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Digenetic Trematodes of Marine Fishes from the Kuwaiti Coast of the Arabian Gulf: Families Pleorchiidae, Fellodistomidae, and Cryptogonimidae, with a Description of Two New Species, *Neoparacryptogonimus sphericus* and *Paracryptogonimus ramadani*

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ABSTRACT: Six digeneans are reported from marine fishes of the Kuwaiti coast of the Arabian Gulf: *Pleorchis sciaenae* Yamaguti, 1938, from *Otolithes argenteus*; *Tergestia pauca* Freitas and Kohn, 1965, from *Scomberoides commersonianus* and *Trachurus trachurus*; *Allobacciger macrorchis* Hafeezullah and Siddiqi, 1970, from *Scolopsis ruppelli* (new host record); *Paradiscogaster farooqii* Hafeezullah and Siddiqi, 1970, from *Scatophagus argus*; *Neoparacryptogonimus sphericus* sp. n. from *Lutjanus coccineus* (type host) and *Batrachus grunniens*; and *Paracryptogonimus ramadani* sp. n. from *Lutjanus fulviflamma*. *Pleorchis arabicus* Al-Yamani and Nahhas, 1981, is a synonym of *P. sciaenae*. *Tergestia pectinata* of Nahhas and Cable (1964), Nahhas and Short (1965), is considered a synonym of *Tergestia pauca*. New locality records are established for *Tergestia pauca*, *Allobacciger macrorchis*, and *Paradiscogaster farooqii*. A key to species of *Paracryptogonimus* and *Neoparacryptogonimus* is given.

KEY WORDS: Arabian Gulf, Kuwait, marine fishes, *Otolithes argenteus*, *Scomberoides commersonianus*, *Trachurus trachurus*, *Scolopsis ruppelli*, *Scatophagus argus*, *Lutjanus coccineus*, *Lutjanus fulviflamma*, *Batrachus grunniens*, Digenea, *Pleorchis*, *Tergestia*, *Allobacciger*, *Paradiscogaster*, *Paracryptogonimus*, *Neoparacryptogonimus*.

During the course of a survey of helminth parasites of the Kuwaiti coast carried out by the second author between 13 June 1992 and 19 December 1996, a large number of digeneans representing several families were obtained. This paper reports 1 known species of pleorchiid and 3 fellodistomids and describes 2 new cryptogonimids from 8 species of fish. Previous surveys on adult digeneans of the Arabian Gulf have been conducted in coastal waters of 3 countries: Kuwait (Al-Yamani and Nahhas, 1981; Abdul-Salam and Khalil, 1987; Abdul-Salam et al., 1990; Abdul-Salam and Sreelatha, 1992, 1993; Sey, 1995; Sey and Nahhas, 1997); Qatar (Saoud et al., 1986a, b, 1987, 1988a, b, c); and the United Arab Emirates (El-Naffar et al., 1992). Despite the seemingly large number of published articles, the digeneans of the Arabian Gulf remain poorly known considering the great diversity of the fish (Kuronuma and Abe, 1986; Randall, 1995) and potential molluscan intermediate hosts (Glayzer et al., 1984).

Materials and Methods

A total of 698 fishes representing 86 species, in 76 genera and 44 families, were obtained from the local fish market and examined. The worms were fixed, stained, and mounted according to standard techniques as described by Sey and Nahhas (1997). Measurements are expressed in micrometers; length followed by width is indicated as a range; the mean, in parentheses, is calculated for all species represented by 3 or more specimens. Drawings were prepared by microprojection, and details were filled in through microscopic observations. Calculations of prevalence, mean intensity, and abundance follow the recommendations of Margolis et al. (1982) and are indicated, with dates of collection, in Table 1. A * preceding a host indicates a new host record, ** a new synonym. Holotypes are deposited in the National Reference Collection (NRC), Department of Biological Sciences, Kuwait University, Kuwait. Paratypes or vouchers are in the United States National Parasite Collection (USNPC), Beltsville, Maryland; The Natural History Museum BM(NH), London; and Harold W. Manter Laboratory (HWML), University of Nebraska State Museum, Lincoln, Nebraska. Fishes were identified using Kuronuma and Abe (1986).

Results

Pleorchiidae

Pleorchis sciaenae Yamaguti, 1938

SYNONYM: *Pleorchis arabicus* Al-Yamani and Nahhas, 1981.

DESCRIPTION (based on 5 specimens): Body broadly elongate, 3,425–6,500 × 1,250–1,930

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Table 1. Prevalence, mean intensity, and abundance of digeneans found in 8 species of marine fish from Kuwait.

Host*	% Prevalence	Mean intensity	Abundance	Collection date†
Otolithes argenteus (4/21)				12 October 1993 3 October 1994 5 March 1995 5 April 1996
Pleorchis sciaenae	19	4.5	0.8	
Scomberoides commersonianus (1/9)				21 June 1995
Tergestia pauca	11	2.0	0.2	
Trachurus trachurus (1/11)				10 November 1995
Tergestia pauca	9	2.0	0.18	
Scolopsis ruppelli (1/6)				15 October 1993
Allobacciger macrorchis	17	31	5.1	
Scatophagus argus (2/9)				13 June 1993 9 July 1993
Paradiscogaster farooqii	22	36.5	8.1	
Lutjanus coccineus (1/5)				25 January 1994
Neoparacryptogonimus sphericus	20	3.0	0.6	
Batrachus grunniens (1/12)				30 September 1995
Neoparacryptogonimus sphericus	8	2.0	0.18	
Lutjanus fulviflamma (1/4)				10 October 1995
Paracryptogonimus ramadani	25	19	4.7	

* Number in parentheses next to host refers to number infected/number examined.
† Collection dates refer to date of collection of fish harboring those digeneans.

(5,430 × 1,696), widest at ovarian level. Forebody 30–36% (33%) of body length; hindbody 58–68% (66%). Tegument spinose; spines extending to near posterior end of body. Eye-spot pigments present. Oral sucker subterminal, 180–392 × 268–420 (314 × 362). Ventral sucker 205–300 × 220–300 (251 × 265), in anterior body fourth. Sucker ratio 1:0.66–1:0.86 (1:0.76). Prepharynx 160–310 (230) in length; pharynx 170–275 × 200–320 (238 × 275); esophagus short; intestinal bifurcation in anterior body fifth; ceca with short anteriorly directed limbs, extending to about midprepharyngeal level; posterior limbs to near posterior end of body. Testes in 4 columns, 2 ventral and 2 dorsal, each of 11 testes or 44 in total (1 worm had 48); cirrus sac dextrodorsal to ventral sucker, 560–900 × 125–200 (703 × 159), widest at base, containing ovoid seminal vesicle, elongate prostatic duct, and short aspinose cirrus. Ovary multilobed, 345–600 × 400–730 (400 × 600); uterus short, preovarian. Ovarian complex masked by ovary and testes. Vitelline follicles numerous, extending laterally, both dorsally and ventrally, from anterior level of ventral sucker to posterior end of body, confluent posterior to testes. Eggs 65–75 × 37–42 (70 × 41). Genital atrium anterior to ventral sucker; pore median. Excretory vesicle tubular, arms extending to ovary; pore terminal.

HOST: *Otolithes argenteus* Cuvier and Valenciennes, 1830 (Sciaenidae).

SITE IN HOST: Intestine.

DEPOSITED SPECIMENS: NRC No. 20, USNPC No. 87742, BM(NH) No. 1998.3.6.1, HWML No. 39703.

REMARKS: Except for larger size and comparatively larger structures, these specimens are in agreement with Yamaguti's description. Al-Yamani and Nahhas (1981) described *P. arabicus* from a single specimen taken from the same host species and characterized it by a cirrus sac sinistral to the ventral sucker. A reexamination of the type (USNPC 75560) indicates that the authors had erred in their interpretation of the position of the cirrus sac; it partially overlaps the ventral sucker dorsally. In his description of *P. sciaenae,* Yamaguti (1938) described the cir-

rus sac as "extending over the acetabulum"; his figure showed one that is dorsal and slightly dextral to the ventral sucker. *P. arabicus* is here considered a synonym of *P. sciaenae.*

Fellodistomidae
Tergestia pauca Freitas and Kohn, 1965 (Fig. 1)

SYNONYMS: *Tergestia mauritanica* (Dollfus, 1973) Bray, 1984; *T. manteri* (Dollfus, 1973) Bray, 1984; *T. pectinata* (Linton, 1905) of Hopkins (1940); *T. pectinata* (Linton, 1905) of Manter (1947); *T. pectinata* (Linton, 1905) of Siddiqi and Cable (1960); ++*T. pectinata* (Linton, 1905) of Nahhas and Cable (1964); ++*T. pectinata* (Linton, 1905) of Nahhas and Short (1965).

DESCRIPTION (based on 2 specimens from *Scomberoides commersonianus*): Body elongate, 2,150–3,680 × 400–600. Forebody 26–32% of body length; hindbody 57–60%. Tegument aspinose. Eye-spot pigments absent. Oral sucker terminal, 165–210 × 168–220, bearing 12 appendages, each 60–90 × 31–35 in greatest width; neck region with 6 pairs of lateral cuticular processes, 3 at pharyngeal level and 3 more posteriorly, each bearing 1 or 2 filaments. Ventral sucker 300–450 × 350–423, in anterior third of body. Sucker ratio 1:1.95–1:2.03. Prepharynx short; pharynx cylindrical, 200–275 × 78–138; esophagus very long, sinuous, almost half body length in 1 well-extended specimen (Fig. 1), intestine bifurcating posterior to ventral sucker; ceca long, extending to near posterior end of body. Testes slightly oblique, near posterior extremity; anterior testis 300–330 × 220–240; posterior testis 350–370 × 180–240. Cirrus sac distinctly bipartite, anterior part globular, 140–220 × 140–190, containing small saccular internal seminal vesicle, short prostatic duct, and folded cirrus; posterior part 440–710 × 80–90, extending from anterior level of ventral sucker dorsally to short distance into hindbody, containing straight seminal vesicle; prostatic cells surrounding small segment at junction of both parts. Ovary weakly trilobed or kidney shaped, 250–260 × 130–170 wide, pretesticular, in posterior body third; Mehlis' gland ventrolateral to ovary; seminal receptacle of uterine type; uterine coils extending posteriorly to junction of testes and anteriorly to posterior level of ventral sucker; metraterm indistinct entering genital atrium at its base close to anterior margin of ventral sucker. Vitelline follicles small, indistinct, extending laterally from midlevel of anterior testis to near posterior level of ventral sucker in 1 specimen and to middle of ovario-acetabular level in another, confluent near posterior margin of ventral sucker in former but not latter. Eggs numerous, operculated, 17–20 × 10–14 (18 × 12). Genital atrium globular; pore median, opening short distance anterior to level of ventral sucker. Excretory vesicle concealed by testes; excretory canals extending to postpharyngeal region.

HOSTS: *Scomberoides commersonianus* Lacépède, 1801 (Carangidae); *Trachurus trachurus* Linnaeus, 1758 (Carangidae).

SITE IN HOSTS: Intestine.

DEPOSITED SPECIMEN: NRC No. 25.

REMARKS: The 2 specimens from *Trachurus trachurus,* the type host of *Tergestia laticollis,* included 1 with the oral sucker and pharynx missing and the other cut in half but with both parts present; these are also identified as *T. pauca* based on similarity in topography of the internal structures to those from *S. commersonianus,* except for a smaller size and larger sucker ratio. Measurements are body, 1,840 × 270; forebody, 32.6%; hindbody, 52.7%; oral sucker, 110 × 88; pharynx, 120 × 70; ventral sucker, 270 × 250; sucker ratio, 1:2.6; anterior testis, 220 × 150; posterior testis, 250 × 120; ovary, 200 × 90; and eggs, 15–18 × 12–13.

Specimens from both hosts agree well with the original description of Freitas and Kohn (1965) and Bray (1984) but differ in having somewhat more posterior ovary and testes. We could count only 12 oral processes in specimens from *S. commersonianus* and 11 in 1 from *T. trachurus,* suggesting uncertainty in determining accurately the number of processes when whole mounts are not properly oriented on slides and only a small number of specimens are available for study. The specimens from both hosts show 2 oblique overlapping testes very near the posterior end of the body. This extreme posterior location of the testes has not been reported, to the best of our knowledge, in those species we accept as, or consider synonyms of, *T. pauca.* We prefer, however, not to name a new species based on this single characteristic. This finding represents a new locality record.

Dollfus (1973) renamed *Tergestia pectinata* of Hopkins (1940), Manter (1947), and Siddiqi and Cable (1960) *T. manteri* and described *T. mauritanica.* He listed egg size for *T. pauca* but

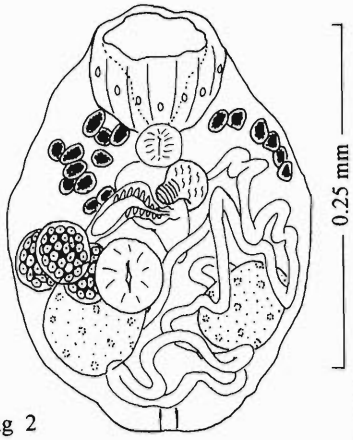


Fig 2

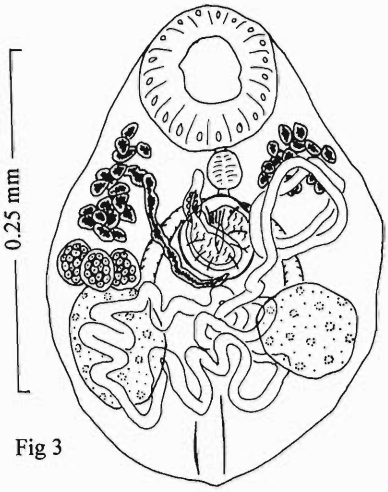


Fig 3

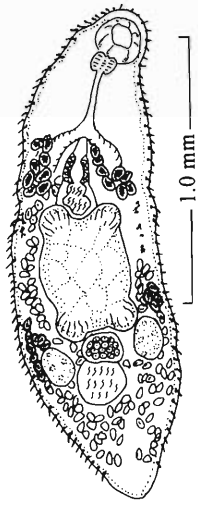


Fig 4

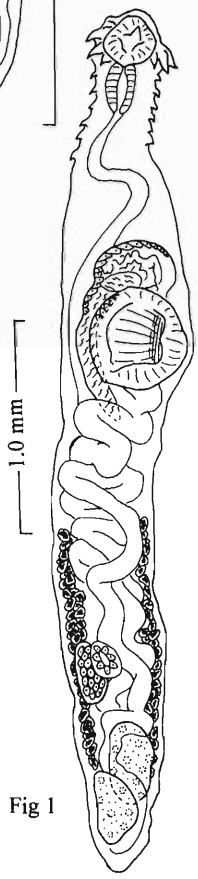
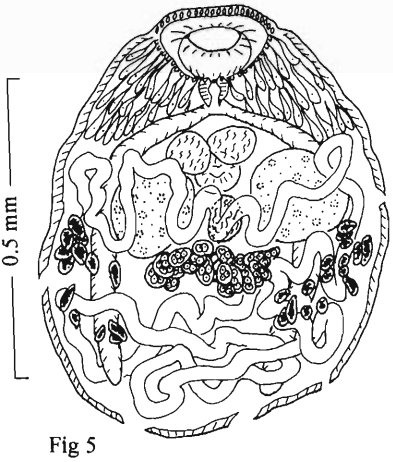


Fig 1



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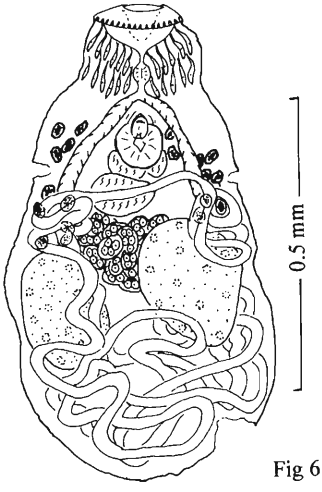

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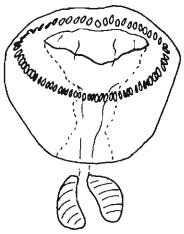

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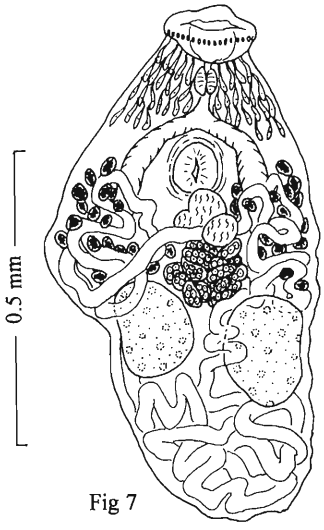

Fig 7

did not compare it with the new taxa. Bray (1984) considered Dollfus' species synonyms of *T. pauca.* Neither Dollfus (1973) nor Bray (1984) made reference to *T. pectinata* of Nahhas and Cable (1964) or Nahhas and Short (1965) from various species of fish. Identification of the Jamaican and Floridian material as *T. pectinata,* at that time, was based on a comparison with Manter's and Siddiqi and Cable's material. We have reexamined several specimens in the collection of the first author from *Selar crumenophthalmus* from Jamaica and from *Bairdiella chrysura* from Apalachee Bay, Florida; there is no evidence of bifurcation anterior to the ventral sucker. We have no specimens from the other hosts to reexamine and no record of where they might be; the specimens from these hosts, as well as those from the other hosts (Nahhas and Cable, 1964; Nahhas and Short, 1965), should also be considered *T. pauca.* The sucker ratio of these specimens is 1:2.0–1:2.5; the ratio of pharyngeal length to width is about 2:1, and the position of the testes is like that shown by Manter (1947, fig. 85). One of the features of the Jamaican and the Floridian specimens is the presence of several muscle fibers around the opening of the ventral sucker, also shown in Manter (1947, fig. 85); these fibers seem to be less conspicuous in Freitas and Kohn's (1965) figure 1.

Several species in the *Tergestia–Theledera–Tergestina* group have been described to date. Dollfus (1973) did not include *Tergestina* Nagaty and Abdel Aal, 1964, in his review; he suggested recognizing 1 genus, *Tergestia* Stossich, 1899, with 2 subgenera, based on the location of the intestinal bifurcation: *Tergestia* (postacetabular) and *Theledera* Linton, 1910 (preacetabular). Bray and Gibson (1980) recognized the 2 taxa as genera, a position with which we concur. *Tergestina* was erected by Nagaty and Abdel Aal (1964) for *Tergestia*-like species with a true seminal receptacle and intercecal uterus not extending posterior to the testes. All 3 species in this genus (*T. abusherai* Nagaty and Abdel Aal, 1964, *T. plataxi* Nagaty and Abdel Aal, 1964, and *T. synganathusi* [*sic*] Gupta and Tandon, 1985) meet these criteria and all, like *Theledera,* have a preacetabular intestinal bifurcation. The preacetabular position of the intestinal bifurcation led Bray (1984) to transfer Nagaty and Abdel Aal's species to the genus *Theledera*; no species of *Theledera,* however, has a true seminal receptacle, and the only species of *Tergestia* reported to have one is *T. bengalensis* Gupta and Singh, 1985, which was described from a single specimen. If generic significance is to be accorded a seminal receptacle, then *T. bengalensis* should be transferred to a new genus. Bray and Gibson (1980) apparently placed greater importance on the location of the intestinal bifurcation than presence or absence of a true seminal receptacle. When we reviewed the Florida and Jamaica *Tergestia* material, we found 1 specimen of *T. acuta* that seemed to have a saclike seminal receptacle. Its location was almost midway between the ovary and the ventral sucker, and no connection to Mehlis' gland–ootype complex was seen. We interpret this as a swollen part of the uterus that can conceivably be mistaken for a true seminal receptacle.

Allobacciger macrorchis Hafeezullah and Siddiqi, 1970 (Figs. 2, 3)

DESCRIPTION (based on 31 specimens, 1 sectioned; measurements on 12): Body ovoid, 280–450 × 180–280 (351 × 229), widest at level of testes. Forebody 38–44% of body length; hindbody 46–54%. Tegument spinose; most spines lost but few seen in posterior end of body. Eye-spot pigments absent. Oral sucker terminal to subterminal, 67–102 × 75–111 (86 × 99). Ventral sucker 38–56 × 38–61 (48), near midbody. Sucker ratio 1:0.48–1:0.59 (1:0.52). Prepharynx very short; pharynx 35–38 (37) in diameter; esophagus short; intestinal bifurcation in

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Figures 1–8. 1. *Tergestia pauca* Freitas and Kohn, 1965, from *Scomberoides commersonianus,* ventrolateral view. 2, 3. *Allobacciger macrorchis* Hafeezullah and Siddiqi, 1970, from *Scolopsis ruppelli,* ventral view; ventral sucker in Figure 3 shown partially. 4. *Paradiscogaster farooqii* Hafeezullah and Siddiqi, 1970, from *Scatophagus argus,* ventral view. 5. *Neoparacryptogonimus sphericus* sp. n., holotype, from *Lutjanus coccineus,* ventral view. 6. *Paracryptogonimus ramadani* sp. n., holotype, from *Lutjanus fulviflamma,* dorsal view. 7. *P. ramadani,* paratype, ventral view showing ventral sucker embedded in body fold. 8. *P. ramadani* oral sucker with circumoral spines, freehand sketch.

anterior body third; ceca extending to near posterior end of body. Testes symmetrical, 63–78 (75) in diameter, globular to slightly ovoid, in posterior body third, each occupying almost one-third of width. Cirrus sac cylindrical to pyriform, containing ovoid to oblong seminal vesicle, short prostatic duct surrounded by few prostate cells, and nonspiny protrusible cirrus. Ovary 3 separate, spherical lobes, each about same size as pharynx, anterodorsal to and often contiguous with right testis; seminal receptacle poorly defined, dorsal to vitelline reservoir; uterus voluminous, with descending, lateral, and ascending coils filling most of hindbody: metraterm consisting of globular posterior vesicle and muscular cylindrical anterior segment. Vitellaria in 2 lateral clusters of several large extracecal follicles, in forebody, extending from near level of oral sucker to just anterior to ovarian level. Eggs numerous, 18–20 × 10–13 (19 × 12). Genital atrium large, between intestinal bifurcation and ventral sucker; pore postbifurcal. Excretory vesicle V shape, arms extending medially to midacetabular level; pore terminal.

HOST: †*Scolopsis ruppelli* Cuvier, 1830 (Nemipteridae).

SITE IN HOST: Intestine.

DEPOSITED SPECIMENS: NRC No. 26, USNPC No. 87743, BM(NH) No. 1998.3.6.2-3, HWML No. 39704.

REMARKS: The genus *Allobacciger,* erected by Hafeezullah and Siddiqi (1970) for *A. macrorchis* Hafeezullah and Siddiqi, 1970, from *Scolopsis vosmeri* (Bloch) from India, was compared with and distinguished from *Bacciger* Nicoll, 1914, and *Pseudobacciger* Nahhas and Cable, 1964, by a uterus terminating "in a spherical dilation filled with sperms followed distally by a short, highly muscular metraterm and lateral pretesticular ovary comprised of three separate, large, and spherical lobes." The structure of the metraterm in *Allobacciger* suggests a certain similarity to monorchiids with a bipartite terminal organ. The absence of spines in the cirrus and/or the metraterm rules it out. Furthermore, in all well-described species of monorchiids with bipartite terminal organ, the uterus enters the terminal organ at some point anterior to the posterior vesicle and not at its posterior end. Our specimens from a related host agree well with the description of Hafeezullah and Siddiqi's 5 specimens, differing only in their smaller size (almost half) and shorter prepharynx and esophagus. This finding represents a new locality record.

Paradiscogaster farooqii Hafeezullah and Siddiqi, 1970 (Fig. 4)

DESCRIPTION (based on 19 specimens): Body somewhat fusiform with rounded ends, 1,125–1,920 × 300–675 (1,352 × 454) at level of ventral sucker. Forebody 28–35% (32%) of body length, hindbody 35–49% (42%). Tegument spinose; spines extending to near posterior end of body. Eye-spot pigments absent. Oral sucker subterminal, 140–180 (154) in diameter. Ventral sucker in midbody, 280–530 × 180–370 (428 × 282) exclusive of its 4 semicircular papillae. Sucker ratio 1:2.1–1:2.8 (1:2.7). Prepharynx absent or very short; pharynx 37–67 × 45–72 (45 × 60); esophagus approximately 1/7–1/8 body length; ceca short, saclike, not reaching ventral sucker. Testes 120–170 × 95–110 (146 × 100), symmetrical to subsymmetrical, globular to ovoid, immediately posterior to, sometimes contiguous with, ventral sucker. Cirrus sac, 230–300 × 75–120 (280 × 90) wide, median, slightly overlapping anterior level of ventral sucker. Ovary 75–120 (101) in diameter, spherical to subspherical, immediately posterior to ventral sucker, often intertesticular; seminal receptacle 82–200 (138) in diameter, posterior to and overlapping ovary; uterus extending laterally and posteriorly to near end of body. Vitelline follicles typically in 4 lateral clusters of 3–9 follicles each; 2 anterior clusters overlapping ceca and 2 posterior ones extending from near posterior level of ventral sucker to level of testes. Eggs 25–33 × 15–20 (28 × 17). Excretory vesicle V shape, arms extending anteriorly to posterior level of ceca; pore terminal.

HOST: *Scatophagus argus* Linnaeus, 1766 (Scatophagidae).

SITE IN HOST: Intestine.

DEPOSITED SPECIMENS: NRC No. 21, USNPC No. 87744, BM(NH) No. 1998.3.6.4, HWML No. 39705.

REMARKS: This is the third report of *Paradiscogaster farooqii*; the measurements and descriptions are in general agreement with those of Hafeezullah and Siddiqi (1970) from the same host in India. Bray (1984) reported this species from *Monodactylus argenteus* (Linnaeus) (Monodactylidae) from Sodwana, Natal; Bray's figure, apparently due to contraction, does not

show the typical distribution of the vitelline follicles seen in Hafeezullah and Siddiqi and the Kuwaiti specimens. The Kuwaiti material keys out quite well to this species using Bray (1984) but to *P. glebulae* Bray et al., 1994, in Bray et al. (1994). Bray noted some differences between the Sodwana and the Indian specimens relating to esophageal length, length and extent of the ceca in relation to the ventral sucker, and the presence of spines. In our specimens, the esophagus is longer than the ceca but shorter than that described by Hafeezullah and Siddiqi. In some specimens, the ceca overlap the anterior level of ventral sucker. The tegument is spiny, with spines extending to the posterior end of the body. The posterior extent of the cirrus sac varies from anterior level to midlevel of the ventral sucker. Mehlis' gland is dextrolateral to the ovary. Hafeezullah and Siddiqi described the ventral sucker as "discoid and emarginate." These authors used the same terms to describe the ventral sucker of another species, *Odontocotyle* (*Odontotrema*) *arabii* Hafeezullah and Siddiqi, 1970, whose figure has distinct semicircular papillae similar to those in our *P. farooqii* (Fig. 4). The ventral sucker in most of our specimens is, however, like those figured for the Indian and Sodwana material. We are certain that all our specimens belong to the same species. In a few specimens, 2–3 follicles are seen laterally on each side at midacetabular level. A vitelline distribution in which the follicles extend from the anterior level of the ventral sucker to its posterior level is characteristic of *Discogasteroides* Strand, 1934. The species in the genera *Paradiscogaster* Yamaguti, 1934, *Discogasteroides,* and *Pseudodiscogasteroides* Gupta, 1955, show overlapping characteristics. Bray et al. (1994) present an excellent review of the group. This finding in the Arabian Gulf represents a new locality record.

Cryptogonimidae
Neoparacryptogonimus sphericus sp. n. (Fig. 5)

DESCRIPTION (based on 5 specimens, 1 sectioned): Body almost spherical to ovoid, 535–770 × 423–616 (640 × 538), widest at level of testes. Forebody 30–33% of body length, hindbody 60–65%. Tegument spinose; spines embedded in thick tegument, extending to posterior end of body. Eye-spot pigments present. Cephalic glands numerous, around oral-pharyngeal area. Oral sucker terminal, 113–160 × 144–209 (128 × 183); circumoral spines up to 80, in 1 uninterrupted circle, each spine about 12 × 4. Ventral sucker 61–76 × 61–90 (69 × 74), in anterior body third, embedded in cuticular fold. Sucker ratio 1:0.40–1:0.54 (1:0.47). Gonotyl absent. Prepharynx absent; pharynx 46–57 × 51–57 (53 × 55); esophagus absent; ceca bifurcating in anterior body fifth, extending to near posterior end of body. Testes 141–143 × 143–144 (142 × 143), spherical to ovoid, symmetrical to subsymmetrical, intercecal to partly cecal, near midbody; seminal vesicle bipartite, consisting of 2 spherical segments, each as large as ventral sucker, overlapping its anterior border; prostatic duct and cirrus short. Posttesticular space 45–50% body length. Ovary median, multilobed (20–30 lobes), posttesticular and overlapping posterior edge of testes, occupying 30–35% of body width; seminal receptacle ovoid, immediately anterior to ovary, often concealed by uterine coils; Laurer's canal not seen; ootype–Mehlis' gland barely visible, concealed by seminal receptacle; uterus with descending, lateral, and ascending coils extending to extracecal space. Vitelline follicles mostly extracecal, extending from near posterior level of testes to about midway between ovary and posterior end of body. Eggs 18–24 × 12–16. Genital pore within ventrogenital sac, surrounded by weakly developed muscle strands. Excretory vesicle Y shape, arms extending to level of intestinal bifurcation.

TYPE HOST: *Lutjanus coccineus* Cuvier and Valenciennes, 1828 (Lutjanidae).

OTHER HOST: *Batrachus grunniens* Linnaeus, 1758 (Batrachoididae).

SITE IN HOSTS: Intestine.

HOLOTYPE: NRC No. 27.

PARATYPES: USNPC No. 87740, BM(NH) No. 1998.3.6.5.

ETYMOLOGY: The species name reflects the body shape of the worm.

REMARKS: This species was placed in the genus *Neoparacryptogonimus* based on Hafeezullah's (1975) revision of the genus *Paracryptogonimus* Yamaguti, 1934; he used the distribution of the vitellaria as a criterion to erect the genus *Neoparacryptogonimus,* to which he transferred *P. ovatus* Yamaguti, 1952, *P. rostratus* Nagaty and Abdel Aal, 1961, *P. saccatus* Manter, 1963, and *P. orientalis* Fischthal and Kuntz, 1964. Hafeezullah argued that differences in pattern of distribution of vitelline fol-

licles had already been used to distinguish the cryptogonimidlike genera *Metadena* Linton, 1910, *Pseudometadena* Yamaguti, 1952, and *Neometadena* Hafeezullah and Siddiqi, 1970. He distinguished *Neoparacryptogonimus* from *Paracryptogonimus* chiefly by vitelline follicles that are "lateral to testes, protruding into pre- and post-testicular lateral fields," in contrast with follicles that are "essentially pre-testicular in lateral or dorsolateral fields." We have reviewed the description of the species that he included in his revision and those described since then and tend to agree that they do fall into 2 distinct groups with almost no overlap.

The only other species in the *Paracryptogonimus-Neoparacryptogonimus* complex with posttesticular ovarian lobes is *N. saccatus* (Manter, 1963) from which *N. sphericus* sp. n. may be distinguished by the absence of a uterine sac, the distribution of the vitelline follicles, and size, shape, and location of the seminal vesicle.

Paracryptogonimus ramadani sp. n. (Figs. 6–8)

DESCRIPTION (based on 10 specimens): Body ovoid, 691–1,408 × 320–666 (906 × 504), widest at level of testes. Forebody 25–30% of body length; hindbody 50–75%. Tegument spinose; most spines lost. Eye-spot pigments present. Cephalic glands numerous, in oral-pharyngeal area. Oral sucker terminal, 80–128 × 70–154 (92 × 113); circumoral spines up to 60, in 1 uninterrupted circle, each spine about 11 × 5; spines lost in many specimens. Prepharynx absent or very short; pharynx 33–64 × 33–76 (46 × 49); esophagus absent or very short; intestinal bifurcation about midway between pharynx and ventral sucker; ceca extending to near posterior end of body. Ventral sucker 60–90 (71) in diameter, embedded in cuticular fold, posterior to intestinal bifurcation. Sucker ratio 1:0.45–1:0.72 (1:0.52). Gonotyl absent. Testes 166–200 × 130–180 (186 × 147), symmetrical to subsymmetrical, ovoid, overlapping ceca, in posterior half of body; seminal vesicle bipartite, each part spherical, overlapping posterior border of ventral sucker; pars prostatica poorly developed, cirrus short. Posttesticular space 20–25% body length. Ovary median, consisting of 20–30 lobes, just anterior to and slightly overlapping testes, occupying about one-third body width; seminal receptacle spherical, between seminal vesicle and anterior level of ovary; Laurer's canal not seen; ootype–Mehlis' gland anterodorsal to ovary concealed by seminal receptacle; uterus with descending and ascending coils extending lateral to ceca, occupying most of hindbody. Vitelline follicles lateral, extending from anterior level of testes to midlevel of ventral sucker, rarely reaching its anterior border. Eggs 15–25 × 9–15 (20 × 12). Genital pore within ventrogenital sac, surrounded by circular muscle. Excretory vesicle Y shape, anterior extent of arms not observed.

TYPE HOST: *Lutjanus fulviflamma* Forsskål, 1775 (Lutjanidae).

SITE OF INFECTION: Intestine.

HOLOTYPE: NRC No. 28.

PARATYPES: USNPC No. 87741, BM(NH) No. 1998.3.6.6, HWML No. 39706.

ETYMOLOGY: This species is named for Professor M. M. Ramadan in recognition of his contributions to the knowledge of digeneans of the Red Sea and the Arabian Gulf.

REMARKS: This species is most similar to *P. aloysiae* (Stossich, 1899) Bartoli and Gibson, 1995, *P. americanus* Manter, 1940, *P. neoamericanus* Siddiqi and Cable, 1960, and *P. sootai* Hafeezullah, 1975. It differs from *P. aloysiae* in body shape, with length greater than 2 times width; the testes are longitudinally rather than transversely ovoid and are in more anterior extent of vitelline follicles. *Paracryptogonimus ramadani* sp. n. differs from *P. americanus* and *P. neoamericanus* in its relatively larger testes, more anterior extent of the vitelline follicles, and globular bipartite seminal vesicle; from *P. sootai,* it is distinguished by its smaller sucker ratio, relatively smaller testes, and smaller eggs.

Saoud et al. (1988a) described *Allacanthochasmus lutjani* from *Lutjanus fulviflamma* from coastal waters of Qatar, Arabian Gulf. This trematode has a superficial resemblance to *P. ramadani* but may be distinguished from it by somewhat more anterior vitelline follicles, fewer circumoral spines, intertesticular ovary, and presence of a gonotyl. *Allacanthochasmus* is a freshwater cryptogonimid genus; its 2 previously known species, *A. varius* Van Cleave, 1922, and *A. artus* Mueller and Van Cleave, 1932, were described, respectively, from the Mississippi River and adjacent lakes and Oneida Lake. The occurrence of a marine species, *A. lutjani,* assigned to a North American freshwater genus in a distant place, such as Qatari waters in the Arabian Gulf, is unusual and unexpected.

The addition of the 2 new taxa reported in this paper brings the total to 33 nominal species assigned to the genera *Paracryptogonimus* and *Neoparacryptogonimus,* 28 in the former and 5 in the latter: *Paracryptogonimus acanthostomus* Yamaguti, 1934; *P. americanus* Manter, 1940; *P. apharei* (Yamaguti, 1942) Velasquez, 1961; *P. mexicanus* Bravo-Hollis, 1956; *P. macrospinus* Caballero, Hidalgo and Grocott, 1956; *P. leilae* (Nagaty, 1957) Manter, 1963; *P. neoamericanus* Siddiqi and Cable, 1960; *P. centropomi* Siddiqi and Cable, 1960; *P. manilensis* Velasquez, 1961; *P. echinostomus* (Oshmarin, Mamaev and Parukhin, 1961) Yamaguti, 1971; *P. hirastrictus* Manter, 1963; *P. morosovi* (Parukhin, 1965) Yamaguti, 1971; *P. ghanensis* Fischthal and Thomas, 1968; *P. vamagutii* Lamothe-Argumedo, 1969; *P. provitellosus* Durio and Manter, 1969; *P. longitestis* Durio and Manter, 1969; *P. catalae* Durio and Manter, 1969; *P. testitactus* Durio and Manter, 1969; *P. apharei* Yamaguti, 1970; *P. muscularis* Yamaguti, 1970; *P. onaga,* Yamaguti, 1970; *P. ula ula* Yamaguti, 1970; *P. sootai* Hafeezullah, 1975; *P. elongatus* Gu and Shen, 1979; *P. lutiani* Wang, 1991; *P. aloysiae* (Stossich, 1885) Bartoli and Gibson, 1995; *P. xiamenensis* Liu, 1996; and *P. ramadani* sp. n.; *Neoparacryptogonimus ovatus* Yamaguti, 1952; *N. rostratus* Nagaty and Abdel Aal. 1960; *N. saccatus* Manter, 1963; *N. orientalis* Fischthal and Kuntz, 1964; and *N. sphericus* sp. n. The status of some species is uncertain: *P. apharei* (Yamaguti, 1942) was described as *Siphoderina apharei,* from *Aphareus furcatus* (Lutjanidae) from Naha, Okinawa, Japan, and later was transferred to *Metadena* by Yamaguti (1953). Velasquez (1961) recovered 4 specimens from *Lutjanus* sp. from Malabon, Luzon Island, the Philippines, which she considered very similar to those of Yamaguti except for the presence of circumoral spines, and transferred it to *Paracryptogonimus*; this transfer was accepted by Lamothe-Argumedo (1969) and Hafeezullah (1975). Yamaguti (1971) made no reference to Velasquez (1961) when he transferred it to *Pseudosiphoderoides* Yamaguti, 1958. Since Velasquez's material was not obtained from the same host species and locality, we prefer to accept Yamaguti's classification. *Paracryptogonimus leilae* from *Lethrinus rostratus* from the Red Sea was returned to the genus *Metadena* by Ramadan according to Saoud et al. (1988a) on the basis that the genus *Metadena,* which has no circumoral spines, "could be separated from *Paracryptogonimus* by the presence of numerous dermal glands in the anterior part of the body, and by the extension and topography of the vitelline follicles." Manter (1963) had studied 2 paratypes of this species and found them to have small circumoral spines. Saoud et al. (1988a), who recovered 2 mature and 5 immature specimens from *Lutjanus fulviflamma* from Qatari waters, agreed with Ramadan "noticing the absence of the crown of oral spines in living specimens." In our opinion, *P. leilae* is very similar to *P. ghanensis* Fischthal and Thomas, 1968, from *Lutjanus guineensis* from Ghana except for slightly less anterior extent of vitelline follicles; for the time being, we will retain its validity based on Manter's examination of paratypes. According to Saoud et al. (1988a), Ramadan also transferred *P. rostratus* to *Metadena.* Manter (1963) had considered it a synonym of *P. ovatus,* with which we agree, and we currently accept it in the genus *Neoparacryptogonimus.* The slight differences between *P. americanus* and *P. neoamericanus* led Overstreet (1969) to consider the latter a synonym of the former. We restudied 1 specimen of *P. neoamericanus* collected from *Ocyurus chrysurus* from Curaçao and tend to agree. *Paracryptogonimus lutiani* Wang, 1991, is the only species assigned to this genus with an entire ovary. It is not adequately described but is retained, for the time being, in *Paracryptogonimus* considering variability in lobation of the ovary in the group, with a few species having 3–5 lobes but most with multilobed ovaries. The only other genus of cryptogonimids with a single ovary is *Mahrosa* Nagaty and Abdel Aal, 1961, which was considered *nomen nudum* by Manter (1963). Liu (1996) described the testes of *P. xiamenensis* as symmetrical or diagonal. His figure shows what we interpret as subsymmetrical, which places it close to *P. ula ula*; if arrangement of testes is considered diagonal, it comes close to *P. manilensis,* from which it may be distinguished by a less elongated body, ovoid rather than elongated testes, shorter ceca, and larger eggs (19–30 × 11–14 compared with 14.5–16 × 7–9.5).

A key to the 30 species of *Paracryptogonimus* and *Neoparacryptogonimus* that we recognize in this paper, including the 2 new ones from Kuwait, follows.

Key to the Species of *Paracryptogonimus* and *Neoparacryptogonimus*

1a. Vitelline follicles lateral to testes, protruding into pre- and posttesticular fields ..... *Neoparacryptogonimus*, 2

1b. Vitelline follicles lateral or dorsolateral, chiefly in pretesticular fields ..... *Paracryptogonimus*, 5

2a. Oral sucker smaller than ventral sucker; sucker ratio 1:1.41; testes symmetrical, intercecal, in posterior half of body; seminal vesicle thin walled, somewhat saccular, dorsal to anterior two-thirds of ventral sucker; ovary 4 lobed, left lobe separated from others by uterine coil; eggs 17–18 × 8–9; circumoral spines 74–80 ..... *N. orientalis*

2b. Oral sucker as large as or larger than ventral sucker 3

3a. Suckers equal or subequal; testes spherical, near midlevel of body or slightly more posterior; seminal vesicle tubular, winding, from near midbody to left side of anterior level of ventral sucker; ovary 3–4 lobes, pretesticular; vitelline follicles extending laterally from level of seminal vesicle to near end of ceca; circumoral spines about 80 ..... *N. ovatus/N. rostratus*

3b. Oral sucker about twice the size of the ventral sucker; ovary multilobed, unless degenerate, posttesticular 4

4a. Uterine sac present ..... *N. saccatus*

4b. Uterine sac absent ..... *N. sphericus* sp. n.

5a. Testes symmetrical or subsymmetrical 6

5b. Testes diagonal 18

6a. Ovarian lobes less than 5; vitelline follicles extending laterally from posterior level of ventral sucker to esophageal-pharyngeal level; sucker ratio 1:0.47; circumoral spines 135 ..... *P. provitellosus*

6b. Ovarian lobes more than 5 7

7a. Body length less than twice 8

7b. Body length more than twice 9

8a. Sucker ratio 1:0.79–1:0.90; testes usually transversely ovoid, small, occupying less than one-third body width; ovary intertesticular; vitelline follicles extending between anterior border of ovary and intestinal bifurcation; terminal end of ceca swollen; circumoral spines 78 ..... *P. aloysiae*

8b. Sucker ratio 1:0.25–1:0.38; testes large, occupying more than two-thirds body width; ovary anterior to testes; vitelline follicles lateral, extending from anterior level of testes to near intestinal bifurcation; terminal end of ceca not swollen; circumoral spines present but many lost ..... *P. sootai*

9a. Vitelline follicles restricted to gonadal-acetabular level 10

9b. Vitelline follicles more extensive reaching to at least anterior level of ventral sucker 12

10a. Body elongate, length at least 2.5× width; ovary near midbody, far removed from testes; circumoral spines 37–39 ..... *P. macrospinus*

10b. Body ovoid to plump; length less than 2.5× width; ovary close to testes 11

11a. Testes large, occupying almost two-thirds body width; vitelline follicles reaching mid- or anterior level of ventral sucker; seminal vesicle globular, bipartite ..... *P. ramadani* sp. n.

11b. Testes relatively small; vitelline follicles barely reaching posterior level of ventral sucker ..... *P. americanus/P. neoamericanus*

12a. Body length more than 3× width; gonads in posterior half of body; seminal vesicle tubular, entirely anterior to ventral sucker; vitelline follicles lateral, in midbody; ovary close to testes; circumoral spines 74–102 ..... *P. yamagutii*

12b. Body length less than 3× width 13

13a. Vitelline follicles extending from anterior level of testes to anterior level of ventral sucker; testes extracecal, at or just anterior to midbody; seminal vesicle bipartite; circumoral spines 64; sucker ratio 1:0.78 ..... *P. centropomi*

13b. Vitelline follicles extending to at least intestinal bifurcation 14

14a. Testes elongate, their length 2× width, extracecal, mostly in posterior body third; ovary in midbody, well removed from testes; sucker ratio 1:0.46–1:0.50; ceca converging in posterior body third ..... *P. longitestis*

14b. Testicular length less than twice width; testes overlap ceca 15

15a. Testes ovoid 16

15b. Testes elongate 17

16a. Oral sucker slightly larger than ventral sucker; transverse sucker ratio 1:0.73; circumoral spines 42–58 ..... *P. ula ula*

16b. Oral sucker much larger than ventral sucker; transverse sucker ratio 1:0.59; circumoral spines 55 ..... *P. xiamenensis*

17a. Testes diagonally elongate; vitelline follicles extending to pharyngeal level; sucker ratio 1:0.65; circumoral spines 70–75 ..... *P. ghanensis*

17b. Testes longitudinally elongate; vitelline follicles extending to intestinal bifurcation; number of circumoral spines unknown ..... *P. leilae*

18a. Ovary entire; testes globular, large; vitelline follicles extending from posterior level of seminal vesicle to just anterior to intestinal bifurcation; sucker ratio 1:0.74; circumoral spines 58–60 ..... *P. lutiani*

18b. Ovary lobed 19

19a. Testes entire or slightly indented 20

19b. Testes usually deeply incised 28

20a. Ventral muscular pads present in acetabulo-pharyngeal region; sucker ratio 1:0.68; circumoral spines up to 55; ovary rosette shaped; vitelline follicles in 4–5 bunches between midovarian level and ventral sucker ..... *P. muscularis*

20b. Ventral muscular pads absent 21

21a. Body elongate, length 5–7× width 22

21b. Body ovoid to plump, length less than 5× width 23
22a. Body length 5× width; posttesticular space about one-sixth body length; circumoral spines 21–27; sucker ratio 1:0.48 ..... *P. elongatus*
22b. Body length at least 6.5× width; posttesticular space one-third body length; sucker ratio 1:0.83 ..... *P. mexicanus*
23a. Testes contiguous, anterior testis intercecal; uterus extending lateral to ceca; sucker ratio 1:0.7; vitelline follicles between anterior testis and posterior level of ventral sucker; circumoral spines 42–46 ..... *P. testitactus*
23b. Testes separated by uterine coils 24
24a. Testes intercecal, either testis more anterior; body ovoid; uterus intercecal; sucker ratio of transverse diameter 1:0.62; circumoral spines 56–58 ..... *P. catalae*
24b. Testes overlap ceca 25
25a. Vitelline follicles extending from ovarian level to near intestinal bifurcation; testes large, elongate; circumoral spines not determined; sucker ratio 1:0.49 ..... *P. manilensis*
25b. Vitelline follicles not extending anterior to ventral sucker 26
26a. Vitelline follicles extending anteriorly to level of ventral sucker and inward, meeting or almost meeting medially; ovarian lobes not tightly compact; excretory canals not extending anterior to pharynx; circumoral spines 80–94 ..... *P. hirastrictus*
26b. Vitelline follicles not close medianly; circumoral spines 49–58 27
27a. Testes ovoid, partially extracecal; intestinal ceca converge medially in area between testes; ovarian lobes compact, rosette shape; circumoral spines 49 ..... *P. acanthostomus*
27b. Testes oval-elliptical, occasionally with lateral incisions, mostly intracecal; ovary rosette shaped; vitelline follicles in several bunch-like clusters between midlevel of anterior testis and posterior level of ventral sucker; circumoral spines 49–58 ..... *P. onaga*
28a. Vitelline follicles extending from midovarian level short distance anterior to ventral sucker but not reaching intestinal bifurcation ..... *P. echinostomus*
28b. Vitelline follicles not extending anterior to ventral sucker 29
29a. Ovary rosette shaped, large, occupying almost half body width; circumoral spines 38–44 ..... *P. apharei*
29b. Ovary relatively small, occupying about one-fifth of body width ..... *P. morosovi*

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Studies on Cercariae from Kuwait Bay. IX. Description and Surface Topography of *Cercaria kuwaitae* IX sp. n. (Digenea: Zoogonidae)

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ABSTRACT: A new zoogonid cercaria, *Cercaria kuwaitae* IX sp. n., from the prosobranch gastropod *Umbonium vestiarium* (Linnaeus) from Kuwait Bay is described. Surface topography of the sporocyst and the cercaria is studied by scanning electron microscopy. The new cercaria is compared with the previously described zoogonid cercariae. This is the first zoogonid cercaria to be recorded from a gastropod from the Arabian Gulf region and the second to be reported from an archaeogastropod host.

KEY WORDS: Digenea, *Cercaria kuwaitae* IX sp. n., Zoogonidae, cercaria, ultrastructure, *Umbonium vestiarium*, Kuwait Bay.

Adult digenetic trematodes of the family Zoogonidae Odhner, 1902, live in the digestive tracts of fishes (Bray and Gibson, 1986). The larval stages utilize prosobranch gastropods as first intermediate host and a wide range of benthic invertebrates, particularly polychaetes and echinoderms, as second intermediate host (Stunkard, 1938, 1943; Køie, 1976). Zoogonid cercariae are tailless xiphidiocercariae (cercariaeum) produced in daughter sporocysts in the digestive gland and gonad of the first intermediate host. Larval zoogonids have been recorded in gastropods from both subtropical and temperate zones, including Chilka Lake, India (Madhavi and Shameem, 1991), the Black Sea (Sinitzin, 1911; Dolgikh, 1970), the Gulf of Mexico (Wardle, 1993), the Mediterranean Sea (Palombi, 1930; Stunkard, 1932), the North Sea (Lebour, 1911; Køie, 1969), and the western Atlantic Ocean (Linton, 1915; Miller and Northup, 1926; Stunkard, 1943).

The trochid gastropod *Umbonium vestiarium* is a common inhabitant of sandy shores of the Indo–Western-Pacific region. Although several species of gastropods in Kuwait Bay are known to host digenean trematodes (Abdul-Salam and Sreelatha, 1991; Abdul-Salam and Al-Khedery, 1992; Abdul-Salam et al., 1994), there are no references to parasitic associations in *U. vestiarium*. The present study describes a new larval zoogonid from *U. vestiarium*.

Materials and Methods

Naturally infected specimens of *Umbonium vestiarium* were collected from the Towers Beach in Kuwait City, southern Kuwait Bay, during February–June 1995. The shells of snails were crushed, and the soft parts were examined under a dissecting microscope. Cercariae were studied live, unstained or vitally stained with 5% neutral red, and after fixation in hot acetic acid–formalin-alcohol (AFA) and staining in acetocarmine. As naturally released cercariae were not found, it was necessary to use the most mature specimens found in snail tissues. Measurements in micrometers, with averages in parentheses, were taken from 20 AFA-fixed specimens. Figures were drawn with the aid of a camera lucida from vitally stained specimens. For scanning electron microscopy, living cercariae and daughter sporocysts were fixed in a solution containing 4% formaldehyde and 1% glutaraldehyde in 0.1 M phosphate buffer (pH 7.2) at 4°C. Following the appropriate buffer wash, the specimens were postfixed in 1% osmium tetroxide in the same buffer for 5 min at 4°C, were dehydrated in a series of anhydrous acetone, and were critical-point dried. The specimens were coated with gold-palladium and then were examined in a Jeol JSM-6300 scanning electron microscope.

The nomenclature for the new cercaria follows the system of Cable (1956) from Sewell (1922).

Results

Cercaria kuwaitae IX sp. n. (Figs. 1–7)

DESCRIPTION: Tailless xiphidiocercariae, body oval, 145–193 (165) long, 53–68 (58) wide. Tegument thick with prominent spines. Body containing abundant refringent granules, rendering body opaque. Oral sucker subterminal, circular, 35–40 (36) long, 30–35 (32) wide. Stylet anteriodorsal to oral sucker, lanceolate, about 0.02 long. Prepharynx very short, pharynx 10–15 (13) long, 12.5 wide. Esophagus 15–30 (25) long, bifurcating in posterior forebody, ceca short, somewhat saccular, terminating anterior to ventral sucker, containing ingesta that stain or-

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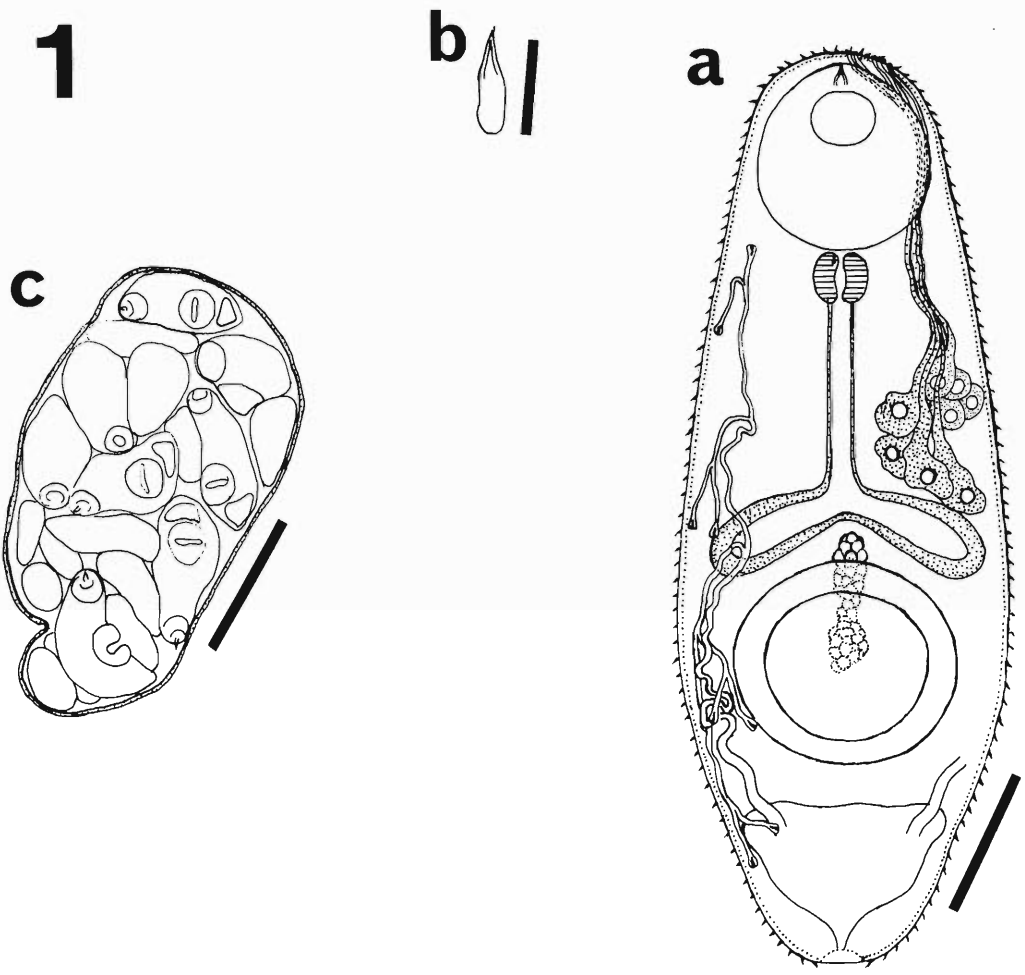


Figure 1. ***Cercaria kuwaitae*** **IX sp. n. from the trochid gastropod** ***Umbonium vestiarium.*** **a. Cercaria, ventral view. Scale bar = 50 μm. b. Stylet. Scale bar = 13 μm. c. Sporocyst. Scale bar = 250 μm.**

ange with neutral red. Ventral sucker posterior to midlevel of body, protrusible, 40–53 (45) long, 40–48 (44) wide. Eight pairs of penetration glands, anteriolateral to ventral sucker, disposed in 2 levels, 4 anterior and 4 posterior, each gland irregular in shape with prominent nucleus and fine granular cytoplasm, posterior group staining deeply with neutral red. Ducts of penetration glands in 2 narrow bundles opening through pores lateral to stylet. Genital primordia elongated mass, dorsal to ventral sucker. Excretory bladder saccate, nonepithelial, containing yellowish material; excretory pore surrounded by sphincter. Primary collecting ducts arising from each side of bladder near its anterior end, dividing posterior to ventral sucker. Flame cell formula 2[(2 + 2) + (2 + 2)] = 16. Sporocyst an oval sac, thin-walled, nonpigmented, 180–320 (269) long, 130–230 (161) wide, containing 2–6 (4) mature cercariae and germ balls.

HOST: *Umbonium vestiarium* Linnaeus, 1758 (Prosobranchia: Trochidae).

LOCALITY: Towers Beach, Kuwait City, Kuwait Bay.

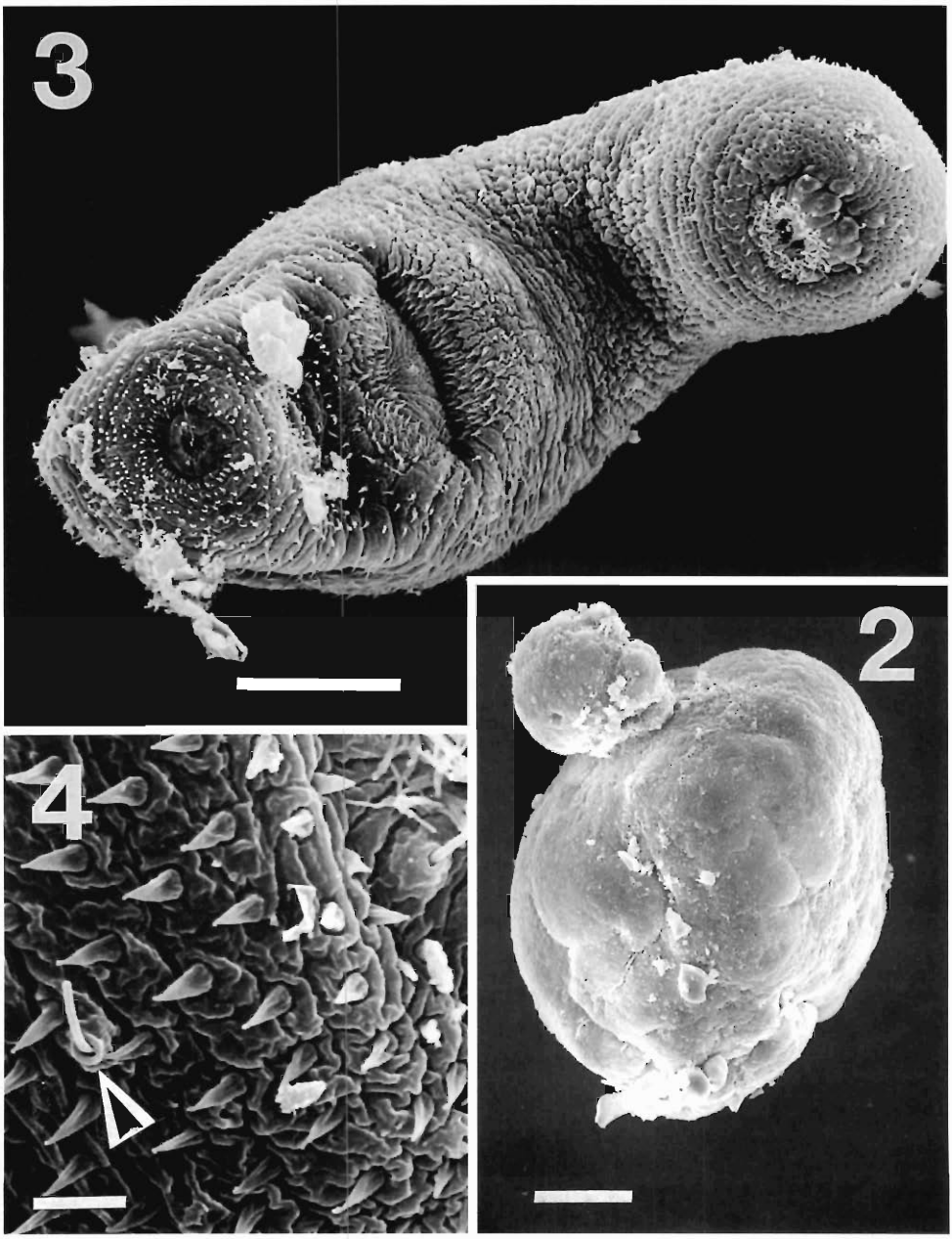
HABITAT: Sandy substrate.

INFECTION SITE: Gonad and hepatopancreas.

PREVALENCE OF INFECTION: 4 of 385 snails (1.0%).

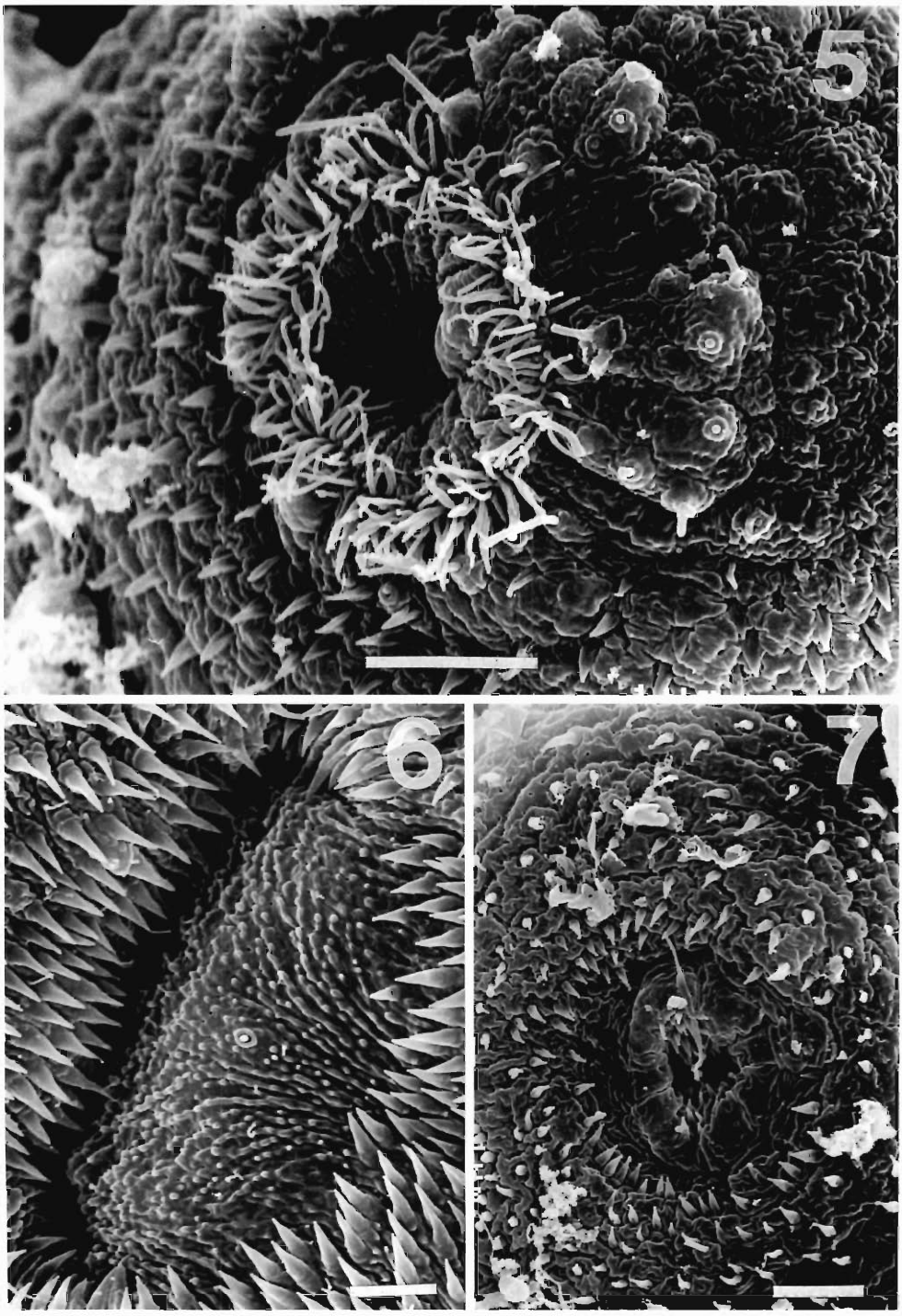
SPECIMENS DEPOSITED: Helminth Collection, Department of Biological Sciences, Kuwait University (Accession No. KUHC-C-ZGI).

SCANNING ELECTRON MICROSCOPY OBSERVA-



Figures 2–4. Scanning electron micrographs of *Cercaria kuwaitae* IX sp. n. from the trochid gastropod *Umbonium vestiarium*. 2. Mature sporocyst showing irregularly shaped spherical mass. Scale bar = 30 μm. 3. Ventral view of entire cercaria showing tegumental annulations and spines, ventral and oral suckers, and excretory pore. Scale bar = 20 μm. 4. Tegument posterior to oral sucker showing concentrically arranged peglike spines and ciliated sensory papilla (arrowhead). Scale bar = 3 μm.

TIONS: Sporocyst appears as irregular spherical mass with rough outer surface (Fig. 2). Cercaria is elongate cylinder with rounded anterior end and slightly blunt posterior end (Fig. 3). Body surface is folded into circumferential ridges bearing rows of spines with simple tips and few ciliated sensory papillae, each with a cilium arising from a circular tegumental collar (Fig. 4).



Figures 5–7. Scanning electron micrographs of *Cercaria kuwaitae* IX sp. n. from the trochid gastropod *Umbonium vestiarium*. 5. Subterminal region showing oral sucker fringed by long microvilli and sensory papillae, each with a cilium protruding from a tegumental swelling. Scale bar = 4 μm. 6. Ventral sucker with lips armed with spikelike spines, and internal surface covered with fine tubercles and bearing a centrally located ciliated sensory papilla. Scale bar = 3 μm. 7. Posterior end showing excretory opening surrounded by a sphincter. Tegumentary spines and minute pores are prominent at this area. Scale bar = 3 μm.

Tegumental spines are dense around oral sucker and excretory pore. Surface tegument bears minute pores. Oral sucker is transversally oval, fringed by 1-μm-long microvilli and sensory papillae, each with a cilium up to 2-μm long protruding from a tegumental mound (Fig. 5). Sensory papillae around oral sucker are disposed single or in groups of 2–4. Ventral sucker is transversally elongate with protruding anterior and posterior lips (Fig. 6). Sucker lips are armed with inwardly directed stout spikelike spines, about 2-μm long. Surface of ventral sucker is covered with fine tubercles (microvilli) and bears a centrally located ciliated sensory papilla. Ventral sucker region is devoid of sensory papillae. Excretory pore is surrounded by protrusible sphincter (Fig. 7).

Discussion

This is the first report of natural infection of the trochid gastropod *Umbonium vestiarium* with a zoogonid larva in the Arabian Gulf region and the second report of a zoogonid infection in an archaeogastropod in addition to the turbinid *Batillus cornutus* host of *Cercaria brachycaeca* (see Shimura and Ito, 1980). All the other previously reported gastropod hosts for zoogonids (tabulated by Madhavi and Shameem, 1991) are neogastropods belonging to genera of the superfamily Buccinidae, i.e., *Buccinum, Mitrella, Nassarius, Natica,* and *Peuroploca.*

Members of the family Zoogonidae Odhner, 1902, have a distinctive type of tailless xiphidiocercariae. So far, only 8 species of zoogonid larvae have been reported worldwide. *Cercaria kuwaitae* IX sp. n. differs from the cercariae of *Zoogonoides laevis* Linton, 1940, *Zoogonus lasius* (Liedy, 1891) Stunkard, 1940, *Zoogonus rubellus* (Olsson, 1868) Odhner, 1902, and *Cercaria chilkaensis* Madhavi and Shameem, 1991, in having intestinal ceca that do not extend posterior to ventral sucker. The present cercaria is similar to the cercariae of *Diphterostomum brusinae* Stossich, 1904 (synonym: *Cercaria inconstans* Sinitzin, 1911), *Cercaria brachycaeca,* and *Cercaria* sp. 'A' Wardle, 1993, in having short and stout ceca but differs in having 8 pairs of penetration glands disposed in 2 levels. The present cercaria differs from the cercaria of *Zoogonoides viviparus* (Olsson, 1868) Odhner, 1902, in its very short prepharynx and lack of disclike posterior end. Other differences between the new species and the previously reported species are in body size, molluscan host species, and geographic locality.

The surface topography and associated structures of the present cercaria, as revealed by scanning electron microscopy, does not differ essentially from that of the cercaria of *Zoogonoides viviparus* (see Køie, 1971). In contrast to larvae and adults of most other trematodes, the ventral sucker of the present cercaria is devoid of dome-shaped papillae and bears a centrally located ciliated papilla. Suckers of the new cercaria are fringed by characteristically long microvilli. Similar structures have been observed in some opecoelid (Lo et al., 1975) and gymnophallid (Russell-Pinto et al., 1996) cercariae. In *Z. viviparus* cercaria, Køie (1976) reported the gradual disappearance of microvilli surrounding the suckers after encystment and suggested that they may be involved in nutrient absorption during migration in the molluscan host.

Acknowledgment

We thank the staff of the Electron Microscopy Unit, Faculty of Science, Kuwait University for technical assistance.

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Obituary Notice

JAMES H. TURNER

13 June 1922–24 December 1997

Elected to Membership 9 March 1949

Recipient of the First Brayton H. Ransom Memorial Award 8 October 1960

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65(2), 1998 p. 147–159

Neotropical Monogenoidea. 34. Species of *Demidospermus* (Dactylogyridae, Ancyrocephalinae) from the Gills of Pimelodids (Teleostei, Siluriformes) in Argentina

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ABSTRACT: The diagnosis of *Demidospermus* Suriano, 1983, is emended, and 9 species (5 new) are described or reported from the gills of 4 species of Pimelodidae (Siluriformes) from Argentina: *D. armostus* sp. n. from *Pimelodus albicans* and *Pimelodus clarias; D. bidiverticulatum* (Suriano and Incorvaia, 1995) comb. n. from *Pimelodus clarias* and *P. albicans* (new host record); *D. cornicinus* and *D. leptosynophallus* spp. n. from *Iheringichthys westermanni; D. idolus* and *D. majusculus* spp. n. from *Pimelodus albicans*; *D. paravalenciennesi* Gutiérrez and Suriano, 1992, and *D. uncusvalidus* Gutiérrez and Suriano, 1992, from *Pimelodus clarias*; and *D. valenciennesi* Gutiérrez and Suriano, 1992, from *Parapimelodus valenciennesi. Omothecium* Kritsky, Thatcher and Boeger, 1987, and *Paramphocleithrium* Suriano and Incorvaia, 1995, are considered junior synonyms of *Demidospermus.*

KEY WORDS: Monogenoidea, Dactylogyridae, Ancyrocephalinae, *Demidospermus, Demidospermus armostus* sp. n., *Demidospermus bidiverticulatum* comb. n., *Demidospermus cornicinus* sp. n., *Demidospermus idolus* sp. n., *Demidospermus leptosynophallus* sp. n., *Demidospermus majusculus* sp. n., *Demidospermus paravalenciennesi, Demidospermus uncusvalidus, Demidospermus valenciennesi, Omothecium, Paramphocleithrium,* Siluriformes, Pimelodidae, *Iheringichthys westermanni, Parapimelodus valenciennesi, Pimelodus albicans, Pimelodus clarias,* Río de la Plata, Argentina.

Demidospermus was proposed by Suriano (1983) for *D. anus,* a previously undescribed species from the gills of *Loricaria anus* (Loricariidae) in Argentina. Suriano (1983) identified the presence of "partially encapsulated" sperm in the testis of the adult worm as the principal diagnostic character for the genus. Gutiérrez and Suriano (1992) added generic characters, labeled encapsulated sperm, as "sperm packets" (although not always visible in their specimens [Gutiérrez, unpubl.]) and described 3 new species: *D. valenciennesi* from *Parapimelodus valenciennesi* (Pimelodidae); *D. paravalenciennesi* from *Pimelodus clarias* (Pimelodidae); and *D. uncusvalidus* from *P. clarias* and *Parauchenipterus galeatus* (Auchenipteridae). In the present study, 9 species of *Demidospermus* (5 new) are described and/or reported from the gills of 4 pimelodid hosts from Argentina. *Omothecium* Kritsky, Thatcher and Boeger, 1987, and *Paramphocleithrium* Suriano and Incorvaia, 1995, both containing species from Neotropical pimelodid hosts, are placed in synonymy with *Demidospermus.*

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Materials and Methods

Hosts (*Iheringichthys westermanni* [Reinhardt], *Parapimelodus valenciennesi* [Kröyer], *Pimelodus albicans* [Valenciennes], and *Pimelodus clarias* [Lacépède]) were collected by net from the Río de la Plata and Río Uruguay in eastern Argentina during January through March 1994. Methods of parasite collection, preservation, preparation for study, measurement, and illustration are those of Kritsky et al. (1986, 1996). Measurements, in micrometers, represent straight-line distances between extreme points and are expressed as the mean followed by the range and number (*n*) of specimens measured in parentheses; lengths of the copulatory organ and haptoral bars are approximations of total lengths obtained by using a Minerva curvimeter on camera lucida drawings. Numbering (distribution) of hook pairs follows that of Mizelle (1936; see Mizelle and Price, 1963) for adult dactylogyrids. Type and voucher specimens of helminths are deposited in the parasite collections of the Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina (MACN); the United States National Parasite Collection, Beltsville, Maryland (USNPC); and the University of Nebraska State Museum (HWML), as indicated in the respective descriptions or accounts of species. In addition, the following specimens were examined: 3 vouchers of *Demidospermus anus* Suriano, 1983 (USNPC 87159); 3 paratypes of *Omothecium piniram-pi* Kritsky, Boeger and Thatcher, 1987 (USNPC 78798); 2 paratypes of *O. luckyi* Kritsky, Boeger and Thatcher, 1987 (USNPC 78795, HWML 22973).

Results

Subclass Polyonchoinea Bychowsky, 1937
Order Dactylogyridea Bychowsky, 1937
Dactylogyridae Bychowsky, 1933
Ancyrocephalinae Bychowsky, 1937
Demidospermus Suriano, 1983

SYNONYMS: *Omothecium* Kritsky, Thatcher and Boeger, 1987; *Paramphocleithrium* Suriano and Incorvaia, 1995.

DIAGNOSIS: Body fusiform, comprising cephalic region, trunk, peduncle, haptor. Tegument thin, smooth. Two terminal, 2 bilateral cephalic lobes; head organs present; cephalic glands unicellular, lateral or posterolateral to pharynx. Eyes present (2 pairs) or absent; granules subspherical. Mouth subterminal, midventral; pharynx muscular, glandular; esophagus present; intestinal ceca 2, confluent posterior to gonads, lacking diverticula. Genital pore midventral near level of intestinal bifurcation. Gonads intercecal, tandem; testis postgermarial. Vas deferens looping left intestinal cecum; seminal vesicle a dilation of vas deferens. Copulatory complex comprising tubular male copulatory organ (MCO) coiled or not, accessory piece; coil (when present) of MCO counterclockwise. Accessory piece sheathlike, serving as guide for MCO. Seminal receptacle pregermarial. Vaginal aperture sinistral; vagina nonsclerotized with distal variably sclerotized vestibule. Vitellaria coextensive with intestine. Haptor subhexagonal, with dorsal and ventral anchor/bar complexes, 7 pairs of hooks; hook distribution ancyrocephaline; hooks variable. Bars elongate, V, W, or U shaped. Parasites of gills of Neotropical siluriform fishes (reported from the Loricariidae, Pimelodidae, and Auchenipteridae).

TYPE SPECIES: *Demidospermus anus* Suriano, 1983, from *Loricaria anus* (Loricariidae).

OTHER SPECIES: *Demidospermus armostus* sp. n. from *Pimelodus albicans* and *P. clarias* (Pimelodidae); *D. bidiverticulatum* (Suriano and Incorvaia, 1995) comb. n. from *Pimelodus clarias, P. c. maculatus,* and *P. albicans* (all Pimelodidae); *D. cornicinus* sp. n. from *Iheringichthys westermanni* (Pimelodidae); *D. idolus* sp. n. from *Pimelodus albicans* (Pimelodidae); *D. leptosynophallus* sp. n. from *Iheringichthys westermanni* (Pimelodidae); *D. luckyi* (Kritsky, Thatcher and Boeger, 1987) comb. n. from *Pinirampus pirinampu* (Pimelodidae); *D. majusculus* sp. n. from *Pimelodus albicans* (Pimelodidae); *D. paravalenciennesi* Gutiérrez and Suriano, 1992, from *P. clarias* (Pimelodidae); *D. pinirampi* (Kritsky, Thatcher and Boeger, 1987) comb. n. from *Pinirampus pirinampu* (Pimelodidae); *D. uncusvalidus* Gutiérrez and Suriano, 1992, from *Pimelodus clarias* (Pimelodidae) and *Parauchenipterus galeatus* (Auchenipteridae); and *D. valenciennesi* Gutiérrez and Suriano, 1992, from *Parapimelodus valenciennesi* (Pimelodidae).

REMARKS: The emended diagnosis characterizes *Demidospermus* with species having (1) tandem gonads (testis postgermarial); (2) a counterclockwise coiled MCO; (3) a sinistral vaginal aperture; (4) U-, W-, or V-shaped haptoral bars; (5) subspherical eye granules; and (6) a sheathlike accessory piece serving as a guide for the MCO. Suriano (1983) considered the presence of encapsulated sperm (sperm packets) within the testis of adult worms an autapomorphic feature of the genus. Since sperm packets are not always present or visible in some specimens of previously described species (Gutiérrez, unpubl.) and they have not been observed in any of our specimens, this character is not reliable in defining the genus.

Although considered diagnostic for *Demidospermus* by Suriano (1983) and Gutiérrez and Suriano (1992), the presence/absence and number of prostatic reservoirs in species of *Demidospermus* are not included in the present diagnosis. The reservoirs did not stain nor were they observed consistently in available specimens. At the present time, we do not feel that these reservoirs are diagnostic.

Omothecium contains 2 species, *O. luckyi* and *O. pinirampi,* from the gills of a pimelodid host from the Amazon Basin. In their diagnosis, Kritsky et al. (1987) characterized this genus with the following features: a vagina opening on the left margin of the trunk near the level of the copulatory complex; tandem gonads (testis postgermarial); "unmodified" anchors and bars; undilated hook shanks; and a clockwise MCO. These features no longer justify separation of this genus from *Demidospermus.* The vagina in all species of *Demidospermus* opens on the left margin of the trunk and, in some species (e.g., *D. armostus* sp. n.), the opening is near the level of the copulatory complex. Characters associated with the gonads and haptoral sclerites are not inconsistent with those present in species of *Demidospermus.* Lastly, our examination of the

paratypes of *O. luckyi* and *O. pinirampi* confirm that the ring of the MCO is counterclockwise. Because no distinguishing features remain, we consider *Omothecium* a junior synonym of *Demidospermus,* and the following new combinations are proposed: *D. luckyi* (Kritsky, Thatcher and Boeger, 1987) comb. n. and *D. pinirampi* (Kritsky, Thatcher and Boeger, 1987) comb. n.

Suriano and Incorvaia (1995) proposed the monotypic *Paramphocleithrium* for their new species, *P. bidiverticulatum,* from the gills of *Pimelodus clarias maculatus* in Argentina. The genus was characterized by the presence of 2 intestinal diverticula extending into the haptor. *Paramphocleithrium bidiverticulatum* was said to lack sperm packets and possess 2 prostatic reservoirs. The authors also suggested that the comparative morphology of the sclerotized components of the haptor could be used to differentiate *Paramphocleithrium* from *Demidospermus.* The "intestinal diverticula" described by Suriano and Incorvaia (1995) are actually large bilateral muscles extending from the peduncular region into the haptor and are not attached to the gut (see the redescription of *D. bidiverticulatum*). In *Demidospermus* spp., the number of prostatic reservoirs varies and sperm packets are not always visible, and Gutiérrez (unpubl.) has observed sperm packets in some specimens of *P. bidiverticulatum.* Further, morphology of the haptoral sclerites of *P. bidiverticulatum* does not exclude this species from *Demidospermus.* Thus, we consider *Paramphocleithrium* a junior synonym of *Demidospermus* since the autapomorphic character and other characters used by Suriano and Incorvaia (1995) to define the genus are either erroneous or fall within the observed variation of *Demidospermus. Demidospermus bidiverticulatum* (Suriano and Incorvaia, 1995) comb. n. is proposed.

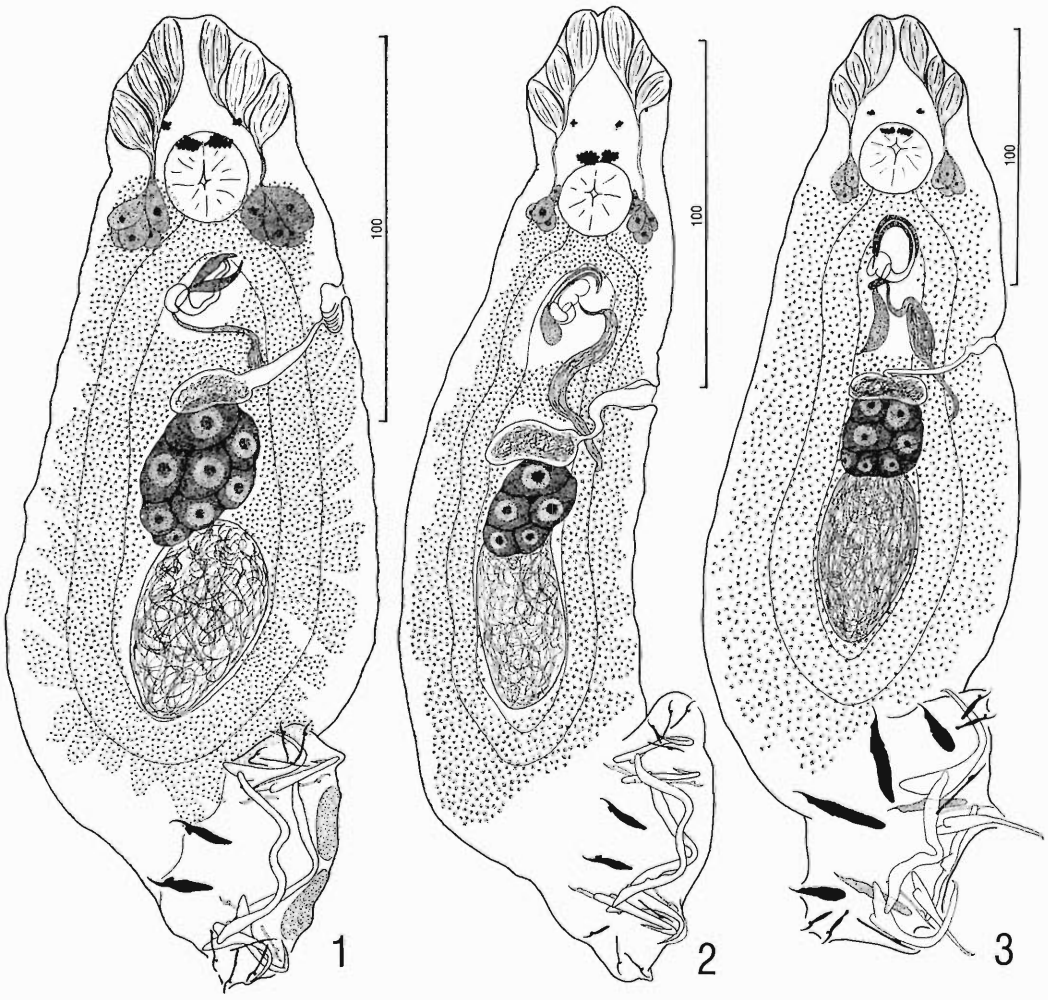
Demidospermus resembles several other genera with species infesting gills of Neotropical siluriform fishes: *Amphocleithrium* Price and Romero, 1969, *Cosmetocleithrum* Kritsky, Thatcher and Boeger, 1986, *Philocorydoras* Suriano, 1986, *Unibarra* Suriano and Incorvaia, 1995, and *Vancleaveus* Kritsky, Thatcher and Boeger, 1986. In *Demidospermus* species, the gonads are tandem (overlapping in *Vancleaveus* and *Philocorydoras* spp.); the dorsal bar lacks 2 posteriorly directed submedial projections (present in *Cosmetocleithrum* spp.); the haptor is armed with 2 elongate, V-, W-, or U-shaped bars (dorsal bar absent in *Unibarra* spp.; bars straight in *Unibarra* and *Amphocleithrium* spp.).

Demidospermus armostus sp. n. (Figs. 1, 4–12)

HOST AND LOCALITY: Gills of *Pimelodus clarias:* Río de la Plata near Buenos Aires, Argentina (28 February 1994; 24 March 1994).

SPECIMENS STUDIED: Holotype, USNPC 87143; 17 paratypes, USNPC 87144, HWML 39346, MACN 34113/A27.

DESCRIPTION: Body 248 (212–307; $n = 7$) long, fusiform; greatest width 92 (87–99; $n = 7$) in posterior trunk. Cephalic lobes poorly developed. Eyes 4; posterior pair larger, closer together than anterior pair; accessory granules uncommon or absent. Pharynx spherical, 21 (19–23; $n = 9$) in diameter; esophagus short. Peduncle broad; haptor subhexagonal, 75 (69–82; $n = 7$) wide, 49 (43–56; $n = 8$) long, with 2 bilateral glandular patches along posterior border. Anchors similar; each with broad base, short shaft, elongate point; ventral anchor 21 (20–22; $n = 6$) long, base 14 (13–16; $n = 5$) wide; dorsal anchor 21–22 ($n = 7$) long, base 13 (12–14; $n = 5$) wide. Ventral bar 66 (60–73; $n = 13$) long, U or W shaped; distance between ends 45 (39–59; $n = 14$). Dorsal bar 57 (50–63; $n = 8$) long, V shaped; distance between ends 33 (21–43; $n = 14$). Hook pair 1—22 (21–24; $n = 8$) long, pair 2—13 (12–14; $n = 3$) long, pairs 3–7—16 (15–17; $n = 11$) long; hook pair 1 with recurved point, heavy shaft, flattened thumb, variably expanded shank; hook pairs 5, 6 with straight point, tapered shaft, depressed or flattened thumb, thin shank; hook pairs 2–4, 7 delicate throughout, point recurved, thumb erect; FH loop 1/2 shank length in pair 1, approaching shank length in remaining pairs. MCO 16 (14–18; $n = 8$) long, an elongate cone, sigmoid distally, base with sclerotized margin, delicately sclerotized proximal double bag. Accessory piece 14 (12–15; $n = 5$) long, bifurcating at midlength. Gonads subovate. Testis 41 (22–53; $n = 7$) long, 24 (18–32; $n = 6$) wide; proximal vas deferens not observed; seminal vesicle indistinct; prostatic reservoir(s) not observed. Ovary 35 (31–44; $n = 7$) long, 23 (18–27; $n = 7$) wide; oviduct, ootype, uterus not observed. Vaginal aperture near level of copulatory complex; vaginal vestibule with ridges in posterior wall; vaginal canal opening into small medial seminal receptacle. Vitellaria dense.



Figures 1–3. Whole mount illustrations of species of *Demidospermus* (composite, ventral). 1. *Demidospermus armostus* sp. n. 2. *Demidospermus paravalenciennesi* Gutiérrez and Suriano, 1992. 3. *Demidospermus uncusvalidus* Gutiérrez and Suriano, 1992. Drawings are to respective 100-μm scales.

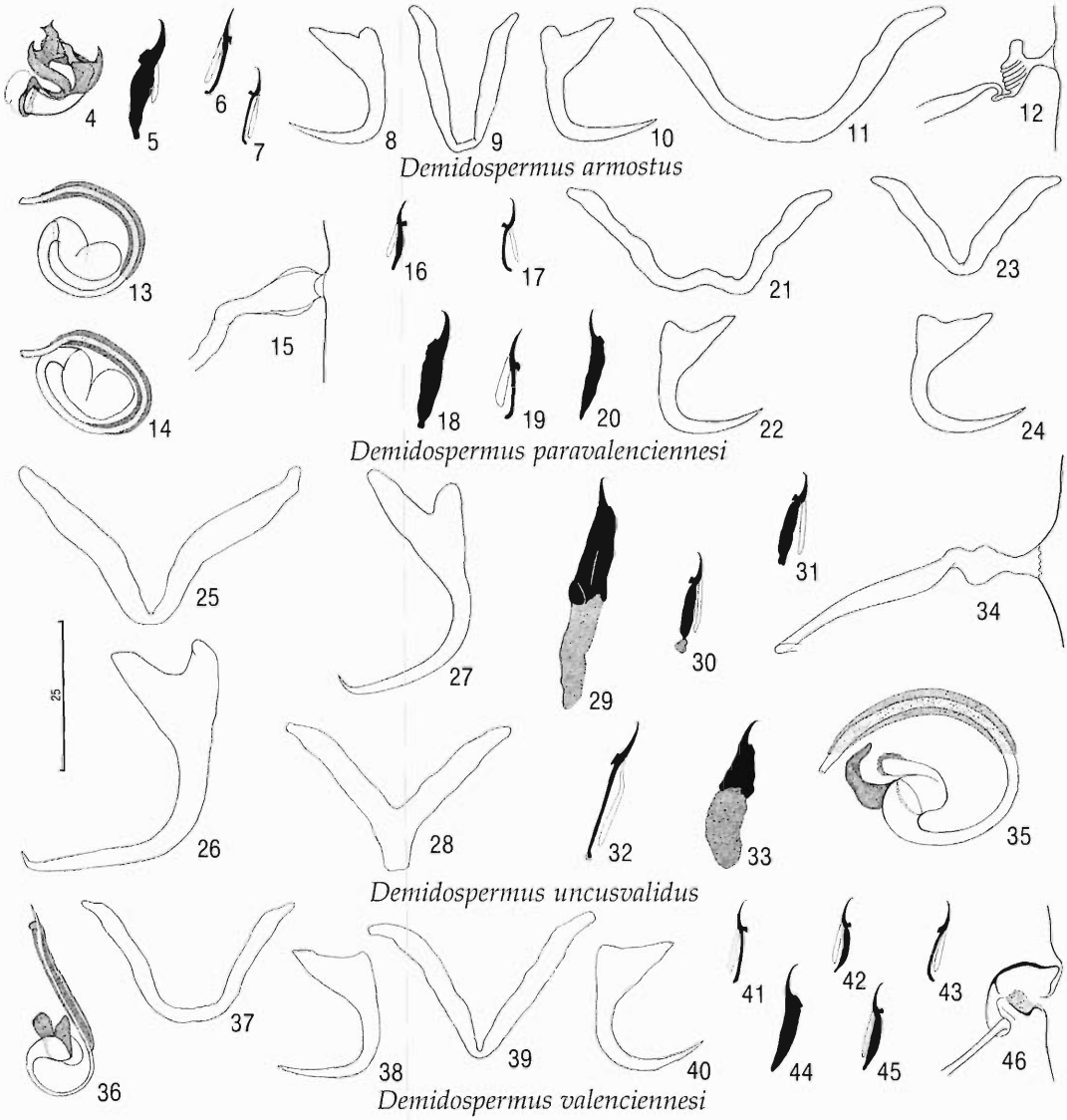
REMARKS: *Demidospermus armostus* differs from congeneric species by possessing a comparatively short MCO with a sigmoid termination. Based on comparative morphology of the anchors, bars, and hook pair 1, *D. armostus* is most similar to *D. valenciennesi* and *D. idolus* sp. n. In the latter 2 species, hook pair 2 has a slightly expanded shank (lacking in *D. armostus*). The specific name is from Greek (*armostos* = suitable) and refers to the apparent relationship of this species with others in the genus.

In a separate investigation of ecological aspects of parasitism on Argentine Siluriformes, Gutiérrez (unpubl.) found 22 specimens of *Demidospermus armostus* on the gills of 10 of 44 *Pimelodus albicans*. These helminth specimens were not available for the current study.

Demidospermus paravalenciennesi Gutiérrez and Suriano, 1992 (Figs. 2, 13–24)

HOST AND LOCALITY: Gills of *Pimelodus clarias:* Río de la Plata near Buenos Aires, Argentina (28 February 1994; 24 March 1994).

PREVIOUS RECORD: *Pimelodus clarias:* Río de la Plata, Puerto de Buenos Aires, Argentina (Gutiérrez and Suriano, 1992).



Figures 4–46. Sclerotized structures of *Demidospermus* species. Figs. 4–12. *Demidospermus armostus* sp. n. 4. Copulatory complex (ventral). 5. Hook pair 1. 6. Hook pair 5 (typical of hook pairs 5, 6). 7. Hook pair 4 (typical of hook pairs 2–4, 7). 8. Dorsal anchor. 9. Dorsal bar. 10. Ventral anchor. 11. Ventral bar. 12. Vagina. Figs. 13–24. *Demidospermus paravalenciennesi* Gutiérrez and Suriano, 1992. 13, 14. Copulatory complexes (ventral). 15. Vagina. 16. Hook pair 2. 17. Hook pair 3 (typical of hook pairs 3, 4). 18. Hook pair 1. 19. Hook pair 5 (typical of hook pairs 5, 6). 20. Hook pair 7. 21. Ventral bar. 22. Ventral anchor. 23. Dorsal bar. 24. Dorsal anchor. Figs. 25–35. *Demidospermus uncusvalidus* Gutiérrez and Suriano, 1992. 25. Ventral bar. 26. Ventral anchor. 27. Dorsal anchor. 28. Dorsal bar. 29. Hook pair 1 (typical of hook pairs 1, 7). 30. Hook pair 4. 31. Hook pair 3. 32. Hook pair 5 (typical of hook pairs 5, 6). 33. Hook pair 2. 34. Vagina. 35. Copulatory complex (ventral). Figs. 36–46. *Demidospermus valenciennesi* Gutiérrez and Suriano, 1992. 36. Copulatory complex (ventral). 37. Ventral bar. 38. Ventral anchor. 39. Dorsal bar. 40. Dorsal anchor. 41. Hook pair 3 (typical of hook pairs 3, 4). 42. Hook pair 2. 43. Hook pair 5 (typical of hook pairs 5, 6). 44. Hook pair 1. 45. Hook pair 7. 46. Vagina. All drawings are to the 25-μm scale.

SPECIMENS STUDIED: 30 vouchers, USNPC 87145, HWML 39347.

MEASUREMENTS: Body 254 (180–312; n = 20) long; greatest width 81 (63–96; n = 22). Pharynx 19 (16–22; n = 21) in diameter. Haptor 78 (67–87; n = 21) wide, 46 (39–54; n = 20) long. Ventral anchor 20–21 (n = 7) long, base 14 (13–15; n = 6) wide; dorsal anchor 21 (20–22; n = 4) long, base 12 (11–14; n = 4) wide. Ventral bar 67 (60–80; n = 14) long, distance between ends 47 (40–59; n = 24); dorsal bar 52 (48–60; n = 9) long, distance between ends 37 (31–42; n = 16). Hook pair 1—21–22 (n = 11) long, pair 2—12 (11–14; n = 4) long, pairs 3–6—14–15 (n = 12) long, pair 7—17–18 (n = 5) long. MCO 63 (60–68; n = 7) long, coiled; ring diameter 19 (16–21; n = 20). Accessory piece 28 (25–30; n = 3) long. Testis 45 (40–51; n = 6) long, 24 (21–27; n = 6) wide; ovary 34 (26–42; n = 12) long, 21 (17–24; n = 11) wide.

REMARKS: *Demidospermus paravalenciennesi* was described from the same host and geographic locality as present specimens, and its original description is adequate (Gutiérrez and Suriano, 1992). In our specimens, the FH loops of hook pairs 1 and 7 were not observed (possibly absent), although 1 was shown by Gutiérrez and Suriano (1992) in their Figure 14a of hook pair 1. Gutiérrez and Suriano (1992) indicated that the prostatic reservoir was absent, but one was observed in current specimens.

Demidospermus uncusvalidus Gutiérrez and Suriano, 1992 (Figs. 3, 25–35)

HOST AND LOCALITY: Gills of *Pimelodus clarias:* Río de la Plata near Buenos Aires, Argentina (28 February 1994; 24 March 1994).

PREVIOUS RECORDS: *Pimelodus clarias:* Río de la Plata, Puerto de Buenos Aires, Argentina (Gutiérrez and Suriano, 1992). *Parauchenipterus galeatus:* Río de la Plata, Puerto de Buenos Aires, Argentina (Gutiérrez and Suriano, 1992).

SPECIMENS STUDIED: 7 vouchers, USNPC 87148, HWML 39349.

MEASUREMENTS: Body 455 (378–532; n = 2) long; greatest width 109 (87–132; n = 2). Pharynx 25 (24–26; n = 2) in diameter. Haptor 118 (117–120; n = 2) wide, 85–86 (n = 2) long. Ventral anchor 37 (35–38; n = 4) long, base 20 (19–22; n = 4) wide; dorsal anchor 39–40 (n = 3) long, base 17 (15–18; n = 3) wide. Ventral bar 64 (58–69; n = 4) long; dorsal bar 45 (39–49; n = 3) long. Hook pairs 1, 7—43 (38–51; n = 8) long, pair 2—28 (25–32; n = 3) long, pair 3—17 (n = 4) long, pair 4—20 (n = 1) long, pairs 5, 6—25 (24–26; n = 4) long. MCO 83 (75–90; n = 2) long, coiled; ring diameter 22 (18–26; n = 3). Accessory piece 28 (26–30; n = 2) long. Testis 64 (56–72; n = 2) long, 30 (27–33; n = 2) wide; ovary 48 (41–55; n = 2) long, 32 (31–33; n = 2) wide.

REMARKS: *Demidospermus uncusvalidus, D. majusculus* sp. n., and *D. leptosynophallus* sp. n. appear related based on the comparative morphology of the haptoral sclerites. In these species, hook pairs 1, 2, and 7 have expanded shanks comprising 2 distinct regions, tips of the points of the dorsal and ventral anchors are recurved, and ventral bars are V shaped. *Demidospermus uncusvalidus* differs from *D. majusculus* by having a coiled MCO with 1 ring (J shaped in *D. majusculus*) and from *D. leptosynophallus* by having a broad posteromedial projection on the V-shaped dorsal bar (dorsal bar V shaped but lacking posteromedial projection in *D. leptosynophallus*).

The original description of *D. uncusvalidus* is adequate, and present specimens correspond both in size and morphology. Gutiérrez and Suriano (1992) reported this species from 2 hosts (*Pimelodus clarias* and *Parauchenipterus galeatus*) but did not designate a type host. Although stated in their paper that representative and type specimens were deposited in the Museo Nacional de Ciencias Naturales de Argentina and the Museum of the Institute of Zoology, Russian Academy of Sciences, St. Petersburg, these specimens were never forwarded for deposition (Gutiérrez, unpubl.). Since a holotype of *D. uncusvalidus* is apparently unavailable and Gutiérrez and Suriano (1992) listed *P. clarias* first in their host list, we consider this fish to be its type host. Our finding of *D. majusculus* and *D. leptosynophallus,* 2 species we initially considered conspecific with *D. uncusvalidus,* on different host species than that of *D. uncusvalidus* suggests that the worm population from *P. galeatus* might represent another related species. A reexamination of *P. galeatus* for species of *Demidospermus* is necessary to confirm the original host record.

Demidospermus valenciennesi Gutiérrez and Suriano, 1992 (Figs. 36–46)

HOST AND LOCALITY: Gills of *Parapimelodus valenciennesi:* Río de la Plata near Buenos Ai-

res, Argentina (28 February 1994); Río Uruguay near Colón, Entre Ríos, Argentina (16 January 1994).

PREVIOUS RECORDS: *Parapimelodus valenciennesi:* Río de la Plata, Puerto de Buenos Aires, Argentina (Gutiérrez and Suriano, 1992).

SPECIMENS STUDIED: 34 vouchers, USNPC 87157, 87158, HWML 39354.

MEASUREMENTS: Body 246 (185–303; n = 12) long; greatest width 91 (78–120; n = 10). Pharynx 21 (16–24; n = 12) in diameter. Haptor 70 (62–75; n = 12) wide, 46 (41–52; n = 13) long. Ventral anchor 23 (22–25; n = 8) long, base 13 (12–14; n = 7) wide; dorsal anchor 23 (22–24; n = 9) long, base 12–13 (n = 9) wide. Ventral bar 60 (50–68; n = 14) long, distance between ends 42 (39–48; n = 15); dorsal bar 55 (48–63; n = 11) long, distance between ends 37 (28–42; n = 13). Hook pair 1—19 (18–20; n = 9) long, pairs 2–6—14 (13–15; n = 30) long, pair 7—17 (16–18; n = 9) long. MCO 58 (55–60; n = 3) long, coiled, ring diameter 12 (11–13; n = 4). Accessory piece 25 (23–28; n = 3) long. Testis 54 (40–76; n = 11) long, 32 (25–46; n = 10) wide; ovary 32 (20–48; n = 11) long, 29 (21–37; n = 10) wide.

REMARKS: In *Demidospermus valenciennesi,* the dorsal bar is V shaped, and the ventral bar occurs as a broad U or W. Based on their drawings and description, Gutiérrez and Suriano (1992) clearly confused the dorsoventral orientation of the haptor and its sclerites; however, positions of the respective anchor/bar complexes were correctly depicted in their figure of the whole mount (a dorsal view). The dorsal and ventral anchors are morphologically similar, but the ventral anchor tends to be slightly larger in our specimens, suggesting that the original drawings of these structures were also reversed in Gutiérrez and Suriano (1992).

Demidospermus bidiverticulatum (Suriano and Incorvaia, 1995) comb. n. (Figs. 47–56)

SYNONYM: *Paramphocleithrium bidiverticulatum* Suriano and Incorvaia, 1995.

HOSTS AND LOCALITIES: Gills of *Pimelodus clarias:* Río de la Plata near Buenos Aires, Argentina (28 February 1994; 24 March 1994). Gills of *Pimelodus albicans:* Río de la Plata near Buenos Aires, Argentina (24 March 1994).

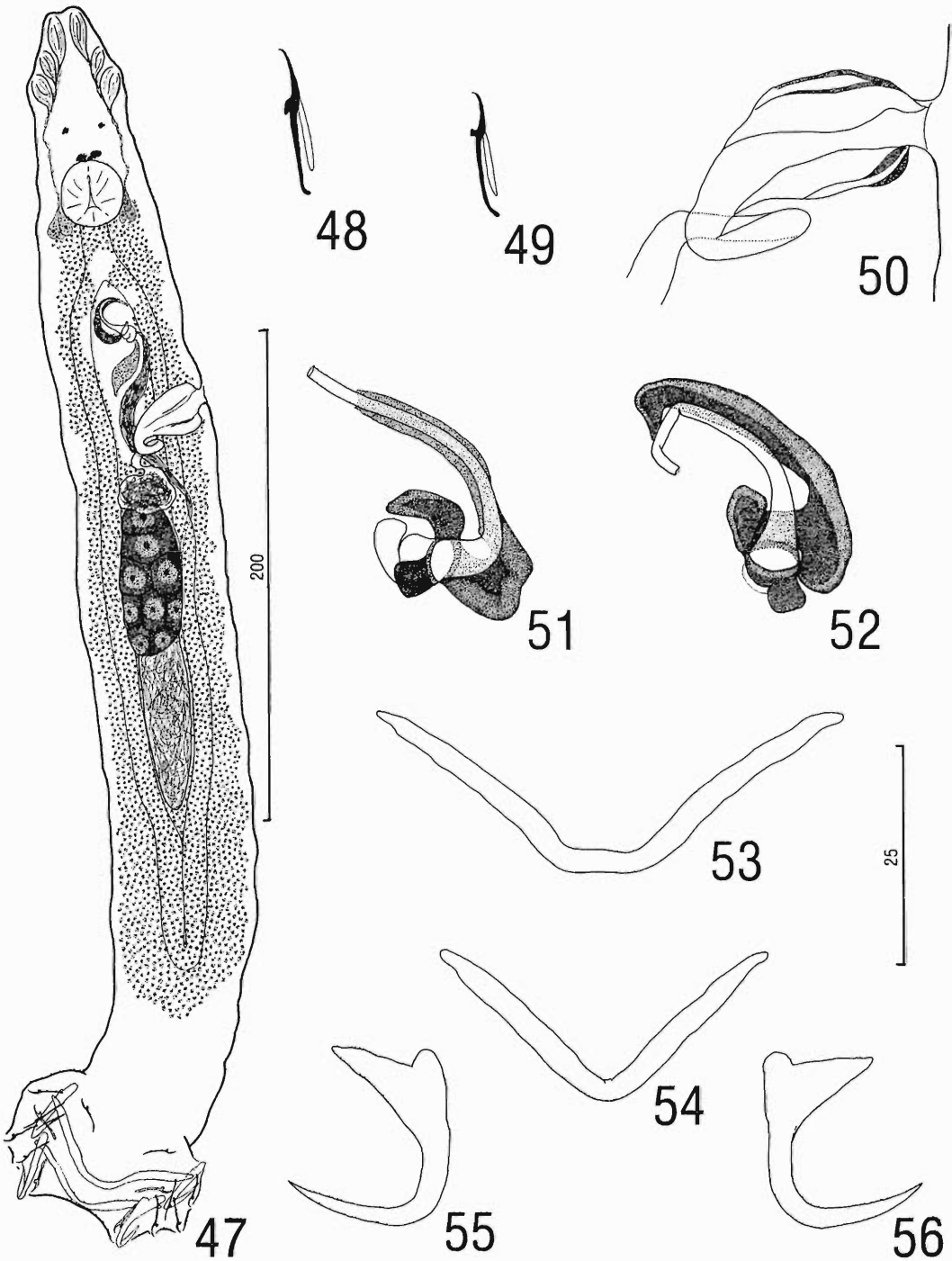
PREVIOUS RECORD: *Pimelodus clarias maculatus:* Río de la Plata, Puerto de Buenos Aires, Argentina (Suriano and Incorvaia, 1995).

SPECIMENS STUDIED: 23 vouchers (from *P. clarias*), USNPC 87146, HWML 39348; 12 vouchers (from *P. albicans*), USNPC 87147.

MEASUREMENTS (dimensions of specimens from *P. albicans* are in brackets): Body 422 (340–510; n = 9) [243 (n = 1)] long; greatest width 74 (62–84; n = 9) [75 (n = 1)]. Pharynx 21 (19–23; n = 9) [22 (n = 1)] in diameter. Haptor 83 (75–88; n = 6) [79 (n = 1)] wide, 61 (49–75; n = 9) [43 (n = 1)] long. Ventral anchor 23 (22–24; n = 9) [23 (21–24; n = 7)] long, base 14 (12–15; n = 9) [13–14 (n = 7)] wide; dorsal anchor 22 (21–24; n = 10) [23 (22–24; n = 10)] long, base 13 (12–14; n = 9) [13 (12–14; n = 10)] wide. Ventral bar 73 (68–78; n = 8) [72 (70–78; n = 8)] long, distance between ends 55 (47–66; n = 9) [50 (42–60; n = 10)]; dorsal bar 60 (55–65; n = 8) [61 (58–68; n = 7)] long, distance between ends 42 (36–49; n = 9) [46 (41–50; n = 9)] wide. Hook pairs 1, 3–7—16 (14–18; n = 32) [16 (14–17; n = 27)] long, pair 2—12–13 (n = 7) [12–13 (n = 5)] long. MCO 45 (40–53; n = 9) [47 (44–48; n = 4)] long, J shaped; accessory piece 34 (31–39; n = 3) [35 (30–41; n = 6)] long. Testis 48 (31–65; n = 7) [28 (n = 1)] long, 23 (17–29; n = 7) [27 (n = 1)] wide; ovary 41 (27–51; n = 9) [27 (n = 1)] long, 23 (20–25; n = 9) [24 (n = 1)] wide.

REMARKS: Our finding of *Demidospermus bidiverticulatum* on *Pimelodus albicans* is a new host record. Specimens from this host were highly contracted, apparently a result of premature fixation while worms were still alive. Contraction is reflected in the comparatively shorter lengths of the body and gonads in specimens from *P. albicans* when compared to respective measurements of worms from *P. clarias.*

Based on comparative haptoral morphology, *Demidospermus bidiverticulatum* most closely resembles *D. anus* Suriano, 1983. It differs from this species by possessing an MCO comprising less than 1 complete ring (about 1.5 rings in *D. anus*). The ventral and dorsal bars were incorrectly labeled in the plate of figures of *D. bidiverticulatum* presented by Suriano and Incorvaia (1995) in that the ventral bar (identified as the dorsal bar in Suriano and Incorvaia's [1995] Figure 26) is U or W shaped and the dorsal bar (Figure 27, ventral bar in Suriano and Incorvaia [1995]) is V shaped.



Figures 47–56. *Demidospermus bidiverticulatum* **(Suriano and Incorvaia, 1995) comb. n. 47. Whole mount (composite, ventral). 48. Hook pair 6 (typical of hook pairs 5, 6). 49. Hook pair 7 (typical of hook pairs 1–4, 7). 50. Vagina. 51, 52. Copulatory complexes (ventral). 53. Ventral bar. 54. Dorsal bar. 55. Ventral anchor. 56. Dorsal anchor. All figures are to the same scale (25-μm) except Figure 47 (200-μm).**

Demidospermus cornicinus sp. n. (Figs. 57–67)

HOST AND LOCALITY: Gills of *Iheringichthys westermanni:* Río de la Plata near Buenos Aires, Argentina (28 February 1994).

SPECIMENS STUDIED: Holotype, USNPC 87155; 30 paratypes (on 28 slides), USNPC 87156, HWML 39353, MACN 34117/A27.

DESCRIPTION: Body 447 (295–571; n = 14) long, fusiform; greatest width 96 (71–112; n = 13) in posterior trunk. Cephalic margin narrow; cephalic lobes moderately developed. Eyes 4; posterior pair larger, closer together than anterior pair; accessory granules uncommon in cephalic, anterior trunk regions. Pharynx spherical, 28 (25–30; n = 15) in diameter; esophagus moderately long. Peduncle broad; haptor subhexagonal, 89 (78–100; n = 15) wide, 70 (48–85; n = 15) long; bilateral posterior glandular patches small, indistinct. Anchors similar, each with poorly differentiated roots, short shaft, elongate point; ventral anchor 24 (23–26; n = 6) long, base 16 (14–18; n = 5) wide; dorsal anchor 24 (23–25; n = 5) long, base 15 (14–16; n = 4) wide. Ventral bar 75 (65–90; n = 12) long, U shaped, ends directed laterally; distance between ends 55 (43–76; n = 16). Dorsal bar 63 (58–70; n = 7) long, V shaped; distance between ends 40 (32–46; n = 14). Hook pair 1—24 (21–26; n = 8) long; pair 2—12–13 (n = 6) long; pairs 3–7—16 (15–18; n = 12) long; hook pair 1 with recurved point, heavy shaft, flattened thumb, inflated shank tapering proximally, apparently lacking FH loop; pair 2 with protruding thumb, slightly expanded shank, FH loop shank length; pairs 3, 4, 7 with protruding thumb, slender shank, FH loop shank length; pairs 5, 6 with small flattened thumb, delicate shank, FH loop about 3/4 shank length. MCO 62 (53–68; n = 12) long, an incomplete ring, frequently appearing J shaped, with flared termination; base with lightly sclerotized margin; proximal double bag small, delicate; coil diameter 18 (14–21; n = 14). Accessory piece 27 (21–34; n = 9) long, comprising variable sheath enclosing distal shaft of MCO. Gonads ovate. Testis 61 (34–77; n = 8) long, 40 (28–56; n = 8) wide; seminal vesicle sigmoid; prostatic reservoir not observed. Ovary 49 (38–60; n = 3) long, 29 (23–38; n = 3) wide; oviduct, ootype not observed. Vaginal aperture midway between ovary, copulatory complex; vaginal vestibule complex with sclerotized ridges; seminal receptacle small; vitellaria dense.

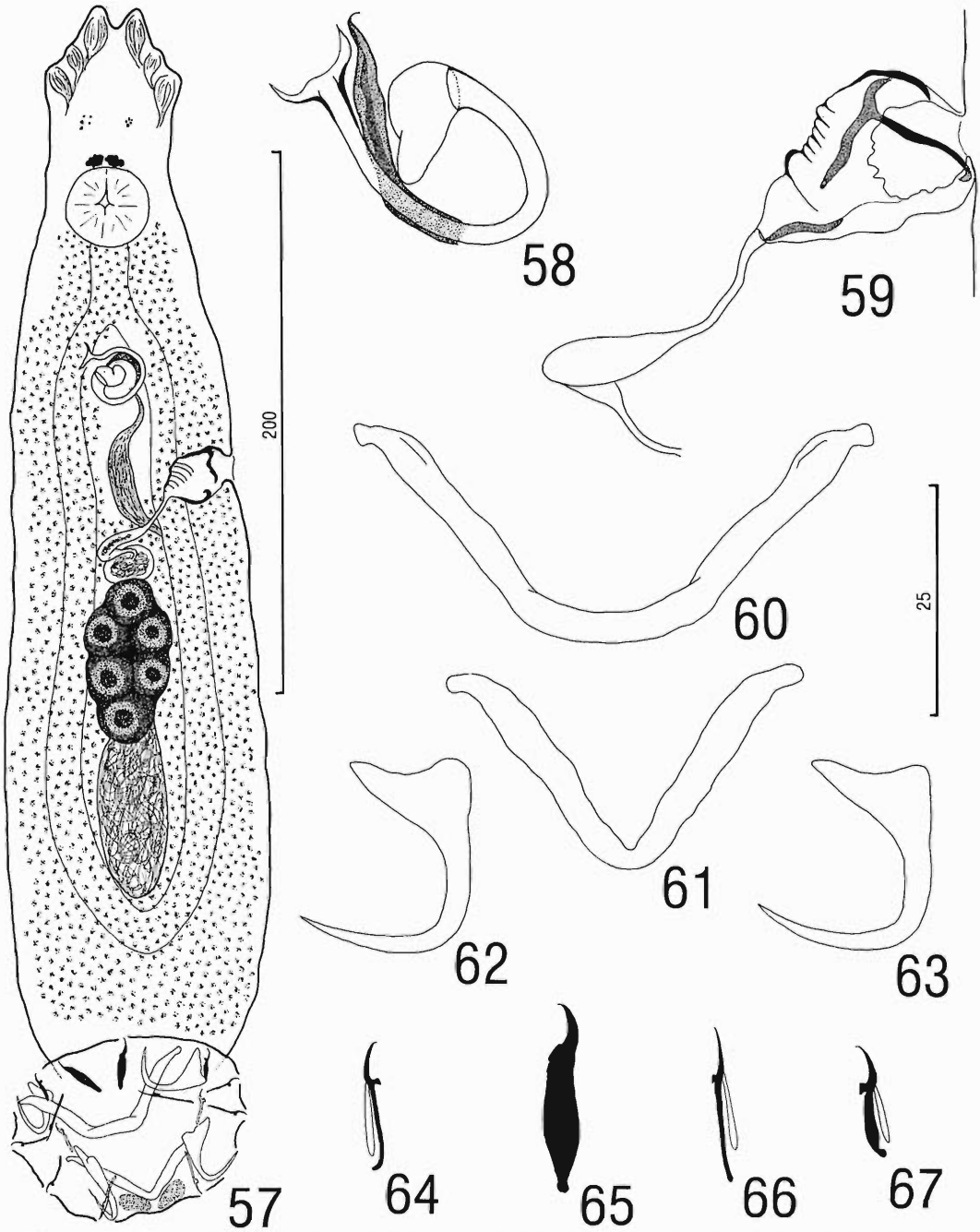
REMARKS: This species resembles *Demidospermus paravalenciennesi* based on comparative haptoral morphology. It differs from *D. paravalenciennesi* by lacking an expanded shank on hook pair 7 and by possessing a flared termination of the MCO. The specific name is from Latin (*cornicinis* = having or a blower of a trumpet) and refers to the termination of the MCO.

Demidospermus idolus sp. n. (Figs. 68–77)

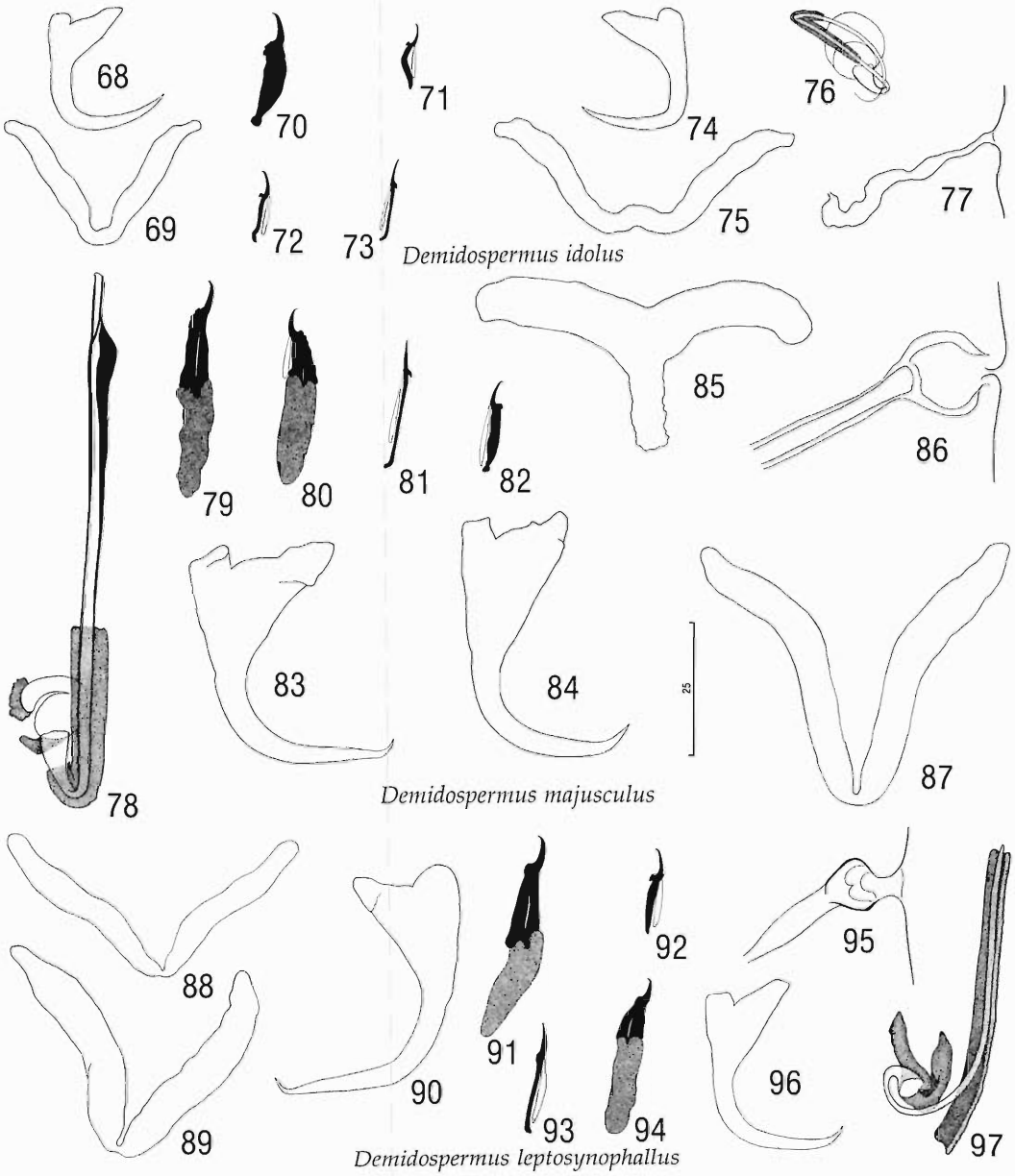
HOST AND LOCALITY: Gills of *Pimelodus albicans:* Río de la Plata near Buenos Aires, Argentina (24 March 1994).

SPECIMENS STUDIED: Holotype, USNPC 87151; 9 paratypes, USNPC 87152, HWML 39351, MACN 34115/A27.

DESCRIPTION: Body 215 (196–236; n = 3) long, robust; greatest width 104 (96–108; n = 3) near midlength. Cephalic margin rounded; cephalic lobes poorly developed. Eyes 4; posterior pair tangent, larger than anterior pair; accessory granules uncommon in cephalic, anterior trunk regions. Pharynx spherical, 23 (n = 3) in diameter; esophagus short. Peduncle broad; haptor subhexagonal, 89 (85–91; n = 3) wide, 49 (44–51; n = 3) long; 2 posterior bilateral glandular patches present. Anchors similar; each with differentiated roots (superficial root longer), short shaft, elongate point; ventral anchor 24 (22–25; n = 7) long, base 15 (14–16; n = 7) wide; dorsal anchor 23 (22–25; n = 5) long, base 16 (14–17; n = 5) wide. Ventral bar 76 (70–80; n = 6) long, W shaped, with ends directed laterally; distance between ends 56 (44–64; n = 9). Dorsal bar 61 (60–63; n = 4) long, V shaped; distance between ends 42 (36–46; n = 6). Hook pair 1—23–24 (n = 7) long, with recurved point, stout shaft, broad flattened thumb, expanded shank tapering proximally, lacking FH loop; pair 2—12–13 (n = 4) long, with erect thumb, slightly inflated shank; pairs 3, 4, 7 with erect thumb, slender shank; pairs 5, 6 with flattened thumb, slender shank; pairs 3–7—16 (15–17; n = 16) long, FH loop about shank length. MCO 83 (n = 1) long, a coil of 1 ring poorly defined, base lacking sclerotized margin; coil diameter 25 (20–30; n = 9). Accessory piece a simple sleeve surrounding 1/3 of MCO shaft. Testis 38 (33–42; n = 3) long, 27 (22–31; n = 3) wide, ovate; sem-



Figures 57–67. *Demidospermus cornicinus* **sp. n. 57. Whole mount (composite, ventral). 58. Copulatory complex (dorsal). 59. Vagina. 60. Ventral bar. 61. Dorsal bar. 62. Ventral anchor. 63. Dorsal anchor. 64. Hook pair 4 (typical of hook pairs 3, 4, 7). 65. Hook pair 1. 66. Hook pair 5 (typical of hook pairs 5, 6). 67. Hook pair 2. All figures are to the same scale (25-μm) except Figure 57 (200-μm).**



Figures 68–97. Sclerotized structures of *Demidospermus* species. Figs. 68–77. *Demidospermus idolus* sp. n. 68. Dorsal anchor. 69. Dorsal bar. 70. Hook pair 1. 71. Hook pair 2. 72. Hook pair 3 (typical of hook pairs 3, 4, 7). 73. Hook pair 5 (typical of hook pairs 5, 6). 74. Ventral anchor. 75. Ventral bar. 76. Copulatory complex (ventral). 77. Vagina. Figs. 78–87. *Demidospermus majusculus* sp. n. 78. Copulatory complex (ventral). 79. Hook pair 1 (typical of hook pairs 1, 7). 80. Hook pair 2. 81. Hook pair 5 (typical of hook pairs 5, 6). 82. Hook pair 3 (typical of hook pairs 3, 4). 83. Ventral anchor. 84. Dorsal anchor. 85. Dorsal bar. 86. Vagina. 87. Ventral bar. Figs. 88–97. *Demidospermus leptosynophallus* sp. n. 88. Ventral bar. 89. Dorsal bar. 90. Ventral anchor. 91. Hook pair 1 (typical of hook pairs 1, 7). 92. Hook pair 4 (typical of hook pairs 3, 4). 93. Hook pair 6 (typical of hook pairs 5, 6). 94. Hook pair 2. 95. Vagina. 96. Dorsal anchor. 97. Copulatory complex (ventral). All drawings are to the 25-μm scale.

inal vesicle sigmoid; 2 prostatic reservoirs saccate. Ovary subspherical, 29 (25–33; n = 3) long, 26 (25–28; n = 3) wide; oviduct, ootype not observed; vagina simple, lacking vestibule, opening at level of copulatory complex; seminal receptacle transversely ovate; vitellaria dense.

REMARKS: Specimens of *Demidospermus idolus* were contracted, apparently a result of premature fixation after collection. This species is similar to *D. valenciennesi* and *D. cornicinus* based on the comparative morphology of the haptoral sclerites. It differs from *D. valenciennesi* by having a more robust hook pair 1 and by lacking a vaginal vestibule and an inflated shank in hook pair 7. It is distinguished from *D. cornicinus* by lacking a flared termination of the MCO. The species name is from Greek (*eidolon* = an image or phantom) and reflects the similarity of the species with its congeners.

Demidospermus majusculus sp. n. (Figs. 78–87)

HOST AND LOCALITY: Gills of *Pimelodus albicans:* Río de la Plata near Buenos Aires, Argentina (24 March 1994).

SPECIMENS STUDIED: Holotype, USNPC 87153; 12 paratypes, USNPC 87154, HWML 39352, MACN 34116/A27.

DESCRIPTION: Body 493 (420–627; n = 3) long, robust, fusiform; greatest width 211 (185–232; n = 3) near midlength or in posterior trunk. Cephalic margin rounded; lobes poorly developed. Eyes 4; posterior pair tangent; anterior eyes widely separated; accessory granules frequent in cephalic, anterior trunk regions. Pharynx spherical, 46 (41–51; n = 3) in diameter; esophagus short. Peduncle broad; haptor subhexagonal, 144 (136–154; n = 3) wide, 93 (86–99; n = 3) long; glandular patches not observed. Ventral anchor 42 (39–45; n = 7) long, with short roots, short shaft, tip of point recurved; base 27 (24–30; n = 5) wide. Dorsal anchor 47 (45–49; n = 5) long, with short roots, short shaft, tip of point slightly recurved; base 23 (22–24; n = 2) wide. Ventral bar 96 (93–100; n = 4) long, V shaped; distance between ends 53 (46–69; n = 7). Dorsal bar broadly V shaped, with rectangular posteromedial process; distance between ends 62 (50–75; n = 10). Hook pairs 1, 7—44 (38–47; n = 11) long, with recurved point, broad flattened thumb, expanded shank comprising 2 subunits, lacking FH loop; pair 2—30 (22–34; n = 7) long, similar to pairs 1, 7 except FH loop reaching junction of shank subunits; pairs 3, 4—20 (19–21; n = 10) long, with slightly expanded shank, FH loop about shank length; pairs 5, 6—25 (24–27; n = 7) long, with flattened thumb, thin shank, FH loop 3/4 shank length. MCO 123 (113–133; n = 8) long, J shaped, with subterminal heavy sclerotization of the wall of the tube; margin of base delicate; proximal basal bags lightly sclerotized. Accessory piece 43 (34–49; n = 5) long, a sheath enclosing about 1/3 of MCO shaft. Testis 124 (101–147; n = 3) long, 84 (72–102; n = 3) wide, ovate; seminal vesicle sigmoid; 1 prostatic reservoir saccate. Ovary transversely ovate, 49 (39–59; n = 3) long, 68 (58–77; n = 3) wide; oviduct, ootype not observed; vagina simple, with thick-walled vestibule, aperture near level of copulatory complex; seminal receptacle transversely ovate; vitellaria dense.

REMARKS: All specimens available for study were contracted. Characters differentiating this species from its apparent relatives, *Demidospermus uncusvalidus* and *D. leptosynophallus,* are given in the remarks for *D. uncusvalidus.* The specific name is from Latin (*majusculus* = somewhat larger) and refers to the size of this helminth compared with its congeners.

Demidospermus leptosynophallus sp. n. (Figs. 88–97)

HOST AND LOCALITY: Gills of *Iheringichthys westermanni:* Río de la Plata near Buenos Aires, Argentina (28 February 1994).

SPECIMENS STUDIED: Holotype, USNPC 87149; 15 paratypes, USNPC 87150, HWML 39350, MACN 34114/A27.

DESCRIPTION: Body 494 (405–648; n = 5) long, robust, fusiform; greatest width 142 (122–163; n = 4) in posterior or anterior trunk. Cephalic margin rounded; lobes poorly developed. Eyes 4, eye granules infrequently dispersed; posterior pair large, proximate; anterior pair small, widely separated. Pharynx spherical, 37 (34–40; n = 5) in diameter; esophagus short. Peduncle broad; haptor subhexagonal, 119 (114–130; n = 5) wide, 90 (75–111; n = 6) long; bilateral glandular patches not observed. Ventral anchor 40 (34–44; n = 7) long, with short roots, short shaft, tip of point recurved; base 21 (19–23; n = 6) wide. Dorsal anchor 38 (35–41; n = 9) long, with short roots, short shaft, tip of point slightly recurved; base 19 (18–20; n = 4) wide. Bars V shaped; ventral bar 85

(80–90; n = 4) long, distance between ends 53 (40–67; n = 9); dorsal bar 69 (63–78; n = 7) long, distance between ends 47 (38–56; n = 10). Hook pairs 1, 2, 7 with recurved point, broad flattened thumb, dilated shank comprising 2 subunits, apparently lacking FH loop; pairs 1, 7—42 (39–46; n = 13) long; pair 2—32 (31–33; n = 7) long. Hook pairs 3, 4—17 (16–18; n = 13) long, with slightly inflated shank, erect thumb, FH loop about shank length; hook pairs 5, 6—23 (22–25; n = 9) long, with flattened thumb, thin shank, FH loop about shank length. MCO coiled forming incomplete ring, frequently appearing J shaped; base with delicate margin, 2 sclerotized flaps; proximal bags not observed; MCO 86 (75–95; n = 7) long, ring diameter 20–21 (n = 3). Accessory piece 63 (62–65; n = 2) long, comprising sleeve enclosing distal MCO shaft. Testis 85 (71–103; n = 3) long, 36 (n = 2) wide, ovate; seminal vesicle sigmoid; 1 prostatic reservoir saccate. Ovary subspherical, 45 (38–57; n = 5) long, 37 (31–42; n = 5) wide; oviduct, ootype, seminal receptacle not observed; vagina with small vestibule, aperture midway between level of ovary, copulatory complex; vitellaria dense. Egg 95 (91–100; n = 2) long, 71 (70–72; n = 2) wide, ovate, with one side slightly flattened; proximal filament a short knob.

REMARKS: This species is most similar to *Demidospermus majusculus* based on the comparative morphology of the haptoral armament and vagina. It differs from *D. majusculus* by lacking a posteromedial projection on the dorsal bar and by lacking a subterminal thickening of the wall of the MCO. The specific name is from Greek (*leptosyne* = slenderness + *phallos* = penis) and refers to the male copulatory organ.

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The authors would like to thank Dr. Ralph Lichtenfels (USNPC) and Mr. Maurice "Skip" Sterner (HWML) for allowing us to examine type specimens in their care.

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Neotropical Monogenoidea. 35. *Pavanelliella pavanellii*, a New Genus and Species (Dactylogyridae, Ancyrocephalinae) from the Nasal Cavities of Siluriform Fishes in Brazil

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ABSTRACT: *Pavanelliella*, a new monotypic genus, is proposed for accommodation of a species with the following features: presence of 2 bilateral pairs of cephalic lobes; a velumlike haptor armed with 14 ventral submarginal hooks evenly spaced along the posterolateral margins of the haptor; hook shank comprising 2 subunits; overlapping, intercecal gonads (testis dorsal); a sinistral vaginal aperture; and absence of a peduncle, haptoral anchors, bars, and 4A's. *Pavanelliella pavanellii* sp. n. is described from the nasal cavities of *Pseudoplatystoma corruscans* (Agassiz), Pimelodidae (type host), from the Rio Paraná drainage near the village of Porto Rico, Paraná, and from *Callophysus macropterus* (Lichtenstein), Pimelodidae, from Rio Solimões, Ilha da Marchantaria, near Manaus, Amazonas, Brazil.

KEY WORDS: Monogenoidea, Dactylogyridae, Ancyrocephalinae, *Pavanelliella* gen. n., *Pavanelliella pavanellii* sp. n., *Pseudoplatystoma corruscans*, *Callophysus macropterus*, Rio Paraná, Rio Solimões, Brazil.

Members of the Dactylogyridae are primarily parasites of the gills of marine and freshwater fishes. Some, however, occur in the nasal cavities of these hosts. In the neotropics, 1 species of *Rhinonastes* Kritsky, Thatcher and Boeger, 1988, 4 species of *Rhinoxenus* Kritsky, Boeger and Thatcher, 1988, and 2 species of *Telethecium* Kritsky, Van Every and Boeger, 1996, have been reported as parasites in the nasal cavities of freshwater fishes (Kritsky et al., 1988a, b, 1996; Boeger et al., 1995). Members of these genera display outstanding features (primarily of the haptor) that distinguish them from all other dactylogyrid genera. In the present paper, another new dactylogyrid genus, *Pavanelliella*, is proposed for parasites collected from the nasal cavities of siluriform fishes in the Rio Paraná and Rio Amazonas in Brazil. *Pavanelliella pavanellii* sp. n. is described.

Pseudoplatystoma corruscans (Agassiz) was collected by gill net from 2 locations in the Rio Paraná drainage near Porto Rico, Paraná, Brazil, during June 1996; *Callophysus macropterus* (Lichtenstein) was obtained by hook-and-line from the Rio Solimões, Ilha Marchantaria, near Manaus, Amazonas, Brazil, during September 1983. Methods of parasite collection from the hosts' nasal cavities and preparation of helminths for study, measurement, and drawing were those of Kritsky et al. (1988a). Measurements (in micrometers) include the average followed by the range and number of specimens measured in parentheses. Type specimens and vouchers are deposited in the collections of the Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil (INPA); the U.S. National Parasite Collection, Beltsville, Maryland (USNPC); and the University of Nebraska State Museum, Lincoln, Nebraska (HWML), as indicated in the description.

Class Monogenoidea Bychowsky, 1937
Order Dactylogyridea Bychowsky, 1937
Dactylogyridae Bychowsky, 1933
Ancyrocephalinae Bychowsky, 1937
Pavanelliella gen. n.

DIAGNOSIS: Body fusiform, comprising cephalic region, trunk, haptor; peduncle absent. Tegument thin, smooth. Cephalic region with 2 pairs of bilateral cephalic lobes, each lobe with head organ; additional bilateral pair of head organs between cephalic lobes. Cephalic glands present. Eyes 4; granules elongate ovate. Mouth midventral; pharynx muscular, glandular; esophagus present; intestinal ceca (2) confluent in posterior trunk, lacking diverticula. Gonads over-

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lapping, intercecal; testis dorsal to germarium. Genital pore midventral in anterior trunk. Vas deferens looping left intestinal cecum; seminal vesicle a dilation of vas deferens; 1 prostatic reservoir. Male copulatory organ consisting of sclerotized coiled tube with counterclockwise rings (Kritsky et al., 1985); accessory piece free from base of male copulatory organ. Vaginal aperture sinistral; seminal receptacle immediately anterior to germarium; uterus ventral along midline. Vitellaria coextensive with gut. Haptor a velumlike extension of posterolateral, posterior margins of trunk; armed with 14 evenly spaced, submarginal hooks. Hooks similar, ventral; each with shank comprising 2 subunits; proximal subunit expanded. Anchors, bars, 4A's absent. Parasites in nasal cavities of Neotropical siluriform fishes.

TYPE AND ONLY SPECIES: *Pavanelliella pavanellii* sp. n. from *Pseudoplatystoma corruscans,* Pimelodidae (type host), and *Callophysus macropterus,* Pimelodidae.

ETYMOLOGY: The generic epithet and specific name of the type species are proposed in honor of Dr. G. C. Pavanelli, Universidade Estadual de Maringá, NUPELIA, Maringá, Paraná, Brazil, in recognition of his work on parasites of fish from the Rio Paraná and in sincere gratitude for hospitality and for arranging the collection of hosts from the research field station at Porto Rico, Paraná, during a visit of the senior author to southern Brazil.

Pavanelliella pavanellii sp. n. (Figs. 1–4)

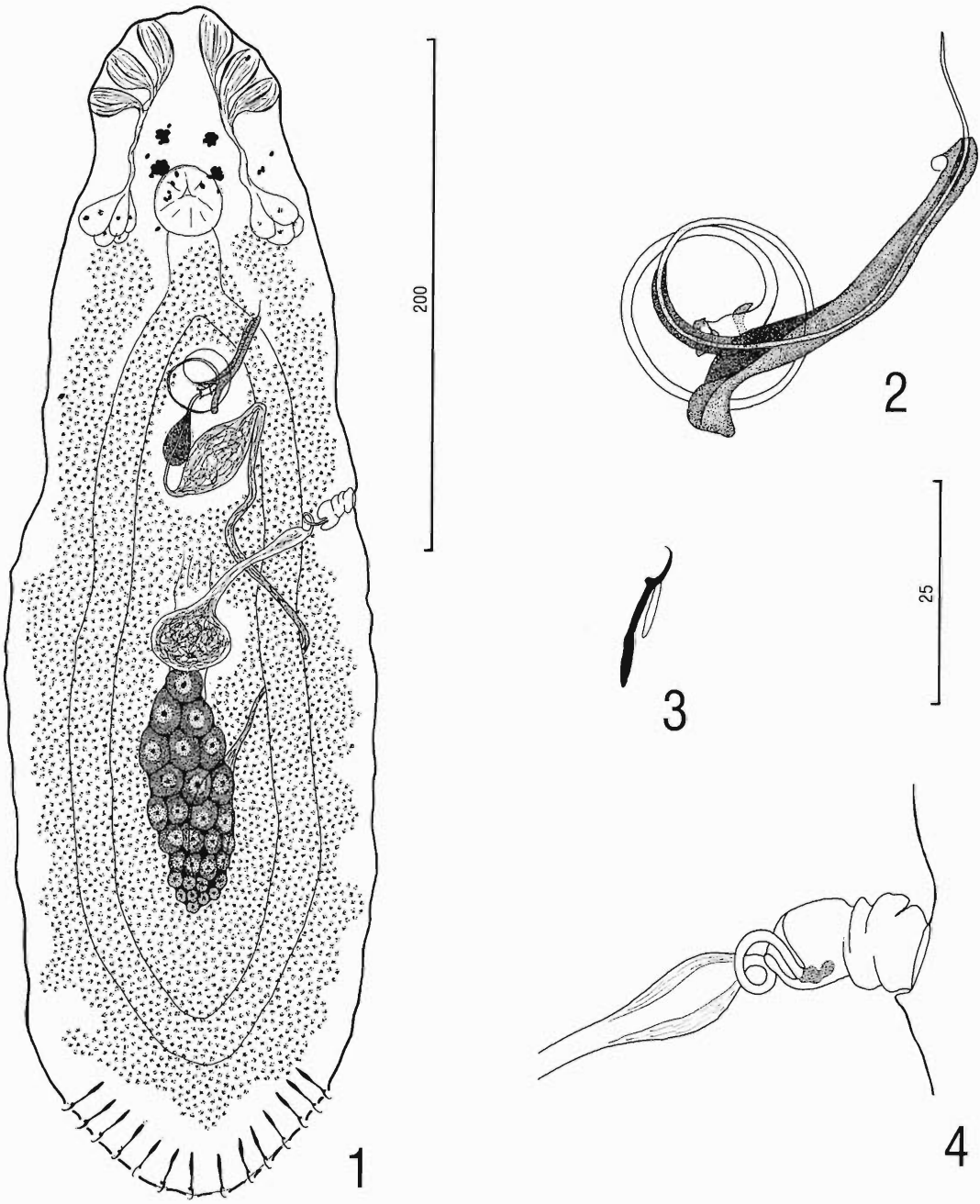
DESCRIPTION: Body 424 (306–514; n = 22) long, fusiform, somewhat flattened dorsoventrally, tapering in anterior trunk; greatest width 124 (82–162; n = 21) in posterior trunk. Cephalic lobes moderately developed. Eyes subequal, equidistant; accessory granules in cephalic, anterior trunk regions. Pharynx spherical, 24 (19–28; n = 22) in diameter; esophagus moderately long. Haptor delicate, a narrow U-shaped velum surrounding posterolateral, posterior margins of trunk; velum 19 (15–20; n = 18) wide at posterior extremity. Hook 18 (17–19; n = 25) long, with truncate protruding thumb, delicate point; FH loop reaching union of shank subunits. Male copulatory organ a coil of about 2 rings, base with proximal and distal sclerotized margins; male copulatory organ 161 (140–175; n = 7) long, ring diameter 24 (21–28; n = 30). Accessory piece 44 (35–52; n = 15) long, comprising sheath enclosing distal portion of shaft of male copulatory organ, subproximal lobe. Testis 53–54 (n = 2) long, 22–24 (n = 2) wide, elongate ovate; seminal vesicle sigmoid, lying to left of midline in anterior trunk; prostatic reservoir saccate. Germarium with irregular margin, elongate ovate, 67 (46–78; n = 5) long, 31 (22–36; n = 5) wide; oviduct, ootype not observed; uterus delicate. Vagina with weakly sclerotized distal vestibule, narrow coiled canal widening internally to thick-walled tube opening into medial seminal receptacle; vitellaria dense, absent in regions of reproductive organs.

HOSTS AND LOCALITIES: Nasal cavities of *Pseudoplatystoma corruscans* (type host); (53°17′W, 22°43′S) Rio Baia, near the village of Guaraná, Mato Grosso do Sul and its confluence with the Rio Paraná (type locality) (18 August 1996) and (53°13′W, 22°44′S) Rio Paraná near the village of Porto Rico, Paraná (19 August 1996), Brazil. Nasal cavities of *Callophysus macropterus*; (59°55′W, 03°09′S) Rio Solimões, Ilha da Marchantaria, near Manaus, Amazonas, Brazil (21 September 1983).

SPECIMENS STUDIED: Holotype, INPA PLH 365; 35 paratypes from *P. corruscans,* INPA PLH 366a-1, USNPC 87646, 87647, HWML 39699; 4 vouchers from *C. macropterus,* USNPC 87648.

Discussion

Pavanelliella gen. n. is monotypic. Characters defining the genus suggest a relationship with *Telethecium* Kritsky, Van Every and Boeger, 1996 (members parasitic in nasal cavities of freshwater Osteoglossidae and Clupeidae), and *Kritskyia* Kohn, 1990 (members parasitic in the urinary bladder and ureters of Siluriformes). Members of the 3 genera share the presence of 14 haptoral hooks, a coiled male copulatory organ with counterclockwise rings, a sinistral vaginal aperture, and absence of haptoral anchors, bars, and 4A's. *Pavanelliella* further resembles *Telethecium* by having overlapping gonads (testis dorsal to germarium); it differs from *Telethecium* by 1) lacking a ventral bag containing the copulatory complex, 2) lacking a body peduncle, 3) having hooks all marginal in the haptor (12 marginal, 2 subcentral in *Telethecium* spp.), 4) having a velumlike haptor (globose in *Telethecium* spp.), 5) having cephalic lobes, and 6) having a nonarticulated male copulatory or-



Figures 1–4. ***Pavanelliella pavanellii*** **gen. et sp. n. 1. Whole mount (composite, ventral view). 2. Copulatory complex (ventral view). 3. Hook. 4. Vagina. Figure 1 is drawn to the 200-μm scale; figures 2–4 are drawn to the 25-μm scale.**

gan and accessory piece (male copulatory organ and accessory piece basally articulated in *Telethecium* spp.; see Kritsky et al., 1996).

Pavanelliella resembles *Kritskyia* by possessing a nonarticulated male copulatory organ and accessory piece, absence of a ventral bag for the copulatory complex, and presence of 14 hooks all marginal in the haptor. It differs from *Kritskyia* by having 1) well-developed cephalic lobes, 2) overlapping gonads (tandem in *Kritskyia*), and 3) a velum-shaped haptor (cup-shaped but lacking an anterior rim in *Kritskyia* spp.) and 4) by lacking a body peduncle (see Kohn, 1990; Kritsky et al., 1996).

Other genera with species from the nasal cavities of Neotropical fishes include *Rhinoxenus* Kritsky, Boeger and Thatcher, 1988, and *Rhinonastes* Kritsky, Thatcher and Boeger, 1988. Members of these genera possess haptoral anchors and bars, which, among other characters, exclude them from *Pavanelliella* (see Kritsky et al., 1988a, b).

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Raillietnema brachyspiculatum sp. n. (Nematoda: Cosmocercidae) from *Lepidophyma tuxtlae* (Sauria: Xantusiidae) from México

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ABSTRACT: *Raillietnema brachyspiculatum* sp. n. (Nematoda: Cosmocercoidea), a new nematode from the large intestine of *Lepidophyma tuxtlae* collected at Los Tuxtlas, Veracruz, México, is described and illustrated. It is distinguished from 4 other Neotropical species by number of male caudal papillae, shorter spicule length, and smaller egg size.

KEY WORDS: *Raillietnema brachyspiculatum* sp. n., nematoda, *Lepidophyma tuxtlae,* lizard.

The genus *Raillietnema* was established by Travassos (1927) for those species of cosmocercoid nematodes possessing simple amphidelphic uteri containing few but relatively large ova. *Oxysomatium simples* Travassos, 1925 from *Hyla faber* Wied-Neuwied, 1821 of Brazil was made the type species. There are currently 21 described species of *Raillietnema,* 14 species from the Ethiopian Realm, 5 from the Neotropical Realm, 1 from the Nearctic Realm, and 1 from the Oriental Realm (Baker, 1987). *Raillietnema brachyspiculatum* sp. n. is the sixth species to be described from the Neotropical Realm.

Lepidophyma tuxtlae Werler and Shannon, 1957, Tuxtla tropical night lizard (Lagartija nocturna de Los Tuxtlas), was originally described from Veracruz and is also currently known from the Mexican states of Chiapas and Oaxaca (Flores-Villela and Gerez, 1994). It is an arboreal lizard occurring at elevations from sea level to 1,500 m (Vogt et al., 1997) but restricted to lower tropical lands, regions 6 and 7 of Flores-Villela (1993), which have a temperate humid climate with a wet summer and dry winter.

Materials and Methods

Nematodes were obtained from the large intestines of 3 *L. tuxtlae* hand collected at night at Los Tuxtlas, Veracruz, México (18°35′N, 95°05′W), during April, May, and November 1995. Lizards were fixed in 10% formalin and dissected in 1996. Nematodes were removed and stored in 70% ethanol. They were placed in glycerol on a glass slide, allowed to clear, and examined with a light microscope. Measurements are given in micrometers unless otherwise noted.

Results

The *L. tuxtlae* collected in April was found to contain 211 individuals of an undescribed species of *Raillietnema*; the May specimen harbored 3 *Spauligodon oxkutzcabiensis* (Chitwood, 1938) Skrjabin, Schikhobalova and Lagodovskaja, 1960; the November specimen contained 86 individuals belonging to the genus *Raillietnema* and 4 *S. oxkutzcabiensis.* A description of the new species of *Raillietnema* follows.

Raillietnema brachyspiculatum sp. n. (Figs. 1–7)

DESCRIPTION: Cosmocercidea, Cosmoceridae, Cosmocercinae. Cylindrical nematodes with finely longitudinally striated cuticle. Males and females of similar length, maximum width occurring at level of esophageal bulb. Lateral alae present, maximum width 2, extending from level of anterior end of esophagus to tail in both sexes. Oral opening triangular, lips large, vestibule and pharynx lined with cuticle. Esophagus composed of anterior cylindrical corpus and posterior isthmus with bulb. Intestine slightly swollen anteriorly, rectilinear; junction with rectum supported by 3 gland cells.

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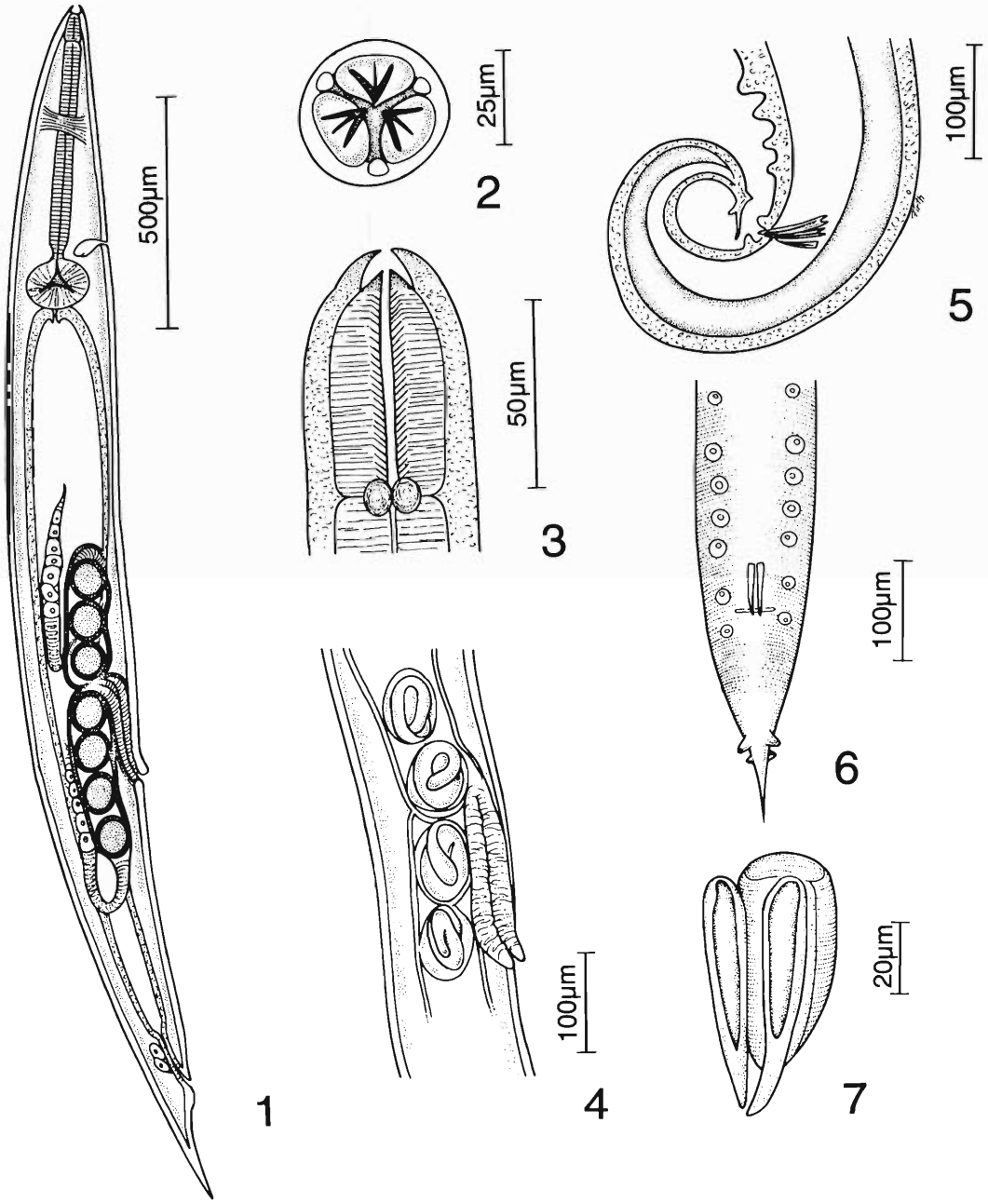

Figures 1–7. ***Raillietnema brachyspiculatum*** **sp. n. 1. Female, entire. 2. Female,** ***en face.*** **3. Female, anterior end, lateral view. 4. Female, vulvar region. 5. Male, posterior end, lateral view. 6. Male, posterior end, ventral view. 7. Spicules and gubernaculatum.**

MALE (10 specimens; mean measurement and range in micrometers): Total length 2,150 (1,910–2,350); width at esophageal bulb 120 (90–130); body tapering posteriorly. Esophagus plus bulb 552 (491–601); bulb length 85 (77–91); bulb width 80 (74–91); pharynx 48 (43–51). Nerve ring, 209 (153–242) and excretory pore 424 (383–459) from anterior end. Spicules

Table 1. Geographical distribution and selected characteristics of species of *Raillietnema*.

Biogeographic Realm *Raillietnema* species	Papillae total: precloacal, postcloacal	Spicule length (μm)	Egg size (μm × μm)	Reference
Ethiopian Realm				
R. bainae Petter, 1966	36: 26, 10	196–210	300 × 250	Petter, 1966
R. chamaeleo Fitzsimmons, 1961	20: 14, 6	35–41	90 × 63	Fitzsimmons, 1961
R. deblocki Chabaud and Brygoo, 1962	24: 12, 12	165	Not given	Chabaud and Brygoo, 1962
R. dupuisi Chabaud and Brygoo, 1962	20: 10, 10	140–160	Not given	Chabaud and Brygoo, 1962
R. kinixys Fitzsimmons, 1964	26: 14, 12	340	260 × 160	Fitzsimmons, 1964
R. loveridgei (Sandground, 1928)	6: 2, 4	206–210	150 × 84	Sandground, 1928
R. multipapillata Walton, 1940	28: 20, 8	280–291	127 × 111	Walton, 1940
R. oligogenos Chabaud and Brygoo, 1962	29: 19, 10	80	Not given	Chabaud and Brygoo, 1962
R. parapetterae Prod'hon, 1968	34: 19, 15	170–180	110 × 60	Prod'hon, 1968
R. petterae Prod'hon, 1968	33: 17, 16	180–190	120 × 60	Prod'hon, 1968
R. travassosi Chabaud and Brygoo, 1962	21: 13, 8	80	Not given	Chabaud and Brygoo, 1962
R. synodontisi Vassiliadès, 1973	31: 21, 10	94	180 × 110	Vassiliadès, 1973
R. vicarians Chabaud and Brygoo, 1962	29: 21, 8	32	Not given	Chabaud and Brygoo, 1962
R. zonosauri Caballero, 1968	26: 16, 10	280	120 × 70	Caballero, 1968
Nearctic Realm				
R. longicaudata (Walton, 1929)	31: 17, 14	179	163 × 95	Baker, 1985
Neotropical Realm				
R. baylisi (Walton, 1933)	16: 8, 8	212	120 × 45	Walton, 1933
R. brachyspiculatum sp. n.	18: 12, 6	57–63	97 × 64	This paper
R. gubernaculatum Freitas and Ibanez, 1965	16: 10, 6	206–253	123 × 53	Gomes, 1967
R. kritscheri Moravec, Maldonado, and Lopez, 1993	25: 17, 8	81–120	220 × 116	Moravec et al., 1993
R. simples (Travassos, 1925)	20: 4, 16	218–221	230 × 105	Walton, 1940
R. spectans Gomes, 1964	20: 10, 10	230–250	115 × 63	Gomes, 1964
Oriental Realm				
R. rhacophori Yuen, 1965	23: 14, 9	200–230	220 × 120	Yuen, 1965

60 (57–63) in length, ventrally curved, equal and similar in morphology, slender and tapering gradually from their proximal ends to a distal point. Gubernaculatum 41 (37–46). Conical tail 490 (459–561) usually ventrally coiled in tight spiral and terminating in fine point. Nine pairs of sessile papillae, 6 preanal, 3 postanal. Anteriormost pair of preanal papillae often small, next 4 pairs equidistant from each other, posterior pair just anterior to cloaca; anteriormost pair of postcloacal papillae just posterior to cloaca, remaining 2 pair on tail filament.

FEMALE (10 gravid specimens): Small, white nematodes tapering posteriorly. Length, 2,420 (2,090–2,810). Width at esophageal bulb 130 (110–150). Esophagus plus bulb 636 (550–700); bulb length 108 (91–120); bulb width 96 (83–108); sclerotized pharynx 56 (40–68). Nerve ring 226 (204–255) and excretory pore 467 (383–510) from anterior end. Amphidelphic uterus containing reduced number of large eggs and supporting short ovaries. Vulva, 1,500 (1,320–1,580) from anterior end, salient anterior lip present. Thick-walled muscular ovijector extending anteriorly 315 (300–330) joining 2 thin-walled uteri, one directed anteriorly and the other posteriorly. Each ovary folded back over its respective uterus such that end of anterior ovary occurs about midbody and end of the posterior ovary lies anterior to vulva. Eggs ovoid 97 (90–102) by 64 (57–70), arranged linearly and larvated at time of deposition; maximum number of eggs per individual 17. Tail 136 (114–160) in length; conical and pointed.

TYPE SPECIMENS: Holotype. Male (Colección Nacional de Helmintos (CNHE), Instituto de Biología de la Universidad Nacional Autónoma de México, CNHE-3190; Allotype: Female CNHE-3191; Paratypes, 9 males, 9 females, CNHE-3192. Voucher specimens were deposited

in the United States National Parasite Collection, Beltsville, Maryland, USNPC No. 87528.

TYPE HOST: *Lepidophyma tuxtlae* Werler and Shannon, 1957, Xantusiidae, April 1995.

SITE OF INFECTION: Large intestine.

TYPE LOCALITY: Los Tuxtlas, Veracruz, México, 18°35′N, 95°05′W.

ETYMOLOGY: The specific name refers to the size of the spicules, which are shorter than of any of the Neotropical species.

Discussion

The assignment of the Los Tuxtlas specimens to the genus *Raillietnema* is based upon the morphology of the female reproductive system. The eggs of *R. brachyspiculatum* sp. n. and *R. chamaeleo* are about the same size (<100 μm); these 2 species have eggs that are smaller than any of the other described species of *Raillietnema* (Table 1). Possession of few large eggs is a characteristic of the genus.

Species of *Raillietnema* can be separated on the basis of male caudal papillae arrangement and length of spicule (Table 1). Six species occur in the Neotropical Realm, namely, *R. baylisi, R. brachyspiculatum* sp. n., *R. gubernaculatum, R. kritscheri, R. simples,* and *R. spectans.* Males of *R. kritscheri* have 25 papillae, *R. baylisi* 22 papillae; *R. simples* and *R. spectans* have 20 each but arranged differently. *Raillietnema brachyspiculatum* has 18 papillae, *R. gubernaculatum* has 16. In females of *R. brachyspiculatum, R. gubernaculatum, R. kritscheri,* and *R. spectans,* the anterior lip of the vulva protrudes beyond the body wall; it does not protrude in *R. baylisi* or *R. simples.* Lateral alae are absent in *R. kritscheri* and present in *R. brachyspiculatum, R. gubernaculatum,* and *R. spectans.* Egg size differentiates *R. brachyspiculatum* from the latter 2 species.

The genus now contains 22 species (Table 1). *Raillietnema kritscheri* and *R. synodontisi* were described from fish hosts; the other species parasitize amphibians and reptiles.

Acknowledgments

We thank Peggy Firth for the preparation of the illustrations constituting Figures 1–7 and Norman Mercado Silva, Guillermina Cabañas Carranza, Rafael Báez Valé, Glizabeth Mayén Peña, Lancy López Flores, and Juan Mánuel Caspeta Mandujano for laboratory assistance.

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The New (XVIII) International Congress of Zoology First Announcement

The date of the New Congress has been set for 28 August–3 September 2000, and the venue will be the Faculty of Philosophy at the University of Athens, Greece, under the auspices of the Hellenic Zoological Society. To reverse the present trend of fragmentation of zoology and the crisis in professional zoological education that became rampant after the suspension of the congresses in 1972, we have decided to dedicate this first renewed congress mainly to a number of integrative symposia and general discussions. We call upon you to participate!

Please inform us **by mid-October 1998 of your intention to participate and/or receive further information contained in our First Circular.** Contact Dr. Rosa Polymeni, University of Athens, Department of Biology, Section of Zoology and Marine Biology, 15784 Athens, Greece. Telephone: 31-1-726-4364; fax: 30-1-728-4604; e-mail: rpolyme@biology.db.uoa.gr. The text of the first circular can be accessed and copied from our web page at http://www.york.biosis.org/zrdocs/new_icz/icz18_1.htm.

Diagnostic Parasitology Course

The Diagnostic Parasitology course is being offered 3–14 August 1998 at the Uniformed Services University of the Health Sciences, Bethesda, Maryland 20814-4799. This course will consist of a series of lectures and hands-on laboratory sessions covering the diagnosis of parasitic infections of humans. In addition to the examination of specimens, participants will be able to practice various methods used in the diagnosis of intestinal, blood, and tissue parasitic diseases. Parasitic diseases encountered throughout the world will be included. Slide presentations and video tapes will be available for study. The course will be held on the University's campus, utilizing up-to-date lecture rooms and laboratory facilities. Microscopes will be available on a loan basis, and laboratory supplies will be provided. Certain reference specimens will also be available for personal use.

The registration fee for the 2-wk course is $1,000. U.S. Government and Military personnel may take the course at a reduced rate. Those interested should register as soon as possible because the number of students will be limited. Previous laboratory experience is recommended.

For further information, contact Dr. John H. Cross, (301) 295-3139, or Ms. Ellen Goldman, (301) 295-3129.

J. Helminthol. Soc. Wash.
65(2), 1998 p. 169–173

Neoechinorhynchus rostratum sp. n. (Acanthocephala: Neoechinorhynchidae) from the Eel, *Anguilla rostrata,* in Estuarine Waters of Northeastern North America

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ABSTRACT: *Neoechinorhynchus rostratum* sp. n. (Neoechinorhynchidae) is described from the eel, *Anguilla rostrata* (Le Sueur), in estuarine waters along the New England and Canadian coasts. The new species is very similar to *N. cylindratus* (Van Cleave, 1913) Van Cleave 1919 with which it has been taxonomically confused. The 2 species can, however, be separated based on egg morphology and the shape of the adult female posterior end, among other features such as host and habitat distribution. Museum specimens of *N. cylindratus* from eels have been examined and reassigned to the new species.

KEY WORDS: Acanthocephala, *Neoechinorhynchus rostratum* sp. n., Neoechinorhynchidae, *Anguilla rostrata,* north Atlantic coast of North America.

Van Cleave (1913) originally described *Neoechinorhynchus cylindratus* based on 41 mature adults from largemouth bass, *Micropterus salmoides* (Lacépède), in Minnesota. He (Van Cleave, 1913, 1919) also indicated that the eel, *Anguilla rostrata* (Le Sueur), was an additional host of the same acanthocephalan species based on material received from Linton identified by him (Linton) as *Echinorhynchus agilis* from eels collected near Woods Hole, Massachusetts. All *Neoechinorhynchus* Hamann, 1892 in Stiles and Hassall, 1905 material found in eels has been routinely classified as *N. cylindratus* since. Bullock (1970) suggested the possibility that specimens from eels may represent a new species of *Neoechinorhynchus.* The recent availability of Bullock's collections of "*Neoechinorhynchus cylindratus*" from the eel verified Bullock's earlier suggestion (see Amin, 1998), and these specimens are herein described as a new species.

Materials and Methods

Acanthocephalans were recovered from eels, *Anguilla rostrata,* in the Oyster River and Johnson Creek in Durham, Stafford County, and in Newington, Rockingham County, New Hampshire. Forty-seven ethanol-preserved worms collected between June and August in 1974 and 1975 were stained in Mayer's acid carmine, dehydrated in ascending concentrations of ethanol, cleared in graduated concentrations of terpineol in 100% ethanol, and whole mounted in Canada balsam.

Other specimens from eels studied include those of Linton from Woods Hole, Massachusetts, and Van Cleave from Baltimore, Maryland, and other unspecified North American locations and from River Denys, Nova Scotia, Canada. Specimens from mummichog, *Fundulus heteroclitus* (Linnaeus), in Salisbury Cove, Maine and Woods Hole, Massachusetts, and from needle fish, *Strongylura marina* (Wallbaum), in Woods Hole were also examined. All above material was identified as "*N. cylindratus*" by Van Cleave or Linton (the latter 2 collections). These specimens were made available from the United States National Parasite Collection (USNPC), Beltsville, Maryland. Other specimens collected from the same and other host species, e.g., Atlantic tomcod, *Microgadus tomcod,* (Walbaum), and grubby, *Myoxocephalus aeneus,* (Mitchill), are available from the Harold W. Manter Laboratory, Nebraska State Museum, Lincoln, Nebraska. For comparative purposes, many *N. cylindratus* from *M. salmoides* in Wisconsin (Amin, 1986a, b) were also studied.

Specimens measured include ours from New Hampshire (10 males, 16 females) and a few of the USNPC specimens that were sufficiently informative (3 males, 5 females). Measurements are in micrometers unless otherwise stated. The range is followed by mean values (in parentheses). Width measurements refer to maximum width. Body (=trunk) length does not include neck, proboscis, or male bursa. Eggs refer to fully developed ripe eggs measured in situ through the body wall of females.

Results

Neoechinorhyncus rostratum sp. n. (Figs. 1–6)

Description

GENERAL: Neoechinorhynchidae, Neoechinorhynchinae with characters of the genus. Shared structures larger in females than in males. Trunk cylindrical and widest in anterior half, normally with 5 dorsal and 1 ventral giant nuclei (Figs. 1, 2).

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Proboscis with prominent apical structure, wider than long, with large hooks in anterior ring heavily rooted and with hooks in posterior ring not much smaller than those of middle ring. Proboscis receptacle single walled, about 3 times as long as proboscis, with brain at its posterior end (Fig. 4). Lemnisci subequal, considerably longer than proboscis receptacle (Figs. 1, 2). Gonopore nearly terminal in both sexes in juveniles and adults (Figs. 1, 2, 5).

MALES (based on 13 specimens with sperm): See Table 1 for measurements. Reproductive system in posterior half of trunk. Anterior testis larger than and contiguous to posterior testis. Cement reservoir 140–343 (297) long by 102–241 (148) wide, marginally overlaps cement gland posteriorly and with 2 main cement ducts (Fig. 1).

FEMALES (based on 21 specimens gravid with eggs and/or ovarian balls): See Table 1 for measurements. Reproductive system 356–826 (629) long in 11 individuals measuring 2.902–8.424 (6.521) mm long (9.6% of trunk length) (Table 2); uterus markedly longer than uterine bell (Fig. 5). Ripe eggs fusiform with polar prolongation of fertilization membrane (Fig. 6).

Taxonomic summary

TYPE HOST: *Anguilla rostrata* (Le Sueur) (Anguillidae).

OTHER HOSTS: *Fundulus heteroclitus* (Linnaeus) (Cyprinodontidae), mostly juveniles in liver; *Strongylura marina* (Wallbaum) (Belonidae), in intestine; *Microgadus tomcod* (Gadidae), immatures in intestine; *Myoxocephalus aeneus* (Cottidae), immatures in intestine.

SITE OF INFECTION: Intestine.

TYPE LOCALITY: Oyster River, Durham, Stafford County, New Hampshire.

OTHER LOCALITIES: Numerous estuarine sites along east coast of North America between Baltimore, Maryland, and Nova Scotia, Canada.

ETYMOLOGY: The new species is named for the specific name of the definitive host.

SPECIMENS DEPOSITED: USNPC No. 87297 (holotype male); No. 87298 (allotype female); No. 87299 (paratypes).

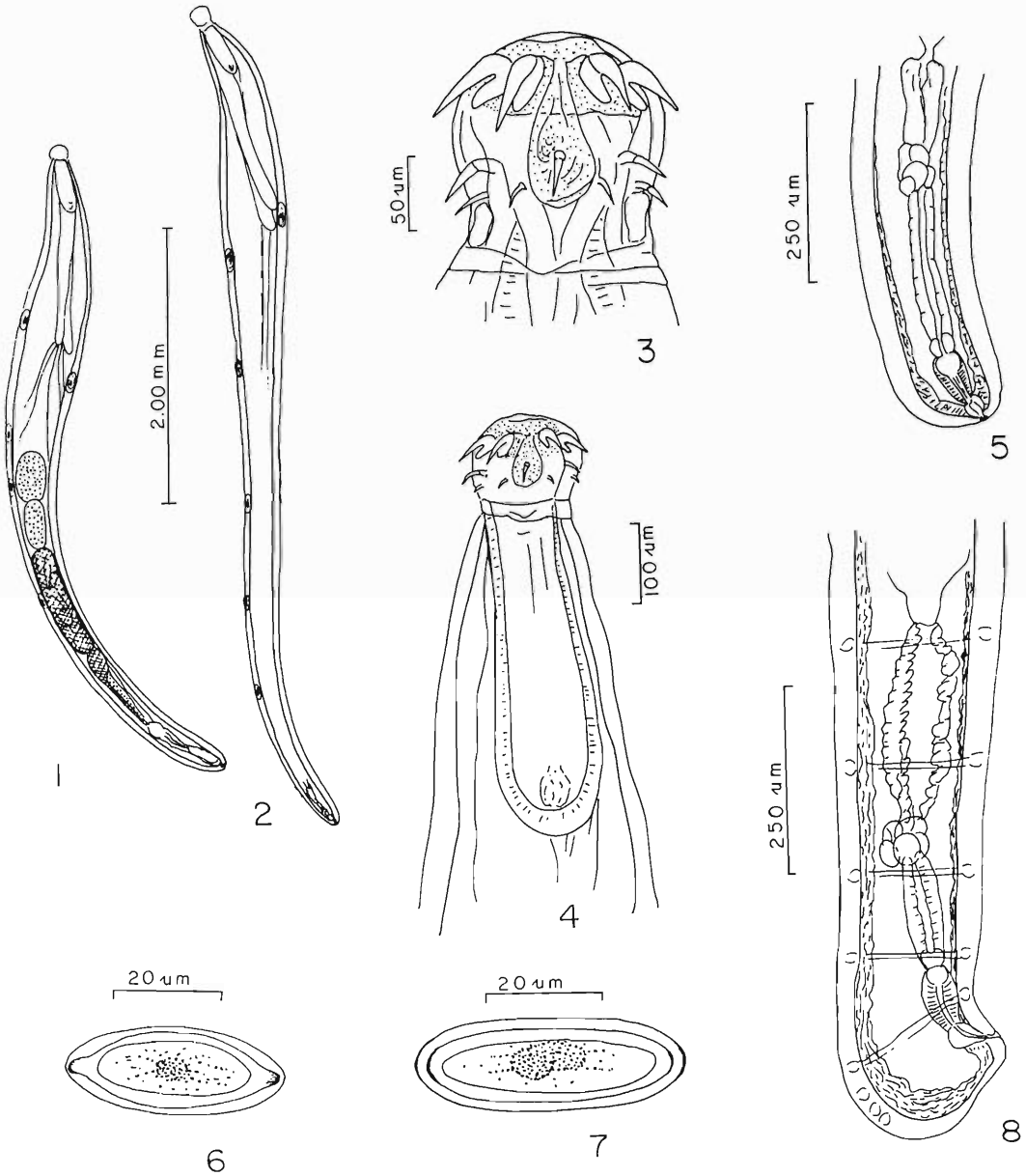
OTHER SPECIMENS EXAMINED: USNPC Nos. 6350, 7629, 38589, 64810, 64812, 64815 from eel, Nos. 64813, 35890 from *F. heteroclitus,* and No. 38591 from *S. marina,* all of which were identified as *N. cylindratus* mostly by Van Cleave; as well as many *N. cylindratus* from the Amin collection from *M. salmoides* in Wisconsin.

Remarks

Neoechinorhynchus rostratum is so similar to *N. cylindratus* that it has been routinely confused with it since Van Cleave's (1913, 1919, 1921) earliest reports of it from eel. Van Cleave's (1921) few measurements of the eel specimens were almost identical to those from *M. salmoides,* upon which he based his original description of *N. cylindratus* (Van Cleave, 1913).

Epidemiologically, *N. rostratum* is an estuarine parasite that matures in the eel. Only immature specimens have been found in the intestine of tomcod, *M. tomcod,* and grubby, *M. aeneus,* in the same localities as infected eels. Liver infections with juveniles in *F. heteroclitus* are occasionally numerous as reported by Manter (1926), who showed that mummichog may serve as a transport host for *N. rostratum* in Mount Desert Island, Maine. The use of transport hosts represents another similarity between *N. cylindratus* and *N. rostratum.* The only infections of the new species in a freshwater centrarchid, normal hosts for *N. cylindratus,* were found in pumpkin seed, *Lepomis gibbosus* collected on numerous occasions from 1 small freshwater pond. This pond was close to the Great Bay, New Hampshire, estuary and emptied into Carter's Brook, a tidal creek. Infected eels and *Fundulus* were common in the same pond. No other infections with *Neoechinorhynchus* were ever found upon the examination of hundreds of *Lepomis* from numerous other localities in New Hampshire. One attempt was made to infect a smallmouth black bass, *Micropterus dolomieui,* by feeding it on *Fundulus* over a 6-mo period. The result was a heavy infection of only immature *Neoechinorhynchus.*

Morphologically, 4 major characteristics separate the 2 species. (1) The ripe egg of *N. rostratum* is somewhat fusiform with polar prolongation of fertilization membrane (Fig. 6). The ripe egg of *N. cylindratus* is longer, oblong, with concentric membranes and no prolongation (Fig. 7). (2) The posterior end of *N. rostratum* females of all stages of growth is almost blunted with a near terminal gonopore (Fig. 5). In *N. cylindratus* juvenile females, the posterior end is similar, but in the maturing adult, the near terminal gonopore begins to develop a distinct body wall pro-



Figures 1–8. Figures 1–6. *Neoechinorhynchus rostratum* sp. n. from *Anguilla rostrata* 1. Holotype male. 2. Allotype female. 3. Proboscis of holotype male. 4. Proboscis and proboscis receptacle of holotype male (lateral view). 5. Reproductive system and posterior end of a paratype female. 6. Ripe egg from the body cavity of a paratype female. Figures 7, 8. *Neoechinorhynchus cylindratus* from *Micropterus salmoides*. 7. Ripe egg from the body cavity of a female. 8. Reproductive system and posterior end of a female.

trusion as it becomes displaced ventrally. This protrusion becomes associated with the development of a well-pronounced posteriorly rounded swelling (Fig. 8). A mass of well-developed muscles lines the swelling internally and connects to the vagina. Adult *N. rostratum* females retain the juvenile form, and no such displacement of gonopore, swelling, or extensive muscle development occurs in mature *N. rostratum*. Similar changes and gonopore displacement be-

Table 1. Morphometric characteristics of adult *Neoechinorhynchus cylindratus* and *N. rostratum*.

		Neoechinorhynchus cylindratus			*Neoechinorhynchus rostratum*	
Reference		Van Cleave (1913, 1919, 1921)	Ward (1940)	Amin (1986a, b)	Van Cleave (1921)	This paper
Host		*Micropterus salmoides*	*Micropterus salmoides*	*Micropterus salmoides*	*Anguilla rostrata*	*Anguilla rostrata*
Locality		Minnesota	Indiana	Wisconsin	Massachusetts	New England
n		41 F, M	22 F, 14 M	150 F, 199 M	?	21 F, 13 M
Females						
Trunk	Length	10.0–15.0	7.0–11	2.32–17.40 (9.7)*	—	2.90–13.01 (7.31)
(mm)	Width	0.7	0.35–0.70	0.28–0.84 (0.54)	—	0.31–0.8 (0.60)
Proboscis	Length	149	100–140	106–160 (140)	150	127–178 (150)
	Width	172	160–190	125–208 (176)	172	140–216 (174)
Hooks	Ant	79–97	61–88	58–109 (91)	79–97	74–93 (82)
	Mid	37	24–40	26–42 (37)	37	38–48 (44)
	Post	21–25	17–27	16–35 (28)	21–25	32–41 (37)
Prob rec	Length	ca. 450	280–350	140–560 (428)	—	317–559 (428)
	Width	—	110–150	56–196 (160)	—	114–190 (155)
Lemnisci	Long	—	950–1,400	378–2,352 (1,378)	—	978–2,146 (1,520)
	Short	—	850–1,340	294–2,044 (1,242)	—	762–1,854 (1,327)
Eggs	Length	49–51	51–61	32–64 (48)	49–51	32–45 (39)
	Width	15–21	17–28	13–25 (17)	15–21	13–22 (17)
Males						
Trunk	Length	4.5–8.5	4.7–6.3	1.84–11.36 (6.66)	—	2.90–7.18 (4.59)
(mm)	Width	0.5–0.7	0.36–0.63	0.28–0.76 (0.52)	—	0.31–0.75 (0.48)
Prob	Length	149	100–140	86–150 (136)	150	114–152 (137)
	Width	172	150–170	112–189 (165)	172	127–178 (155)
Hooks	Ant	79–97	58–82	51–102 (86)	79–97	74–83 (77)
	Mid	37	24–34	22–45 (36)	37	42–48 (45)
	Post	21–25	17–24	16–32 (26)	21–25	32–32 (32)
Prob rec	Length	ca. 450	240–350	140–504 (398)	—	229–483 (399)
	Width	—	130–140	56–252 (144)	—	114–178 (151)
Lemnisci	Long	—	840–1,200	378–1,792 (1,109)	—	965–1,905 (1,375)
	Short	—	740–1,050	322–1,792 (1,020)	—	900–1,333 (1,223)
Ant testis	Length	700	400–700	224–1,722 (690)	—	317–635 (475)
	Width	260	180–250	112–350 (228)	—	140–381 (222)
Post testis	Length	smaller	210–550	140–1,372 (607)	—	317–749 (466)
	Width	—	170–270	98–378 (226)	—	140–267 (201)
Cement gl	Length	1.050 mm	670–1,200	196–2,184 (1,057)	—	470–1,651 (741)
	Width	—	130–280	98–350 (195)	—	140–292 (182)

* Range (mean).

Table 2. Comparison between the measurements of the reproductive system of female *Neoechinorhynchus cylindratus and *N. rostratum*.**

	Trunk length (TL) mm	Reproductive system length (RSL) mm	RSL/TL %
N. rostratum (n = 11)	2.902–8.424 (6.521)†	0.356–0.826 (0.629)	9.6
N. cylindratus (n = 8)	5.772–8.424 (6.486)	0.394–0.737 (0.587)	9.1
N. cylindratus (n = 9)	9.672–16.538 (13.295)	0.698–1.270 (0.980)	7.4
N. cylindratus (total, n = 17)	5.772–16.538 (10.090)	0.394–1.270 (0.795)	7.9

* From Wisconsin *M. salmoides* (Amin, 1986a, b).

† Range (mean).

tween juvenile and adult acanthocephalans are also known in other species of *Neoechinorhynchus,* e.g., *N. idahoensis* Amin and Heckmann 1992. (3) The female reproductive system is of similar length and proportion to trunk length in worms of comparable body length of both species (Table 2). However, the uterus is markedly longer than uterine bell in *N. rostratum* (Fig. 5); the opposite is true in *N. cylindratus* (Fig. 8). (4) Morphometric differences are minimal, except for the relatively longer proboscis hooks in middle and posterior rings and the shorter testes and cement gland of *N. rostratum* compared to *N. cylindratus* (Table 1).

The very close similarities, as well as differences, between *N. rostratum* and *N. cylindratus* are well documented. However, the uniquely fusiform egg with polar prolongation in the first species brings *N. rostratum* closer to species of the genus *Hebesoma* (Van Cleave 1928), which is primarily separated from most *Neoechinorhynchus* spp. based on its egg structure. Other species of *Neoechinorhyncus* with fusiform eggs and/or polar prolongation include *N. agilis* (Rudolphi, 1819) Van Cleave, 1916, *N. doryphorus* Van Cleave and Bangham, 1949, *N. chrysemydis* Cable and Hopp, 1954, and *N. lingulatus* Nickol and Ernst, 1987. *Neoechinorynchus rostratum* may be separated from these other 4 species of *Neoechinorynchus* as follows: anterior proboscis hooks of *N. agilis* are larger (84–140 long); those of *N. doryphorus* are unequal in size; the 2 laterals are conspicuously larger (105–132 long) compared to others in the same circle (61–72 long); the lateral anterior proboscis hooks of *N. chrysemydis* are also larger (80–140 long) than others in the same circle (48–82 long), and eggs are larger (55–60 by 19–22); the proboscis of *N. lingulatus* is considerably larger (192–240 long by 197–254 wide) than in *N. rostratum,* and the lateral hooks of its anterior circle are longer (106–125) than others in the same circle (82–110 long) and set distinctly posterior to them. The latter 2 species are parasitic in turtles; female worms in both species have a prominent papilla/process near their subterminal gonopore. More careful study of *Hebesoma* may show it to be much more closely related to *Neoechinorhynchus* than previously thought.

The above findings shed some light on host and environmental segregation of the 2 species of *Neoechinorhynchus* that are morphologically so similar and raise interesting questions on the speciation in the genus.

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Sphaerechinorhynchus macropisthospinus sp. n. (Acanthocephala: Plagiorhynchidae) from Lizards, Frogs, and Fish in Thailand

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ABSTRACT: *Sphaerechinorhynchus macropisthospinus* sp. n. (Acanthocephala: Plagiorhynchidae: Sphaerechinorhynchinae) is described from females with ovarian balls obtained from the house gecko, *Hemidactlyus frenatus,* and from 2 species of frogs, *Kaloula pulchra* and *Microhyla* sp. collected in the Doi Suthep-Pui National Park, suburban Chiang Mai, Thailand. One unidentified juvenile female now assigned the same species (this paper) was previously reported from the body cavity of the murrel fish, *Ophicephalus striatus,* also in Thailand. For a parasite that probably matures in snakes, the above represents an unusual assortment of paratenic host taxa that sheds some light on the possible biology of these unusual acanthocephalans. The new species is distinguished from the 3 other known species of the genus by having the largest number of proboscis hooks per row (9: 3 anterior rooted hooks and 6 spines) with the third (posteriormost) hook being the largest, among other features.

KEY WORDS: Acanthocephala, *Sphaerechinorhynchus macropisthospinus* sp. n., Thailand, reptiles, amphibians, fish.

Three species of the genus *Sphaerechinorhynchus* Johnston and Deland, 1929 are known. All mature in snakes from Australia or southeast Asia. Johnston and Deland (1929) described adult *S. rotundocapitatus* from the lower intestine of the black snake *Pseudechis porphyriacus* Shaw, 1802 in various parts of Australia. Schmidt and Kuntz (1966) described subadult *S. serpenticola* from the body cavity of the Asian cobra, *Naja naja* (Cantor), and Kiel and Schmidt (1984) reported adults of the same species from the intestine of king cobras, *Ophiophagus hannah* (Cantor, 1836). Bolette (1997) described *S. ophiograndis* adults from the anterior intestine of the king cobra in southeast Asia. Subadult females of an undescribed fourth species of the same genus were collected from 1 species of lizard and 2 species of frogs in Thailand. The following is a description of females of that new species, which is compared to those of the 3 other species of the genus.

Materials and Methods

Eight of 30 (27%) house geckos, *Hemidactylus frenatus* Dumeril and Bibron, 1836 (Gekkonidae), examined between January and June 1994 yielded 21 acanthocephalans ($\bar{x}$ = 0.70). Two species of frogs (Microhylidae) were also examined. Three of 59 (5%) *Kaloula pulchra* Gray, 1831 examined during September and October 1996 yielded 3 worms ($\bar{x}$ = 0.05). Two of 21 (10%) *Microhyla* sp. Tschudi, 1838 examined between 1993 and 1996 yielded 3 worms ($\bar{x}$ = 0.14). All collections were made in the Doi Suthep-Pui National Park, suburban Chaing Mai, Thailand (lat 18°50′–18°56′N and long 98°47′–98°57′E). Specimens were routinely processed, stained in Delafield hematoxylin, and mounted in permount. Measurements are in micrometers unless otherwise indicated. The range is followed by mean values (in parentheses).

Results

Only 3 subadult females (with ovarian balls), 1 from each host species, were available for this study. The largest and most developed worm was from the house gecko and the smallest from *Microhyla* sp. The following description is based on these 3 specimens. See Table 1 for measurements.

Sphaerechinorhynchus macropisthospinus sp. n. (Figs. 1–8)

Description

PLAGIORHYNCHIDAE: SPHAERECHINORHYNCHINAE: Trunk elongate and cylindrical, widest anteriorly and tapers in both directions, more gradually posteriorly; posterior area widens somewhat,

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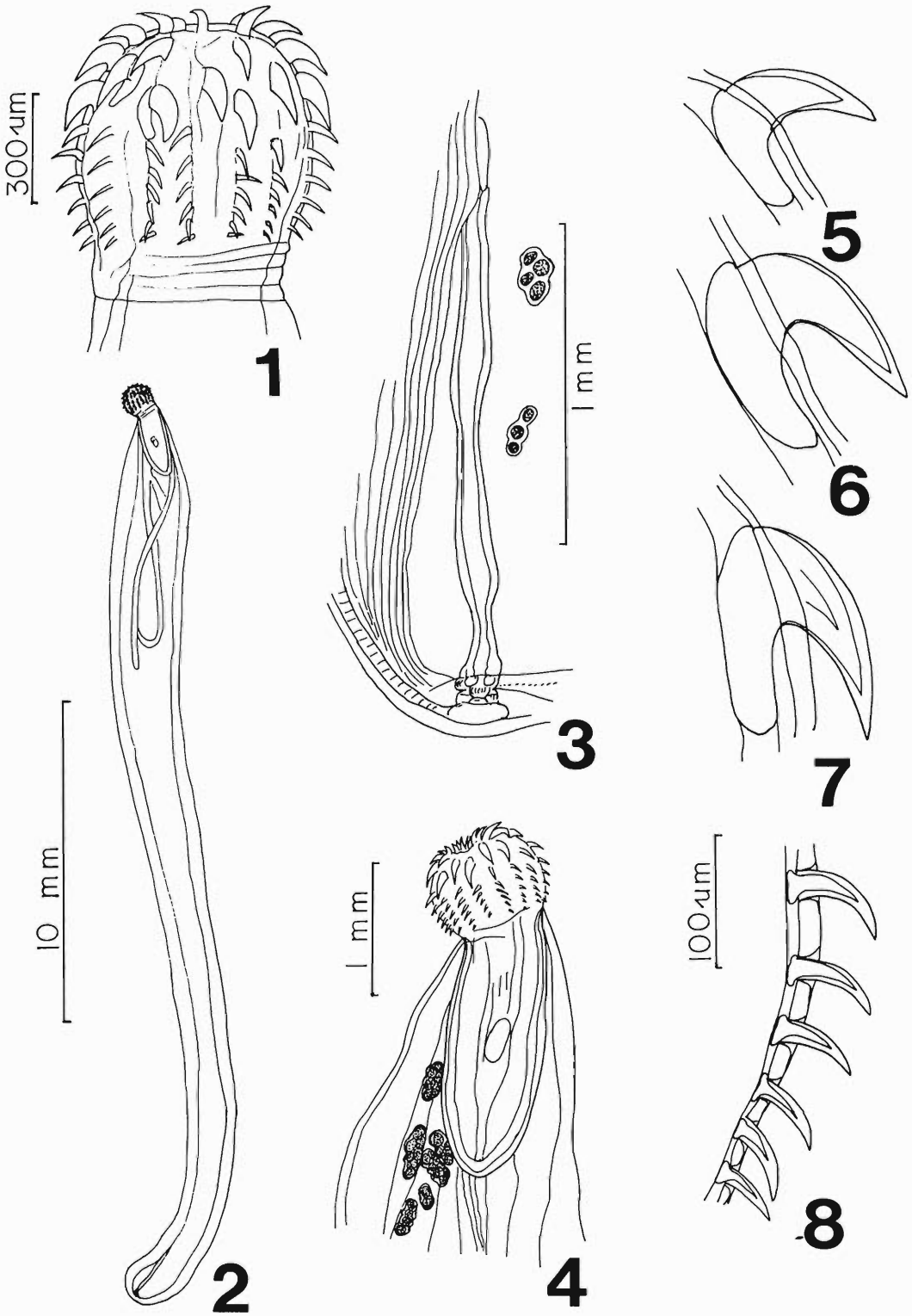
Table 1. A comparison among females of the 4 known species of *Sphaerechinorhynchus*.

	S. rotundocapitatus	*S. serpenticola*	*S. ophiograndis*	*S. macropisthospinus*	
Reference	Johnston (1912), Johnston and Deland (1926)	Schmidt and Kuntz (1966); Kiel and Schmidt (1984)	Bolette (1997)	Farooqi and Sirikanchana (1987)	This paper
Host	*Pseudechis porphyriacus*	*Naja naja, Ophiophagus hannah*	*Ophiophagus hannah*	*Ophicephalus striatus*	*Hemidactylus frenatus, Kaloula pulchra, Microhyla* sp.
Site	Posterior intestine, rectum	Mesenteries; anterior intestine	Anterior intestine	Body cavity	Intestinal mesenteries
Locality	Australia	Borneo (Malaysia) Thailand	Southeast Asia	Bangkok, Thailand	Thailand
Number	Many	Less than 17	4	1	3
Developmental stage	Gravid	Nearly adults, gravid	Gravid	Juvenile	Nearly adults
Trunk L × W (mm)	30–37 × 4–5	17–24 × 1.5–2.0; 50 × ? (adults)	35–47 (39) × 3.5–5 (4.2)	12.0 × 1.25	9.39–28.18 (18.63) × 1.0–2.24 (1.79)
Proboscis L × W	620* × 700–850	522–615 × 615–754	719–869 (815) × 822–891 (865)	850 × 700	635–762 (685) × 635–864 (775)
Hook rows × hooks/row	18 × 6–7	12–17 × 7–8	15–16 × 8 (rarely 7)	15 × 9	14–15 × 9 (rarely 8 or 10)
(No. hooks) length from anterior	(3) 165, 154, 132	(2) 115–136, 160–197	(3) 117–136 (128), 161–188 (177), 86–186 (151)	(3) 80, 120, 150	(3) 84–104 (95), 112–129 (121), 157–182 (168)
Hook roots	Simple, posteriorly directed	Simple, posteriorly directed	Simple, posteriorly directed	Simple, posteriorly directed	Simple, posteriorly directed
Occasional transitional hook length; root	—	71–118; large complex manubrium	75–100 (89); small root	—	106, rare
(No. spines) length from anterior	(3–4) —	(4–5) 84–98 (87), 78–90 (84), 73–84 (78), 70–84 (76), 70–81 (74)*	(4–5) 59–83 (75), 59–83 (71), 59–83 (69), 59–83 (66)	(6) 60 in all 6 spines (?)	(usually 6) 90–101 (96), 75–95 (85), 76–84 (79), 70–84 (78), 70–81 (74), 56–73 (68)
Neck L × W	333 × 833*	230 × 460	286–343 (313) × 697–891 (800)	? × 500*	127–178 (144) × 508–762 (656)
Proboscis receptacle L × W	2.5–2.7 mm × 1.05–0.75 mm (?)	1.7–2.2 mm × 400–612	2.023–2.217 mm (2.120) × 418–445 (432)	1.5 mm × 750	1.270–2.121 mm (1.837) × 571–939 (756)
Lemnisci L (mm);	17–18; unbranched	6.5–9.2; usually branched	9.1–14.1 (11.8); usually unbranched	3.0; unbranched	3.939–7.878 (5.615) usually unbranched
Reproductive syst. length (mm), % of trunk length	4.0, 11.9%*	1.8–2.2 (2.0)* 8.3–11.7% (9.7%)*	2.73–2.89 (2.81) 6.6–7.4% (7.0%)	2.214, 18% (?)*	1.079–1.841 (1.460), 6.5–11.5% (7.8%)
Posterior trunk end	Bifid	Simple	Simple	Simple	Simple
Egg L × W	70–87 × 25–27	Ovarian balls (*N. naja*), eggs (*O. hannah*)	78.6–104.3 (90.6) × 37.1–47.1 (43.9)	No ovarian balls or eggs	Only ovarian balls

* Values derived from authors' accounts and/or examination of deposited specimens.



then becomes broadly pointed at gonopore (Fig. 2). Two major longitudinal lacunar canals present, secondary lacunar canals many, lateral, and tightly spaced. Body wall thick with many randomly distributed, usually rounded, subdermal nuclei that appear associated with ameboid branches observed anteriorly. Proboscis globular, slightly wider than long. Proboscis hooks in 14 or 15 alternating longitudinal rows of 9 hooks each including 3 anterior rooted robust hooks and 6 posterior rootless spiniform hooks (spines) (Figs. 1, 4). Rarely, an occasional transitional hook may be present or 1 spine missing. Anterior hooks progressively increase in size posteriorly as they become more widely spaced; all have roots slightly shorter than blades and slightly humped anteriorly (Figs. 5–7). Spines become more tightly spaced posteriorly as they invariably get smaller; all have anchoring discoid bases (Fig. 8). Transitional hook, if present, slightly longer than anteriormost largest spine. Neck relatively short, broader at base. Proboscis receptacle double walled, attached at base of proboscis, and about 3 times as long as it, with brain (cerebral ganglion) at its middle (Fig. 4). Lemnisci considerably longer than proboscis receptacle, ribbon shaped, subequal, and may rarely branch (Fig. 2). Reproductive system with relatively long uterus that is slightly constricted at middle (Fig. 3). Posterior end simple with terminal gonopore. Eggs not seen. Ovarian balls in clusters of 2–8 arranged in 1 or 2 rows (Figs. 3, 4).

Taxonomic summary

TYPE HOST: House gecko, *Hemidactylus frenatus* Dumeril and Bibron, 1839 (Gekkonidae: Reptilia).

OTHER PARATENIC HOSTS: *Kaloula pulchra* Gray, 1831; *Microhyla* sp. Tschudi, 1838 (Microhylidae: Amphibia); murrel fish, *Ophicephalus striatus* Bloch, 1797 (Ophicephalidae: Pisces) (see Farooqi and Sirikanchana, 1987).

SITE OF INFECTION: Probably intestinal mesenteries.

TYPE LOCALITY: Doi Suthep-Pui National Park, suburban Chiang Mai, Thailand.

OTHER LOCALITIES: An unidentified fish stream, Bangkok, Thailand.

SPECIMENS DEPOSITED: USNPC No. 87621 (holotype female from *H. frenatus*), No. 87622 (paratype female from *Microhyla* sp.).

OTHER SPECIMENS EXAMINED: *Spaerechinorhynchus serpinticola* (USNPC Nos. 60767, 60768); *S. ophiograndis* (USNPC Nos. 86855, 86857, 86858).

ETYMOLOGY: The name of the new species is descriptive of the size of the posteriormost rooted hook being largest compared to the 2 anterior ones.

Remarks

The 3 other species of *Spaerechinorhynchus* are distinguished from *S. macropisthospinus* as follows. *Spaerechinorhynchus serpenticola* has only 2 anterior hooks with simple roots and 4 or 5 posterior rootless spines; occasional transitional hooks with large complex manubria. In *S. rotundocapitatus,* females have bifid posterior end and only 3 or 4 rootless spines behind the 3 anterior rooted hooks; anterior hooks progressively decrease in size posteriorly. The third of the 3 anterior hooks of *S. ophiograndis* is smaller than the second, and the number of posterior rootless spines is only 4 or 5.

Discussion

The 3 other species of *Sphaerechinorhynchus* are known to mature only in snakes. The undocumented speculation of Bolette (1997) that the use of reptile paratenic hosts may implicate birds as possible definitive hosts thus justifying Golvan's (1960) inclusion of the genus *Sphaerechinorhynchus* and his subfamily Sphaerechinorhynchinae under bird parasitic Plagiorhynchidae is not justified. As Schmidt and Kuntz (1966) observed, the unusual proboscis of sphaerechinorhynchid acanthocephalans is very unlike that of Plagiorhynchidae or any other

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Figures 1–8. ***Sphaerechinorhynchus macropisthospinus*** **sp. n. 1. Proboscis of paratype female from** ***Microhyla*** **sp. 2. Holotype female from** ***H. frenatus*****; few scattered ovarian ball clusters and laterally branching secondary lacunal system canals not shown. 3. Reproductive system of holotype female; uterine bell partially obscured. 4. Proboscis and proboscis receptacle of holotype female; note ovarian ball clusters here and in Figure 3. 5–7. Anterior, middle, and posterior rooted hooks on the proboscis of paratype female; note anteriorly humped roots of all hooks. 8. Spines of same row of hooks in Figures 5–7. Figures 5–8: Same scale.**

known family. More information is needed before this question can be answered.

The fact that *S. macropisthospinus* has been recovered in paratenic hosts from 3 classes of vertebrates is most unusual. The fish, amphibian, and reptilian hosts represent a succession from aquatic to terrestrial habitat probably leading to a yet to be identified snake definitive host. Epizootically, the above suggests an aquatic crustacean intermediate host as is common in the life cycle of palaeacanthocephalans. This suggestion is supported by the identification of the semiaquatic water skink *Eulamprus quovii* (Dumeril and Bibron) and the semiterrestial lizards *Hemiergis decresiensis* Fitzinger and *Lampropholis guichenoti* Dumeril and Bibron as hosts of *S. rotundocapitatus* cystacanths (Daniels and Simbotwe, 1984; Daniels, 1985, 1990). More field collections and experimental documentation of the crustacean intermediate hosts and the feeding behavior of the vertebrate paratenic hosts are needed to elucidate the cycle.

The reptilian, amphibian, and fish hosts of *S. macropisthospinus* reported in this study are limited to south and southeastern Asian distribution (Taylor, 1962; Nelson, 1976). Snake hosts of *S. serpenticola* and *S. ophiograndis* have similar distribution. The genus *Microhyla* is prolific and comprises small lowland forms (Zug, 1993). *Kaloula pulchra* is the more common of the 2 species of the genus and is widespread in many ponds in Thailand and is also found in Malaysia, Sri Lanka, and parts of India (Taylor, 1962). Australian black snakes were fairly commonly infected with *S. rotundocapitatus* in New South Wales, Victoria; Southern Queensland; and South Australia (Johnston and Deland, 1929). Skinks were also reported commonly infected in New South Wales, Australia (Daniels and Simbotwe, 1984; Daniels, 1985, 1990). If the genus originally radiated in southern Asia, its spread into Australia would be an example of more recent invasion of a vacant niche, which would explain its relative abundance there.

The new species was considerably more common in the gecko, *H. frenatus,* than in the 2 amphibian species. We do not know how many murrel fish were examined by Farooqi and Sirikanchana (1987). It appears that the reptilian host is the more typical paratenic host, in which *S. macropisthospinus* attains a larger size and further development than the other vertebrate hosts, which is the reason for selecting it as the type host.

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Redescription of *Bolbosoma capitatum* (Acanthocephala: Polymorphidae) from False Killer Whale off Vancouver Island, with Taxonomic Reconsideration of the Species and Synonymy of *B. physeteris*

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ABSTRACT: Many individuals of the acanthocephalan *Bolbosoma capitatum* von Linstow (1880) Porta, 1908 were collected from a stranded false killer whale, *Pseudorca crassidens* (Owen, 1846), off Vancouver Island, British Columbia, Canada, in 1989. This material provided the source of the first comprehensive description of the species, whose identity has been in dispute for over 100 yr. Many specimens collected from whales in 18 locations in the Mediterranean and off Faeroe Islands, North and South America, Caribbean, Africa, Great Britain, Japan, and Australia were examined and determined to belong to *B. capitatum*. Specimens of *Bolbosoma physeteris* Gubanov, 1952 collected from the same type host and locality listed in the original description were also determined to be *B. capitatum*, making *B. physeteris* a junior synonym. The most important determining characters are proboscis armature and variations in the spination of the area between the anterior and posterior cephalic bulbs.

KEY WORDS: *Bolbosoma capitatum*, redescription, Canada, worldwide variability, *B. physeteris*.

Polymorphid acanthocephalans belonging to *Bolbosoma capitatum* (von Linstow, 1880) Porta, 1908 have been reported from various species of whales in widely separated parts of the world over the last 100 yr. The original Italian literature describing *B. capitatum* is based on many specimens collected from one 4-m pilot whale, *Globiocephalus melaena* (Traill, 1809), in the unusual Meditarranean location of "Sea" (Bay) of Genoa. The above observers reported the confluence of the anterior and posterior cephalic fields of spines. The poor initial description of von Linstow (1880), based on specimens from false killer whale, *Pseudorca crassidens* (Owen, 1846) from an unknown location, made no reference to any spines connecting the 2 cephalic fields of spines for which he was criticized by Sabbatini (1895).

Meyer (1932) based his description on Porta's (1908) description and included the Faeroe Islands, East Atlantic, as an additional typical location. Petrochenko (1958) recasted Meyer's (1932) description as did Delyamure (1955) (with alterations), and Yamaguti (1963) quoted Meyer (1932) and Petrochenko (1958). None of these authors examined new material.

In the meantime, *B. capitatum* lacking connecting spines between the 2 cephalic fields was reported from many other parts of the world without making reference to the fact that this material differed from Porta's (1908) description of *B. capitatum* (with rows of connecting spines). In contrast, Gubanov (*in* Delyamure, 1955) described a new species, *Bolbosoma physeteris*, from sperm whale, *Physeter catadon* Linnaeus, which was primarily differentiated from *B. capitatum* by the lack of spines connecting the 2 cephalic fields. It was clear that a complete evaluation of variability in this and other significant taxonomic characteristics, e.g., proboscis armature, was needed to assess the identity of these forms compared to a comprehensive description that removes all the inconsistencies and inadequacies marring previous accounts. This report attempts to accomplish those objectives.

Materials and Methods

A false killer whale stranded on the west coast of Vancouver Island, British Columbia, Canada, on 1 October 1989 yielded many acanthocephalans identified as *B. capitatum*. Worms were extended, fixed, stained in Mayer's acid carmine, dehydrated in ascending concentrations of ethanol, cleared in graded terpineol—100% ethanol, and whole mounted in Canada balsam.

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Measurements are in micrometers unless otherwise stated. The range is followed by mean values (in parentheses). Width measurements refer to maximum width unless otherwise stated. Body (=trunk) length does not include neck, proboscis, or male bursa. The male reproductive system occupies the area between the anterior margin of the anterior testis and the posterior end of the trunk. Egg measurements are made of the outer shell of fully developed acanthors through the body wall of females. Specimens have been deposited in the United States National Parasite Collection (USNPC), Beltsville, Maryland; Dr. J. R. Lichtenfels, Curator.

A few other specimens from our Vancouver material were processed for SEM (Fig. 1) at Dr. Sherwin S. Desser's laboratory, University of Toronto, Canada. Specimens received in absolute ethanol were rehydrated and fixed using phosphate buffered 2.5% glutaraldehyde, postfixed with phosphate buffered 1.0% osmium tetroxide, dehydrated through an ascending ethanol series, dried by sublimation using Peldric II (Pelco International, no longer commercially available), mounted on aluminum specimen stubs, coated with gold/palladium, and examined using a Hitachi S2500 scanning electron microscope operated at 20 kV.

Other specimens examined were collected from various species of whales in the Meditarranean, Faeroe Islands, North and South America, Caribbean, Africa, Great Britain, Russia, Japan, and Australia (Table 1). Some of the British, East Atlantic, Japanese, and Australian materials were processed and mounted with permission.

Results

Our Canadian material is recognized as representing the polymorphid acanthocephalan *Bolbosoma capitatum*. The description below is based solely on material obtained from the false killer whale that was stranded on the west coast of Vancouver Island, British Columbia, Canada, in 1989.

Bolbosoma capitatum (von Linstow, 1880) Porta, 1908 (Figs. 1–3)

Description

GENERAL: Polymorphidae; with characters of the genus *Bolbosoma* Porta, 1908. Shared structures larger in females than in males. Trunk cylindrical, of medium length, and armed anteriorly in 2 cephalic fields separated by an area incompletely and variably free of spines. A constriction up to 4.0 mm long separates the bulbous posterior cephalic field from a long posterior trunk with almost parallel sides. Anterior cephalic bulb with up to 13 irregularly alternating circles of spines that become progressively smaller anteriorly, with the anteriormost spines being the smallest and in an almost perfect circle, delimiting the relatively narrowing bulb from the neck. The interbulbar area widens into a posterior cephalic bulb with up to 14 irregularly alternating circles of spines that are larger posteriorly and markedly larger than those of the anterior cephalic field.

The posteriormost circles of spines of the anterior cephalic field are usually incomplete laterodorsally and are made up of a few ventral spines that extend through the spine-free zone toward the posterior cephalic field of spines, to variable degrees (Figs. 1, 2), occasionally almost merging with it. Occasional spines may also extend anteriorly from the anterior margin of the posterior cephalic field into the bare zone between the 2 fields, also ventrally opposite above spines extending from the anterior field to occasionally almost connect both fields (Fig. 3). These variations contrast with the outer margins of the 2 cephalic fields that are invariably uniform and even.

Proboscis cylindrical, truncated-rounded anteriorly, broadest near its base, with 16–18 rows of 8–9 hooks each. Proboscis hooks of 3 types: anterior hooks medium sized with posteriorly directed simple roots shorter than blades; middle hooks largest with posteriorly directed robust simple roots longer than blades; posterior hooks spinelike, about as long as anterior hooks, and with laterally directed winglike roots. Prominent broadly conical neck almost as long as proboscis. Proboscis receptacle extends posteriorly beyond posterior cephalic bulb region, and the longer subequal lemnisci usually extend past the proboscis receptacle into the anterior portion of the trunk constriction. One specimen (a male) had a number of random cuticular plaques between the posterior cephalic bulb and the constriction.

MALES (based on 10 mature adults with sperm): Trunk 33.990–44.880 (38.620) mm long by 1.551–3.663 (2.332) mm wide. Anterior cephalic field 0.759–1.155 (0.917) mm long by 1.056–1.320 (1.191) mm wide with 6–13 (9.1) circles of at least 24–32 (29) spines each measuring 26–52 (41) long anteriorly and 104–130 (122) long posteriorly (Table 2). Posterior cephalic bulb 0.891–1.320 (1.129) mm long by 2.013–2.871 (2.455) mm wide with 7–12 (8.3) circles of at least 34–52 (45.8) spines each measuring 91–169 (133) long anteriorly and 130–208 (173) long posteriorly (Table 2). Total

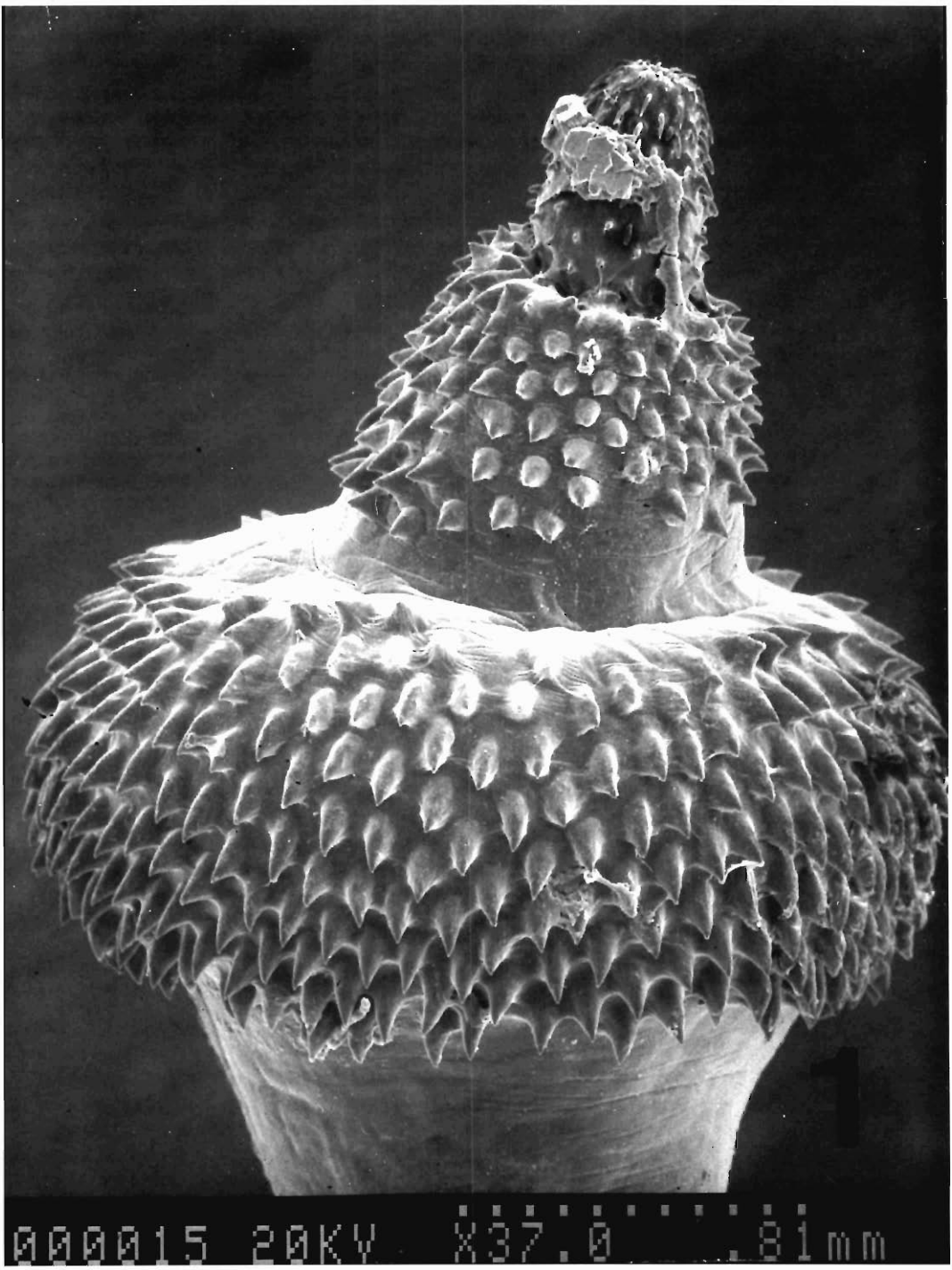

Figure 1. An SEM photo of the anterior portion of an individual *Bolbosoma capitatum* from a false killer whale, Vancouver Island, Canada, showing typical proportions of presomal parts, distribution of cuticular spines of the 2 cephalic fields, and some posterior extension of anterior bulbar spines ventrally (left center).

Table 1. Specimens of *Bolbosoma* examined.

Geographical location	Host species	Specimens	Identification		
		Number	Slides/ vials	By	As
Mediterranean	*Globiocephalus melaena*	2 F	S	Parona (1893)	*E. capitatus*
Sea of Genoa				Van Cleave	*B. capitatum*
Faeroe Islands	*Globiocephalus melaena*	2 M, 3 F	S	Amin	*B. capitatum*
North America					
Newfoundland	*Globiocephalus melaena*	2 juv.	V	Becklund	*B. capitatum*
Prince Edward	*Physeter macrocephalus*	3 F	S	Hoberg et al. (1993)	*B. capitatum*
Island	*Physeter macrocephalus*	6	S/V	Hoberg et al. (1993)	*B. capitatum*
Vancouver Island	*Pseudorca crassidens*	10 M, 10 F	S	Amin and Margolis	*B. capitatum*
		Many	V	(this paper)	
Caribbean	*Globiocephalus macrorhynchus*	3 M, 6 F	S	Hoberg	*B. capitatum*
South America					
Brazil	*Globiocephalus melaena*	2 M	S	Machado Filho (1964)	*B. capitatum*
Argentina	*Pseudorca crassidens*	3 F	V	Amin	*B. capitatum*
West Africa	*Steno rostratus*	1 juv.	V	NHM	*B. capitatum*
South Africa	*Pseudorca crassidens*	2 adults/1 juv.	V	NHM	*B. capitatum*
	Pseudorca crassidens	2 adults	V	NHM	*B. capitatum*
North Sea	*Pseudorca crassidens*	2 adults	V	Verkänfer	*B. capitatum*
Great Britain					
Cornwall	*Globiocephalus melaena*	2 juv.	V	NHM	*B. capitatum*
Lincolnshire	*Pseudorca crassidens*	4 adults	V	NHM	*B. capitatum*
Norfolk	Unknown cetacean	1 adult/2 juv.	V	NHM	*B. capitatum*
Scotland	*Pseudorca crassidens*	4 adults	V	NHM	*B. capitatum*
Russia					
Pacific Ocean	*Physeter catodon*	3 adults/2 juv.	V	Skrjabin	*B. physeteris*†
Japan					
Katsuura Bay	*Pseudorca crassidens*	3 M, 4 F	S	Kikuchi and Nakajima	*B. capitatum*
		6	V	(1991, 1993)	
Australia					
West Australia	*Pseudorca crassidens*	5 M, 5 F	S	Edmonds (1987)	*B. capitatum*
New South Wales	*Pseudorca crassidens*	4 adults	V	NHM	*B. capitatum*
Unknown location	*Physeter macrocephalus*	1 juv.	V	NHM	*B. capitatum*‡

* AHC, SAM: Australian Helminthological Collection, South Australian Museum, Adelaide, Australia (S. Pichelin, Curator); HCIOC: Helminthological Collection, Institute Oswaldo Cruz, Rio de Janeiro, Brazil (Dalynoronha, Curator); NBM: New Brunswick Museum, St. John, New Brunswick, Canada (D. McAlpine, Curator); NHM: The Natural History Museum, London, United Kingdom (Eileen Harris, Curator, Parasitic Worms Division); USNPC: United States National Parasite Collection, Beltsville, Maryland, U.S. (J. R. Lichtenfels, Curator); UV: University of Valencia, Valencia, Spain (T. Raga, Department of Animal Biology); VIGIS: VIGIS Museum; ZM: Zoological Museum, Berlin, Germany (Dr. Neuhaus, Naturhistorisches Forschungsinstitut, Museum für Naturkunde).

† Not *B. physeteris* but *B. capitatum.*

‡ Not *B. capitatum.*

length of cephalic fields including interbulbar area 1.980–2.640 (2.347) mm. Trunk constriction 1.980–3.465 (2.363) mm long by 0.528–1.155 (0.716) mm narrow. Neck 561–910 (757) long by 585–693 (634) wide. Proboscis 715–871 (775) long by 494–546 (519) wide with 16–18 (17.4) rows of 8–9 (8.4) hooks each. See Table 3 for measurements of hook length and diameter at base. Proboscis receptacle 2.640–3.366 (2.948) mm long by 396–495 (458) wide. Longer lemniscus 3.465–4.290 (3.988) mm long by 231–693 (419) wide; shorter lemniscus 2.970–3.696 (3.361) mm long by 264–693 (429) wide.

Testes ovoid, not contiguous, tandem; anterior testis, shortly posterior to trunk constriction; 1.254–2.310 (1.737) mm long by 0.693–1.089 (0.842) mm wide; posterior testis 1.419–2.145 (1.827) mm long by 0.594–1.254 (0.841) mm wide. Two pairs of long cement glands 18.310–26.400 (21.743) mm long by 264–660 (409)

Table 1. Extended.

Inner margins of bulbar spine fields	Source		Remarks
	Museum*	Accession no.	
Obscured	USNPC	6299	Some Parona material used by Sabbatini (1895), Porta (1906, 1908, 1909)
Confluent	UV	136, 286, 3	Locality first reported by Meyer (1932); in 1987, 1989
Extended	USNPC	59341	Bonavista Bay (Cowan, 1967)
Obscured	USNPC	82700	Near Covehead Harbor on north shore of island, in 1989
Obscured	NMB	10211	
Merging	USNPC		Off west coast of island, in 1989
Extended	USNPC	?	Mignucci-Giannoni (1996); Puerto Rico, Virgin Islands
Obscured	HCIOC	29832–29835	Originating from Paulista Museum
Merging	UV	RNP-1419	Off Tierra del Fuego
Obscured	NHM	1934.10.3.31	Near Cape Verde by Discovery Comm. in October 1925
Obscured	NHM	1982.1693–1702	At Tsitikamma Coastal Park, Cape Province by G. Ross
Extended	NHM	1982.138–167	
Confluent	ZM	4409	Original von Linstow material, received from Neuhaus
Obscured	NHM	1932.3.3.55–58	In January 1932
Extended	NHM	1935.12.30.294–303	At Donna Nook, N. Somercotes by F. C. Fraser in October 1935
Merging	NHM	1994.8.10.11–15	At Sherringham by P. Jepson in May 1991
Merging	NHM	1928.12.4.51–100	At Domoch Firth, Ross-shire by J.L.C. Musters & M.A.C. Hinton in December 1927
Extended	VIGIS	N17150, N17159	At K/K Podgornyi, Kuril Islands in June and August 1955; type locality and host of original description
Extended	USNPC	87344	In situ, received from Kazuya Nagasawa, NRIFSF, Shimizu, December 1995
Extended	AHCSAM	16307	In situ, at Augusta by E. Sedlak-Weinstein in July 1986
Extended	NHM	1985.2021–2031	At Crowdy Heads by K. Rohde
—	NHM	1952.12.5.52	By W. F. McIllroy

wide begin one behind the other just posterior to testes and end at posterior margin of Saeffftigen's pouch 1.089–2.310 (1.709) mm long by 0.561–1.254 (0.888) mm wide. Cirrus 0.990–1.320 (1.084) mm long by 0.759–1.254 (0.976) mm wide. Bursa 1.320–2.640 (1.907) mm long by 1.320–2.640 (2.061) mm wide.

FEMALES (based on 10 gravid specimens): Trunk 38.115–68.310 (49.046) mm long by 2.310–3.465 (2.796) mm wide. Anterior cephalic field 0.990–1.155 (1.047) mm long by 0.924–1.452 (1.240) mm wide with 9–13 (10.4) circles of at least 22–32 (27.7) spines each measuring 39–52 (48) long anteriorly and 117–182 (143) posteriorly (Table 2). Posterior cephalic bulb 0.990–1.584 (1.216) mm long by 1.353–3.234 (2.442) mm wide with 8–14 (9.5) circles of at least 36–52 (44.7) spines each measuring 130–182 (154) long anteriorly and 195–234 (210) long posteriorly (Table 2). Total length of cephalic fields including interbulbar area 2.310–3.135 (2.706) mm. Trunk constriction 1.650–3.630 (2.991) mm long by 660–990 (804) wide at narrowest point. Neck 0.594–1.040 (0.819) mm long by 594–754 (692) wide. Proboscis 767–949 (873) long by 494–559 (531) wide with 16–18 (17.2) rows of 8–9 (8.5) hooks each. See Table 3 for measurements of hook length and diameter at base. Proboscis receptacle 2.640–3.300 (3.036) mm long by 462–594 (495) wide. Longer lemniscus 4.026–5.379 (4.798) mm long by 198–495 (323) wide; shorter lemniscus 3.465–5.049 (4.217) mm long by 165–627 (409) wide. Ripe eggs fusiform with polar prolongation of fertilization membrane 130–169 (144) long by 32–39 (36) wide.

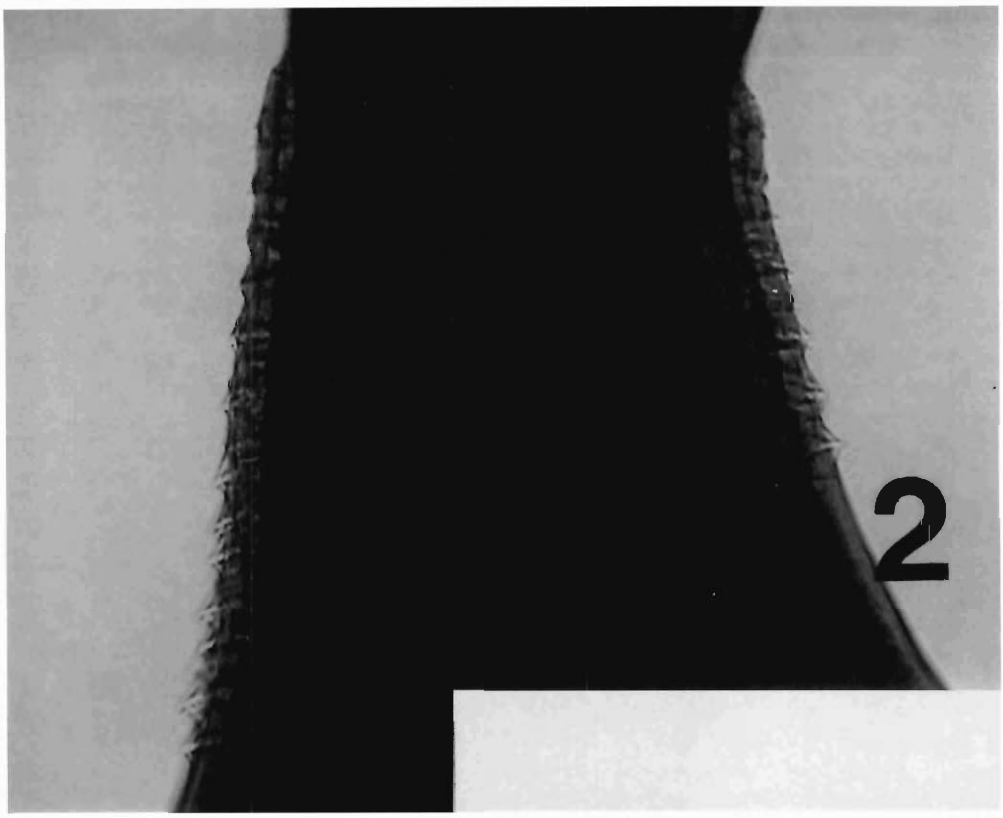

Figure 2. Interbulbar space of an individual *Bolbosoma capitatum* showing pronounced posterior extension of anterior bulbar spines ventrally (left).

SPECIMENS DEPOSITED: USNPC No. 87338 (19 slides and 2 vials).

OTHER MATERIAL EXAMINED: See Table 1.

OTHER SPECIMENS DEPOSITED: USNPC Nos. 87339–87341 (British specimens); USNPC No. 87344 (Japanese specimens); USNPC No. 87343 (Australian specimens); USNPC No. 87342 (Faeroe Islands specimens).

Many other specimens of *B. capitatum* collected from various species of whales in 17 other geographical locations were studied (Table 1). These locations cover practically the full range of geographical distribution of *B. capitatum* with the exception of Antarctica (Golvan, 1960; Dailey and Vogelbein, 1991). In all specimens where the inner margins of bulbar spine fields were not obscured, all collections included individuals having extended-merging fields (as described in our Vancouver specimens above) or confluent fields (the Faeroe Islands specimens).

Discussion

The 2 most important taxonomic characters, interbulbar spines and proboscis armature, are discussed in detail below.

INTERBULBAR SPINES: The early Italian literature describing *B. capitatum* (see Sabbatini, 1895; Porta, 1906, 1908, 1909) was based on Parona's (1893) many specimens collected from 1 pilot whale in the Mediterranean. Sabbatini (1895) made the initial but most definitive statement describing the variation in connecting interbulbar spines as between 0 and 2 rows. This account has been grossly overlooked in all the subsequent taxonomic literature that was content in referring to Porta's (1906, 1908, 1909) descriptions, which also overlooked it. Sabbatini (1895) stated that "more than anything else characterizing the worm . . . is an (interbulbar) area free of spines . . . that is always present, *sometimes can even be crossed by 1 or 2 oblique*

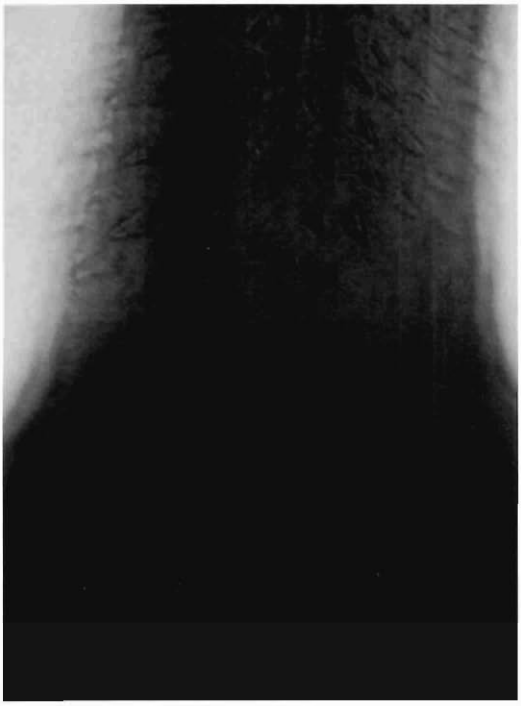

Figure 3. Ventral aspect of interbulbar space of an individual *Bolbosoma capitatum* showing merging of anterior and posterior bulbar spines.

Table 3. Size of proboscis hooks in 10 male and 10 female *Bolbosoma capitatum* from *Pseudorca crassidens*.

Proboscis hooks (from anterior)	Hook length		Hook diameter at base	
	Males	Females	Males	Females
1	68 (52–82)*	71 (52–78)	18 (13–26)	19 (13–26)
2	87 (78–96)	87 (78–91)	23 (20–32)	27 (26–30)
3	95 (91–104)	104 (91–104)	31 (26–39)	33 (26–45)
4	101 (85–109)	112 (98–130)	41 (26–52)	41 (39–45)
5	108 (91–118)	118 (104–143)	47 (39–52)	52 (45–58)
6	105 (91–130)	105 (104–111)	30 (20–39)	51 (45–58)
7	92 (78–104)	95 (78–104)	23 (20–26)	32 (26–39)
8	94 (85–104)	89 (78–104)	16 (13–20)	21 (20–26)
9	76 (65–91)	86 (65–104)	13 (13–16)	17 (13–20)

* Mean (range) in micrometers.

rows of spines. It is surprising that this has escaped Linstow who does not make any hint of it in his description nor does he give any illustration of it" (p. 3). Hoberg et al. (1993) stated that the 2 voucher specimens of Parona (USNPC 6299) had distinct fields of spines and that von Linstow (1880) described "2 fields of spines that were confluent ventrally." We are not certain about the status of the above Parona specimens, and note that von Linstow (1880) only stated that there were about 20 rows of spines on a "bell-shaped swollen receptaculum" (the bulb). Sabbatini (1895) examined 2 of von Linstow's (1880) specimens and found them with contiguous interbulbar ventral spines. In his formal description, Porta (1908) only acknowledged that the interbulbar space is "armed only ventrally with 1–3 oblique rows of spines." Meyer (1932) based his description of *B. capitatum* on Porta's (1908), and subsequent taxonomic accounts, e.g., Petrochenko (1958), Delyamure (1955), and Yamaguti (1963), were primarily based on Meyer's (1932) and made no reference to Sabbatini (1895). There is no evidence that any new

Table 2. Length of trunk spines in anterior and posterior cephalic fields of 10 male and 10 female *Bolbosoma capitatum* from *Pseudorca crassidens*.

Trunk spines (from anterior)	Anterior cephalic field		Posterior cephalic field	
	Males	Females	Males	Females
1	41 (26–52)*	48 (39–52)	133 (91–169)	154 (130–182)
2	55 (26–78)	80 (65–104)	140 (65–182)	160 (143–182)
3	70 (52–91)	95 (78–130)	148 (104–195)	167 (156–182)
4	83 (65–104)	104 (91–143)	149 (104–195)	174 (156–195)
5	90 (65–117)	111 (104–143)	154 (130–195)	179 (156–195)
6	101 (78–117)	119 (104–143)	159 (130–208)	185 (169–195)
7	109 (78–130)	126 (117–156)	166 (130–208)	191 (182–195)
8	116 (78–156)	130 (117–156)	167 (130–208)	199 (182–221)
9	130 (91–195)	137 (117–156)	171 (130–208)	206 (182–234)
10	122 (104–130)	143 (117–182)	173 (130–208)	210 (195–234)

* Mean (range) in micrometers.

specimens were examined by these authors. Porta's (1908) interpretation of Parona's (1893) specimens remains the ultimate source of information on the armature of the bulb in *B. capitatum.*

The specimens examined by us from our various sources throughout the world (Table 1) included individuals having extended or merging fields of bulbar spines or confluent fields in each collection. We consider all of these to be *B. capitatum* as they all fit within the now recognized range of variation for that trait of 0–3 oblique rows of interbulbar spines; 0–2 (Sabbatini, 1895) and 1–3 (Porta, 1906, 1908). Von Linstow (1880) may have actually observed only a few individuals with incomplete confluence of spines like ours from Vancouver. It is possible, but unlikely, that authors dealing with such specimens (Table 1) assigned them to *B. capitatum* after having considered Sabbatini's (1895) work but never mentioned it.

The controversy regarding the von Linstow (1880) specimens, e.g., what did he really observe, was resolved by the examination of 2 original materials from his *P. crassidens* study in the North Sea (Table 1). The larger of the 2 specimens showed considerable posterior and ventral extension of anterior bulbar spines, like our specimens from Vancouver (Figs. 1–3). The spine fields were connected ventrally accross the reduced interbulbar space with 1 longitudinal row of only 3 spines. One adjacent spine was positioned as though it represented an incomplete row. Dorsolaterally, 2 transverse "occasional" spines almost connected the 2 spine fields that appeared very close at 1 other point near where the opposite incomplete inner circles of bulbar spines were. Von Linstow's younger specimen showed some ventral merging of spine fields, but no confluence was evident. The full range of variation in interbulbar spines reported above (Table 1) appears to be represented in the 2 von Linstow specimens. The historical discrepancies that plagued the systematics of *B. capitatum* for so long are thus considered resolved.

The Russian specimens examined by us (Table 1) were collected by A. S. Skrjabin in 1955 from 2 sperm whales near the Kuril Islands and were labeled as having been identified in 1959. These specimens were probably obtained during the expedition referred to by Skrjabin (1959) and apparently are not the original ones based on which Gubanov (*in* Delyamure, 1955) described his new species, *B. physeteris,* in his thesis. The latter specimens were collected during an expedition conducted in 1950 in the same general area. Gubanov (1952, *in* Delyamure, 1955) distinguished *B. physeteris* from *B. capitatum* by the absence of confluence of bulbar spines in the former but not the latter species. Delyamure (1955) and Petrochenko (1958) concurred; otherwise, the 2 species are rather similar. Examination of the Skrjabin specimens revealed that they fall within the same range of variation observed in other *B. capitatum* examined by us (Table 1).

PROBOSCIS ARMATURE: Porta (1906) described 12–18 *transverse* rows of hooks on the proboscis of *B. capitatum.* In his 2 later papers (Porta, 1908, 1909), he omitted the word "transverse" and referred only to 12–18 rows of hooks. Meyer (1932), Petrochenko (1958), and Yamaguti (1963) incorrectly interpreted Porta's descriptions as 12–18 *longitudinal* rows of hooks, without data on the number of hooks per "longitudinal" row. Actually, neither the number of longitudinal rows of hooks nor the number of hooks in each transverse row was given by Porta in any of his papers. However, the 12–18 transverse rows of hooks translates into 6–9 hooks per longitudinal row, because of the alterating "transverse" arrangement of hooks in adjacent longitudinal rows.

Delyamure (1955) correctly cited the number of *transverse,* i.e., circular, rows of hooks as 12–18; his description of 18–20 longitudinal rows may have come from Baylis (1929), who stated "18 (–20?)." We can not determine the source of the Baylis (1929) number. Edmonds (1957) gave a formula of 14–16 longitudinal rows of 8 hooks each. Yamaguti (1963) cited these numbers also, attributing them to Edmonds (1957), who later (Edmonds, 1987) reported 15–17 longitudinal hook rows from an additional collection.

Kikuchi and Nakajima's (1991) description of 10–20 longitudinal rows must be considered a typographical error for 16–20 rows, which is the number given in Kikuchi and Nakajima's 1993 description (16–20 in males, 18–20 in females). In their 1991 abstract, they report 12–16 circular (transverse) rows of hooks on the proboscis. In their 1993 paper, the number of transverse rows was given as 12–18 in males and 15–18 in fe-

males. This translates into 6–9 hooks per longitudinal row in males and 7–9 in females.

In *B. physeteris,* Delyamure (1955) described 6–8 hooks per row in both sexes, with variations in females of 6–7 or 7–8. Delyamure (1955) examined 7 specimens collected by Gubanov from the sperm whale. Petrochenko (1958) reported 6–8 hooks per row in males (with variations from 5–6 to 7–8) and armature in females "almost the same" as in males. There is no indication that Petrochenko examined any specimens. He noted that his description was taken from Gubanov (*in* Delyamure, 1955), which was a thesis. This leaves open the question of why Petrochenko (1958) gave a range of 6–8 when he quotes the variations as 5–6 to 7–8, i.e., 5–8. This is the range given in a comparative table by Skrjabin (1959). Otherwise, the data in Skrjabin's (1959) table appear to be taken from Delyamure (1955). The number of longitudinal rows of proboscis hooks appears to be 18–20 in *B. physeteris.* Both Delyamure (1955) and Petrochenko (1958) report the same number. The key by Petrochenko (1958) has a strange error; there are no characters leading to *B. physeteris.* The number of 20–24 longitudinal rows of hooks applies to "*Bolbosoma serpenticola* (Fukui, 1929) Meyer, 1932" (=*Diplospinifer serpenticola* Fukui, 1929). Skrjabin (1970) gives the hook numbers as 20–24 by 7–8, which is the result of failing to recognize the error in Petrochenko's (1958) key.

Conclusions

The interbulbar spine pattern in all specimens described in the literature or examined in this study (Table 1) falls within the range of 0–3 transverse rows in *B. capitatum* as established above. Similarly, proboscis armature is basically the same, irrespective of host or geographical distribution. Also, the size and shape of proboscis hooks, roots, bulb spines, trunk, proboscis, proboscis receptacle, and eggs are similar. These similarities also include those of *B. physeteris.* A comprehensive comparative listing of measurements of these structures, among others, will not be attempted. The following, however, should be noted. Only 2 sets of hook measurements were given for *B. physeteris* proboscis hooks. Measurements of its "anterior hooks" (actually, the middle hooks) are similar to those middle hooks of other *B. capitatum* populations. The size of bulb spines of *B. physeteris* is the same as that given for the larger of these spines in *B. capitatum* by Kikuchi and Nakajima (1993).

It is concluded that in the absence of any outstanding difference justifying the retention of a specific status for *B. physeteris,* this species becomes a junior synonym of *B. capitatum.* It is further concluded that all populations of *Bolbosoma* examined in this study and included in Table 1 (except the last collection) belong in *B. capitatum.*

Acknowledgments

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1998–1999 Meeting Schedule

14 October 1998	Walter Reed Army Institute of Research, Washington, DC, 7:30 pm (Contact person: Joan Jackson, 202-782-1236)
18 November 1998	Anniversary Dinner—Meeting Location TBA
20 January 1999	Armed Forces Institute of Pathology (WRAMC), Washington, DC, 7:30 pm (Contact person: Ronald Neafie, 202-782-1829)
10 March 1999	Uniformed Services University of the Health Sciences, Bethesda, MD, 7:30 pm (Contact person: John Cross, 301-295-3139)
8 May 1999	University of Pennsylvania, New Bolton Center, Kennett Square, PA, 2:00 pm (Contact person: Jay Farrell, 215-898-8561)

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Description of *Mediorhynchus papillosus* (Acanthocephala: Gigantorhynchidae) from a Colorado, U.S.A., Population, with a Discussion of Morphology and Geographical Variability

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ABSTRACT: The original description of *Mediorhynchus papillosus* Van Cleave, 1916 included misinterpretations of such taxonomically important structures as proboscis armature. The species was briefly redescribed from Asian material by Schmidt and Kuntz (1977) as well as by various Russian and other workers before and after 1977. The present collection from Colorado provided important taxonomic information previously unreported or erroneously interpreted. The first description of *M. papillosus* from North American specimens collected from a sage thrasher, *Oreoscoptes montanus* Baird, 1858, in Colorado, U.S.A., is presented with new features reported for the first time. A comprehensive comparison of the North American, Asian, and Russian populations is presented and discussed. *Mediorhynchus papillosus* appears to be a geographically variable species, particularly in size of proboscis and its armature, and relative space occupied by the neck and posterior proboscis. The geographically isolated Taiwanese population was markedly different from the Colorado population; the latter was more similar to others from various Soviet republics, particularly the Ukraine. Distinctiveness of geographical populations appears to be related to geographical restrictions, intermediate and definitive host specificity and distribution, and host feeding behavior.

KEY WORDS: *Mediorhynchus papillosus* morphology, *Oreoscoptes montanus*, Colorado, U.S.A., Russia, China, Taiwan, Brazil, Bulgaria.

Van Cleave's (1916) description of 3 imperfect specimens of *Mediorhynchus papillosus* Van Cleave, 1916 was marred by the misinterpretation of proboscis armature. His subsequent treatments (Van Cleave, 1918, 1947) did not contribute additional accounts. Schmidt and Kuntz's (1977) brief redescription, based on specimens from Taiwan and associated Pescadores Islands, corrected some of Van Cleave's interpretations, but lacked information on some taxonomically important structures. It also did not include taxonomic accounts previously reported by other, particularly Russian, observers. The present material from Colorado yielded additional information that is sufficiently new or at variance from published observations to warrant a new treatment of the species.

This report includes the first complete description of the species from the United States, based on new material collected from *Oreoscoptes montanus* Baird, 1858, a sage thrasher. It also includes a comprehensive comparison between the North American, Asian, and East European populations. Type and voucher specimens were examined, and a description of juveniles is provided for the first time. Intraspecific variability among worldwide geographical populations is considered to be a key factor in morphological differences.

Materials and Methods

A total of 27 specimens was collected legally from 1 young road-kill *O. montanus*, 5 km south of Gunnison, 38°32′30″N and 106°56′30″W, 2,438 mi elevation, in the mountains of Gunnison County, Colorado, on 31 July 1995. The bird may have just fledged in June. The body was still warm when first examined. Acanthocephalans were firmly attached to the wall of the small intestine, but did not penetrate into the body cavity. No abnormal inflammation around attachment sites was observed.

Worms were individually teased from the gut wall, extended in refrigerated tap water, and preserved in 70% ethanol. They were later stained in Mayer's acid carmine, dehydrated in ascending concentrations of ethanol, cleared in graduated concentrations of terpineol in 100% ethanol, and whole mounted in Canada balsam.

Measurements are of the longest and widest dimensions. Trunk measurements do not include neck or male bursa. Hooks and spines were measured only in complete profile and counted from at least 2 adjacent rows. This task was made difficult because of the unusually deep cuticular folds within which the almost transparent hooks and spines were embedded. Hook and spine counts in some individuals were problematic

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because of the presence or absence of additional or other hooks as well as because of the slightly spiral arrangement of rows, particularly of spines. Despite these variations, proboscis hooks and spines were arranged in nearly longitudinal rows and were studied, and counted accordingly. Schmidt and Kuntz (1977) made the same observations. Any reference to proboscis hook or spine rows indicates longitudinal rows as observed directly or as converted longitudinal counts from diagonal rows if originally reported as such. Russian workers counted hooks in diagonal rows; their figures were helpful in confirming converted hook/spine counts. All measurements are in micrometers unless otherwise specified. Range is given followed by the mean in parentheses. All juveniles and adults measured were from a single host specimen; measurements do not reflect variability among individual hosts.

The complexities of the praesomal structures and musculature were comparable to those studied by Schmidt (1977), whose terminology is selectively used and/or modified in our work where applicable.

Specimens were deposited at the United States National Parasite Collection (USNPC), Beltsville, Maryland. Specimens examined were borrowed from USNPC and from the University of Nebraska State Museum, Harold W. Manter Laboratory Collection (HWMLC), Lincoln, Nebraska.

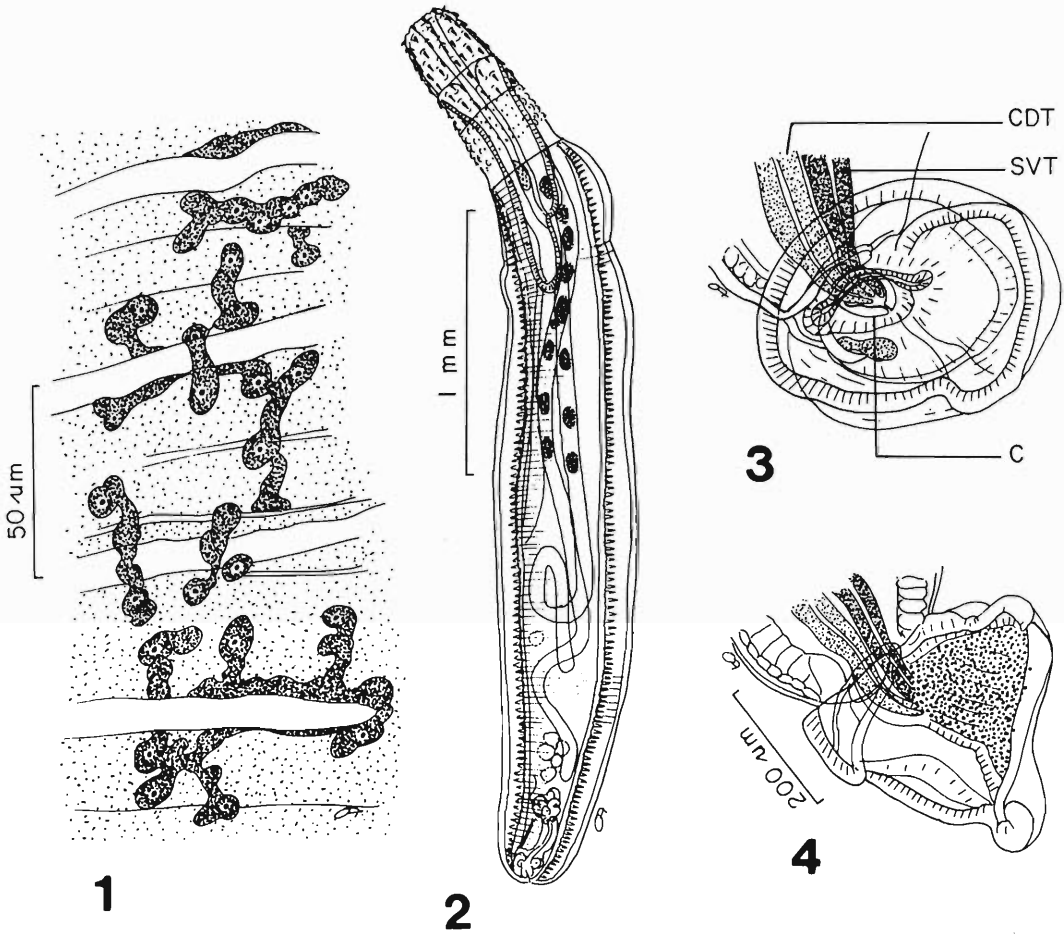
Results

The 27 specimens collected from the single young Colorado sage thrasher included 5 mature males with sperm, 15 females gravid with unripe eggs and ovarian balls (2 with cement plugs), and 7 juveniles (2 males, 5 females). The following descriptions are based on all the Colorado specimens. Measurements are of 4 males, 10 females, and 5 juveniles (1 male, 4 females). Only previously undescribed structures, or those at variance with previous reports, are illustrated.

Mediorhynchus papillosus Van Cleave, 1916 (Figs. 1–10)

GENERAL: With characters of the genus *Mediorhynchus* as described by Van Cleave (1916) and discussed by Schmidt (1977) and Schmidt and Kuntz (1977). Trunk cylindrical, somewhat tapering anteriorly and pointed posteriorly. Juveniles of both sexes with straight trunk, of equal size (2.5–3.0 mm long). Males with straight trunk (6.0–8.0 mm long) and females, with dorsally arched trunk (16.0–21.0 mm long). Sexual dimorphism occurs in all shared structures. These structures are also larger in adults than in juveniles of the same sex. Lacunar system clearly discernible with distinct lateral branches, resembling internal segmentation, spaced at regular intervals. Branches closely spaced in juveniles. Hypodermal nuclei multinucleated, multibranched, amoeboid, often aligned along transverse lacunar branches with terminal ends usually spheroid (Fig. 1).

Proboscis conical, truncate, and thick walled; anterior end flat containing apical organ and sensory pits. Proboscis gradually widening posteriorly into the unarmed neck, divided into 2 parts: anterior part (anterior proboscis) with rooted hooks and posterior part (posterior proboscis) with rootless spines. The posterior proboscis occupies 31–32 (31%) of the total length of the whole proboscis of juveniles, but the length increases to 36–43 (40%) in adult males and 34–41 (39%) in adult females. The 2 parts are clearly separated by a distinct ridge that is NOT marked by the insertion of the proboscis receptacle. Receptacle attached anterior to the separation line just posterior to the insertion of the posterior proboscis inflator muscles in juveniles and slightly more posteriorly in adults (Fig. 5). Hooks and spines are almost transparent and deeply embedded in cuticular folds with only the distal part of blades free to variable degrees (Figs. 6–8). Shape of cuticular folds commensurate with shape, size, and orientation of armature. Those surrounding the hooks are elongate vertically and flat externally, appearing rectangular in profile. Those of spines are crescent or dome shaped and interface with hook folds along the above mentioned ridge. Hooks and spines are arranged in near longitudinal rows that may not regularly alternate. Rows may appear irregular because of the presence of additional hooks or the absence of others as well as because of the slightly spiral arrangement of rows (particularly of spines) in some individuals. Hooks in 18–24 rows each with 4–7 hooks and spines in 26–34 rows each with 4–6 spines. Hooks and spines are largest in females and smallest in juveniles; largest anteriorly and gradually decrease in size posteriorly. Longest anteriormost spines as long as shortest posteriormost hooks. Hook blades sharply curved posteriorly with well-developed powerful roots. Roots are consistently longer than blades, having somewhat less strong broadly rounded proximal end (Fig. 6). Proportion of length of blade to length of root about same throughout anterior proboscis. Spine blades extend out laterally for most of their length and curve sharply posteriorly near their distal end; roots replaced by discoidal tubercles at the proximal end (Figs. 7, 8). Neck well developed with 2 lateral sensory pits

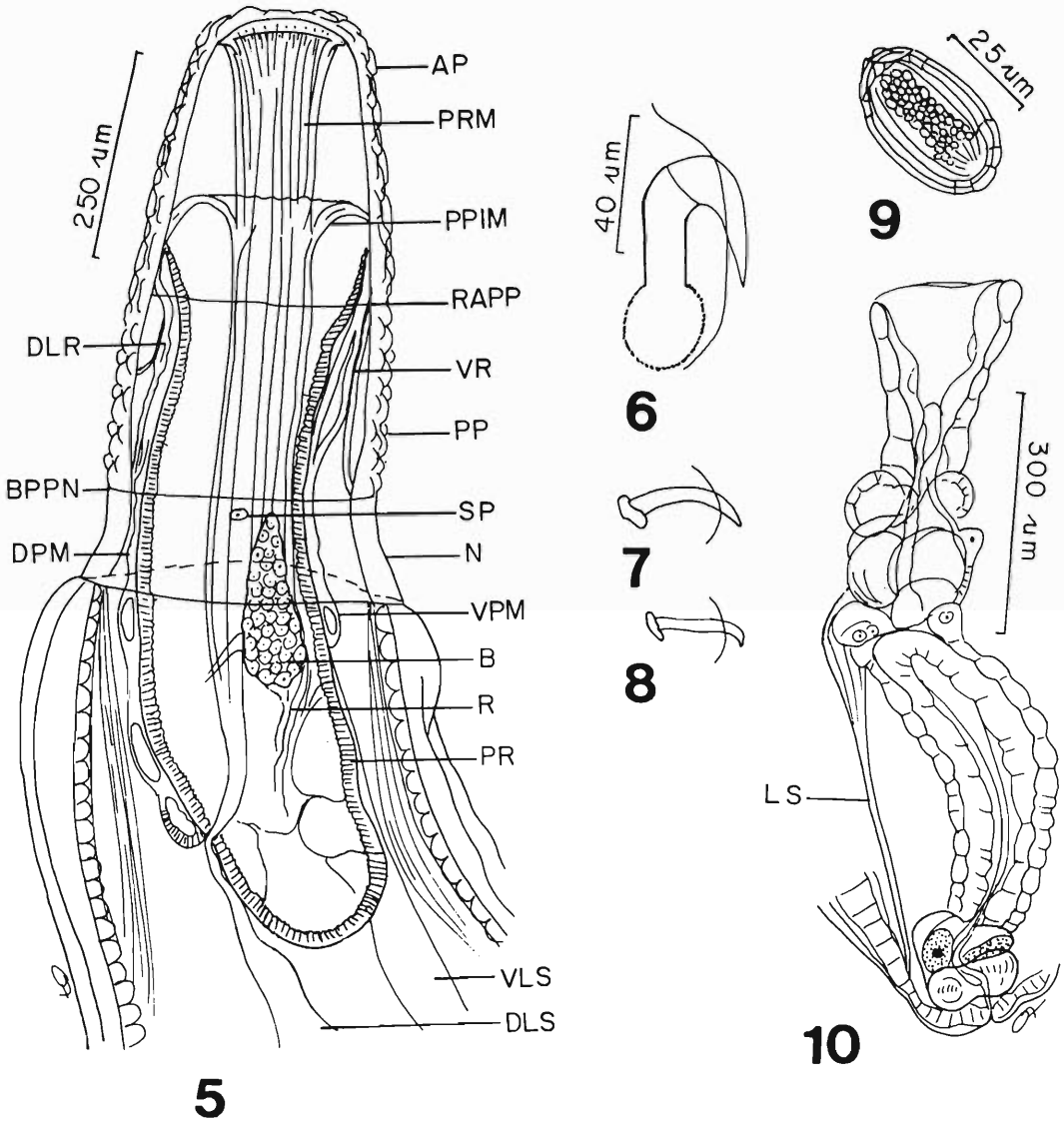


Figures 1–4. ***Mediorhynchus papillosus*** **from** ***Oreoscoptes montanus*** **in Colorado. 1. Branched multinucleated amoeboid hypodermal nuclei in the body wall of a female; clear lateral ducts are transverse lacunar branches. 2. Juvenile female. 3. Ventral view of a bursa showing the terminal portions of the male reproductive system. C, cirrus (penis); CDT, cement duct terminalia; SVT, seminal vesicle terminalia. 4. Lateral view of bursa showing same; stippled portion on top is heavily stained seminal-cement secretions.**

near posteriormost circle of spines, length 22–23% of proboscis of juveniles and adults of both sexes.

Proboscis receptacle (Fig. 5) slightly longer than proboscis in juveniles but ca. 1.5 times as long in adult males and females, complex, single walled throughout except for a short distance at the base of prominent dorsal protrusor muscles. Ventral protrusor muscles, ventral retractors and dorsolateral retractors well developed. Powerful proboscis retractor muscles begin at the anterior end of the proboscis, split dorsoventrally to surround the large ovoid-spindle-shaped cerebral ganglion (brain). Cerebral ganglion located at level of anterior margin of trunk, with larger dorsal branch penetrating the dorsal side of the receptacle a short distance from posterior end. Branched proboscis retractor muscles extend posteriorly as ligament strands to near middle of trunk where they attach to the inner surface of body wall. Near base of the anterior proboscis, exterior fibers of the main retractor muscle mass split laterally, becoming inflator muscles of posterior part of proboscis and attaching to inner wall of proboscis anterior to the ridge separating the 2 proboscis halves (Fig. 5).

Lemnisci long, ribbonlike, usually slightly subequal in length, somewhat broader in anterior half where 5–8 (usually 6) giant nuclei are present. Lemnisci about as long as trunk in juveniles,



Figures 5–8, 10. ***Mediorhynchus papillosus*** **from** ***Oreoscoptes*** **in Colorado. 5. Anatomy of proboscis and receptacle; hooks, spines, and lemnisci not shown. AP, anterior proboscis; BPPN, borderline between posterior proboscis and neck; B, brain (cerebral ganglion); DLS, dorsal ligament strand; DPM, dorsal protrusal muscles; DLR, dorsal lateral retractor; N, neck; PP, posterior proboscis; PPIM, posterior proboscis inflator muscles; PR, proboscis receptacle; PRM, proboscis retractor muscles; R, retina culum; RAPP, ridge between anterior and posterior proboscis, evident upon examination of surface topography where the cuticular folds of hooks and spines interface; SP, sensory pit; VLS, ventral ligament strand; VPM, ventral protrusal muscles; VR, ventral retractor. 6. Hook, root, and cuticular fold near middle of anterior proboscis of a female. 7. Anteriormost spine and fold from posterior proboscis of same female. 8. Posteriormost spine and fold from posterior proboscis of same specimen. 10. Female reproductive system. LS, ligament strand. Figure 9. Egg of** ***Mediorhynchus papillosus*** **from the body cavity of a female from** ***Alauda gulgula wattersi*** **Swinhoe in Taiwan (USNPC No. 74359); note delicate sculpturing and anterior spines of embryo.**

5 times as long as proboscis receptacle in juveniles and adults, and reaching middle of posterior testis in males. Genital opening terminal in both sexes.

JUVENILE FEMALES (based on 4 specimens) (Fig. 2): Trunk with some anterior constriction, but less pronounced than that of cystacanths, 2.50–3.12 (2.772) mm long by 500–690 (580) wide. Whole proboscis 596–660 (634) long; anterior proboscis 406–457 (436) long by 254–381 (305) wide at base; posterior proboscis 190–203 (199) long by 292–406 (334) wide at base. Anterior proboscis with 20–22 (20.7) near longitudinal rows each with 6 rooted hooks; posterior proboscis with 30 near longitudinal rows of 5 rootless spines each. Length of hooks (from anterior to posterior): 38, 35–38 (36), 35, 32, 26–29 (28), 26–29 (27). Length of spines 26, 26, 22–26 (24), 19, 19. Neck 127–152 (140) long by 330–419 (364) wide at base. Proboscis receptacle 711–749 (732) long from insertion to posterior end and 470–533 (512) long from insertion to point of emergence of dorsal retractor muscles by 190–241 (216) wide anterior to emergence and 102–140 (123) wide just posterior to emergence. Cerebral ganglion 165–190 (178) long by 76–89 (80) wide. Lemnisci 2.286–2.794 (2.553) mm long by 89–102 (92) wide. Reproductive system 330–381 (365) long and 12–14 (13%) of trunk length.

JUVENILE MALE (1 specimen): Trunk 2.50 mm long by 590 wide. Proboscis 482 long; anterior proboscis 317 long by 241 wide at base; posterior proboscis 165 long by 254 wide at base. Neck 102 long by 267 wide at base. Anterior testis 241 long by 102 wide; posterior testis 267 long by 127 wide.

ADULT MALES (based on 4 mature specimens with sperm): Trunk 6.80–7.89 (7.510) mm long by 750–870 (810) wide. Proboscis 558–622 (581) long; anterior proboscis 330–381 (349) long by 305–330 (317) wide at base; posterior proboscis 203–254 (231) long by 317–343 (333) wide at base. Anterior proboscis with 19 near longitudinal rows each with 4–6 (5.4) rooted hooks; posterior proboscis with 26–33 (29) near longitudinal rows of 4–6 rootless spines each. Neck 114–140 (127) long by 356–406 (374) wide at base. Proboscis receptacle 838–1,016 (895) long from insertion to posterior end and 610–749 (673) long from insertion to point of emergence of dorsal retractor muscles by 229–254 (241) wide anterior to emergence and 152–229 (197) wide just posterior to emergence. Cerebral ganglion 165–190 (182) long by 76–114 (97) wide. Lemnisci 4.000–4.318 (4.159) mm long by 127–165 (144) wide. Reproductive system in posterior half of trunk. Testes about equal in size; anterior testis 1.206–1.422 (1.279) mm long by 330–419 (378) wide; posterior testis 1.168–1.219 (1.197) mm long by 356–444 (394) wide. Cement glands 8 or 9, orbicular, each with a single large nucleus in a less dense sphere, each 254–406 (318) long by 190–254 (225) wide. Saefftigen's pouch 571 long by 127 wide (n = 1). Seminal vesicle and common cement duct terminate in genital atrium of muscular penis (cirrus) in center of bell-shaped bursa. Bursa 368–381 long by 406–470 wide (n = 2) with well-developed muscular rim and weak ribs (Figs. 3, 4).

ADULT FEMALES (based on 10 specimens gravid with unripe eggs and ovarian balls of which 2 had cement plugs): Trunk 15.60–20.90 (17.684) mm long by 560–840 (688) wide. Proboscis 610–687 (648) long; anterior proboscis 381–444 (397) long by 279–368 (333) wide at base, posterior proboscis 229–267 (250) long by 330–381 (347) wide at base. Anterior proboscis with 18–24 (21.1) nearly longitudinal rows each with 4–7 (5.3) rooted hooks. Posterior proboscis with 29–34 (30.8) nearly longitudinal rows of 4–6 (5.0) rootless spines each. Length of hooks (from anterior to posterior) 32–48 (42), 42–48 (44), 32–48 (40), 32–42 (37), 32–38 (35), 32–35 (33). Length of spines 32–35 (33), 32–35 (33), 26–35 (30), 26–29 (27), 22–26 (24), 22–26 (24). Neck 127–178 (151) long by 394–457 (418) wide at base. Proboscis receptacle 889–1,067 (999) long from insertion to posterior end and 660–851 (740) long from insertion to point of emergence of dorsal retractor muscles by 241–279 (261) wide anterior to emergence 241–267 (257) wide just posterior to emergence. Cerebral ganglion 190–229 (204) long by 102–127 (109) wide. Lemnisci 3.810–5.080 (4.520) mm long by 114–190 (160) wide. Reproductive system robust 864–1,016 long and 5–6 (5%) of trunk length. Vagina and sphincters very well developed. Uterus thick walled, outer layer appears beady, held anteriorly with ligament strand attached to near posterior end of trunk causing it to curve on same side. This is the first report of uterine ligament strands in *Mediorhynchus*. Wall of uterine bell thick, somewhat similar to that of uterus (Fig. 10). Eggs unripe.

Table 1. Morphological variability among geographical populations of *Mediorhynchus papillosus* in selected morphometric characteristics.

	Maryland, U.S.A. Van Cleave, 1916	Colorado, U.S.A. This paper*	Taiwan Schmidt and Kuntz, 1977
Hosts	*Myiochanes virens* *Porzana carolina*	*Oreoscoptes montanus*	*Alauda gulgula* *Alauda arvensis* *Erithaeus calliope* *Dicrurus macrocercus*
Males			
Trunk L × W (mm)	9.3 × 0.75	6.80–7.89 × 0.75–0.87	6.0–9.0 × 0.68–0.70
Proboscis L × W	650 × 300	558–622 × 317–343	350–370 × 240–280
Hooks/row × hook rows	6–7 or 4–6 × 18	4–6 × 19	5–9 × 20–28
Spines/row × spine rows	4–6 × 18 (error)	4–6 × 26–33	3–4 × 45–55
Hook L from anterior	27 (largest)	—	20–28, 20–28, 20–22, 20–22, 20–22, 18–24
Spine L from anterior	—	—	—
Post. prob. L/total prob. L	—	36–43 (40%)	19–30 (26%)†
Neck L/prob. L	—	22%	31%†
Prob. recept. L × W	—	838–1,016 × 229–254	470–500 × 150–180
Anter. testis L × W	—	1,206–1,422 × 330–419	900–1,300 × 300–320
Females			
Trunk L × W (mm)	18.0 × 0.75	15.60–20.90 × 0.56–0.84	11.0–25.0 × 0.72–1.10
Proboscis L × W	650 × 300	610–687 × 330–381	440–510 × 370–400
Hooks/row × hook rows	6–7 × 18	4–7 × 18–24	5–9 × 20–28
Spines/row × spine rows	4–6 × 18 (error)	4–6 × 29–34	3–4 × 45–55
Hook L from anterior	27 (largest)	32–48, 42–48, 32–48, 32–42, 32–38, 32–35	20–28, 20–28, 20–22, 20–22, 20–22, 18–24
Spine L from anterior	—	32–35, 32–35, 26–35, 26–29, 22–26, 22–26	—
Post. prob. L/total prob. L	—	34–41%	22–29 (26%)†
Neck L/prob. L	—	23%	38%†
Prob. recept. L × W	—	889–1,067 × 241–279	520–800 × 200–300
Egg L × W	38–47 × 18–24	—	46–50 × 26–28

* See text for more complete measurements.

† Calculated from available specimens and/or published accounts.

DEFINITIVE HOST: *Oreoscoptes montanus* Baird, 1858, sage thrasher (Mimidae).

SITE OF INFECTION: Small intestine.

PATHOLOGY: None observed.

LOCALITY: Gunnison, Gunnison County, Colorado.

SPECIMENS DEPOSITED: USNPC No. 86963.

ADDITIONAL SPECIMENS EXAMINED (except for specimens from Taiwan and Pescadores Islands, all others are from U.S.A.): From USNPC, No. 6320 (holotype male, allotype female) and No. 6303 (paratype male), No. 74359 (many specimens on 25 slides, Taiwan, Schmidt and Kuntz, 1977), No. 79277 (1 gravid female, Texas), No. 79505 (1 specimen, Colorado), No. 80827 (2 cystacanths, Georgia). From HWMLC, Nos. 34914–34923 (5 males, 8 females on 10 slides, Taiwan), No. 34477 (1 male, Alaska), Nos. 33930, 33931, 34968 (1 male, 5 females, Colorado), Nos. 30276, 30277, 30280, 30281 (1 male, 3 females, Oklahoma), Nos. 30240, 30359 (2 juveniles, unspecified U.S. locations). These are all the specimens that have been deposited in museum collections that were made available for this study.

Discussion

THE TYPE MATERIAL: Van Cleave (1916) described *M. papillosus* (3 specimens) and 2 other species of his new genus *Mediorhynchus* Van Cleave, 1916, which he included with his other new genus *Centrorhynchus* Van Cleave, 1916 in the new family Centrorhynchidae Van Cleave, 1916, because of the insertion of proboscis receptacle at mid-proboscis in both genera. In keying out these new taxa, he distinguished the

Table 1. Extended.

Yakutia, Transbaikal Petrochenko, 1958	Lower Yenesei River, etc. Khokhlova, 1966	Volga, Oren Byrg, etc. Khokhlova, 1986	Ukraine Lisitsyna, 1994	Bulgaria Dimitrova and Genov, 1992
Motacilla alba *Passer domesticus*	*Anthus cervina*	Sparrows and others	Sparrows and others	*Tringa erythropus*
No males				No males
—	7–10 × 0.920–0.995	4.5–10 × 0.68–0.995	6.58–10.04 × 0.56–0.76	—
—	459–579 × 260–381†	430–601 × 210–381†	520–720 × 350–590	—
—	4–7 × 20–24†	4–7 × 20–24†	4–8 × 20–26†	—
—	3–6 × 32–34†	4–6 × 32–34†	5–8 × 42–46†	—
—	31–34	30–40 to 23–40	35–48, 40–45 (2nd) to 28–38 (last)	—
—	15–19	15–20	25–33	—
—	33–34%†	35–37%†	38–40%†	—
—	32–40%†	9–30%	17–22%†	—
—	1,830–2,130 × —	450–2,130 × —	670–1,120 × 180–270	—
—	1,073–1,535 × 306–535	630–1,680 × 300–610	684–1,010 × 250–260	—
Females				
31 × 0.9–1.2	19–33 × 1.22–1.38	11–13 × 0.68–1.38	27.0–36.0 × 0.82–1.13	11.10 × 1.17
630 × 360	534–564 × 273†	450–564 × 273–350†	520–720 × 350–590	586 × 321†
5–7 × 21–24†	4–7 × 20–24†	4–7 × 20–24†	4–8 × 20–26†	6.7 × 22†
5–7 × 32–34†	3–6 × 32–34†	4–6 × 32–34†	5–8 × 42–46†	5–6 × 22–30†
26–30	34–40	30–40 to 23–40	35–48, 40–45 (2nd) to 28–38 (last)	Longest 25–27
16	19–25	15–20	25–33	—
				—
38%†	29–32%†	27–32%†	38–40%†	35%†
22%†	32–34%†	31–37%†	17–22%†	35%†
—	2,430–3,510 × —	520–3,510 × —	670–1,120 × 180–270	2,180 × —
42 × 23	62–68 × 28–40	52–68 × 26–40	60–65 × 40–43	—

closely related *M. robustus* Van Cleave, 1916 as having 24 longitudinal rows of hooks on the proboscis and a maximum diameter: length of body of 1:5 (or 6) as compared to 18 and 1:9 in *M. papillosus* (Van Cleave, 1916). However, he stated that *M. papillosus* has "single layered" proboscis receptacle and that "anterior and posterior regions of proboscis with the same number (18) longitudinal rows of hooks." He described 6 or 7 hooks and 4–6 spines per row, but his figure 6 shows 9 hooks and 6 spines in profile of 1 row. Van Cleave (1916) adequately described other structures (Table 1) and provided sketchy illustrations of a male whose lemnisci extended to the anterior testis, posterior part of male reproductive system with invaginated bursa, barely visible eggs, proboscis surface without hooks, and outline of proboscis and receptacle walls and retractor muscles. Later, Van Cleave (1918) designated *M. papillosus* as the type of the genus *Mediorhynchus*. His original description (Van Cleave, 1916) and 3 illustrations were used as is by Meyer (1932) and Petrochenko (1958, in part). In his review, Van Cleave (1947) provided a tabular key to North American species of *Mediorhynchus* in which he revised the number of *M. papillosus* hooks to 8–10 per diagonal row or 4–6 per longitudinal row, but presented no specific description or additional information. The holotype male (USNPC No. 6320) demonstrates a proboscis receptacle insertion at a level anterior to the separation line between anterior and posterior proboscis, as observed in our material from Colorado. Both holotype and paratype males had 8 cement glands each and contiguous testes.

OTHER U.S. MATERIAL: The other material from Colorado examined (HWMLC Nos. 33930, 33931, 34968) included 4 gravid females and 1 male from the G. D. Schmidt collection and 1

female cystacanth. The females were largely uninformative, but the male was similar to our material, particularly in proboscis and armature characteristics (Table 1). The male specimen from Alaska (HWMLC No. 34477) had a partly retracted proboscis, and accurate observations were not possible. The Oklahoma specimens (HWMLC Nos. 30276, 30277, 30280, 30281) (1 male, 3 females) were poor, contracted, and largely opaque. One female (?) was beyond recognition, but another female had a proboscis that appeared similar to that of our Colorado specimens. Specimens from unknown U.S. locations include a similar female with comparable proboscis to the latter material and 2 unremarkable juveniles (HWMLC Nos. 30210 and 30359, respectively).

Of the 8 species of *Mediorhynchus* occurring in North American birds, *M. papillosus* appears to be the most common; it has been reported in the most number of host species (43) (Nickol, 1977). Most reports, however, present only host and locality records or incidental remarks, e.g., Wallace and Olsen (1966), Nickol (1969), Kayton and Schmidt (1975). The present study represents the first taxonomic treatment of any North American material of *M. papillosus* since its original description in 1916.

NON-U.S. MATERIAL: *Mediorhynchus papillosus* is also well represented in birds from South America, Asia (Taiwan, China, Russia and other former Soviet republics), and Eastern Europe (Bulgaria) and has been described from populations in many of these regions. A distinct degree of morphological variability associated with its geographical populations is clearly evident. Factors related to intermediate and definitive host specificity associated with geographical restrictions, intermediate host distribution, and the apparent lack or scarcity of paratenic hosts possibly are involved. This geographical variability is consistent and is best illustrated by a comparison between the North American population from Colorado described herein and the Asian population from Taiwan. This variability does not appear to be related to host species, because the many specimens we examined from Taiwan (USNPC and HWMLC) were collected from 6 different host species and were consistently morphologically homogeneous.

THE TAIWANESE MATERIAL: The Kuntz collection from Taiwan and associated Pescadores Islands was briefly described by Schmidt and Kuntz (1977), who provided 3 figures of a very small male, female, and proboscis and neck. In spite of their statement that "many specimens . . . from a variety of passeriform birds on Taiwan . . . together with specimens from North America, including type specimens, allow[ed] the . . . redescription" of *M. papillosus,* it is likely that Schmidt and Kuntz (1977) used only Taiwanese material. Our conclusion is based on the complete agreement between their description and our study of their Taiwanese material (USNPC No. 74359). Schmidt and Kuntz (1977) provided a good description; however, it lacked information on some male and female reproductive structures, proboscis receptacle anatomy, sexual dimorphism in proboscis armature, and insertion points. They also did not include other taxonomic accounts previously reported by previous authors, e.g., Petrochenko (1958) and Khokhlova (1966). These, along with other Russian studies of *M. papillosus,* are discussed below. Information from the description of the Taiwanese population relevant to the comparison with our Colorado population is summarized in Table 1. Compared to our specimens from Colorado, those from Taiwan have characteristically and consistently smaller proboscis, proboscis hooks and spines, and proboscis receptacle. They also have more hooks per row but many more rows of spines (45–55) each with only 3 or 4 spines. This results in the posterior proboscis occupying a considerably shorter portion of the proboscis (26%) in males and females and the neck a longer portion (31% in males and 38% in females) (Table 1). The latter percentages were calculated from the Taiwanese material, which provided the additional following information: lemnisci with 6 to 8 giant nuclei in thicker proximal half and extend to middle of posterior testis, males usually with contiguous testes and 7 to 9 (usually 8) cement glands, females of same size as our Colorado females but contained many ripe eggs.

The other Taiwanese material examined (HWMLC Nos. 34914–34923) was part of the G. D. Schmidt collection, which constituted 5 males, 2 young and 6 gravid females that were collected by various Taiwanese workers, mostly between 1958 and 1961 (3 in 1976). These specimens were very similar to the other Taiwanese specimens examined (USNPC No. 74359) and agreed with the description of Schmidt and Kuntz (1977) (see Table 1).

THE FORMER SOVIET REPUBLICS MATERIAL: Belopolskaia (1958) and Petrochenko (1958) were the first to report *M. papillosus* from Russia. Belopolskaia (1958) only recorded the acanthocephalan from white wagtails, *Motacilla alba,* in the Sudzukhinsk reserve during May, July, and September, and noted females reaching up to 36 mm long. Petrochenko (1958) described only females from the same host species as well as from *Passer domesticus* from the collections of the All-Union 100th Helminthological Expedition in Yakutia and the 11th expedition in the Transbaikal area (Table 1). His specimens were very similar to ours from Colorado in proboscis size, relative space occupied by posterior proboscis and neck, and arrangement and number of hooks and spines but not their size; he provided only 1 measurement of each. Petrochenko (1958) recognized that the proboscis receptacle is "one-layered throughout and in the posterior part two-layered on one side." Two discrepancies, however, were made in his original figures. In his figure 129d, the insertion of proboscis receptacle was shown exactly at the level between the anterior and posterior proboscis. In his figure 129e, the proximal end of spines was shown bifurcated and nondiscoidal. In addition, he indicated a surprising number (35–36) of nuclei in each lemniscus.

Khokhlova (1966) described a small collection of male and female *M. papillosus* from *Anthus cervina* in the lower Yenisei River and Norilsk lakes area. She did not observe sexual dimorphism in proboscis armature and provided only 1 measurement each for hooks and spines. Khokhlova's (1966) worms were similar to ours from Colorado in proboscis size, arrangement and number of hooks and spines, and size of hooks, but had a relatively longer neck, a very long proboscis receptacle, and large eggs (Table 1). Several discrepancies are noted: she described, and illustrated (her fig. 7b), a "double-walled proboscis receptacle ... consists of a short thick-walled sac, located inside a long thick-walled sac" (Khokhlova, 1966), clearly mistaking the protrusal muscles for the "outer sac." In the same figure (7b), the proboscis receptacle is shown inserted anterior to the "constriction" between anterior and posterior proboscis (as it should be), while the text indicated insertion at that "constriction." In her figure 7a, she shows a proboscis receptacle not pierced by missed retractor muscles and makes no reference to such muscles anywhere in the text. The female reproductive system (her fig. 8b) does not show any sphincters, and the eggs (her fig. 8c) had thin unsculptured single-membraned shells.

Khokhlova (1978) provided a list of 34 host species of *M. papillosus* in 13 regions of the "USSR." In her expanded review, Khokhlova (1986) redescribed *M. papillosus* listing 45 species of bird hosts from "land along Volga, Oren Byrg Oblast, West Siberia, Yakutiya, Tuva, Seaside, Okhotsky shoreline, Chukotka, Komandorskiye Islands, Ukraine, Georgia, Armenia, Azer Baijan, Turkmen, and Uzbekistan." Worms described by Khokhlova (1986) were similar to those described earlier (Khokhlova, 1966), with some variations in size of trunk, hooks, proboscis receptacle, and relative space occupied by the neck in males (Table 1). Both agree with our description of the Colorado specimens in size of proboscis and hooks, arrangement and numbers of hooks and spines, but their specimens had a relatively longer neck and a very long proboscis receptacle (Table 1). The errors noted above in her earlier description (Khokhlova, 1966) (above) persisted in this one. Her (Khokhlova, 1986) bibliography did not include Schmidt (1977), which suggests that she may have not been privileged to his interpretation of proboscis receptacle musculature and associated structures. New illustrations of hooks and spines, after other authors, poorly represented their form, with hook roots lacking the proximal rounded end and proximal end of spines being forked.

Peresado'ko (1980) described specimens of *M. papillosus* from charadriiform birds in Western Siberia: new host and locality records. His specimens were similar to those described in Bulgaria (see following section).

Lisitsyna (1994) described *M. papillosus* from *Perdix perdix, Glareola pratincola, Alauda arvensis, Hirundo rustica, Sturnus vulgaris, Turdus viscivorus,* and *Silvia nisoria* in Kherson Oblast (Black Sea Biosphere National Park), Crimea, after considering the descriptions of Van Cleave (1916, 1947) and Schmidt and Kuntz (1977). Her material included other *Mediorhynchus* specimens erroneously identified by others as *M. armenicus* Petrochenko, 1958, *M. micracanthus* (Rudolphi, 1819) Meyer, 1932, *M. tenuis* Meyer, 1931, and other previously unidentified material from the Ukraine. In her description, Lisitsyna (1994) reported no sexual dimorphism in the size of proboscis, hooks,

spines, neck, and lemnisci or in number and distribution of armature. Her specimens, however, appeared most similar to ours from Colorado in practically all characters listed in Table 1, with the exception of her longer females, somewhat wider proboscis with more spine rows, and smaller testes. Unfortunately, she described and illustrated (her fig. 1a) a proboscis receptacle that is double walled throughout and "attached at the region of constriction" between anterior and posterior proboscis. Lisitsyna (1994), however, recognized (but did not include in her fig. 1a) the proboscis retractor muscles and their penetration of the proboscis receptacle wall "mediolaterally." Hook roots (her fig. 1b) were poorly depicted and appeared atypical of the species.

Other reports from the former Soviet republics that are not taxonomically or morphologically oriented dealt primarily with new host and/or locality records of *M. papillosus,* e.g., in *Columba livia* in Turkmenia (Meredov, 1976), in *Passer montanus* in European U.S.S.R. (Kostyunin, 1978), in *Falco naumanni* in Azerbaidzhan (Samedov, 1979). No attempt will be made to discuss this literature here.

THE BULGARIAN MATERIAL: In Eastern Europe, *M. papillosus* was recorded from various bird species in Bulgaria by Stoimenov (1962, 1963), Tsacheva (1967), and Tsacheva-Petrova (1971). Dimitrova and Genov (1992) described only 1 female in *Tringa erythropus* from near Bourgas, Bulgaria. Measurements and counts (Table 1) were similar to those of most Russian specimens, especially those of Peresado'ko (1980), except for having smaller proboscis hooks and a larger proboscis receptacle. The ratio of neck length to proboscis length was similar to that reported by Khokhlova (1966, 1986). The number of spine rows was small, but that was questioned by the authors.

OTHER MATERIAL: The non-American distribution of *M. papillosus* extends into South America and beyond the former Soviet republics to China and Taiwan to the east and Eastern Europe to the west. In China, it was reported in Fujian from *Pica pica sercea, Glaucidium cuculcidium,* and *Eurystomus orientalis* by Wang (1966). In Brazil, *M. papillosus* was reported from sparrows, *Passer domesticus,* by Brasil and Amato (1992). The above reports from China and Brazil dealt only with host records.

Conclusions

Mediorhynchus papillosus has a wide distribution outside of North and South America in Asia from Taiwan to the east into China, many of the former Soviet republics, and to Eastern Europe to the west. The present paper represents the first complete description of adults and juveniles in North America. The distribution of proboscis armature is interpreted as being in nearly longitudinal rows. New features, or those that have been previously reported erroneously, are presented and illustrated for the first time. These include (1) the branched, multinucleated amoeboid hypodermic nuclei and their association with the transverse lacunar branches, (2) the anatomy of proboscis receptacle, its associated structures, and its insertion anterior to the ridge between anterior and posterior proboscis, (3) detail of proboscis hooks and spines and the different cuticular folds in which they are deeply embedded, (4) juveniles are described for the first time, (5) terminal male genitalia and bursa described for the first time, (6) female reproductive system properly described and uterine ligament strands described for the first time.

A comparison among the geographical populations of *M. papillosus* indicates its marked variability in certain key characteristics presented in Table 1, with the U.S. population from Colorado and the Taiwanese population being at opposite ends of the variability spectrum. Specimens from Taiwan characteristically had smaller proboscis, proboscis hooks and spines, and proboscis receptacle. They also had a comparatively shorter posterior proboscis with more rows of spines each with fewer spines, more hooks per row in the anterior proboscis, and a comparatively longer neck. It appears as though, within the space available for the proboscis neck region, the distribution of armature becomes a function of how this space is divided between anterior proboscis, posterior proboscis, and neck.

Although all Russian workers interpreted proboscis armature as being in diagonal rows (converted in Table 1) and misinterpreted the proboscis receptacle (except Petrochenko, 1958), its insertion and associated structures, and proboscis armature, their *M. papillosus* material, particularly that from Ukraine (Lisitsyna, 1994), was considerably closer to ours from Colorado than that from Taiwan. Variability is considered

as being geographically, rather than host, related because the many specimens examined from Taiwan were collected from 4 different host species and yet were morphologically homogeneous. Geographical restriction of intermediate (and adult) hosts in the apparent absence or scarcity of paratenic/reservoir hosts is probably a factor contributing to the apparently disjunct distribution of *M. papillosus*. Disjunct populations would promote distinct geographical diversity with consistent morphological difference from each other. The characteristically distinct population of Taiwan is a good case in point, representing an extreme case of disjunction on the island. Taxonomic features of that population render the key of Schmidt and Kuntz (1977) inoperable, at least for *M. papillosus*, where hook length is the major character used in the key.

Van Cleave (1947) was the first to note that "reservoir intermediate hosts are lacking or at least play little role in pyramiding infections of the definitive host." This makes the distribution of adults in the final host totally dependent on the distribution of larval forms in their invertebrate intermediate hosts and on bird feeding behavior. Records of *M. papillosus* larvae are known only from various species of beetles (Coleoptera) of the family Tenebrionidae (darkling beetles) from Uzbekistan and Turkmen (Kabilov, 1969), Crimea (Ivashkin and Shmytova, 1969), and Tajikistan (Gafurov, 1975). Ivashkin and Shmytova (1969) described 1.80–1.87 mm long *M. papillosus* cystacanths that were encysted in the body cavity of *Tenthyria taurica* (most) and *Pimelia subglobosa* (Coleoptera) in the steppe region of Crimea Oblast and noted the corresponding distribution of adults "among sparrows, chickens, and other birds of this area." Khokhlova (1986) described 1.2–1.9 mm and 1.30–1.53 mm long cystacanths that were encysted in intermediate and "reservoir" hosts, respectively. Khokhlova (1986) speculated that reptiles may represent possible "reservoir" hosts.

The intermediate hosts of larval *M. papillosus* in the United States are not known. The stomach of the sage thrasher reported in this study contained small beetle, grasshopper, and sow bug parts. There are over 1,400 North American species of tenebrionid beetles, most of which are of western distribution throughout the arid regions of the United States (Borror and DeLong, 1971). The tenebrionid *Adesmia gebleri* was shown to harbor natural infections of *M. micracanthus* (Rudolphi, 1819) Van Cleave, 1924 in Kara Kum, "USSR" (Ryzhikov and Dizer, 1954). In the United States, the life history of only 2 other species of *Mediorhynchus*, *M. grandis* Van Cleave, 1916 and *M. centrurorum* Nickol, 1969, is known. Moore (1962) experimentally infected the dock beetle, *Castroidea cyanea* (Chrysomelidae), 4 species of grasshoppers, and the cricket *Gryllus* sp. (Orthoptera) with eggs of *M. grandis* that successfully completed development to cystacanth stage, and suggested that first and last host species represented "potential intermediate hosts." Nickol (1977) demonstrated natural and experimental infection of woodroaches, *Parcoblatta pensylvanica* (Blattidae), with *M. centurorum*. Nickol (1977) obtained naturally infected woodroaches from foraging and nesting sites of frequently infected woodpecker definitive hosts, and Jackson and Nickol (1979) reported that nesting site, foraging behavior, and food items apparently limit, in nature, the number of species hosting *M. centurorum*. The above suggestions provide additional support for our contention that the distinctiveness of geographical populations of *M. papillosus* is enhanced by its geographical restriction to habitats containing viable populations of proper intermediate and definitive hosts where parasite transmission is optimized by compatible host specificity and feeding behavior. This is particularly evident in the case of the isolation of the Taiwan and Pescadores Islands population from those of the United States, on the one hand, and of the former Soviet republics, on the other.

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Parasites of Bluegill, *Lepomis macrochirus,* from Two Lakes and a Summary of Their Parasites from Michigan

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ABSTRACT: Seventy-five bluegill, *Lepomis macrochirus* (Rafinesque), collected in July 1996 from 2 small eutrophic lakes in central lower Michigan, were examined for parasites. Bluegill harbored 13 parasite taxa (5 Digenea, 1 Cestoda, 1 Acanthocephala, 3 Nematoda, 1 Copepoda, 1 Myxozoa, 1 Ciliophora). *Spinitectus micracanthus* was the most common gastrointestinal species, whereas *Posthodiplostomum* sp. was the most common species outside the digestive tract. The mean parasite species richness values ± SD in bluegill from the 2 lakes were 3.88 ± 1.42 and 4.80 ± 1.21. Quantitatively, the helminth fauna of bluegill was dominated by larval helminths represented by 7 taxa. The parasites of bluegill from Michigan waters are summarized.

KEY WORDS: parasites, bluegill, *Lepomis macrochirus,* Michigan.

The bluegill, *Lepomis macrochirus* (Centrarchidae), is a common species in the Great Lakes area and is important in Michigan as both a forage and game fish. Published studies are limited on the parasites of bluegill from Michigan and include Hughes (1928), Dobrovolny (1939), Esch (1971), Esch et al. (1976), Muzzall (1982, 1983), and Wilson et al. (1996). The few parasitological studies on bluegill in Michigan surprised us because the species is cultured in a large number of privately owned facilities and is commonly stocked in aquatic environments. The present study reports on parasites of bluegill from 2 lakes in central lower Michigan and summarizes the parasites of bluegill from Michigan waters.

Materials and Methods

Bluegill were collected by angling from 2 eutrophic lakes in Michigan in July 1996, put on ice, packaged, and frozen within 2 hr of collection. Five Lakes and North Porcupine Lake are approximately 1 and 2 mi NW of Gaylord, respectively, in Otsego County, Michigan. In addition to bluegill, both lakes have pumpkinseed, *Lepomis gibbosus,* and largemouth bass, *Micropterus salmoides.* Five Lakes has a surface area of approximately 25 acres and a mean depth of 1.8 m. North Porcupine Lake has a surface area of approximately 16 acres and a maximum depth of 5.5 m. Bluegill data include information on location, number examined, and total length with range in millimeters (followed by $\bar{x}$ ± SD): Five Lakes, n = 60, 98–201 (134 ± 22.3); North Porcupine Lake, n = 15, 88–157 (123 ± 14.7).

The entire fish was examined for parasites. Total length (millimeters) and sex of each fish were recorded at necropsy. After the position of the parasites was noted, they were removed, counted, and preserved in 70% alcohol. Prevalence is the percentage of fish infected, mean intensity is the mean number of parasites of each species per infected fish, and mean abundance is the mean number of parasites per examined fish. Voucher specimens have been deposited in the United States National Parasite Collection, Beltsville, Maryland 20705: *Crepidostomum cornutum* (87494), *Spinitectus micracanthus* (87495), *Leptorhynchoides thecatus* (87496), and *Ergasilus caeruleus* (87497).

Results

All bluegill from each lake were infected with 1 or more parasites. A total of 13 parasite taxa (12 from Five Lakes and 8 from North Porcupine Lake) infected bluegill (Table 1). *Clinostomum* sp., *Contracaecum* sp., *Ergasilus caeruleus* Wilson, 1911, *Myxobolus* sp., and *Trichodina* sp. were found in bluegill only from Five Lakes. *Diplostomum* sp. only infected bluegill from North Porcupine Lake. *Spinitectus micracanthus* Christian, 1972 was the most common gastrointestinal parasite of bluegill from both lakes. Of the helminth species found, only *Crepidostomum cornutum* (Osborn, 1903) Stafford, 1904, *S. micracanthus,* and *Leptorhynchoides thecatus* (Linton, 1891) Kostylew, 1924 were represented by gravid worms. The remaining 7 helminth taxa were represented by larval stages. Of the larval helminth taxa in bluegill, *Posthodiplostomum* sp. had the highest prevalence, mean intensity, and abundance from both lakes. Larval *Posthodiplostomum* sp. were densely clumped en masse in the liver of bluegill from North Porcupine Lake.

The mean abundance values of *Posthodiplostomum* sp. and *C. cornutum* were significantly higher in bluegill from North Porcupine Lake than from Five Lakes fish (Mann-Whitney test,

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Table 1. Prevalence (P), mean intensity (MI), maximum number of parasites (max.) and mean abundance (MA) of parasites found in *Lepomis macrochirus* from 2 lakes in central lower Michigan.

Species	Five Lakes (60)† P (%)	Five Lakes (60)† MI ± 1 SD (max.)	Five Lakes (60)† MA ± 1 SD	North Porcupine Lake (15)† P (%)	North Porcupine Lake (15)† MI ± 1 SD (max.)	North Porcupine Lake (15)† MA ± 1 SD	Site
Digenea							
Clinostomum sp.*	2	1	0.02 ± 0.13	—	—	—	Muscle
Diplostomum sp.*	—	—	—	13	2.0 ± 1.4 (3)	0.27 ± 0.80	Lens
Neascus sp.*	18	2.8 ± 3.3 (12)	0.52 ± 1.76	93	7.2 ± 7.4 (23)	6.73 ± 7.40	Muscle, branchiostegal rays, operculum
Posthodiplostomum sp.*	98	48.5 ± 34.1 (210)	47.0 ±34.9	100	812.1 ± 259.3 (1,341)	812.1 ± 259.3	Heart, gonads, liver, mesentery, spleen
Crepidostomum cornutum	13	1.9 ± 0.8 (3)	0.25 ± 0.70	53	9.1 ± 6.5 (21)	4.87 ± 6.60	Cecum, anterior intestine
Cestoda							
Proteocephalus sp.*	15	1.8 ± 1.2 (4)	0.27 ± 0.78	20	2.0 ± 1.7 (4)	0.40 ± 1.06	Liver
Nematoda							
Contracaecum sp.*	3	1	0.03 ± 0.18	—	—	—	Intestine
Spinitectus micracanthus	88	7.8 ± 6.8 (27)	6.90 ± 6.90	100	11.3 ± 6.9 (31)	11.3 ± 6.9	Intestine
Spiroxys sp.*	38	10.9 ± 21.1 (103)	4.18 ± 13.9	87	2.9 ± 2.8 (11)	2.53 ± 2.75	Encysted in/on stomach wall
Acanthocephala							
Leptorhynchoides thecatus	35	9.4 ± 13.6 (60)	3.28 ± 9.12	13	1	0.13 ± 0.35	Cecum, anterior intestine
Copepoda							
Ergasilus caeruleus	70	3.8 ± 3.3 (15)	2.67 ± 3.25	—	—	—	Gills
Myxozoa							
Myxobolus sp.	2	—	—	—	—	—	Mesentery
Ciliophora							
Trichodina sp.	3	—	—	—	—	—	Gills

* Larval or immature stages.
† (Number of bluegill examined.)

W = 1,830, $P < 0.0001$; Mann-Whitney test, W = 2,069, $P < 0.001$, respectively). Small numbers of bluegill infected with the other species precluded statistical analyses. The only significant correlation coefficient at Five Lakes was between *Posthodiplostomum* sp. intensity and host length (Spearman's Correlation = 0.632, $P < 0.01$). There were no significant correlations between parasite intensities and host length in North Porcupine Lake. There were no significant differences in the intensity or abundance (Mann-Whitney test, $P > 0.05$) and prevalence (chi-square analysis, $P > 0.05$) for the parasite species between female and male bluegill.

The mean parasite species richness values ± SD (with the range in brackets) for bluegill from Five Lakes (3.88 ± 1.42 [1–8]) and North Porcupine Lake (4.80 ± 1.21 [3–7]) were significantly different (Mann-Whitney *U*-test, $U = 2,107$, $P < 0.05$). A total of 3,942 individuals of 10 parasite taxa infecting bluegill from Five Lakes were counted. The parasite community composed of these species consisted of (number of individuals, percentage of community): *Posthodiplostomum* sp. (2,864, 73%); *S. micracanthus* (414, 10%); *Spiroxys* sp. (251, 6%); *L. thecatus* (187, 5%); *E. caeruleus* (160, 4%); and *Neascus* sp., *C. cornutum*, *Clinostomum* sp.,

Table 2. Summary of bluegill parasites and their prevalences from Michigan waters.

Parasite	Prevalence (%)	Reference
Monogenea		
Dactylogyrus sp.	2	Wilson et al. (1996)
Digenea		
Clinostomum sp.*	3	Wilson et al. (1996)
	2	Present study§
Crepidostomum cornutum	19	Esch (1971)
	13, 53	Present study§‖
Diplostomum sp.*	2	Wilson et al. (1996)
	13	Present study‖
Neascus sp.*	74	Wilson et al. (1996)
	18, 93	Present study§‖
Plagioporus lepomis	—†	Dobrovolny (1939)
*Posthodiplostomum minimum**	—†	Hughes (1928)
	95	Wilson et al. (1996)
Posthodiplostomum sp.	98, 100	Present study§‖
Cestoda		
*Proteocephalus ambloplitis**	91	Wilson et al. (1996)
Proteocephalus sp.*	—†	Esch (1971)
	15, 20	Present study§‖
Nematoda		
Capillaria sp.	1	Wilson et al. (1996)
Camallanus oxycephalus	5	Wilson et al. (1996)
Contracaecum sp.*	3	Present study§
Spinitectus micracanthus	50	Muzzall (1982)
	88, 100	Present study§‖
Spinitectus sp.	69	Esch (1971)
	5	Wilson et al. (1996)
Spiroxys sp.*	1	Wilson et al. (1996)
	38, 87	Present study§‖
Acanthocephala		
Leptorhynchoides thecatus	7–71‡	Esch et al. (1976)
	35, 13	Present study§‖
Leptorhynchoides sp.	24	Esch (1971)
Neoechinorhynchus cylindratus	9	Wilson et al. (1996)
Pomphorhynchus bulbocolli	32–93‡	Esch et al. (1976)
	20	Muzzall (1983)
Pomphorhynchus sp.	61	Esch (1971)
Copepoda		
Ergasilus caeruleus	70	Present study§
Myxozoa		
Myxobolus sp.	8	Wilson et al. (1996)
	2	Present study§
Ciliophora		
Trichodina sp.	3	Present study§

* Larval or immature stages.
† Present but prevalence not indicated.
‡ Ranges presented.
§ Five Lakes.
‖ North Porcupine Lake.

Proteocephalus sp., and *Contracaecum* sp., each less than 1%. In bluegill from North Porcupine Lake, *Posthodiplostomum* sp. comprised 97% of all parasites counted.

Discussion

Published reports on the parasites of bluegill from Michigan waters are Fife Lake (Hughes, 1928), Huron River (Dobrovolny, 1939), Gull Lake (Esch, 1971; Esch et al., 1976), Red Cedar River (Muzzall, 1982), St. Marys River (Muzzall, 1983), Holcomb Lake (Wilson et al., 1996), and Five Lakes and North Porcupine Lake (present study). Muzzall et al. (1995) also found 63 bluegill from Gull Lake negative for parasitic copepods.

The high mean intensity of *Posthodiplostomum* sp. in bluegill from North Porcupine Lake is not unusual. Colley and Olson (1963) and Mitchell et al. (1983) reported mean metacercariae intensities of 991 and 1,685, respectively. The latter authors found 5,333 metacercariae in 1 bluegill. The significant increase in *Posthodiplostomum* sp. in bluegill from Five Lakes probably occurred because metacercariae accumulate in larger, older fish.

Posthodiplostomum sp., quantitatively, was the dominant species in bluegill from both lakes. The mean abundance values of *Posthodiplostomum* sp. and *C. cornutum,* and parasites species richness in bluegill from North Porcupine Lake were significantly higher than in Five Lakes. *Diplostomum* sp., *Neascus* sp., *Proteocephalus* sp., and *S. micracanthus* were also more common in bluegill from North Porcupine Lake than from Five Lakes. This may be due to a larger number of intermediate hosts for these helminth species in North Porcupine Lake.

All digenean species found in the present study utilize snails as first intermediate hosts; all except *C. cornutum* use bluegill as second intermediate hosts and mature in piscivorous birds. *Crepidostomum cornutum* uses mayfly nymphs as second intermediate hosts, and *Spinitectus micracanthus* uses them as first intermediate hosts; both species mature in fish. *Leptorhynchoides thecatus* uses amphipods as intermediate hosts and matures in fish. Amphipods, *Hyallela azteca,* and mayfly nymphs often were found in our study in the stomachs of bluegill from both lakes. *Contracaecum* sp. may utilize various invertebrates as intermediate hosts. *Myxobolus* sp. probably utilizes tubificid oligochaetes as inter-

mediate hosts. *Ergasilus caeruleus* and *Trichodina* sp. have direct life cycles.

A total of 19 parasite genera (1 Monogenea, 6 Digenea, 1 Cestoda, 5 Nematoda, 3 Acanthocephala, 1 Copepoda, 1 Myxozoa, 1 Ciliophora) are reported from Michigan bluegill in 8 studies (Table 2). Of the 15 helminth genera, 7 are represented by larval or immature stages. Bluegill parasite data in Table 2 from Wilson et al. (1996) were combined for the open water and littoral zone. Dobrovolny (1939) experimentally infected bluegill with *Plagioporus lepomis,* but it is not clear if bluegill from the Huron River were naturally infected with this trematode. It is included, however, in Table 2. If a common parasite taxon is arbitrarily designated as one with a ≥25% prevalence in a study, 11 parasite taxa (*C. cornutum, Neascus* sp., *Posthodiplostomum* sp., *P. ambloplites, S. micracanthus, Spinitectus* sp., *Spiroxys* sp., *L. thecatus, P. bulbocolli, Pomphorhynchus* sp., and *E. caeruleus*) are common parasites of Michigan bluegill. Also, any given parasite taxon may exhibit variation in its occurrence as well as prevalence between environments. Jilek and Crites (1980) listed 16 parasite genera and 21 species in their summary of parasites of bluegill from Ohio waters. The following parasites have been found in bluegill from Michigan and Ohio: *C. cornutum, Neascus* sp., *Posthodiplostomum* sp., *P. ambloplites, L. thecatus, Neoechinorhynchus cylindratus, Camallanus oxycephalus, S. micracanthus, Spiroxys* sp., and *E. caeruleus.*

Hoffman (1967) listed over 100 parasite species infecting bluegill from North America, which far exceeds the total found in Michigan bluegill (Table 2). Interestingly, there are no published studies on the parasites of bluegill raised in culture conditions in Michigan. This indicates more parasitological studies need to be performed in Michigan on this important fish species.

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Ecology of *Megalodiscus temperatus* (Digenea: Paramphistomatidae) in Red-spotted Newts, *Notophthalmus v. viridescens,* from West Virginia

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ABSTRACT: One hundred twenty-four red-spotted newts (55 females and 69 males) were collected from a marsh in western West Virginia throughout 1995. The large intestines of these salamanders were examined for the amphistome *Megalodiscus temperatus.* Prevalence of infection at 63.6% for female newts and 47.8% for males was not significantly different ($\chi^2 = 2.48$, $P > 0.05$). Mean intensities of 5.6 and 3.5 were recorded for female and male newts, respectively, and the difference between those means was significantly different (Mann–Whitney $U = 780$, $P < 0.05$). Numbers of amphistomes were positively correlated with host weight. Mean adult worm length was negatively correlated with numbers of individuals in a host. *Megalodiscus temperatus* adults were smallest in the May/June collection period and attained their maximum lengths in October and December. May/June appeared to be the primary recruitment period because of the high proportion of juveniles and small size of adult forms.

KEY WORDS: density dependence, *Megalodiscus temperatus, Notophthalmus,* red-spotted newt, West Virginia.

A considerable amount of information on prevalence and mean intensity of *Megalodiscus temperatus* (Stafford, 1905) Harwood, 1932, infections in newts exists today primarily because of the efforts of Mann (1932) and Rankin (1937) in North Carolina, Rankin (1945) in Massachusetts, Russell (1951) in Virginia, Fischthal (1955) in New York, Jackson and Beaudoin (1967) in Pennsylvania, and Price and Buttner (1982) in Illinois. Still, *M. temperatus* infections by host sex are seldom reported, and some investigators have presented data gathered over ambiguously defined or brief time frames (Rankin, 1945; Fischthal, 1955; Jackson and Beaudoin, 1967; Price and Buttner, 1982), leaving questions about the composition of the amphistome population at different times of the year. As a result, one of the goals of this study was to segregate newts by sex and provide information on *M. temperatus* prevalences and mean intensities by host sex for each of 5 defined collection periods throughout 1995. Because collections of *M. temperatus* individuals were sufficiently large in each of the collection periods, we expanded the scope of our investigation to address questions pertaining to 1) the numbers of amphistomes as a function of host size, 2) the size of these worms as a function of their numbers in a host (i.e., a crowding or density-dependent effect), 3) the life cycle stages of worms present by collection period, and 4) the size of adult worms in each of 3 defined reproductive categories by period of collection. The first of these 4 questions was prompted by Rankin's (1937, p. 219) generalization that the number of parasites per host increased with size and age of hosts. The second question arose in response to the observation (without supporting data) by Fischthal (1955) that smaller sexually mature forms of *M. temperatus* were obtained when crowding occurred in the large intestine. The second question took on added meaning with the realization that density-dependent mechanisms are considered of central importance in stabilizing the population growth of parasitic organisms (Anderson, 1978; Anderson and May, 1978) at least in part by suppressing parasite survival or fecundity (Anderson and Gordon, 1982). Density dependence in parasite survival and fecundity might arise as a result of 2 distinct phenomena: intraspecific competition for finite resources such as food or space and/or the generation of immune responses (Anderson, 1978; Keymer, 1982). The general view that fitness of individual worms is reduced within hosts as worm density increases was reiterated by Goater (1992). *Megalodiscus temperatus* appears to be a good model to examine the intraspecific competition phenomenon because this species is confined to the newt's large intestine, a relatively small region of the gastrointestinal tract that could present, presumably, food and space constraints. The third and fourth questions were prompted by the realization that our collections could reveal

Table 1. Numbers of *Megalodiscus temperatus* juveniles and adults collected from newts, specifying by collection period those adults used for length and reproductive category determinations.

Collection period	No. worms*							
	n_C	n_X	n_O	n_J	n_A	n_{Az}	n_{Aa}	n_{Ab}
Feb/Mar	59	26	33	0	0/33	0/0	0/13	0/20
May/Jun	75	8	67	20	33/47	1/1	26/36	6/10
Aug	71	3	68	1	55/67	6/8	39/49	10/10
Oct	61	2	59	1	58/58	0/0	13/13	45/45
Dec	46	1	45	1	44/44	8/8	10/10	26/26
Total	312	40	272	23	190/249	15/17	88/121	87/111

* n_C = total number *M. temperatus* collected at necropsy (shown in Fig. 1); n_X = number lost or damaged; n_O = number observed ($n_C - n_X$); n_J = number of juveniles (not measured for length); n_A = number of observed adults ($n_O - n_J$). Numerator indicates number of adults suitable for length measurements and corresponds to collection period/All n_A values in Figure 2. Denominator indicates number of adults suitable for determining reproductive category. n_{Az} = nongravid adults; n_{Aa} = gravid adults with 1–25 eggs; n_{Ab} = gravid adults with >25 eggs. Relative proportions of adults in each of these reproductive categories by collection period are depicted in Figure 3, and relative lengths are shown in Figure 4.

some new information about *M. temperatus* biology (e.g., period of recruitment, worm size at different times during the year, and relative fecundity levels of adults).

Megalodiscus temperatus is a common digenetic trematode of amphibians in the United States (Cheng, 1986). Eggs laid by adults reach the water via the hosts' feces and hatch into miracidia, which infect *Helisoma* spp. snails. Polyembryonic development within these molluscs results in the production of cercariae, which escape from the snail and encyst in the skin of larval and adult newts. There is no second intermediate host characteristic of so many digenetic trematode life cycles; adult newts ingest their sloughed skin (Morgan and Grierson, 1932) or cannibalize their larvae (Burton, 1977) to acquire infective metacercariae.

Materials and Methods

One hundred twenty-four newts (55 females and 69 males) were collected by hand or in funnel traps from Shoals Marsh, a permanently flooded marsh in Wayne County, West Virginia (38°19′45″N, 82°28′18″W) over 5 collection periods; February/March, May/June, August, October, and December. Each newt was sexed, weighed to the nearest 0.1 g, and then euthanized by pithing within 24 hr of capture. The large intestine was then removed, and all *M. temperatus* were counted and killed by fixation in 10% buffered formalin at room temperature (adults only) under slight coverslip pressure. All adults and a few metacercariae were stained in acid carmine, dehydrated in an ethanol series, cleared in xylene, and mounted in Permount®. Adult amphistomes were measured with a calibrated ocular micrometer. Voucher specimens of *M. temperatus* were deposited in the U.S. National Parasite Collection, Beltsville, Maryland: accession numbers 87276 (juveniles), 87277 (nongravid adult), 87278 (gravid adult with 1–25 eggs), and 87279 (gravid adult with >25 eggs). Juveniles were characterized by the absence of reproductive organs and the presence of distinctly branching eyespots. Nongravid forms possessed testes and ovaries but lacked eggs. Eyespots were sometimes present in these adults but were less extensive than those seen in metacercariae. The 2 different categories of gravid adults were simply determined by egg counts.

Upon examining our total data set, 1 problem was immediately apparent; although we had collected 312 *M. temperatus* individuals, some were lost and thus their length measurements and reproductive status could not be determined. The problem was compounded by the fact that no attempt was made to prepare adult trematodes for measurements in the initial collection period of February/March, but the reproductive status could be determined for 33 of those adults. In other cases, length measurements could not be obtained because the trematodes had been damaged upon removal from their host (or improperly fixed after removal), yet their reproductive status could still be ascertained. To deal with these deficiencies in our data set, we constructed Table 1 to provide an accounting of numbers of juveniles and those adult worms in various reproductive categories suitable for body length measurements and reproductive status determination. Sample numbers for each reproductive category in Table 1 carry over into Figures 1–4.

Gender differences in prevalences were evaluated with a chi-square test. Because density data were not normally distributed, differences in mean intensities were analyzed using a nonparametric Mann–Whitney *U*-test. When data were normally distributed (e.g., host weights), *t*-tests were employed. *F*-tests were used in determining the significance of *b*-values for all regressions. Statistical analyses were performed according to Sokal and Rohlf (1995), and *P*-values <0.05 were considered significant for all tests. Prevalence and mean intensity of infection follow the definitions of Bush et al. (1997).

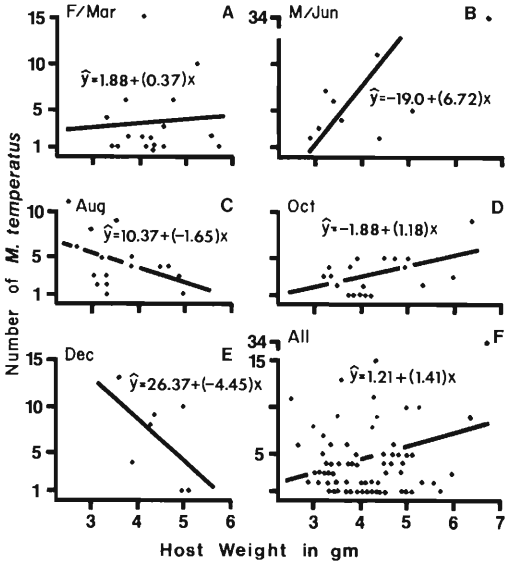

Figure 1. Scatterplots of the relationship between total *Megalodiscus temperatus* and host weight (sexes combined) by collection period (A–E) and for all periods combined (F). Relationships are significant (i.e., $b \neq 0$) for May/June, October, and all collection periods combined.

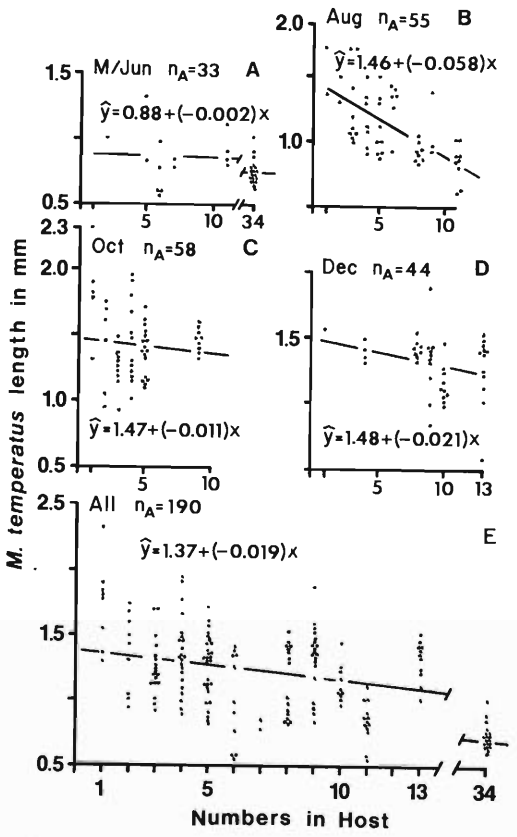

Figure 2. Scatterpolots depicting length of *Megalodiscus temperatus* individuals as a function of numbers present in a given host by collection period (A–D) and for all collection periods combined (E). Negative relationships for August and all collection periods combined are significant (i.e., $b \neq 0$). Each dot represents 1 measured individual, n_A = the number of adults suitable for measurement (see Table 1).

Results

Prevalences and mean intensities of infection

Prevalence of *M. temperatus* infection in female newts (63.6%) was not significantly different from that of males (47.8%) ($\chi^2 = 2.48$, $P = 0.139$) (Table 2). Based on pooled samples, there was an observable seasonal pattern in prevalence: 37.8% in February/March, rising steadily to 86.4% in October, and then declining to 35.0% in December (Table 2). Temporal change in prevalence appeared unrelated to host size. The highest (86.4%) and second lowest (37.8%) prevalence values were recorded in collection periods when infected hosts had mean comparable weights of 4.29 g and 4.31 g, respectively. In addition, the second highest prevalence (76.2%) was recorded in August, when mean infected host weight was the lowest (3.60 g).

Mean intensities of *M. temperatus* infection for female (5.6) and male (3.5) hosts were significantly different (Mann–Whitney $U = 780$, $P < 0.05$) (Table 2). Seasonal differences in mean intensity between female and male newts were not critically examined because of high sample variances associated with small sample sizes of 1 or both infected host sexes in most collection periods (Table 2). Male newts infected by *M. temperatus* were heavier ($\bar{x} \pm SD = 4.25 \pm 0.69$ g) than infected females (3.99 ± 1.01 g), but this difference was not significant ($t_{0.05,66} = 1.23$; $P > 0.05$). There was no significant difference ($t_{0.05,53} = 0.495$; $P > 0.05$) in weights of infected females (3.99 ± 1.01 g) versus uninfected females (4.17 ± 1.69 g), but infected males (4.25 ± 1.69 g) were significantly heavier ($t_{0.05,67} = 3.84$; $P < 0.05$) than uninfected males (3.44 ± 1.02 g).

Relationships between parasite numbers and host size

Numbers of *M. temperatus* individuals as a function of host weight (worms from both sexes

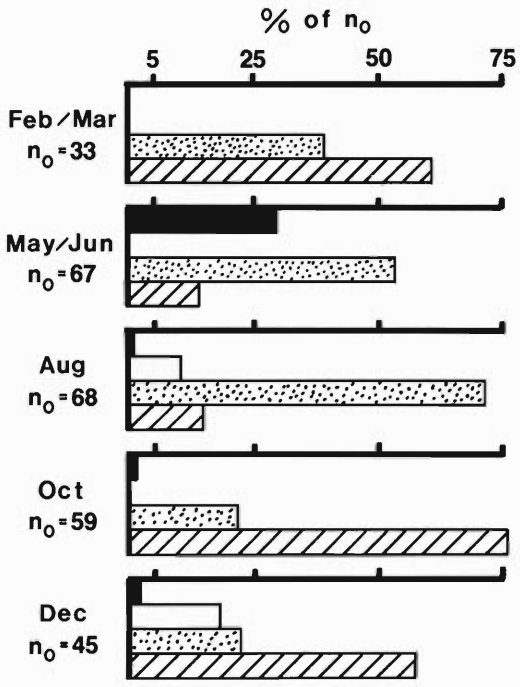

Figure 3. Relative frequencies of *Megalodiscus temperatus* life cycle stages in red-spotted newts by collection period (see n_o, Table 1, for sample sizes). Solid bars = juveniles; open bars = nongravid adults; stippled bars = gravid adults with 1–25 eggs; cross-hatched bars = gravid adults with >25 eggs.

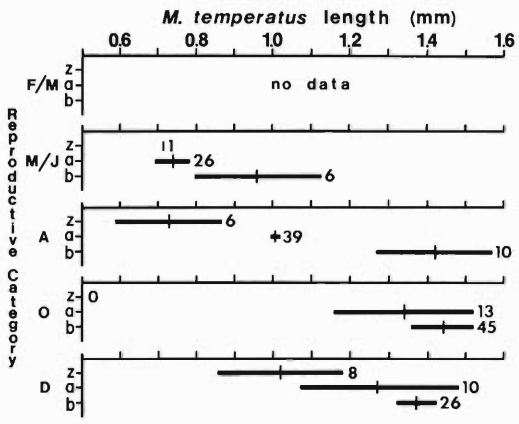

Figure 4. Mean lengths of adult *Megalodiscus temperatus* individuals by reproductive category and collection period. z = nongravid adults; a = gravid adults with 1–25 eggs; b = gravid adults with >25 eggs, respectively. Vertical lines = means; horizontal lines = 95% confidence limits around the means. Numbers to the right of confidence limits are the numbers of worms measured to calculate means and correspond to the collection period numerators in columns n_{Az}, n_{Aa}, and n_{Ab} of Table 1.

of infected newts combined) varied with collection period (Fig. 1A–E). This relationship was positive and significant in May/June ($b \neq 0$, $F_{0.05[1,7]} = 14.66$, $P < 0.05$) and October ($b \neq 0$, $F_{0.05[1,17]} = 5.91$, $P < 0.05$) (Fig. 1B, D). A positive relationship observed in February/March ($b = 0$, $F_{0.05[1,15]} = 0.067$, $P > 0.05$) and negative relationships in August ($b = 0$, $F_{0.05[1,14]} = 3.34$, $P > 0.05$) and December ($b = 0$, $F_{0.05[1,5]}$, $P > 0.05$) were not significant (Fig. 1A, C, E). Overall (Fig. 1F), numbers of *M. temperatus* were positively and significantly correlated with host weight ($b \neq 0$, $F_{0.05[1,66]} = 4.52$, $P < 0.05$).

Density-dependent analyses

Lengths of those adult *M. temperatus* individuals suitably prepared for measurement (Table 1) were negatively correlated with total numbers of individuals present in a host for every collec-

Table 2. Prevalence and mean intensities for *Megalodiscus temperatus* infections in newts at Shoals Marsh by sex of host and collection period.

Collection period	Prevalence*			$\bar{x}$ intensity (SD)	
	Females	Males	Pooled	Females	Males
Feb/Mar	3/8 (37.5)	14/37 (37.8)	17/45 (37.8)	3.0 (2.6)	3.6 (4.4)
May/Jun	5/8 (62.5)	4/8 (50.0)	9/16 (56.3)	10.4 (13.4)	5.8 (3.8)
Aug	16/21 (76.2)	0/0	16/21 (76.2)	4.4 (2.9)	
Oct	8/11 (72.7)	11/11 (100.0)	19/22 (86.4)	4.3 (2.4)	2.4 (1.4)
Dec	3/7 (42.9)	4/13 (30.8)	7/20 (35.0)	9.7 (2.1)	4.0 (4.2)
Total	35/55 (63.6)†	33/69 (47.8)†	68/124 (54.8)	5.6‡ (5.7)	3.5‡ (3.4)

* No. infected/no. in sample (%).
† $\chi^2 = 2.48$; 1 df; $P = 0.139$.
‡ Mann–Whitney $U = 780$; $P = 0.0161$.

tion period (Fig. 2A–D) and for all collection periods combined (Fig. 2E). This negative relationship was not, however, significant for May/June ($b = 0$, $F_{0.05[1,31]} = 3.56$, $P > 0.05$), October ($b = 0$, $F_{0.05[1,56]} = 0.541$, $P > 0.05$), or December ($b = 0$; $F_{0.05[1,42]} = 3.63$; $P > 0.05$) (Fig. 2A, C, D). Negative correlations were significant for Aug ($b \neq 0$, $F_{0.05[1,53]} = 38.60$, $P < 0.05$) (Fig. 2B) and for all collection periods combined ($b \neq 0$, $F_{0.05[1,188]} = 68.90$, $P < 0.05$) (Fig. 2E).

Life cycle stages of *M. temperatus* by collection period

All worms observed in the February/March collection period were gravid (Table 1), and 60.6% of these worms had in excess of 25 eggs (Fig. 3). In May/June, relative frequencies of life cycle stages were quite different from those in the previous collection period (Fig. 3). Those worms with 1–25 eggs (i.e., n_{Aa} in Table 1) dominated, but nearly 30% of the worms were identified as juveniles, and <15% were individuals with >25 eggs (i.e., n_{Ab} in Table 1) (Fig. 3). In August, individuals with 1–25 eggs were clearly dominant, making up approximately 72% of the worms (juveniles and adults) for that collection period. October and December collection periods were dominated by individuals containing >25 eggs (Fig. 3).

Adult worm size by reproductive category and collection period

Those gravid adults with 1–25 eggs and >25 eggs in May/June were significantly smaller than their counterparts of August, October, and December (Fig. 4). Mean lengths of worms with 1–25 eggs were essentially the same for October and December and were significantly longer than the lengths of their 1–25-egg counterparts of May/June and August (Fig. 4). There were no significant differences in mean lengths of those *M. temperatus* individuals with >25 eggs for August, October, and December (Fig. 4). August was the only collection period where mean lengths of adult worms in the 3 reproductive categories were significantly different from each other (Fig. 4).

Discussion

Lack of gender-related differences in the prevalence of infection of *M. temperatus* from West Virginia was similar to the findings of Jackson and Beaudoin (1967) and Price and Buttner (1982). In an earlier study of frog parasites, Fortner (1923, p. 85) stated that the "—percentage of infection between the two sexes does not differ to any great extent." Differences in newt weights was not a factor in sex-based prevalences. We compared weights of females and males (infected and uninfected) for the entire newt sample population. Females were heavier (4.06 ± 1.29 g) than males (3.86 ± 0.99 g), but these mean weights were not significantly different ($t_{0.05,122} = 0.990$; $P > 0.05$). Because prevalences for both sexes of newts were essentially the same, we pooled *M. temperatus* infection data (Table 2) so that comparisons of prevalences could be made with those of previous investigators. The combined prevalence of 54.8% for *M. temperatus* from West Virginia is comparable to the values of 50.6% in Pennsylvania (Jackson and Beaudoin, 1967) and 43.8% in New York (Fischthal, 1955). In contrast, lower prevalences of infection have been noted in North Carolina (25.9–31.8%) by Rankin (1937) and Mann (1932), in Virginia (20.8%) by Russell (1951), and in Massachusetts (16%) by Rankin (1945). Price and Buttner (1982) observed a prevalence of 2.6% for *M. rankini* (=*M. temperatus*) in *N. v. louisianensis* from 2 ponds in Illinois.

Prevalence of *M. temperatus* varies with season of newt collection. Rankin (1937) found that prevalences of amphistome infection in newts were highest (38–42%) in April, July, and October, decreasing to 11.1% and 25.0% (for 2 different ponds) in December. Russell (1951) recorded peak prevalences for *M. rankini* in March (51%) and July (46.4%) but found only 7.6% of the newts infected in October and none in December. The prevalence trend observed in the present study (i.e., low in February/March, increasing steadily through October, then declining in December) was reminiscent of the pattern described by Rankin (1937). Although snails were not examined for developmental stages of *M. temperatus,* it appears that rising prevalence for the May/June newt sample is a likely consequence of increased cercarial production by infected snails. This conclusion is based on the high proportion of juvenile worms recovered at necropsy during the May/June sample period (Fig. 3). This presence of juveniles, coupled with the relatively small size of adult worms (Fig. 2A), also indicates that May/June is the major recruitment period. Cannibalism of their

own larvae is an important dietary strategy for adult newts in late July and August (Burton, 1977). This adult feeding behavior may represent an additional factor contributing to increased prevalence of infection observed in the August and October collections (Table 2), because larval newts may harbor infective metacercariae. The low prevalences of February/March and December are understandable, given that cercarial production is likely low or nonexistent and that newts, being ectothermic, may exhibit reduced feeding activity during these colder months.

Observed mean intensities of 5.6 for female and 3.5 for male newts are significantly different (Table 2). Although no other published studies record mean intensities of *M. temperatus* by host sex, means observed in the present study do not appear unusual when compared with means of 4.2 noted by Mann (1932), 4.0 noted by Price and Buttner (1982), and 3.7 noted by Russell (1951).

The relationship between numbers of *M. temperatus* and size of host has not been reported. Our data suggest a positive correlation between worm numbers and host weight (Fig. 1F). However, the strength of the correlation varied inconsistently with time of collection. Intensity of digenean infection in other amphibians as a function of host size has been recently reported, also with mixed outcomes. Wetzel and Esch (1996) found no significant correlation between total numbers of *Halipegus occidualis* and snout–vent length (SVL) of *Rana clamitans,* but numbers of *H. eccentricus* were positively and significantly correlated with host SVL.

Mean lengths of *M. temperatus* individuals decreased as a function of their total numbers in a host for every collection period and overall. These negative correlations were not always significant, but their consistency coupled with the significance of the overall regression (Fig. 2E) strongly suggests a density-dependent relationship. Because there is a finite amount of space and nutrients available in the large intestines of newts, intraspecific competition for these finite resources offers a plausible explanation for density dependence. Two alternative mechanisms for density dependence, such as parasite-induced host mortality and parasite fecundity, were considered in the present study. There was no evidence of gross pathology in the large intestines of infected newts, and the health of infected newts (if body weight can be viewed as a measure of host health) did not appear to be compromised; weights of infected newts were either comparable to their uninfected counterparts (in females) or significantly greater (in males). The question of a density-dependent effect on *M. temperatus* fecundity arose because Goater (1992) argued convincingly that high densities of the nematode *Rhabdias bufonis* (in *Bufo bufo*) were associated with a decline in worm fecundity. Density-dependent effects on fecundity of *M. temperatus* have not been addressed by previous workers nor could such effects be evaluated definitively in the present work. We have, however, some intriguing empirical data. For example, in the December collection period 4 newts harbored relatively dense *M. temperatus* populations of 8, 9, 10, and 13 worms, respectively. In 1 newt, all 8 worms were in the highest reproductive category (i.e., >25 eggs), whereas 11 of 13 worms in another newt were in the >25 egg reproductive category (1 worm was nongravid and 1 worm was lost). This observation, although limited, cautions against arguing that density dependence inhibits fecundity in *M. temperatus* populations. The newt with 10 worms appeared to represent a recent infection rather than an inhibition of fecundity; 8 of the 10 worms were nongravid with the remaining 2 worms in the 1–25-egg reproductive category. In the newt with 9 worms, 7 worms were in the 1–25-egg reproductive category and 2 worms were in the >25-egg category. This last example, however, was complicated by the fact that 3 worms in the 1–25-egg category were quite large (Fig. 2D) and may have released many of their eggs. The last example also illuminates the drawbacks of evaluating worms in natural populations, e.g., not knowing the time of initial infection(s) or exposure dose(s) as compared with assessing the growth and sexual maturation of worms monitored under laboratory conditions.

In summary, overall and seasonal prevalence of *M. temperatus* in newts from West Virginia is relatively high and is comparable to infection patterns in Pennsylvania and New York. Mean intensity levels are similar to those of previous studies. This study is the first to provide information on amphistome numbers as a function of host size at different times of the year and an evaluation of the relationship between size of amphistomes as a function of their total numbers (i.e., density dependence) and mean size of

worms by season. Studies of a similar nature in different geographic regions should be encouraged.

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Endoparasites of Cope's Gray Treefrog, *Hyla chrysoscelis,* and Western Chorus Frog, *Pseudacris t. triseriata,* from Southeastern Wisconsin

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ABSTRACT: Sixty-five Cope's gray treefrogs, *Hyla chrysoscelis,* and 6 western chorus frogs, *Pseudacris t. triseriata,* were collected from southeastern Wisconsin during April through June 1996 and 1997 and examined for endoparasites. Fifty-one (78%) treefrogs and 5 (83%) chorus frogs were infected with 1 or more endoparasites. Two species of protozoa, 2 species of nematodes, 3 species of larval and adult digeneans, 1 species of monogenean, and 3 species of metacestodes infected the treefrogs. The chorus frogs were infected by 1 species of protozoan, 1 species of nematode, and 2 species of larval and adult digeneans. New host and distribution records for protozoan and metazoan parasites of Wisconsin anurans are reported.

KEY WORDS: *Hyla chrysoscelis, Pseudacris t. triseriata, Opalina* sp., *Nyctotherus cordiformis, Polystoma nearcticum, Glypthelmins pennsylvaniensis, Mesocestoides* sp., *Cosmocercoides variabilis, Oswaldocruzia pipiens,* Wisconsin.

Cope's gray treefrog, *Hyla chrysoscelis* Cope, 1880, is a large treefrog occurring in prairie ponds, oak savannas, dry and dry-mesic northern hardwoods, and lowland forests and has been distinguished from the eastern gray treefrog, *H. versicolor* Le Conte, 1825 (Ralin, 1968). Because of the similarity between these two species, different ranges have not been determined and little information on the natural history of *H. chrysoscelis* is available (Ralin, 1968; Jaslow and Vogt, 1977). The composite range covers most of the eastern United States from Ontario and southern Maine to the Gulf of Mexico (Vogt, 1981). The western chorus frog, *Pseudacris t. triseriata* Wied, 1839, is a small treefrog that ranges from the east end of Lake Ontario, west to central Minnesota, and south through Kansas and Oklahoma, with disjunct populations in New Mexico and Arizona (Vogt, 1981). A number of studies have been conducted on the endoparasites of the western chorus frog, but only two prior studies have been conducted on Cope's gray treefrog (see Table 1). Both species are common around moist prairies in southeastern Wisconsin, yet no studies exist on their endoparasites in this area. Here we present new information on the parasites of Wisconsin treefrogs.

Materials and Methods

Between May and June 1996 and April and June 1997, 65 Cope's gray treefrogs, 53 males and 12 females (mean ± SD snout–vent length [SVL] = 41 ± 3 mm, range = 33–48 mm) and 6 western chorus frogs, 4 males and 2 females (24 ± 1 mm, 22–25 mm) were collected from two adjacent ephemeral ponds in Waukesha County, Wisconsin (42°54′N, 88°29′W). Cope's gray treefrogs were identified by mating call and mean erythrocyte length, as described by Bolek (1997). Specimens were collected by hand or dip-net during the night breeding chorus. Animals were transported to the laboratory and euthanized in MS 222 (ethyl m-aminobenzoate methane sulfonic acid) within 72 hr of capture. SVL and wet weight (WW) were recorded for each individual. At necropsy the digestive tract, limb and body wall musculature, and internal organs were examined for endoparasites. Intestinal protozoans were affixed to glass slides with albumin fixative and glycerol, fixed in modified Schaudinn's fixative, stained with hematoxylin, dehydrated in a graded ethanol series, cleared in xylene, and mounted in Canada balsam. Nonencapsulated immature and adult digeneans and cestodes were relaxed and killed by slowly warming them in staining dishes containing 0.25% saline and then fixed in alcohol–formaldehyde–acetic acid (AFA). Monogeneans were relaxed under slight coverslip pressure in a refrigerator and then frozen and fixed in AFA, stained with acetocarmine, dehydrated in a graded ethanol series, cleared in xylene, and mounted in Canada balsam. Nematodes were killed in hot AFA, dehydrated to 70% ethanol, cleared in glycerol, and identified as temporary mounts. All tissue containing metacestodes was removed and fixed in 10% formalin, embedded in Paraplast, sectioned at 7 μm, affixed to slides, stained with Harris's hematoxylin and eosin, and mounted in Canada balsam. All undigested stomach contents were identified to taxonomic class or order following Borror et al. (1989). Stomach contents were reported as a percentage, i.e., number of arthropods in a given class or order divided by total number of arthropods recovered. Prevalence, mean intensity, and abundance are according to Bush

Table 1. Endoparasites reported from *Hyla chrysoscelis* and *Pseudacris t. triseriata*.

Parasite species	*Hyla chrysoscelis*		*Pseudacris t. triseriata*	
	Locality	Reference	Locality	Reference
Protozoa				
Opalina sp.	Wisconsin	This study		
	Texas	Metcalf, 1923		
O. obtrigonoidea			Ohio	Odlaug, 1954
O. chorophili			Ohio	Odlaug, 1954
Cepedea sp.	Texas	Metcalf, 1923		
Nyctotherus cordiformis	Wisconsin	this study	Ohio	Odlaug, 1954
			Wisconsin	this study
Trichomonas augusta			Ohio	Odlaug, 1954
Digenea				
Brachycoelium salamandrae			Ohio	Odlaug, 1954
Glypthelmins hyloreus			Colorado	Ubelaker et al., 1967
			Nebraska	Brooks, 1976
G. pennsylvaniensis	Wisconsin	this study	Michigan	Muzzall and Peebles, 1991
			Wisconsin	this study
G. quieta			Ohio	Ashton and Rabalais, 1978
Glypthelmins sp.			Indiana	Whitaker, 1971
Haematoloechus complexus	Nebraska	Brooks, 1976		
Megalodiscus temperatus	Nebraska	Brooks, 1976		
Unidentified immature trematode	Wisconsin	this study		
Unidentified metacercariae	Wisconsin	this study	Wisconsin	this study
Monogenea				
Polystoma nearcticum	Wisconsin	this study		
Cestoidea				
Mesocestoides sp.	Wisconsin	this study		
Unidentified plerocercoid	Wisconsin	this study		
Unidentified cestode cyst	Wisconsin	this study		
Nematoda				
Cosmocercoides variabilis	Wisconsin	this study	Ohio	Odlaug, 1954
			Wisconsin	this study
			Texas	Harwood, 1930
			Canada	Vanderburgh and Anderson, 1987a
C. dukae			Ohio	Ashton and Rabalais, 1978
			Michigan	Muzzall and Peebles, 1991
Oswaldocruzia pipiens	Wisconsin	this study	Canada	Baker, 1977
O. leidyi			Ohio	Ashton and Rabalais, 1978
Falcaustra catesbeianae			Arizona	Goldberg et al., 1996
Gyrinicola batrachiensis†			Canada	Adamson, 1981
Rhabdias ranae			Canada	Baker, 1978b

† In tadpoles.

et al. (1997). Voucher specimens have been deposited in the H. W. Manter Helminth Collection, University of Nebraska State Museum, Lincoln (accession numbers HWML 39468, *Opalina* sp.; 39483, *Nyctotherus cordiformis*; 39469, *Polystoma nearcticum*; 39470, *Glypthelmins pennsylvaniensis*; 39471, immature trematode; 39472, unidentified metacercariae; 39473, unidentified plerocercoid; 39474, *Mesocestoides* sp.; 39482, unidentified cestode cyst; 39475, male *Cosmocercoides variabilis*; 39476, male *Oswaldocruzia pipiens*).

Results and Discussion

Eleven species of endoparasites infected Cope's gray treefrogs and 4 species infected western chorus frogs (Table 2). Of the 51 (78%) treefrogs infected with endoparasites, 26 harbored only 1 species, 19 harbored 2 species, and 6 harbored 3 species. Prevalence ranged from 52% for *Opalina* sp. to 1.5% for *Glypthelmins pennsylvaniensis* Cheng, 1961. Overall mean

Table 2. Prevalence, abundance, and mean intensity of endoparasites of *Hyla chrysoscelis* and *Pseudacris t. triseriata* from southeastern Wisconsin.

	Hyla chrysoscelis			*Pseudacris t. triseriata*			
	Prevalence*	Mean (±SD) abundance	Mean (±SD) intensity (range)	Prevalence*	Mean (±SD) abundance	Mean (±SD) intensity (range)	Location†
Protozoa							
Opalina sp.	34 (52)	NC‡	NC	absent	absent	absent	SI, LI
Nyctotherus cordiformis	5 (8)	NC	NC	1 (17)	NC	NC	SI, LI
Monogenea							
Polystoma nearcticum	10 (15)	0.2 ± 0.5	1.3 ± 0.7 (1–3)	absent	absent	absent	UB
Digenea							
Glypthelmins pennsylvaniensis	1 (1.5)	0.02 ± 0.1	1	3 (50)	1 ± 1.5	2 ± 1.7 (1–4)	SI
Unidentified immature trematode	3 (5)	2 ± 9	42.3 ± 3 (39–45)	absent	absent	absent	SI
Unidentified metacercariae	5 (8)	1.3 ± 8.7	16.8 ± 29.6 (1–69)	1 (17)	1 ± 2.4	6	LM, BC
Cestoidea							
Unidentified plerocercoid	1 (1.5)	0.2 ± 1.7	14	absent	absent	absent	BC, L
Unidentified cestode cyst	1 (1.5)	0.1 ± 0.9	7	absent	absent	absent	S
Mesocestoides sp.	8 (12)	NC	NC	absent	absent	absent	BC, SI, LI, LV, M
Nematoda							
Cosmocercoides variabilis	14 (22)	0.7 ± 3	3.3 ± 5 (1–23)	4 (67)	1 ± 0.9	1.5 ± 0.6 (1–2)	SI, LI, L
Oswaldocruzia pipiens	4 (6)	0.08 ± 0.3	1.3 ± 0.5 (1–2)	absent	absent	absent	SI

* Number (%) infected.
† BC = body cavity; L = lungs; LI = large intestine; LM = leg muscles; LV = liver; M = musculature; S = stomach; SI = small intestine; UB = urinary bladder.
‡ NC = not counted.

helminth abundance for all worm species that could be counted accurately in the treefrogs was 4.4 ± 12.9. Of the 5 (83%) infected chorus frogs, 2 harbored 1 species, 2 harbored 2 species, and 1 harbored 3 species. Prevalence and mean intensities were highest for *Cosmocercoides variabilis* Harwood, 1930, and *G. pennsylvaniensis*. Overall mean helminth abundance in the chorus frogs was 3.0 ± 3.3. There was no significant correlation ($P > 0.05$) between helminth abundance for any of the worm species that could be counted accurately and WW or SVL for treefrogs or chorus frogs. Twenty-nine (45%) treefrogs had identifiable stomach contents, but only 2 chorus frogs had stomach contents. The treefrog diet consisted of insects, with coleopterans making up 43% of the diet followed by lepidoptera larvae (24%), unidentifiable insects (22%), and orthopterans (11%). The stomachs of the 2 chorus frogs contained coleopterans and unidentifiable arthropods.

The protozoan *Opalina* sp. Purkinje and Valentin, 1840, was found in the small and large intestine of the treefrogs. These protozoans were not identified to species because of lack of range of forms as suggested by Sandon (1976). *Opalina* spp. were previously reported in *H. chrysoscelis* from Texas by Metcalf (1923) and the sister species *H. versicolor* from various locations in the midwestern and southern parts of the United States. The absence of *Opalina* sp. from the western chorus frogs may be due to the small sample of frogs collected. A number of previous reports have shown that the western chorus frog and other *Pseudacris* species harbor these protozoans (Metcalf, 1923; Brandt, 1936; Odlaug, 1954; McAllister, 1987, 1991).

Nyctotherus cordiformis Ehrenberg, 1838, infected both host species in this study. These ciliates are common parasites of *Hyla* and *Pseudacris* (Brandt, 1936; McAllister, 1987, 1991; McAllister et al., 1993) and have been reported previously from *H. versicolor* from a number of locations throughout its range, although the prevalence reported was much higher than that in this study (Wichterman, 1936; Campbell, 1968). *Hyla chrysoscelis* is a new host record for this ciliate. Prevalence of infection in this hylid species was more comparable to that of terrestrial anurans such as *Bufo* (Campbell, 1968; McAllister et al., 1989) and may reflect differences in habitat utilization from *H. versicolor*. Blair (1958) reported that *H. chrysoscelis* is a grassland species in parts of its range, whereas in Wisconsin its distribution in general corresponds to prairies, oak savannas, and pine savannas (Jaslow and Vogt, 1977). Another explanation for the low prevalence observed may be the time of year these frogs were collected. Brandt (1936) reported low prevalence of this ciliate in *Pseudacris* and *Hyla* during early summer.

Polystoma nearcticum Paul, 1938, infected the urinary bladder of *H. chrysoscelis*. This species has been reported previously from *H. versicolor* from Minnesota and *H. cinerea* Schneider, 1799, the green treefrog, from Florida (Paul, 1938). Brooks (1976), in his survey of Nebraska amphibians, found no *H. chrysoscelis* infected with this monogenean. *Hyla chrysoscelis* is a new host record and Wisconsin is a new locality record for *P. nearcticum*.

Three chorus frogs and 1 treefrog were infected with *G. pennsylvaniensis*. This trematode has been reported from Wisconsin spring peepers, *P. c. crucifer* Wied, 1839, by Coggins and Sajdak (1982) and Yoder and Coggins (1996). This is the first report from Wisconsin chorus frogs and the first report from Cope's gray treefrogs.

Three treefrogs were infected with an unidentified immature digenean located in the small intestine. These trematodes were small and showed some development of testes and ovary, but vitellaria, genital pore, or uterus could not be seen. Both frog species were infected at low prevalence with an unidentified metacercaria located in the leg muscles and body cavity. Metacercariae have previously been reported at low prevalence from leg muscle and body cavity musculature in other *Hyla* and *Pseudacris* species (Ulmer, 1970; Yoder and Coggins, 1996).

Ten treefrogs were infected with numerous metacestodes. Eight of the 10 treefrogs were heavily infected with tetrathyridia of *Mesocestoides* sp. Valunt, 1863. These organisms were encapsulated in the intestine, liver, and musculature, but a few were also found free in the body cavity. Three of the treefrogs harbored heavy infections under the skin of the hind legs, with as many as 300 metacestodes/leg. These treefrogs displayed small abrasions on the outer surface of the skin, which appeared red or pink in color instead of the usual cream white color. Although a number of bufonids and ranids have been reported to be infected with *Mesocestoides*

sp. (see McAllister et al., 1989; McAllister and Conn, 1990; McAllister et al., 1995) only one hylid is known to be infected with this metacestode (McAllister, 1987). Therefore, Cope's gray treefrog is a new host record. Two other Cope's gray treefrogs were infected with other unidentified metacestodes; 1 treefrog harbored 14 plerocercoids, 13 in the body cavity and 1 in a lung. All metacestodes possessed a tetracetabulate scolex with an apical organ. The other treefrog possessed 7 cestode cysts on the outer mesentery of the stomach. These cestodes lacked an excretory antrum and did not appear to be *Mesocestoides* sp. Plerocercoids and other cestode cysts have been previously reported from *H. versicolor* in Missouri and other hylids from North Carolina (Brandt, 1936; Shannon, 1988).

Two species of nematodes, *Oswaldocruzia pipiens* Walton, 1929, and *Cosmocercoides variabilis* Harwood, 1930, infected Cope's gray treefrog, and *C. variabilis* infected the western chorus frogs. Four male and 1 gravid female *O. pipiens* were found in the small intestine of 4 treefrogs. Cope's gray treefrog is a new host record for *O. pipiens*.

A total of 46 *C. variablis* (16 males, 20 females, and 10 J_4 larvae) were recovered from 14 of the treefrogs, and 6 (1 male, 3 females, and 2 J_4 larvae) were recovered from 4 of the chorus frogs. Vanderburgh and Anderson (1987a) reported that *C. variabilis* is a parasite of amphibians but *C. dukae* Holl, 1928, is a parasite of terrestrial molluscs, with inadvertent occurrences in animals that feed upon terrestrial molluscs (Anderson, 1960). The major difference in the 2 nematode species is the number of rosette papillae per subventral row in males; male *C. dukae* have 9–21 rosette papillae (averaging 13 or 14) and *C. variabilis* have 15–25 (averaging 20 or 21). All males in the present study possessed 17–23 rosette papillae, averaging 19.6. Measurements of gubernaculum length of males and esophagus length and bulb width for males and females fell in the ranges for those measurements in *C. variabilis* as given by Vanderburgh and Anderson (1987a) for toads. The J_4 larvae were also located in the lungs and small intestine, and all adult females were gravid with developing larvae in the eggs. The diet of Cope's gray treefrog, as indicated by this study and previous work (Ralin, 1968), consists mostly of insects, and molluscs probably play an insignificant role if any in their diet. Therefore, the specimens collected in the present study probably are *C. variabilis*. This nematode has a direct life cycle that includes skin penetration, molting in the lungs or body cavity, and maturing in the intestine (Baker, 1978c). It was suggested that this parasite may be restricted to certain amphibian groups such as hylids, microhylids, and bufonids (Vanderburgh and Anderson, 1987a). *Cosmocercoides variabilis* is a common parasite of the eastern American toad *Bufo a. americanus* Holbrook, 1836 (Vanderburgh and Anderson, 1987a, b; Joy and Bunten, 1997), and has previously been reported from the western chorus frog in Canada (Vanderburgh and Anderson, 1987a). This is the first report from Cope's gray treefrog and the first report from Wisconsin chorus frogs.

The breeding pond probably serves as the most important focus of infection with these endoparasite species, and diet of adult frogs plays a lesser role. Brandt (1936) suggested that an arboreal habitat is less conductive to metazoan parasitism than are terrestrial or aquatic habitats. The arboreal nature of Cope's gray treefrogs probably has an effect on parasite colonization during the tadpole stage or breeding period of these frogs. Of the 11 endoparasites recovered, 6 have been reported to have their life cycles synchronized to the amphibian tadpole stage and their emergence period from the pond (Brandt, 1936; Wichterman, 1936; Paul, 1938; Cheng, 1961; El Mofty and Smyth, 1964; El Mofty, 1973; Sullivan and Byrd, 1970; Baker, 1978a). The 3 metacestode species recovered are probably acquired by frogs feeding on intermediate hosts. Stomach content analysis revealed that the diet of these frogs is less diverse than that of other Wisconsin anurans (Vogt, 1981). Accordingly, endoparasites dependent on intermediate hosts were found at a lower prevalence in these hosts than in other Wisconsin frogs (Williams and Taft, 1980; Coggins and Sajdak, 1982; Yoder and Coggins, 1996).

Results of the current survey support previous work on treefrog endoparasites, indicating that most are not host specific. In the present study, both frogs utilized the same breeding ponds, with the western chorus frog breeding from late March to late June and Cope's gray treefrog breeding from mid May to late June (pers. obs.). Because of the overlap in habitat utilization by adults and tadpoles of these hosts, transmission of parasites between them is likely. Although

prevalence, mean intensity, and mean abundance was not compared among the two host species because of the low number of chorus frogs examined, the 2 hosts shared 4 endoparasite species, and 2 other species found in Cope's gray treefrogs have been previously reported in western chorus frogs (Metcalf, 1923; Baker, 1977). *Polystoma nearcticum* is the only parasite in this study that is host specific to the genus *Hyla* and has not been reported in *Pseudacris* (see Paul, 1938; Campbell, 1968). Therefore, despite the occurrence of some parasite species in certain amphibian hosts, if the opportunity arises, some parasites are capable of infecting several different host species, confirming that ecological influences can affect host specificity (Prudhoe and Bray, 1982).

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Effect of Season, Sex, and Age on Prevalence of Parasitism in Dogs from Southeastern Wisconsin

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ABSTRACT: Examination of fecal samples from 309 animal shelter dogs in Milwaukee County, Wisconsin, was made to evaluate the effect of season, host age, sex, and care status on the prevalence of single and multiple infections of intestinal parasites. One or more species of parasite were identified in 42% of fecal samples. Intestinal parasites were present in all months of the year, but prevalence was higher in warmer than in colder seasons. *Toxocara canis* was the most common parasite egg recovered (21.4%). Other helminth eggs recovered were *Ancylostoma* sp. (11.3%), *Trichuris vulpis* (8.7%), and *Toxascaris leonina* (4.2%). The protozoans *Isospora canis* (5.2%) and *Giardia lamblia* (4.5%) also were recovered. No cestode eggs were seen during the study. There was no significant difference in overall prevalence between 168 male (41.7%) and 141 female (41.9%) dogs. Ascarids were more common in younger dogs. Hookworm prevalence also decreased with increasing host age. Male dogs were more frequently infected with hookworms. Whipworms were found less often in very young and in older dogs. Multiple infections comprised 27% of positive fecal samples but were not clustered by season. Neutered animals of both sexes were infected less often than were intact animals. Stray animals were significantly more frequently infected than were previously owned dogs.

KEY WORDS: dog, canine, helminth, protozoa, *Toxocara canis, Toxascaris leonina, Trichuris vulpis, Ancylostoma* sp., hookworm, *Isospora canis,* coccidia, *Giardia lamblia,* Milwaukee, Wisconsin.

Zoonotic disease transmitted by dogs is an important aspect of public health. Increasing pressure for use of available land coupled with an increasing canine population makes this problem particularly important in urban areas. Environmental contamination with the infective eggs and larvae of dog parasites may pose a significant risk to humans. The dog population in the U.S.A. is estimated to be >55 million (Schantz, 1991). Dubin et al. (1975) found one-third of soil samples from public parks to be contaminated with nematode eggs. A significant body of literature exists on visceral larva migrans and its causative agent *Toxocara canis* Werner, 1782 (Glickman et al., 1979). Hookworms may cause cutaneous larva migrans in humans who come in contact with the eggs shed in dog feces (Schad, 1994). Both types of parasites may have high prevalence rates in dogs because of transplacental or transmammary transmission (Soulsby, 1969; Schad, 1994).

Numerous surveys of canine intestinal parasites have been reported (Wright, 1930; Vaughn and Murphy, 1962; Worley, 1964; Jaskoski, 1970; Schantz et al., 1977; Palmieri et al., 1978; Stewart et al., 1986; Jordan et al., 1993). However, few studies have included an examination of the effects of dog sex or age on the prevalence of intestinal parasites (Visco et al., 1977; Kazacos, 1978; Hoskins et al., 1982; Blagburn et al., 1996). No data exist on seasonality of canine infections or prevalence of single or multiple infections in Wisconsin.

The present study was undertaken to evaluate the effect of seasonality, host age, host sex, and care status (stray animal or unwanted pet) on the prevalence of single and multiple infections of intestinal parasites in dogs collected in Milwaukee County, Wisconsin.

Materials and Methods

From November 1994 to October 1995, 309 fecal samples taken from dogs housed at the Wisconsin Humane Society (WHS) shelter were examined for the presence of intestinal parasites. Dogs to be included in this study were selected by WHS personnel and were divided evenly by sex into 6 age groups, ranging from <3 mo to >60 mo of age. Shelter records indicated whether the dogs were stray animals or unwanted pets (care status). Fecal samples were collected from fresh scats or directly from the rectum, stored in capped Styrofoam cups, and refrigerated until transported to the laboratory. Samples were always examined within 24 hr of collection.

Approximately 3 g of feces was placed in a 15-ml centrifuge tube and washed once in tap water. Flotation was performed using zinc sulfate (specific gravity = 1.18) or Sheather's sugar solution. Tubes were centrifuged at 1,500 rpm for 5 min. The liquid on the attached coverslips was examined microscopically for the presence of helminth eggs and protozoan cysts. Because better results were obtained using zinc sulfate,

Table 1. Monthly parasite prevalence and number of multiple infections in fecal samples from dogs from southeastern Wisconsin.

Month	No. dogs examined	No. dogs infected	Prevalence (%)	No. dogs with multiple infections		
				1 species	2 species	3 species
Jan	22	6	27.3	5	1	0
Feb	25	9	36.0	7	2	0
Mar	26	15	57.7	11	2	2
Apr	24	9	37.5	9	0	0
May	26	10	38.5	8	1	1
Jun	27	10	37.0	10	0	0
Jul	26	12	46.2	9	2	1
Aug	25	11	44.0	9	2	0
Sep	28	13	46.4	9	3	1
Oct	29	17	58.6	8	7	2
Nov	25	8	32.0	4	4	0
Dec	26	9	34.6	5	4	0
Total	309	129	41.8	94	28	7

sugar flotation was discontinued after 2 monthly sampling periods. Statistical analysis was conducted using the chi-square test for goodness of fit (Sokal and Rohlf, 1973).

Results and Discussion

A total of 129 (41.8%) of the 309 fecal samples examined were positive for intestinal parasites. Monthly prevalence values ranged from a low of 27.3% (6/22) in January to a high of 58.6% (17/29) in October (Table 1). Seasonal prevalence trends were not distinct, but infection rates were higher during warmer months and lower in winter. Prevalence in July through October were all >44%, whereas infections in November though February never exceeded 36%.

The most common parasite egg identified from fecal samples was that of the ascarid *Toxocara canis,* found in 66 (21.4%) of the 309 fecal samples examined (Table 2). A wide range of prevalence values have been reported for this parasite from shelter dogs in the U.S.A. Smith and Seaton (1981) found an ascarid prevalence of 30% from dogs in Texas, and Palmeri et al. (1978) reported *T. canis* in 49% of their samples from Utah. Marron and Schroeder (1978) described ascarids in 49% of "younger dogs" in California. In Indiana, Kazacos (1978) reported that 18.3% of examined dogs were infected with *T. canis.* However, Hoskins et al. (1982) found this parasite in only 8.5% of dog fecal samples examined in Louisiana. Blagburn et al. (1996) reported *T. canis* in 14.54% of fecal samples nationally and in 15.80% of samples from the Midwest.

Table 2. Prevalence of intestinal parasites in fecal samples from dogs from southeastern Wisconsin.

Parasite	No. dogs infected	Prevalence (%)
Nematoda		
Ascarids		
Toxocara canis	66	21.4
Toxascaris leonina	13	4.2
Anclyostoma sp.	35	11.3
Trichuris vulpus	27	8.7
Protozoa		
Isospora canis	16	5.2
Giardia lamblia	14	4.5

Very young dogs were more frequently infected with ascarids (Table 3). This finding was expected because this parasite has a transplacental route of infection (Glickman et al., 1979). Prevalence of ascarids decreased with increasing age of male dogs, from 54.5% in males 0–3 mo to 3.8% in males >60 mo of age. Females were also most frequently infected at a very young age (52.2% at 0–3 mo), and prevalence also decreased with increasing age. The least common helminth egg recovered from this study was that of *Toxascaris leonina* von Linstow, 1902, recovered from only 13 (4.2%) samples. Because this helminth constituted such a small percentage of the total parasite burden, it was combined with *Toxocara canis* in subsequent tables (Tables 3, 4). However, the low level of *Toxascaris leonina* in total parasite burden is consistent with most previous reports. The prevalence of *T. leonina* reported in our study (4.2%) is markedly higher that the *T. leonina* prevalence (0.46%) reported by Blagburn et al. (1996) for the Midwest but lower than that reported by Kazacos (1978), who employed a necropsy procedure rather than fecal flotation.

Hookworm, identified as *Ancylostoma* spp. Dubini, 1843, based on egg size (Georgi and McCulloch, 1989), was the second most common type of parasite egg detected, found in 35 (11.3%) samples. *Ancylostoma* may have a transmammary infection route (Lindsay and Blagburn, 1995), accounting for the higher prevalence in very young dogs. Exclusive of the high prevalence in very young dogs, hookworm prevalence appeared to be independent of host age (Table 3). Prevalence in males ranged from 10%

Table 3. Effect of sex and age on number and prevalence of intestinal parasites in fecal samples from dogs from southeastern Wisconsin.

Infection category	Dog age (mo)						Total
	0–3	3–6	6–12	12–36	36–60	60+	
Male dogs							
Ascarids	12 (54.5)*	10 (33.3)	3 (15.0)	9 (18.4)	4 (19.1)	1 (3.8)	39 (23.2)
Hookworms	5 (22.7)	3 (10.0)	5 (25.0)	5 (10.2)	3 (14.3)	4 (15.4)	25 (14.9)
Whipworms	0	3 (10.0)	2 (10.0)	8 (16.3)	0	0	13 (7.7)
Coccidia	3 (13.6)	0	1 (5.0)	1 (2.0)	1 (4.8)	0	6 (3.6)
Giardia	2 (9.1)	2 (6.7)	0	0	0	0	4 (2.4)
Uninfected	5 (22.7)	18 (60.0)	10 (50.0)	28 (57.1)	15 (71.4)	22 (84.6)	98 (58.3)
Total	22	30	20	49	21	26	168
Female dogs							
Ascarids	12 (52.2)	4 (25.0)	8 (40.0)	8 (3.8)	2 (22.2)	2 (13.3)	36 (25.5)
Hookworms	2 (8.7)	1 (6.3)	1 (5.0)	5 (8.6)	0	1 (6.7)	10 (7.1)
Whipworms	0	1 (6.3)	6 (30.0)	6 (10.3)	0	1 (6.7)	14 (9.9)
Coccidia	3 (13.0)	2 (12.5)	1 (5.0)	4 (6.9)	0	0	10 (7.1)
Giardia	3 (13.0)	1 (6.3)	0	5 (8.6)	0	1 (6.7)	10 (7.1)
Uninfected	8 (34.8)	9 (56.3)	9 (45.0)	37 (63.8)	7 (77.8)	12 (73.3)	82 (58.2)
Total	23	16	20	58	9	15	141

* No. (%) of dogs in each category.

in younger to 15% in dogs >60 mo of age. Prevalence in females was lower than that in males but also appeared independent of age, exclusive of the 0–3 mo age class. Hookworms are the most common type of canine parasite in most reports. Visco et al. (1977) reported hookworms in 35.8% of their samples from Missouri, Hoskins et al. (1982) found 38.5% of dogs in Louisiana harboring hookworm eggs, and Blagburn et al. (1996) reported *A. caninium* present in 20.66% of fecal samples in the Midwest and in 19.19% of samples nationally. Reasons for the almost 2-fold difference in prevalence between Blagburn et al.'s (1996) and our findings are unclear. Their Midwest results were based on a pooled sample from several cities, whereas our study was conducted only in metropolitan Milwaukee, a mostly urban area. Their samples were collected at only 1 time of year. In Milwaukee, those samples were collected on only 1 day of the year (Castelein, pers. comm.). Low sample size, a necessity in such a comprehensive national survey, cannot be ruled out as an additional contributing factor.

Table 4. Number and prevalence of single and multiple infections of intestinal parasites in dogs from southeastern Wisconsin.

Parasite	No. dogs infected	Prevalence (%)
Ascarid	46	14.2
Hookworm	20	6.5
Whipworm	18	5.8
Coccidia	7	2.3
Giardia	5	1.6
Ascarid + hookworm	8	2.6
Ascarid + whipworm	6	1.9
Ascarid + coccidia	5	1.6
Ascarid + *Giardia*	5	1.6
Hookworm + whipworm	1	0.3
Hookworm + *Giardia*	2	0.6
Coccidia + *Giardia*	1	0.3
Ascarid + hookworm + whipworm	2	0.6
Ascarid + hookworm + coccidia	2	0.6
Ascarid + coccidia + *Giardia*	1	0.3

Hookworm eggs and free-living larvae are sensitive to environmental conditions (Schad, 1994). The lower prevalence in the present study may reflect climatic differences between Wisconsin and the warmer areas surveyed in several previous studies. Seah et al. (1975) found a hookworm prevalence of only 12.5% in stray dogs from Montreal, Canada, data more consistent with our findings. Cold winters probably contribute to low egg viability in scats and low survival of free-living larvae. Even though fewer dogs passed hookworm eggs during winter, at least one hookworm-infected dog was present in each monthly sample. Very young and the oldest males had similar rates of infection. Almost

twice as many males as females were infected with hookworms (14.9% vs. 7.1%). Females displayed a prevalence pattern similar to that in males but at lower levels; hookworms were absent in females 36–60 mo of age and increased to 8.6% in females 12–36 mo of age (Table 3).

Eggs of the whipworm *Trichuris vulpis* Froelich, 1789, were found in 27 (8.7%) samples. Whipworm eggs were absent in very young (0–3 mo) dogs and were absent or found in low prevalence in most age groups (Table 3). The highest prevalence of whipworm found in this study was in females 6–12 mo old (30%). Whipworms were found in 15% (Hoskins et al., 1982) and 27% (Smith and Seaton, 1981) of hosts by other workers. Both of these previous studies were conducted in areas with warmer climates than Wisconsin. Working in Canada, Seah et al. (1975) reported whipworms in only 4.6% of their samples. Thus, weather may play a role in egg survival for this parasite. However, Blagburn et al. (1996) reported whipworms in 14.29% of fecal samples nationally and in 16.39% of samples in the Midwest. These workers further stated that dogs in the Midwest are at increased risk of whipworm infection. Based on a much lower whipworm prevalence in our study (8.7%), our results do not support this conclusion for the southeastern Wisconsin area.

Two types of protozoan cysts were identified during this study. Coccidia oocysts, identified as *Isospora canis* Nemeseri, 1959, and *Giardia lamblia* Kofoid and Christiansen, 1915, were found in 16 (5.2%) and 14 (4.5%) samples, respectively (Table 2). Coccidia infections were more common in younger dogs and decreased with host age (Table 3). Females were consistently more frequently infected with this protozoan. The prevalence of coccidia oocysts in our study was similar to results of prior studies (Streitel and Dubey, 1976; Jordan et al., 1993; Blagburn et al., 1996), although Hoskins et al. (1982) found coccidia in only 1.1% of their samples. Few prior surveys have reported *Giardia* infections (Hoskins et al., 1982; Jordan et al., 1993; Blagburn et al., 1996). *Giardia lamblia* was found more frequently in females and in younger dogs. Hoskins et al. (1982) found *Giardia* in only 0.8% of their samples and found that *Giardia* was more common in younger dogs, but there did not appear to be a sex difference in this infection. Blagburn et al. (1996) found *Giardia* in <1% of dogs nationally and in the Midwest. However, these workers believed that they greatly underestimated the actual prevalence of *Giardia* in the canine population because of their choice of flotation medium. Our results, using zinc sulfate, support their conclusion. Canine giardiasis was reviewed recently by Barr and Bowman (1994).

No tapeworm eggs were identified during the present study, which was not surprising considering the nature of our egg recovery procedure. Eggs of tapeworms that are common in dogs are not readily identified by zinc sulfate flotation. Scats of all dogs collected for this study were examined visually for the presence of proglottids, but none were observed.

Multiple infections were found in 35 (27%) of 129 positive fecal samples, comprising 11.3% of the total 309 samples examined (Table 1). Multiple infections were not clustered by month or season but were found in small numbers throughout the year and were absent only in April and June. The highest number of double infections were recorded in October, also the month of highest overall prevalence. In October, the occurrence of double infections (7) almost equaled that of single infections (8). Throughout this study, only 7 samples containing 3 different parasites were found; they were detected in 5 different monthly collections and were scattered throughout the year. No more than 3 parasites were found in any fecal sample examined. The frequency of multiple infections appears consistent with results of most previous studies utilizing fecal flotation techniques (Hoskins et al., 1982; Blagburn et al., 1994) but lower than results of previous studies utilizing necropsy (Kazacos, 1978).

Ascarids were a component of most multiple infections. Four dogs were concurrently infected with both ascarid species. Thus, the number shown in Table 2 (79) is higher than numbers in Tables 3 and 4, where the 2 ascarids are combined. Ascarids were found in combination with every other parasite recovered in this study (Table 4). Only 3 multiple infection combinations occurred that did not involve ascarids. Hookworm eggs, the second most common parasite found in the present study, also were found in combination with every other type of intestinal parasite. Infections involving 3 different parasite species were found in only 3 fecal samples. Ascarids always accounted for 1 of the 3; hookworm occurred in 2 of the 3.

Of 309 fecal samples examined, 168 (54.4%) were from male dogs. Of these males, 70 (41.7%) harbored 1 or more intestinal parasites (Table 3). Eighteen (10.7%) of the male dogs were neutered. All but 1 male dog were >6 mo old. The neutered males were a mix of unwanted (10) and stray (8) dogs. Five neutered males were each infected with a single species of intestinal parasite. No multiple infections were observed in this group. All parasites recovered in the study were represented in this group of neutered males except the coccidian. Prevalence of infection among neutered males was significantly less (28%) than the 42% prevalence among intact males ($\chi^2 = 6.48$, df = 1, $P < 0.05$).

Fifty-nine (41.9%) of the 141 fecal samples from female dogs were positive for intestinal parasites. There was no significant difference in overall prevalence between males and females ($\chi^2 = 2.42$, df = 1, $P > 0.05$). Five fecal samples were from spayed females. Four of these females were 12–36 mo of age, and the fifth was >60 mo of age. None of the 5 spayed females were infected. All of the spayed females were identified as unwanted pets; none were strays. The sample of spayed females is too low to draw definitive conclusions, but other workers have speculated that spayed females tend not to roam as much and may receive better care (Visco et al., 1977). The results of the present study appear to be consistent with those of previous reports (Hoskins et al., 1982; Blagburn et al., 1996).

Regarding the issue of care status, dogs classified as stray animals accounted for 179 (58%) of the 309 total fecal samples; 101 (56%) were infected with 1 or more intestinal parasites. One hundred thirty (42%) fecal samples were from animals classified as unwanted pets; 49 (38%) of these animals were infected. This difference in prevalence between unwanted and stray animals was highly significant ($\chi^2 = 9.47$, df = 1, $P < 0.01$), probably reflecting a difference in care level, including frequency of veterinary care, use of anthelminthics, and the degree to which the animal roams and comes in contact with infective stages of parasites.

Acknowledgments

Dr. Charles Castelein, D.V.M., and the staff of the Wisconsin Humane Society collected the fecal samples and collaborated in experimental design of this study. Alex Kendziorski and Craig Schley assisted with sample preparation and egg identification.

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New Editor

My five-year term as editor of the *Journal* comes to a close with volume 65. I appreciate the opportunity to serve in this capacity for the Society, for I believe that it was a positive experience. I would also like to thank the members of the Editorial Board, the staff at Allen Press, and most of all, the authors who were kind enough to work with me bringing their research output to the *Journal*. I feel that thorough the efforts of all involved, the *Journal* has maintained the high standards and quality set by my predecessors.

The new editor is Dr. Willis A. Reid, Jr. Starting immediately, all manuscripts and correspondence concerning the *Journal* are to be sent to him at 6210 Hollins Drive, Bethesda, MD 20817. His e-mail address is: jwrassoc@erols.com.

Sherman S. Hendrix
Editor

Editor's Acknowledgment

In addition to the members of the Editorial Board, I would like to acknowledge, with thanks, the following persons for providing their valuable help and insights in reviewing manuscripts for the *Journal*: Alexander Acholonu, Martin Adamson, Omar Amin, Carter Atkinson, Reva Berman, Ernest Bernard, Ian Beveridge, David Bolette, Rod Bray, Chris Bryant, Richard Buckner, Charles Bursey, Al Bush, Joseph Camp, Ron Campbell, N. O. Christensen, David Cone, D. Bruce Conn, M. A. Curtis, Ray Damian, Terry Dick, Norman Dronen, Jr., Tommy Dunnagan, Marie-Claude Durett-Desset, William Dyer, Eugene Foor, Gary Foster, Bernard Fried, Linda Gibbons, Tim Goater, Stephen Goldberg, Thaddeus Graczyk, Willard Granath, Jr., John Greve, Ronald Hathaway, Richard Heard, W. Hominick, S.-J. Hong, Allen Johnson, Hugh Jones, James Joy, Mike Kinsella, Marianne Køie, Patricia Kommuniecki, Delane Kritsky, Harold Laubach, Fred Lewis, David Linsay, Scott Monks, Frantisek Moravec, Patrick Muzzall, Raphael Payne, Kirk Phares, Mike Pokras, S. Rabatin, Dennis Richardson, Grover Smart, Robert Sorensen, Mike Sukhedo, William Wardle, and Tim Yoshino.

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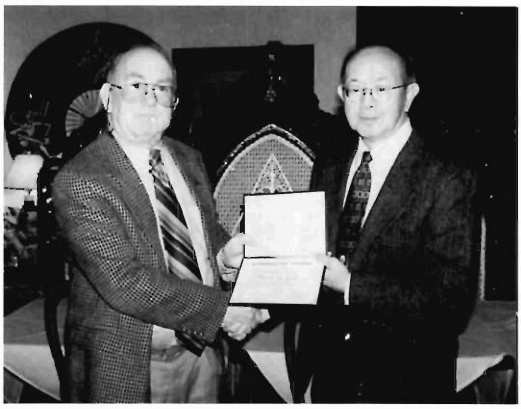
Anniversary Award

The Helminthological Society of Washington

BURTON Y. ENDO



Willis A. Reid, Jr. (Editor-Elect), left, presenting the 1997 Anniversary Award to Burton Y. Endo.

The highest honor that can be bestowed by the Helminthological Society of Washington is its Anniversary Award. Our Constitution stipulates that the Anniversary Award can be given for outstanding contributions in parasitology, an exceptional paper presented at a meeting of the Society or published in its *Journal,* or outstanding service to the Society.

Our 1997 recipient of the award is an exemplary representation of these criteria. I have been asked to make this year's presentation—not because of some deep significance but, I think, simply because I am the only one here who knew the recipient back in the dark ages of the 1950's, when he was a graduate student at North Carolina State College of Agriculture and Engineering, as it was called then. I was 12 yr old, and he was my Scoutmaster at Boy Scout Troop 306 at Pullen Memorial Baptist Church in Raleigh, North Carolina.

Burton Yoshiaki Endo was born in Castroville, California. He received his B.S. degree in Horticulture from Iowa State College in 1951, an M.S. degree in Horticulture, with a minor in Plant Pathology, from North Carolina State University in 1955, and a Ph.D. degree in Plant Pathology in 1958. His Master's research focused on the breeding of disease-resistant tomatoes and cucurbits, and the title of his doctoral dissertation was "Studies on Certain Ecological Factors Affecting the Biology of the Lesion Nematode." Throughout his career, Burt has continually participated in and received additional training at various universities, institutes, and workshops in such areas as insect morphology and anatomy, organic chemistry, biochemistry, histochemistry, cytochemistry, radioisotope procedures, electron microscopy, and supervisory and administrative methodologies.

Burt's entire professional career has been with the United States Department of Agriculture (USDA). While working on his Ph.D. degree, he was first offered a position by Al Taylor as an Agent Nematologist in 1955. In this role, he collaborated with J. N. Sasser in the first field fumigation experiments to control the soybean cyst nematode in North Carolina, where it had just been detected for the first time. Doctoral dissertation in hand, Burt moved to the USDA facility at Jackson, Tennessee, where he was given the title of Nematologist. At Jackson, Burt continued his studies of the soybean cyst nematode, initially focusing on its desiccation and survival at different temperatures and humidities. Slowly, he became involved in studies of the interactions of this nematode with soybean roots. While in Jackson, he was the first scientist to study the histoanatomical changes that occur as nematodes develop in both susceptible and resistant soybean roots.

Burt left Tennessee in 1963 and arrived at the Beltsville Agricultural Research Center (BARC), where he took full advantage of the excellent electron microscopy facilities there. He focused most of his attention on the ultrastructure of the interactions between *Heterodera glycines* and soybean roots and the ultrastructure of *H. glycines* and *Meloidogyne* spp. Because of the innovation, technical excellence, and impeccable detail and clarity of his research, Burt rapidly achieved international recognition.

As a result of his research excellence, Burt was appointed Chairman of the Plant Protection Institute at Beltsville in 1974. He served in that capacity for 13 yr, until the reorganization of BARC in 1987. In this role, he coordinated, supervised, and directed the research activities of over 50 research scientists plus 100 support staff in numerous disciplines within plant pathology and entomology. Under his guidance, research activities within the Plant Protection Institute thrived, and Beltsville was regarded as an international leader in all areas of plant protection.

Despite his administrative workload, Burt maintained an active research career, to which he was able to devote greater energy upon his return to the laboratory in 1987. He pursued cytochemical and ultrastructural examinations of infection sites of root-knot and cyst nematodes and discovered many tissue and cellular changes in hosts during the infection process. Burt made many key discoveries about the structure of the nervous, reproductive, digestive, neurosensory, and neurosecretory systems of these species and their interactions with resistant and susceptible host plants. Especially outstanding are his contributions toward an understanding of the function of the root-knot nematode amphid and its role in neurosecretion. He discovered under the anterior cuticle of nematodes ciliated neural terminals that function as tactoreceptors. He demonstrated that neurosecretory materials produced by the amphidial gland nerve processes are involved in the formation of a feeding plug at the feeding site of the soybean cyst nematode. His detailed observations of the stylet in molting *H. glycines* juveniles provided the first ultrastructural descriptions of the process of stylet formation. His detailed observations of the secretory granules in the esophageal glands of *Meloidogyne incognita* and of the muscles that control their release are being used by nematologists exploiting the biochemical and physiological aspects of nematode salivary contents. In recent years, Burt has turned his attention to a few other nematode species. He has performed comparative studies of the entomogenous nematodes *Steinernema* and *Heterorhabditis,* learning much about them and how they carry their bacterial symbionts that kill insect pests. His most recent research has examined the ultrastructure of the filarial nematode *Onchocerca volvulus* and the male reproductive system in *Pratylenchus penetrans.*

Although he retired in 1995, Burt continues to work on a daily basis as an unpaid Collaborator at the Agricultural Research Service. His technician of many years (Sharon Ochs) estimates that during his career Burt has used ca. 25,000 electron microscopy copper grids and 36,909 photoplates, which laid end to end would cover nearly 4 km. The prints from such plates would cover 10,000 hectares!

Besides the Helminthological Society, Burt is or has been a member of several other professional societies: American Association for the Advancement of Science, American Institute of Biological Sciences, American Phytopathological Society, Council on Agricultural Sciences and Technology, European Society of Nematology (ESN), Sigma Xi, Society of Nematologists (for which he has served as President and Secretary and received its Fellow award in 1988), Washington Academy of Sciences, and Washington Society of Electron Microscopy. He has been active in the International Nematology Symposia sponsored by ESN, and since 1974 he has attended 8 such symposia, presenting several invitational talks. He received the award of Fellow of the European Society of Nematologists in 1996. He has had professional research collaborations with investigators from around the globe, including Egypt, England, Germany, Israel, and Japan. Burt has over 100 published papers, book chapters, and reviews in nematology.

Over 45 yr ago, Burt probably presented me with my First Class Scout rank. On behalf of the Helminthological Society of Washington, I have the pleasure and honor of presenting the Society's Anniversary Award to a first class person and scientist, Burton Y. Endo.

Willis A. Reid, Jr.
(with biographical information contributed by
David J. Chitwood)

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Ultrastructure of the Male Gonad and Spermatogenesis in the Lesion Nematode, *Pratylenchus penetrans* (Nemata: Pratylenchidae)

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ABSTRACT: Transmission electron microscopy was used to elucidate the structural anatomy of the male reproductive system of *Pratylenchus penetrans*. The male gonad has an elongated telogonic testis with a single row of spermatogonia in the germinal zone. The spermatogonia increase in size to spermatocytes in the growth zone. The spermatocytes then undergo meiosis to form spermatids. Synaptonemal complexes in the spermatocytes signify the pachytene stage of the first meiotic division. Spermatids are characterized by an abundance of fibrous bodies surrounding prominent electron-opaque spheroid nuclei. Spermatids in the proximal region of the seminal vesicle are transformed to spermatozoa as they accumulate in the seminal vesicle. During this process, filopodia decrease in number, residual bodies are lost, and sperm nuclei become irregularly shaped and surrounded by mitochondria and fibrous bodies. Spheroid spermatozoa retain a modified morphology with large sectors of flocculent cytoplasm devoid of cellular organelles. The electron-transparent region of the sperm extends into a pseudopod that controls the crawling form of motility that is typical of the spermatozoa of many nematode species. Seminal fluid produced by cells of the vas deferens accumulates and appears to cause aggregation of sperm within the seminal vesicle. Sperm morphology in the spermatheca of female specimens is similar to that in the vas deferens of the male.

KEY WORDS: electron microscopy, lesion nematode, male gonad, *Pratylenchus penetrans*, spermatogenesis, testis, ultrastructure.

The feeding habits and pathogenicity of *Pratylenchus penetrans* and related species of the lesion nematode have been well documented (Dropkin, 1989; Townshend and Stobbs, 1981; Townshend et al., 1989; Zunke and Institut für den Wissenschaftlichen Film, 1988; Zunke, 1990a, b). Previous light-microscopic studies have provided a basis for understanding gametogenesis, embryogenesis, and postembryogenesis in several species of *Pratylenchus*, including *P. penetrans* (Roman and Hirschmann, 1969; Roman and Triantaphyllou, 1969). Electron microscopic studies have depicted the structure of the male copulatory organs of *P. penetrans* (Wen and Chen, 1976; Mai et al., 1977; Bird and Bird, 1991) and spermatogenesis and sperm morphology in the cyst nematodes *Globodera rostochiensis* (Wollenweber, 1923) Behrens, 1975, *G. virginiae* (Miller and Gray, 1968) Behrens, 1975, *Heterodera schachtii* Schmidt, 1871, and *H. avenae* Wollenweber, 1924 (Shepherd et al., 1973). To identify new phylogenetic characters in the Heteroderinae, the fine structure of *Verutus volvingentis* was compared with that of *Meloidodera floridensis*. The study compared sperm size, distribution of filopodia, condition of chromatin after insemination, and persistence of fibrous bodies (Cares and Baldwin, 1994a). In *Ekphymatodera thomasoni*, the sperm originated from germ cells connected to a central rachis (Cares and Baldwin, 1994b). This character was shared with *Globodera* but not with other Heteroderinae. Fibrous bodies were abundant in spermatids but did not persist in sperm of *Ekphymatodera* as they did in sperm of *Meloidodera* and *Verutus* (Cares and Baldwin, 1994a, b).

In a recent review, Scott (1996) emphasized that nematode sperm did not contain actin or myosin. This observation could account for the crawling motility of spermatozoa. The review summarized that locomotion of nematode sperm appeared to depend on a simple cytoskeleton consisting of small, basic sperm-specific proteins that were designated as major sperm proteins (MSP). The MSP were synthesized in spermatocytes and assembled in cytoplasmic paracrystalline arrays or fibrous bodies. After meiosis, fibrous bodies segregated into the cytoplasm of developing spermatids. After spermatid budding or separation from the residual body, the fibrous bodies disassembled and the MSP were released into the cytoplasm where they were maintained in an unpolymerized state.

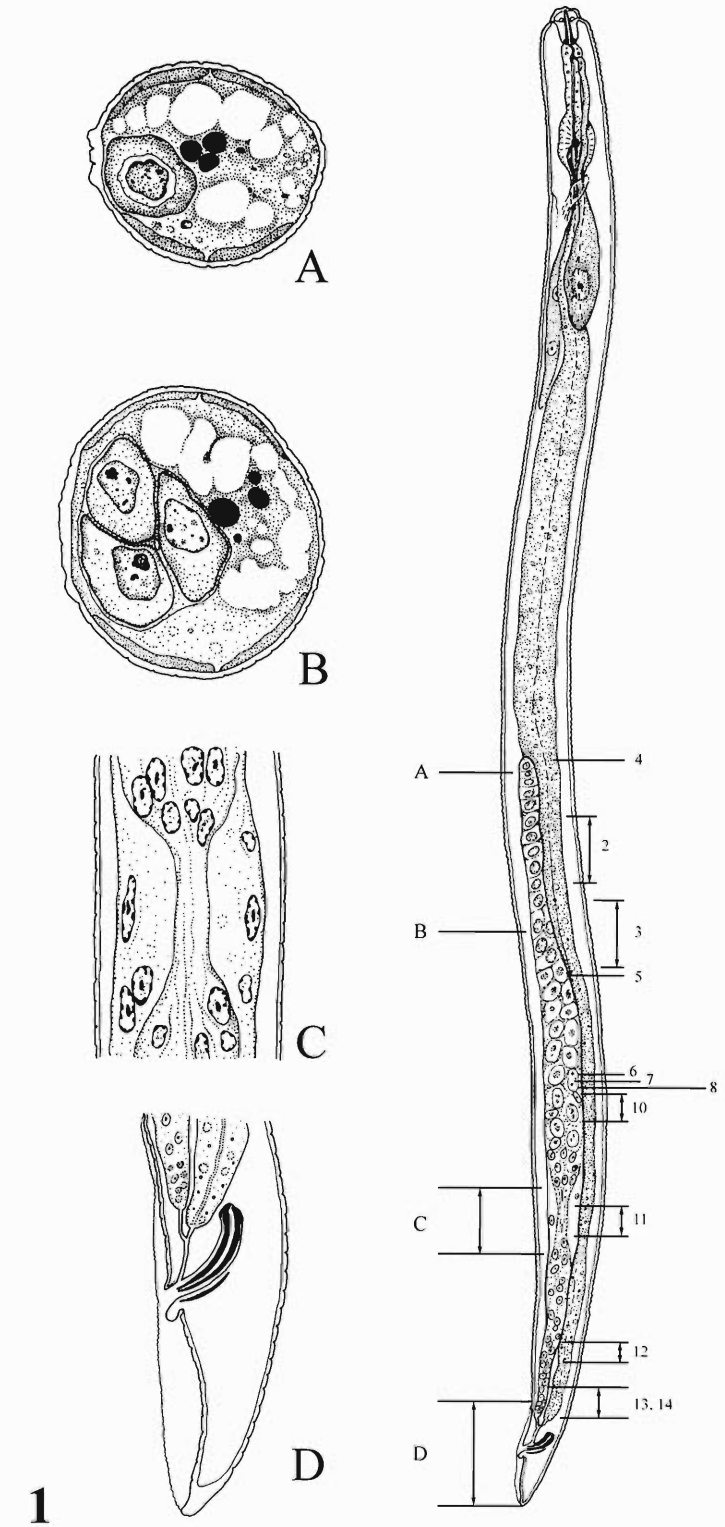

Figure 1. Male specimen of *Pratylenchus penetrans* emphasizing gonad morphology. Numbers indicate approximate sites of the gonad. A = spermatogonium; B = spermatocytes; C = spermatozoa; D = spicules.

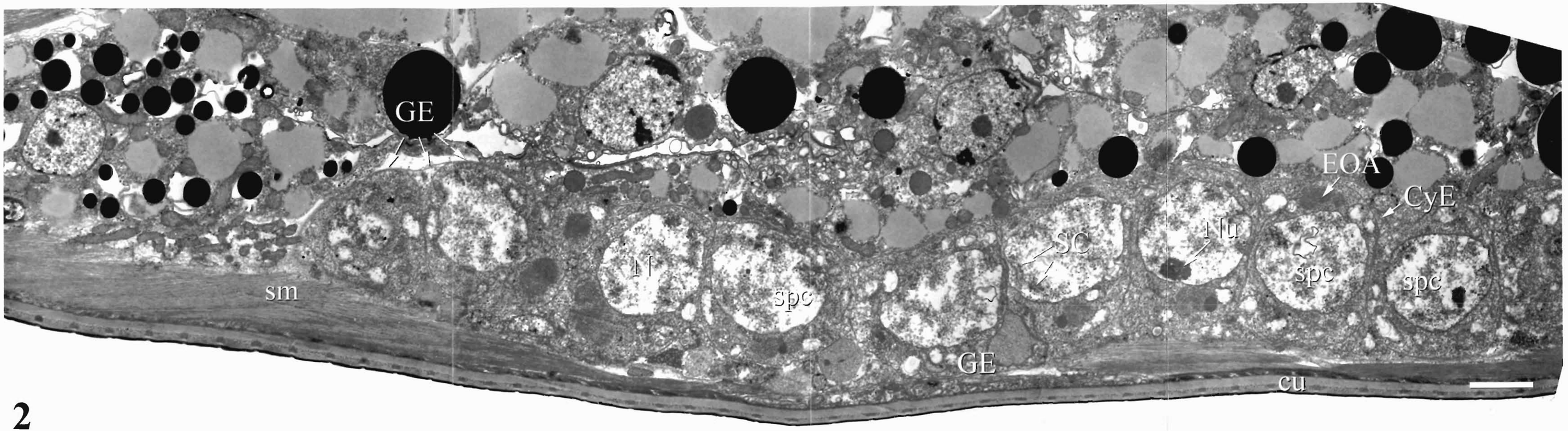

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Figure 2. Distal region of male gonad of *P. penetrans* showing single row of cells enclosed by gonad epithelium (GE). Most cells show prominent nuclei (N) with enclosed fragments of synaptonemal complexes (SC) that join 2 paired homologous chromosomes at pachytene stage of meiosis. Membrane invaginations (CyE) of gonad epithelium partially fill the spaces between the spermatocytes. cu = cuticle; EOA = electron-opaque accumulation; Nu = nucleolus; sm = somatic muscle. Scale bar = 1.0 μm.

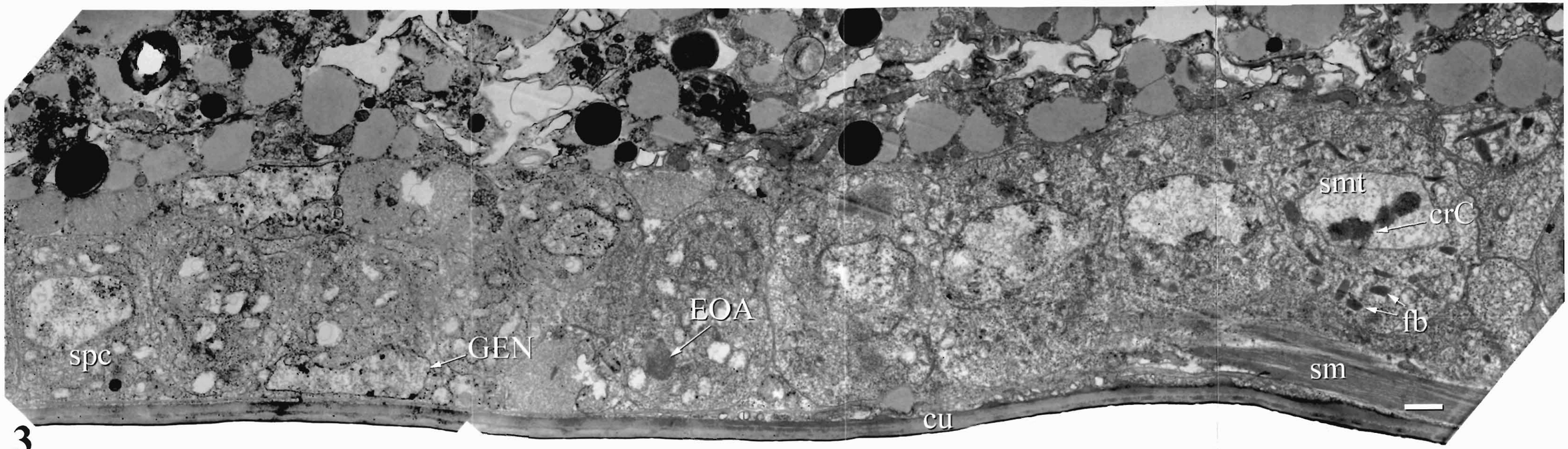

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Figure 3. Longitudinal section of the same specimen shown in Figure 2, illustrating the transitional zone of the testis of *P. penetrans*. Spermatocytes (spc) undergo meiosis to form spermatids (smt). Early stage of spermatid development indicated by chromatin clumping (crc) and appearance of fibrillar bodies (fb). cu = cuticle; EOA = electron-opaque accumulations; GEN = gonad epithelial nucleus; Sm = somatic muscle. Scale bar = 1.0 μm.

The MSP became concentrated in the pseudopods where they were reassembled into filaments. The composition and role of the fibrous bodies that occur in spermatids and sperm of *P. penetrans* and related plant-parasitic species have not been determined.

In a recent study, we used transmission and low-temperature scanning electron microscopy to observe the anatomy of the esophagus, intestine, and reproductive system of *P. penetrans* (Cobb, 1917) Sher and Allen, 1953 (Endo et al., 1997). The current study continues observations on the ultrastructure of the male reproductive system of *P. penetrans*. We examined morphological features of the male gonad along with the development of spermatocytes into spermatids, the storage of spermatids and sperm within the seminal vesicle, and sperm assembly and passage through the vas deferens.

Materials and Methods

Specimens of *P. penetrans* were obtained from root cultures of corn (*Zea mays* L. 'Iochief') grown in Gamborg's B-5 medium without cytokinins or auxins (Gamborg et al., 1976). Adults and juveniles were collected from infected root pieces that were incubated in water. The samples were prepared for electron microscopy as previously described (Endo and Wergin, 1973; Wergin and Endo, 1976). Nematodes, which were embedded in 2% water agar, or infected root segments were fixed in buffered 3% glutaraldehyde (0.05 M phosphate buffer, pH 6.8) at 22°C for 1.5 hr, washed for 1 hr in 6 changes of buffer, postfixed in buffered 2% osmium tetroxide for 2 hr, dehydrated in an acetone series, and infiltrated with a low viscosity embedding medium (Spurr, 1969). Silver-gray sections were cut on an ultramicrotome with a diamond knife and mounted on uncoated 75- × 300-mesh copper grids. The sections were stained with uranyl acetate and lead citrate and viewed in a Philips 301 or 400T electron microscope operating at 60 kV with a 30-μm objective aperture.

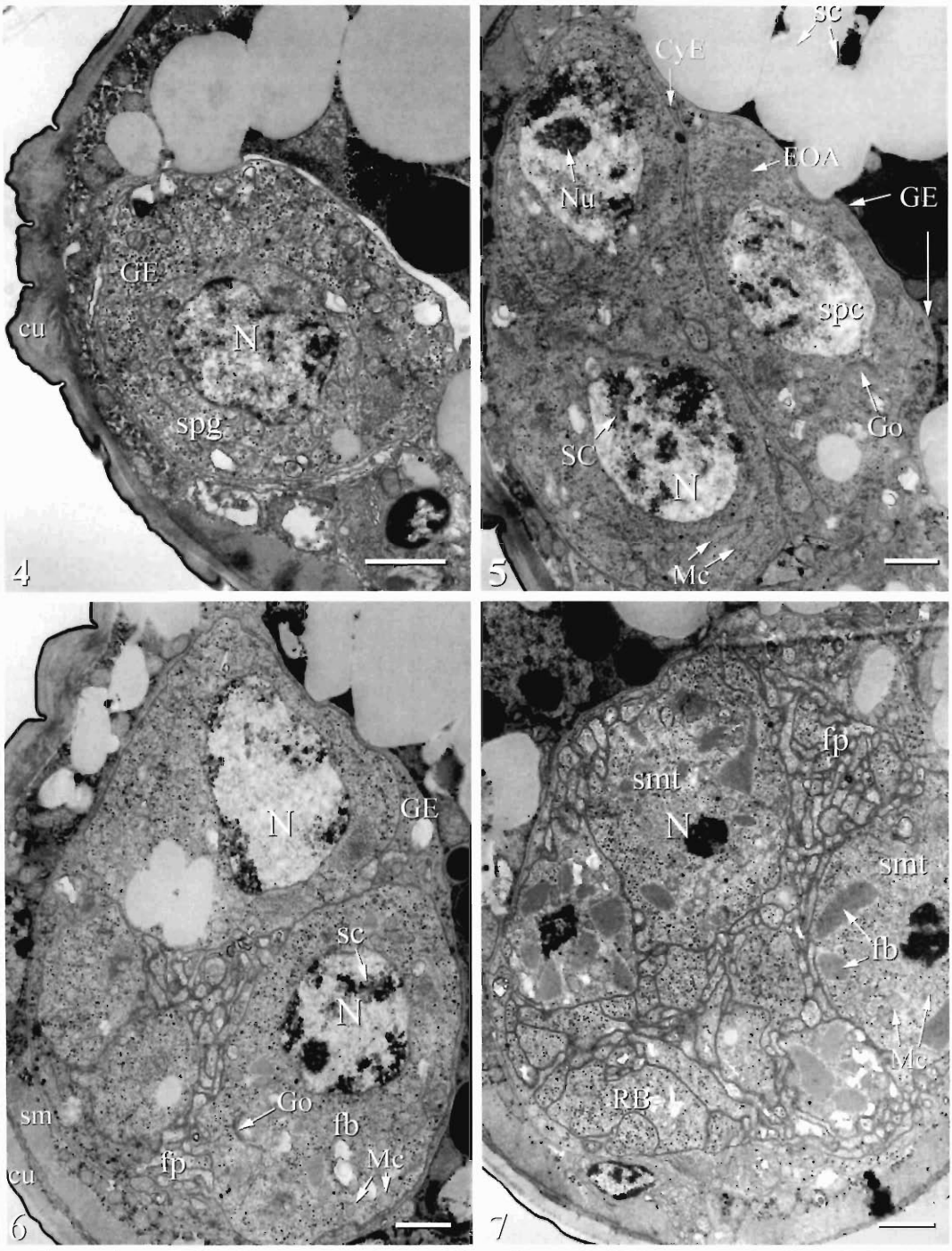
Results

The male gonad of *P. penetrans* has a mean length of 234 μm and a width of 14.5 μm within a body length of 520 μm and body width of 20 μm (Fig. 1). The most distal region of the testis contains a single row of cells comprising spermatogonia of the germinal zone of the testis (Figs. 4–7). Linearly arranged spermatocytes of the testis contain synaptonemal complexes that occur during pachytene stage of meiosis (Fig. 2). An abrupt increase in girth of the testis occurs in the region where spermatocytes accumulate as multiple rows of cells that undergo meiosis and cellular division to produce spermatids (Fig. 3). The spermatozoa, developing from spermatids, fill the seminal vesicle that extends through a major sector of the gonad and joins the multicellular, glandular vas deferens (Fig. 1).

The telogonic testis of *P. penetrans,* is characterized by several portions of synaptonemal complexes within the spermatocytes. These complexes, which occur at the pachytene stage of prophase during the first meiotic division (Figs. 2, 5, 8, 9), have 2 lateral elements, each with chromatin of sister chromatids and a central striated element (Figs. 2, 5, 8, 9). Additional chromatin is dispersed throughout the nucleoplasm, which is delineated by the nuclear membrane. Depending on the stage of division, the nuclei also contain distinct nucleoli (Figs. 2, 5). The cytoplasm of spermatocytes contains rough endoplasmic reticulum, free ribosomes, mitochondria, Golgi bodies, and clusters of electron-opaque masses that can appear granular, fibrillar, or paracrystalline (Figs. 2, 5, 6). The closely appressed spermatocytes are retained within the gonad epithelium, which extends between the cells of the gonad (Figs. 2, 5, 6). The spermatocytes are associated with a modified central rachis consisting of a cylindroid cytoplasmic unit located at the center of rows of spermatocytes (Figs. 5, 6).

Beyond the linearly arranged row of spermatocytes, which are located along the lateral chord, the gonad epithelium widens as each of the spermatocytes undergoes 2 divisions to form 4 spermatids (Figs. 1, 7). During this process, chromatin tends to accumulate inside the nuclear membrane; shortly thereafter, the membrane breaks down (Fig. 6). The chromatin of the spermatid aggregates in a electron-opaque spherical unit, which is surrounded by clusters of fibrous elements, Golgi bodies, and mitochondria (Figs. 7, 10). In individual spermatids, the cytoplasm, which becomes flocculent and electron translucent, contains a highly condensed nucleus, mitochondria, and fibrous bodies (Figs. 7, 10, 11). Portions of the limiting membrane of the spermatids evaginate to form filopodia that have cytoplasmic, microtubular, and filamentous continuity with the central body. Microtubules also accumulate along the inner surface of the membrane of spermatids and spermatozoa (Figs. 10, 11).

The structural transition from spermatids to spermatozoa is not morphologically distinct. The



Figures 4–7. Series of transverse sections of the male gonad of *P. penetrans* showing a single row of cells in the most distal region of the gonad and its relation to multiple cells in the transitional zone that leads to spermatid formation and aggregation. 4. Single spermatogonial (spg) cell within the boundaries of the gonad epithelium (GE). cu = cuticle; N = nucleus. 5. Testis in the expanding region of the gonad showing 3 tightly arranged spermatocytes (spc) surrounded by gonad epithelium (GE) that extends into the interspermatocyte spaces (CyE). Spermatocytes with prominent nuclei (N) have cytoplasm with free

spermatozoa tend to be spherical to oblong with considerable variation in shape and organelle content, depending on the site of the section (Fig. 12). Membrane evaginations form filopodia similar to those found in newly formed spermatids (Figs. 10, 11). Sperm near the terminus of the vas deferens occasionally lack filopodia (Fig. 13. The nuclei of sperm are electron opaque, similar to those observed in spermatids. Mitochondria and narrow strands of fibrous bodies occur near the chromatin masses of each sperm nucleus, whereas a large region of the spheroid or elongated cell is often devoid of organelles and merely contains flocculent cytoplasm. This region, when elongated, probably functions as a pseudopod (Figs. 12, 14) that is used for movement of sperm in the uterus. Spermatids and sperm are contained within an elongated membrane-bound region termed the seminal vesicle (Figs. 1, 12). The seminal vesicle usually is filled with sperm and spermatids, but large sectors may be filled with electron-transparent material, possibly seminal fluid, that arises from secretions by the glandular cells of the vas deferens (Figs. 13, 14). The electron-transparent fluidlike region of the vas deferens may be interrupted by elongated strands and clumps of material resembling collapsed filopodia and remnants of residual bodies of spermatids (Fig. 11). The distal region of the vas deferens (Fig. 13) contains electron-transparent to -opaque secretory granules that apparently are derived from secretory cells at the base of the vas deferens (Fig. 14). The cells of this proximal region of the vas deferens (Fig. 14) contain numerous electron-opaque secretory granules and associated Golgi bodies. The juncture of the lumen of the vas deferens and the rectal canal was obscure in thin sections but their terminal openings join posteriad to form the cloaca.

Spermatozoa, which are located in the proximal region of the seminal vesicle and adjacent to the cellular region of the vas deferens (Fig. 13), are similar in morphology to sperm observed in the spermatheca of the female gonad (Fig. 15). In general, the spermatozoa lack filopodia, which are abundant on the spermatid and on the sperm located at the distal end of the seminal vesicle. The spermatozoa of the male and those present in the spermatheca of the female are also similar in their distribution of cellular organelles. In the spermatheca, the nuclei, mitochondria, and a few fibrous strands of fiber bodies occur at 1 end of the sperm, and the other end, which is almost devoid of organelles, is filled with flocculent cytoplasm. The chromatin of the nuclei is concentrated but irregular in shape (Fig. 15). The nuclei tend to be crescent shaped and differ from the spheroid, highly electron-dense nuclei of spermatids (Figs. 10, 11). Membrane specialization or membrane organelles do not appear to form along the inner boundary of sperm or spermatids of this species.

Discussion

Fragments of synaptonemal complexes within pachytene nuclei in spermatocytes of *P. penetrans* structurally resemble synaptonemal complexes described in spermatocytes and oocytes of *Ascaris suum* (Goldstein and Moens, 1976), and in oocytes of various plant-parasitic species, including *Meloidogyne hapla* (Goldstein and Triantaphyllou, 1978), *M. spartinae* (Goldstein and Triantaphyllou, 1995), *Heterodera glycines* (Goldstein and Triantaphyllou, 1979), and many other organisms (for review, see Westergaard and von Wettstein, 1972). The ultrastructure of the synaptonemal complexes, which occur as incomplete units in *P. penetrans,* resembled that of the reconstructed synaptonemal complexes

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ribosomes, rough endoplasmic reticulum, mitochondria (Mc), Golgi bodies (Go), and moderate electron-opaque accumulations (EOA). Nuclei of the primary spermatocytes in the cross-section of testis show synaptonemal complexes (SC) indicative of the pachytene stage of the first meiotic division. 6. Testis shows 2 spermatocytes containing nuclei with intact membranes. One of the spermatocytes has synaptonemal complexes (SC) in the nucleus (N) and fibrillar bodies (fb) within the cytoplasm. The other nucleated cell showing dispersed chromatin is probably a primary spermatocyte at diplotene. Filopodia (fp) between the cells indicate that the section is near the developing spermatids or sperm in the male gonad. cu = cuticle; GE = gonad epithelium; Go = Golgi apparatus; Mc = mitochondrion; Sm = somatic muscle. 7. Broad region of the testis shows an accumulation of several spermatids (smt) in the midst of filopodia (fp) and other cell components that include residual bodies (RB). Early stages of spermatid formation characterized by dense clumping of nuclear (N) chromatin and absence of discernable nuclear membranes. The major organelles in the cytoplasm are fibrous bodies (fb) and mitochondria (Mc). Scale bars = 1.0 μm.

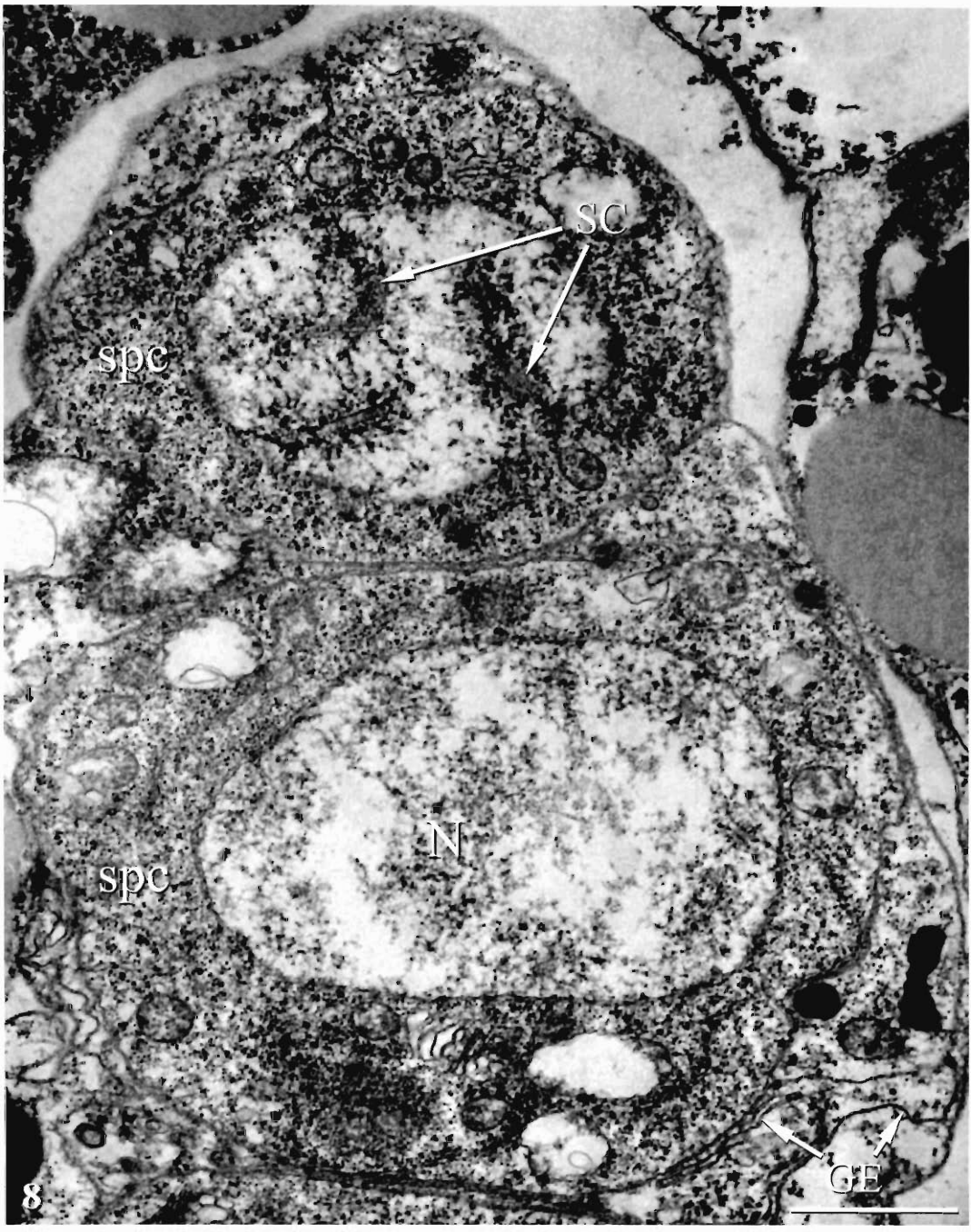


Figure 8. Longitudinal section of 2 spermatocytes (spc) near site of spermatid development in gonad of *P. penetrans*. Tangential section of a nucleus (N) of 1 spermatocyte shows parts of synaptonemal complexes (SC). GE = gonad epithelium. Scale bar = 1.0 μm.

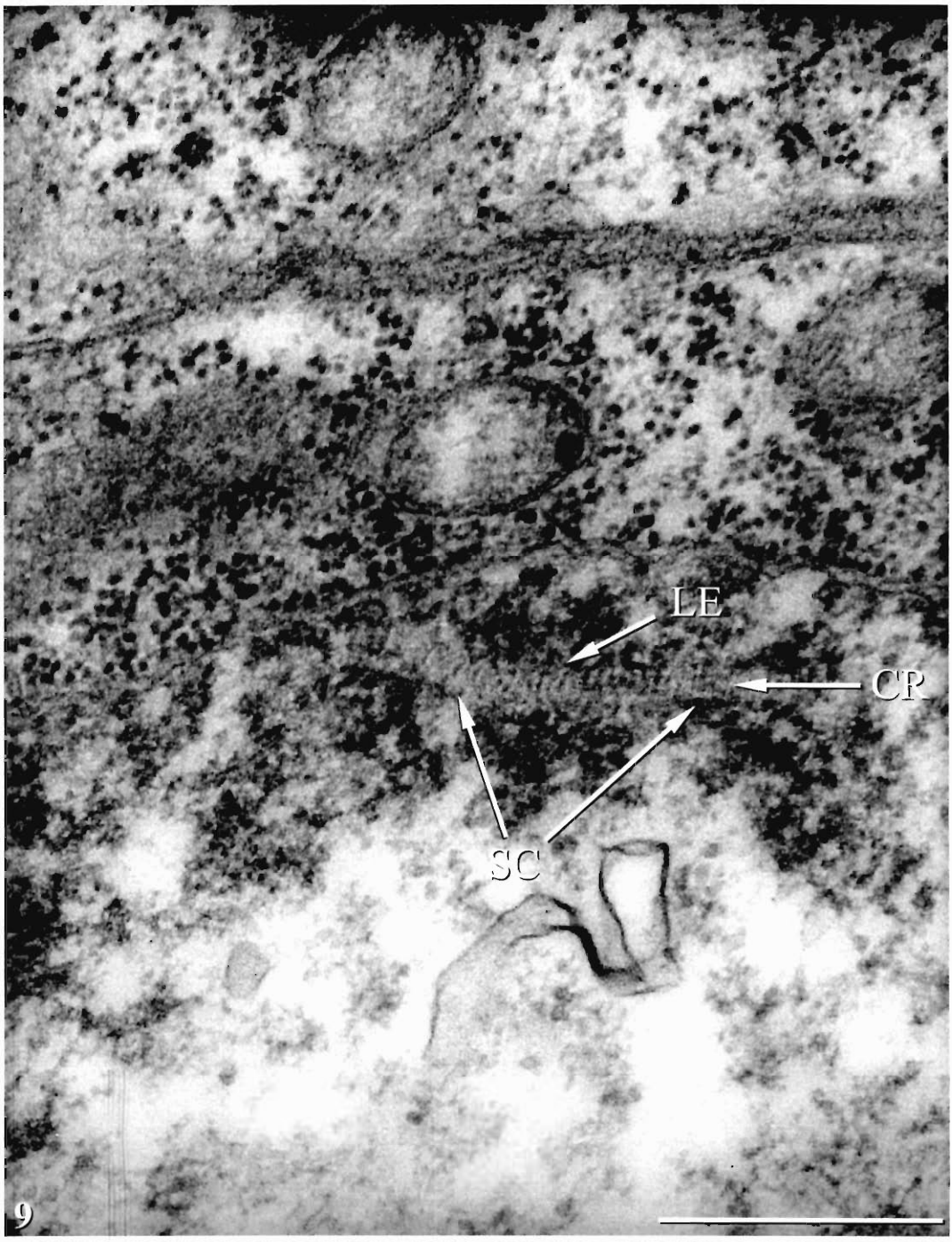
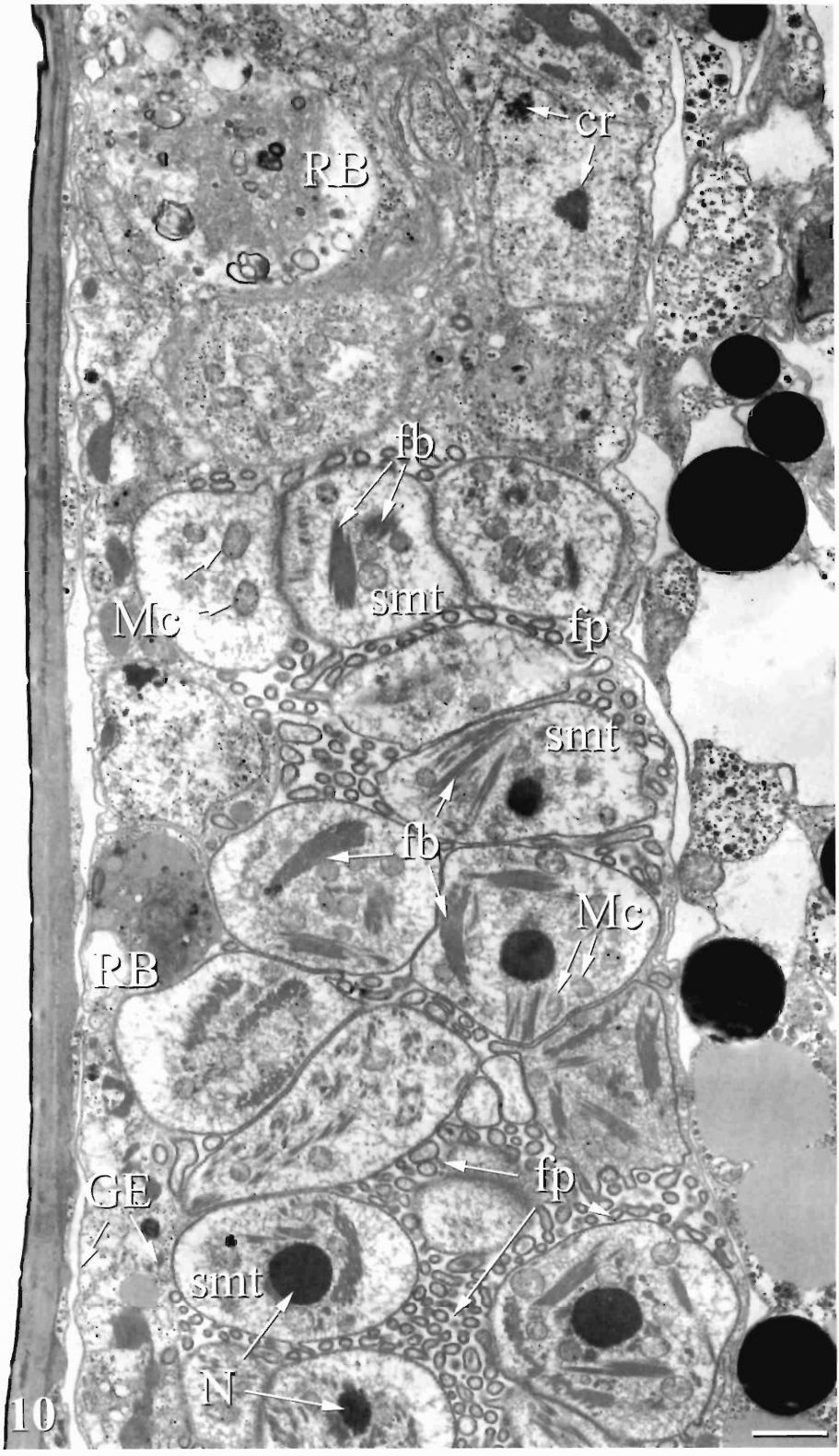


Figure 9. Enlargement of synaptonemal complex (SC) during pachytene in spermatocyte of *P. penetrans*. CR = central region; LE = lateral element. Scale bar = 0.5 μm.



observed in oocytes and spermatocytes of *Ascaris lumbricoides suum* (Goldstein and Moens, 1976). In both nematodes, the complexes had lateral amorphous elements and a central striated element. In contrast, at meiotic pachytene, the synaptonemal complexes in oocytes of several species of *Meloidogyne,* with the exception of *M. microtyla,* were bipartite and consisted of 2 lateral elements; a central striated element was lacking. *Meloidogyne spartinae* had 7 synaptonemal complexes signifying a 1N haploid chromosome count for this species (Goldstein and Triantaphyllou, 1995). The number of synaptonemal complexes of *P. penetrans* has not been determined; however, the structure of the synaptonemal complexes of spermatocytes is similar to that in oocytes of *Meloidogyne,* with their central striated elements bordered by lateral elements.

The testes of most male gonads of nematodes are similar (Foor, 1983). The testis is a single tubular organ composed of a blind terminal end where germ cells form and an elongate region where spermatocytes enlarge and differentiate into spermatids and spermatozoa. Nematode sperm differ from those of most other organisms in that they may be rounded, conical, lobate, or elongate. Furthermore, they lack flagella and acrosomes. Moreover, in some nematodes, the spermatozoa in the seminal vesicle of a male may be round and nonmotile but can become amoeboid and motile when transferred into a female gonad (Foor, 1970). Many investigators assume that spermatozoan changes occur in response to substances present in the female reproductive system. However, studies of *A. lumbricoides* have provided evidence that spermatozoan changes actually originate in the glandular vas deferens of the male gonad (Foor and McMahon, 1973; Foor, 1976). For example, when materials from the vas deferens of *A. lumbricoides* were injected into the seminal vesicle of an *Ascaris* male, the normally enclosed spherical cells, which contained mitochondria, dense lipidlike particles, a non-membrane-bound nucleus, and numerous membranous elements or organelles, became transformed. Lipidlike particles coalesced to form large refringent bodies, membrane specializations fused with the plasma membranes, and prominent pseudopods were formed (Foor, 1970).

The influence of seminal fluid on spermatozoan morphology has not been determined in *P. penetrans.* Although the plasma membranes of

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Figure 10. Longitudinal section through transitional zone of the testis of *P. penetrans* showing spermatid formation and maturation. Lateral anterior view of the testis shows cells without nuclear membranes prior to the aggregation of chromatin (cr) into electron-dense spheroid nuclei. Enlarged cells adjacent to developing spermatids appear to be residual bodies (RB), which are nonnucleated regions that are sloughed during spermatid maturation. The proximal region of the transitional zone shows spermatids (smt) with characteristic fibrous bodies (fb) and mitochondria (Mc). Filopodia (fp) are formed from outer membrane evaginations. Sections through some spermatids show electron-opaque spheroid nuclei (N) without discernable nuclear membranes. Cellular bodies along the gonad epithelium (GE) appear to be residual bodies. Scale bar = 1.0 μm.

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Figure 11. Longitudinal section though the proximal sector of the vas deferens of *P. penetrans* showing a centralized accumulation of spermatids (smt) surrounded by broad region of electron-transparent seminal fluid (sf) containing remains of Golgi bodies (RGo) and filopodia (Rfp). Spermatid body shape ranges from ovoid to oblong. cu = cuticle; fp = filopodia. Scale bar = 1.0 μm.

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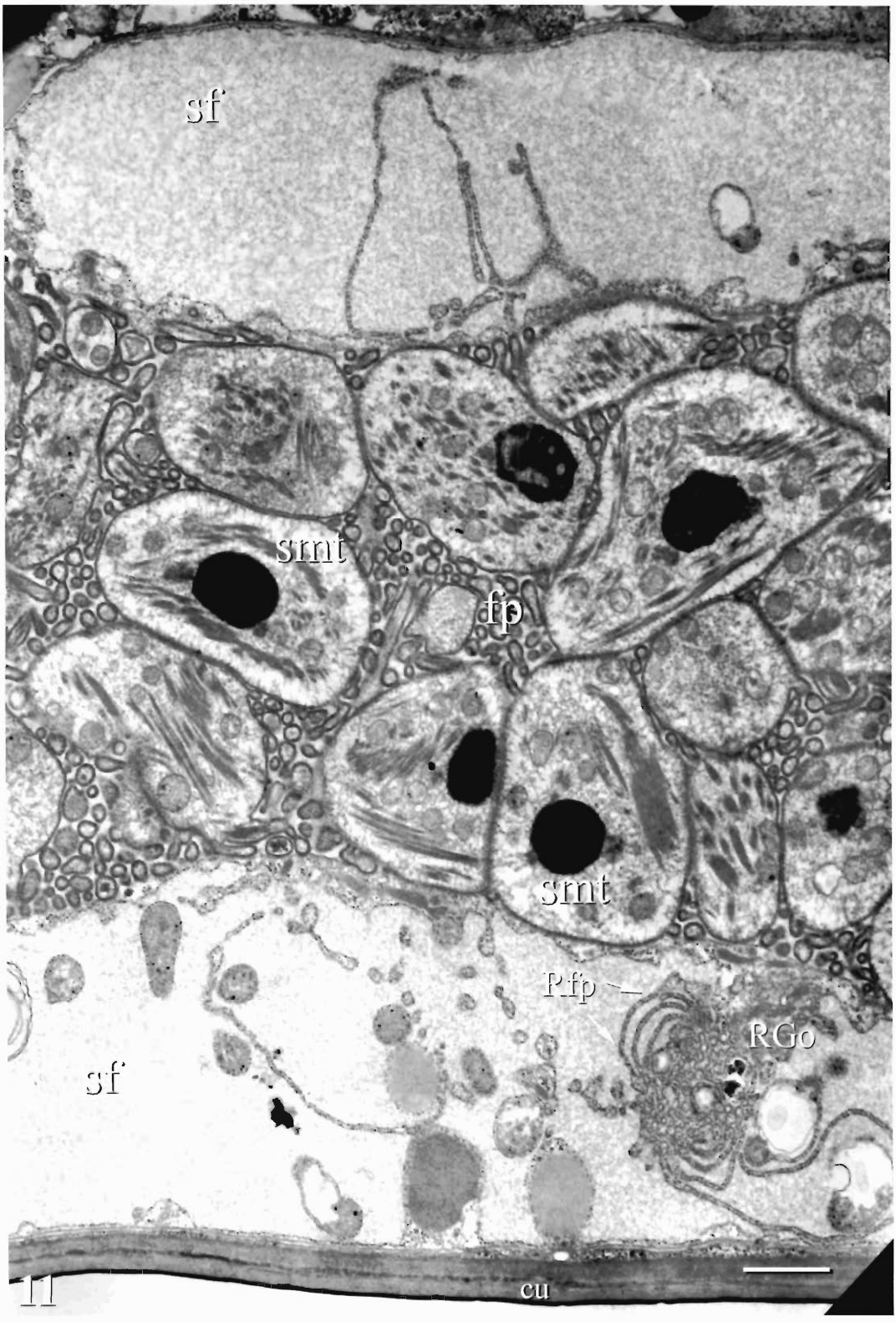
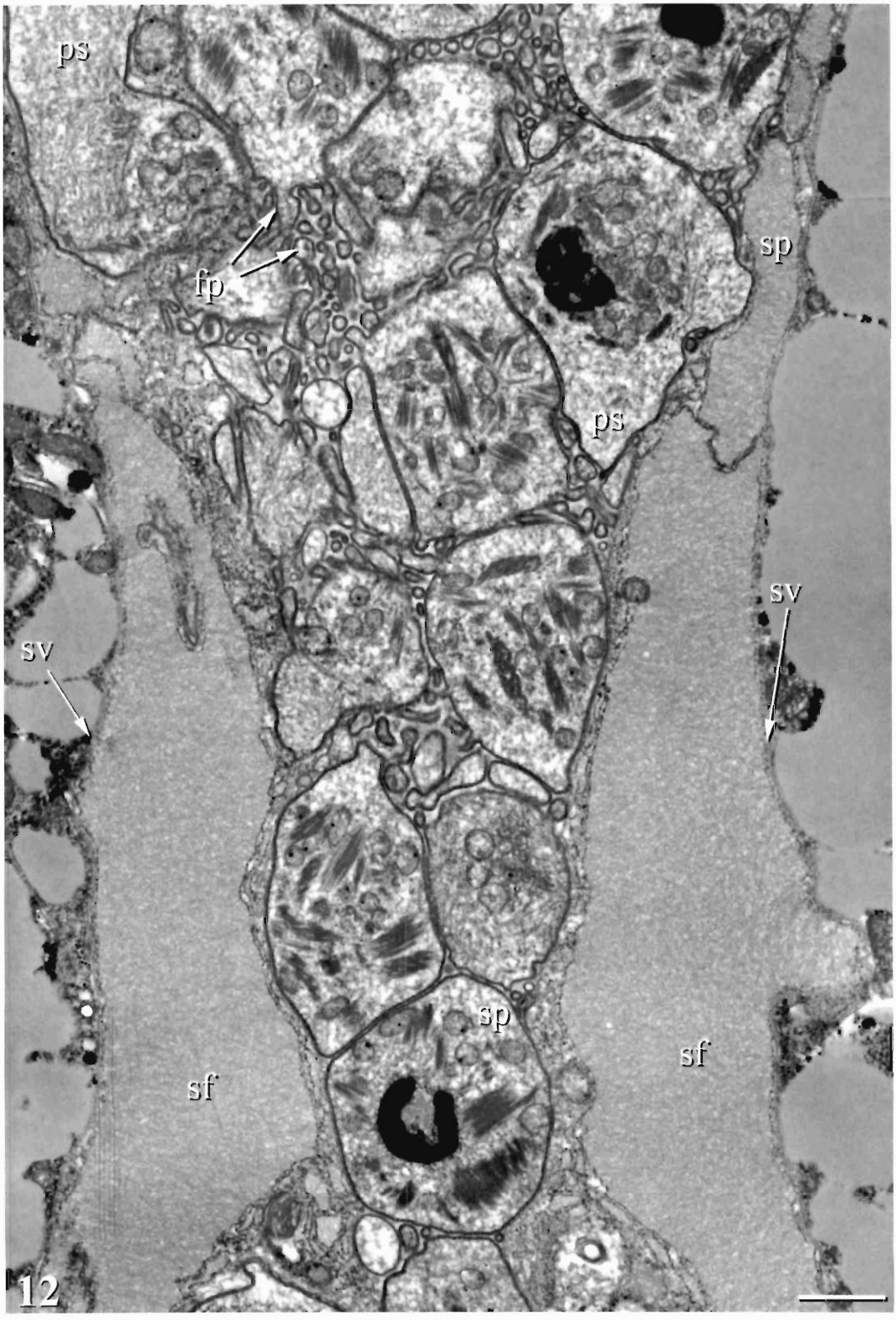
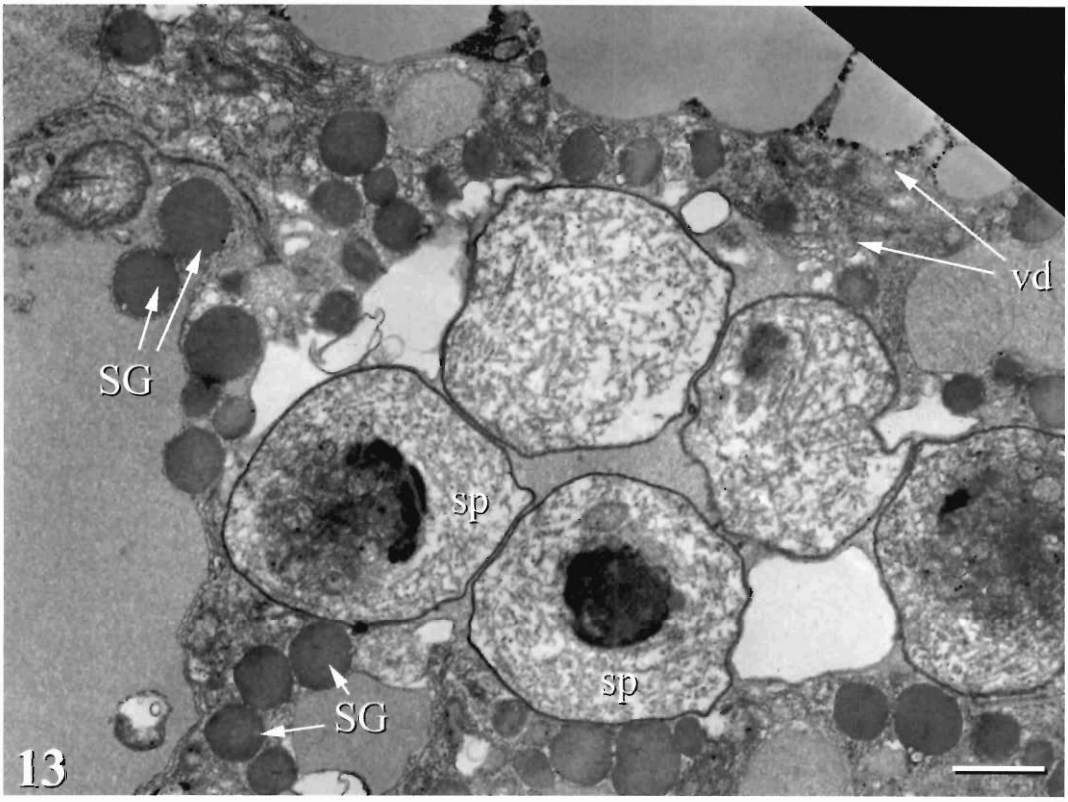
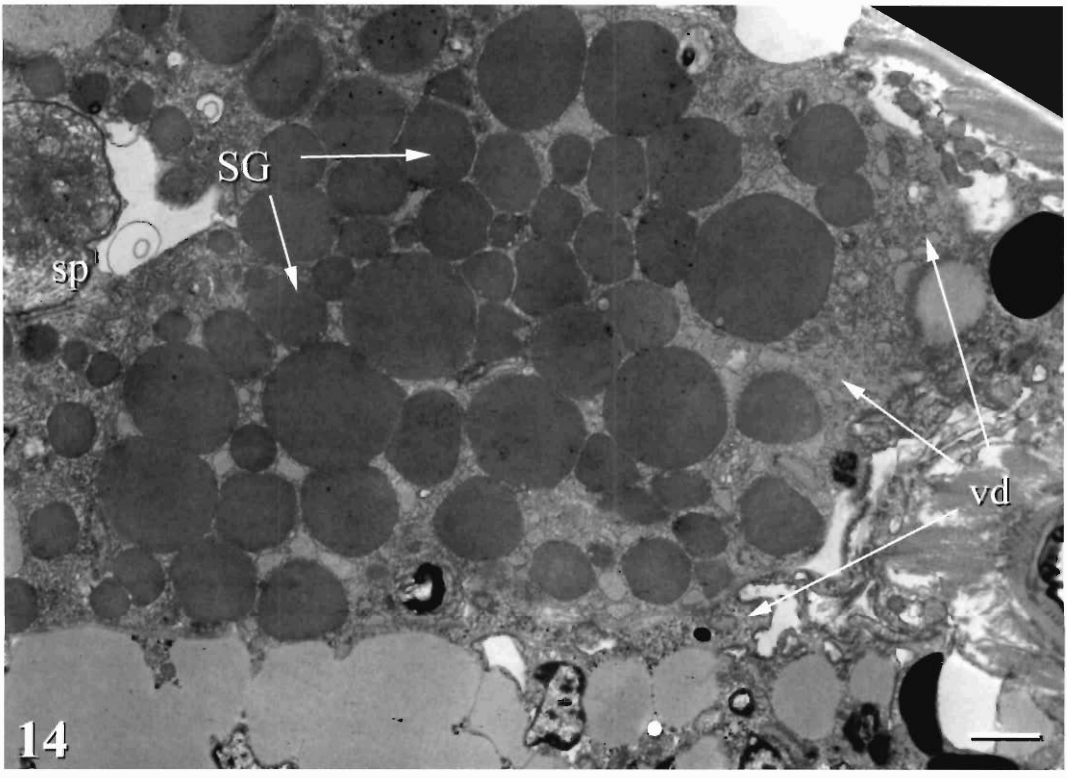
Figure 12. Longitudinal section of the vas deferens of *P. penetrans* showing a region filled with seminal fluid (sf) in which sperm (sp) are localized prior to ejaculation. Filopodia (fp) of mature spermatids and sperm are greatly reduced in number. Mitochondrial and fibrous bodies accumulate around irregularly shaped nuclear chromatin, and a flocculent cytoplasm, usually devoid of organelles, characterizes the pseudopodial (ps) extensions. Spermatozoa appear to be at a more advanced stage of spermatozoan development than those shown in Figure 11. sv = seminal vesicle. Scale bar = 1.0 μm.









spermatozoa at the most distal portion of the seminal vesicle usually are associated with numerous filopodia, these structures rarely occur on spermatozoa located at the base of the vas deferens or in the spermatheca of inseminated females. The fragments of filopodia and other cellular remnants, consisting of organelles such as Golgi bodies within large masses of electron-translucent material, may be part of a transformation in which filopodia are separated from the plasma membrane of the maturing spermatozoan. In *G. rostochiensis* males, similar fragments of filopodia were reported in the fluid within the seminal vesicle of the vas deferens (Shepherd et al., 1973).

The sperm of *P. penetrans* do not contain the prominent lipidlike mass called a refringent body, which is unique among ascarids. Furthermore, sperm of *P. penetrans* do not have the membrane specializations that occur in many of the animal-parasitic and microbivorous species, such as *Caenorhabditis elegans* (Wolf et al., 1978). Membrane specializations in the insect-parasitic species *Heterorhabditis bacteriophora* are closely associated with the fibrous bodies of sperm (Poinar and Hess, 1985). Among the plant-parasitic species, membrane specializations occur in the sperm of the vermiform *Aphelenchoides blastophthorus* (Shepherd and Clark, 1976) but are lacking in sperm of cyst nematodes, *Heterodera* and *Globodera* spp. (Shepherd et al., 1973). Membranous organelles are prominent in spermatocytes but disappear in the older spermatids of *Xiphinema theresiae* (Kruger, 1991). Membrane specializations, also called membrane organelles, arise in the spermatocytes and may combine with the fibrous body to form a membrane complex that appears to be important in the delivery and storage of sperm protein. In the mature sperm, a glycoprotein released by the membrane organelle may be important for sperm motility (Kimble and Ward, 1988; Scott, 1996). In the absence of these membrane organelles in *P. penetrans,* the mechanism for sperm protein assembly and sperm release may differ.

Spermatozoa of *P. penetrans* have prominent pseudopods similar to those described in animal-parasitic species (Foor, 1970), plant-parasitic species including *G. rostochiensis* (Shepherd et al., 1973) and *E. thomasoni* (Cares and Baldwin, 1994b), and free-living forms such as *C. elegans* (Wolf et al., 1978). Pseudopod morphology and activity, as they relate to sperm motility, have been discussed in a recent review (Scott, 1996). Sperm motility, along with other features unique to nematodes, were highlighted as potential targets for control of human-parasitic species. Those targets included 1) disrupting early events of spermatogenesis to inhibit sperm maturation, 2) blocking processes that activate spermatid maturation, and 3) obstructing molecules involved in maintaining sperm positions in the spermatheca or blocking molecules involved in sperm–egg recognition (Scott, 1996). Whether nematode reproduction can be inhibited will depend on the unique components that contribute to spermatogenesis and their possible disruption.

In *P. penetrans,* the abundance of fibrous elements in the cytoplasm of spermatids, and to a lesser extent in spermatozoa, is very similar to that described in *Heterodera* and *Globodera* spp. The fibrous elements appear to form spontaneously. Although the initially large masses present in spermatids are gradually replaced, they are retained in sperm of *H. schachtii* but are dispersed in *G. rostochiensis* (Shepherd et al., 1973). Similarly, fibrous elements of *P. penetrans* occur in large masses in spermatids and are retained as narrow elongated strands in spermatozoa. These strands accumulate in the seminal vesicle and vas deferens of the male gonad and within the spermathecae of inseminated females. Fertilization of oocytes occurs in a specialized region of the uterus, the spermatheca, and in the uterine duct (Bird and Bird, 1991). Scott (1996) discussed the role of paracrystalline

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Figures 13, 14. Longitudinal section of the basal region of the vas deferens of the *P. penetrans* specimen of Figure 12. 13. A group of spermatozoa (sp) within the vas deferens (vd) channel supported by tissue containing secretory granules (SG) in various stages of dispersal. 14. Extension of Figure 13 illustrating the basal terminus of the vas deferens (vd), where electron-opaque secretory granules (SG) dominate the contents of supporting cells of the vas deferens. sp = sperm. Scale bars = 1.0 μm.

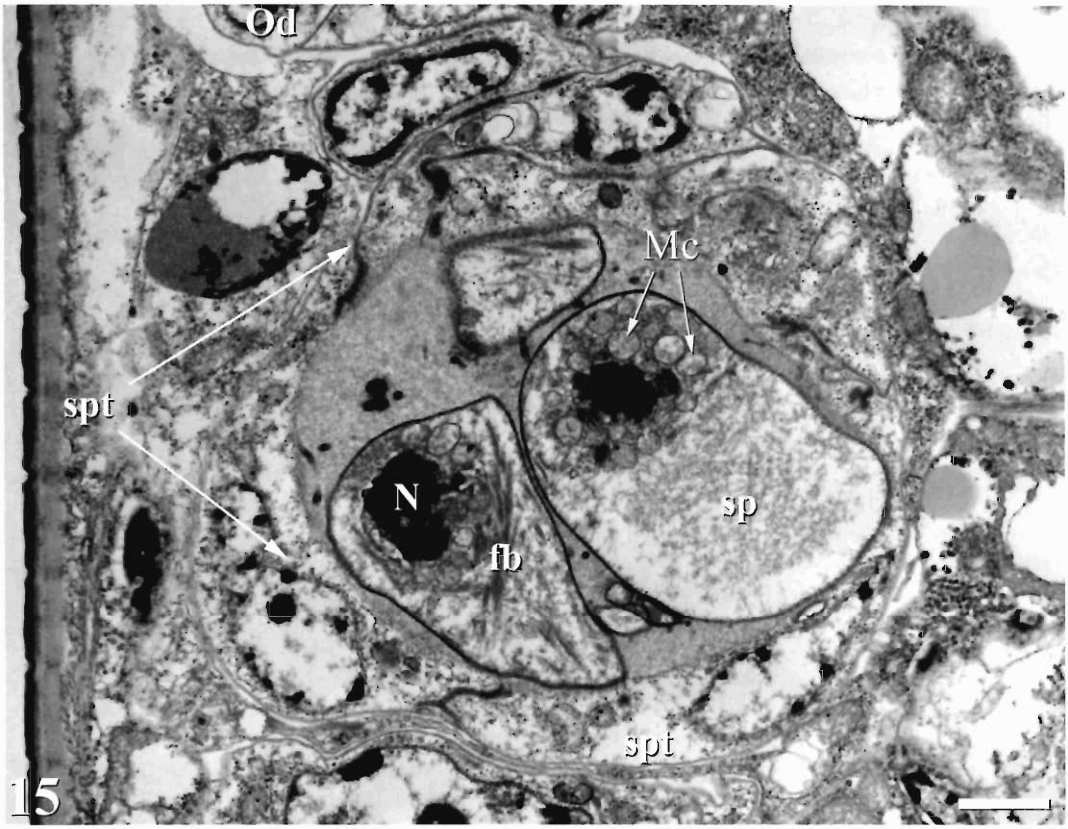

Figure 15. Longitudinal section through a female specimen of *P. penetrans* showing spermatozoa (sp) within the spermatheca (spt). Two of the spermatozoa show the mitochondria (Mc) closely surrounding the nuclear (N) chromatin. Od = oviduct. Scale bar = 1.0 μm.

arrays or fiber bodies synthesized in spermatocytes and their role in nematode sperm motility. Instead of the crawling motility of nematode sperm being dependent on actin or myosin, locomotion apparently depends on a simple cytoskeleton derived primarily from a family of small, basic MSP (Scott, 1996). MSP genes in various copy numbers have been identified in over 25 nematode species representing 20 genera (Scott, unpubl.). In observing the development and motility of sperm in *C. elegans,* Nelson et al. (1982) used gel electrophoresis to show that actin, a common component of motile systems, comprised only 0.02% of the total protein in sperm. Apparently, 1 of the MSP is the major component of *C. elegans* and *Ascaris* sperm. This small polypeptide, which comprises 15% of the total sperm protein, forms the fibrous bodies during spermatogenesis and becomes concentrated in the pseudopod during spermiogenesis (Ward and Klass, 1982). Similar sperm protein studies may reveal the composition of the fibrous bodies of *P. penetrans* and their role in sperm motility. Ward et al. (1982) demonstrated that *C. elegans* spermatozoa have a novel mechanism of motility called propulsion by bulk membrane flow. Future studies on *P. penetrans* and other plant-parasitic species may demonstrate similar mechanisms of motility and could provide insights into the composition and role of the fibrous bodies that represent the MSP found in a wide range of nematodes.

Many of the concepts of spermatogenesis and interactions of sperm motility studied in *C. elegans* and animal-parasitic species as reviewed by Scott (1996) should be applicable to plant-parasitic species. The uniqueness of nematode motility and sperm protein may be a target for the disruption of fertilization and possible control strategies for plant-parasitic nematodes.

Acknowledgments

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The Brayton H. Ransom Memorial Trust Fund was established in 1936 to "Encourage and promote the study and advance of the Science of Parasitology and related sciences." Income from the Trust currently provides token support of the *Journal of the Helminthological Society of Washington* and limited support for publication of meritorious manuscripts by authors lacking institutional or other backing. Donations or memorial contributions may be directed to the Secretary-Treasurer. Information about the Trust may be found in the following articles: *Proceedings of the Helminthological Society of Washington* (1936) 3:84–87; (1983) 50:200–204 and (1993) 60:144–150.

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Balance on hand, January 1, 1997		$18,374.51
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WAAVP Workshop funds contributed by Hoechst-Roussel Vet, Merial, Pfizer Corporation and Ransom Memorial Trust Fund	$16,050.00	
In memory of A. O. Foster*	$25.00	
Interest received in 1997	$1,117.65	
Disbursements		($13,364.16)
Support of author's page charges	($610.00)	
Grant to the Helminthologial Society of Washington for 1997	($50.00)	
Membership in the American Association for Zoological Nomenclature	($50.00)	
Grant, WAAVP Workshop	($50.00)	
Expenses of WAAVP Workshop	($12,604.16)	
On hand, December 31, 1997		$22,203.00

*Donations from members of the Helminthological Society of Washington for 1996 in the amount of $247 and for 1997 in the amount of $195 will be credited in 1998.

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Research Note

Scanning Electron Microscopy Study of a Copulating Monorchiid (Trematoda: Digenea)

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ABSTRACT: During a survey of parasites of fishes from the Kuwaiti coast of the Arabian Gulf, a pair of digeneans were found in copulation in the intestine of 1 of 4 *Gnathodon speciosus*; the digeneans were recovered and studied by scanning electron microscopy (SEM). SEM micrographs suggest a 1-way transfer of sperm and reveal the presence of longitudinal ridges with openings or depressions in the metratermal segment of the terminal organ of the recipient. The digeneans were identified as monorchiid species of *Lasiotocus*. This is the first evidence of copulation in a digenean demonstrated by SEM.

KEY WORDS: *Lasiotocus* sp., Monorchiidae, scanning electron microscopy, copulation, metraterm, *Gnathodon speciosus*, marine fish.

Trematodes, with few exceptions, are hermaphroditic flatworms that are capable of both cross- and self-fertilization. Most investigators believe that cross-fertilization is the rule. In cross-fertilization, sperms are transferred by the process of copulation from 1 individual to another in 1 direction or by reciprocal exchange.

The act of copulation has rarely been observed directly. Among the earlier studies are those of Fuhrmann (1930) on *Prosotocus confusus* (Looss, 1894) and Rausch (1947) on *Microphallus opacus* (Ward, 1894). Palombi (1932) reported copulation via Laurer's canal in *Diphtherostomum brusinae* (Stossich, 1889) and *Haploporus benedeni* (Stossich, 1887) and through the uterus in *Podocotyle fractum* (Rudolphi, 1819). (For more recent reviews dealing with copulation and fertilization, see Fried and Harris, 1971; Nollen 1983, 1997.) It is very probable, however, that most acts of copulation occur through the genital atrium by insertion of the cirrus or ejaculatory duct into the metraterm or the uterus. Here, we present an observation, which we consider direct evidence, of copulation through the metraterm in a monorchiid.

During the course of a survey of helminth parasites of Kuwaiti marine fishes conducted between October 1992 and December 1994, 4 golden trevally, *Gnathodon speciosus* (Forsskål, 1775) (Carangidae), were found to harbor monorchiids; in 1 of these hosts, a pair of digeneans in copula and 8 unpaired specimens were found. The digeneans were washed in saline, fixed in alcohol–formaldehyde–acetic acid, and stored in 70% ethanol. The copulating pair was dried for scanning electron microscopic (SEM) examination using the critical point technique, coated with gold-palladium, observed, and photographed using a JEOL, JSM-6300 SEM. The other specimens, which seem to represent 2 species, were stained in alum carmine, dehydrated through an ascending series of ethanol, cleared in clove oil, and mounted in Canada balsam.

Scanning electron micrographs show the copulating pair in a parallel but reverse position, the anterior end of 1 facing the posterior end of the other (Fig. 1A, B). Both the large cirrus sac and the metraterm part of the terminal organs are extruded (Figs. 1, 2), with the cirrus sac hooking up with the metraterm in an apparent 1-way transfer. The 1-way transfer is in contrast with the 2-way transfer described by Fuhrmann (1930) in *Prosotocus confusus*. The micrographs (Figs. 1, 2) show a conspicuous preacetabular genital pore that is wide open. The impression is that the recipient (Fig. 1B) is responding to the approach of the cirrus of the partner (the insertor) by opening its genital pore and protruding the metraterm. In the fixed specimens, the genital pore is barely visible, and no evidence of any metratermal protrusion is seen. The micrographs (Figs. 3, 4) also reveal that the metraterm has longitudinal ridges with pores or depressions. The function of these ridges is not

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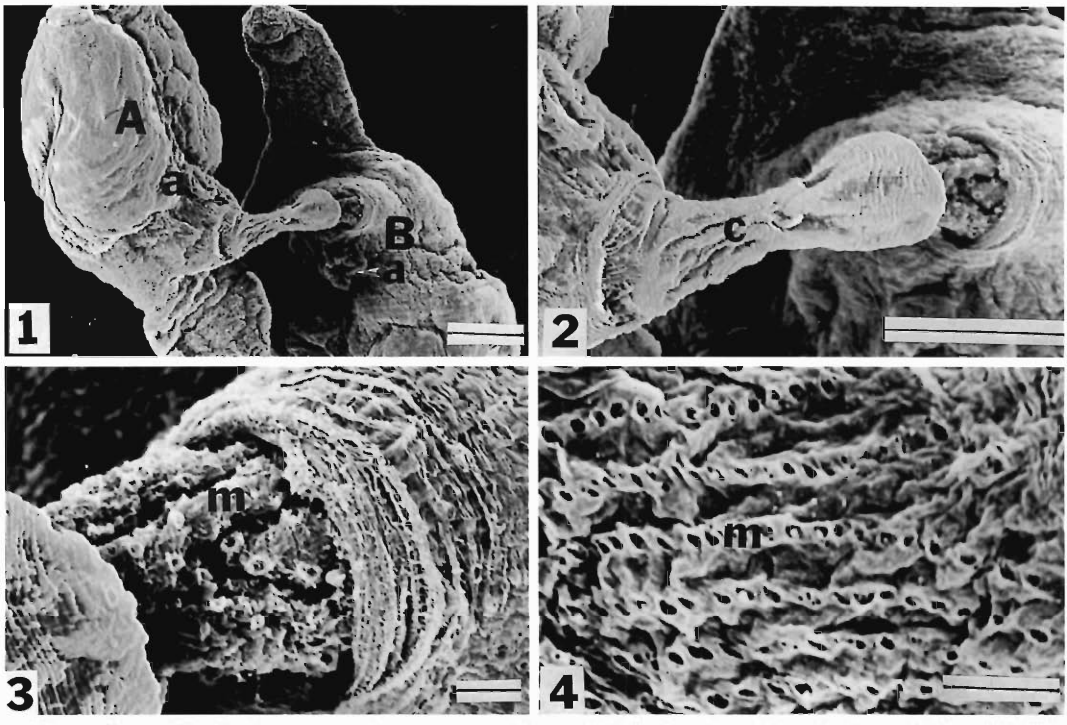

Figure 1–4. Copulating worms in reverse position, with the insertor (A) and the recipient (B). The anterior end of the insertor is pointing posteriorly, and the oral sucker of the recipient is near the upper edge of the picture; the acetabulum (a) is just posterior to the genital pore in B and the protruded cirrus in A. Scale bar = 100 μm. 2. Protruded cirrus (c) and its connection with the genital pore. Scale bar = 100 μm. 3. Protruded metraterm (m) showing ridges and pores or depressions. Scale bar = 10 μm. 4. Same worm as in Figure 3, from a slightly different angle, showing metratermal ridges, with pores or depressions, in a parallel arrangement. Scale bar = 1 μm.

known. Whether the pores or the depressions are openings of secretory glands or for chemoattractants can only be postulated. The production and secretion of chemoattractants has been reported previously (see Nollen, 1997).

The copulating digeneans were identified as a species of *Lasiotocus,* a monorchiid genus represented by at least 46 nominal species. The 10 specimens, including the copulating pair, recovered from 1 of 4 golden trevallys belong to 2 species. One species, represented by 1 specimen, is characterized by having small eggs, a small cirrus sac, and vitelline follicles that are confluent in the acetabular region; the other 7 specimens have larger eggs, a large cirrus sac, and vitelline follicles extending laterally from the acetabular level to the ovariotesticular level. Both species are to be described elsewhere. The assignment of the copulating pair to 1 or the other of these 2 species cannot be determined with certainty; in all likelihood, the specimen with the protruded cirrus, the insertor, (Fig. 1A) belongs to the species with the larger eggs and larger cirrus; whether the other partner belongs to the same species or to the other species cannot be determined from the micrographs. Both species were also found in the other 3 golden trevallys.

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Research Note

Seasonal Occurrence of Helminths of the Whistling Frog, *Eleutherodactylus johnstonei* (Amphibia: Leptodactylidae), in Bermuda

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ABSTRACT: Four hundred twenty-seven *Eleutherodactylus johnstonei* from 13 study sites in Bermuda were examined for helminths during March, July, and November 1995. Four nematode species, *Parapharyngodon garciae, Aplectana* sp., *Abbreviata* sp., and *Batracholandros* sp., and 2 trematode species, *Mesocoelium monas* and an unidentified species belonging to the family Opecoelidae, were found. The *Batracholandros* sp. and the opecoelid trematodes represent new records of parasitism in this frog species and for Bermuda.

KEY WORDS: *Eleutherodactylus johnstonei,* Leptodactylidae, Nematoda, *Parapharyngodon garciae, Aplectana* sp., *Abbreviata* sp., Oxyuridae, *Batracholandros* sp., *Mesocoelium monas,* Opecoelidae.

The leptodactylid frog *Eleutherodactylus johnstonei* Barbour, 1914, inhabits a number of Caribbean islands, including Anguilla, Antigua, Barbados, Barbuda, Grenada, Guadeloupe, Jamaica, Montserrat, Nevis, Saba, St. Barthelemy, St. Christopher, St. Eustatius, St. Lucia, St. Martin, and St. Vincent (Schwartz and Henderson, 1991). Between 1880 and 1886, *E. johnstonei* was introduced into Bermuda at Admiralty House, Pembroke Parish, probably from the Lesser Antilles (Wingate, 1965). The species is currently found throughout the 7 major islands comprising Bermuda.

Fifty-three *E. johnstonei* (16 males, 37 females) were collected from 2 sites during 20–24 March 1995: 12 (4 males, 8 females) were taken on the grounds of the Bermuda Biological Station for Research (BBSR) in St. George's Parish, and 41 (12 males, 29 females) were taken from a Harrington Sound banana patch in Smith's Parish. Mean (±SE) snout–vent length (SVL) = 22.5 ± 0.32 mm, range = 17–30 mm. Mean weight = 0.74 ± 0.03 g, range = 0.4–1.4 g. One hundred fifty-five frogs (99 males, 56 females) were taken during 10–21 July 1995 from 11 sites: BBSR (18), Harrington Sound banana patch (14), the Bermuda Perfumery in Hamilton Parish (18), Paget Cemetery in Paget Parish (20), Turks Head Lane in Devonshire Parish (20), Soundview Drive in Sandy's Parish (21), Fort Albert in St. George's Parish (10), St. David's Island in St. George's Parish (19), Lukes Pond Road in Southampton Parish (10), and Sea Swept Farm in Southampton Parish (5). Mean (±SE) SVL = 22.8 ± 0.24 mm, range = 16.5–33 mm. Mean (±SE) weight = 0.8 ± 0.03 g, range = 0.28–1.98 g. Two hundred nineteen frogs (88 males, 131 females) were taken during 18–24 November 1995 from 13 sites: Bermuda Perfumery (20), Soundview Drive (19), Lukes Pond Road (20), Sea Swept Farm (17), Cameron

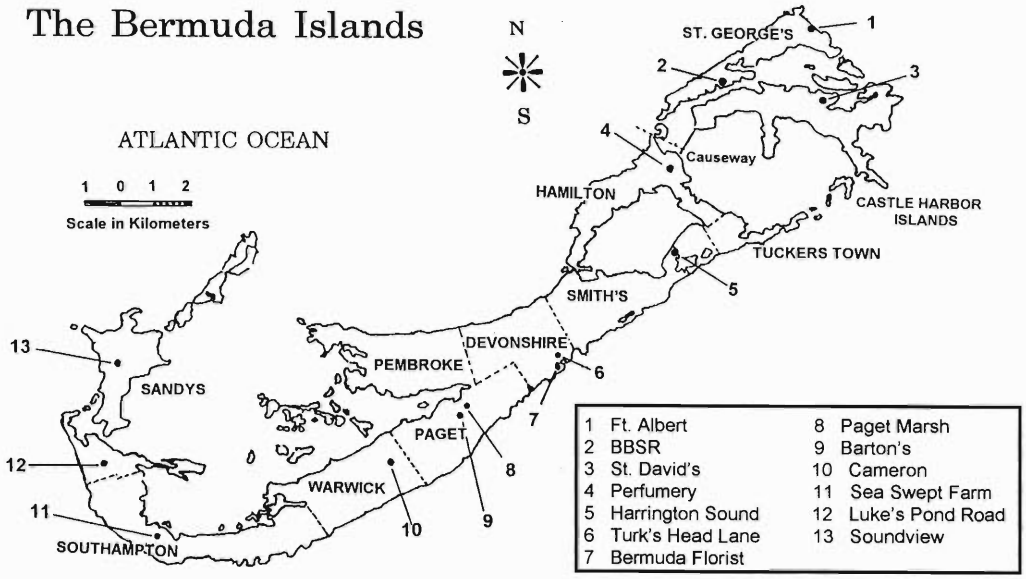

Figure 1. Study sites for *Eleutherodactylus johnstonei* in Bermuda.

in Warwick Parish (20), David Barton's in Paget Parish (16), Paget Marsh (10), Bermuda Florist in Devonshire Parish (20), Harrington Sound banana patch (20), St. David's Island (17), BBSR (20), and Fort Albert (20). Mean (±SE) SVL = 23.5 ± 0.22 mm, range = 15–34 mm. Mean (±SE) weight = 0.81 ± 0.03 g, range = 0.23–2.3 g.

Study sites are shown in Figure 1. Approximate straight-line distances from the BBSR are Ft. Albert, 2.5 km NE; St. David's, 2.5 km E; Bermuda Perfumery, 2.75 km SW; Harrington Sound banana patch, 4.5 km SW; Turks Head Lane and Bermuda Florist, 8.5 km SW; Paget Marsh and D. Barton's, 10.5 km SW; Cameron, 13.0 km SW; Sea Swept Farm, 18.5 km SW; Lukes Pond Road, 20.0 km SW; and Soundview Drive, 17.0 km SW.

All specimens were frozen immediately upon return to the BBSR. Later, each individual was thawed, measured, and weighed. The lungs, liver, gall bladder and bile duct, stomach, small intestine, large intestine, and urinary bladder were removed and examined separately under dissecting and compound microscopes. Nematodes were identified utilizing the standard glycerol wet-mount procedure. Trematodes were stained with Ehrlich's hematoxylin and mounted in Canada balsam. Terminology follows that of Bush et al. (1997). Selected helminths were deposited in the U.S. National Parasite Collection (USDA, Beltsville, Maryland): *Parapharyngodon garciae,* 87200; *Aplectana* sp., 87197; *Abbreviata* sp., 87196; *Mesocoelium monas,* 87204; and Opecoelidae, 87202, 87203.

Seasonal prevalence, mean abundance, and mean intensity for each helminth are given in Tables 1–3. For March, 49 of 53 (92%) *E. johnstonei* harbored helminths; for July, 130 of 155 (84%); and for November, 194 of 219 (89%).

Aplectana sp. (females only) was found in the small and large intestines in March: 17 of 53 frogs (32%), 4/16 (25%) males, 13/37 (35%) females; July: 54 of 155 frogs (35%), 38/99 (38%) males, 16/56 (29%) females; and November: 65 of 219 frogs (30%), 30/89 (34%) males, 35/131 (27%) females. Differences in seasonal infection rates (March, July, and November) were highly significant at the BBSR ($\chi^2 = 8.85$, 2 df, $P < 0.01$) but not at Harrington Sound ($\chi^2 = 1.04$). At the BBSR, differences in prevalence between March and November were highly significant (χ^2

Table 1. Seasonal prevalence, mean abundance, and mean intensity of *Aplectana* sp. infection in *Eleutherodactylus johnstonei* in Bermuda, 1995.

	March			July			November		
Study site	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)
Ft. Albert				60 (6/10)	4.1 ± 7.2	6.8 (1–24)	85 (17/20)	4.9 ± 4.7	5.8 (1–20)
BBSR	50 (6/12)	3.4 ± 6.9	6.8 (1–25)	22 (4/18)	0.3 ± 0.7	1.5 (1–2)	5 (1/20)	0.05 ± 0.2	1.0
St. David's				63 (12/19)	3.8 ± 5.3	6.0 (1–21)	41 (7/17)	1.6 ± 2.5	3.9 (1–8)
Perfumery				17 (3/18)	0.2 ± 0.5	1.3 (1–2)	25 (5/20)	0.6 ± 1.1	2.2 (1–4)
Harrington Sound	27 (11/41)	3.7 ± 1.3	2.0 (1–7)	36 (5/14)	0.6 ± 1.0	1.8 (1–3)	20 (4/20)	0.5 ± 1.4	2.5 (1–6)
Turks Head				50 (10/20)	0.9 ± 1.2	2.0 (1–4)			
Bermuda Florist							10 (2/20)	0.2 ± 0.5	1.5 (1–2)
Paget Marsh				20 (4/20)	0.5 ± 1.3	2.2 (1–6)	40 (4/10)	3.0 ± 1.7	3.0 (1–4)
Barton's							19 (3/16)	1.3 ± 0.6	1.3 (1–2)
Cameron							10 (2/20)	0.4 ± 1.4	4.0 (2–6)
Sea Swept				20 (1/5)	0.6 ± 1.2	3.0	12 (2/17)	0.4 ± 1.4	3.5 (1–6)
Lukes Pond				10 (1/10)	0.1 ± 0.3	1.0	5 (1/20)	0.05 ± 0.2	1.0
Soundview				29 (8/21)	0.8 ± 1.3	2.0 (1–5)	100 (19/19)	4.3 ± 3.3	4.3 (1–12)

* Numbers in parentheses are no. frogs infected/no. frogs examined.

Table 2. Seasonal prevalence, mean abundance, and mean intensity of *Abbreviata* sp. infection in *Eleutherodactylus johnstonei* in Bermuda, 1995.

	March			July			November		
Study site	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)
Ft. Albert				60 (6/10)	1.4 ± 1.9	2.3 (1–6)	45 (9/20)	1.8 ± 3.4	3.9 (1–12)
BBSR	17 (2/12)	10.4 ± 23.7	62.5 (50–75)	56 (10/18)	2.9 ± 4.8	5.3 (1–16)	95 (19/20)	11.6 ± 13.4	11.6 (2–53)
St. David's				74 (14/19)	2.3 ± 2.6	3.1 (1–9)	47 (8/17)	2.4 ± 5.2	5.1 (1–22)
Perfumery				83 (15/18)	8.2 ± 8.8	9.8 (1–38)	75 (15/20)	9.5 ± 11.1	12.6 (1–49)
Harrington Sound	76 (31/41)	6.9 ± 8.4	9.2 (1–30)	79 (11/14)	5.4 ± 5.4	6.9 (1–16)	95 (19/20)	8.6 ± 6.4	9.1 (1–22)
Turks Head				80 (16/20)	4.5 ± 5.7	18.0 (1–21)			
Bermuda Florist							70 (14/20)	5.8 ± 7.5	8.3 (2–30)
Paget Marsh				65 (13/20)	3.5 ± 5.0	5.3 (1–18)	10 (1/10)	0.1 ± 0.3	1.0
Barton's							94 (15/16)	27.7 ± 18.0	29.5 (1–65)
Cameron							90 (18/20)	5.6 ± 5.6	6.2 (1–21)
Sea Swept				100 (5/5)	9.6 ± 10.1	9.6 (2–28)	65 (11/17)	2.2 ± 2.6	3.4 (1–8)
Lukes Pond				70 (7/10)	2.4 ± 3.6	3.4 (1–12)	95 (19/20)	8.1 ± 6.8	8.5 (2–26)
Soundview				52 (11/21)	2.9 ± 3.7	5.5 (1–11)	79 (15/19)	4.1 ± 7.8	5.2 (1–36)

* Numbers in parentheses are no. frogs infected/no. frogs examined.

Table 3. Seasonal prevalence, mean abundance, and mean intensity of *Parapharyngodon garciae* infection in *Eleutherodactylus johnstonei* in Bermuda, 1995.

	March			July			November		
Study site	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)	Prevalence (%)*	Mean Abundance ($\bar{x}$ ± SD)	Mean intensity (range)
Ft. Albert				0 (0/10)			0 (0/10)		
BBSR	42 (5/12)	0.5 ± 0.7	1.2 (1–2)	33 (6/18)	0.6 ± 0.9	1.7 (1–3)	50 (10/20)	2.7 ± 1.6	2.7 (1–5)
St. David's				42 (8/19)	0.6 ± 0.8	1.4 (1–2)	24 (4/17)	0.3 ± 0.6	1.3 (1–2)
Perfumery				33 (6/18)	0.4 ± 0.6	1.2 (1–2)	20 (4/20)	0.2 ± 0.4	1.0 (1–1)
Harrington Sound	42 (17/41)	0.6 ± 0.9	1.5 (1–4)	14 (2/14)	0.1 ± 0.4	1.0 (1–1)	45 (9/20)	0.8 ± 1.0	1.7 (1–4)
Turks Head				20 (4/20)	0.3 ± 0.6	0.7 (1–2)			
Bermuda Florist							20 (4/20)	0.3 ± 0.5	1.3 (1–2)
Paget Marsh				5 (1/20)	0.1 ± 0.4	2.0	10 (1/10)	0.1 ± 0.3	1.0
Barton's							13 (2/16)	0.1 ± 0.3	2.0 (1–1)
Cameron							35 (7/20)	0.6 ± 0.9	1.7 (1–3)
Sea Swept				20 (1/5)	0.2 ± 0.4	1.0	59 (10/17)	1.1 ± 1.1	1.8 (1–3)
Lukes Pond				10 (1/10)	0.2 ± 0.6	2.0	55 (11/20)	0.9 ± 0.9	1.7 (1–2)
Soundview				0 (0/21)			0 (0/19)		

* Numbers in parentheses are no. frogs infected/no. frogs examined.

= 8.9, 1 df, $P < 0.01$), whereas differences between March and July ($\chi^2 = 2.5$) and July and November ($\chi^2 = 0.66$) were not significant. The difference in infection rate between July and November at the Soundview site was highly significant ($\chi^2 = 17.43$, 1 df, $P < 0.0005$).

Cysts containing larvae of *Abbreviata* sp. were present on the walls of the stomach, small intestine, large intestine, and urinary bladder in March: 34 of 53 frogs (64%), 10/16 (63%) males, 24/37 (65%) females; July: 107 of 155 frogs (69%), 66/99 (67%) males, 41/56 (73%) females; and November: 161 of 219 frogs (73%), 66/89 (74%) males, 95/131 (73%) females. A highly significant difference in the seasonal infection rate (March, July, and November) was recorded at the BBSR ($\chi^2 = 20.029$, 2 df, $P < 0.01$) but not at the Harrington Sound site ($\chi^2 = 3.415$, 2 df, $P > 0.05$). The differences between July and November infection rates were not significant at Sea Swept ($\chi^2 = 2.43$), Soundview ($\chi^2 = 3.10$), Lukes Pond ($\chi^2 = 3.61$), or St. David's ($\chi^2 = 2.68$).

Parapharyngodon garciae was found in the small and large intestines in March: 22 of 53 frogs (43%), 6/16 (38%) males, 16/37 (43%) females; July: 29 of 155 frogs (19%), 20/99 (20%) males, 9/56 (16%) females; and November: 62 of 219 frogs (28%), 29/88 (33%) males, 33/131 (25%) females. Differences in infection rates were not significant at any site except Lukes Pond, where the difference between July and November infection rates was highly significant ($\chi^2 = 5.63$, 1 df, $P < 0.01$).

One immature male oxyurid nematode was found in the small intestine of a female frog from Fort Albert in St. George's Parish. It was identified as *Batracholandros* sp. by Jean-Pierre Hugot, who noted that because pinworms are rare in anurans and none have ever been described from Bermuda, this specimen probably represents an undescribed species. The poor condition of the specimen, however, made further identification impossible.

One specimen of the trematode *Mesocoelium monas* was taken from the stomach of a female from Paget Cemetery in Paget Parish in July 1995 (prevalence = 5% [1/20]; abundance = 0.05 ± 0.22 [SD]; mean intensity = 1.0). During July, 34 opecoelid trematodes were identified in the liver, gall bladder, and bile ducts of a female frog from Harrington Sound in Smith's Parish (prevalence = 7% [1/14]; abundance 0.29 ± 1.03; mean intensity = 4.0) and a female frog from Paget Cemetery (prevalence = 5% [1/20]; abundance = 1.5 ± 6.54; mean intensity = 30.0). During November, a total of 48 trematodes were identified in 1 female frog from St. David's Island in St. George's Parish (prevalence = 6% [1/17], abundance = 0.18 ± 0.71, mean intensity = 3.0), 1 male frog from Fort Albert in St. George's Parish (prevalence = 5% [1/20], abundance = 0.5 ± 2.17, mean intensity = 10.0), 2 males from Soundview Drive in Sandy's Parish (prevalence = 11% [2/19], abundance = 0.89 ± 3.56, mean intensity = 8.5, range = 1–16), and 4 females from D. Barton's in Paget Parish (prevalence = 25% [4/16], abundance = 1.13 ± 2.02, mean intensity = 4.5, range = 3–6).

There are 3 previous reports on helminths of amphibians from Bermuda. Williams (1959) reported *Cosmocerca* sp., *Aplectana* sp., and *Thelandros* sp. Goldberg et al. (1995) reported *Aplectana* sp., *Parapharyngodon garciae,* and larval physalopterans. Burnie (1989) found metacercariae of the feline liver fluke, *Platynosomum concinnum,* in *Eleutherodactylus* spp.

Goldberg et al. (1995) found *Aplectana* sp. in 18 of 84 (21%) *E. johnstonei* and *Parapharyngodon garciae* in 25 of 84 (30%) of these frogs on the grounds of the BBSR. Williams (1959) reported 18 of 26 *E. johnstonei* to be infected by nematodes of the genera *Cosmocerca, Aplectana,* or *Thelandros*; specific rates of infection were not given. In this study, 136 of 427 (32%) *E. johnstonei* harbored *Aplectana* sp. and 102 of 427 (24%) of these frogs harbored *P. garciae.* There is no significant difference between the results of Goldberg et al. (1995) and those of this study for *P. garciae* ($\chi^2 = 1.32$, 1 df, $P > 0.05$); however, there is a significant difference between the studies concerning *Aplectana* sp. ($\chi^2 = 3.87$, 1 df, $P < 0.05$).

The *Batracholandros* sp. and the opecoelid trematodes represent new records of parasitism in *E. johnstonei* and in Bermuda. The single immature male oxyurid found in the small intestine of a female *E. johnstonei* may represent the ingestion of a nematode normally found within insect prey of the frog. The opecoelids were found in the liver, gall bladder, and bile ducts of 10 frogs, with 30 of the 82 trematodes found in a single female frog. The trematode intestinal ceca were fused to form a uroproct, and an accessory sucker and papillae were present around the ven-

tral sucker. No ova were present. Species of opecoelids encyst in amphipods (Schell, 1985); amphipods were identified as food items at each site except Paget Cemetery and Harrington Sound.

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Research Note

Seasonal Occurrence of Helminths of the Giant Toad, *Bufo marinus* (Amphibia: Bufonidae), in Bermuda

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ABSTRACT: One hundred sixty-seven giant toads, *Bufo marinus*, from 7 study sites in Bermuda were examined for helminths during March, July, and November 1995, August 1996, and May 1997. Three nematode species, *Rhabdias fuelleborni, Aplectana* sp., and *Abbreviata* sp., and 2 trematode species, *Mesocoelium monas* and *Clinostomum* sp., were found. Prevalence for *Rhabdias fuelleborni* was 25–100%, for *Aplectana* sp. was 0–67%, for *Abbreviata* sp. was 20–100%, and for *Mesocoelium monas* was 0–100%.

KEY WORDS: *Bufo marinus* (Bufonidae), Nematoda, *Rhabdias fuelleborni, Aplectana* sp., *Abbreviata* sp., Trematoda, *Mesocoelium monas, Clinostomum* sp.

Natural populations of the giant toad, *Bufo marinus* (Linnaeus, 1758), occur continuously from extreme southern Texas and northwestern Mexico to central Brazil (Easteal, 1986). The species has, however, been widely introduced in Bermuda, the Caribbean (Jamaica, Puerto Rico, U.S. Virgin Islands, Hispaniola, Barbados, Grenada, St. Vincent, St. Lucia, Martinique, Guadeloupe, St. Christopher, Nevis, Montserrat, Antigua) (Schwartz and Henderson, 1991), and the Pacific (Australia, New Guinea, Fiji, the Philippines) (Easteal, 1981). In Bermuda, approximately 24 individuals from Guyana were released in a garden in Devonshire Parish about

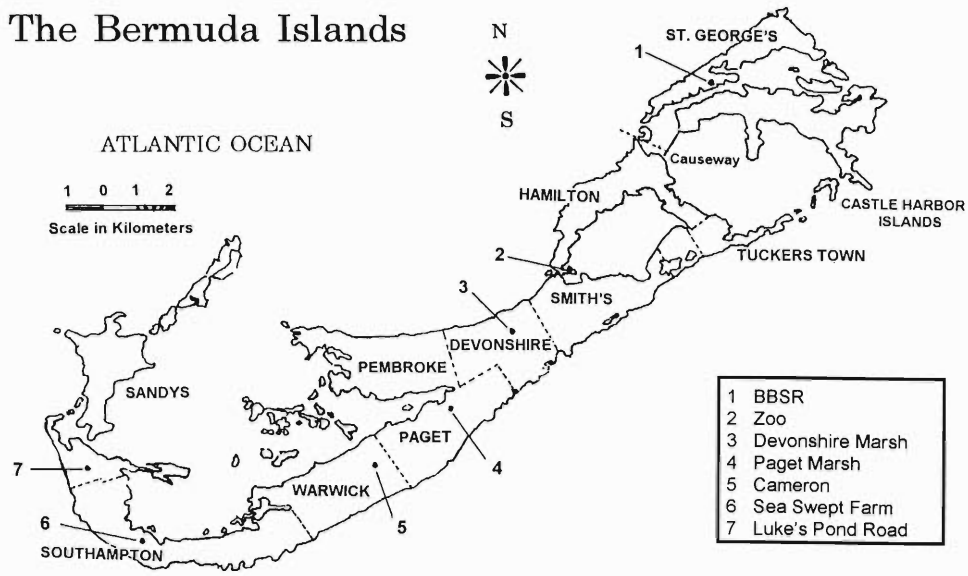

Figure 1. Study sites for *Bufo marinus* in Bermuda.

1885 by Captain Nathaniel Vesey (Wingate, 1965). For the next 100 yr, the toad population flourished and became extremely abundant. About 1990, a significant decline in numbers was noticed (Dow, 1993). In March 1995, a long-term study was begun to gather baseline data and to determine the cause(s) for this decline. The purpose of this study was to identify parasites harbored by *Bufo marinus*, to compare seasonal parasite loads among various populations on the islands, and to compare annual changes over time.

Thirty-one *B. marinus* (29 males, 2 females) were collected from 2 sites during 21–24 March 1995: 26 (25 males, 1 female) were taken on the grounds of the Bermuda Biological Station for Research (BBSR) in St. George's Parish and 5 (4 males, 1 female) were taken at Devonshire Marsh in Devonshire Parish. Mean (±SE) snout–vent length (SVL) = 130.5 ± 9.2 mm, range = 107–147 mm. Mean (±SE) weight = 209.5 ± 45.8 g, range = 100–290 g. Forty-nine toads (39 males, 10 females) were obtained during 11–22 July 1995 from 6 sites: BBSR (11), Devonshire Marsh (10), Flatts in Hamilton Parish (13), Paget Marsh in Paget Parish (10), Cameron in Warwick Parish (2), and Sea Swept Farm in Southampton Parish (3). The SVL = 115.9 ± 18.0 mm, range = 77–158 mm. Weight was 156.7 ± 75.0 g, range = 34.9–383.1 g. Thirty-four toads (16 males, 18 females) were taken from sites during 21–23 November 1995: BBSR (8), Devonshire Marsh (3), Flatts (4), Paget Marsh (2), Sea Swept Farm (10), and Lukes Pond Road in Southampton Parish (7). The SVL = 114.1 ± 15.0 mm, range = 82–160 mm. Weight was 144.5 ± 68.2 g, range = 50.7–357.4 g. Twenty toads (13 males, 7 females) were taken from the BBSR during 8–9 August 1996. The SVL = 111.5 ± 9.8 mm, range = 93.0–124.0 mm. Weight was 136.6 ± 43.3 g, range = 62.0–229.0 g. Thirty-three toads (15 males, 18 females) were taken from 5 sites on 20 May 1997: BBSR (10), Devonshire Marsh (6), Flatts (6), Paget Cemetery (5), and Sea Swept Farm (6). The SVL = 121.4 ± 2.31 mm, range = 94.0–150.0 mm. Weight was 171.3 ± 10.60 g, range = 54.7–345.6 g.

Study sites are shown in Figure 1. Approximate straight-line distances from the BBSR are Flatts, 6 km SW; Devonshire Marsh, 8 km SW; Paget Marsh, 11 km SW; Cameron, 13 km SW;

Sea Swept Farm, 18.5 km SW; and Lukes Pond Road, 20 km SW.

All specimens were frozen immediately upon return to the BBSR. Later, each individual was thawed, measured, and weighed. The lungs, liver, gall bladder and bile duct, stomach, small intestine, large intestine, and urinary bladder were removed and examined separately using dissecting and compound microscopes. Nematodes were identified using the standard glycerol wet-mount procedure. Trematodes were stained with Ehrlich's hematoxylin and mounted in Canada balsam. Terminology follows that of Bush et al. (1997). Selected helminths were deposited in the U.S. National Parasite Collection (USDA, Beltsville, Maryland): *Rhabdias fuelleborni,* 87195; *Abbreviata* sp., 87196; *Aplectana* sp., 87197; and *Mesocoelium monas,* 87198.

Seasonal prevalence, mean abundance, and mean intensity for each helminth are given in Tables 1–4. For March, 29 of 31 (94%) *B. marinus* harbored helminths; for May, 10 of 10 (100%); for July and August, 69 of 69 (100%); and for November, 29 of 34 (85%).

Rhabdias fuelleborni Travassos, 1926, was found only in the lungs in March: 27 of 31 toads (87%), 25/29 males (86%), 2/2 females (100%); May: 19 of 33 toads (58%), 15/18 males (83%), 4/15 females (27%); July–August: 52 of 69 toads (76%), 39/51 males (76%), 13/18 females (72%); and November: 20 of 34 toads (59%), 10/16 males (63%), 10/18 females (56%).

Aplectana sp. (females only) were found in the large intestines in March: 4 of 31 toads (13%), 2/29 males (7%), 2/2 females (100%); May: 0 of 33 toads; July–August: 3 of 69 toads (4%), 2/51 males (4%), 1/18 females (6%); and November: 1 of 34 toads (3%), 1/16 males (6%).

Cysts containing larvae of *Abbreviata* sp. were found in the walls of the stomach and urinary bladder in March: 20 of 31 toads (65%), 19/29 males (66%), 1/2 females (50%); May: 27 of 33 toads (82%), 14/18 males (78%), 13/15 females (87%); July–August: 34 of 69 toads (49%), 26/52 males (50%), 8/17 females (47%); and November: 20 of 34 toads (59%), 11/16 males (69%), 9/18 females (50%).

The trematode *M. monas* (Rudolphi, 1819) Freitas, 1958, was found in the duodenum and jejunum of 16 of 31 toads (52%) in March, 15/29 males (52%), 1/2 females (50%); 23 of 33 toads (70%) in May, 11/18 males (61%), 12/15 females (80%); 50 of 69 toads (72%) in July and August, 40/52 males (77%), 10/17 females (59%); and in 16 of 34 toads (47%) in November, 8/16 males (50%), 8/18 females (44%).

Two trematodes identified as *Clinostomum* sp. metacercariae were found in the small intestine of a male *B. marinus* from Paget Parish.

There are 3 published reports on helminths of *B. marinus* from Bermuda. Williams (1959, 1960) reported *Rhabdias sphaerocephala* and *Aplectana vellardi,* and Goldberg et al. (1995) reported *Aplectana* sp., *R. fuelleborni,* and *Mesocoelium monas.* One unpublished 1992 student report from the Bermuda Biological Station library reported *R. bufonis* and a "pinworm" (Lightbourne, unpubl.)

Goldberg et al. (1995) examined 45 adult *B. marinus* collected on the grounds of the BBSR 14–18 August 1992 and reported *R. fuelleborni* in 32 (71%) toads. Williams (1959, 1960) reported *R. sphaerocephala* from 33 of 40 toads (83%) taken between 9 June and 21 July 1957 from the parishes of St. George's, Smith's, Pembroke, and Devonshire. The unpublished student project reported *R. bufonis* in 1 of 5 toads (20%) taken in Pembroke Parish. Baker (1987) considered both *R. bufonis* and *R. sphaerocephala* to be European species and stated that American records of *R. sphaerocephala* need to be confirmed. Specimens of *Rhabdias* from Bermuda lack the anterior body wall swelling and cuticular inflation and the anterior esophageal swelling of *R. sphaerocephala,* and they are somewhat shorter in total length. They best fit the description of *R. fuelleborni* as given by Travassos (1926). No significant differences were found when the combined infection rates from 3 collecting periods in this study (March, July–August, and November) were compared with those of the summer sample of Williams (1959) ($\chi^2 = 0.84$, 1 df, $P > 0.05$) and the August sample of Goldberg et al. (1995) ($\chi^2 = 0.92$, 1 df, $P > 0.05$).

Goldberg et al. (1995) also reported 39 of the 45 toads (87%) harboring *Aplectana* sp. Because only females of this worm were found, identification to species was not attempted. Williams (1959) reported 10 of 40 toads (25%) harboring *Aplectana vellardi.* In the present study, 8 of 134 toads (6%) were infected by *Aplectana* sp. Identification to species was not attempted because of the lack of male specimens. When the combined prevalences from 3 collecting periods from this study (March, July–August, and No-

Table 1. Seasonal prevalence, mean abundance, and mean intensity of *Rhabdias fuelleborni* infection in *Bufo marinus* in Bermuda.

	BBSR								
	1995	1996	1997	Flatts	Devonshire Marsh	Paget Marsh	Cameron	Sea Swept	Lukes Pond
March 1995 (n = 31)									
Prevalence (%)*	85 (22/26)				100 (5/5)				
Mean Abundance (±SD)	12.5 ± 12.5				4.4 ± 4.3				
Mean intensity	14.8				4.4				
(range)	(1–44)				(1–8)				
May 1997 (n = 33)									
Prevalence (%)*			80 (8/10)	67 (4/6)	67 (4/6)	60 (3/5)		0/6	
Mean Abundance (±SD)			21.2 ± 21.5	13.8 ± 15.8	8.8 ± 11.6	8.8 ± 12.2			
Mean intensity			26.5	20.8	13.3	14.7			
(range)			(2–61)	(6–37)	(1–28)	(2–32)			
July–August 1995–1996 (n = 69)									
Prevalence (%)*	64 (7/11)	60 (12/20)		85 (11/13)	70 (7/10)	80 (8/10)	100 (2/2)	67 (2/3)	
Mean Abundance (±SD)	12.4 ± 20.9	6.3 ± 10.6		28.0 ± 32.7	5.5 ± 5.8	27.1 ± 23.9	7.0 ± 6.0	3.0 ± 1.7	
Mean intensity	19.4	10.6		33.1	7.9	33.9	7.0	4.5	
(range)	(1–76)	(1–21)		(3–114)	(1–16)	(3–53)	(1–8)	(1–8)	
November 1995 (n = 34)									
Prevalence (%)*	88 (7/8)			25 (1/4)	100 (3/3)	50 (1/2)		40 (4/10)	57 (4/7)
Mean Abundance (±SD)	3.0 ± 2.6			6.0 ± 10.4	21.3 ± 14.8	3.5 ± 3.5		5.4 ± 13.2	9.7 ± 17.3
Mean intensity	3.4			24.0	21.3	7.0		13.5	17.0
(range)	(1–8)				(8–42)			(1–45)	(1–50)

* Numbers in parentheses are no. toads infected/no. toads examined.

Table 2. Seasonal prevalence, mean abundance, and mean intensity of *Aplectana* sp. infection in *Bufo marinus* in Bermuda.

	BBSR								
	1995	1996	1997	Flatts	Devonshire Marsh	Paget Marsh	Cameron	Sea Swept	Lukes Pond
March 1995 (n = 31)									
Prevalence (%)*	4 (1/26)				60 (3/5)				
Mean Abundance (±SD)	0.04 ± 0.2				5.8 ± 8.22				
Mean intensity	1.0				9.7				
(range)					(2–13)				
May 1997 (n = 33)									
Prevalence (%)*			0/10	0/6	0/6	0/5		0/6	
July–August 1995–1996 (n = 69)									
Prevalence (%)*	0/11	0/20		0/13	0/10	20 (2/10)	50 (1/2)	67 (2/3)	
Mean Abundance (±SD)						17.8 ± 52.1	21.0 ± 21.0	3.0 ± 1.7	
Mean intensity						89.0	42.0	4.5	
(range)						(4–174)		(1–8)	
November 1995 (n = 34)									
Prevalence (%)*	0/8			0/4	33 (1/3)	0/2		0/10	0/7
Mean Abundance (±SD)					0.3 ± 0.5				
Mean intensity					1.0				
(range)									

* No. toads infected/no. toads examined.

Table 3. Seasonal prevalence, mean abundance, and mean intensity of *Abbreviata* sp. infection in *Bufo marinus* in Bermuda.

	BBSR								
	1995	1996	1997	Flatts	Devonshire Marsh	Paget Marsh	Cameron	Sea Swept	Lukes Pond
March 1995 (n = 31)									
Prevalence (%)*	62 (16/26)				80 (4/5)				
Mean Abundance (±SD)	5.5 ± 10.8				22.0 ± 16.0				
Mean intensity	11.4				27.5				
(range)	(1–46)				(20–50)				
May 1997 (n = 33)									
Prevalence (%)*			70 (7/10)	100 (6/6)	100 (6/6)	40 (2/5)		100 (6/6)	
Mean Abundance (±SD)			28.2 ± 39.4	40.2 ± 29.0	23.3 ± 20.3	12.2 ± 23.9		30.5 ± 20.2	
Mean intensity			40.3	40.2	23.3	30.5		30.5	
(range)			(1–121)	(10–83)	(4–58)	(1–60)		(4–64)	
July–August 1995–1996 (n = 69)									
Prevalence (%)*	55 (6/11)	35 (7/20)		54 (7/13)	20 (2/10)	80 (8/10)	100 (2/2)	67 (2/3)	
Mean Abundance (±SD)	10.0 ± 10.4	7.8 ± 15.4		4.5 ± 10.4	2.4 ± 6.0	19.1 ± 17.5	20.0 ± 0.0	13.3 ± 9.4	
Mean intensity	18.3	22.1		8.3	12.0	23.9	20.0	20.0	
(range)	(10–30)	(1–60)		(1–40)	(4–20)	(1–50)	(20–20)	(20–20)	
November 1995 (n = 34)									
Prevalence (%)*	88 (7/8)			100 (4/4)	33 (1/3)	50 (1/2)		30 (3/10)	57 (4/7)
Mean Abundance (±SD)	21.3 ± 13.6			102 ± 98.0	1.7 ± 2.4	2.5 ± 2.5		6.0 ± 9.2	11.4 ± 11.0
Mean intensity	24.3			102.0	5.0	5.0		20.0	20.0
(range)	(10–50)			(3–200)				(20–20)	(10–25)

* Numbers in parentheses are no. toads infected/no. toads examined.

Table 4. Seasonal prevalence, mean abundance, and mean intensity of trematode *Mesocoelium monas* infection in *Bufo marinus* in Bermuda.

	BBSR								
	1995	1996	1997	Flatts	Devonshire Marsh	Paget Marsh	Cameron	Sea Swept	Lukes Pond
March 1995 (n = 31)									
Prevalence (%)*	54 (14/26)				40 (2/5)				
Mean Abundance (±SD)	76.1 ± 167.9				15.0 ± 20.0				
Mean intensity	123.6				37.5				
(range)	(2–754)				(25–50)				
May 1997 (n = 33)									
Prevalence (%)*			90 (9/10)	67 (4/6)	67 (4/6)	40 (2/5)		67 (4/6)	
Mean Abundance (±SD)			78.9 ± 95.9	64.7 ± 110.7	37.7 ± 27.0	38.6 ± 70.0		36.8 ± 67.2	
Mean intensity			87.7	97.0	56.5	96.5		55.3	
(range)			(1–320)	(8–309)	(52–66)	(15–178)		(1–186)	
July–August 1995–1996 (n = 69)									
Prevalence (%)*	45 (5/11)	95 (19/20)		92 (12/13)	70 (7/10)	60 (6/10)	0/2	0/3	
Mean Abundance (±SD)	8.6 ± 16.0	75.2 ± 142.1		263.3 ± 516.9	2.6 ± 2.9	240.6 ± 353.0			
Mean intensity	19.0	79.1		285.2	8.7	401.0			
(range)	(1–55)	(1–648)		(18–2,000)	(1–10)	(6–1,000)			
November 1995 (n = 34)									
Prevalence (%)*	63 (5/8)			100 (4/4)	33 (1/3)	100 (2/2)		0/10	57 (4/7)
Mean Abundance (±SD)	23.1 ± 25.6			88.5 ± 72.8	3.3 ± 4.7	205.0 ± 195.0			151.0 ± 347.0
Mean intensity	37.0			88.5	10.0	205.0			264.2
(range)	(10–75)			(4–200)		(10–400)			(3–1,000)

* Numbers in parentheses are no. toads infected/no. toads examined.

vember) were compared with those of the summer sample of Williams (1959) ($\chi^2 = 12.03$, 1 df, $P < 0.001$) and the August sample of Goldberg et al. (1995) ($\chi^2 = 113.29$, 1 df, $P < 0.001$), the differences were highly significant. The reason for the significant differences among these 3 reports is unknown. Lees (1962) found both prevalence and intensity of infection by *R. bufonis* and *Aplectana acuminata* of *Rana temporaria* from England to be lowest in summer. Baker (1979) found a similar relationship for *R. ranae* in *Rana sylvatica* from Ontario; prevalence and intensity of infection were lowest in summer and highest in spring and early fall. Because species of the genus *Aplectana* are monoxenous, this difference may simply reflect the patchiness of infective larvae.

Goldberg et al. (1995) reported 1 of 45 (2%) *B. marinus* captured on the grounds of the BBSR in August 1992 to be infected by *M. monas*. In this study, toads from the same site, 14 of 26 (56%) in March, 9 of 10 (90%) in May, 24 of 31 (77%) in July–August, and 5 of 8 (63%) in November, had a significantly greater infection rate ($\chi^2 = 46.33$, 1 df, $P < 0.001$). Additional seasonal collections will be necessary at this and other sites to determine whether this variation is a normal perturbation in the prevalence of this trematode or whether the high rate of infection will be maintained.

The metacercariae of 2 trematodes (*Clinostomum* sp.) were found in the small intestine of 1 male *B. marinus* and represent new records of parasitism. The genital pores are posterior in position, the ovaries and testes form a group, and the anterior ends are retractable. Ova were not present; thus, we believe the specimens to be immature or in an unsuitable host. Species of *Clinostomum* are known to encyst in frog tissues (Schell, 1985).

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Research Note

Helminths of the Lizard *Anolis cristatellus* (Polychrotidae) from the British Virgin Islands, West Indies

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ABSTRACT: Sixty-two *Anolis cristatellus* from 7 islands of the British Virgin Islands were examined for helminths. One species of trematode, *Mesocoelium monas*, 1 species of cestode, *Oochoristica maccoyi*, 6 species of nematodes, *Parapharyngodon cubensis*, *Spauligodon anolis*, *Trichospirura teixeirai*, *Physaloptera* sp. (larva), *Porrocaecum* sp. (larvae), and *Rhabdias* sp., and 2 species of acanthocephalans, *Centrorhynchus* sp. (cystacanths) and unidentified oligacanthorhynchid cystacanths, were found. *Anolis cristatellus* represents a new host record for *O. maccoyi*, *T. teixeirai*, *Physaloptera* sp., *Porrocaecum* sp., and oligacanthorhynchid cystacanths.

KEY WORDS: *Anolis cristatellus*, Polychrotidae, helminths, British Virgin Islands.

Anolis cristatellus Duméril and Bibron, 1837, occurs in Puerto Rico and its offshore islands and the U.S. and British Virgin Islands and has been introduced into the eastern Dominican Republic and southeast Florida (Schwartz and Henderson, 1991). The only reports of helminths have been from populations of *A. cristatellus* from Puerto Rico (Chitwood, 1934; Cofresí-Sala, 1964; García-Díaz, 1966; Bain and Chaniotis, 1975; Acholonu, 1976). The purpose of this note is to report helminths of *A. cristatellus* from the British Virgin Islands.

Sixty-two *A. cristatellus* from the British Virgin Islands were borrowed from the Texas Memorial Museum, University of Texas–Austin (TNHC) and examined for helminths: accession nos. TNHC 55696–55707, 55762–55781, 55808–55809, 55814–55824, and 55831–55847. Lizards were collected by hand-held noose in 1993 and 1995, preserved in 10% formalin, and stored in ethanol. They were from 7 islands: Anegada Island (N = 6, mean ± SD snout–vent length [SVL] = 55.8 ± 8.6 mm, range = 47–68 mm), Beef Island (N = 8, SVL = 63.9 ± 4.6 mm, range = 56–68 mm), Guana Island (N = 3, SVL = 58.0 ± 3.6 mm, range = 55–62 mm), Necker Island (N = 12, SVL = 66.3 ± 2.5 mm, range = 61–70 mm), Norman Island (N = 12, SVL = 59.9 ± 4.6 mm, range = 51–68 mm), Tortola Island (N = 11, SVL = 60.8 ± 2.0 mm, range = 57–64 mm), Virgin Gorda Island (N = 10, SVL = 54.2 ± 3.8 mm, range = 49–61 mm). There are significant differences among SVLs for these populations (Kruskal–Wallis test = 30.5, 6 df, $P < 0.001$).

The body of each anole was opened by a longitudinal incision from vent to throat, and the digestive tract was removed by cutting across the anterior esophagus and rectum. The esophagus, stomach, and small and large intestines were slit longitudinally and examined under a dissecting microscope. The gallbladder, liver, and body cavity were also searched for helminths. Each helminth was initially placed in a drop of glycerol on a glass slide. Nematodes were identified from these temporary mounts. Trematodes, cestodes, and acanthocephalans were stained with hematoxylin and mounted in balsam for identification. Selected encysted nematode larvae and acanthocephalan cystacanths were embedded in paraffin, and histological sections were cut at 8 μm and stained with hematoxylin and eosin. Terminology follows that of Bush et al. (1997).

The helminth fauna of *A. cristatellus* from the British Virgin Islands consisted of 1 species of trematode, *Mesocoelium monas* (Rudolphi, 1819), 1 species of cestode, *Oochoristica maccoyi* Bursey and Goldberg, 1996, 6 species of nematodes, 4 of which were represented by mature individuals, *Parapharyngodon cubensis* (Baruš and Coy Otero, 1969), *Spauligodon anolis* (Chitwood, 1934), *Trichospirura teixeirai* (Baruš and Coy Otero, 1968), and *Rhabdias* sp., 2 of which were represented by larvae, *Physa-*

Table 1. Island of occurrence, number, prevalence, mean intensity, range, and mean abundance of helminths in 62 *Anolis cristatellus* from the British Virgin Islands.

Island Helminth	No. lizards	No. helminths	Prevalence (%)	Mean Intensity $\bar{x} \pm SD$	Mean Intensity Range	Mean Abundance ($\bar{x} \pm SD$)
Anegada	6					
Parapharyngodon cubensis		8	67	2.0 ± 1.4	1–4	1.3 ± 1.5
Porrocaecum sp. (larvae)		4	33	2.0 ± 1.4	1–3	0.7 ± 1.2
Centrorhynchus sp. (cystacanths)		20	17	20.0		3.3 ± 8.2
Beef	8					
Parapharyngodon cubensis		16	50	4.0 ± 2.2	2–7	2.0 ± 2.5
Spauligodon anolis		99	38	33.0 ± 32.1	12–70	12.4 ± 24.2
Trichospirura teixeirai		5	25	2.5 ± 2.1	1–4	0.6 ± 1.4
Porrocaecum sp. (larvae)		4	25	2.0		0.5 ± 0.9
Centrorhynchus sp. (cystacanths)		3	13	3.0		0.4 ± 1.1
Oligacanthorhynchidae (cystacanths)		8	38	2.7 ± 1.2	2–4	1.0 ± 1.5
Guana	3					
Parapharyngodon cubensis		8	67	4.0 ± 2.8	2–6	2.7 ± 3.1
Porrocaecum sp. (larvae)		8	67	4.0 ± 4.2	1–7	2.7 ± 3.8
Centrorhynchus sp. (cystacanths)		3	67	1.5 ± 0.7	1–2	1.0 ± 1.0
Necker	12					
Parapharyngodon cubensis		24	83	2.4 ± 2.2	1–8	2.0 ± 2.2
Trichospirura teixeirai		1	8	1.0		0.8 ± 0.3
Physaloptera sp. (larva)		1	8	1.0		0.8 ± 0.3
Porrocaecum sp. (larvae)		77	83	7.7 ± 8.0	2–28	6.4 ± 7.8
Centrorhynchus sp. (cystacanths)		8	25	2.7 ± 1.2	2–4	0.7 ± 1.3
Oligacanthorhynchidae (cystacanth)		1	8	1.0		0.1 ± 0.3
Norman	12					
Parapharyngodon cubensis		8	58	1.1 ± 0.4	1–2	0.7 ± 0.6
Porrocaecum sp. (larva)		1	8	1.0		0.1 ± 0.3
Centrorhynchus sp. (cystacanths)		60	75	6.6 ± 3.4	2–11	5.0 ± 4.2
Tortola	11					
Oochoristica maccoyi		1	9	1.0		0.1 ± 0.3
Parapharyngodon cubensis		20	55	3.3 ± 2.5	1–7	1.8 ± 2.5
Trichospirura teixeirai		8	27	2.7 ± 2.9	1–6	0.7 ± 1.8
Porrocaecum sp. (larvae)		13	27	4.3 ± 2.9	1–6	1.2 ± 2.4
Rhabdias sp.		2	18	1.0		0.2 ± 0.4
Centrorhynchus sp. (cystacanths)		27	36	6.8 ± 6.9	2–17	2.5 ± 5.1
Oligacanthorhynchidae (cystacanths)		2	18	1.0		0.2 ± 0.4
Virgin Gorda	10					
Mesocoelium monas		72	60	12.0 ± 6.3	5–23	7.2 ± 7.8
Parapharyngodon cubensis		18	80	2.3 ± 1.3	1–4	1.8 ± 1.5
Trichospirura teixeirai		4	10	4.0		0.4 ± 1.3
Porrocaecum sp. (larvae)		137	90	15.2 ± 25.0	1–77	13.7 ± 24.1
Centrorhynchus sp. (cystacanth)		1	10	1.0		0.1 ± 0.3
Oligacanthorhynchidae (cystacanths)		25	60	4.2 ± 5.1	1–14	2.5 ± 4.4

loptera sp. and *Porrocaecum* sp., and 2 species of acanthocephalans represented by cystacanths, *Centrorhynchus* sp. and an unidentified oligacanthorhynchid acanthocephalan. The specimens of *Rhabdias* sp. had damaged anterior regions and could not be identified to species. *Anolis cristatellus* represents a new host record for *O. maccoyi, T. teixeirai, Physaloptera* sp., *Porrocaecum* sp., and the oligacanthorhynchid cystacanths.

Representative helminths were placed in vials of alcohol and deposited in the U.S. National Parasite Collection (USNPC) Beltsville, Maryland: *Mesocoelium monas* 87534; *Parapharyngodon cubensis* 87535; *Spauligodon anolis* 87536; *Trichospirura teixeirai* 87537; *Physaloptera* sp.

87538; *Porrocaecum* sp. 87539; *Rhabdias* sp. 87540; *Centrorhynchus* sp. (cystacanths) 87541; oligacanthorhynchid cystacanths 87542.

Helminths were site specific. *Mesocoelium monas* and *O. maccoyi* were found in the small intestine. *Parapharyngodon cubensis* and *S. anolis* occurred in the large intestine. *Trichospirura teixeirai* was found in the gallbladder. *Rhabdias* sp. occurred in the lungs. The larva of *Physaloptera* sp. was found free in the stomach. Larvae of *Porrocaecum* sp., cystacanths of *Centrorhynchus* sp., and the unidentified oligacanthorhynchid acanthocephalan were encysted in the peritoneum of the coelom. The walls of these connective tissue cysts were constructed of several layers of fibrocytes and surrounding fibers.

Island of occurrence, number of lizards, number of helminths, prevalence, mean intensity, range, and mean abundance are presented in Table 1. Three helminth species were found on all islands, i.e., *Parapharyngodon cubensis, Porrocaecum* sp., and *Centrorhynchus* sp. There was no significant difference among prevalences by island for *Parapharyngodon cubensis* ($\chi^2 = 4.35$, 6 df, $P > 0.05$), but significant differences were found among prevalences by island for *Porrocaecum* sp. ($\chi^2 = 25.18$, 6 df, $P < 0.001$) and *Centrorhynchus* sp. ($\chi^2 = 15.92$, 6 df, $P < 0.05$). More anoles will need to be examined before the distribution differences for helminth species shown in Table 1 can be explained.

All helminths found in the present study are known from other anole hosts (Acholonu, 1976; Goldberg et al., 1997a, b; Torres Ortiz, 1980). These helminths fall into 2 groups: 1) species for which anoles are definitive hosts, i.e., *M. monas, O. maccoyi, Parapharyngodon cubensis, S. anolis, T. teixeirai,* and *Rhabdias* sp., and 2) species for which anoles are paratenic hosts, i.e., helminths occur only as immature stages and have no chance of completing their life cycles: *Porrocaecum* sp., *Centrorhynchus* sp., and oligacanthorhynchid cystacanths.

The only other populations of *A. cristatellus* examined for helminths are from Puerto Rico. Three species of trematodes, *Allopharynx puertoricensis, A. riopedrensis,* and *M. monas*; 4 species of nematodes, *Befilaria puertoricensis, S. anolis* (=*Pharyngodon anolis* sensu Acholonu, 1976), *Parapharyngodon cubensis* (=*Pharyngodon travassosi* sensu Acholonu, 1976), and *Rhabdias* sp.; and 2 species of acanthocephalans, *Centrorhynchus* sp. and *Lueheia inscripta,* have been reported from these populations (Chitwood, 1934; Cofresí-Sala, 1964; García-Díaz, 1966, Bain and Chaniotis, 1975; Acholonu, 1976; Torres Ortiz, 1980). Thus, British Virgin Island and Puerto Rican populations of *A. cristatellus* currently have 5 helminth species in common: *M. monas, S. anolis, Parapharyngodon cubensis, Rhabdias* sp., and *Centrorhynchus* sp. Because sample sizes for the populations of *A. cristatellus* examined to date have been small, more individuals will need to be examined before biogeographic patterns of the various helminth species can be evaluated.

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Research Note

Prevalence and Distribution of Cystacanths of an Oligacanthorhynchid Acanthocephalan from the Longnose Snake, *Rhinocheilus lecontei* (Colubridae), in Southwestern North America

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ABSTRACT: Cystacanths of an oligacanthorhynchid acanthocephalan were found in 161 of 554 (29%) *Rhinocheilus lecontei* from southwestern North America: Arizona, 134/311 (43%); California, 4/107 (4%); Texas, 2/23 (9%); Mexico, 21/53 (40%). No cystacanths were found in *R. lecontei* from Nevada (0/42), New Mexico (0/17), or Utah (0/1). Infections varied from few cystacanths to many cystacanths per snake, but a tissue inflammatory reaction was not observed. The geographic distribution of oligacanthorhynchid cystacanths in *R. lecontei* suggests that these cystacanths are most prevalent in Arizona and Mexico.

KEY WORDS: Acanthocephala, oligacanthorhynchid cystacanths, snake, *Rhinocheilus lecontei*, Colubridae.

Juvenile stages of oligacanthorhynchid acanthocephalans have been found in amphibians (Moore, 1946), reptiles (Elkins and Nickol, 1983; McAllister et al., 1991, 1995; McAllister, 1992; Stuart and Miller, 1993; Bolette, 1997a, b), and mammals (Elkins and Nickol, 1983; Radomski et al., 1991). Elkins and Nickol (1983) and Bolette (1997a, b) considered reptiles in these instances to be paratenic hosts. Juvenile stages of oligacanthorhynchid acanthocephalans have also been recovered from reptiles in experimental procedures (Elkins and Nickol, 1983; Fahnestock, 1985).

The longnose snake, *Rhinocheilus lecontei* Baird and Girard, 1853, occurs from central Texas, southeastern Colorado, and southwest Idaho through southern California to central Baja California and in Mexico to San Luis Potosí and southern Tamaulipas at elevations from below sea level to around 1,650 m (Stebbins, 1985). *Rhinocheilus lecontei* is nocturnal and is active primarily in the spring (Klauber, 1941). Although its biology has been summarized by Medica (1975), the only information on parasites from this snake is from Bolette (1997b), who reported oligacanthorhynchid cystacanths from a single *R. lecontei* from Maricopa County, Arizona. The purpose of this note is to present prevalence and distribution data for oligacanthorhynchid cystacanths from populations of *R. lecontei* collected in southwestern North America.

Five hundred fifty-four *R. lecontei* were obtained from museum collections: 168 from Arizona State University (ASU), 194 from the Natural History Museum of Los Angeles County (LACM), and 192 from the University of Arizona (UAZ). These snakes were collected March–September 1939–1987. At the time of capture, the snakes were fixed in 10% formalin and then stored in 70% ethanol (ASU, LACM) or isopropanol (UAZ). A midventral incision was made in the body wall and the caudal portion of the body cavity and those organ surfaces

and mesenteries were visually checked for structure and appearance. Oblong whitish bodies, approximately 1 × 3 mm, were frequently seen; microscopic examination revealed encysted oligacanthorhynchid acanthocephalan cystacanths. Five cystacanths and surrounding tissues were embedded in paraffin by standard histological methods, sectioned at 5 μm, and stained with hematoxylin and eosin. Forty cystacanths were cleared in glycerol, and 20 cystacanths were bisected along the midlateral longitudinal plane and cleared in lactophenol. Voucher specimens were deposited in the U.S. National Parasite collection, Beltsville, Maryland (USNPC 86924). Terminology usage follows Bush et al. (1997).

Cystacanths were slightly flattened and somewhat annulated. The retracted proboscis was spherical and supported 36 hooks, 6 circles of 6 rows each. Hooks of the second circle were largest, and hooks of other circles progressively decreased in size. All hooks had distinctly asymmetrical roots, and the anterior root of hooks of the first, second, and third circles exhibited bifurcation to various degrees. Infections ranged from a few to many cystacanths per snake.

In section, cystacanths were surrounded by a delicate membranous envelope composed of flattened to low cuboidal mesothelial-type cells associated with a very thin collagenous stroma. There was no tissue inflammatory reaction in the host's tissue surrounding the cystacanth. No necrotic or calcified cystacanths were found.

One hundred sixty-one of the 554 (29%) *R. lecontei* were infected: males, 111/360; females, 48/161; juveniles, 2/33. There was no significant difference in infection rate between adult male and female snakes ($\chi^2 = 0.08$, 1 df, $P > 0.05$). There was a significant difference between adult and juvenile snakes ($\chi^2 = 9.11$, 1 df, $P < 0.001$); adults were more frequently infected.

Prevalence of cystacanths for *R. lecontei* examined in this study is listed by county for the United States and by state for Mexico in Table 1, and the distribution is plotted in Figure 1. Infection rates were not uniform across the range of *R. lecontei*. Heaviest infections occurred in central Arizona and northern Mexico. Infection prevalences of oligacanthorhynchid cystacanths in *R. lecontei* for Arizona were 134/311 (43%), for California were 4/107 (4%), for Texas were 2/23 (9%), and for Mexico were 21/53 (40%). In California, cystacanths were found only in

Table 1. Prevalence of oligacanthorhynchid cystacanths in *Rhinocheilus lecontei*.

State County	No. infected/ total snakes	Prevalence (%)
Arizona		
Cochise	9/30	30
Gila	5/10	50
Graham	2/5	40
Maricopa	18/77	23
Mohave	2/8	25
Pima	46/92	50
Pinal	44/68	65
Santa Cruz	3/11	27
Yavapai	5/8	63
Yuma	0/2	0
California		
Fresno	0/1	0
Imperial	0/4	0
Inyo	0/3	0
Kern	0/10	0
Los Angeles	0/4	0
Riverside	4/55	7
San Bernadino	0/14	0
San Diego	0/16	0
Nevada		
Nye	0/37	0
Clark	0/3	0
Lincoln	0/2	0
New Mexico		
Bernalillo	0/1	0
Doña Ana	0/5	0
Eddy	0/1	0
Hidalgo	0/1	0
Luna	0/1	0
Quay	0/1	0
San Miguel	0/2	0
Socorro	0/5	0
Texas		
Brewster	2/9	22
Coryell	0/1	0
Hudspeth	0/3	0
Llano	0/2	0
McLennan	0/1	0
Tom Green	0/3	0
Travis	0/1	0
Webb	0/1	0
Wise	0/1	0
Val Verde	0/1	0
Utah		
Washington	0/1	0
Mexico		
Baja California del Norte	1/8	13
Chihuahua	2/2	100
Coahuila	5/9	56
Durango	2/2	100
Sinaloa	2/6	33
Sonora	9/26	35

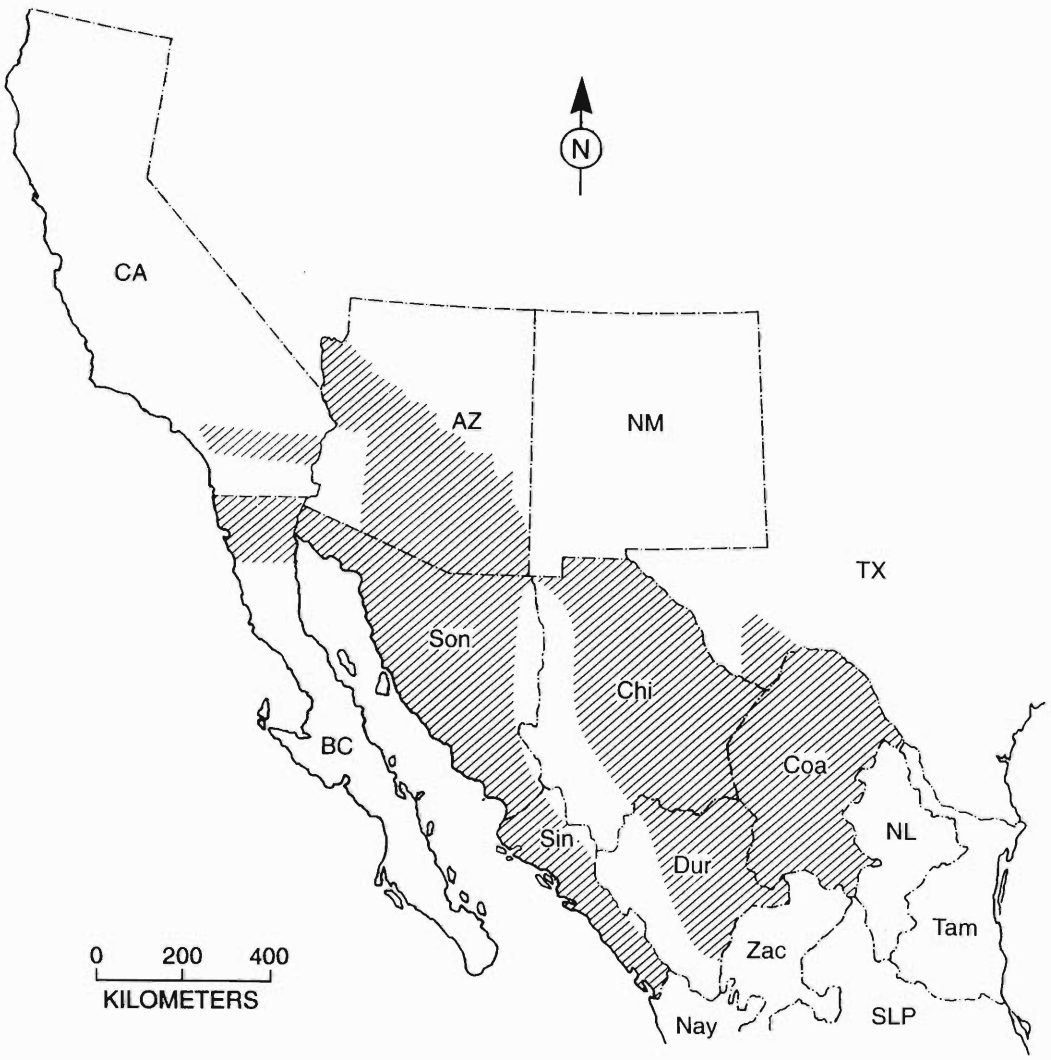

Figure 1. Map of Southwestern North America. Shaded sectors represent areas from which *Rhinocheilus lecontei* with oligacanthorhynchid cystacanths were found. Mexico: BC = Baja California; Coa = Coahuila; Chi = Chihuahua; Dur = Durango; Nay = Nayarit; NL = Nuevo Leon; Sin = Sinaloa; SLP = San Luis Potosí; Son = Sonora; Tam = Tamaulipas; Zac = Zacatecas.

snakes from Riverside County; in Texas, they were found only in snakes from Brewster County. No cystacanths were found in snakes from Nevada, (0/42), New Mexico (0/17), or Utah (0/1). The distribution pattern (Fig. 1) suggests that infected snakes are distributed primarily in Arizona and Mexico.

This is the fourth report of oligacanthorhynchid cystacanths from snakes of North America. Elkins and Nickol (1983) collected cystacanths from naturally infected *Agkistrodon piscivorous, Coluber constrictor, Lampropeltis getula, Nerodia cyclopion,* and *N. fasciata* from southern Louisiana and recovered cystacanths from experimentally infected *Thamnophis sirtalis, N. cyclopion,* and *N. fasciata.* Bolette (1997a) reported *Pachysentis canicola* from the western diamondback rattlesnake, *Crotalus atrox,* collected in Nolan County, Texas, and oligacanthorhynchid cystacanths from *Crotalus scutulatus* and *R. lecontei* collected in Maricopa County, Arizona (Bolette, 1997b).

For those acanthocephalans parasitic in terrestrial animals, the intermediate hosts are usually insects (Nickol, 1985). *Rhinocheilus lecontei* is known to eat insects (Stebbins, 1954) and thus might be expected to become infected. The significant difference in infection frequencies between adult and juvenile snakes may be a function of the number of insects eaten as well as the number of cystacanths in the insects eaten. Subsequent study will be required to more precisely determine the geographical distribution of the acanthocephalans found in this study; however, the absence of oligacanthorhynchid cystacanths in *R. lecontei* from Nevada, New Mexico, and much of California and Texas suggests an absence of definitive hosts in these areas.

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Research Note

The Effects of *Echinostoma trivolvis* Infection on the Fertility and Fecundity of Golden Hamsters (*Mesocricetus auratus*) and on the Infectivity of Their Progeny

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ABSTRACT: The effects of *Echinostoma trivolvis* infection on fertility and fecundity in the golden hamster (*Mesocricetus auratus*) was studied. The infectivity in the progeny from infected mothers was evaluated. The average litter size for infected hamsters was 8.4 ± 2.7 compared with 9.4 ± 4.0 ($P > 0.05$) from uninfected hamsters. Neonates from infected mothers showed decreased infectivity at ages 6, 7, and 8 wk postinfection. Neonates from uninfected mothers showed a greater infectivity when compared with animals born from infected mothers. The calculated percentage of resistance at 6, 7, and 8 wk of age was 48.9%, 69.3%, and 71.5%, respectively. Spleens from infected mothers showed a depletion of white pulp. The adrenal cortex from infected mothers was widened and composed predominately of lipid-poor reticularis-type cells.

KEY WORDS: *Echinostoma trivolvis*, fertility, fecundity, infectivity, *Mesocricetus auratus*.

Intestinal trematode infections are widespread in humans and animals. The factors that determine the innate resistance or susceptibility of a host to parasites are of considerable interest. Recent studies have centered on acquired resistance to echinostome infections in experimental rodent hosts. Little is known about the effects of helminths on their pregnant host. Bindseil and Hau (1991) showed that infection of BALB/cBOM mice with *Echinostoma caproni* had a negative influence on pregnancy; fewer fetuses were present in infected mice than in controls. Ovulation, fertilization, and egg implantation were not affected.

Pregnancy and lactation in the host do not appear to affect the course of cestode or trematode infections. Reproductive processes in the female host, however, increase susceptibility to infection with nematodes (Ogilvie and Jones, 1973).

Huffman and Fried (1990) suggested that a complex set of interrelating factors may govern the immune response in echinostome infections. The environment into which the young are born contains a myriad of infectious organisms from which the neonate must be protected. There are 2 routes whereby the neonate may gain protection from infectious organisms: via the placenta before birth and via colostrum and milk after birth (Paul, 1989). Both of these routes transfer maternal antibodies to the young (Carlier and Truyens, 1995).

The objectives of this study were to provide evidence for the effects of infection on fertility and fecundity in the golden hamster and to evaluate infectivity in the progeny from infected mothers. The relative adrenal and splenic weights and number of lymphatic nodules are reported from infected and noninfected animals. Parasite recovery, location, and dry weights are reported from infected animals.

Metacercarial cysts of *Echinostoma trivolvis* were obtained from the kidney and pericardial sac of laboratory-infected *Biomphalaria glabrata*. Outbred golden hamsters (*Mesocricetus auratus*) were obtained from the East Stroudsburg University Animal Care Facility. All animals were provided food and water ad libitum throughout the study.

Twenty-four female hamsters 20 wk of age were divided into 2 groups of 12 hamsters each. Group A was infected with 30 cysts of *E. trivolvis* per os, and group B animals were not infected. Fecal samples from group A hamsters were checked periodically to verify infection.

On day 52 postinfection (PI), all animals were bred after completion of 2 consecutive estrous cycles. Cyclicity was assessed by the presence of a postovulatory vaginal discharge on the morning after ovulation (Greenwald, 1962). Pregnancy was confirmed by obtaining a vaginal smear and staining with Papanicolau stain and identifying the characteristic cells present during

Table 1. Percentage of infectivity, relative splenic and adrenal weights, and number of lymphatic nodules for hamsters and mean worm dry weights.

Group*	Hamster age (wk)		% Infectivity	Mean (±SD) worm dry weight (mg)	Relative spleen weight ($\bar{x}$ ± SD)	Relative adrenal weight ($\bar{x}$ ± SD)	Mean (±SD) no. lymphatic nodules
	At infection	At necropsy					
A	20	36	39.7	1.70 ± 0.4	80.0 ± 5.0	35.0 ± 5.0	4.3 ± 1.9
B	20	36	0	0	118 ± 10.0	11.5 ± 5.0	3.6 ± 1.3
C	4	6	52.2	1.28 ± 0.1	100.3 ± 8.5	11.6 ± 3.2	3.6 ± 1.1
	5	7	67.6	2.09 ± 0.2	101.5 ± 19.6	12.8 ± 2.4	7.6 ± 1.2
	6	8	48.2	1.73 ± 0.1	85.9 ± 16.2	10.7 ± 3.7	6.8 ± 1.4
D	4	6	21.2	2.06 ± 0.6	108.6 ± 23.1	15.3 ± 3.3	5.3 ± 1.4
	5	7	20.7	1.50 ± 0.6	87.0 ± 20.8	15.3 ± 3.5	4.8 ± 0.7
	6	8	14.1	1.40 ± 0.4	100.0 ± 43.2	17.1 ± 0.8	5.3 ± 1.6

* A = infected mothers; B = uninfected controls; C = infected progeny from noninfected mothers; D = infected progeny from infected mothers.

pregnancy. The number, vigor, and average pup weight from both groups was recorded. Total pup weight was recorded daily for 2 wk postpartum.

The offspring from groups A and B were divided into 2 groups: group C consisted of 24 animals from uninfected mothers, and group D consisted of 24 animals from infected mothers. Sixteen juvenile hamsters from group C or group D were administered 15 cysts of *E. trivolvis* at 4, 5, or 6 wk of age. Eight hamsters from each group and from each age category were necropsied on day 14 PI. The hamsters from groups A and B were necropsied 16 wk PI. The small intestine was removed, and the serosal lymphatic nodules were counted. The intestine was opened, and the number of parasites was recorded and the percentage of infectivity was determined as follows:

$$\frac{\text{(number of parasites recovered)}}{\text{(number of cysts administered)}} \times 100.$$

The number of cysts administered was 30 for group A and 15 for groups C and D. The percentage of resistance was also calculated for the animals from groups C and D as follows (Christensen et al., 1986):

$$100 - [\text{(average worm burden of experimental group D)} \div \text{(average worm burden of control group C)}] \times 100.$$

The mean dry weight per worm was determined after drying the parasites from all the infected groups at 60°C for 48 hr. At necropsy, the relative splenic and adrenal weights were determined from all the groups as follows (Huffman et al., 1988):

$$\frac{\text{weight of organ (g)}}{\text{weight of hamster (g)}}.$$

Spleens were fixed in 10% neutral buffered formalin, dehydrated through a graded alcohol series, embedded in paraffin, sectioned at 6 μm, and stained with hematoxylin and eosin. For detection of lipids, adrenal glands were embedded at −20°C in O.C.T. (Ames Co., Elkhart, IN), sectioned at 8 μm on a CTF microtome-cryostat (International), and stained with oil red O in propylene glycol.

Student's *t*-test was applied to determine significance between experimental groups ($P < 0.05$).

There was no significant difference in the average litter size between infected hamsters (group A, 8.4 ± 2.7) and uninfected hamsters (group B, 9.4 ± 4.0). The litters from group A did not differ in weight when compared with controls when monitored daily for 2 wk postparturition.

At necropsy, gross pathology was noted for groups A, C, and D. The small intestine of the uninfected controls (Group B) typically had 2–5 enlarged serosal lymphatic nodules, $\bar{x}$ ± SD = 3.6 ± 1.3. Infected animals (group A) had 4.3 ± 1.9 (range, 0–7) lymphatic nodules. All parasites were found in the lower two-thirds of the small intestine.

The percentage of infectivity for groups A, C, and D are given in Table 1. In group C, the animals born from uninfected mothers showed a greater infectivity at ages 6, 7, and 8 wk when

compared with animals (group D) born from infected mothers. The calculated resistance for the various age classes at 6, 7, and 8 wk of age was 48.9%, 69.3%, and 71.5%, respectively.

Relative splenic weights decreased significantly ($P < 0.05$) in group A animals as compared with group B (uninfected) animals (Table 1). Histological examinations of spleens revealed a depletion of white pulp in spleens of group A as compared with those of group B. Spleens of groups C and D were not significantly different from each other.

Relative adrenal weight was greater in group A animals than in group B animals. Histologically, the cortex was widened and composed predominantly of lipid-poor reticularis-type cells. Differences between groups C and D were insignificant.

The mean dry weights of *E. trivolvis* adults from infected hamsters (groups A, C, and D) are shown in Table 1. No significant difference was observed between groups C and D. Group A worms were not compared with those of groups C and D because of the differences in worm ages.

Bindseil et al. (1990) reported that infection of BALB/cABom mice with *E. caproni* reduced mouse fertility, as determined on day 18 of pregnancy by counting and weighing fetuses from infected versus noninfected females. These researchers suggested that effects on fertility were not due to parasite-induced lesions in the intestine but to some undefined pathophysiological disorders. In the present study, average litter size was not significantly different between infected and uninfected mothers. Neonatal weights from group C were not significantly different from those of group D.

Group D hamsters, ages 6, 7, and 8 wk, demonstrated resistance of 48.9%, 69.5%, and 71.5%, respectively. These values provide a means for quantifying the infectivities of progeny from infected female hamsters. The increase in resistance may represent a transfer of antibody protection from infected females.

The decreased infectivity in group D animals may be the result of passive transfer of maternal antibodies. McMaster et al. (1995) reported that sera taken from hamsters 14 days after infection with *E. trivolvis* tested negatively for *E. trivolvis*-specific IgG by ELISA. Simonsen et al. (1991), utilizing ELISA, SDS-PAGE, western Blot, and indirect immunofluorescent antibody technique, examined serum antibody responses in golden hamsters infected with *E. caproni*. These methods showed that hamsters developed a delayed positive humoral response to the infection. In hamsters, an antibody response to *E. caproni* appeared at 11–13 wk PI. In rats and mice, IgG is acquired both before birth and after birth by maternal transfer. The availability of maternal IgG in offspring has been estimated to last between 1 and 2 mo for both mice and rats (Carlier and Truyens, 1995).

Relative splenic weights were significantly lower in group A hamsters than in hamsters from group B. Histological examination of spleens from group A showed that splenic atrophy was due to depletion of white pulp in response to chronic infection. The increased relative adrenal weights may reflect cortisol effects related to stress associated with infection (Cotran et al., 1989).

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Endorsement by the Helminthological Society of Washington of the Great Smoky Mountains National Park All-Taxa Biotic Inventory (ATBI)

The **Helminthological Society of Washington,** founded in 1910, has a rich and deep tradition of excellence in basic parasitology, focusing on taxonomy, systematics, ecology, and what is now recognized as biodiversity assessment through survey and inventory. Interdisciplinary and cross-cutting, parasitology links contemporary biodiversity studies with historical approaches to biogeography, ecology, and coevolution within a cohesive framework. Parasitology, among the most integrative of the biological sciences, provides data critical to elucidation of general patterns of global biodiversity.

The seminal importance of parasitology resides in part on the predictability of life cycles and on patterns of transmission that are dependent on historically continuous trophic associations within ecosystems. Consequently, helminths and other parasites can be indicators of habitat use, endemism, migratory patterns, and food web structure and track broadly and predictably across trophic levels as representatives of biological structure from the level of populations to that of communities. Thus, parasitology has exceptional relevance to broader studies in vertebrate and invertebrate biodiversity.

The **Helminthological Society of Washington** recognizes the contributions to be made by the Taxonomic Working Groups (TWIGS) for Endoparasites of Vertebrates and Ectoparasitic Arthropods of Vertebrates within the broader context of the Great Smoky Mountains National Park (GRSMNP) ATBI. Inclusion of these TWIGS in this biodiversity program has great significance for parasitology and is expected to directly augment TWIGS for free-living invertebrate and vertebrate faunas.

The **Helminthological Society of Washington** endorses the concept and foundations for GRSMNP ATBI. The **Society** will urge its membership to participate at appropriate levels in the development of this program to document biodiversity of this unique region of North America. Dissemination of information from the GRSMNP ATBI may be facilitated through peer-reviewed publication in the **Journal of the Helminthological Society of Washington.** The **Society** will promote the goals of the ATBI and the national and international partnerships for science and education represented by the umbrella project, Discover Life in America, centered at the GRSMNP. The **Society** endorses the broad opportunities for educational experiences linked to biodiversity and conservation management.

Additional information about the Great Smoky Mountain National Park All-Taxa Biodiversity Inventory, and the proposed activities of the taxonomic parasitological taxonomic working groups can be obtained from the following coordinators. Endoparasites of Vertebrates TWIG: Daniel R. Brooks (coordinator), Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1, phone: 416-978-3139, fax: 416-978-6665; Eric P. Hoberg (co–coordinator), USDA, Agricultural Research Service, Biosystematics and National Parasite Collection Unit, BARC-East, 1180, 10300 Baltimore Avenue, Beltsville, Maryland 20705, phone: 301-504-8588, fax: 301-504-8979, ehoberg@ggpl.arsusda.gov. Ectoparasitic Arthropods TWIG: Barry O'Connor (coordinator), Museum of Zoology, University of Michigan, Ann Arbor, Michigan 48109, phone: 313-763-4354; Lance Durden (co–coordinator), Institute of Arthropods and Parasites, Georgia Southern University, Landrum Box 8056, Statesboro, Georgia 30460, phone: 912-681-5564, fax: 912-681-0559, ldurden@gsvms2.cc.gasou.edu.

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A Proposal: New Name for the Journal of the Helminthological Society of Washington

The **Helminthological Society of Washington,** the founding society representing parasitology in North America, has an illustrious history extending over this century. Founded in 1910 by a dedicated group of parasitologists in the Washington, D.C. area, and for over the past 90 years, the **Society** has come to represent parasitology nationally and internationally. The identity of the **Society** has been linked firmly to its publication, the **Journal of the Helminthological Society of Washington**. Interests of members of the **Society** now encompass the diversity and complexity of organismal to molecular approaches in parasitology, but with a continuing focus on our traditional strengths in taxonomy, systematics, ecology and biodiversity research.

It was recently observed that perhaps the current name of the **Journal** did not reflect adequately the diversity of our membership. Moreover, broader recognition may be hindered because many individuals have considered us to be parochial and geographically limited. The situation is reflected in a limited readership, a gradually declining membership, and a perception that the **Journal** is restricted to helminthology, although manuscripts by protozoologists and acarologists are sporadically published.

It was within this context that the Executive Committee considered a proposal during the 658th Meeting in January 1998 for a new name to replace the **Journal of the Helminthological Society of Washington**. New names have been proposed that would reflect the scope and depth of the research programs of current and potential members and reflect the resurgence of interest in basic biology, natural history, ecology, population biology and biodiversity of parasites and their hosts: **Comparative Parasitology, Parasite Biodiversity, Integrative Biology of Parasites, Parasite Comparative Biology and Biodiversity**

At this time we are opening these deliberations to the membership at large. We solicit your comments on changing the identity of the **Journal**. We welcome your contributions to this process over the summer (to the President or Editor). At the first fall meeting (October 1998) we plan to present a written proposal to the membership; a vote will follow in November. This process is mandated by the constitution of the **Society**. A new name for the **Journal** will take effect with the January 2000 issue.

As we approach the new millennium, the **Society** must build on its foundations in basic parasitology and at the same time forge new linkages in the broader zoological community. The names above recognize the truly integrative and cross cutting nature of our discipline. We can use the unique multidisciplinary strengths of parasitology to integrate contemporary biodiversity research (from communities to molecules) and historical programs examining the complexity of coevolution and biogeography. We can effectively take actions to place us in a strong position for another century of contributions to parasitology.

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MINUTES

Six Hundred Fifty-Sixth Through Six Hundred Fifty-Ninth Meeting

656th Meeting: Naval Medical Research Institute, Bethesda, MD, 22 October 1997. Vice President Eric P. Hoberg presided over the business meeting and announced a slate of candidates for the coming year: Eric Hoberg for President, Ronald Neafie for Vice President, Pat Carney for Recording Secretary, and Harley Sheffield for Corresponding Secretary-Treasurer. Dr. Kevin Baird presided over the scientific session which consisted of three presentations: Dr. Baird's paper was on "Age-related characteristics of naturally acquired immunity to *Plasmodium falciparum*"; Dr. Daniel Carucci then demonstrated "Desk top computer video technology for the presentation of scientific information"; and Dr. Thong Le discussed "Clinical trials of malaria DNA vaccines."

657th Meeting: Sabang Indonesian Restaurant, Wheaton, MD, 19 November 1997. The Anniversary Dinner Meeting and Program was presided over by Vice President Eric P. Hoberg. Dr. Willis Reid, Jr. introduced the recipient of the Anniversary Award, Dr. Burton Y. Endo, United States Department of Agriculture, Nematology Laboratory, Beltsville, MD. In his acceptance comments, Dr. Endo reviewed the highlights of his career in the Nematology Laboratory. The slate of officers for 1998 was elected and installed: Eric P. Hoberg, President; Ronald Neafie, Vice President; and Patrick Carney, Recording Secretary. Corresponding Secretary-Treasurer, Harley Sheffield, and Editor, Sherman Hendrix continued in office.

658th Meeting: The Johns Hopkins University Montgomery County Center, Rockville, MD, 21 January, 1998. The business meeting was presided over by Dr. Eric Hoberg. An initiative to change the name of the *Journal* was discussed. It was suggested that the name should reflect the wide scope and depth of research papers that the *Journal* would like to attract. With the completion of his 5 year term, Sherman Hendrix is stepping down from editorship of the *Journal* which will change with the January, 1999 issue. Dr. Willis Reid, Jr. will assume the duties of Editor and, with the approval of the membership, Dr. Janet Reid will serve as Associate Editor. Dr. Thaddeus Graczyk presided over the scientific session which consisted of 4 presentations: Dr. Clive Shiff presented a "Review of seasonal distribution of schistosomal stages"; Dr. Gregory Curri-Glass provided a summary of "Hantaviruses in the USA'; Dr. Allen Scott discussed "From genes to parasites'; and Dr. Thaddeus Graczyk ended the session with a review of "Waterborne transmission of *Cryptosporidium parvum.*"

659th Meeting: U.S. Department of Agriculture, Nematology Laboratory, Beltsville, MD, 18 March, 1998. The business meeting was presided over by Dr. Eric Hoberg. There was further discussion of a proposal to change the name of the *Journal.* The President and Editor agreed to draft a message to the membership for inclusion in the July issue of the *Journal* in order to encourage feedback from the membership by e-mail, fax, or letter. Dr. David Chitwood presided over the scientific session which consisted of 3 presentations: Dr. Edward Masler reviewed his studies of "Nematode neuropeptides as a potential target of control"; Dr. Andrea Skantar summarized current knowledge of "Molecular genetics of developmental arrest in plant-parasitic nematodes"; and Dr. Susan Meyer provided an "Overview of Chinese research efforts to control nematodes that infect soybeans with fungi."

670th Meeting: The New Bolton Center, University of Pennsylvania, Kennett Square, PA, with the New Jersey Society of Parasitologists, 9 May, 1998. The business meeting was presided over by Dr. Eric Hoberg and Dr. Jay Farrell, University of Pennsylvania, chaired the scientific session which consisted of 3 presentations in a mini-symposium on "Modern Aspects of Parasitology." Dr. Christopher Hunter's paper was entitled "Pathogenic and protective responses to *Toxoplasma*"; Dr. Judy Appleton, Cornell University, discussed "Invasion of intestinal epithelium by a parasitic nematode, *Trichinella spiralis*"; Dr. Edward Pearce, Cornell University, re-

viewed "The role of nitric oxide during acute schistosomiasis." After the scientific session, Dr. Gerhard Schad provided closing remarks and invited participants to a reception at the Allam House, New Bolton Center.

The following new members were elected at the respective meetings: 658th: Charles Criscione, Christopher Pritchett, Monica Santin-Durin, and Leslie R. Warner; 659th: Jesem Abdul-Salam, David P. Bolette, Ramon A. Carreno, James R. Coggins, William H. Dees, Raymond M. Kaplin, Masataka Koga, J. Daniel McLaughlin, Steven Nadler, Thomas Nolan, Allen L. Richards, and Lic Liliana Semenas; 660th: Donald Linzey and Elizabeth Wright.

Obituary Notice

BRYCE C. WALTON

5 June 1923–10 May 1998

Elected to Membership at the

313th Meeting, 18 February 1953

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KEYWORD AND SUBJECT INDEX FOR VOLUME 65

The Helminthological Society of Washington

Application for Membership

Any person interested in parasitology or related fields is eligible for membership. Subscription to the Society's Journal is included in the dues. Members are privileged to publish therein at reduced rates. The annual dues of $25.00 domestic or $28.00 foreign are payable on notification of election. Send this completed form to:

Dr. Harley G. Sheffield
11831 Enid Drive
Potomac, MD 20854

Print name _____ Date of birth _____

Mailing address: _____

_____

_____

Degree and year received: _____

Present position: _____

Field of interest: _____

_____

Signature of applicant: _____ Date: _____

Signature of sponsor: _____
(a member)

ANNIVERSARY AWARD RECIPIENTS

*Edna M. Buhrer	1960	*Everett E. Wehr	1979
*Mildred A. Doss	1961	*O. Wilford Olsen	1980
*Allen McIntosh	1962	*Frank D. Enzie	1981
*Jesse R. Christie	1964	Lloyd E. Rozeboom	1982
*Gilbert F. Otto	1965	*Leon Jacobs	1983
*George R. LaRue	1966	Harley G. Sheffield	1984
*William W. Cort	1966	A. Morgan Golden	1985
*Gerard Dikmans	1967	Louis S. Diamond	1986
*Benjamin Schwartz	1969	Everett L. Schiller	1987
*Willard H. Wright	1969	Milford N. Lunde	1988
*Aurel O. Foster	1970	J. Ralph Lichtenfels	1989
*Carlton M. Herman	1971	A. James Haley	1990
*May Belle Chitwood	1972	Francis G. Tromba	1991
*Elvio H. Sadun	1973	Thomas K. Sawyer	1992
E. J. Lawson Soulsby	1974	Ralph P. Eckerlin	1993
David R. Lincicome	1975	Willis A. Reid, Jr.	1994
Margaret A. Stirewalt	1975	Gerhard A. Schad	1995
*Leo A. Jachowski, Jr.	1976	Franklin A. Neva	1996
*Horace W. Stunkard	1977	Burton Y. Endo	1997
*Kenneth C. Kates	1978		

HONORARY MEMBERS

*George R. LaRue	1959	E. J. Lawson Soulsby	1990
*Vladimir S. Ershov	1962	Roy C. Anderson	1991
*Norman R. Stoll	1976	Louis Euzet	1992
*Horace W. Stunkard	1977	John C. Holmes	1993
*Justus F. Mueller	1978	Purnomo	1994
John F. A. Sprent	1979	Naftale Katz	1995
Bernard Bezubik	1980	*Robert Traub	1996
Hugh M. Gordon	1981		

CHARTER MEMBERS 1910

*W. E. Chambers	*Philip E. Garrison	*Maurice C. Hall	*Charles A. Pfender
*Nathan A. Cobb	*Joseph Goldberger	*Albert Hassall	*Brayton H. Ransom
*Howard Crawley	*Henry W. Graybill	*George F. Leonard	*Charles W. Stiles
*Winthrop D. Foster			

LIFE MEMBERS

*Maurice C. Hall	1931	*Mildred A. Doss	1977
*Albert Hassall	1931	*Everett E. Wehr	1977
*Charles W. Stiles	1931	Marion M. Farr	1979
*Paul Bartsch	1937	John T. Lucker, Jr.	1979
*Henry E. Ewing	1945	George W. Luttermoser	1979
*William W. Cort	1952	*John S. Andrews	1980
*Gerard Dikmans	1953	*Leo A. Jachowski, Jr.	1981
*Jesse R. Christie	1956	*Kenneth C. Kates	1981
*Gotthold Steiner	1956	Francis G. Tromba	1983
*Emmett W. Price	1956	A. James Haley	1984
*Eloise B. Cram	1956	*Leon Jacobs	1985
*Gerald Thorne	1961	*Paul C. Beaver	1986
*Allen McIntosh	1963	*Raymond M. Cable	1986
*Edna M. Buhrer	1963	Harry Herlich	1987
*Benjamin G. Chitwood	1968	Glenn L. Hoffman	1988
*Aurel O. Foster	1972	Robert E. Kuntz	1988
*Gilbert F. Otto	1972	Raymond V. Rebois	1988
*Theodor von Brand	1975	Frank W. Douvres	1989
*May Belle Chitwood	1975	Thomas K. Sawyer	1989
*Carlton M. Herman	1975	*J. Allen Scott	1990
Lloyd E. Rozeboom	1975	Judith H. Shaw	1990
*Albert L. Taylor	1975	Milford N. Lunde	1991
David R. Lincicome	1976	Everett L. Schiller	1991
Margaret A. Stirewalt	1976	Harley G. Sheffield	1991
*Willard H. Wright	1976	Louis S. Diamond	1994
*Benjamin Schwartz	1976	Mary Hanson Pritchard	1994

*Deceased.

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