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Acanthocephalans from Red Sea fishes. Family Cavisomidae Meyer, 1932: The seasonal cycle of *Diplosentis nudus* (Harada, 1938) Pichelin et Cribb, 2001 in a definitive fish host, and a comment on *Sclerocollum* Schmidt et Paperna, 1978

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Abstract

Specimens of the fishes *Rastrelliger kanagurta* (Scombridae) and *Siganus luridus* (Siganidae) were caught in the Red Sea off the coast of Sharm El-Sheikh, South Sinai, Egypt. *R. kanagurta* was parasitised by *Diplosentis nudus* (Harada, 1938) Pichelin et Cribb, 2001 (Acanthocephala, Cavisomidae), and *S. luridus* by *Sclerocollum rubrimaris* Schmidt et Paperna, 1978 (Acanthocephala, Cavisomidae). The infection of *R. kanagurta* was followed monthly for one year (from September, 2004 to August, 2005). As a result, the seasonal cycle of *D. nudus* in its definitive host is described herein for the first time. The cycle is well-defined and extends for about 11 months (from October to August); in October, new generation of *D. nudus* starts to appear in the intestine of *R. kanagurta*; during the winter, the juvenile worms continued their growth; during the spring, most of the worms attained maturity and the mature worms copulated; during the summer, the worms began to die off naturally prior to their elimination from the intestine of the host. *Sclerocollum rubrimaris* is redescribed and *Sclerocollum* Schmidt et Paperna, 1978 is retained as a valid genus within the Cavisomidae.

Key words

Acanthocephala, Cavisomidae, *Diplosentis nudus*, *Sclerocollum rubrimaris*, seasonal cycle, Red Sea fishes

Introduction

In the rhadinorhynchid acanthocephalan genus *Rhadinorhynchus* Lühe, 1911, the trunk is spined, but in both *R. aspinosus* Fukui et Morisita, 1936 and *R. nudus* Harada, 1938, the trunk is unspined. Therefore, Yamaguti (1939) erected *Neorhadinorhynchus* as a subgenus of *Rhadinorhynchus* to include these species, the former from *Teuthis fuscescens* (now *Siganus fuscescens*) off Japan and the latter from *Trachurus japonicus* off Taiwan. Later, Yamaguti (1963) raised the subgenus to full generic status within the family Echinorhynchidae Cobbold, 1879 and subfamily Cavisomatinae Meyer, 1932. He also considered *Echinorhynchoides* Achmerov et Dombrovskaja-Achmerova, 1941 a synonym of *Neorhadinorhynchus*, and transferred *E. dogieli* Achmerov et Dombrovskaja-Achmerova, 1941, the type and the only species of the genus to *Neorhadinorhynchus*. Golvan (1969) described *N. madagascariensis* from the stomach of an unnamed marine fish off Madagascar, and transferred *Neogorgorhynchus robustus* Edmonds, 1964 to *Neorhadinorhynchus* as a new combination. Gaevskaya and Nigmatullin (1977) described *N. atlanticus* from the stomach of *Sthenoteuthis pteropus* in the Atlantic Ocean. Amin (1985) resurrected *Echinorhynchoides* with its type-species, and raised the Cavisomatinae Meyer, 1932 to full family status (Cavisomidae Meyer, 1932) and included *Neorhadinorhynchus* within it. Two further species of *Neorhadinorhynchus* have been described: *N. myctophumi* from a *Myctophid* sp. in the “World Ocean” by Mordvinova (1988) and *N. macrospinosus* from *Siganus vermiculatus* off Fiji Islands by Amin and Nahhas (1994). Accordingly, six species of *Neorhadinorhynchus* have been recognised, i.e. *N. aspinosus* (Fukui et Morisita, 1936) Yamaguti, 1939 (type-species), *N. nudus* (Harada, 1938) Yamaguti, 1939, *N. madagascariensis* Golvan, 1969, *N. atlanticus* Gaevskaya et Nigma-

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tullin, 1977, *N. myctophumi* Mordvinova, 1988 and *N. macrospinosus* Amin et Nahhas, 1994. No further species have been ascribed to *Neorhadinorhynchus*.

Schmidt and Paperna (1978) erected *Sclerocollum* for *S. rubrimaris* Schmidt et Paperna, 1978 from the intestine of three fish species (*Siganus rivulatus*, *S. rostratus* and *Pseudobalistes fuscus* in the Gulf of Elat, Red Sea. They referred the genus to the family Rhadinorhynchidae Travassos, 1923 and subfamily Gorgorhynchinae Van Cleave et Lincicome, 1940, and differentiated it from *Neorhadinorhynchus* Yamaguti, 1939 by the conspicuous sclerotised plaques which are embedded in the tegument at the anterior region of the trunk (vs absent) and by the basal hooks of the proboscis which alternate with each other (vs arranged at the same level to form a ring). These two characteristics were also observed by Schmidt and Paperna (1978) in the original specimens of *N. robustus* (Edmonds, 1964) Golvan, 1969. Therefore, they transferred this species to *Sclerocollum*, which had been collected from *Siganus lineatus* on the Southern Great Barrier Reef by Edmonds (1964). No further species have been included in *Sclerocollum*.

In a revision of the family Diplosentidae Tubangui et Masiluñgan, 1937, Pichelin and Cribb (2001) redefined *Diplosentis* Tubangui et Masiluñgan, 1937, transferring it and its type-species, *D. amphacanthi* Tubangui et Masiluñgan, 1937 to the family Cavisomidae. However, and on the basis of a striking similarity, they considered *Neorhadinorhynchus* and *Sclerocollum* as synonyms of *Diplosentis*. Accordingly, the above six valid species of *Neorhadinorhynchus* and the two valid species of *Sclerocollum* were transferred by Pichelin and Cribb (2001) to *Diplosentis* as new combinations.

In the present work, *D. nudus* (Harada, 1938) Pichelin et Cribb, 2001 is redescribed and its seasonal cycle in a definitive fish host from the Red Sea is explored for the first time. However, *Sclerocollum rubrimaris* Schmidt et Paperna, 1978 is redescribed and *Sclerocollum* is retained as a valid genus within the Cavisomidae.

Materials and methods

A total of 984 specimens of the fish *Rastrelliger kanagurta* (Scombridae) were examined from September, 2004 to August, 2005 (72–90 specimens/month). However, 78 specimens of the fish *Siganus luridus* (Siganidae) were also examined during March, 2005. These fishes were caught in the Red Sea off the coast of Sharm El-Sheikh, South Sinai, Egypt, and kept alive in aquaria. Fish identifications were based on Randall (1983) and the modern names follow Froese and Pauly (2004). Standard parasitological techniques were used to examine the alimentary canal of the fish. Acanthocephalans were removed from their host fishes and observed live under a dissecting stereomicroscope. The intensity of infection was estimated as the total number of collected worms/number of infected fishes. The female worms were divided into four developmental stages, juveniles (with indistinct ovarian balls), with ovarian balls, with ovarian balls and eggs and fully-gravid with embryonated eggs. Some worms were fixed in Berland's fluid (1 ml of 95% glacial acetic acid and 5% formalin diluted in 10 ml of tap water) under a slight coverslip pressure and preserved in 75% ethyl alcohol. Wholemounts were stained in acid carmine, cleared in terpineol and mounted in Canada balsam. Measurements are quoted as the range, with the mean in parentheses, and are given in micrometres, except where indicated. Drawings were made with aid of a camera lucida. The specimens are deposited in Helminthological Collection of the Red Sea Fishes, Marine Science Department, Faculty of Science, Suez Canal University, Ismailia, Egypt.

Results

Cavisomidae Meyer, 1932
Diplosentis Tubangui et Masiluñgan, 1937

***Diplosentis nudus* (Harada, 1938) Pichelin et Cribb, 2001**
(Fig. 1A-F)

Description: Based on 30 male and 30 fully-gravid female wholemounts. General: Body moderate in size. Males slightly larger than females. Trunk thick-walled, unspined. Proboscis relatively long, cylindrical, usually slightly curved, armed with 14 alternating longitudinal rows of sharp recurved hooks; each row includes 24–25 hooks of variable length; basal hooks arranged at same level to form ring. Neck short. Proboscis receptacle double-walled, long, subcylindrical. Ganglion near middle of proboscis receptacle. Lemnisci claviform, equal in length, slightly longer than proboscis receptacle. Genital pores subterminal.

Males: Trunk elongate-fusiform, 7,421–11,132 (9,276) in length, 1,103–1,642 (1,372) in greatest width in its anterior region. Proboscis 1,151–1,713 × 162–241 (1,432 × 201). Proboscis hooks: first 5 hooks, 31–50; next 7, 60–68; next 7, 45–50; and the remaining 6, 32–40 in length. Neck 182–271 (226) in length. Proboscis receptacle 1,981–2,931 × 232–341 (2,456 × 286). Lemnisci 2,101–3,061 × 81–122 (2,581 × 101). Testes 2, oval, tandem, contiguous, in middle of trunk; anterior testis 999–1,462 × 563–841 (1,230 × 702), posterior testis 922–1,353 × 582–873 (1,137 × 727). Cement glands 4, tubular, in 2 overlapping tandem pairs; anterior pair 981–1,454 × 253–394 (1,217 × 323); posterior pair 1,086–1,595 × 193–291 (1,340 × 242). Seminal vesicle long, irregularly tubular. Copulatory bursa well-developed, hemispherical, 503–732 (618) in diameter. In copulating male, the extrusion of the bursa appears to induce a slight displacement of the sexual organs toward the posterior end.

Females: Trunk elongate, 7,281–10,911 (9,096) in length, 1,292–1,931 (1,611) in greatest width in its anterior region. Proboscis 1,356–1,781 × 168–211 (1,568 × 189). Proboscis hooks very similar to those of males in size. Neck 221–315 (268) in length. Proboscis receptacle 1,996–2,991 × 226–312

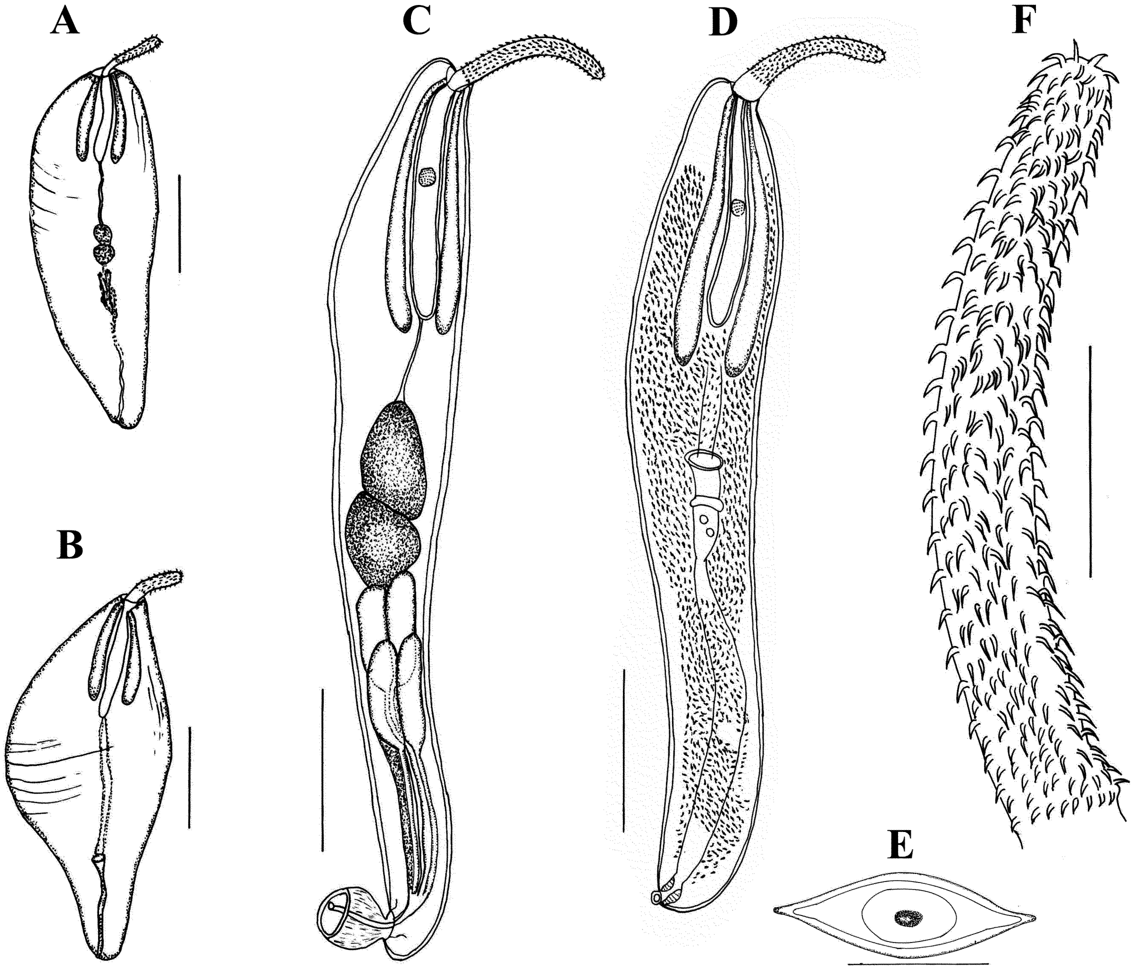

Fig. 1A-F. *Diplosentis nudus* (Harada, 1938) Pichelin et Cribb, 2001 from *Rastrelliger kanagurta*, Red Sea. **A.** Male juvenile. **B.** Female juvenile. **C.** Mature male. **D.** Fully-gravid female. **E.** Egg. **F.** Proboscis. Scale bars = 1 mm (A and B), 2 mm (C and D), 20 µm (E), 500 µm (F)

(2,493 × 269). Lemnisci 2,511–3,612 × 251–360 (3,061 × 305). Uterine bell short, 396–571 × 231–331 (483 × 281), its base 3,718–5,432 (4,575) from the posterior end. Selector apparatus 567–772 × 256–311 (669 × 283). Uterus tubular, long, 2,961–4,181 (3,571) long. Vagina short, guarded by a sphincter muscle on each side. Eggs small, fusiform, with polar swelling of middle membrane, 36–41 × 8–12 (38 × 10).

Host: *Rastrelliger kanagurta* Cuvier (Scombridae).

Site: Intestine.

Locality: Red Sea, off Sharm El-Sheikh, South Sinai, Egypt.

Material: Voucher specimens are deposited in the Helminthological Collection of the Red Sea Fishes, Marine Science Department, Faculty of Science, Suez Canal University, Ismailia, Egypt.

The infection of *R. kanagurta* with *D. nudus* was followed monthly for one year (from June, 2004 to May, 2005). The corresponding prevalence and intensity of infection, and the successive maturation of the female worms of *D. nudus* were recorded (Table I).

Prevalence and intensity of infection

In September, 2004, a few naturally dead worms of *D. nudus* were recovered from the intestine of *R. kanagurta*, where they were found suspended in the lumen and enclosed within mucous material. These worms were probably remnants of the previous generation, since they were large and the females were fully distended with embryonated eggs. In October, a new generation of *D. nudus* started to appear in the intestine of *R. kanagurta* with a relatively high prevalence of 36.9% and intensity of 25.48 worms/host. These values seemed to be stable in the next month. During the winter months, both the prevalence and intensity increased gradually to peak in February, where the prevalence was 46.05% and the intensity 43.11 worms/host; this points to the continuous accumulation of new infections during this season. During the spring and summer months, a significant gradual decline was observed in both the prevalence and intensity to reach their minimum values in August, where the prevalence was 7.5% and the intensity was 7.83 worms/host.

Successive maturation of the female worms of D. nudus

During the autumn of 2004, new generation of *D. nudus* was first observed in the intestine of *R. kanagurta* in October, and all the female worms examined to the end of this season were juveniles (without ovarian balls).

During the winter, female worms containing ovarian balls were first observed in January in 28.1% of the examined females and, as maturation continued, their percentage increased in February to 52.2%.

During the spring, no juvenile female worms were observed in March, where the percentage of female worms containing ovarian balls increased to 81.87%, and females containing ovarian balls and eggs were first observed in 18.13% of the examined females. In April, female worms containing ovarian balls were not observed, while the percentage of the females containing ovarian balls and eggs increased to 77.17%, and the fully-gravid females (distended with embryonated eggs) were first observed in 22.83% of the examined females. In May, females containing ovarian balls and eggs decreased to 14.14%, and the percentage of the fully-gravid females increased to 85.86%; in most of these females, cement plugs were observed attached to their posterior ends, indicating that copulation and insemination has occurred.

During the summer months, all the examined female worms were fully distended with embryonated eggs; most of these worms were naturally dead, and some worms were seen hanging out of the anus in many fishes. However, embryonated eggs of *D. nudus* were not observed among the intestinal contents of *R. kanagurta*.

Remarks

Diplosentis nudus was originally collected from *Trachurus japonicus* (Carangidae) off Taiwan. In its original description (see Harada 1938), the female was briefly described but not figured, the ovarian balls and eggs were not mentioned, and the measurements were not given in ranges. Thus, the original description was probably based on a few juvenile specimens. Amin and Nahhas (1994) redescribed this species from one male and one female (with ovarian balls) from *Euthynnus affinis* (Scombridae) off the Islands of Fiji, but without figures. In the present work, *D. nudus* is collected from a new scombrid host (*R. kanagurta*), redescribed from a large number of fully-mature specimens, and its female is figured for the first time. However, the infection of *R. kanagurta* with *D. nudus* was followed monthly for one year (from September, 2004 to August, 2005). During this period, the prevalence and intensity of infection followed a simple trend, in which both were nearly stable in autumn, increased gradually during the winter months to peak in February, then declined gradually during the spring and the summer months to reach their minimum values in August. The winter increase in the prevalence

Table I. Infection of *Rastrelliger kanagurta* with *Diplosentis nudus*: monthly prevalence and intensity of infection, and the successive maturation of the female worms

Season	Month	No. examined fishes	No. infected fishes	Prevalence (%)	No. collected worms	Intensity of infection (mean no. of worms/host)	New generation of *Diplosentis nudus*				
								successive maturation of female worms			
							no.	juveniles	with ovarian balls	with ovarian balls and eggs	fully-gravid with embryonated eggs
Autumn	Sept. 2004	80	5	06.25	14*	02.80	–	–	–	–	–
	Oct.	84	31	36.90	790	25.48	439	439 (100%)	–	–	–
	Nov.	80	28	35.00	654	23.35	347	374 (100%)	–	–	–
Winter	Dec.	80	30	37.50	1031	34.36	501	501 (100%)	–	–	–
	Jan. 2005	82	33	40.24	1192	36.12	612	440 (71.90%)	172 (28.10%)	–	–
	Feb.	76	35	46.05	1509	43.11	795	380 (47.80%)	415 (52.20%)	–	–
Spring	Mar.	80	30	37.50	1065	35.50	513	–	420 (81.87%)	93 (18.13%)	–
	Apr.	84	30	35.71	932	31.06	495	–	–	382 (77.17%)	113 (22.83%)
	May	88	29	32.95	730	25.17	396	–	–	56 (14.14%)	340 (85.86%)
Summer	Jun.	80	20	25.00	408	20.40	225	–	–	–	225 (100%)
	Jul.	90	17	18.88	165	09.70	87	–	–	–	87 (100%)
	Aug.	80	6	07.50	47	07.83	21	–	–	–	21 (100%)

*Naturally dead worms, probably remnants of the previous generation.

and intensity of infection points to the continuous accumulation of new infections during this season. According to Amin *et al*. (1980), such accumulation may be due to the feeding activity of the fish, and does not extend the seasonal cycle of the worm in its fish host, since cystacanths (infective stages) ingested by the fish during winter are larger and more developed than those ingested earlier during autumn, and require less time to mature and for females to produce eggs in the fish host. The gradual declining in prevalence and intensity during the spring and summer months may be due to the natural mortality of the worms, which indicates that the life span of *D. nudus* in its definitive host is about 11 months. The embryonated eggs of the worms were not observed among the intestinal contents of *R. kanagurta*, and some male and female worms were seen hanging out of the anus in many fishes. These results suggest that females of *D. nudus* may not lay eggs, but they pass out of the intestine of *R. kanagurta* and degenerate in the environment. The released embryonated eggs are ingested by the intermediate host. This is in accordance with the suggestion of Muzzall and Rabalais (1975) when explaining a similar case in their study of the seasonal cycle of *Acanthocephalus jacksoni* Bullock, 1962. Chubb (1964) and Muzzall and Rabalais (1975) postulated that in an acanthocephalan infection, water temperature may play a major role in determining the presence or absence of a well-defined seasonal periodicity.

Generally, the results obtained revealed that, in its definitive host, *D. nudus* has a well-defined seasonal cycle which extends for about 11 months (from October, 2004 to August, 2005); in October, the new generation of *D. nudus* starts to appear in the intestine of *R. kanagurta*; during the winter, the juvenile worms continue their growth; during the spring, most of the worms attain their maturity and the mature females copulate; and during the summer, the worms begin to die off naturally prior to their elimination from the intestine. Similar seasonal cycles were reported for *Gracilisentis gracilisentis* Van Cleave, 1913 by Van Cleave (1916), *Acanthocephalus lucii* (Müller, 1776) Lühe, 1911 by Komarova (1950), *Echinorhynchus gadi* Zoega in Müller, 1776 by Shulman and Shulman-Albova (1953), *Acanthocephalus parksidei* Amin, 1974 by Amin (1975), *A. jacksoni* Bullock, 1962 by Muzzall and Rabalais (1975), and *Neoechinorhynchus rutili* (Müller, 1776) Stiles et Hassall, 1905 by Valtonen (1979). In most of these cycles, the acanthocephalans were virtually eliminated from the intestine of their fish hosts for variable periods of time including summer.

Sclerocollum Schmidt et Paperna, 1978

***Sclerocollum rubrimaris* Schmidt et Paperna, 1978** (Fig. 2 A-D)

Description: Based on 30 male and 30 female wholemounts. General: Body moderate in size. Females much larger than males. Trunk thick-walled, unspined. Proboscis relatively short, cylindrical, armed with 14 alternating longitudinal rows of sharp recurved hooks; each row includes 8–10 hooks of variable length; basal hooks alternate with each other (not forming ring). Neck short. Proboscis receptacle double-walled, relatively short, claviform. Ganglion near middle of proboscis receptacle. Lemnisci claviform, equal in length, slightly longer than proboscis receptacle.

Males: Trunk elongate-fusiform, 8,610–12,730 (10,670) in length, 1,101–1,530 (1,315) in greatest width in its anterior region. Proboscis 492–766 × 130–280 (630 × 205). Proboscis hooks: First 3 hooks, 32–38; next 3, 43–49; and the remaining 3–4, 23–27 in length. Neck 91–138 (115) in length. Proboscis receptacle 1,121–1,572 × 98–140 (1,346 × 119). Lemnisci 1,131–1,743 × 97–136 (1,437 × 117). Testes 2, oval, tandem, contiguous, in middle of trunk or slightly anterior; anterior testis 89–1,262 × 427–693 (1,076 × 560); posterior testis 751–1,123 × 381–573 (990 × 477). Cement glands four, tubular, in two tandem pairs; anterior pair 1,435–2,101 × 172–261 (1,768 × 217); posterior pair 1,483–2,171 × 157–221 (1,827 × 189). Seminal vesicle long, irregularly tubular. Copulatory bursa well-developed, hemispherical, 512–701 (607) in diameter. Genital pore subterminal.

Females: Trunk elongate, 12,317–18,421 (15,369) in length, 1,301–1,742 (1,526) in greatest width in its anterior region. Proboscis 465–636 × 149–211 (551 × 180). Proboscis hooks closely similar to those of males in size. Neck 102–140 (121) in length. Proboscis receptacle 1,316–1,471 × 156–181 (1,393 × 169). Lemnisci 1,467–1,682 × 129–171 (1,574 × 150). Uterine bell short, 179–272 × 221–356 (226 × 293), its base 2,516–4,002 (3,260) from posterior end. Selector apparatus 264–345 × 206–281 (303 × 244). Uterus tubular, short, 2,961–4,181 (3,571) long. Vagina short, guarded by sphincter muscle on each side. Genital pore terminal. Eggs fusiform, small, with polar swelling of middle membrane, 48–55 × 13–17 (25 × 15).

Host: *Siganus luridus* Rüppell (Siganidae).

Site: Intestine.

Prevalence: 25/78 fishes examined; 32%.

Locality: Red Sea, off Sharm El-Sheikh, South Sinai, Egypt.

Material: Voucher specimens are deposited in the Helminthological Collection of the Red Sea Fishes, Marine Science Department, Faculty of Science, Suez Canal University, Ismailia, Egypt.

Remarks

Schmidt and Paperna (1978) stated that "*Sclerocollum* is similar to *Neorhadinorhynchus* Yamaguti, 1939, differing from it only in the presence of thick, conspicuous, sclerotised plaques in the anterior wall of the trunk", and added that in the type-species of *Neorhadinorhynchus*, *N. aspinosus*, the basal hooks of proboscis are at the same level, forming a ring of hooks, a condition may prove to be a diagnostic character of *Neorhadinorhynchus*, but in both species of *Sclerocollum*, i.e. *S. rubrimaris* and *S. robustus*, the basal hooks of proboscis alternate with each other (not forming ring). This character

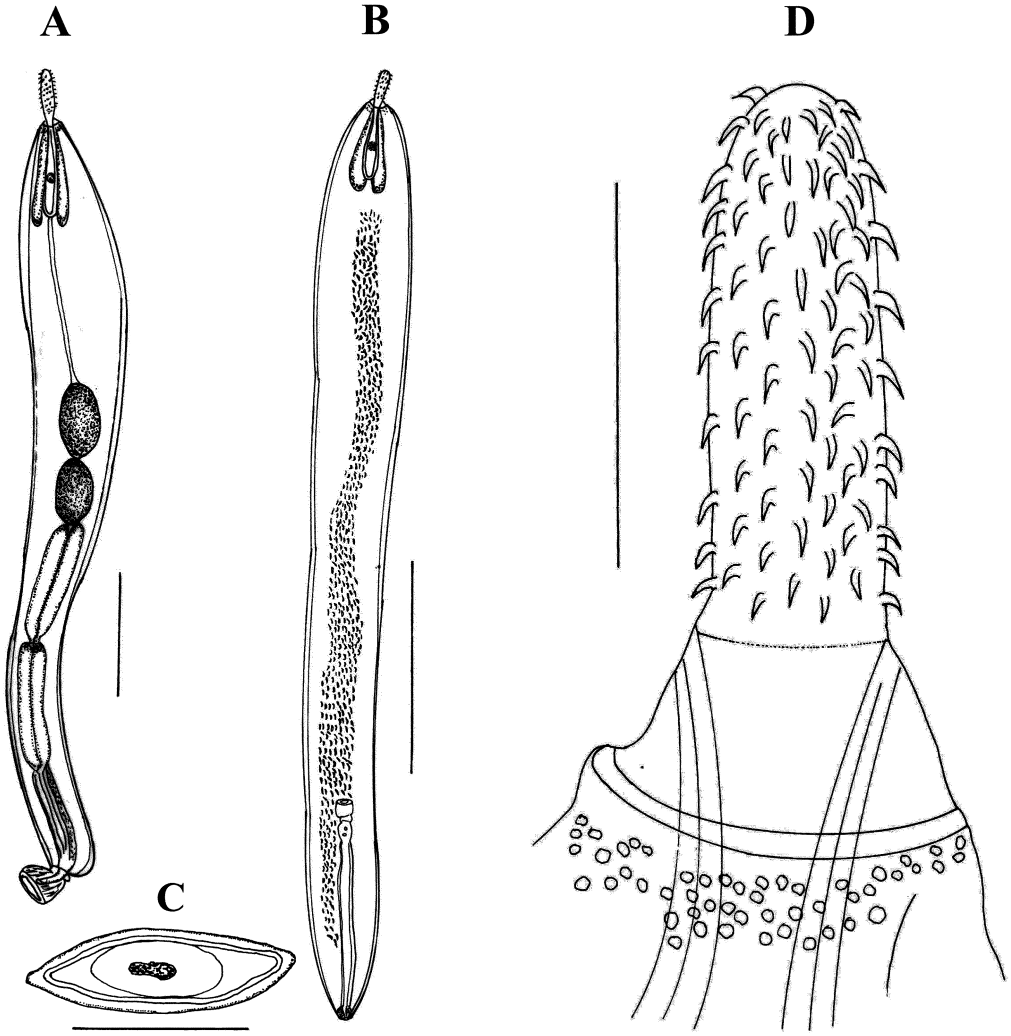

Fig. **2A-D.** *Sclerocollum rubrimaris* Schmidt et Paperna, 1978 from *Siganus luridus*, Red Sea. **A.** Male. **B.** Fully-gravid female. **C.** Egg. **D.** Proboscis. Scale bars = 2 mm (A), 4 mm (B), 32 µm (C), 500 µm (D)

was not mentioned by Schmidt and Paperna (1978) in their diagnosis of *Sclerocollum*. Pichelin and Cribb (2001) observed that in the original specimens of *S. rubrimaris*, the presence of the sclerotised plaques varies from specimen to specimen, in some specimens of *Sclerocollum* collected by them, the plaques were completely absent, and in Yamaguti's (1938) specimens of *N. aspinosus* (type-species of *Neorhadinorhynchus*), the plaques are present and clearly visible. So, they concluded that the presence of sclerotised plaques is variable and not restricted to *Sclerocollum*, and did not represent a generic difference between *Sclerocollum* and *Neorhadinorhynchus* which they considered a synonym of *Diplosentis*. Accordingly, they considered *Sclerocollum* a synonym of *Diplosentis* which they transfer to the family Cavisomidae. In fact, Pichelin and Cribb (2001) believed that sclerotised plaques are the only difference between *Sclerocollum* and *Neorhadinorhynchus* (as they mentioned), since they did not refer to the arrangement of the basal proboscis hooks. Therefore, *Sclerocollum* should be considered as a valid cavisomid genus for the present time, since in its members, the basal hooks of proboscis alternate with each other (not forming ring), a character lacking in *Diplosentis* and its synonym, i.e. *Neorhadinorhynchus*. Accordingly, *Sclerocollum* should be redefined to be as follows:

Cavisomidae. Trunk elongate, stout, somewhat dilated anteriorly, without spines. Proboscis cylindrical, relatively short, armed with 14 longitudinal rows of recurved hooks, each contains 8–13 hooks; basal hooks smaller than middle and apical hooks, alternate with each other (not forming ring). Neck short. Proboscis receptacle double-walled. Ganglion about mid-proboscis receptacle. Lemnisci claviform, equal or slightly longer than proboscis receptacle. Testes oval, tandem, contiguous; anterior testis about equatorial. Cement glands four, in two tandem or slightly overlapped pairs. Genital pore subterminal. Eggs elongate, with polar swelling of middle membrane. Intestinal parasites of marine (especially siganid) teleosts. Type-species *S. rubrimaris* Schmidt et Paperna, 1978. Other species: *S. robustus* (Edmonds, 1964) Schmidt et Paperna, 1978.

Sclerocollum rubrimaris is the best known, since it has been recorded in many siganid species (*Siganus argenteus*, *S. canaliculatus*, *S. luridus*, *S. oramin*, *S. rivulatus*, *S. rostratus* and *S. sutor*) from the Red Sea, Arabian Gulf and Kenyan coast (see Amin *et al.* 1984, Diamant 1989, El-Naffar *et al.* 1992, Martens and Moens 1995, Geets and Ollevier 1996), while *S. robustus* is still known only from its original description.

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