

# Description of two new species of *Rhadinorhynchus* (Acanthocephala, Rhadinorhynchidae) from marine fish in Halong Bay, Vietnam, with a key to species

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## Abstract

Two rhadinorhynchid species of acanthocephalans, *Rhadinorhynchus dorsoventrospinosus* sp. nov. and *Rhadinorhynchus laterospinosus* sp. nov. are described from the redbelt scad, *Decapterus kurroides* Bleeker, and the trigger fish *Balistes* sp., respectively. The hosts were collected off Cat Ba Island, Halong Bay, Gulf of Tonkin, Vietnam in May, 2009. This brings the total number of species of *Rhadinorhynchus* Lühe, 1911 to 38. Specimens of the first species are characterized by having 11–12 proboscis hook rows with 30–31 hooks each, large dorsal and ventral spines in the posterior field of trunk spines, large eggs (100 × 20), and subterminal gonopore in both males and females. It is further characterized by many prominent fragmented nuclei in the body wall. The 1 female of the second species has 18 proboscis hook rows with 24 hooks each, smaller eggs (62 × 17), lateral trunk spines connecting those in the anterior and the posterior fields, and subterminal female gonopore. Notes on the genus *Rhadinorhynchus*, lists of the invalid and valid species, and a key to species are provided. *Raorhynchus* Tripathi, 1959 is proposed to be a junior synonym of *Rhadinorhynchus* pending a revision of the species of *Raorhynchus*.

## Keywords

Acanthocephala, *Rhadinorhynchus dorsoventrospinosus* sp. nov., *Rhadinorhynchus laterospinosus* sp. nov., key to species, marine fish, Halong Bay, Vietnam

## Introduction

A number of acanthocephalan species from freshwater fish and other vertebrates were previously described in Vietnam by Amin and Ha (2008) and Amin *et al.* (2000, 2004, 2008a, b, c). Eleven species of acanthocephalans were collected from marine fish off the eastern seaboard of Vietnam at Halong Bay in 2008 and 2009. Of these, 6 new species belonging to *Neoechinorhynchus* Stiles and Hassall, 1905 one new species of *Heterosentis* Van Cleave, 1931, and 3 new species of *Acanthocephalus* Koelruther, 1771, *Gorgorhynchus* Chandler, 1934, and *Neorhadinorhynchus* Yamaguti, 1939 were recently described (Amin *et al.* 2010a, b, c). Two new species of *Rhadinorhynchus* Lühe, 1911 are reported herein from marine fishes in the same Bay. Three other species of *Rhadinorhynchus* were previously reported from marine fishes in Vietnam (see Arthur and Te 2006).

## Materials and methods

Of the 45 species of marine fish netted at Cat Ba Island, Halong Bay, Tonkin Gulf, Vietnam (107°05'E, 20°45'N) during the spring of 2008 and 2009, 13 species were found infected with acanthocephalan parasites. Of these, 2 fish species, *Decapterus kurroides* and *Balistes* sp. harbored specimens of 2 species of acanthocephalans belonging to *Rhadinorhynchus* in May, 2009.

Upon collection, fish were measured and photographed then brought to the laboratory for examination. Worms were placed in water for 2–5 h or until fully extended then fixed in 70% ethanol. Worms were punctured with a fine needle and subsequently stained in Mayer's acid carmine, destained in 4% hydrochloric acid in 70% ethanol, dehydrated in ascending concentrations of ethanol (24 h each), and cleared in graduated concentrations of terpineol in 100% ethanol to

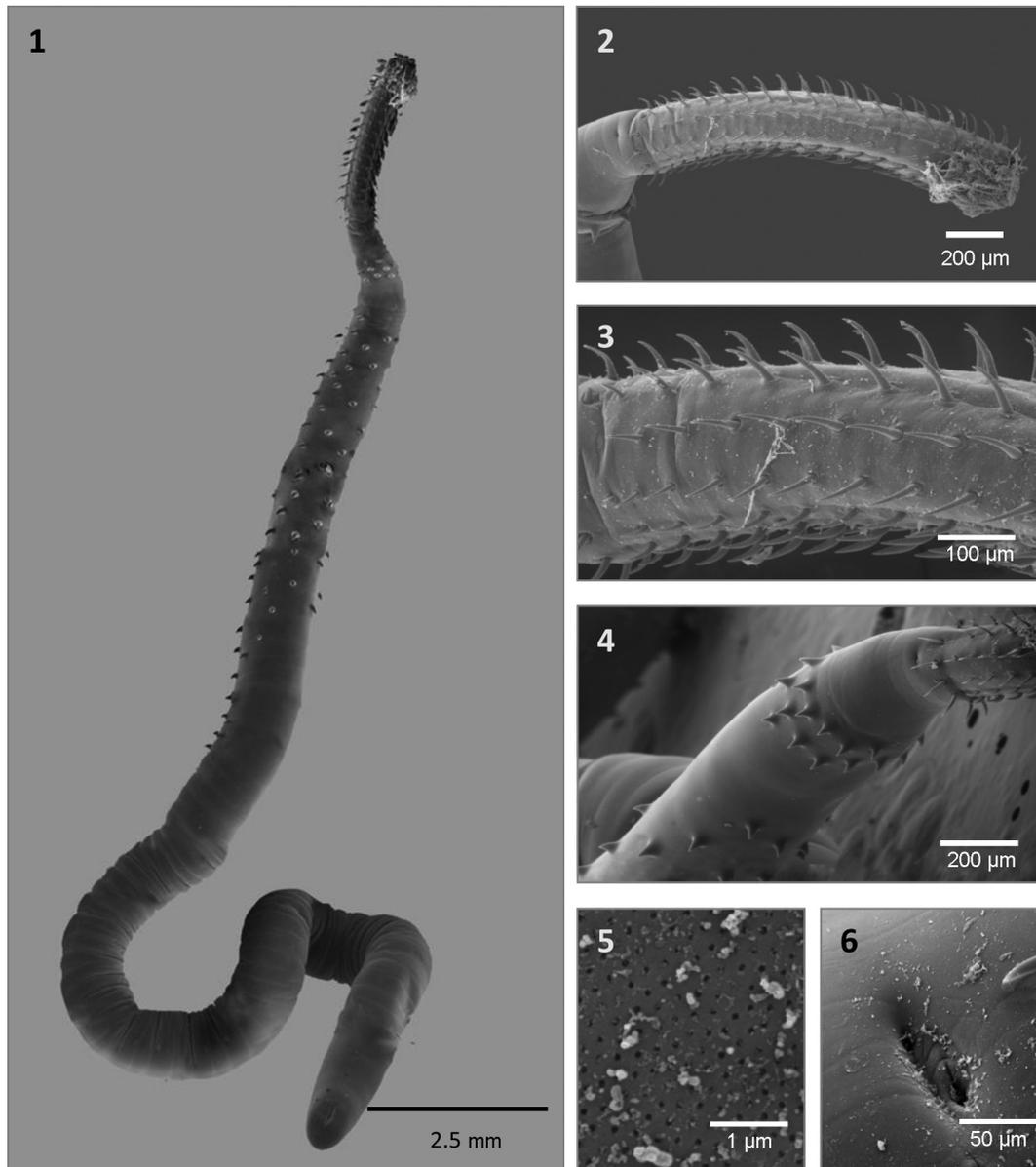
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100% terpineol, then 50% terpineol in 50% Canada balsam (24 h each). Whole worms were then mounted in Canada balsam.

For SEM, a few specimens of *Rhadinorhynchus dorsoventrospinosus* previously fixed in 70% ethanol were placed in CPD baskets and dehydrated using ETOH series of 95% and 3N 100% for at least 10 minutes per soak followed by critical point drying (Lee 1992). Samples were then mounted on SEM sample mounts, gold coated and observed with a scanning electron microscope (FEI X L30 ESEMFEI). Digital images

of the structures were obtained using digital imaging software attached to a computer.

Measurements are in micrometers, unless otherwise stated. Range values are followed by the mean in parentheses. Length measurements are given before the width; the latter refers to maximum width. Trunk length does not include the neck, proboscis, or bursa. Eggs refer only to fully developed eggs usually removed from the body cavity. Specimens were deposited in the University of Nebraska's State Museum's Harold W. Manter Laboratory (HWML) collection in Lincoln, Nebraska, USA.



**Figs 1–6.** SEM of *Rhadinorhynchus dorsoventrospinosus* sp. nov. from *Decapterus kurroides* in Vietnam. **1.** A collage of a paratype female showing the extent of distribution of trunk spines. Ventral trunk spines are on left. **2.** A slightly invaginated proboscis of same females in Fig. 1. **3.** A higher magnification of a part of the proboscis in Fig. 2 showing dorsal (top) and ventral (bottom) hooks. **4.** The posterior end of a proboscis of a paratype female showing the circle of the long basal hooks and 1 sensory pit directly posterior to it, and the anterior trunk spines separated from the posterior spines with an unarmed zone. **5.** Epidermal micropores from the anterior trunk of a paratype female. The whole trunk was covered with similar micropores. **6.** A higher magnification of the sensory pit shown in Fig. 4

## Results and discussion

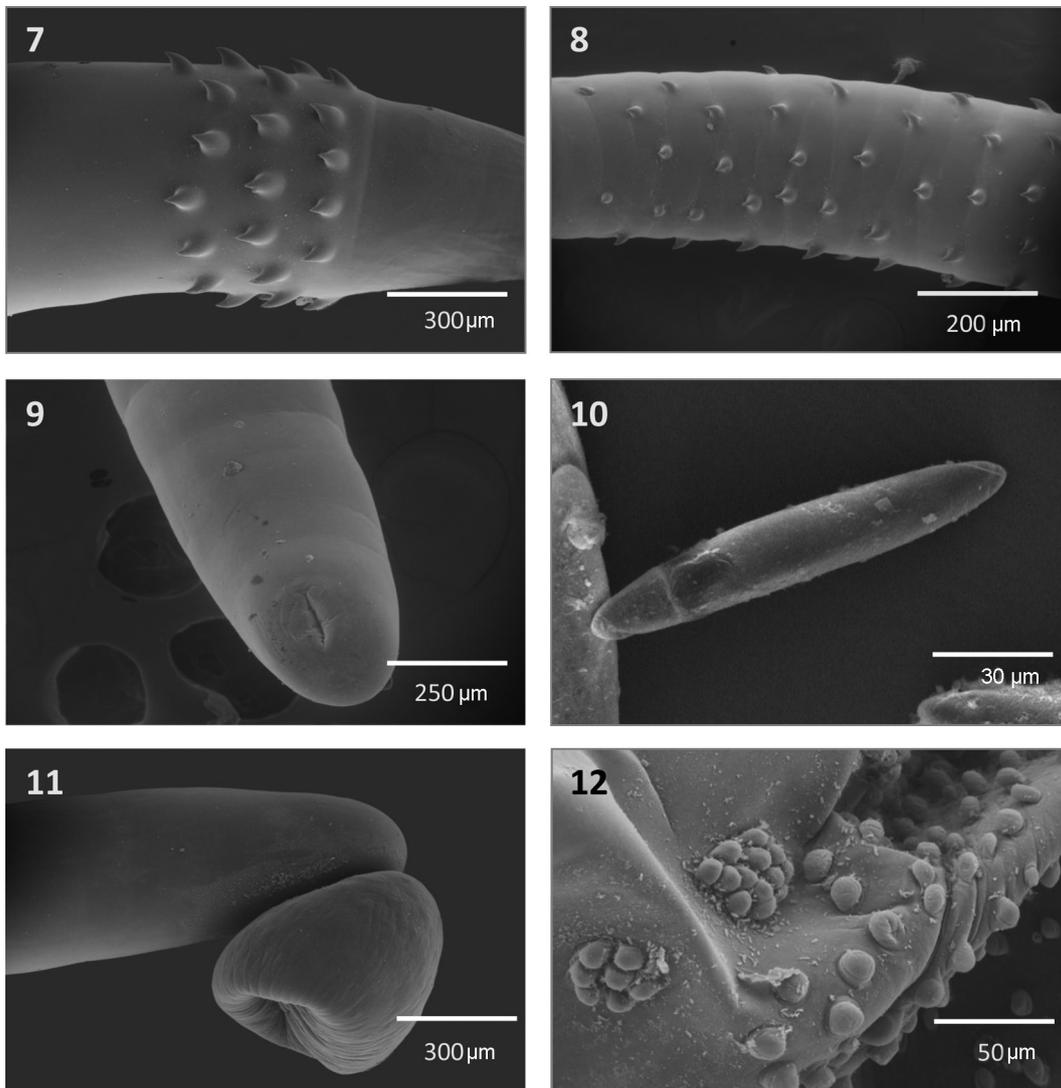
### *Rhadinorhynchus dorsoventrospinosus* sp. nov. (Figs 1–20)

A total of 34 adult specimens of the new species of *Rhadinorhynchus* was collected from the intestines of 4 infected out of 5 examined specimens of redbtail scad, *Decapterus kurroides*, collected in Halong Bay, Vietnam, in May, 2009. Twelve males and 4 females were processed and whole mounted for microscopical studies. The remaining specimens were used for SEM studies. Scads were 18.5 to 22.0 long (mean of 20.7 cm). The redbtail scad is a reef associated pelagic marine fish that occurs in inshore waters of the continental shelf and continental slope into deep waters with a depth range

of 100–300 m where it feeds on small planktonic invertebrates. It is an Indo-West Pacific species that extends from East Africa to the Philippines, north to southern Japan and south to western Australia (Paxton *et al.* 1989).

### Description

General: With characters of the genus. Shared structures larger in females than in males. Trunk long, uniformly cylindrical, spinose anteriorly in 2 fields separated by apinose zone that does not correspond dorso-ventrally (Figs 1, 4, 7, 13–15). Anterior field in 1–4 complete circles of 10–15 spines per circle with 2–4 dorsal and 1–3 ventral spines (Figs 7, 13–15). Posterior field extending from just past proboscis receptacle to



**Figs 7–12.** SEM of *Rhadinorhynchus dorsoventrospinosus* sp. nov. from *Decapterus kurroides* in Vietnam. **7.** A high magnification of anterior trunk spines of a paratype female. Dorsal spines are on top. **8.** A segment of the anterior trunk showing posterior trunk spines of the same female in Fig. 7. **9.** The posterior end of a paratype females showing vertical slit (lips) of the subterminal gonopore. **10.** An egg released from the body cavity of a gravid female. **11.** A bursa of a male showing the subventral position of the gonopore. **12.** A high magnification of the inner lip of a bursa showing elevated saucer-like sensory cups in cluster and single formations

**Table I.** Distribution and measurements of trunk spines in male and female specimens of *Rhadinorhynchus dorsoventrospinosus* sp. nov.

	Males				Females			
	anterior		posterior		anterior		posterior	
	dorsal	ventral	dorsal	ventral	dorsal	ventral	dorsal	ventral
No. of spines	2–4 (3.1)*	1–3 (2.1)	7–16 (10.4)	11–28 (18.7)	3–4 (3.5)	2–3 (2.3)	16–27 (21.3)	25–43 (34.0)
Spines/circle	10–13 (11.3)		7–11 (8.8)		12–15 (13.3)		7–11 (9.0)	
Longest spine length	65–87 (70)	60–90 (76)	72–87 (74)	69–92 (83)	95–102 (100)	80–90 (86)	95–122 (108)	90–120 (103)
Shortest ant. spine	32	50	72	69	57	75	92	90
Shortest post. spine	57	60	70	37	62	75	95	90

near mid trunk with 7–27 dorsal and 11–43 ventral spines (Figs 8, 13–15). Spines more frequent in females than in males and longer in posterior than in anterior field; anteriormost and posteriormost spines in both fields shortest (Table I; Figs 18, 19). Cuticular surface flat with electron dense micropores (Fig. 5). Body wall with many prominent fragmented nuclei (Figs 13, 14). Proboscis long, cylindrical, slightly widening anteriorly (Fig. 13), with 11–12 longitudinal rows of 30–31 hooks each. Dorsal hooks slender and project more laterally than more robust and longer ventral hooks that project posteriorly (Figs 3, 20). Basal hooks similar to dorsal hooks, in a complete ring projecting laterally (Figs 2, 3). Anteriormost hooks smallest, increasing in size to about middle of proboscis then gradually decrease posteriorly except at basal ring when they become abruptly larger (Table II). Hook roots simple, about 1/2 as long as hooks, posteriorly directed (Fig. 20). Neck prominent with 1 pair of sensory pits just posterior to posterior ring of hooks (Figs 4, 6). Proboscis receptacle long, about twice as long as proboscis, with cephalic ganglion near its

middle. Lemnisci slightly subequal, digitiform, about 3/4–4/5 length of receptacle (Figs 13–15). Gonopore subterminal in both sexes (Figs 1, 9, 16).

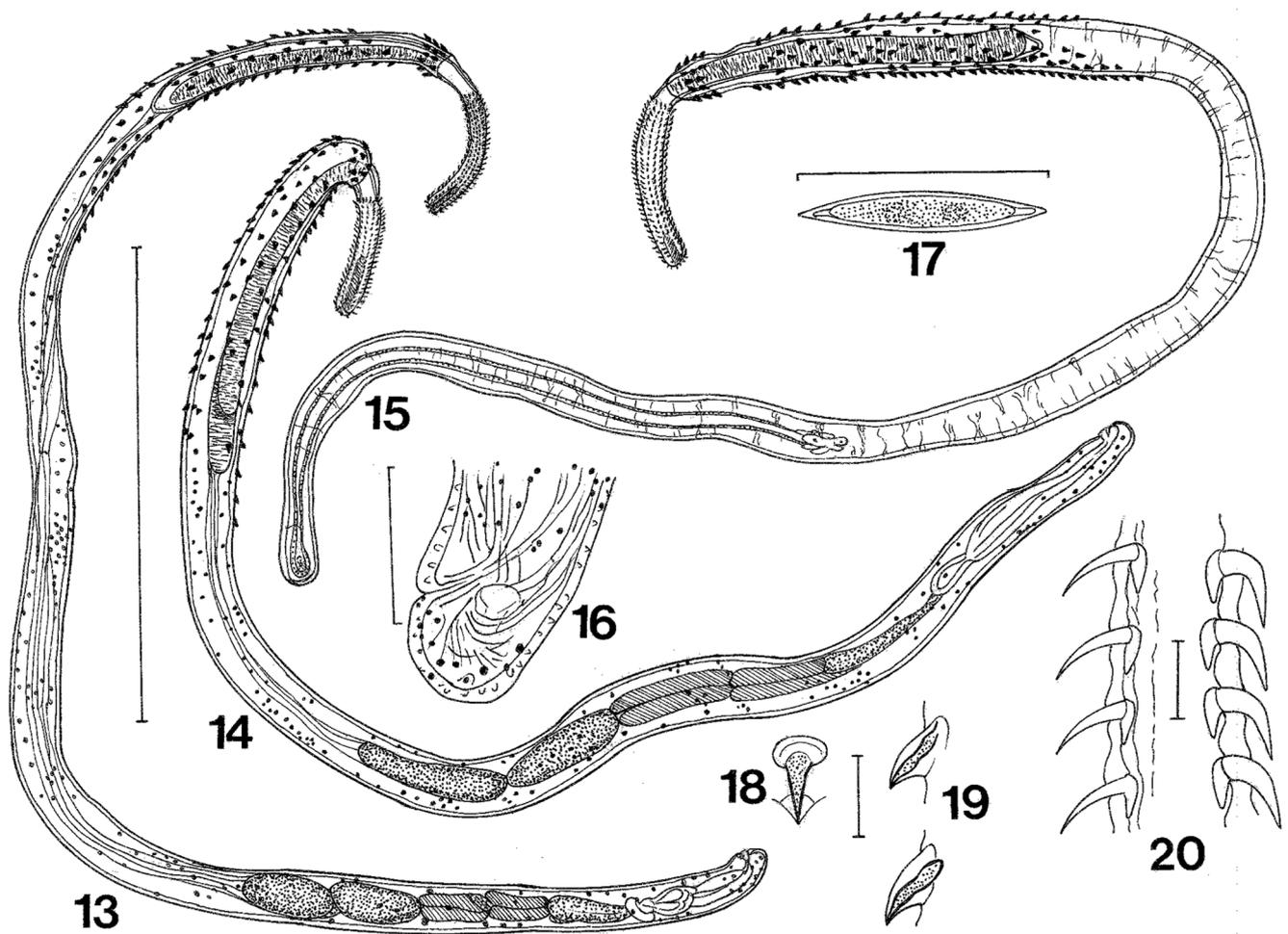
Male (based on 12 adult specimens with sperm): Trunk 10.75–20.25 (15.28) mm long by 0.47–0.82 (0.71) mm wide anteriorly. Proboscis 1.75–2.47 (2.18) mm long by 0.21–0.31 (0.25) mm wide anteriorly. Neck 270–447 (389) long dorsally by 180–384 (341) wide posteriorly. Proboscis receptacle 3.12–5.12 (4.12) mm long by 0.23–0.41 (0.29) mm wide. Lemnisci 2.87–3.95 (3.43) mm long by 0.10–0.21 (0.14) mm wide. Testes oblong, contiguous, in middle to posterior third of trunk (Figs 13–14). Anterior testis 0.83–1.75 (1.38) mm long by 0.27–0.50 (0.38) mm wide, larger than posterior testis 0.47–1.62 (1.08) mm long by 0.29–0.47 (0.37) mm wide. Cement glands 4, in 2 pairs, 0.52–1.10 (0.84) mm long by 0.16–0.32 (0.22) mm wide (Figs 13, 14). Internal rim of bursa with sensory papillae singly or in clusters (Figs 11, 12).

Female (based on 4 mature worms with ovarian balls and rarely ripe eggs): Trunk 17.5–37.75 (26.04) mm long by 0.47–

**Table II.** Comparison between the size of dorsal and ventral proboscis hooks of 1 male and 1 female specimens of *Rhadinorhynchus dorsoventrospinosus* sp. nov.

No. hooks	Male		Female	
	dorsal hooks	ventral hooks	dorsal hooks	ventral hooks
1	67 × 10*	60 × 15	62 × 12	75 × 17
3	82 × 15	95 × 21	87 × 17	95 × 30
5	87 × 16	97 × 24	90 × 20	112 × 37
7	90 × 17	100 × 27	105 × 20	117 × 37
9	92 × 17	102 × 30	112 × 22	115 × 35
11	95 × 20	102 × 29	112 × 22	117 × 37
13	95 × 17	106 × 29	120 × 25	117 × 37
15	92 × 17	105 × 27	130 × 25	112 × 37
17	87 × 17	107 × 32	120 × 22	110 × 30
19	80 × 17	105 × 27	115 × 22	105 × 30
21	75 × 15	97 × 27	110 × 20	110 × 37
23	67 × 17	95 × 26	110 × 21	105 × 30
25	65 × 17	95 × 26	110 × 20	90 × 22
27	65 × 17	92 × 25	100 × 17	90 × 17
29	67 × 17	90 × 25	95 × 19	82 × 22
31	102 × 20	100 × 25	120 × 22	117 × 35

\*Hook length × hook width at base.



**Figs 13–20.** *Rhadinorhynchus dorsoventrospinosus* sp. nov. from *Decapterus kurroides* in Vietnam. **13** and **14**, 2 paratype males showing fragmented nuclei in the body wall, and differences in the distribution of trunk spines and testes being in middle third to posterior third of trunk (Figs 13 and 14, respectively). **15**, Allotype female. Note the long reproductive system. **16**, Posterior end of a paratype male showing the sub-ventral position of the gonopore. **17**, Ripe egg released from the body cavity of a paratype female. **18**, Face view of a trunk spine from the posterior field of spines of a paratype female. **19**, Lateral view of an anterior (top) and posterior (bottom) trunk spines of a paratype female. **20**, Dorsal (left) and ventral (right) hooks and roots from the middle of the proboscis of allotype female in Fig. 15. Measurement bars: Figs 13–15 = 5 mm; Fig. 16 = 0.5 mm; Figs 17–20 = 100  $\mu$ m

0.95 (0.71) mm wide. Proboscis 2.50–2.74 (2.60) mm long by 0.27–0.31 (0.28) mm wide anteriorly. Neck 426–499 (462) long dorsally by 426–468 (447) wide posteriorly. Proboscis receptacle 3.87–4.75 (4.31) mm long by 0.27–0.41 (0.33) mm. Lemnisci 3.54–4.27 (3.90) mm long by 0.17–0.19 (0.18) mm wide. Ripe egg fusiform with polar prolongation of fertilization membrane, 100 by 20 (Figs 10, 17). Reproductive system long, 9.15 mm long in one 22.87 mm long specimen (40%). Gonopore without any outstanding features around orifice (Fig. 9).

#### Taxonomic summary

Type host: Redtail scad, *Decapterus kurroides* (Carangidae).

Type locality: Cat Ba Island, Halong Bay, Gulf of Tonkin, Vietnam (107°05' E, 20°45' N).

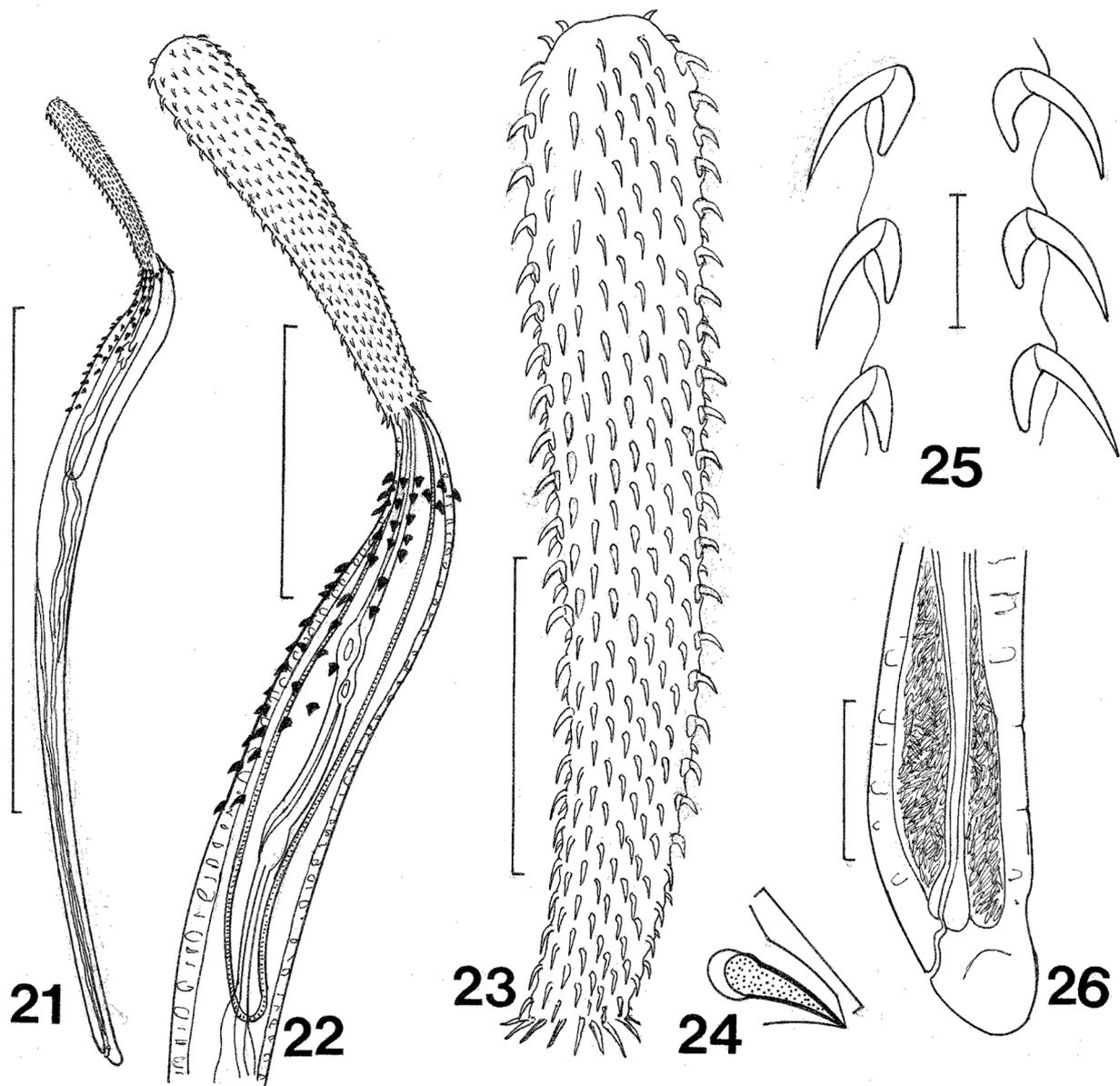
Site of infection: Intestine.

Type specimens: HWML collection no. 49295 (holotype male and paratypes on 1 slide, and no. 49296, 49297 (allotype female and paratypes).

Etymology: The name of the new species describes the distribution of trunk spines in the posterior field.

#### Remarks

Only 3 other species of *Rhadinorhynchus* have both dorsal and ventral trunk spines in the posterior field: *Rhadinorhynchus erumei* Gupta et Fatima, 1981, *Rhadinorhynchus cadenati* (Golvan et Houin, 1964) Golvan, 1969, and *Rhadinorhynchus lintoni* Cable et Linderoth, 1963. In *R. cadenati*, the proboscis has more hook rows (14–16) and less hooks per row (25–26), posterior trunk spines are only 0–2 dorsally and 3–6 ventrally, and eggs are smaller (65–80  $\times$  17–20) (Golvan 1969). In *R. erumei*, the anterior trunk spines are more nu-



**Figs 21–26.** *Rhadinorhynchus laterospinosus* sp. nov. from *Balistes* sp. in Vietnam. **21.** holotype female. **22.** Anterior end of holotype female showing the proportion between the size of the proboscis and the receptacle and the distribution of trunk spines showing the lateral spines bridging anterior and posterior fields of spines, and the lack of posterior dorsal spines. **23.** Detail of the proboscis. **24.** Lateral view of a posterior trunk spine. **25.** Dorsal (right) and ventral (left) proboscis hooks and roots at the middle of the proboscis. **26.** Posterior end of trunk showing the simple vagina and the beginning of the long uterus. Measurement bars: Fig. 21 = 5 mm; Fig. 22 = 1 mm; Fig. 23 = 0.5 mm; Figs 24 and 25 = 80  $\mu$ m; Fig. 26 = 200  $\mu$ m

merous (in 8–9 rings) and the posterior spines are fewer (in 5–6 rings) reaching a maximum of 22–25 in length, the proboscis has only 10 rows of 26 much smaller hooks each reaching a maximum of 26 long (Gupta and Fatima 1981). In *R. lintoni*, the dorsal trunk spines in the posterior field may be totally absent or may reach a maximum of 8 and ventral spines may reach up to 16–17. The proboscis of *R. lintoni* has 14–16 rows of hooks (compared to 11–12 in *R. dorsoventrosinosus*) each with 28–32 hooks. The proboscis receptacle is considerably longer in *R. lintoni* (6.1 mm long in males, 7.5

mm long in females (compared to 4.1 mm and 4.3 mm in *R. dorsoventrosinosus*) (Cable and Linderoth 1963). The following key will distinguish the new species from all others in *Rhadinorhynchus* further.

***Rhadinorhynchus laterospinosus* sp. nov.** (Figs 21–26)

One female specimen of another new species of *Rhadinorhynchus* was found in 1 of 2 examined 25 cm long individuals of the trigger fish *Balistes* sp. in May, 2009.

### Description

General: With characters of the genus. Trunk relatively long, uniformly cylindrical, spinose anteriorly in 2 regions bridged with a few lateral spines (Figs 21, 22). Anterior spines in complete circles with 1 dorsal and 3 ventral spines. Posterior spines 8, only ventral. Proboscis long, cylindrical, widening anteriorly, with 18 rows of 24 hooks each (Fig. 23). Dorsal and ventral hooks similar in shape, size, and in their posteriorly directed angle of projection from proboscis; dorsal hooks, however, slightly more slender than ventral (Fig. 25). Hooks increase in size from anterior to middle of proboscis then decrease more posteriorly until abruptly increase once more at complete basal ring. Hook roots simple, posteriorly directed. Neck 239 long dorsally by 229 wide posteriorly. Proboscis receptacle about 1.5 times as long as proboscis with cephalic ganglion near its middle. Lemnisci not extending past receptacle but hidden behind it.

Female (based on one adult female with barely ripe eggs): Trunk 7.82 mm long by 0.41 mm wide. Anterior dorsal spine 62 long, 3 anterior ventral spines 50, 40, and 47 long from anterior. Posterior 8 ventral spines 55, 75, 77, 70, 85, 77, 80, 80 long from anterior (Figs 22, 24). Proboscis 1.62 mm long by 0.27 mm wide. Length and width at base of dorsal and ventral proboscis hooks from anterior: hook # 1: 55 × 10, 60 × 12; # 3: 75 × 17, 77 × 20; # 5: 75 × 19, 72 × 17; # 7: 70 × 19, 67 × 14; # 9: 72 × 19, 67 × 15; # 11: 77 × 17, 77 × 16; # 13: 80 × 20, 80 × 15; # 15: 82 × 17, 80 × 15; # 17: 82 × 19, 75 × 15; # 19: 80 × 19, 75 × 15; # 21: 62 × 16, 55 × 14; # 23: 55 × 15, 45 × 10; last: 75 × 14, 70 × 12. Reproductive system long with simple vagina (Fig. 26). Gonopore subterminal. Egg with polar prolongation of fertilization membrane, 62 long by 17 wide.

### Taxonomic summary

Type host: Triggerfish *Balistes* sp. (Balistidae).

Type locality: Cat Ba Island, Halong Bay, Gulf of Tonkin, Vietnam (107°05' E, 20°45' N).

Site of infection: Intestine.

Type specimens: HWML collection no. 49298 (holotype female).

Etymology: The name of the new species describes the lateral trunk spines bridging the anterior and posterior fields.

### Remarks

*Rhadinorhynchus stunkardi* Gupta et Fatma, 1987 is the only other species of *Rhadinorhynchus* that has lateral trunk spines connecting the anterior and posterior fields of spines. *Rhadinorhynchus stunkardi*, however, has only 3–4 posterior trunk spines on the ventral side, only 8–10 proboscis hook rows each with 24–26 small hooks that reach a maximum length of only 46, considerably larger eggs, 120–150 × 25–28, and a terminal gonopore (Gupta and Fatma 1987). The following key will further separate *R. laterospinosus* from the other species of *Rhadinorhynchus* recognized as valid.

### Notes on the genus *Rhadinorhynchus*

The controversy regarding the diagnosis of *Rhadinorhynchus* as having 8 cement glands (Van Cleave and Lincicome 1940, Petrochenko 1956) or 2 cement glands (Yamaguti 1963) was settled by Golvan (1969) who diagnosed the genus with 4 cement glands which has now become the accepted norm. Few valid species, however, are known to have 2 or 8 cement glands; see key and comments following. The normal position of the cerebral ganglion is at the middle of the proboscis receptacle in *Rhadinorhynchus*. The cerebral ganglion, however, appears to be present at the posterior end of the receptacle in a few species; see key and comments following. Variability in these characters appears to exist within *Rhadinorhynchus* and perhaps should not be allowed to disqualify membership in the genus. If this premise is to be accepted, the diagnosis of the genus should be emended.

Another controversy which is yet to be settled has to do with the differences between *Rhadinorhynchus* and *Raorhynchus* Tripathi, 1959. The 2 genera are very similar but are presumably differentiated from each other by 2 characteristics: the distribution of trunk spines and position of the female gonopore. Trunk spines are in 2 fields separated by a non-spinose area and male gonopore is terminal and female gonopore is subterminal in *Rhadinorhynchus* while spines are in 1 field with male and female gonopores being subterminal in *Raorhynchus* (Yamaguti 1963 and Golvan 1969). Of the 38 accepted species of *Rhadinorhynchus* studied and reported below, 1 field of trunk spines was found in at least 10 species of *Rhadinorhynchus* including some described by Golvan (1969), and the male and female gonopore position was variable in many species, e.g., the female gonopore was terminal in at least 9 species of *Rhadinorhynchus*. The lines of separation between these 2 genera are now sufficiently blurred to reconsider the present distinct status of each of these 2 genera. Based on these differences alone, *Raorhynchus* should be considered as a junior synonym to *Rhadinorhynchus* pending a revision of the species of *Raorhynchus* is completed, which is beyond the scope of this paper.

### Synonyms of *Rhadinorhynchus* Lühe, 1911

See Amin (1985) for synonyms of *Rhadinorhynchus* including *Nipporhynchus* Chandler, 1934; *Echinosoma* Porta, 1907; and *Protorhadinorhynchus* Petrochenko, 1956.

### Invalid species of *Rhadinorhynchus*

Petrochenko (1956) listed 10 species in *Rhadinorhynchus*, Yamaguti (1963) listed 8, Amin (1985) listed 25, and Golvan (1969 and 1994) listed 21 and 33 species, respectively. Reasons for these discrepancies were found to be related to the description of new species as well as to reported synonymies.

The following 30 species are considered invalid by reason of relegation to other genera or synonymy with other species of the same genus.

1. *Rhadinorhynchus arii* Wang, 1966: synonym of *Metarhadinorhynchus cyprini* (Wang, 1966) Wang, 1986.
2. *Rhadinorhynchus aspinosus* Fukui et Morisita, 1937.
3. *Rhadinorhynchus celebensis* Yamaguti, 1954: synonym of *Gorgorhynchus celebensis* (Yamaguti, 1954) Golvan, 1969.
4. *Rhadinorhynchus epinephali* Yamaguti, 1939: synonym of *Gorgorhynchus epinephali* (Yamaguti, 1939) Golvan, 1960.
5. *Rhadinorhynchus exilis* Van Cleave, 1928: synonym of *Cathayacanthus exilis* (Van Cleave, 1928) Golvan, 1969.
6. *Rhadinorhynchus horridus* Lühe, 1912: synonym of *Megistacantha horridum* (Lühe, 1912) Golvan, 1960.
7. *Rhadinorhynchus indicus* Tripathi, 1959: synonym of *Indorhynchus indicus* (Tripathi, 1959) Golvan, 1969.
8. *Rhadinorhynchus johni* Baylis, 1929: synonym of *Aspersentis johni* (Baylis, 1929) Chandler, 1934.
9. *Rhadinorhynchus katsuwonis* Harada, 1928: synonym of *Rhadinorhynchus ornatus* Van Cleave, 1918.
10. *Rhadinorhynchus medius* (Linton, 1908) Van Cleave, 1918: synonym of *Gorgorhynchus medius* (Linton, 1908) Chandler, 1934.
11. *Rhadinorhynchus meyeri* Heinze, 1934: synonym of *Raorhynchus meyeri* (Heinze, 1934) Golvan, 1969.
12. *Rhadinorhynchus niloticus* Meyer, 1932: synonym of *Tenuisentis niloticus* (Meyer, 1932) Van Cleave, 1936.
13. *Rhadinorhynchus nudus* Harada, 1938: synonym of *Neorhadinorhynchus nudus* (Harada, 1938) Yamaguti, 1939.
14. *Rhadinorhynchus peltorhamphi* Baylis, 1944: synonym of *Heteracathocephalus peltorhamphi* (Baylis, 1944) Petrochenko, 1956.
15. *Echinorhynchus pristis* sensu Linton, 1891, in part: synonym of *Rhadinorhynchus ornatus* Van Cleave, 1918.
16. *Echinorhynchus pristis tenuicornis* Linton, 1891 (= *Rhadinorhynchus tenuicornis* Van Cleave, 1947) synonym of *Dollfusentis longispinus* Cable et Linderoth, 1963.
17. *Rhadinorhynchus pristis* sensu Lühe, 1911, in part: synonym of *Rhadinorhynchus lintoni* Cable et Linderoth, 1963.
18. *Rhadinorhynchus pristis* sensu Fukui et Morisita, 1937: synonym of *Rhadinorhynchus seriola* (Yamaguti, 1963) Golvan, 1969.
19. *Rhadinorhynchus pristis* sensu Chandler, 1943: synonym of *Rhadinorhynchus selkirki* Van Cleave, 1921.
20. *Rhadinorhynchus pristis* sensu Johnston et Edmonds, 1947: synonym of *Rhadinorhynchus johnstoni* Golvan, 1969.
21. *Rhadinorhynchus pristis* sensu Zhukov, 1960: synonym of *Rhadinorhynchus zhukovi* Golvan, 1969.
22. *Rhadinorhynchus pristis* sensu Cable et Linderoth, 1963: synonym of *Rhadinorhynchus dujardini* Golvan, 1969.
23. *Rhadinorhynchus pristis* sensu Solonchenko, 1968 and Kovaleva, 1970 is another species (Golvan, 1994).
24. *Rhadinorhynchus tenuicornis* (Linton, 1891) sensu Van Cleave, 1947: synonym of *Dollfusentis longispinus* (Cable et Linderoth, 1963) Golvan, 1969.
25. *Rhadinorhynchus tenuicornis* (Linton, 1905) sensu Van Cleave, 1947, in part: synonym of *Dollfusentis chandleri* Golvan, 1969.
26. *Rhadinorhynchus tenuicornis* sensu Chandler, 1934: synonym of *Dollfusentis chandleri* Golvan, 1969.
27. *Rhadinorhynchus tenuirostris* Van Cleave, 1918: error, actually *R. tenuicornis*.
28. *Rhadinorhynchus terebra* (Rudolphi, 1819) Lühe, 1911: synonym of *Raorhynchus terebra* (Rudolphi, 1819) Tripathi, 1959.
29. *Rhadinorhynchus vancleavei* Golvan, 1969: synonym of *Rhadinorhynchus ornatus* Golvan, 1969 sensu Amin, Heckmann, Radwan, Mantuano et Alcivar, 2009.
30. *Rhadinorhynchus wheeleri* Baylis, 1929: synonym of *Aspersentis megarhynchus* (von Linstow, 1892) Golvan, 1960.

#### *Valid species of Rhadinorhynchus*

The authors recognize 38 species of *Rhadinorhynchus* as valid. These are known from marine fishes throughout the world and include 2 new species from Vietnamese waters at Halong Bay (this paper). Four species are tentatively retained in the genus even though the patterns of trunk spination or proboscis armature, and egg dimensions remain unknown; these species are marked in the following list with an asterisk.

1. *Rhadinorhynchus africanus* (Golvan, Houin et Deltour, 1963) Golvan, 1969 from Gabon.
2. *Rhadinorhynchus alosae*\* (Hermann, 1782) Meyer, 1932 from the basin of the Rhine River.
3. *Rhadinorhynchus asturi*\* Gupta et Lata, 1967 from India.
4. *Rhadinorhynchus atheri* (Farooqi, 1981) Amin, 1985 from Lagos, Nigeria.
5. *Rhadinorhynchus bicircumspinus* Hooper, 1983 from New South Wales, Australia.
6. *Rhadinorhynchus cadenati* (Golvan et Houin, 1964) Golvan, 1969 from Senegal and Nigeria.
7. *Rhadinorhynchus camerounensis* Golvan, 1969 from Cameroun.
8. *Rhadinorhynchus capensis* Bray, 1974 from South Africa.
9. *Rhadinorhynchus carangis* Yamaguti, 1939 from Japanese Inland Sea.
10. *Rhadinorhynchus chongmingnensis*\* Huang, Zheng, Deng, Fan et Ni, 1988 from Chongming, China.
11. *Rhadinorhynchus cololabis* Laurs et McCauley, 1964 from Oregon, USA.
12. *Rhadinorhynchus decapteri* Parukhin et Kovalenko, 1976 from Hawaii.
13. *Rhadinorhynchus ditrematis* Yamaguti, 1939 from Japanese Inland Sea.
14. *Rhadinorhynchus dollfusi* Gupta et Fatma, 1987 from Kerala, India.
15. *Rhadinorhynchus dorsoventrospinosus* sp. nov. from Halong Bay, Vietnam.
16. *Rhadinorhynchus dujardini* Golvan, 1969 from Cração, Brazil.
17. *Rhadinorhynchus echeneisi* Gupta et Gupta, 1980 from the Arabian Sea.

18. *Rhadinorhynchus erumei* (Gupta et Fatma, 1981) Amin, 1985 from India.
19. *Rhadinorhynchus ganapatti* Chandra, Rao et Shyamasundari, 1985 from India.
20. *Rhadinorhynchus hiansi* Soota et Bhattacharya, 1981 from India.
21. *Rhadinorhynchus japonicus* Fujita, 1920 from Japan.
22. *Rhadinorhynchus johnstoni* Golvan, 1969 from South Australia.
23. *Rhadinorhynchus keralensis* Gupta et Fatma, 1987 from Kerala, India.
24. *Rhadinorhynchus laterospinosus* sp. nov. from Halong Bay, Vietnam.
25. *Rhadinorhynchus lintoni* Cable et Linderoth, 1963 from the Mediterranean and Atlantic Ocean.
26. *Rhadinorhynchus ornatus* Van Cleave, 1918 from the Atlantic coast of the USA, Japan, and the Pacific Ocean off South America.
27. *Rhadinorhynchus pelamysi* Gupta et Gupta, 1980 from the Arabian Sea.
28. *Rhadinorhynchus plagioscionis* Thatcher, 1980 from Amazonia.
29. *Rhadinorhynchus plotosi* Parukhin, 1985 from the Gulf of Oman.
30. *Rhadinorhynchus polynemi* Gupta et Lata, 1967 from India.
31. *Rhadinorhynchus pristis* (Rudolphi, 1802) Lühe, 1911 (type) from North Atlantic Ocean.
32. *Rhadinorhynchus saltatrix* Troncy et Vassiliadès, 1973 from West Africa.
33. *Rhadinorhynchus selkirki* Van Cleave, 1920 from Juan Fernández Island.
34. *Rhadinorhynchus seriolae*\* (Yamaguti, 1963) Golvan, 1969 from Japan.
35. *Rhadinorhynchus stunkardi* Gupta et Fatma, 1987 from Orissa, India.
36. *Rhadinorhynchus trachuri* Harada, 1935 from a Tokyo market, Japan.
37. *Rhadinorhynchus trivandricus* George et Nadakal, 1978 from India.
38. *Rhadinorhynchus zhukovi*\* Golvan, 1969 from the Kourile Islands.

#### Key to valid species of *Rhadinorhynchus*

The following key is initially based on the distribution of trunk spines which has traditionally been given little attention. Twenty one species were found to have trunk spines in 2 separate fields (including 4 species with both dorsal and ventral spines in the posterior field, 16 species with no posterior spines on the dorsal side, and 1 species with uncertain spine count). Two species had anterior and posterior spine fields bridged with lateral spines. Trunk spines in another 11 species were distributed in only 1 field. In the remaining 4 species, the distribution of trunk spines was not known. Subsequent characters used in the key included proboscis armature, egg

measurements, proportion of lemnisci to proboscis receptacle length, and other unique or unusual features characteristic of certain species. When there was a discrepancy between the descriptive text and accompanying illustrations, precedence is given to the illustrations. For instance, in the description of *R. camerounensis*, Golvan (1969) described trunk spines as “en deux champs séparés par une zone inerme” but his figure no. 38A shows a male with clearly one field of 4 equally spaced circles of spines. In all species with two separate fields of trunk spines, the anterior field invariably includes complete circles of spines. Where applicable, the number of dorsal trunk spines is mentioned first followed by the number of ventral spines, e.g., in the case of *P. trivandricus*, “trunk spines in 18 (dorsal) to 20 (ventral) circles.” The key does not include species currently recognized as belonging to *Raorhynchus*.

1. Trunk spines in 1 or 2 fields ..... 2
  - Trunk spines of uncertain distribution ..... 35
2. Trunk spines in 1 field ..... 3
  - Trunk spines in 2 fields ..... 13
3. Trunk spines covering entire body. Proboscis with 12 rows of 23–24 hooks each. Eggs large, 110 × 23.....
  - ..... *R. plagioscionis*
  - Trunk spines only anterior. Proboscis armature different. Eggs variable ..... 4
4. Proboscis hooks in 16–22 rows ..... 5
  - Proboscis hooks in 10–15 rows ..... 6
5. Proboscis hooks in 16–18 rows. Trunk spines in 5 or 4 circles ..... *R. ganapatti*
  - Proboscis hooks in 18–22 rows. Trunk spines in 18 to 20 circles ..... *R. trivandricus*
6. Proboscis hooks in 10 rows ..... 7
  - Proboscis hooks in 12–15 rows ..... 8
7. Proboscis hook rows with 35–36 hooks each. Trunk spines in 20 to 17 circles ..... *R. carangis*
  - Proboscis hook rows with 20–21 hooks each. Trunk spines in 9–10 to 15–19 circles ..... *R. polynemi*
8. No dorsal trunk spines; only lateral and ventral spines present ..... 9
  - Dorsal, ventral and lateral trunk spines present ..... 10
9. Only 1 ventral trunk spine present ..... *R. camerounensis*
  - Sixteen ventral trunk spines present ..... *R. capensis*
10. With 12–14 proboscis hook rows each with 42–46 hooks ..... *R. africanus*
  - With 12 proboscis hook rows each with 29–36 hooks .... 11
11. With 29 proboscis hooks per row and 11 to 23 circles of trunk spines ..... *R. plotosi*
  - With 30–36 proboscis hooks per row and different distribution of trunk spines. .... 12
12. With 30–36 proboscis hooks per row and 19 to 29 circles of minute (10 µm) trunk spines ..... *R. atheri*
  - With 32–33 proboscis hooks per row and 15 to 16 circles of markedly larger trunk spines ..... *R. decapteri*
13. Trunk spines of unknown distribution in 2 fields. Proboscis hooks in 12 rows each with 24 hooks. Lemnisci much shorter than receptacle. Eggs 71 × 14 ..... *R. seriolae*

- Worms with different combination of characters ..... 14
- 14. Trunk spines in 2 fields connected with lateral spines ... 15
  - Trunk spines in 2 fields clearly separated by unarmed zone ..... 16
- 15. Proboscis hooks in 18 rows each with 24–25 hooks. Trunk with no dorsal and 8 ventral posterior spines. Eggs  $62 \times 17$  ..... *R. laterospinus* sp. nov.
  - Proboscis hooks in 8–10 rows each with 24–26 hooks. Trunk with no dorsal and 3–4 ventral posterior spines. Eggs much larger,  $120\text{--}150 \times 25\text{--}28$  ..... *R. stunkardi*
- 16. Posterior field includes dorsal, ventral, and lateral spines ..... 17
  - Dorsal spines absent in posterior field..... 20
- 17. Anterior trunk spines short (22–25 long), in 8–9 circles. Proboscis hooks in 10 rows each with 26 small hooks (22–26 long at middle)..... *R. erumei*
  - Anterior trunk spines longer (50–100 long) in 1–4 circles. Proboscis hooks in 11–16 rows each with 25–32 larger hooks (50–130 long at middle)..... 18
- 18. Trunk with many fragmented nuclei. Proboscis with 11–12 hook rows. Posterior trunk spines in 7–27 to 11–43 circles..... *R. dorsoventrospinus* sp. nov.
  - No fragmented nuclei in trunk. Proboscis with 14–16 hook rows. Posterior trunk spines in 0–8 to 3–17 circles ..... 19
- 19. Proboscis with 25–26 hooks per row. Posterior trunk spines in 0–2 to 3–6 circles. Eggs  $65\text{--}80 \times 17\text{--}20$ . Female gonopore terminal ..... *R. cadenati*
  - Proboscis with 28–32 hooks per row. Posterior trunk spines in 0–8 to 16–17 circles. Eggs  $110 \times 22$ . Female gonopore subterminal ..... *R. lintoni*
- 20. Female 17 mm long. Anterior trunk spines in 2 to 2 circles. Ventral posterior trunk spines 7. Lemniscus as long as receptacle. Eggs  $62 \times 12$  ..... *R. johnstoni*
  - Combination of characters different ..... 21
- 21. Ventral posterior trunk spines 10–18. Proboscis with 12–14 rows of 24 hooks each. Largest proboscis hooks 94–120 long ..... 22
  - Ventral posterior trunk spines usually less than 10. Proboscis armature variable. Largest proboscis hooks variable but usually smaller ..... 23
- 22. Males and females 14 and 35 mm long, respectively. Proboscis with 14 hook rows. Ventral posterior trunk spines 10–18. Bursa with papillae ..... *R. saltatrix*
  - Smaller worms; males and females 6 and 14–20 mm long, respectively. Proboscis with 12–14 hook rows. Ventral posterior trunk spines 10–11. Presence of papillae on bursa unknown ..... *R. selkirki*
- 23. Proboscis with 20–25 rows of 30–44 hooks each ..... 24
  - Proboscis with 10–18 rows of 17–28 hooks each ..... 26
- 24. Proboscis with 20–22 rows of 40–44 hooks each. No dorsal trunk spines in anterior field and posterior field with 5 ventral spines ..... *R. hiansi*
  - Proboscis with 22–25 rows of 30–40 hooks each. Dorsal anterior trunk spines 2–6 and posterior field with 7–13 ventral spines ..... 25
- 25. Proboscis with 22–24 rows of 38–40 hooks each. Posterior ventral trunk spines 5–13. Lemnisci shorter than receptacle. Eggs  $59\text{--}85 \times 20\text{--}28$ . Female gonopore subterminal ..... *R. ornatus*
  - Proboscis with 22–25 rows of 30–40 hooks each. Posterior ventral trunk spines 7–9. Lemnisci longer than receptacle. Eggs  $70 \times 17$ . Female gonopore dorso-terminal ..... *R. dujardini*
- 26. Proboscis with 10–12 rows of 17–24 hooks each ..... 27
  - Proboscis with 12–18 rows of 23–28 hooks each ..... 30
- 27. Proboscis with 12 rows of 23 hooks each. Posterior end of proboscis receptacle with 2 rows of minute spines. Anterior trunk spines in 2 to 2 circles ..... *R. bicircumspinus*
  - Proboscis with 10–12 rows of hooks with 17–24 hooks each. No spines at posterior end of receptacle. Anterior trunk spines in 3–4 to 3–4 circles ..... 28
- 28. Proboscis with 12 rows of 17–18 hooks each. Posterior ventral trunk spines 5 ..... *R. japonicus*
  - Proboscis with 10–12 rows of 20–24 hooks each. Posterior ventral trunk spines 1–4 ..... 29
- 29. Proboscis with 10–12 rows of 20–21 hooks each. Testes oblong. Lemnisci as long as receptacle. Eggs  $57\text{--}75 \times 9\text{--}14$  ..... *R. cololabis*
  - Proboscis with 12 rows of 22–24 hooks each. Testes ovoid. Lemnisci longer than receptacle. Eggs  $73\text{--}20$  ..... *R. trachuri*
- 30. Proboscis with 12–14 rows of 24–26 spines each. Cephalic ganglion at base of proboscis receptacle. Cement glands 2. Eggs large  $120\text{--}130 \times 30\text{--}35$ . Female gonopore terminal ..... *R. dollfusi*
  - Proboscis with 12–18 rows of 23–28 hooks each. Cephalic ganglion near middle of receptacle except in *R. keralensis* (also at base of receptacle). Cement glands 2 or 4. Eggs variable but usually smaller. Female gonopore subterminal ..... 31
- 31. Proboscis with 14–18 rows of 24–26 hooks each. Cement glands 2 ..... *R. echeneisi*
  - Proboscis with 12–16 rows of 23–28 hooks each. Cement glands 4 ..... 32
- 32. Proboscis with 15–16 rows of 24 hooks each. Proboscis receptacle single-walled. Posterior ventral trunk spines 6 in males and 8 in female ..... *R. ditrematis*
  - Proboscis with 12–16 rows of 23–28 hooks each. Receptacle double-walled ..... 33
- 33. Large worms, males 20 mm long, females up to 70 mm long. Proboscis with 14–16 rows of 26 hooks each and with weak anterior ventral hooks. Posterior ventral trunk spines 6. Eggs  $120 \times 20$  ..... *R. pristis*
  - Considerably smaller worms. Proboscis with 12–16 rows of 23–28 normal hooks each. Posterior ventral trunk spines 1–4. Eggs of similar or smaller size ..... 34
- 34. Worms 7–8 mm long. Proboscis with 14–16 rows of 26–28 hooks each; anterior hooks 45–48 long, decreasing in size posteriorly. Cephalic ganglion at base of receptacle. Eggs  $100\text{--}120 \times 30\text{--}32$  ..... *R. keralensis*
  - Males and females 5–12 mm and 7–20 mm long, respec-

- tively. Proboscis with 12–14 rows of 23–24 hooks each in males and 14–16 rows of 26–27 hooks each in females. Anterior hooks 60–80 long, larger than basal hooks. Position of cephalic ganglion unknown. Eggs 62–75 × 11–14 ..... *R. pelamysi*
35. Female 50 mm long. Proboscis with 8 rows of hooks ..... *R. alosae*
- Worms smaller. Proboscis with 8, 14 or 16 rows of hooks ..... 36
36. Males and females average 18 mm and 25 mm in length, respectively. Proboscis with 14 rows each with 29–32 hooks. Lemnisci as long as trunk. Cerebral ganglion at posterior end of proboscis receptacle ..... *R. chongmingnensis*
- Worms much smaller. Proboscis with 16 or 8 rows of 24–26 hooks each. Lemnisci shorter. Location of cerebral ganglion unknown ..... 37
37. Worms 10–12 mm long. Proboscis with 16 rows of hooks ..... *R. zhukovi*
- Female 8.5 mm long. Proboscis with 8 rows of hooks ..... *R. asturi*

### Comments

Unusual features that do not fit the generic diagnosis of *Rhadinorhynchus* and that warrant further consideration include (1) the number of cement glands being 2 in *R. dollfusi* and *R. eche-neisi*, and 7 or 8 in *R. capensis* and *R. trivandricus*, (2) the cephalic ganglion being at the posterior end of the proboscis receptacle in *R. chongmingnensis*, *R. dollfusi*, *R. ganapatti*, and *R. keralensis*, and (3) the single-walled proboscis receptacle in *R. ditrematis*.

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