***PSEUDOPHYSALOPTERA ENIGMATICA* SP. NOV. (NEMATODA: PHYSALOPTERIDAE) FROM *DACTYLOPSILA TRIVIRGATA* GRAY, 1858 (MARSUPIALIA: PETAURIDAE) IN AUSTRALIA, WITH A REVIEW OF THE GENUS**

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Summary:

The nematode *Pseudophysaloptera enigmatica* sp. nov. is described from the stomach of *Dactylopsila trivirgata* Gray, 1858, in Queensland, Australia. The new species is distinguished from congeners by its size and features present on the tail of the male. *P. enigmatica* sp. nov. is considerably larger than virtually all congeners, and can be differentiated by the presence of spicules and the shape and distribution of caudal papillae in the male tail. This is the first record of the genus in Australia and in marsupials. A review of the genus is provided.

KEY WORDS: *Pseudophysaloptera enigmatica* sp. nov., Nematoda, Spirurida, marsupial, Australia.

Résumé : DESCRIPTION DE *PSEUDOPHYSALOPTERA ENIGMATICA* SP. NOV., PARASITE D'UN MARSUPIAL, *DACTYLOPSILA TRIVIRGATA* GRAY, 1858, PROVENANT DE L'Australie ET UNE RÉVISION DU GENRE

Le nématode *Pseudophysaloptera enigmatica* sp. nov. est décrit de l'estomac de *Dactylopsila trivirgata* Gray, 1858, provenant du Queensland, Australie. La nouvelle espèce se distingue par sa taille (*P. enigmatica* sp. nov. est plus grand que les autres espèces du genre) et la queue du mâle, surtout par la présence de spicules et la distribution des papilles caudales. La présence du genre chez un marsupial australien, la première notification, est discutée. Une révision du genre est donnée.

MOTS CLÉS : *Pseudophysaloptera enigmatica* sp. nov., Nematode, Spiruridie, marsupial, Australie.

INTRODUCTION

Members of the genus *Pseudophysaloptera* Baylis, 1934, parasitise the stomachs of insectivorous animals including shrews, primates, rodents, bats and birds across four continents, Europe, Asia, North America and Africa (Baylis, 1934; Chen 1937; Morgan 1941; Crusz, 1946, 1950; Lincicome & McConnaughey, 1948; Lincicome, 1948; Kobulej & Versenyi, 1953; Morozov, 1960; Schad, Kuntz & Wells, 1960; Chabaud, Rausch & Desset, 1963; Farooqui & Ali, 1965a, b; Lovekar, 1969; Quentin, 1969; Mas-Coma & Gallego, 1977; Naidu & Thakare, 1979; Okulewicz, 1979; Rehana, 1981; Gupta & Jaiswal, 1989; Hemkar & Renapurkar, 1991). No prior occurrence of the genus is known in Australian animals, although spirurid nematodes, including physalopterids have been reported from the insectivorous marsupial families Dasyuridae and Peramelidae (Spratt *et al.*, 1991). The current paper describes a new species of the genus from the petaurid marsupial, *Dactylopsila trivirgata* Gray, 1858, from Queensland, Australia. Most petaurids are nectarivores or folivores; *D. trivirgata* is unique amongst

Australian petaurids in that it is primarily insectivorous (Rawlins & Handasyde, 2002).

MATERIALS AND METHODS

Ten road-kill specimens of *D. trivirgata* were collected from various sites in north Queensland, Australia, between 1994 and 1997 and were frozen prior to necropsy. The helminths collected were fixed in 70 % ethanol, cleared in lactophenol or beechwood creosote and mounted on slides for examination. Drawings were prepared using a drawing tube attached to an Olympus BH light microscope. Measurements were made with an ocular micrometer and are quoted in millimetres as the range of ten measurements followed by the mean in parentheses, unless otherwise specified.

Several specimens were examined using scanning electron microscopy. These were dehydrated in graded alcohols, dried in hexamethyldisilazane (ProSciTech, Townsville), mounted on stubs with double-sided tape, sputter-coated with gold and viewed with a Siemens Autoscanner microscope at an accelerating voltage of 5 kV.

Type specimens are deposited in the South Australian Museum, Australian Helminth Collection (SAM AHC), Adelaide, Australia, the Natural History Museum (BMNH), London, United Kingdom, and the Muséum National d'Histoire Naturelle (MNHN), Paris, France.

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Additional specimens examined were in the collection of CSIRO, Canberra, Australia (WL HC).

PSEUDOPHYSALOPTERA ENIGMATICA SP. NOV.

(Figs 1-11)

Type material: holotype ♂, SAM AHC 32156; allotype ♀, SAM AHC 32157. Paratypes: 12 ♂, 13 ♀, SAM AHC 32158; 1 ♂, 1 ♀, BMNH 2003.2.7.5-6; 1 ♂, 1 ♀, MNHN 64 HG, local N720.

Geographical origin: El Arish, Queensland, Australia (17° 49'S; 146° 00'E), coll. R. Martin, 1996.

Host: *Dactylopsila trivirgata*

Site: Stomach.

Other material examined: 3♂, 1♀, Shipton's Flat, (15° 48'S; 145° 15'E), coll. K. Handasyde, 1994 (SAM AHC 32159); 4♂, 5♀, Mission Beach, (17° 53-56'S; 146° 06'E), coll. K. Handasyde, 1995 & R. Martin, 1996 (SAM AHC 32160-2); 7♂, 5♀, Cowley Beach, (17° 43'S; 146° 06'E), coll. K. Handasyde, 1995 (SAM AHC 32163); 1♂, 4♀, Tully, (17° 56'S; 145° 56'E), coll. R. Martin, 1996 (SAM AHC 32164); 1♀, Daintree, (16° 15'S; 145° 19'E), coll. K. Handasyde, 1997 (SAM AHC 32165); 6♂, 3♀, Cardwell, (18° 11'S; 146° 00'E), coll. K. Handasyde, (SAM AHC 32166); 4♂, 4♀ ? loc. coll. K. Handasyde, (SAM AHC 32167); 1♀, Julatten, (16° 26'S; 145° 20'E), coll. D.M. Spratt (WL HC N4499).

DESCRIPTION

Worms robust, long, cylindrical and cream to pink. Anterior extremity comprised of two domed, lateral pseudolabia, each invested with two prominent submedian cephalic papillae, lateral amphid and trident-like internolateral tooth. Wrinkled, inflated cuticle frequently extends beyond pseudolabia to form anterior cephalic collarette. Buccal cavity inconspicuous with mouth opening into bipartite oesophagus comprised of short anterior muscular portion and long posterior glandular portion. Nerve ring anterior to junction between muscular and glandular oesophagus. Two lateral deirids and ventral excretory pore posterior to this junction.

Male: Body length 16.6-27.1 (19.5); body width 0.768-1.05 (0.870); muscular oesophagus length 0.490-0.632 (0.577); muscular oesophagus width 0.102-0.112 (0.105); glandular oesophagus length 2.79-4.10 (3.62); glandular oesophagus width 0.265-0.358 (0.296); anterior extremity to nerve ring 0.439-0.561 (0.507); anterior extremity to deirids 0.632-0.959 (0.827, $n = 8$); anterior extremity to excretory pore 0.806-1.06 (0.939, $n = 6$); cloaca to tail tip 1.02-1.63 (1.37); left spicule length 0.117 ($n = 1$); right spicule length 0.092 ($n = 1$). Subequal, poorly sclerotized spicules and gubernaculum observed in one specimen. Anterior margins of

caudal alae meet ventrally. When flattened, tail resembles shovel or triangle, tapering to tip of tail. Ventral aspect of tail invested with cuticular corrugations and papillae; arrangement varies between individual specimens. Three pairs of pedunculated papillae, one rudimentary unpaired sessile papilla anterior to cloaca, two pairs of sessile papillae located pre-cloacal and five pairs post-cloacal; fingerprint-like area of cuticular corrugations immediately anterior to unpaired sessile papilla. Alae invested with streaks lateral to tail.

Mature female: Body length 24.3-33.2 (29.8); body width 1.25-1.61 (1.38); muscular oesophagus length 0.561-0.693 (0.638); muscular oesophagus width 0.102-0.122 (0.109); glandular oesophagus length 3.51-4.40 (4.07); glandular oesophagus width 0.307-0.388 (0.349); anterior extremity to nerve ring 0.408-0.612 (0.530); anterior extremity to deirids 0.704-1.02 (0.844, $n = 4$); anterior extremity to excretory pore 0.816-1.10 (0.947, $n = 9$); anterior extremity to vulva 6.40-13.3 (11.1); anus to tail tip 0.384-0.538 (0.435); egg dimensions $0.036 \times 0.053 \times 0.018$ - 0.024 (0.042×0.022).

Mature females thicker than males and distended with ovoid, thick-shelled, embryonated eggs. Vulva occurs at obvious saddle shaped constriction on ventral aspect of anterior half of body. Vagina arcs anteriorly, widening at junction with uterus. Uterine trunk extends anteriorly, dividing into two opisthodelphic egg-laden uteri. Tail short and bluntly conical. Immature females thinner and shorter than males and mature females. Three pairs observed *in copula*, in which male wraps caudal alae around saddle-shaped depression containing female vulva, such that pair form a "T".

DISCUSSION

The genus *Pseudophysaloptera* was erected for *P. soricina* recovered from *Crocidura* sp. in Tanzania, Africa (Baylis, 1934). *P. soricina* was subsequently described from *Suncus caeruleus* in China (Chen, 1937), *Sorex personatus*, *Sorex fumeus* and *Blarina brevicauda* in North America (Morgan, 1941), *Suncus caeruleus* in Sri Lanka (Baylis, 1944; Crusz, 1946), *Sorex araneus* and *Neomys fodiens* in Russia (Morozov, 1960), *Crocidura russula* in Turkey (Schad, Kuntz & Wells, 1960) and *Turdus merula* in Poland (Okulewicz, 1979).

A second species, *P. riukiuana*, was described from *Suncus murinus* in Japan (Lincicome & McConnaughey, 1948). Crusz (1950) redescribed *P. riukiuana* from *Suncus caeruleus* in Sri Lanka. Another physalopterid discovered in East Asia, *Physaloptera formosana*, described from *Sorex* sp. in Taiwan (Yokogawa, 1922), was considered to belong more appropriately in the genus *Pseudophysaloptera*, and was thus

Figs 1-7. – *Pseudophysaloptera enigmatica* sp. nov. 1, anterior end, lateral view. 2, cephalic extremity, dorso-ventral view. 3, female reproductive tract, lateral view. 4, mouth, apical view. 5, male tail, ventral view. 6, female tail, lateral view. 7, spicules and gubernaculum, ventral view. Scale bars: 0.1 mm.

Figs 8-11. – Scanning electron micrographs of *Pseudophysaloptera enigmatica* sp. nov. 8, cephalic extremity, apical view, showing cephalic collar (co), labial papilla (l) and tridentate tooth (t). 9, male tail, lateral view. 10, cloaca (c), unpaired pre-cloacal papilla (p) and cuticular corrugations (r), male tail, ventral view. 11, male tail, ventral view, showing cloaca (c). Scale bars: 8, 0.15 mm.; 9,11, 1 mm; 10, 0.1 mm.

renamed *Pseudophysaloptera formosana* (Lincicome, 1948). *P. lincicomei* was described from *Sorex unguiculatus* in Japan (Chabaud, Rausch & Desset, 1963). In Europe, *P. kotlani* was described from *Sorex minutus* and *Crocidura leucodon* in Hungary (Kobulej & Versenyi, 1953). Kobulej (1955) redescribed *P. kotlani* from *S. araneus* in Hungary, while Prokopic (1958) redescribed *P. kotlani* in *S. araneus*, *S. minutus* and *Sorex alpinus* in the former Czechoslovakia. *Pseudophysaloptera kahmanni* was described from the rodent *Eliomys quercinus* from the Balaeric Islands, Spain (Mas-Coma & Gallego, 1977).

Schad (1963) attempted to clarify the “confusion characterizing the literature on the genus” by synonymising all the previously described species and setting criteria for the recognition of *Pseudophysaloptera*. Schad (1963) considered the genus included only one species, *P. formosana*, with two geographically distinct and morphologically differentiable subspecies, *P. f. formosana* and *P. f. soricina*. Mas-Coma and Gallego (1977) considered these two full species and their opinion is followed here.

Several authors have reported occurrences of *Pseudophysaloptera* in India, including *P. f. formosana* from *Sorex perroteti* (Farooqui & Ali, 1965a), *P. indiana* from *Sorex murinus* (Farooqui and Ali, 1965b), *P. indiana* from *Suncus caeruleus* (Hemkar & Renapurkar, 1991), *P. multipapillata* from *Suncus murinus* (Naidu & Thakare, 1979), *P. simbai* from *Suncus suncus* (Gupta & Jaiswal, 1989), and *P. alii* from the micro-bat *Taphozous kacchensis* (Lovekar, 1969). Lovekar's (1969) description does not meet Schad's (1963) criteria for *Pseudophysaloptera*. Further investigation might support the allocation of *P. alii* to a different or entirely new genus. *P. petaloidi* was described from *Suncus murinus* in neighbouring Pakistan by Rehana (1981).

Quentin (1969) described *P. vincenti* recovered from *Galagoides demidovii* in the Central African Republic, found third-stage larvae of this parasite in the earwig, *Labidura riparia* and succeeded in experimentally infecting a rodent, *Thamnomys surdaster*, with them. These results extended the host range of the genus to include primates and identified an arthropod species capable of transmitting it.

P. kotlani and *P. riukiuanana* are considered synonyms of *P. soricina* and *P. formosana* respectively by Schad (1963), leaving ten described species in the genus, which parasitise the stomachs of shrews and insectivorous primates, rodents, bats and birds.

The new species described above agrees closely with Schad's (1963) criteria for *Pseudophysaloptera*, viz. labial dentition, disposition of uteri and the male tail. *P. enigmatica* is larger in all measurements than *P. alii*, *P. indiana*, *P. lincicomei*, *P. vincenti*, *P. kahmanni*, *P. soricina* and *P. petaloidi* (for example, male body length: *P. enigmatica* 16.6–27.1 mm compared to 3.79–10.6 mm in the seven other species).

Although some measurement ranges overlap between females of *P. formosana* and *P. enigmatica*, (for example, female body length: *P. formosana* 21.0–30.5 mm compared with *P. enigmatica* 24.3–33.2 mm), males of *P. formosana* are clearly smaller. *P. enigmatica* males have at least three pairs of stalked papillae and a pair of rudimentary spicules and gubernaculum, which differentiate it from *P. formosana*. *P. enigmatica* is larger than *P. simbai* in most measurements. Males of *P. simbai* lack cuticular ornamentation, a gubernaculum and have twenty-three caudal papillae, in direct contrast to *P. enigmatica* which has the aforementioned features and between fifteen and twenty-one caudal papillae. *P. multipapillata*, though similar in size, lacks spicules, pedunculated caudal papillae and cuticular corrugations of *P. enigmatica* males, and has a single prominent median pre-cloacal protuberance, which is rudimentary in *P. enigmatica*.

Considerable emphasis has historically been placed on the pattern of caudal papillae of the male for distinguishing *Pseudophysaloptera* sp. However, variation exists even between individual specimens in *P. enigmatica*. If the taxonomy of the genus is to be resolved let alone to accurately reflect its phylogeny, then genetic studies are required.

The host from which *P. enigmatica* was recovered, *D. trivirgata*, is primarily insectivorous (Rawlins & Handasyde, 2002), consistent with the likely role of arthropod intermediate hosts in the life cycle of *Pseudophysaloptera* spp. Direct evidence for this contention was established with third-stage larvae of *P. vincenti* discovered in the earwig, *Labidura riparia* by Quentin (1969).

Dactylopsila spp. occur in north Queensland, New Guinea and neighbouring Indonesian archipelagoes (Flannery, 1995a & b). The occurrence of *Pseudophysaloptera* spp. in *Dactylopsila* spp. from other geographic locations remains to be determined.

This is the only species of *Pseudophysaloptera* recovered from marsupials, and the only one identified in Australia. There are several possible means by which the genus might have reached Australia. *P. soricina* has

been described in the blackbird, *T. merula*, (Okulewicz, 1979) and it is possible that the genus might have been introduced by migratory birds. Alternatively, migratory bats might have been responsible as *P. alii* was described in the bat *T. kaccensis* (Lovekar, 1969). Spratt (1985) suggested that *Spirura aurangabadensis* Lovekar & Ali, 1967, found in dasyurid marsupials, arrived in Australia either in bats or in an arthropod intermediate host, while *Cyathospirura* Baylis, 1934, has been introduced recently in eutherian carnivores (Beveridge & Spratt, 1996). The proposed specific name for this new species refers to its enigmatic origin in Australia.

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