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Meteterakis saotomensis n. sp. (Nematoda: Heterakidae) from *Schistometopum thomense* (Bocage) (Gymnophiona: Dermophiidae) on São Tomé Island

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Abstract *Meteterakis saotomensis* n. sp. is described from *Schistometopum thomense* (Bocage), a gymnophionan endemic to the oceanic island of São Tomé in the Gulf of Guinea. The specimens were assigned to *Meteterakis* Karve, 1930, based on the possession of a head with three rounded lips, not set-off from the body, the absence of interlabia and cordons, females with a long vagina and males with a preanal sucker, surrounded by a cuticularised rim and caudal alae that are supported by fleshy papillae. The new species is characterised by: body length 4.2–4.5 mm (males) and 5.1–6.4 mm (females); total length of oesophagus, including pharyngeal portion and oesophageal bulb, 820–856 μm (males) and 898–1,070 μm (females); length of pharynx 57–58 μm (males) and 65–68 μm (females); spicules equal, 410–521 μm long, with tessellated ornamentation throughout their length and alae, and with bevelled tip; gubernaculum or 'gubernacular mass' absent; tail length 164–176 μm (males) and 214–239 μm (females), with elongated tip; vulva at 2.3–2.8 mm from anterior end, with anterior lip forming small flap. This is the second species of *Meteterakis* reported from gymnophionan hosts and the first from the Afrotropical region. Selected comparative morphological data for *Meteterakis* spp. are presented, and data on host range and geographic distribution are updated. The name *M. striaturus* Oshmarin & Demshin, 1972 is corrected to *M. striatura* to reflect the female gender of the genus name.

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Introduction

The heterakid genus *Meteterakis* Karve, 1930 was originally erected to accommodate *M. govindi* Karve, 1930, a parasite described from a bufonid toad *Duttaphrynus melanostictus* (Schneider) (syn. *Bufo melanostictus* Schneider) (Bufonidae) in Burma (Karve, 1930). The genus was revised by Inglis (1958), recognising eight species. Subsequently, Baker (1984) compiled systematic and zoogeographic

data on the then 16 species considered valid by him. The genus currently comprises 23 species parasitising amphibian and reptilian hosts in the Indomalayan, Australasian and Palaearctic Realms (see below). *Meteterakis sinharajensis* Crusz & Ching, 1975, originally described from the agamid lizard *Lyriocephalus scutatus* (L.) and the uropeltid snake *Pseudotyphlops philippinus* (Mueller) (Crusz & Ching, 1975), is the only *Meteterakis* species recorded from gymnophionans so far. It was found in *Ichthyophis glutinosus* (L.) and *Ichthyophis orthoplicatus* Taylor (Ichthyophiidae) in Sri Lanka (Crusz & Santiapillai, 1982). To date, there are no reports of representatives of *Meteterakis* from hosts in the Afrotropical region. In the present paper, we describe a new species of *Meteterakis* recovered from *Schistometopum thomense* (Bocage) (Dermophiidae), a gymnophionan endemic to the island of São Tomé.

Materials and methods

The nematodes described here had been collected from a single *S. thomense* in Obo Natural Park, São Tomé Island during an unrelated study of selected ecological and evolutionary aspects of this gymnophionan. Additional information on the host's biology and capture site are presented in Delêtre & Measey (2004), Measey & van Dongen (2006) and Stoelting et al. (2014). The nematodes were stored in 70% ethanol and deposited in the Natural History Museum of Geneva (MHNG), Switzerland. For morphological studies, specimens were cleared and examined as temporary mounts in glycerol, using a compound microscope with interference contrast optics and equipped with a drawing tube. Measurements were taken from the drawings or made with the use of an ocular graticule. All measurements are in micrometres unless otherwise indicated. For ease of reference, some of the tail papillae are arbitrarily numbered in the description and Fig. 1 accordingly. The classification of amphibian hosts follows Frost (2014), that of reptilians Uetz & Hošek (2014).

Meteterakis saotomensis n. sp.

Type-host: *Schistometopum thomense* (Bocage) (Gymnophiona: Dermophiidae). An adult male (total length 383 mm), collected on 24 October 2002. The host along with other animals in the collection have been deposited in the Natural History Museum, London (BMNH 2000.301–347 inclusive).

Type-locality: In the forests below Lagoa Amelia, Obo Natural Park, São Tomé Island (0.281583°N, 6.590889° E).

Site in host: Posterior part of the intestine.

Intensity of infection: A single host harbouring six specimens.

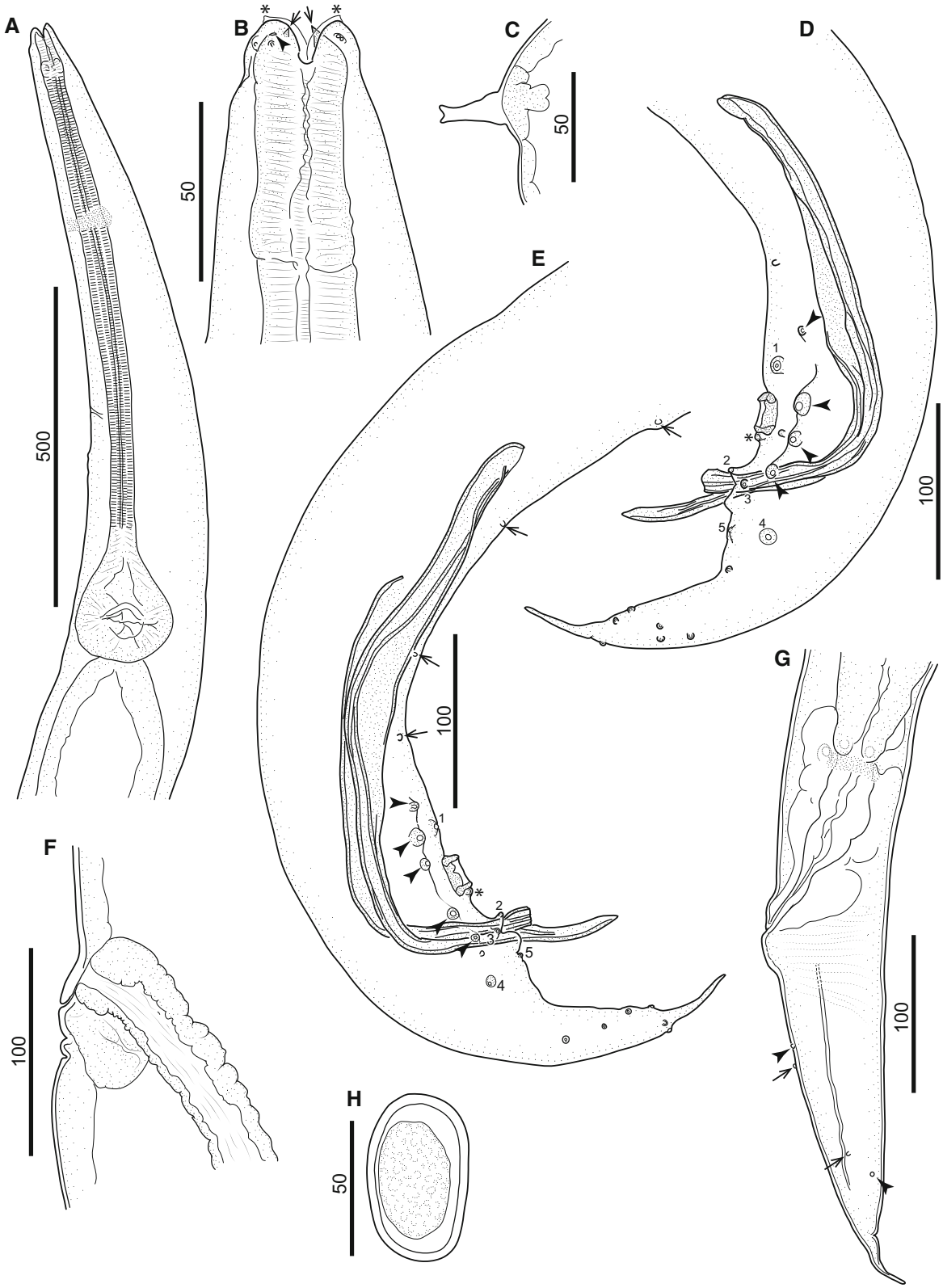
Type-specimens: Holotype: MHNG-INVE-89822 (male); Paratypes: MHNG-INVE-89823 (three females, one male in cuticle of fourth-stage larva), MHNG-INVE-89828 (posterior end of one male).

Etymology: The name of the new species refers to the type-locality.

Description (Fig. 1)

General. Nematodes with slender body, tapering at both ends. Body cuticle with fine transverse striations. Deirids not observed. Lateral alae extending from level close to nerve-ring to anterior to caudal alae in males and to posterior third of tail in females (Fig. 1G), bifid in transverse section (Fig. 1C). Anterior end with 3 rounded lips not set-off from body; interlabia absent (Fig. 1B). Dorsal lip with 2 subdorsal double papillae. Subventral lips each with one subventral double papilla, one smaller lateral papilla, and amphids. Inner edge of each lip with membranous cuticular flange. Anterior end of oesophagus divided into 3 lobes, one dorsal and 2 subventral, each with anteriorly projecting cuticular tooth-like process.

Fig. 1 *Meteterakis saotomensis* n. sp. A, Anterior end, female, lateral view; B, Cephalic region, female, lateral view, note the amphid (*arrowhead*), tooth-like processes (*arrows*) and cuticular flange of lips (*asterisk*); C, Part of transverse section with bifid lateral ala, female. D, Posterior end, male, sinistral view, note papillae supporting caudal alae (*arrowheads*) and single ventral papilla situated at posterior rim of precloacal sucker (*asterisk*), for reference to the numbered papillae see description of male; E, Posterior end of male, dextral view, note somatic papillae (*arrows*), papillae supporting caudal alae (*arrowheads*) and single ventral papilla situated at posterior rim of precloacal sucker (*asterisk*), for reference to the numbered papillae see description of male; F, Vulva, vagina and part of ovejector, lateral view; G, Posterior end, female, lateral view, note end of lateral ala, and somatic papillae from the left and the right side of the tail (*arrowheads* and *arrows*, respectively); H, Egg. Scale-bars are in micrometres ▶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Oesophagus muscular, divided into short anterior pharynx and long cylindrical posterior part which widens into pear-shaped, prominently valved bulb (Fig. 1A). Nerve-ring surrounds anterior portion of cylindrical part of oesophagus. Excretory pore posterior to nerve-ring, in posterior half of cylindrical portion of oesophagus. Anterior walls of intestine thick.

Male [Based on two entire males; when available, additional measurements of male posterior end are included in parentheses.] Body length 4.2–4.5 mm. Maximum body width near midbody, 165–185. Total length of oesophagus, including pharyngeal portion and oesophageal bulb, 820–856 (18.1–19.8% of body length); pharynx 57–58 long, 22–25 wide; oesophageal bulb 116–148 long, 93–103 wide. Nerve-ring and excretory pore at 248–264 and 347–457, respectively, from anterior end. Caudal alae narrow, supported by 4 or 5 ventrolateral fleshy papillae on each side: one small pair anterior to precloacal sucker, followed by 2 larger pairs on level of precloacal sucker or slightly anterior, one large pair on level between precloacal sucker and anterior rim of cloaca; single smaller papilla on level of cloaca observed on right side, absent on left (Fig. 1D, E). In addition, a variable number of caudal papillae with variable size present: one pair of ventral papillae situated anterior to precloacal sucker (no. 1), one pair at anterior rim of cloaca (no. 2), one adcloacal pair close to cloacal aperture (no. 3); one ventrolateral pair of well distinct papillae (no. 4), one pair of ventral postcloacal papillae (no. 5), 2 or 3 lateral papillae on each side on posterior half of tail, followed by one pair of subventral papillae and one pair of dorsolateral papillae at base of elongated tail tip; single ventral papilla at posterior rim of precloacal sucker present; 2 single subventral papillae observed on left side, at level of third pair of papillae supporting lateral alae and posterior to pair no. 5, respectively; one tiny single papilla observed on right side, just posterior to last papilla supporting lateral ala. Precloacal sucker with prominent cuticularised ring, diameter at base 23 (29), situated 21–26 (30) from cloaca. Spicules equal, robust, alate with finely tessellated ornamentation throughout their length and alae, 410–415 (487 and 521) long (8.9–9.5% of body length), with bevelled tip. Gubernaculum or 'gubernacular mass' not observed. Tail bent ventrally, 164–176 (156) long (3.6–4.0% of body length), with elongated tip. Minute subventral somatic papillae anterior to cloaca present; anteriormost somatic papilla in holotype male at 560 from tail tip (Fig. 1E).

Female [Based on three females; the range is followed by the mean in parentheses.] Body length 5.1–6.4 (5.8) mm. Maximum body width near midbody, 170–250 (213). Nerve-ring and excretory pore at 301–326 (312) and 527–589 (566), respectively, from anterior end. Total length of oesophagus, including pharyngeal portion and oesophageal bulb, 898–1,070 (999) [16.8–17.5 (17.1)% of body length]; pharynx 65–68 (67) long, 23–28 (26) wide; oesophageal bulb 175–200 (188) long, 128–153 (136) wide. Rectum elongated, with thick walls (Fig. 1G). Vulva at 2.3–2.8 (2.6) mm [44.3–45.2 (44.8)% of body length] from anterior end. Anterior lip of vulva forming small flap covering vulvar opening (Fig. 1F). Reproductive system didelphic. *Vagina vera* very short, anteriorly directed; *vagina uterina* posteriorly directed, 1.1 mm long in single measured specimen. Tail slightly bent dorsally, subconical with elongated tip, 205–250 (231) long [3.7–4.2 (4.0)% of body length]; bearing 2 pairs of somatic papillae (Fig. 1G). Eggs oval, with thick, smooth shells, unembryonated in uterus, 57–63 × 36–45 (60 × 39; n = 13).

Discussion

Meteterakis saotomensis n. sp. is characterised as a member of *Meteterakis* on the basis of its head with three rounded lips that are not set-off from the body, the absence of interlabia and cordons, as well as the presence of pharyngeal teeth, females with a long vagina and males with a preanal sucker, surrounded by a cuticularised rim and caudal alae that are supported by fleshy papillae (Inglis, 1958; Chabaud, 1978; Baker, 1980).

The new species resembles *M. sinharajensis* known from reptilian and gymnophionan hosts with regard to its body dimensions (2.4–5.2 mm in males, 2.6–8.3 mm in females) and length of spicules ranging between 344–537 μm, as given by Crusz & Ching (1975) and Crusz & Santiapillai (1982). It can, however, be distinguished from the latter by a number of characters. In *M. sinharajensis*, the cuticle of the head is distinctly inflated, giving the head an appearance of being set-off from the rest of the body and its

pharynx is longer (63–107 μm in males, 63–119 μm in females). *Meteterakis sinharajensis* is characterised by spicules with a conical to spatulate tip and well-developed manubrium, while in the new species the tip is bevelled and the posterior extremity is not well developed. Males of *M. sinharajensis*, have four pairs of fleshy papillae supporting the caudal alae from which two pairs are approximately on the same level, lateral to the precloacal sucker, and two pairs are approximately on the same level, lateral to the cloaca in contrast to those of the new species which are arranged along the caudal alae. Therefore, *M. saotomensis* n. sp. is the second species of this genus recorded from gymnophionans.

Since some species of the genus exhibit low host specificity and are known from both reptiles and amphibians (Inglis, 1958; Crusz & Ching, 1975; Crusz & Santiapillai, 1982; Hasegawa, 1990), the new species is compared to all its congeners. The species of the genus *Meteterakis* can be divided into four groups on the basis of the length of their spicules and whether these are equal or not. The new species, with a spicule length of 410–521 μm, belongs to a group whose spicules are equal and intermediate in length (ranging from 227–690 μm). These are:

- *M. amamiensis* Hasegawa, 1990 (spicules 227–640 μm long) from *Odorrana ishikawae* (Stejneger) [syn. *Rana ishikawae* (Stejneger)] (Ranidae), and from *Ateuchosaurus pellopleurus* (Hallowell) and *Plestiodon oshimensis* (Thompson) (syn. *Eumeces marginatus oshimensis* Hikida) (Scincidae) on Amami-Oshima Island, Japan (Hasegawa, 1990);
- *M. andamanensis* Soota & Chaturvedi, 1972 (spicules 400–500 μm long) from *Bufo* sp. on the Andaman Islands (Soota & Chaturvedi, 1972). The name has been published as a *nomen nudum* by Soota & Chaturvedi (1970);
- *M. baylisi* Inglis, 1958 (spicules 420–450 μm long) from *Ceratophora stoddartii* Gray (Agamidae) in Sri Lanka (Inglis, 1958);
- *M. crombiei* Bursey, Goldberg & Kraus, 2005 (spicules 427–488 μm long) from *Sphenomorphus jobiensis* (Meyer) (Scincidae) in Papua New Guinea (Bursey et al., 2005);
- *M. guptai* Gupta & Naiyer, 1993 (spicules 490 μm long) from *Calotes versicolor* (Daudin) (Agamidae) in Lucknow, India (Gupta & Naiyer, 1993);
- *M. ishikawanae* Hasegawa, 1987 (spicules 520–650 μm long) from *O. ishikawae* (syn. *R. ishikawae*) on Okinawa Island, Japan (Hasegawa, 1987);
- *M. japonica* (Wilkie, 1930) Inglis, 1958 (syns. *Spinicauda japonica* Wilkie, 1930; *Africana howardi* Li, 1933) (spicules 460–690 μm long) from a 'Bull frog' in Japan; comparison based on type-specimens redescribed by Inglis (1958);
- *M. paucipapillosa* Wang, 1980 (spicules 400–416 μm long) from *Plestiodon elegans* (Boulenger) (syn. *Eumeces elegans* Boulenger) (Scincidae) in China (Wang, 1980);
- *M. striatura* Oshmarin & Demshin, 1972 (spicules 680 μm long) from *Mauremys mutica* (Cantor) (syn. *Clemmys mutica* Siebenrock) (Geomydidae) in North Vietnam (Oshmarin & Demshin, 1972). The original spelling of the name was "*Meteterakis striaturus*" (see Oshmarin & Demshin, 1972). Since the generic name is of feminine grammatical gender, the ending of the species name is corrected in the present article.

These species can be distinguished from *M. saotomensis* n. sp. by a number of characters. *Meteterakis striatura*, *M. guptai*, *M. andamanensis*, *M. paucipapillosa* and *M. japonica* have nonalate spicules. In addition, the spicules of *M. striatura* have a well distinct manubrium, a gubernacular mass is present and the tail is longer (250 μm in males, 300 μm in females), despite its body being only slightly larger (5.9 mm in males, 5.4 mm in females); the vulvar lips are prominent but a flap is absent. In *M. guptai* a gubernaculum is present, whereas a vulvar flap is absent. *Meteterakis andamanensis* and *M. paucipapillosa* have only ten and six pairs of caudal papillae, respectively.

In contrast to *M. saotomensis* n. sp., in which the vulvar flap is inconspicuous, it is prominent in *M. amamiensis* and *M. baylisi*, whereas it is absent or strongly modified in *M. ishikawanae*.

Meteterakis crombiei is similar in body size (males 3.8–4.7 mm, females 4.5–5.3 mm), but differs from *M. saotomensis* n. sp. by its sharply pointed spicules, longer tail (244–293 μm in males, 357–510 μm in females), and a total of nine pairs of caudal papillae (*vs* 12 pairs and a number of single papillae in *M. saotomensis* n. sp.). *Meteterakis japonica* is similar in body size to the new species as well (males 3.0–6.1

mm, females 4.6–7.7 mm), but has a longer tail (180–300 μm in males, 340–550 μm in females).

Another group within the genus is characterised by having unequal spicules and encompasses two species only:

- *M. bufonis* (Biswas & Chakravarty, 1963) Baker, 1984 (syn. *Heterakis bufonis* Biswas & Chakravarty, 1963) from *D. melanostictus* in India, as described by Biswas & Chakravarty (1963), has a right spicule that is slightly longer than the left one (310 and 270 μm, respectively); both spicules are shorter than those of the new species, despite *M. bufonis* being similar in body size (male 4.3 mm, females 5.6–5.9 mm); in addition, *M. bufonis* has a longer tail (200 μm in males, 320–360 μm in females).
- *M. lyriocephali* (Crusz & Ching, 1975) Chabaud, 1978 (syn. *Cometeterakis lyriocephali* Crusz & Ching, 1975) from *Lyriocephalus scutatus* (L.) (Agamidae) in Sri Lanka, has a distinct difference between the length of the right and left spicule (340–561 μm and 595–754 μm, respectively) (Crusz & Ching, 1975). Furthermore, *M. lyriocephali* has a longer pharynx (74–82 μm in males, 78–94 μm in females) and longer tail (246–303 μm in males, 397–524 μm in females) (Crusz & Ching, 1975).

Another group is formed by species having equal and comparatively long spicules (ranging from 620–1,242 μm):

- *M. aurangabadensis* Deshmukh & Choudhari, 1980 (spicules 620–720 μm long) from *D. melanostictus* in India (Deshmukh & Choudhari, 1980);
- *M. karvei* Naidu & Thakare, 1981 (spicules 660–840 μm long) from *D. melanostictus* in India (Naidu & Thakare, 1981);
- *M. longispiculata* (Baylis, 1929) Inglis, 1958 [syns. *Spinicauda longispiculata* Baylis, 1929; *Spinicauda cophotis* Baylis, 1935; see Crusz & Sanmugasunderam (1973)] (spicules 630–680 μm long) from *Gekko gecko* (L.) (Gekkonidae) in Java; comparison based on type-specimens redescribed by Inglis (1958);
- *M. louisi* Inglis, 1958 (spicules 970–1,100 μm long) from a 'Tree lizard' in India (Inglis, 1958);
- *M. singaporensis* (Sandosham, 1954) Inglis, 1958 (syn. *Africana singaporensis* Sandosham, 1954) (spicules 740–960 μm long) from *D. melanostictus* in Singapore (Sandosham, 1954);
- *M. vaucheri* Adamson, 1986 (spicules 1,057–1,242 μm long) from *Varanus olivaceus* Hallowell (syn. *Varanus grayi* Boulenger) (Varanidae) in the Philippines (Adamson, 1986);
- *M. wangi* Zhang & Zhang, 2011 (spicules 740–930 μm long) from *Indotestudo elongata* (Blyth) (Testudinidae) in Hebei Province, China (Zhang & Zhang, 2011).

In addition, the spicules of *M. aurangabadensis*, *M. karvei*, *M. vaucheri* and *M. wangi* are non-alate. Despite being similar in body length (males 2.8–4.9 mm, females 5.3–6.0 mm), *M. aurangabadensis* has a longer tail (250–260 μm in males, 260–290 μm in females). Both *M. wangi* (males 7.6–8.8 mm, females 7.6–9.0 mm) and *M. vaucheri* (males 6.1–7.8 mm, females 5.0–8.4 mm) are distinctly larger than the new species. Other than in *M. saotomensis* n. sp., in which the vulvar flap is inconspicuous, it is prominent in *M. karvei*, *M. longispiculata*, *M. singaporensis* and *M. vaucheri*. Moreover, both *M. longispiculata* and *M. karvei* have a gubernaculum. *Meteterakis karvei*, being of similar body length (males 3.1–4.4 mm, females 3.6–4.9 mm), also has a longer pharynx (60–75 μm in males, 75–105 μm in females).

Meteterakis louisi while being only slightly larger (males 5.0–7.4 mm, females 6.5–7.6 mm), can be distinguished from the new species in having a longer pharynx (73–79 μm in males, 76–81 μm in females) and longer tail (260–340 μm in males and 310–360 μm in females).

The fourth group of *Meteterakis* spp. comprises species with short, equal spicules (ranging from 180–380 μm):

- *M. gambhiri* Zhang & Zhang, 2011 (spicules 220–270 μm long) from *D. melanostictus* in Manipur, India, was proposed as a name to replace *M. bufonis* Gambhir, Tarnita, Chinglenkhomba, Gyaneswori & Indranich, 2006 (see Gambhir et al., 2006), which is a junior homonym of *Meteterakis bufonis* (Biswas & Chakravarty, 1963) (see Zhang & Zhang, 2011); the description provided by Gambhir et al. (2006) is used in the present comparisons;
- *M. govindi* Karve, 1930, type-species [syns. *Heterakis govindi* (Karve, 1930) Baylis, 1936; *Ganguleterakis govindi*, Skrjabin, 1949; *Africana*

varani Maplestone, 1931; *Spinicauda bufonis* Yamaguti, 1935; see Inglis (1958)] (spicules 180–270 µm long) from the type-host *D. melanostictus* in Myanmar, and from a 'Tree frog' and *Varanus bengalensis* (Daudin) in China and India; comparison based on type-specimens redescribed by Inglis (1958);

- *M. mabuyi* (Chakravarty, 1944) Inglis, 1958 (syn. *Africana mabuyae* Chakravarty, 1944) (spicules 300 µm long) from *Eutropis carinata* (Schneider) (syn. *Mabuya carinata* Schneider) (Scincidae) in India (Chakravarty, 1944);
- *M. triaculeata* (Kreis, 1933) Inglis, 1958 (syn. *Ganguleterakis triaculeatus* Kreis, 1933) (spicules 380 µm long) from *Corucia zebrata* Gray (Scincidae) on the Solomon Islands; as type-specimens were redescribed by Inglis (1958).

Meteterakis saotomensis n. sp. and *M. vaucheri* share the bifid aspect of their lateral alae in transverse section (Adamson, 1986). However, in no other species of *Meteterakis* have the lateral alae been studied in this view. Adamson (1986) also described an internal circle of head papillae for *M. vaucheri*. Due to the limited number of specimens available, it was not possible to prepare an apical view of *M. saotomensis* n. sp. for comparison. A similar internal circle of papillae was observed in *M. japonica, M. ishikawanae* and *M. amamiensis* (see Hsü, 1933; Hasegawa, 1987, 1990). We did not observe any somatic papillae in the region of the vulva as reported in the original descriptions of *M. striatura* and *M. ishikawanae*.

The host range of the genus *Meteterakis* is diverse. It currently includes 13 species from saurians of the families Agamidae, Scincidae, Varanidae and Gekkonidae, 12 species from anurans of the families Bufonidae and Ranidae, two species from turtles of Geomydidae and Testudinidae, a single species from snakes of Uropeltidae and two species from the gymnophionan families Dermophiidae and Ichthyophiidae (Baker, 1984; Adamson, 1986; Hasegawa, 1987, 1990; Gupta & Naiyer, 1993; Bursey et al., 2005; Gambhir et al., 2006; Zhang & Zhang, 2011; present study). Association with either reptilian or amphibian hosts does not appear to be exclusive, and three of the 24 species, *M. amamiensis*, *M. govindi* and *M. sinharajensis*, are known to infect hosts from both classes of vertebrates (Inglis, 1958; Crusz & Ching, 1975; Crusz & Santiapillai, 1982; Hasegawa, 1990).

The present record of *M. saotomensis* n. sp. collected on São Tomé Island, part of the Afrotropical Realm, constitutes a remarkable expansion of the known geographical range of the genus. In keeping with Baker's (1984) analysis, by far the highest diversity of *Meteterakis* species is still seen in the Indomalayan Realm, with sixteen species, but in addition, five species have been recorded from the eastern Palaearctic, two from Australasia and one from the Afrotropics (Baker, 1984; Bursey et al., 2005; Zhang & Zhang, 2011).

While not many comprehensive studies have been conducted on the helminth fauna of amphibians and reptiles in the Afrotropics, there have been some localised studies as well as literature surveys with regard to helminth parasites in these host groups (e.g. Myers et al., 1960; Hering-Hagenbeck & Boomker, 2000; Canaris & Gardner, 2003; Aisien et al., 2004, 2009; McAllister et al., 2010). Interestingly, none of these list members of *Meteterakis*, despite the fact that the checklist of Hering-Hagenbeck & Boomker (2000), for example, represented 20 snake and 21 lizard species, including members of the four saurian families known to be hosts of *Meteterakis* spp. It stands to reason that, as more parasite surveys are being conducted, the host and geographic range of hitherto less intensively studied groups of nematodes will increase.

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Compliance with ethical standards

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Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All applicable institutional, national and international guidelines for the care and use of animals were followed.

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