–	–	–	4 9 4 (–)	–
Seuratoidea gen sp. (larvae)	–	–	–	–	–
	–	–	–	–	#

Physalopteridae

Species of *Physalopteroides* are common in the Southern Hemisphere and are known from Africa, South America, Australia, South America and also Cuba (Baker 1987). *Physalopteroides* sp. in *C. peninsularis* is a new host record.

Physalopteridae gen. sp. include three subfamilies which occur in the stomachs of reptiles, birds and mammals, where they firmly attach to the gastric mucosa; only species in the Physalopterinae have been studied (Chabaud 1975). Encysted physalopterid larvae are common in the digestive tracts of reptiles (Jones 1995). As development to the adult does not occur, infected reptiles serve as paratenic (transport) hosts. Physalopteridae in *C. limi* and *C. nuicamensis* are new host records.

Cucullanidae

Seuratoidea gen. sp. are a disparate group of helminth genera, that are thought to connect the Cosmocercoidea to the advanced Ascaridida or Spirurida (Chabaud 1978). Le-Van-Hoa (1966) experimentally found the intermediate hosts of *Seuratum nguyenvanaii*, a parasite of the house shrew in Vietnam, were the cockroaches *Blatta orientalis* and *Periplaneta americana*. *Seuratoidea* gen. sp. in *C. biocellata* and *C. grimeri* are new host records.

Riticulariidae

The Riticulariidae is composed of a homogeneous group of about 50 species, divided into two genera and several subgenera (Quentin 1969a, 1969b; Chabaud 1975). They are heteroxenous and likely require an insect intermediate host (Anderson 2000). Riticulariidae gen. sp. in *C. grimeri* is a new host record.

Ascaridida

Ascarid larvae represent the diverse Order Ascaridida which contains monoxenous superfamilies (Cosmocercoidea, Heterakoidea), auto-infective species (Atractidae) and heteroxenous groups such as Ascaridoidea, Seuratoidea and Subuluroidea. Ascarid larvae in *C. baueri*, *C. limi*, *C. nuicamensis* and *C. pemanggiensis* are new host records.

A total of 577 helminths (one cestode, 576 nematodes) were collected from 73 (70.1%) of the 104 individuals examined. Of these, 525 were mature individuals representing six species; 52 were larvae representing four species. It should be noted that although 10 helminth species were in the sample, no host species harboured more than four species: two host species harboured four helminth species; four host species harboured three; two harboured two; four harboured one. On average, there were 2.33 ± 1.55 (range 1–4) helminth species per host species.

Hanski (1982) introduced the concept of core and satellite species – that is, core species occur with relatively high prevalence and abundance while satellite species occur less frequently and with less abundance. Roca (1993) defined core species as those with greater than 30% prevalence and satellite species as those with prevalences between 10 and 30%. In this study (Table 1), *M. singaporensis* (28%) represents a core species, while *B. schadi* (14%) represents a satellite species. The remaining seven species have prevalences of less than 10%. Roca (1993) suggested the prevalence of encysted larval nematodes in a lizard population may indicate the importance of the host in food webs because lizards can serve as transport (paratenic) hosts. In conclusion, it appears *Cnemaspis* from Southeast Asia are dominated by two species of generalist helminths, *B. schadi* and *M. singaporensis*. We should note that our conclusions are based upon our host sample; further surveys of these hosts will no doubt increase the number of harboured helminths and change prevalence values.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix 1. *Cnemaspis* specimens from Peninsular Malaysia and VietNam examined from the herpetology collection of LaSierra University (LSUHC), Riverside, California, USA.

Peninsular Malaysia

Cnemaspis affinis (n = 4) LSUHC 6758, 6759, 6788, 10347; West Malaysia, Pulau Penang (5°24'00"N, 100°13'59"E) Penang State, August 2004.

Cnemaspis baueri (n = 17) LSUHC 4700, 4701, 4717, 4718, 4720–4723, 4725, 4808, West Malaysia, Pulau Aur (4°12'37"N, 101°58'32"E) Johor State, July 2002; LSUHC 7272, 7273, 7285, 7301–7303, 7319; July 2005.

Cnemaspis biocellata (n = 12) LSUHC 8787, 8788, 8790–8792, 8802, 8804, 8805, 8817, West Malaysia, Gua Kelam (6°39'26"N, 100°12'19"E), Perlis State, March 2008; LSUHC 9682–9684, West Malaysia, Gua Kelam (6°39'26"N, 100°12'19"E), Perlis State, March 2010.

Cnemaspis chanthaburiensis (n = 5) LSUHC 9338, Cambodia, Phnom Tumpor (12°22'00"N, 103°03'00"E) Pursat Province, July 2009; LSUHC 9507, 9508, Thailand, Khao Khitchakut (12°48'17"N, 102°06'54"E), Chantaburi Province, October 2009; LSUHC 10110, 10111, Cambodia, O'Som (02°04'10"N, 103°09'5"E), Pursat Province, August, 2011.

Cnemaspis grismeri (n = 8) LSUHC 9969–9973, West Malaysia, Lenggong (5°07'34"N, 100.58'01"E) Perak State, May 2010; LSUHC 10941, 10943, 10944, West Malaysia, Lenggong, Gua Puteri (5°07'56"N, 100°58'80"E) Perak State, July 2012.

Cnemaspis kumpoli (n = 11) LSUHC 8846–8849 West Malaysia, Perlis State Park (6°41'51"N, 100°11'89"E) Perlis State, March, 2008; LSUHC 8990–8995, 9035; West Malaysia, Perlis State Park, June, 2008.

Cnemaspis limi (n = 9) LSUHC 4410, 4485, West Malaysia, Pulau Tioman (2°48'00"N, 104°11'00"E), Pahang State, March, 2002, LSUHC 4616, West Malaysia, Pulau Tioman (2°48'00"N, 104°11'00"E), Pahang State, July 2002; LSUHC 5424, 5510, 5515, 5521, West Malaysia, Pulau Tioman (2°49'0"N, 104°10'59"E), Pahang State, July 2003; LSUHC 6206, 6210, West Malaysia, Pulau Tioman (2.8167°N, 104.1833E), Pahang State, June 2004.

Cnemaspis monachorum (n = 7) LSUHC 9115–9118, West Malaysia, Pulau Langkawi (6°22'41"N, 99°47'24"E), Kedah State, October 2008; LSUHC 10807, 10809, 10811, West Malaysia, Pulau Tioman (2°49'0"N, 104°10'59"E), Kedah State, August, 2012.

Cnemaspis pemanggilensis (n = 10) LSUHC 4457, 4458, 4476, 4495, West Malaysia, Pulau Pemanggil (2°34'59"N, 104°19'59"E), Johor State, March 2002; LSUHC 8011–8016, August 2006.

Cnemaspis peninsularis (n = 8) LSUHC 9171–9173, 9176, 9178–9181 Borneo, Santubong (1°40'47"N, 110°20'17"E), Sarawak Province, February 2009.

VietNam

Cnemaspis nuicamensis (n = 6) LSUHC 8246, 9549–9551, 9552, 9554, VietNam, Nui Cam Mountains (10°35'30"N, 107°5'38"E) An Giang Province, Tien Bien District, December 2005.

Cnemaspis tuidupensis (n = 7) LSUHC 8248, 8249, 9558, 9560, 9561, 9562, 9563, VietNam, Tuc Dup Hill (10°30'0"N, 105°09'38"E), An Giang Province, Tri Ton District, December 2005.

Appendix 2. Harold W. Manter Laboratory (HWML) accession numbers for helminths from *Cnemaspis* specimens collected in Peninsular Malaysia, Cambodia, Thailand or Vietnam, taken from the herpetology collection of LaSierra University (LSUHC), Riverside, California, USA.

Cnemaspis affinis: *Bakeria schadi* (HWML 64662), *Meteterakis singaporensis* (HWML 64663);
Cnemaspis baueri: *Meteterakis singaporensis* (HWML 64664), *Parapharyngodon maplestonii* (HWML 64665), ascarid larva (HWML 64666);

Cnemaspis biocellata: *Bakeria schadi* (HWML 64667), *Meteterakis singaporensis*, (HWML 64668), Seuratoidea gen. sp. (HWML 64669);

Cnemaspis chanthaburiensis: *Maxvachonia* sp. (HWML 64670);

Cnemaspis grismeri: *Bakeria schadi* (HWML 64671), *Meteterakis singaporensis*, (HWML 64672), Seuratoidea gen. sp. (HWML 64673);

Cnemaspis kumpoli: *Meteterakis singaporensis* (HWML 64675);

Cnemaspis limi: *Bakeria schadi* (HWML 64677), Ascarididae gen. sp. (HWML 64678), Physalopteridae gen. sp. (HWML 64679);

Cnemaspis monachorum: *Bakeria schadi* (HWML 64680);

Cnemaspis nuicamensis: *Meteterakis singaporensis*, (HWML 64681), Ascarididae gen. sp. (HWML 64682), Physalopteridae gen. sp. (HWML 64683);

Cnemaspis pemanggilensis: *Bakeria schadi* (HWML 64684), *Meteterakis singaporensis* (HWML 64685), *Parapharyngodon maplestonii* (HWML 64686), Ascarididae gen. sp. (HWML 64687);

Cnemaspis peninsularis: *Physalopteroides* sp. (HWML 64674);

Cnemaspis tuidupensis: *Cylindrotaenia malayanus* (HWML 75077).