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Redescription of *Procyrnea uncinipenis* (Molin, 1860) (Nematoda: Habronematidae) based on material from *Rhea americana* (L.) (Aves: Rheidae)

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Abstract A detailed description of *Procyrnea uncinipenis* (Molin, 1860) (Habronematidae) is provided based on light- and scanning electron microscopy of newly collected material ex *Rhea americana* (L.) from a private conservation breeding park located in Cachoeiro de Itapemirim (State of Espírito Santo, Brazil). Of the four host specimens analysed, two were infected with *P. uncinipenis*; a total of 441 nematodes were collected in the proventriculus and gizzard. The specimens represented large nematodes, sexually dimorphic, with females larger than males, reddish *in vivo*, with two well developed lateral pseudolabia and two interlabia, one dorsal and one ventral, long oesophagus, divided into a muscular and glandular portion, didelphic ovaries, opisthodelphic uteri, two phasmids and a rounded chitinous structure near the caudal end. Males possess posterior extremity curved in spiral ventrally, with bilateral caudal alae and unequal in size and shape spicules. This study adds new morphological data, thus contributing to the knowledge on *P. uncinipenis*, a common parasite of *R. americana*.

This article is part of the Topical Collection Nematoda.

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Introduction

Rheas, *Rhea americana* (L.), are native to South America, where they inhabit almost the entire continent. Rheas are used as birds of ornamentation or commercially raised (Huchzermeyer, 2005). There are few studies investigating the parasitic fauna that affect the rheas; however, parasitosis is the main cause of limitation of the captive breeding of ratite birds (Ederli & Oliveira, 2014).

Procyrnea uncinipenis (Molin, 1860) is a spirurid nematode of the family Habronematidae Chitwood & Wehr, 1932, a parasite of the gastrointestinal tract of rheas that causes lesions in the gizzard and proventriculus, which can result in death when heavy parasite loads occur (Ederli & Oliveira, 2014). This species is apparently host-specific since it has not been found parasitising other species of birds, especially other ratites.

Three species of the Spirurida Railliet, 1914, have been reported in *R. americana*: *P. uncinipenis*, which lacks lateral alae along the body, has a spicule ratio of approximately 1:4 and is located in the gizzard; *P. waltoni* (Freitas & Lent, 1947), which also lacks lateral alae along the body and is located in the gizzard

but has a spicule ratio of approximately 1:8; and *Odontospirura zschokkei* (Railliet & Henry, 1911), which, unlike the previous species, has lateral alae along the body and is located in the proventriculus (Freitas & Lent, 1947a). Recently, another species, *P. choique* Bagnato, Frixione, Digiani & Cremonte, 2018 was described from the lesser rhea *Rhea pennata* d'Orbigny in Patagonia, Argentina (Bagnato et al., 2018). However, the morphology of these species has not been thoroughly elucidated to date. The present paper provides a redescription of *P. uncinipenis*, including details of its ultrastructure based on a scanning electron microscopy examination and elucidating missing data.

Materials and methods

Four adult rheas (2 males and 2 females) from a private conservation breeding park located in the city of Cachoeiro de Itapemirim in the State of Espírito Santo, Brazil, were necropsied, and the gastrointestinal tract was collected and examined for the presence of parasites. The contents of proventriculus and gizzard were passed through a sieve with 75 μm mesh, and the mucosa was observed under a stereomicroscope. The koilin membrane was removed and examined for the presence of nematodes. The collected specimens were washed in saline solution (0.65% NaCl). Some specimens were processed for light microscopy, and others were prepared for scanning electron microscopy.

Light microscopy

Nematodes were fixed in hot (70°C) AFA (ethanol: formaldehyde: glacial acetic acid at a ratio of 93:5:2) overnight, transferred to a solution containing 70% ethanol and 5% glycerin, cleared and mounted on slides with lactophenol (1 part distillated water, 2 parts glycerin, 1 part lactic acid, 1 part phenic acid) and observed under a light microscope.

Measurements are in micrometres unless otherwise stated, with the range followed by the mean in parentheses and are taken from mature adult specimens (20 males and 20 females) and 200 embryonated eggs *in utero* from multiple nematodes from different birds. Morphology was examined under an Axioplan Zeiss light microscope (Carl Zeiss, Germany) equipped with a Canon Power-Shot A640 digital camera (Canon, China) and Zeiss AxioVision Sample Image Software (Carl Zeiss, Germany) for image analysis. Drawings were performed with the aid of an Axioplan Zeiss light microscope (Carl Zeiss, Germany) that was equipped with a camera lucida and were digitized using Adobe Photoshop Elements 8.0 software with the aid of an Intuos4 Wacon® pen tablet (Wacon Co. Ltd., Japan). Transverse sections from the oesophageal, midbody and posterior regions of a male and a female were cut by hand with a curved bistoury surgical blade and mounted in glycerin jelly to allow the determination of the presence or absence of a synlophe.

Specimens of other species deposited at the Smithsonian National Museum of Natural History (NMNH) in Washington, D.C. (USA) were examined for comparative purposes as follows: (i) *Habronema uncinipenis* (USNM 1329748, voucher); (ii) *Odontospirura cetiopenis* (USNM 1329459, voucher; USNM 1329747, type); (iii) *Odontospirura alata* (USNM 1356305, voucher); and (iv) *Spirura* sp. (USNM 1329732, voucher) Representative specimens were deposited in the Harold W. Manter Parasite Collection at the University of Nebraska-Lincoln (UNL/USA) under the registration number HWML 67092.

Scanning electron microscopy

The nematodes were fixed for 2 h in 2.5% glutaraldehyde, 4% freshly prepared paraformaldehyde, and 5 mM calcium chloride in 0.1 M cacodylate buffer, pH 7.2, and postfixed in 2% osmium tetroxide in 0.1 M cacodylate buffer. The samples were dehydrated in an acetone series, critical-point-dried with CO_2, sputter-coated with gold and examined in a Zeiss 962 scanning electron microscope (SEM) operating at 15 kV.

Family Habronematidae Chitwood & Wehr, 1932

Genus *Procyrnea* Chabaud, 1958

Procyrnea uncinipenis (Molin, 1860)

Host: *Rhea americana* Linnaeus (Aves: Rheidae), greater rhea.

Locality: Cachoeiro do Itapemirim, State of Espírito Santo, Brazil.

Site in host: Proventriculus and gizzard.

Prevalence and intensity: In 2 out of 4 birds; mean intensity: 220.5 (range: 37–404).
Voucher material: 4 voucher specimens (HWML no. 67092).

Description (Figs. 1–6)

General. Females larger than males (body length ratio 1.49:1) (Tables 1 and 2), reddish *in vivo*; sexually dimorphic. Cuticle with transverse striations along body; synlophe absent. Lateral pseudolabia 2, well developed, interlabia 2, 1 dorsal and 1 ventral; pseudolabia trilobed, triangular-shaped, narrow at base, becoming wide towards free edge; ventral and dorsal lobes with one larger denticle directed to dorsal and ventral plane, respectively. Denticles: 2 major denticles near central lobe, bent toward each other and 3 smaller denticles facing anteriorly; central lobulation with 1 long central denticle and 4 smaller denticles on each side thereof. Interlabia formed by 3 lobes, 2 lateral triangular-shaped and a central dumbbell-shaped lobe; central lobe articulates, fitting between lateral pseudolabia; lateral lobes fit into base of lateral pseudolabia. Oral opening small, surrounded by cup-like suction structure. Cephalic papillae 4, circular, submedian, located laterally to base of pseudolabia. Amphids 2, circular-shaped, on pseudolabia. Buccal capsule well developed; oesophagus long, divided into anterior muscular and posterior glandular portion; oesophago-intestinal valve poorly developed; cervical papillae rounded.

Male [Measurements based on 20 specimens; Table 1.] Males smaller than females (Table 1); length 22–31 (25) mm; maximum width at mid-body region 659–827 (752); body width at anterior region 149–181 (162), at oesophagus base 591–823 (686), at level of nerve-ring 282–373 (324), at level of excretory pore 302–318 (310). Buccal cavity 46–68 (60) deep, 24–40 (31) wide; muscular oesophagus 351–455 (396) long, with maximum diameter at anterior region 74–108 (88); glandular oesophagus 2,685–3,568 (3,127) long, with maximum diameter at posterior region 164–249 (208); ratio oesophagus total length: total body length 1:0.14. Nerve-ring at 282–490 (405), excretory pore at 529–658 (586), cervical papillae at 361–411 (384) from anterior extremity. Posterior extremity curved in spiral ventrally; bilateral caudal alae present, ornamented with linear interrupted ridges 2,455–3,776 (3,246) long, 237–347 (296) wide; central area with longer, more widely-spaced ridges than lateral regions; ratio total body length: caudal alae length 1:0.13. Cloacal aperture 419–776 (585) from posterior extremity; body width at level of cloaca 354–585 (469). Precloacal papillae 8, rounded, with bilateral symmetry. Postcloacal papillae 4, disordered. Ad-cloacal papilla single, larger than precloacal and postcloacal papillae. Spicules unequal in size and shape; left spicule long, thin; right spicule short, thick. Left spicule: total length 3,206–3,774 (3,494); maximum width 34–61 (40); neck width 35–56 (46); head width 66–101 (81); distal end with thinner projection at the tip 105–161 (131) long. Right spicule: total length 740–982 (849); maximum width 35–54 (46); neck width 41–70 (51); head width 66–110 (93); distal end curved, hook-shaped, with dilation at tip 20–48 (31) long. Ratio total body length: left and right spicule length, 1:0.14 and 1:0.03, respectively. Ratio left spicule: right spicule length 1:4.13. Gubernaculum well sclerotised, 102–169 (137) long, 51–99 (72)

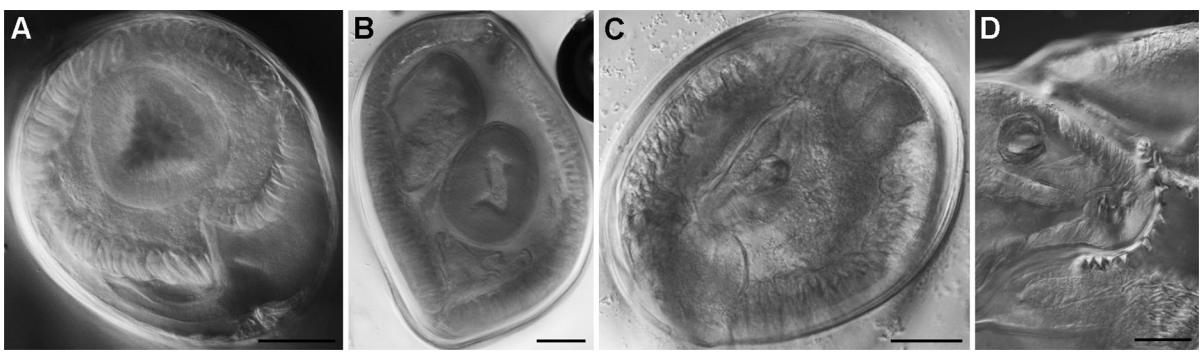

Fig. 1 Cross-sections of *Procyrnea uncinipenis* ex *Rhea americana* at different body regions (light microscopy, DIC). A, At level of oesophagus; B, Male, at mid-body length; C, Female, at posterior body region; D, Male, posterior body region. *Scale-bars*: 100 μm

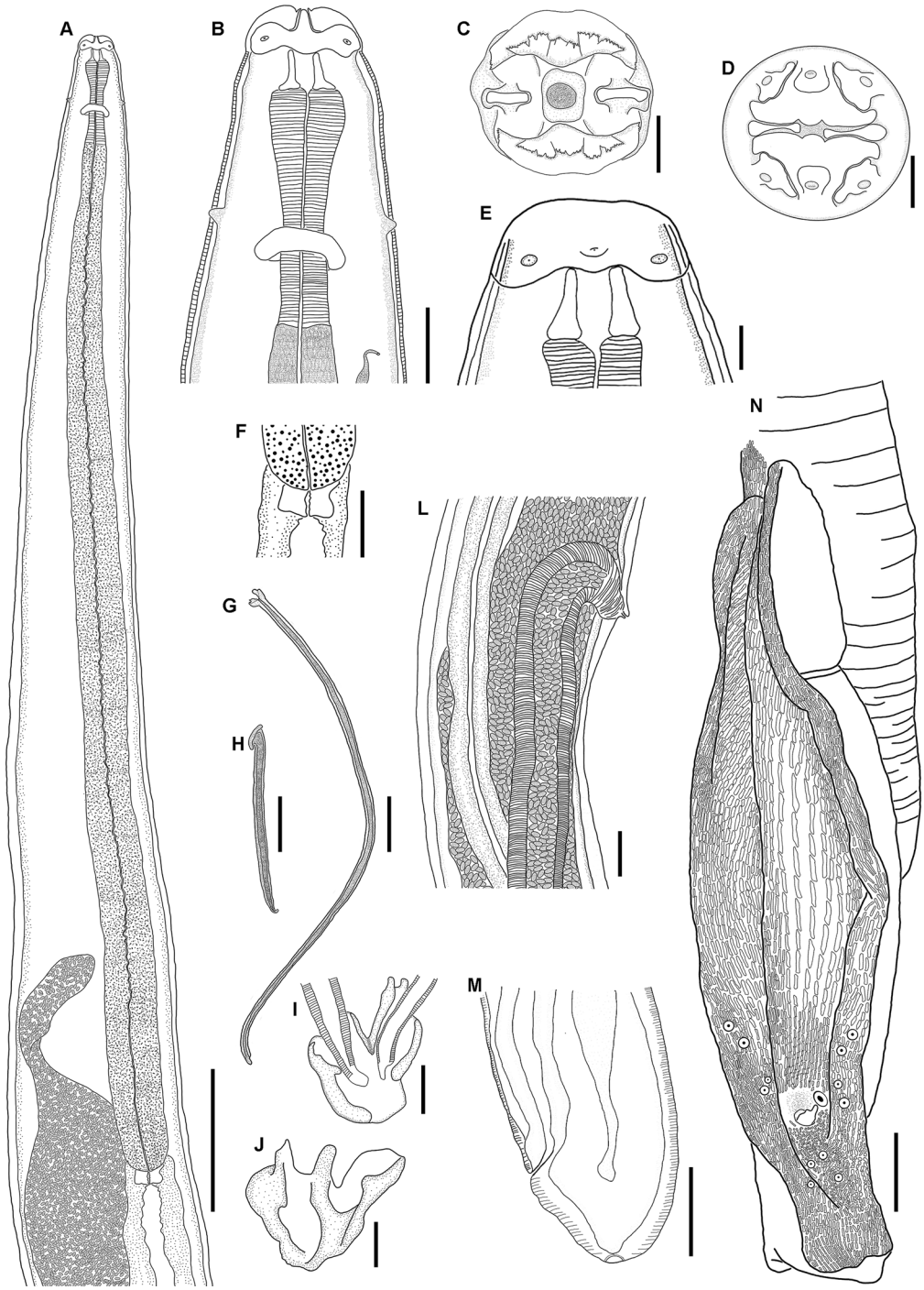

Fig. 2 Line drawings of *Procyrnea uncinipenis* ex *Rhea americana*. A, Anterior region of the body showing muscular and glandular oesophagus, ventral view; B, Anterior extremity, details (buccal cavity, cervical papillae, nerve-ring, excretory pore and muscular oesophagus), ventral view; C, Anterior extremity, apical view with open labia; D, Anterior extremity, apical view with closed labia; E, Anterior extremity, lateral view; F, Oesophago-intestinal valve; G, Left spicule; H, Right spicule; I, Gubernaculum with distal ends of spicules; J, Gubernaculum; L, Region of vulva, lateral view; M, Female, posterior extremity, lateral view; N, Male, posterior extremity, ventral view. *Scale-bars*: A, 1,500 μm; B, G, H, L–N, 250 μm; C–E, I, J, 50 μm; F, 25 μm

wide, formed by a double V-shaped structure, where each spicule passes through one of its units.

Female [Measurements based on 20 specimens; Table 2.] Females longer than males (Table 2); length 35–43 (38) mm; maximum width at mid-body region 887–1,055 (963); body width at anterior region 173–227 (196), at level of oesophagus base 693–952 (839), at level of nerve-ring 342–562 (413), at level of excretory pore 411–430 (421), at level of vulva 821–998 (911), at level of anus 356–623 (407). Buccal cavity 44–80 (69) deep, 30–48 (41) wide; muscular oesophagus 393–737 (496) long, with maximum width at anterior region 78–143 (97); glandular oesophagus 3,350–4,684 (3,881) long, with maximum width at posterior region 195–360 (264); ratio oesophagus total length: total body length 1:0.11. Nerve-ring at 387–786 (529), excretory pore at 652–804 (697), cervical papillae at 319–952 (608) from anterior extremity. Ovaries didelphic, uteri opisthodelphic. In adult worms, uterine loops occupy large part of the body, filled with embryonated eggs. Uterine vagina muscular 162–346 (202) wide; vulva with small prominent lips, opening a transverse slit in mid-body region, at 13,596–17,766 (15,649) from posterior extremity. Anus opening a transverse slit; tail 180–287 (235) long; 2 phasmids and 1 rounded chitinous structure present near caudal end. Eggs small, 35–51 × 21–32 (45 × 26), with thick, smooth shell, bi-operculated, containing larvae.

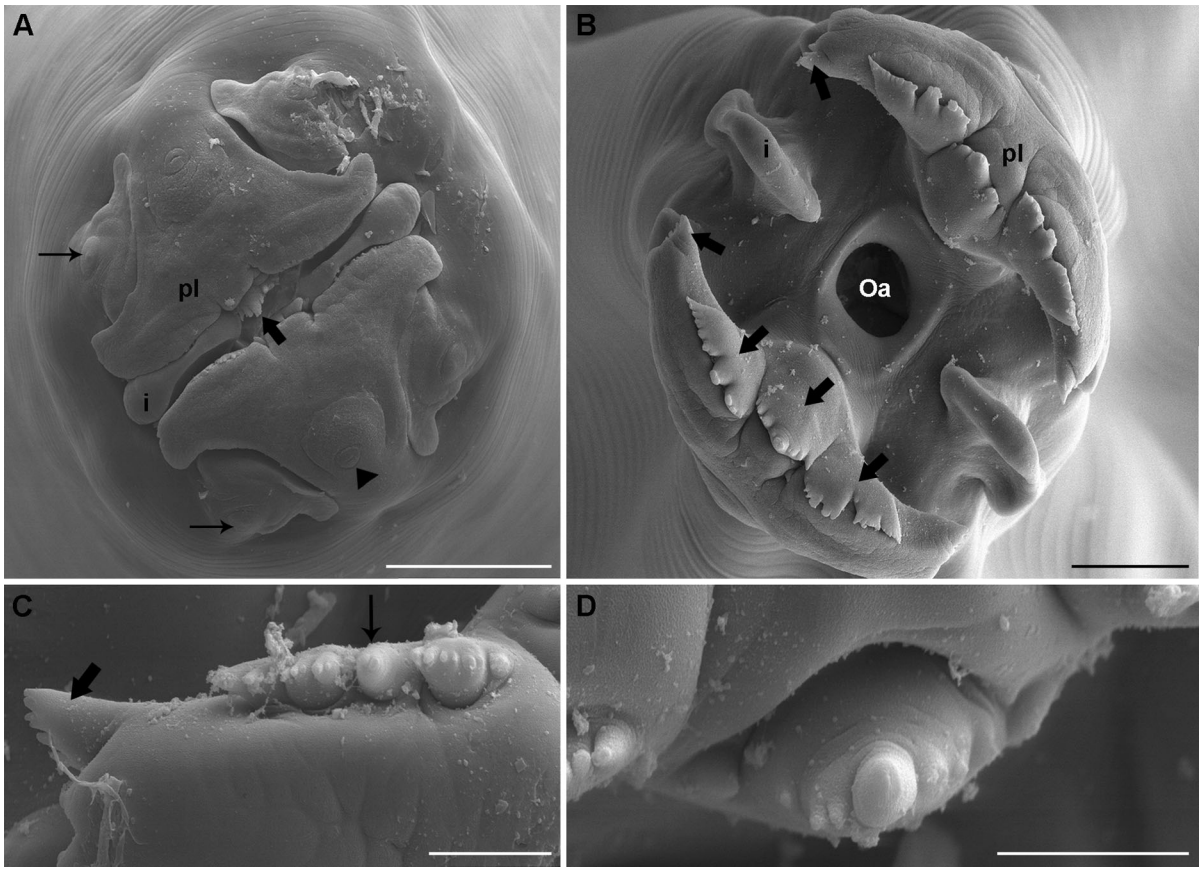

Fig. 3 Scanning electron micrograph of anterior extremity of *Procyrnea uncinipenis* ex *Rhea americana*. A, Lateral pseudolabia (li), amphidis (*arrowhead*), labial papillae (*narrow arrows*), pseudolabia denticules (*thick arrow*); B, Oral aperture (Oa), lateral pseudolabia (li), dorsal and ventral interlabia (i) and pseudolabia denticles (*arrows*); C, Enlargement of the lateral lobe of the pseudolabia, showing a larger denticule at the extremity of the pseudolabia (*thick arrow*) and a group of denticles (*narrow arrow*); D, Enlargement of the central lobe of the pseudolabia, with group of denticles. *Scale-bars*: A, B, 50 µm; C, D, 10 µm

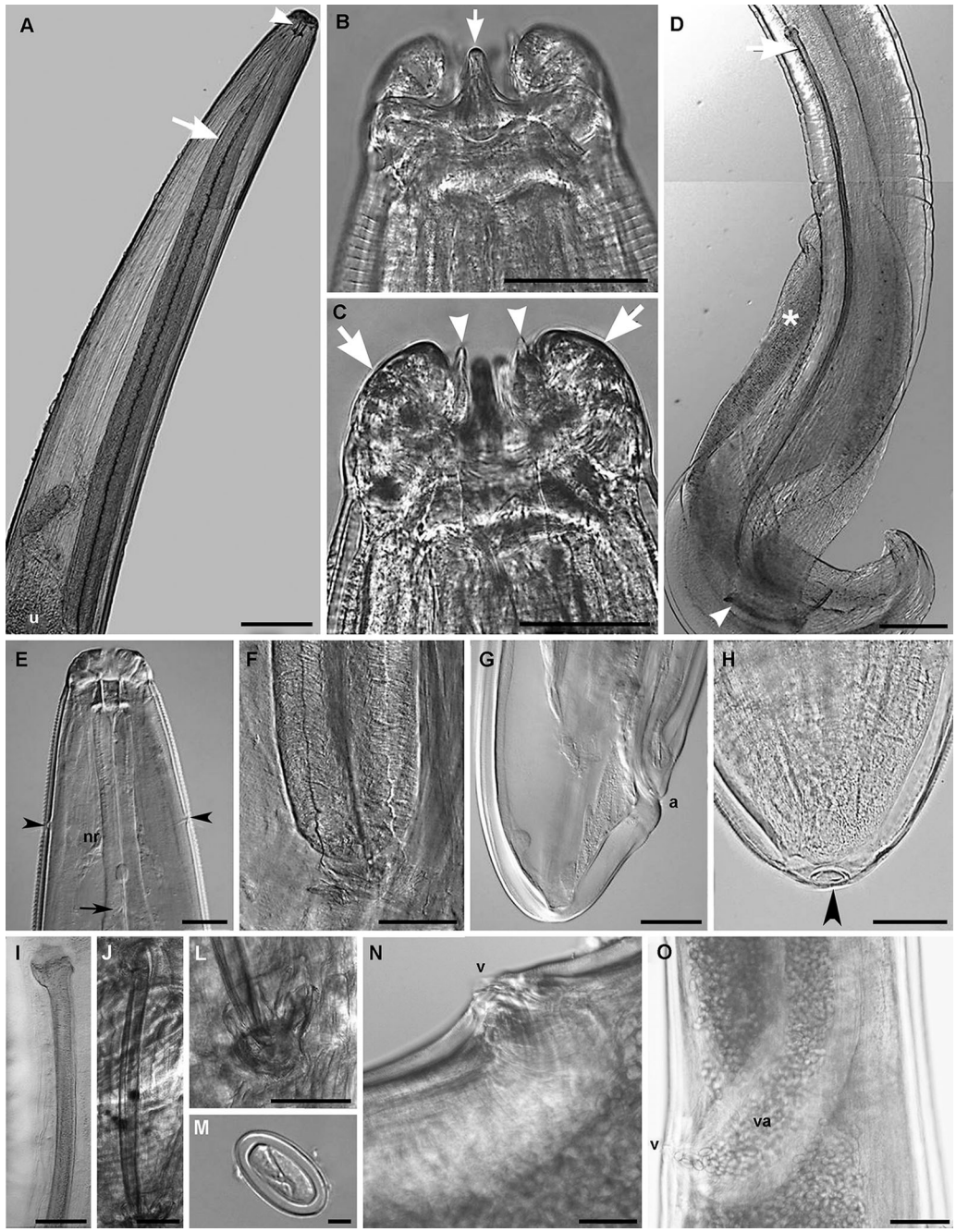

Fig. 4 *Procyrnea uncinipenis* ex *Rhea americana* (light microscopy, DIC). A, Anterior region showing buccal cavity (*arrowhead*), oesophagus (*arrow*), and a portion of the uterus filled with eggs (u), lateral view; B, Anterior extremity, ventral view, showing ventral interlabia (*arrow*); C, Anterior extremity, ventral view, showing lateral pseudolabia (*arrows*) with denticles (*arrowheads*); D, Posterior region of a male specimen, showing left spicule (*arrow*), right spicule (*arrowhead*), and caudal alae (*); E, Anterior extremity showing muscular oesophagus, nerve-ring (nr), a pair of cervical papillae (arrowheads), and the border between the muscular and glandular oesophagus (*arrow*); F, Distal end of the oesophagus, showing oesophago-intestinal valve; G, Female, posterior extremity showing anus (a); H, Female, posterior extremity showing the circular structure at the tip tail (*arrowhead*); I, Left spicule, proximal end; J, Right spicule; L. Gubernaculum with distal ends of spicules; M, Larvated egg; N, Region of vulva, showing vulva opening (v), followed by a muscular vagina; O, Anterior portion of the muscular vagina (va) filled with eggs, and vulva opening (v). *Scale-bars*: A, 300 μm; B, C, E–L, N, O, 100 μm; D, 200 μm; M, 10 μm

Discussion

Molin (1860) described *P. uncinipenis* as *Spiroptera uncinipenis* Molin, 1860. Later, Zschokke (1889) briefly described another species, *Spiroptera alata* Zschokke, 1889 (syn. of *Odontospirura zschokkei)* based on a male specimen collected from the proventriculus of a rhea from a zoo in Brazil however not describing the spicules (see Freitas & Lent, 1947a), which are extremely long, thin and subequal in length in this species (Wehr, 1933). However, this description indicates some characteristics worthy of consideration, such as the presence of cuticular alae along the body and the microhabitat (proventriculus), which differ from the species described by Molin, *P. uncinipenis*, which was reported to be located in the gizzard. However, in the present study, *P. uncinipenis* was observed in one of the birds in both microhabitats, proventriculus and gizzard. Recently, based on light and SEM microscopy studies, another species of *Procyrnea* Chabaud, 1858 was described from the proventriculus of another species of rhea, *R. pennata*, with the lateral alae lacking, *P. choique* (see Bagnato et al., 2018).

The classification of *P. uncinipenis* has long been the target of studies mainly in relation to its systematics and morphology. Freitas & Lent (1947a) reviewed the genus *Sicarius* from rheas (syn. of *Procyrnea*, see Chabaud, 1958), redescribed *S. uncinipenis* (syn. of *P. uncinipenis*), and described *S. waltoni* (syn. of *P. waltoni*) and the genus *Vaznema* Freitas & Lent, 1947 where he placed *S. zschokkei* (syn. of *O. zschokkei*), differentiating them based on the presence of lateral alae along the body and the spicular ratio. According to these authors, there are three species of spirurid nematodes that infect *R. americana*: *P. uncinipenis* and *P. waltoni*, located in the gizzard, and *O. zschokkei*, located in the proventriculus, all possessing trilobed pseudolabia with small denticles and interlabia. *Odontospirura zschokkei* differs from the other two species by the presence of clear cervical alae on the left side of the body, ending at the level of the middle of the oesophagus in males and extending to the posterior region of the body in females, where they become less prominent, and by spicules that are subequal in size (Table 1). In addition, this species exhibits 11 pairs of caudal papillae (3 pairs precloacal, relatively robust, and decreasing in size towards the posterior end; 1 pair adcloacal and smaller than precloacal pairs; and 7 pairs post-cloacal, 3 of which are close to the cloaca opening and clearly pedunculated and 4 pairs of which are smaller and weakly pedunculated). Females have one pair of phasmids and one cuticular circular protuberance at the tip of the tail (Freitas & Lent 1947a).

In his original description, Molin described the species *Spiroptera uncinipenis* (syn. of *P. uncinipenis*) with a spicular ratio of 1:4, and subsequent studies by Diesing (1861), Drasche (1884), Railliet & Henry (1911) and Vaz (1936) also reported this ratio, indicating they have dealt with *P. uncinipenis*. However, Leidy (1890), Linstow (1889) and Walton (1927) described this species with a spicular ratio of 1:8 (see Freitas & Lent, 1947a). Due to this difference in the spicular ratio, Freitas & Lent (1947a) considered the latter records to be for a different species, *P. waltoni* (syn. *Sicarius waltoni*), located in the gizzard of the rhea.

According to the descriptions of the three species mentioned above and the morphological and morphometric investigation performed in the present study, the nematodes collected from the proventriculus and gizzard of rheas from Brazil were identified as *P. uncinipenis*. However, it can be inferred that the descriptions of the other two species, *P. waltoni* and *O. alata*, are still confused probably due to mixed infections with these three species and mixed descriptions of the characteristics, which should be studied more thoroughly *via* experimental infections by these species if possible, allowing the study of males and females of each species separately.

In the specimens described in the present study, no lateral alae were observed in both males and females (Fig. 4A), discarding the possibility of the material to belong to *O. alata*, and the spicular ratio observed was approximately 1:4, as described for *P. uncinipenis*. Light and scanning electron microscopy revealed the presence of a pair of phasmids close to the posterior extremity in females and a circular structure at the tail tip (Figs. 4H and 6C). According to Freitas & Lent (1947a), *O. alata* possesses these phasmids (described by the authors as papillae), a fact not described by other authors for the species of *Procyrnea* (syn. *Sicarius*) parasites of the rhea, which suggests a possible mixture of species in the previous descriptions. In the present study, no small sensilla were observed at the tail region of the males in the SEM

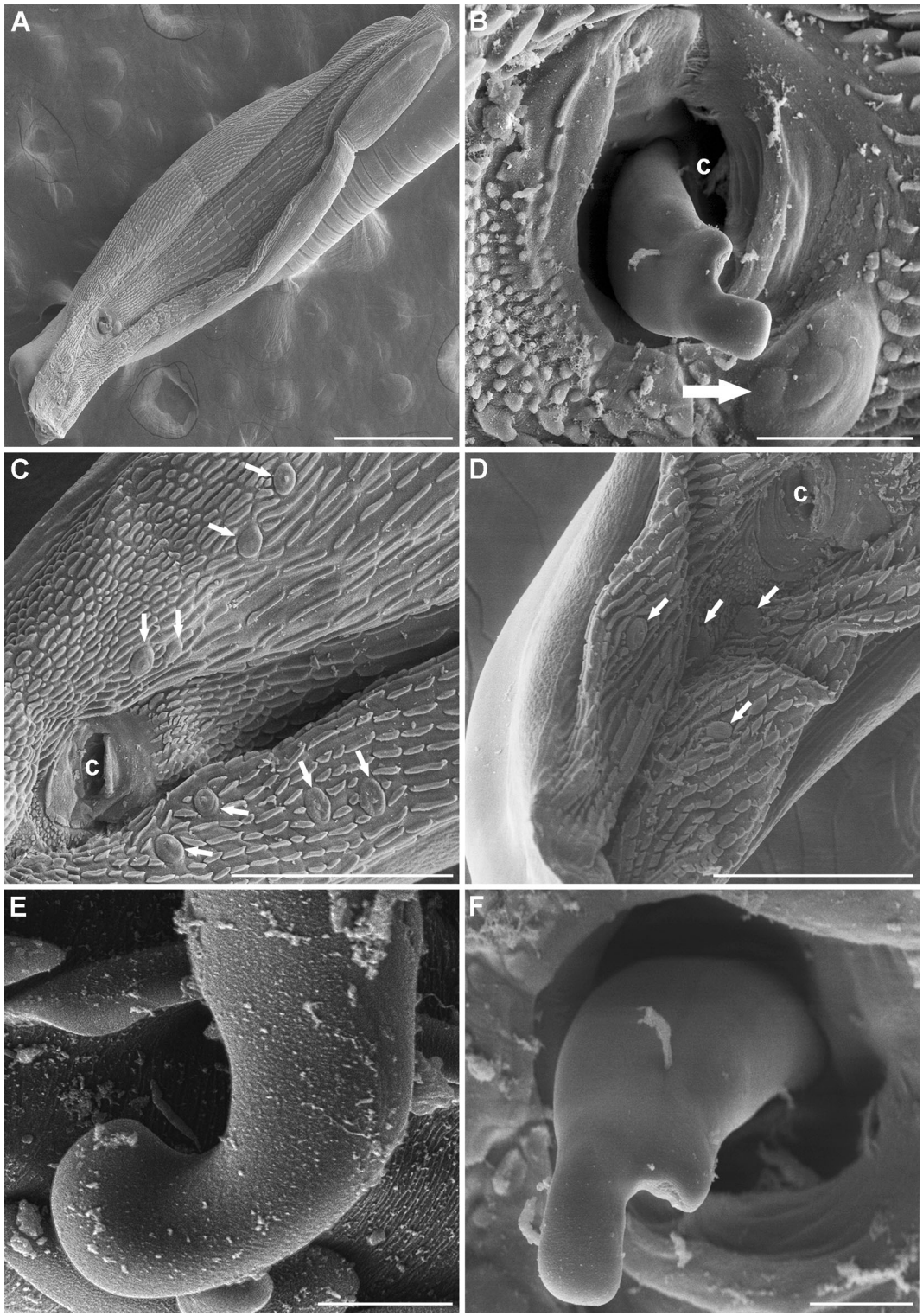

Fig. 5 Scanning electron micrographs of the posterior extremity of male *Procyrnea uncinipenis* ex *Rhea americana*. A, Caudal alae; B, Ad-cloacal papillae (*arrow*), near cloaca opening (c); C, Precloacal papillae (*arrows*) and cloaca (c); D, Postcloacal papillae (*arrows*) and cloaca (c); E, Right spicule, distal end; F, Left spicule, distal end. *Scale-bars*: A, 1 mm; B, 50 µm; C, D, 200 µm; E, 10 µm; F, 20 µm

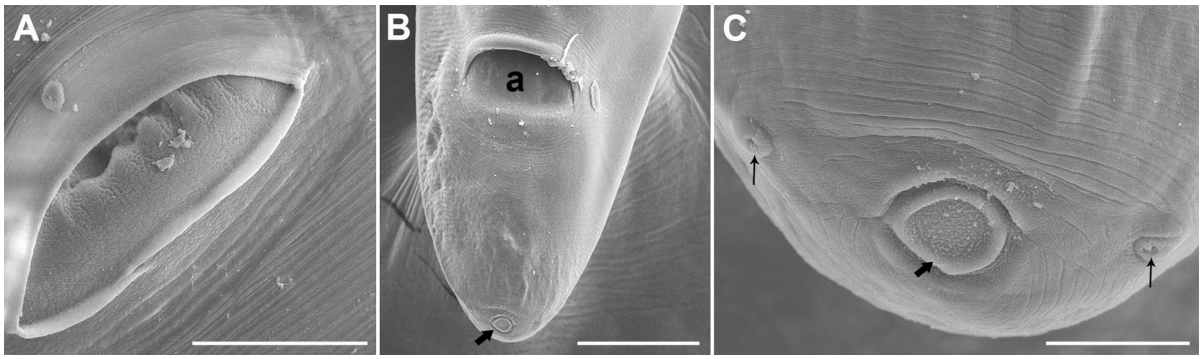

Fig. 6 Scanning electron micrographs of females of *Procyrnea uncinipenis* ex *Rhea americana*. A, Vulva; B, Posterior extremity, showing anus (a) and circular structure at the tip tail (*arrow*); C, Enlargement image of the tip of female tail, showing a pair of lateral papillae (*narrow arrows*) and the circular structure (*thick arrow*). *Scale-bars*: A, 50 µm; B, 100 µm; C, 20 µm

Table 1 Metrical data for males of spirurid nematodes parasitic in rheas

Species	*Procyrnea uncinipenis*			*P. waltoni*	*P. choique*	*Odontospirura zschokkei*
Host	*Rhea americana*			*R. americana*	*R. pennata*	*R. americana*
Source	Present study	Freitas & Lent (1947b)	Vaz (1936)[b]	Walton (1927)[c]	Bagnato et al. (2018)[d]	Freitas & Lent (1947b)[e]
Body length (mm)	22.55–30.98 (25.41)	17.75–21.77	25–28	20	8.25–9.85	15.91–17.42
Body width	659–827 (752)	600–740	600–700	700	350–400	470
Buccal cavity length	46–68 (60)	55–63	62	120–130	30–40	55–67
Buccal cavity width	24–40 (31)	67–84	37	–	25–30	42–55
Muscular oesophagus length	351–455 (396)	300–360	400–420	425–450	200–300	500–530
Muscular oesophagus width	74–108 (88)	70–83	–	–	40	61–70
Glandular oesophagus length	2,685–3,568 (3,127)	2,660–3,650	3,220–3,400	2,600–2,900	2,640–3,560	3,650–3,730
Glandular oesophagus width	164–249 (208)	170–230	–	–	80–120	200–220
Nerve-ring[a]	282–490 (405)	330–390	420	360–400	120–200	330–360
Excretory pore[a]	529–658 (586)	500–610	–	–	250–290	–
Cervical papillae[a]	361–411 (384)	290–340	–	–	140–180	360–410
Right spicule length	740–982 (849)	660–800	700–720	300–420	300–360	10,290–10,620
Left spicule length	3,206–3,774 (3,494)	3,000–3,700	3,050–3,170	2,400–2,650	970–1,050	10,870–11,120
Right spicule: Left spicule length	1:4	1:4	1:4	1:8	*c.*1:4	Subequal
Gubernaculum length	102–169 (137)	110–140	100	–	60–80	100–110

[a]Distance to anterior extremity; [b]Described as *Sicarius nobregai* (syn. of *P. uncinipenis*); [c]Described as *S. uncinipenis* (synonym of *P. waltoni*); [d]Parasite of *Rhea pennata*; [e]Described as *Vaznema zschokkei* (syn. of *O. zschokkei*)

Table 2 Metrical data for females of spirurid nematodes parasitic in rheas

Species	*Procyrnea uncinipenis*			*P waltoni*	*P. choique*	*Odontospirura zschokkei*
Host	*Rhea americana*			*R. americana*	*R. pennata*	*R. americana*
Source	Present study	Freitas & Lent (1947b)	Vaz (1936)[c]	Walton (1927)[d]	Bagnato et al. (2018)[e]	Freitas & Lent (1947b)[f]
Body length (mm)	35.17–43.32 (37.98)	26.46–33.16	33–36	25	13.4–17.8	16.75–25.12
Body width	887–1,055 (963)	670–800	700–900	750	400–600	400–670
Buccal capsule length	44–80 (69)	52–70	62	120–140	45–50	50–63
Buccal capsule width	30–48 (41)	78–96	37	–	30–40	34–50
Muscular oesophagus length	393–737 (496)	320–410	400–420	390–410	340–460	450–560
Muscular oesophagus width	78–143 (97)	91–104	–	–	40–55	59–67
Glandular oesophagus length	3,350–4,684 (3,881)	3,490–3,980	3,220–3,400	3,250–3,550	1,870–5, 300	3,570–4,510
Glandular oesophagus width	195–360 (264)	220–230	–	–	70–80	220–250
Nerve-ring[a]	387–786 (529)	390–400	420	360–400	250–330	350–400
Excretory pore[a]	652–804 (697)	530–650	–	–	350–550	–
Cervical papillae[a]	319–952 (608)	340–400	–	–	170–230	430–510
Vulva (mm)[b]	13.60–17.77 (15.65)	11.05–12.06	16.3–16.5	6.6–7.1	6.2–7.1	6.03–9.55[a]
Tail length	180–287 (235)	220–250	260	260	80–100	220–280
Egg length	35–51 (45)	46–50	47	45–50	50–55	46
Egg width	21–32 (26)	25	25	24–26	30–35	17

[a]Distance from anterior extremity; [b]Distance from posterior extremity; [c]Described as *Sicarius nobregai* (syn. of *P. uncinipenis*); [d]Described as *S. uncinipenis* (syn. of *P. waltoni*); [e]Parasite of *Rhea pennata*; [f]Described as *Vaznema zschokkei* (syn. of *O. zschokkei*)

images, as described by Vaz (1936) for *S. nobregai* Vaz, 1936 (syn. of *P. uncinipenis*), by Walton (1927) and Freitas & Lent (1947a) for *S. uncinipenis* (syn. of *P. uncinipenis*), and by Sharma (1971) for *Sicarius hoopoe* Sharma, 1971, a parasite of *Upupa epops* L., a bird of the order Upupiformes.

Freitas & Lent (1947a) described the females as didelphic and amphidelphic with a rounded vulvar opening and a long ovejector directed towards the posterior region. However, the nomenclature of the ovejector with direction from the anterior to the posterior region should be opisthodelphic and not amphidelphic, as described by Freitas & Lent (1947a). The same authors also mistakenly named the same structure in *Deletrocephalus dimidiatus* Diesing, 1851, a strongylid nematode parasite located in the intestine of *R. americana*, which they described as opisthodelphic (Freitas & Lent, 1947b), but it is prodelphic. However, in both studies, the authors described the direction of the structure correctly, erring only regarding its nomenclature. In the present study, through SEM, a transverse vulva aperture, not rounded as described by Freitas & Lent (1947a), was observed (Fig. 6A).

The measurements of the specimens of the present study are in agreement with the descriptions of the other authors (Vaz, 1936; Freitas & Lent, 1947a) (Tables 1 and 2). The larger width of the buccal cavity in the description of Freitas & Lent (1947a) is due to the place where the measurement was taken, i.e. from the outer edge, while in this study, we measured the internal width of the buccal cavity (Tables 1 and 2).

Comparative data for the spirurid parasites of the rhea reveal that both males and females of *P. uncinipenis* are larger than those of *P. waltoni* and *O. zschokkei* (Tables 1 and 2). The smallest species is *P. choique* (see Bagnato et al., 2018). Furthermore, *P. waltoni* has a longer buccal cavity than *P. uncinipenis* but with a similar width (Tables 1 and 2).

In females, the measurements are similar (except in *P. choique* from *R. pennata*) (Table 2), so it is only possible to distinguish *O. zschokkei* from *P. uncinipenis* and *P. waltoni* by the presence of cephalic alae in *O. zschokkei*. However, there is no diagnostic character that separates females of the genus *Procyrnea* from *R. americana*. A future study of females of *P. waltoni* is necessary in order to identify possible morphological differences to distinguish the females of these species and in order to redescribe the ultrastructure of *O. alata* to elucidate the morphology of the spirurid species parasitic in the rhea.

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Compliance with ethical standards

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

Ethical approval All applicable institutional, national and international guidelines for the care and use of animals were followed (IBAMA no. 18981-1).

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