# Two New Species of *Camallanus* (Nematoda: Camallanidae) From Freshwater Turtles in Queensland, Australia

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# TWO NEW SPECIES OF *CAMALLANUS* (NEMATODA: CAMALLANIDAE) FROM FRESHWATER TURTLES IN QUEENSLAND, AUSTRALIA

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ABSTRACT: We describe 2 new species of *Camallanus* (Nematoda: Camallanidae) from freshwater turtles collected in Queensland, Australia: *Camallanus nithoggi* n. sp. from *Elseya latisternum* (Gray) and *Camallanus waelhreow* n. sp. from *Emydura krefftii* (Gray), *Emydura macquarrii* (Gray), and *Em. macquarrii dharra* Cann. The only *Camallanus* sp. previously reported from turtles is *C. chelonius* Baker, 1983 (all other species in the family have been transferred to *Serpinema*). The 2 new species described here differ from *C. chelonius* in the number of male preanal papillae (7 vs. 6 in *C. chelonius*), the number of male postanal papillae (5 vs. 4 in *C. chelonius*), and the number of buccal capsule ridges. Additionally, we removed the tissues overlying the buccal capsule and used scanning electron micrographs (SEM) to show that the peribuccal shields extend laterally from the buccal capsule, the basal ring is separated from the buccal capsule by a narrow isthmus, and there is a buttress along the lateral margin of the buccal capsule that has not previously been observed in species of *Camallanus*.

We found nematode specimens belonging to *Camallanus* (Nematoda: Camallanidae) during recent studies of the gastrointestinal parasites of freshwater turtles from Queensland (Australia). One species, *C. chelonius* Baker, 1983, has been reported from the same turtle species that were examined in Queensland by Ferguson and Smales (1998). Examination of the *Camallanus* specimens that we found in Queensland revealed 2 species; neither was conspecific with *C. chelonius* or any other known species of *Camallanus*. Therefore, both of the *Camallanus* species that we collected in Queensland are described herein as new species.

## MATERIALS AND METHODS

Turtles were identified according to Cann (1998). All turtles were killed by injection with sodium pentobarbital. Nematodes were killed by placing them in hot 0.7% saline solution until the worms were straight. The worms were then transferred to, and stored in, 70% ethanol with 5% glycerin. For examination under light microscopy, nematodes were placed in temporary glycerin whole mounts after clearing in lactophenol.

Voucher specimens of *C. chelonius* deposited by Ferguson and Smales (1998) in the Queensland Museum (Brisbane, Australia; accession numbers G213999, G214000, and G214001) were examined for comparative purposes.

Measurements of morphological features were made with a light microscope using a calibrated ocular micrometer. Tridents were measured from the anterior end of the trident base, i.e., the thickened area just anterior to where all 3 prongs unite, to the posterior end of each prong. One lateral and 1 central prong were randomly selected per worm and then measured. Measurements (in μm) are given as the mean ± SE, followed by the range in parentheses. Line drawings were made using a drawing tube attached to a compound microscope.

The buccal capsules of at least 3 specimens of each sex were examined using SEM. To remove the tissues surrounding the buccal capsule, the anterior ends of the worms were digested in acid-pepsin (1% HCl:1% pepsin) at 37 C until the buccal capsules were free of tissue. Buccal capsules were rinsed in 70% ethanol, mounted on conductive carbon tabs, air-dried at 36 C, sputter coated with gold, and examined using SEM.

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## DESCRIPTION

### *Camallanus nithoggi* n. sp.
(Figs. 1–3)

*Description:* Nematoda, Spirurida, Camallanoidea, Camallanidae, Camallaninae, *Camallanus*. Translucent red in life. Medium-sized fusiform worms. Cuticle annulated. Buccal opening oval to rectangular. Cephalic papillae arranged in single ring of 4; 2 papillae overlying each buccal capsule valve. No other cephalic papillae observed. Amphids not observed. Buccal capsule laterally compressed, composed of 3 parts (2 valves and a basal ring); slightly wider than long. Valves marked internally by longitudinal ridges. Buccal capsule ridges divided into 3 groups, central ridges running parallel to the longitudinal axis of the worm; groups of ridges on each side angled toward central group posteriorly. Variable numbers of complete, i.e., extending from the anterior buccal capsule margin to the posterior margin, longitudinal ridges present on each valve. Incomplete ridges usually terminate before middle of buccal capsule; average of 4 incomplete ridges in males and 5 in females. Four peribuccal shields, i.e., darkened bands just posterior to oral opening, present (Figs. 1A, 1B, 2); 2 on lateral surface of each valve, parallel to buccal capsule anterior margin. Peribuccal shields rise vertically from buccal capsule. Lateral external buttresses present, not visible using light microscopy, 1 on each valve, posterior to peribuccal shields (Fig. 2). Free space present underneath posterior portion of buttresses, although extent unclear (Fig. 3). Buttresses continue posteriorly to posterior margin of buccal capsule. At posterior margin, buttresses widen dorsoventrally, occasionally meeting tridents (Fig. 2). Buccal capsule valves supported by 2 dorsoventral tridents, 1 on each side, consisting of 3 posteriorly directed prongs extending beyond basal ring; prongs equal, club-shaped (Fig. 1A). Tridents attached to buccal capsule at posterior end of raised ridge on dorsoventral edge of each valve, slightly anterior to buccal capsule posterior. Basal ring wider than buccal capsule base, separated from buccal capsule by short, concave isthmus (Fig. 2); isthmus not visible using light microscopy. Nerve-ring well posterior to distal end of tridents (Fig. 1B). Lateral hypodermal cords visible, rugose. Excretory pore posterior to nerve-ring, anterior to junction between glandular and muscular esophagi (Fig. 1B). Cervical papillae (anterior deirids) small, posterior to excretory pore, and anterior to end of muscular esophagus (Fig. 1B). Esophagus long, divided into muscular and glandular portions (Fig. 1B). Anterior two-thirds of muscular esophagus cylindrical, enlarged posteriorly. Glandular esophagus longer, enlarged posteriorly, projecting slightly into intestine in valve-like formation.

*Male (n = 9, unless otherwise indicated):* Length 10,413 ± 398 (7,950–12,200), maximum width near midbody 266 ± 11 (200–300). Buccal capsule, excluding basal ring, 109 ± 2 (100–120) long, 127 ± 3 (115–135) wide; length:width ratio 0.86 ± 0.02 (0.81–0.96). Basal ring 13 ± 0.9 (10–15) long, 68 ± 1 (60–75) wide. Buccal capsule with 7 ± 0.2 (6–8) complete ridges and 4 ± 0.4 (2–6) incomplete ridges. Buccal capsule anterior margin with 12 ± 0.4 (10–13) ridges, with 5

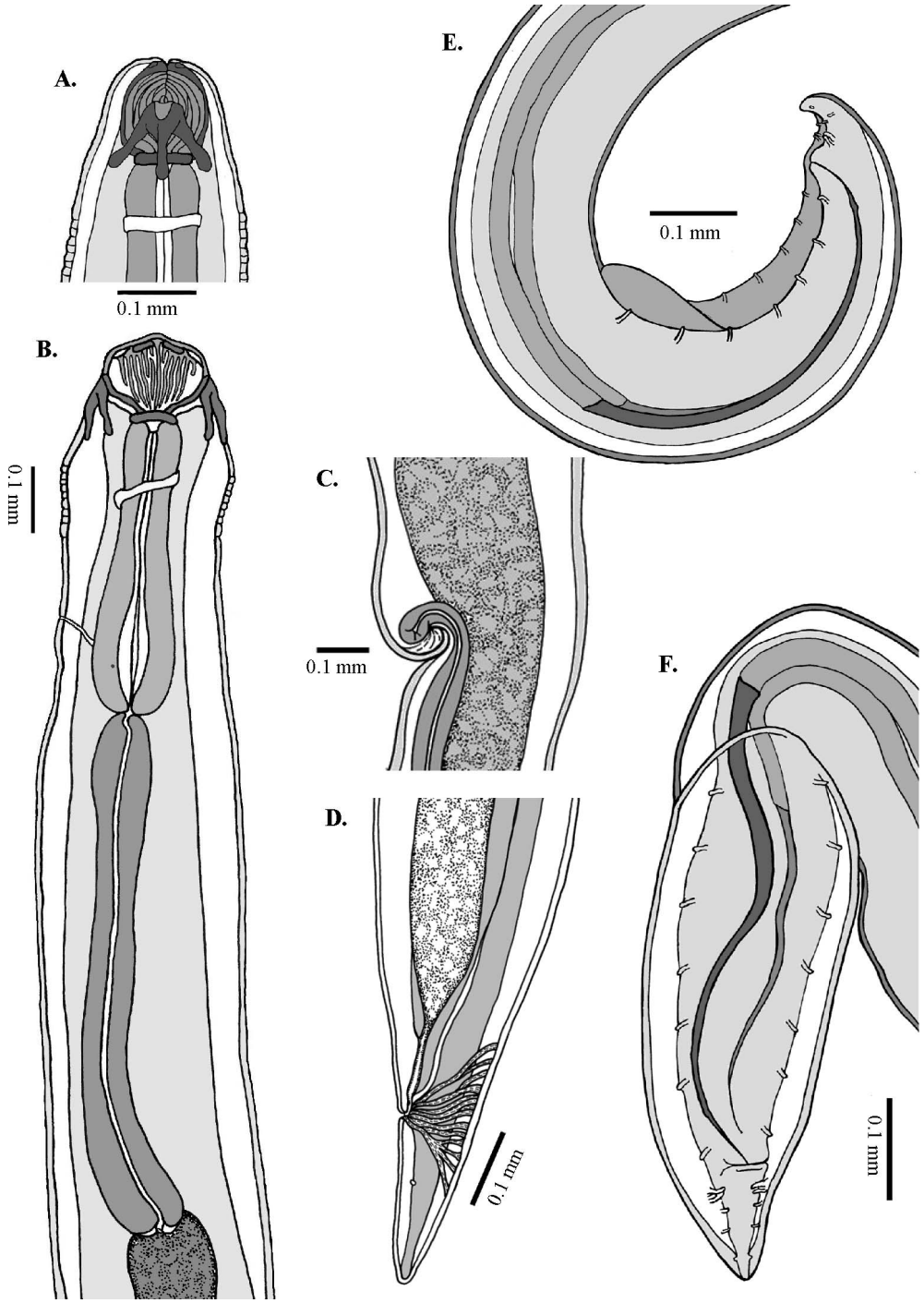


FIGURE 1. *Camallanus nithoggi* n. sp. (**A**) Dorsoventral view of female anterior extremity. (**B**) Lateral view of female anterior extremity. (**C**) Lateral view of vulva. (**D**) Lateral view of female posterior extremity. (**E**) Lateral view of male posterior extremity. (**F**) Ventral view of male posterior extremity.

± 0.3 (4–6) ridges on left side, 0.9 ± 0.1 (0–1) ridges in center, 6 ± 0.2 (5–6) ridges on right side. Buccal capsule anterior to posterior midpoint with 9 ± 0.3 (8–11) ridges, with 4 ± 0.2 (3–5) ridges on left side, 0.8 ± 0.1 (0–1) ridges in center, 4 ± 0.2 (4–5) ridges on right side. Buccal capsule posterior margin with 7 ± 0.2 (6–8) ridges, with 3 ± 0.2 (3–4) ridges on left side, 0.4 ± 0.2 (0–1) ridges in center, 4 ± 0.2 (3–4) ridges on right side. Trident prongs equal, middle prong of tridents 102 ± 2 (90–110) long; lateral prong 106 ± 3 (90–120) long. Ratio of length of middle trident prong to buccal capsule (excluding basal ring) 0.93 ± 0.01 (0.90–1.00). Nerve-ring 200 ± 7 (160–230) from apex. Excretory pore 356 ± 9 (320–390) from apex. Deirid (n = 8) 451 ± 9 (410–480) from apex. Muscular esophagus 396 ± 7 (370–430) long, glandular esophagus 673 ± 22 (560–750) long; ratio 0.59 ± 0.02 (0.52–0.68). Anus 108 ± 3 (95–120) from posterior extremity. Alae well developed, extending 549 ± 18 (470–670) from posterior extremity. Fourteen pairs caudal papillae: 7 pairs preanal pedunculate papillae, 2 pairs adanal pedunculate papillae not attached to alae, 5 pairs postanal pedunculate papillae. Phasmids lateral, near posterior terminus.

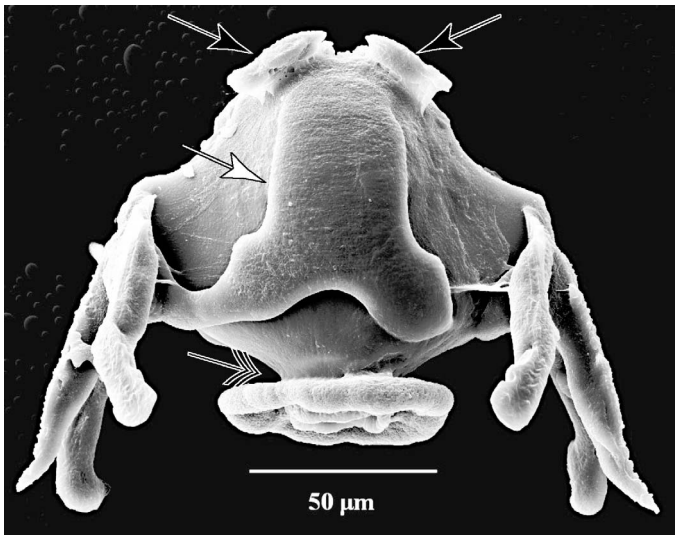


FIGURE 2. *Camallanus nithoggi* n. sp. SEM showing lateral view of buccal capsule after removing overlying tissues. Black arrows indicate the peribuccal shields. White arrow indicates the ''buttress'' and black double-headed arrow indicates the isthmus separating the buccal capsule from the basal ring.

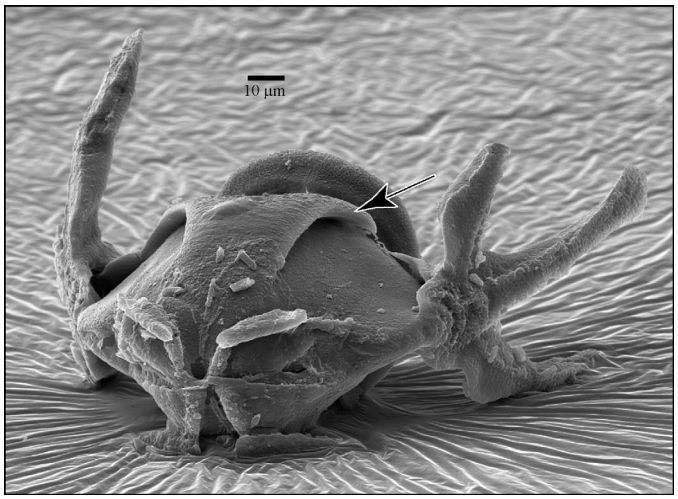


FIGURE 3. *Camallanus nithoggi* n. sp. Scanning electron micrograph showing en face view of buccal capsule after removing overlying tissues. Note that the buttress is separated from the buccal capsule posteriorly (black arrow).

Preanal papillae generally evenly spaced. First 3 pairs postanal papillae grouped, remaining 2 evenly spaced. Phasmids lateral, 19 ± 0.6 (15–20) from posterior extremity. Positions of caudal features, expressed as percent of the distance from anterior union of alae to posterior extremity, as follows: first pair preanal papillae 10 ± 2 (4–22), second pair preanal papillae 23 ± 1 (19–33), third pair preanal papillae 36 ± 1 (33–43), fourth pair preanal papillae 48 ± 2 (42–61), fifth pair preanal papillae 57 ± 0.8 (54–61), sixth pair preanal papillae 65 ± 0.7 (62–69), seventh pair preanal papillae 78 ± 0.5 (76–81), anus 80 ± 0.5 (78–84), first pair postanal papillae 85 ± 0.4 (83–87), second and third pair postanal papillae 86 ± 0.4 (85–88), fourth pair postanal papillae 89 ± 0.2 (88–90), fifth pair postanal papillae 91 ± 0.2 (90–92), phasmid 96 ± 0.1 (96–97). Spicules dissimilar, unequal. Right spicule strongly sclerotized, longer, composed of 2 parts: proximal third with deep ventral groove, remaining two-thirds without ventral groove. Left spicule weakly sclerotized, short, simple. Longer (right) spicule 522 ± 6 (500–550) long, smaller (left) spicule 346 ± 13 (300–420) long, ratio 1.53 ± 0.05 (1.31–1.83). Gubernaculum absent. Tail ventrally flexed, tapering to a simple point, without spinelike projections (mucrons).

*Female (n = 11, unless otherwise indicated):* Length 19,021 ± 345 (16,940–21,460), maximum width near midbody 414 ± 5 (390–450). Buccal capsule, excluding basal ring, 122 ± 2 (115–130) long, 145 ± 1 (140–150) wide; length:width ratio 0.84 ± 0.01 (0.79–0.90). Basal ring 15 ± 1 (10–20) long, 78 ± 1 (70–85) wide. Buccal capsule with 8 ± 0.4 (6–10) complete ridges and 5 ± 0.9 (2–12) incomplete ridges. Buccal capsule anterior margin with 13 ± 0.7 (10–18) ridges, with 6 ± 0.4 (5–9) ridges on left side, 1 ± 0 (1–1) ridge in center, 5 ± 0.4 (4–8) ridges on right side. Buccal capsule anterior to posterior midpoint with 9 ± 0.2 (9–11) ridges, with 4 ± 0.09 (4–5) ridges on left side, 1 ± 0 (1–1) ridge in center, 4 ± 0.1 (4–5) ridges on right side. Buccal capsule posterior margin with 8 ± 0.4 (6–10) ridges, with 3 ± 0.3 (2–5) ridges on left side, 1 ± 0.1 (0–1) ridge in center, 3 ± 0.2 (3–5) ridges on right side. Trident prongs equal, middle prong of tridents 112 ± 3 (100–130) long; lateral prong 114 ± 2 (100–120) long. Ratio of length of middle trident prong to buccal capsule (excluding basal ring) 0.92 ± 0.03 (0.77–1.08). Nerve-ring 228 ± 4 (210–250) from apex. Excretory pore 387 ± 9 (340–440) from apex. Deirids 462 ± 11 (420–550) from apex. Muscular esophagus 452 ± 6 (425–500) long, glandular esophagus 818 ± 18 (700–940) long; ratio 0.55 ± 0.006 (0.53–0.61). Vulva 9,425 ± 193 (8,100–10,690) from apex, or 50 ± 0.3 (48–51) percent of body length. Amphidelphic, with developing larvae in utero. Anus 218 ± 6 (185–250) from posterior extremity. Phasmids (n = 10) 139 ± 4 (120–150) from posterior extremity. Tail tapering to a simple point, without spinelike projections (mucrons).

## Taxonomic summary

*Type host: Elseya latisternum* (Gray).

*Site of infection:* Small intestine.

*Type locality:* Paluma Dam (18°57′S, 146°10′E), Queensland, Australia.

*Type locality habitat:* Freshwater reservoir.

*Date of collection:* 19–20 October 1993.

*Prevalence:* 100% (2 of 2 turtles examined).

*Mean intensity:* 22.5 worms/host (intensities of 20 and 25 in the 2 turtles examined).

*Specimens deposited:* Queensland Museum G 230331 and G 230332.

*Previously reported:* As *C. chelonius* by Ferguson and Smales (1998) from freshwater turtles in Queensland, Australia.

*Etymology:* This species is named after Niðhogg, the serpent of ancient Norse myth that ''gnaws at the root [of the world-tree] from below'' (Young, 1954).

## Remarks

Following Yeh (1960), Chabaud (1975), Petter (1979), and Moravec (1998), the species described here belongs to *Camallanus* due to the presence of 2 lateral buccal capsule valves marked by smooth longitudinal ridges that are divided into 3 groups, i.e., dorsal, central, and ventral, and the absence of an enlarged female posterior extremity.

Many species of *Camallanus* have previously been reported from turtles. However, most of them have been re-assigned to *Serpinema* (see Baker, 1979; Moravec and Vargas-Vazquez, 1998), including *Serpinema microcephalus* (Dujardin, 1845), which is still reported in the literature as *Camallanus microcephalum* (Muzzall, 2005), and *Serpinema intermedius* (Hsü and Hoeppli, 1931), which is still reported as *Camallanus intermedius* (Murray et al., 2004). Aside from *C. nithoggi* n. sp., there are only 2 species in *Camallanus* known from turtles that have not been reassigned to *Serpinema*, i.e., *C. chelonius* and *C. waelhreow* n. sp.

According to the description of *C. chelonius* by Baker (1983), *C. nithoggi* may be differentiated from *C. chelonius* by the absence of mucrons (present in both males and females of *C. chelonius*), the number of buccal capsule ridges (10–18 vs. 9–10 in *C. chelonius*), the shape of the right spicule (simple tip vs. hooked tip in *C. chelonius*; basal third with a ventral groove vs. simple in *C. chelonius*), the number of preanal papillae in males (7 vs. 6 in *C. chelonius*), and the number of postanal papillae in males (5 vs. 4 in *C. chelonius*). The present worms may also be differentiated from *C. waelhreow* by the shorter isthmus in *C. nithoggi*, the absence of protrusions on the buccal capsule pos-

teriolateral to the peribuccal shields (present in *C. waelhreow*), the dorsolateral extent of the buccal capsule buttressing (occasionally reaching tridents vs. connected to tridents in *C. waelhreow*, although more study is required to characterize this character is both species), the number of buccal capsule ridges (males: 10–13 vs. 9 in *C. waelhreow*; females: 10–18 vs. 9–11 in *C. waelhreow*), and the number of incomplete buccal capsule ridges (males: 2–6 vs. 0–3 in *C. waelhreow*; females: 2–12 vs. 0–2 in *C. waelhreow*). Due to the differences cited above, we believe that the present worms are not conspecific with either *C. chelonius* or *C. waelhreow*.

Species of *Camallanus* with the same suite of characteristics (i.e., the same number of male caudal papillae [7 preanal, 2 adanal, 5 postanal, and 1 phasmid], no mucrons in both males and females, and a female tail that tapers to a point) have also been described from fish and amphibian hosts. Unfortunately, most of those descriptions are inadequate, prohibiting comparison. However, there are 3 adequately described species that are similar and bear comparison: *C. dimitrovi* Durette-Desset and Batcharov, 1974; *C. hampalae* Moravec and Scholz, 1991; and *C. carangis* Olsen, 1954. *Camallanus nithoggi* may be distinguished from the description of *C. dimitrovi* (see Durette-Desset and Batcharov, 1974) by the number of ridges at the anterior buccal capsule margin (10–18 vs. 19–21 in *C. dimitrovi*), the ratio of the length of the middle trident prong to the length of the buccal capsule (excluding the basal ring) in males (0.9–1.0 vs. [illustrated as] 0.7 in *C. dimitrovi*), and the position of the preanal papillae in males (evenly spaced vs. papillae 6 and 7 grouped in *C. dimitrovi*). *Camallanus nithoggi* may be distinguished from the description of *C. hampalae* (see Moravec and Scholz, 1991) by the number of ridges at the anterior buccal capsule margin (10–18 vs. 13–17 in *C. hampalae*), the number of incomplete buccal capsule ridges (2–12 vs. 6–8 in *C. hampalae*), and the ratio of the length of the buccal capsule (excluding the basal ring) to the middle trident in males (0.9–1.0 vs. [illustrated as] 1.1 in *C. hampalae*). *Camallanus nithoggi* may be distinguished from the description of *C. carangis* (see Rigby et al., 1998; Moravec et al., 2006) by the number of ridges at the anterior buccal capsule margin (10–18 vs. 24–40 in *C. carangis*), the number of incomplete buccal capsule ridges (2–12 vs. 6–29 in *C. carangis*), the shape of incomplete buccal capsule ridges (short ridge vs. short ridge followed by a series of dots in *C. carangis*), and the presence of a colorless sclerotized cup joining the buccal capsule to the esophagus (absent in *C. nithoggi*).

Based on the differences reported above, we believe that the present worms are not conspecific with any other species of *Camallanus*. Therefore, we designate *C. nithoggi* as a new species.

Ferguson and Smales (1998) also collected *Camallanus* from this host species in Queensland and identified them as *C. chelonius*. They noted that the right spicule had a spur near the center and did not have a hooked tip. In our examination of their specimens, we noted that there was a fold in the spicule that Ferguson and Smales (1998) interpreted as a spur and that the caudal papillae in the male were consistent with *C. nithoggi*, i.e., 7 preanal papillae in males versus 6 in *C. chelonius*, and 5 postanal papillae versus 4 in *C. chelonius*. Thus, the specimens that Ferguson and Smales (1998) collected from *E. latisternum* should be regarded as *C. nithoggi*.

### ***Camallanus waelhreow*** **n. sp.**
(Figs. 4–7)

*Description:* Nematoda, Spirurida, Camallanoidea, Camallanidae, Camallaninae, *Camallanus*. Translucent red in life. Medium-sized fusiform worms. Cuticle annulated. Buccal opening oval to rectangular. Cephalic papillae arranged in single ring of 4; 2 papillae overlying each buccal capsule valve. No other cephalic papillae observed. Amphids not observed. Buccal capsule laterally compressed, composed of 3 parts (2 valves and a basal ring); slightly shorter than wide in males, but length and width approximately equal in females. Valves marked internally by longitudinal ridges. Buccal capsule ridges divided into 3 groups: central ridges running parallel to the longitudinal axis of the worm and groups of ridges on each side, with longer ridges angled toward central group posteriorly. Variable numbers of complete, i.e., extending from the anterior buccal capsule margin to the posterior margin, longitudinal ridges present on each valve. Incomplete ridges usually terminate before middle of buccal capsule; average of 1 incomplete ridge in both males and females. Four peribuccal shields, i.e., darkened bands just posterior to oral opening (Figs. 4A–D, 6) present; 2 on lateral surface of each valve, parallel to buccal capsule anterior margin. Peribuccal shields rise vertically from buccal capsule. Lateral external buttresses present, not visible using light microscopy, 1 on each valve, posterior to peribuccal shields (Fig. 6). Free space present underneath posterior portion of buttresses, although extent unclear (Fig. 7). Buttresses continue posteriorly to posterior margin of buccal capsule, widening dorsoventrally to meet tridents (Fig 6). Buccal capsule valves supported by 2 dorsoventral tridents, 1 on each side, consisting of 3 posteriorly directed prongs extending slightly beyond basal ring; prongs equal, club-shaped (Fig. 4D). Tridents attached to buccal capsule at posterior end of raised ridge on dorsoventral edge of each valve, slightly anterior to buccal capsule posterior. Four protrusions (Fig. 6) present just posteriolateral to peribuccal shields, 2 per valve. Basal ring wider than buccal capsule base, separated from buccal capsule by long, concave isthmus (Figs. 4A, 6). Lateral hypodermal cords visible, rugose. Nerve-ring well posterior to distal end of tridents (Fig. 4A). Excretory pore well posterior to nerve-ring, anterior to junction between glandular and muscular esophagi (Fig. 4A). Cervical papillae (anterior deirids) small, posterior to excretory pore, anterior to end of muscular esophagus (Fig. 4A). Esophagus long, divided into muscular and glandular portions (Fig. 4A). Anterior two-thirds of muscular esophagus cylindrical, enlarged posteriorly. Glandular esophagus longer, enlarged posteriorly, projecting slightly into intestine in valvelike formation.

*Male (n = 13, unless otherwise indicated):* Length 8,340 ± 232 (6,470–9,840), maximum width near midbody 188 ± 5 (160–210). Buccal capsule, excluding basal ring, 126 ± 3 (105–140) long, 115 ± 2 (105–135) wide; length:width ratio 1.1 ± 0.02 (1.0–1.2). Basal ring 18 ± 0.7 (15–20) long, 65 ± 1 (60–75) wide. Buccal capsule with 8 ± 0.2 (6–9) complete ridges and 1 ± 0.2 (0–3) incomplete ridges. Buccal capsule anterior margin with 9 ± 0 (9–9) ridges, with 4 ± 0 (4–4) ridges on left side, 1 ± 0 (1–1) ridge in center, 4 ± 0 (4–4) ridges on right side. Buccal capsule anterior to posterior midpoint with 9 ± 0.2 (7–9) ridges, with 4 ± 0.1 (3–4) ridges on left side, 1 ± 0 (1–1) ridge in center, 4 ± 0.08 (3–4) ridges on right side. Buccal capsule posterior margin with 8 ± 0.2 (6–9) ridges, with 3 ± 0.1 (3–4) ridges on left side, 0.9 ± 0.08 (0–1) ridges in center, 4 ± 0.1 (3–4) ridges on right side. Isthmus (n = 8) 8 ± 2 (0–15) long. Trident prongs equal, middle prong tridents 95 ± 2 (80–110) long; lateral prong 97 ± 2 (80–110) long. Ratio of length of middle trident prong to buccal capsule (excluding basal ring) 0.76 ± 0.02 (0.57–1.86). Nerve-ring 239 ± 3 (210–250) from apex. Excretory pore 422 ± 12 (340–480) from apex. Deirids 467 ± 8 (410–520) from apex. Muscular esophagus 468 ± 10 (380–500) long, glandular esophagus 736 ± 17 (670–860) long; ratio 0.64 ± 0.01 (0.56–0.72). Anus 137 ± 4 (110–150) from posterior extremity. Alae well developed, extending 592 ± 13 (520–660) from posterior extremity. Fourteen pairs caudal papillae; 7 pairs preanal pedunculate papillae, 2 pairs adanal pedunculate papillae not attached to alae, 5 pairs postanal pedunculate papillae. Phasmids lateral, near posterior terminus. Preanal papillae generally evenly spaced. First 3 pairs postanal papillae grouped. Phasmids lateral, 13 ± 0.7 (10–15) from posterior extremity. Positions of caudal features, expressed as percent of the distance from anterior union of alae to posterior extremity, as follows: first pair preanal papillae 13 ± 1 (5–19), second pair preanal papillae 25 ± 0.8 (18–28), third pair preanal papillae 37 ± 1 (32–46), fourth pair preanal papillae 44 ± 0.7 (41–49), fifth pair preanal papillae 53 ± 0.7 (51–58), sixth pair preanal papillae 62 ± 0.8 (58–66), seventh pair preanal papillae 74 ± 0.9 (69–83), anus 77 ± 0.4 (74–80), first pair postanal papillae 80 ± 0.3 (78–82), second and third pair postanal papillae 81 ± 0.3 (79–83), fourth pair postanal papillae 86 ± 0.3 (84–88), fifth pair postanal papillae 88 ± 0.2 (87–89), phasmid 98 ± 0.1 (97–98). Spicules simple, unequal. Right spicule strongly sclerotized, longer, composed of 2 parts; proximal third with deep ventral groove, remaining two-thirds without ventral groove; tip slightly widened (Fig. 5B). Left spicule weakly sclerotized, short, simple. Longer (right) spicule (n = 9) 483 ± 8 (450–550) long, smaller (left) spicule (n = 9) 282 ± 19 (200–350) long, ratio 1.76 ± 0.1 (1.34–2.29). Gubernaculum absent. Tail flexed ventrally, tapering to a simple point, without spinelike projections (mucrons).

*Female (n = 15, unless otherwise indicated):* Length 13,733 ± 380 (10,860–15,890), maximum width near midbody 321 ± 13 (240–390). Buccal capsule, excluding basal ring, 141 ± 2 (130–160) long, 139 ± 2 (125–155) wide; length:width ratio 1.01 ± 0.01 (0.93–1.10). Basal ring 21 ± 0.7 (15–25) long, 75 ± 2 (65–90) wide. Buccal capsule with

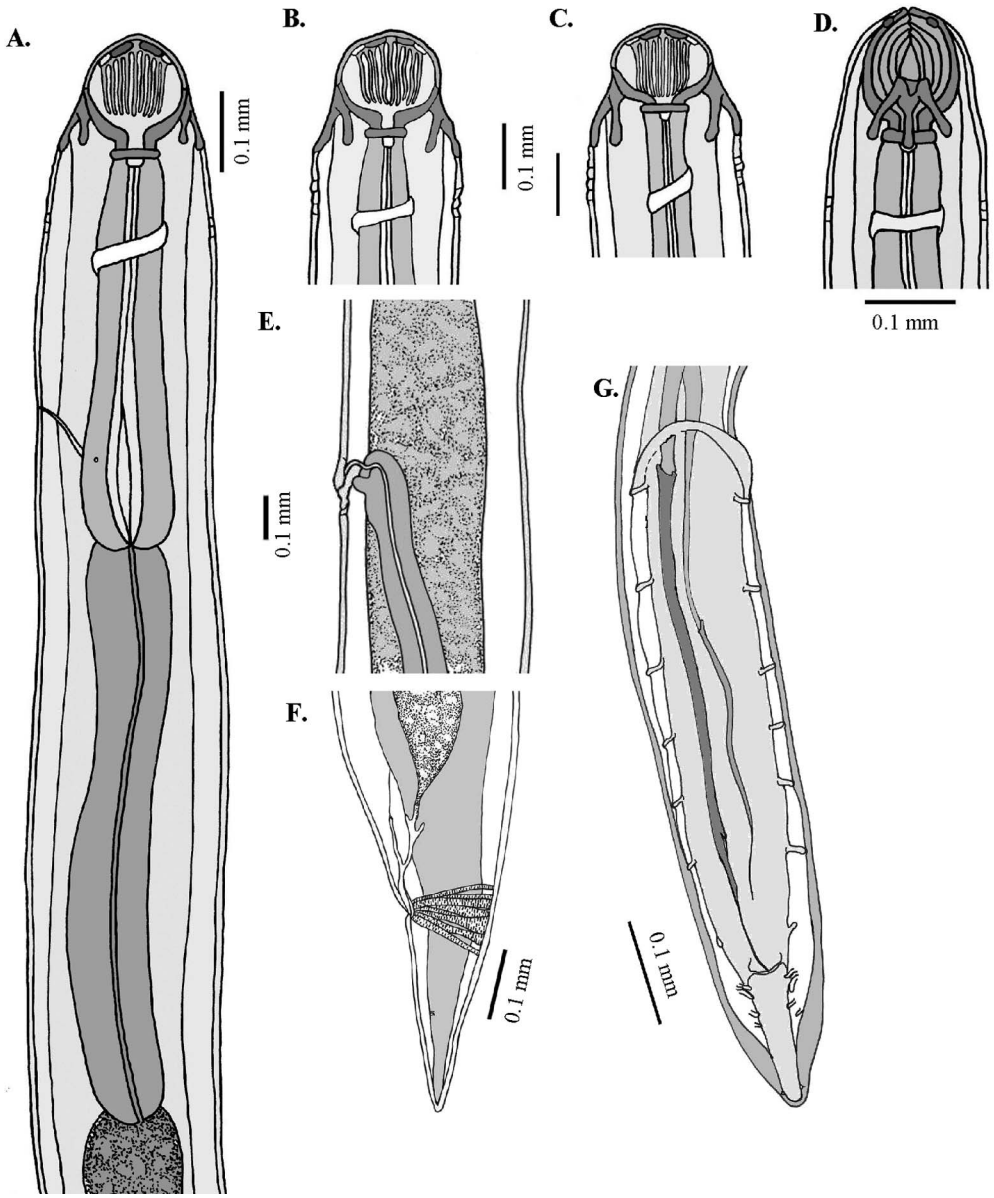


FIGURE 4. *Camallanus waelhreow* n. sp. (**A**) Lateral view of male anterior extremity. (**B**), (**C**) Lateral views of female anterior extremity showing variation in isthmus length. (**D**) Dorsoventral view of male anterior extremity. (**E**) Lateral view of vulva. (**F**) Lateral view of female posterior extremity. (**G**) Ventral view of male posterior extremity.

8 ± 0.2 (7–9) complete ridges and 0.9 ± 0.2 (0–2) incomplete ridges. Buccal capsule anterior margin with 9 ± 0.1 (9–11) ridges, with 4 ± 0.07 (4–5) ridges on left side, 1 ± 0 (1–1) ridge in center, 4 ± 0.07 (4–5) ridges on right side. Buccal capsule anterior to posterior midpoint with 9 ± 0.2 (7–10) ridges, with 4 ± 0.1 (3–5) ridges on left side, 1 ± 0.07 (0–1) ridge in center, 4 ± 0.07 (3–4) ridges on right side. Buccal capsule posterior margin with 8 ± 0.2 (7–9) ridges, with 4 ± 0.2 (3–5) ridges on left side, 1 ± 0.1 (0–1) ridge in center, 4 ± 0.1 (3–4) ridges on right side. Isthmus (n = 24) 5 ± 1 (0–20) long. Trident prongs equal, middle prong 114 ± 4 (90–140) long; lateral prong 111 ± 3 (90–130) long. Ratio of length of middle trident prong to buccal capsule (excluding basal ring) 0.81 ± 0.02 (0.69–1.00). Nerve-ring 270 ± 6 (220–300) from apex. Excretory pore 499 ± 16 (360–560) from apex. Deirids 578 ± 19 (410–640) from apex. Muscular esophagus 556 ± 13 (420–630), long, glandular esophagus 917 ± 29 (720–1,080) long; ratio 0.61 ± 0.01 (0.54–0.68). Vulva 6,650 ± 183 (5,500–7,800) from apex, or 48 ± 0.5 (45–53) percent of body length. Amphidelphic, with developing larvae in utero. Anus 236 ± 6 (200–290) from posterior extremity. Phasmids (n = 7) 100 ± 14 (65–145) from posterior extremity. Tail tapering to a simple point, without spinelike projections (mucrons).

### Taxonomic summary

*Type hosts: Emydura krefftii* (Gray); *Em. macquarrii* (Gray); and *Em. macquarrii dharra* Cann.

*Site of infection:* Small intestine.

*Localities:* Jurona Station (19°33′S, 147°16′E), Leslie Dam (28°1′S, 152°55′E), and Smith Creek (31°53′S, 151°55′E), respectively. All in Queensland, Australia.

*Locality habitats:* Cattle pond, freshwater reservoir, and stream, respectively.

*Dates of collection:* 6 September 1993; 19 February 1994; and 20 October 1993, respectively.

*Prevalence:* 75% (3/4), 100% (11/11), 72.7% (8/11), respectively. Overall prevalence 68% (15/22).

*Mean intensity:* (1) 11.7 (5–20), (2) 34.8 (16–81), (3) 5 (3–9), respectively. Overall mean intensity 3.9 (1–20).

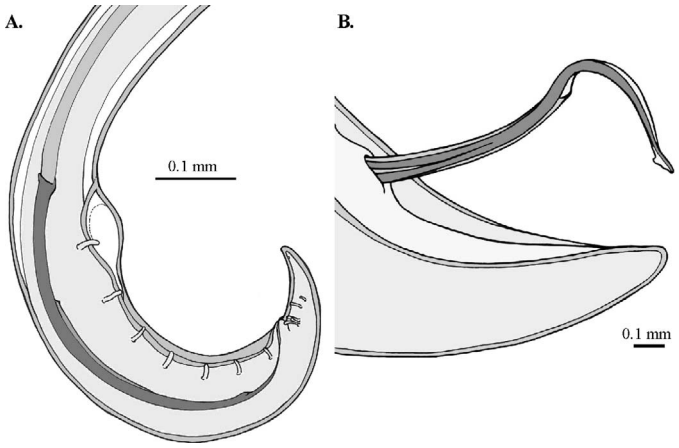


FIGURE 5. *Camallanus waelhreow* n. sp. (**A**) Lateral view of male posterior extremity. (**B**) Lateral view of male posterior showing everted spicule (papillae not illustrated).

*Specimens deposited:* Queensland Museum G 230333 and G 230334.

*Etymology:* This species is named for its diet of blood, i.e., ''Waelhreow'' means ''bloodthirsty'' in Old English (Hall, 1960).

### Remarks

Following Yeh (1960), Chabaud (1975), Petter (1979), and Moravec (1998), the species described here belongs to *Camallanus* due to the presence of 2 lateral buccal capsule valves marked by smooth longitudinal ridges that are divided into 3 groups, i.e., dorsal, central, and ventral, and the absence of an enlarged female posterior extremity. Aside from the present worms, there are only 2 species in *Camallanus* known from turtles, i.e., *C. chelonius* and *C. nithoggi*.

According to the description of *C. chelonius* by Baker (1983), *C. waelhreow* n. sp. may be differentiated from *C. chelonius* by the absence of mucrons (present in both males and females in *C. chelonius*), the shape of the right spicule (widened vs. hooked tip in *C. chelonius*), the number of preanal papillae in males (7 vs. 6 in *C. chelonius*), and the number of postanal papillae in males (5 vs. 4 in *C. chelonius*). The present worms may also be differentiated from *C. nithoggi* by the shorter buccal capsule isthmus in *C. nithoggi*, by the presence of protrusions on the buccal capsule posteriolateral to the peribuccal shields (absent in *C. nithoggi*), the dorsolateral extent of the buccal capsule buttressing (connected to tridents vs. occasionally reaching tridents in *C. nithoggi*), the number of buccal capsule ridges (males: 9 vs. 10–13 in *C. nithoggi*; females: 9–11 vs. 10–18 in *C. nithoggi* n. sp.), the number of incomplete buccal capsule ridges (males: 0–3 vs. 2–6 in *C. nithoggi*; females: 0–2 vs. 2–12 in *C. nithoggi*). Due to the differences cited above, we believe that the present worms are not conspecific with either *C. chelonius* or *C. nithoggi*.

As stated above for *C. nithoggi*, there are 3 additional adequately described species that are similar to *C. waelhreow* and bear comparison: *C. dimitrovi*, *C. hampalae*, and *C. carangis*. All of these species have the following similar characteristics: the same number of male caudal papillae (7 preanal, 2 adanal, 5 postanal, and 1 phasmid), no mucrons in both males and females, and a female tail that tapers to a point. *Camallanus waelhreow* may be distinguished from the description of *C. dimitrovi* (see Durette-Desset and Batcharov, 1974) by the number of ridges at the anterior buccal capsule margin (9–11 vs. 19–21 in *C. dimitrovi*), by the number of incomplete buccal capsule ridges (0–3 vs. [illustrated as] 7 in *C. dimitrovi*), and by the position of the preanal papillae in males (evenly spaced vs. papillae 6 and 7 grouped in *C. dimitrovi*). *Camallanus waelhreow* may be distinguished from the description of *C. hampalae* (see Moravec and Scholz, 1991) by the number of ridges at the anterior buccal capsule margin (9–11 vs. 13–17 in *C. hampalae*), by the number of incomplete buccal capsule ridges (0–3 vs. 6–8 in *C. hampalae*), and by the ratio of the length of the middle trident prong to the length of the buccal capsule (excluding the basal ring) in males (0.6–0.9 vs. [illustrated as] 1.1 in *C. hampalae*). *Camallanus waelhreow* may be distinguished from the description of *C. carangis* (see Rigby et al., 1998; Moravec et al., 2006) by the number of ridges at the anterior buccal capsule margin (9–11 vs. 24–40 in *C. carangis*), by the number of incomplete buccal capsule ridges (0–3 vs. 6–29 in *C. carangis*), by the shape of incomplete buccal capsule ridges (short ridge vs. short ridge followed by a series of dots in *C. carangis*), and by the presence of a colorless sclerotized cup joining the buccal capsule to the esophagus (absent in *C. waelhreow*).

Based on the differences reported above, we believe that the present worms are not conspecific with any other species of *Camallanus*. Therefore, we designate *C. waelhreow* as a new species.

As noted above, the specimens of *Camallanus* spp. that Ferguson and

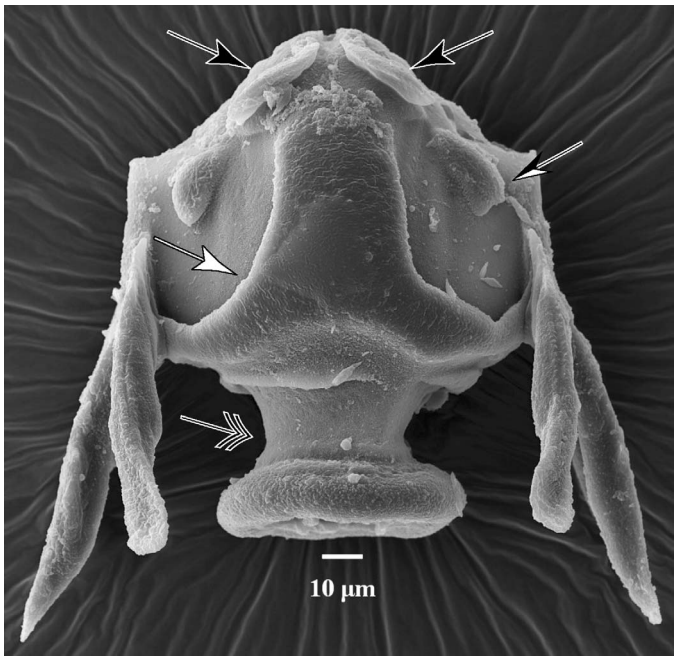


FIGURE 6. *Camallanus waelhreow* n. sp. SEM showing lateral view of buccal capsule after removing overlying tissues. Black arrows indicate the peribuccal shields. White arrow indicates the ''buttress,'' black double-headed arrow indicates the isthmus separating the buccal capsule from the basal ring, and arrow with black and white head indicates protrusions posterio-lateral to peribuccal shields.

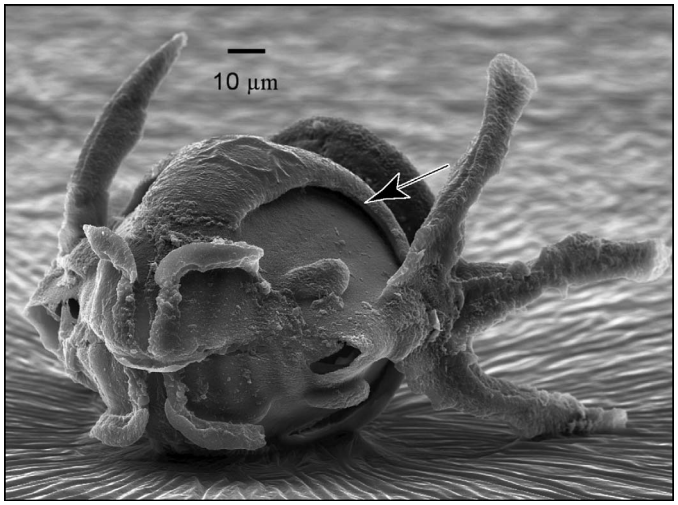


FIGURE 7. *Camallanus waelhreow* n. sp. SEM showing en face view of buccal capsule after removing overlying tissues. Note that the buttress is separated from the buccal capsule posteriorly (black arrow).

Smales (1998) collected from this *E. latisternum* in Queensland should be identified as *C. nithoggi*. Ferguson and Smales (1998) also collected specimens from *Em. krefftii*, but did not note any differences between the worms from the different host species. In our examination of their specimens, we noted that the caudal papillae in the male were consistent with those of *C. waelhreow*, i.e., 7 preanal papillae in males versus 6 in *C. chelonius*, and 5 postanal papillae versus 4 in *C. chelonius*. However, we were unable to examine Ferguson and Smales' (1998) specimens from *E. krefftii* in sufficient detail to make a specific identification.

## DISCUSSION

The SEMs show unique buccal capsule features that have not been previously observed in any species of *Camallanus*. The protrusions posteriolateral to the peribuccal shields observed in *C. waelhreow* (Fig. 6) are of unknown function. The buttressing observed on both of the new species described here (Figs. 2, 6) is also unique and without obvious function. However, it is possible that the peribuccal shields and buttresses may play a role in strengthening the buccal capsule or in muscle attachment. We suspect that future SEM work will reveal additional differences in the buccal capsules of camallanids and that these characters may be taxonomically informative.

A narrow isthmus separating the buccal capsule and the basal ring, as seen in *C. nithoggi* and *C. waelhreow*, has not previously been observed in species of *Camallanus*. Usually, the basal ring is described as being flush with the posterior end of the buccal capsule. However, in species of *Paracamallanus* and *Oncophora*, there are 3 compartments to the buccal capsule. Using the terminology of this paper to describe *Oncophora* spp., the isthmus of *Oncophora* spp. appears to be thickened, enlarged, and wider than the basal ring (see Moravec et al., 1999). In *Paracamallanus* spp., the isthmus appears to be almost as large as the main portion of the buccal capsule, while the basal ring is again comparatively small (see Moravec, 1998). The isthmus in *C. nithoggi* and *C. waelhreow* may represent an intermediate step in the evolution of the posterior buccal capsule in species of *Paracamallanus* and *Oncophora*. This hypothesis requires further investigation using phylogenetic methods.

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