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REVISION OF THE GENUS ANGUILLICOLA YAMAGUTI, 1935 (NEMATODA: ANGUILLICOLIDAE) OF THE SWIMBLADDER OF EELS, INCLUDING DESCRIPTIONS OF TWO NEW SPECIES, A. NOVAEZELANDIAE SP. N. AND A. PAPERNAI SP. N.

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Abstract. The genus *Anguillicola* is reviewed on the basis of the examination of some type specimens and other material. Two new species are described: *A. novaezelandiae* sp. n. from *Anguilla australis* (type host) from New Zealand and *A. anguilla* from Italy (conspecific nematodes were originally reported from Italy as *A. australiensis*) and *A. papernai* sp. n. from *Anguilla mossambica* from South Africa. At present the genus *Anguillicola* comprises the following five valid species: *A. globiceps* Yamaguti, 1935, *A. australiensis* Johnston et Mawson, 1940, *A. crassus* Kuwahara, Niimi et Itagaki, 1974, *A. novaezelandiae* sp. n., and *A. papernai* sp. n. Two *Anguillicola* species, *A. crassus* and *A. novaezelandiae*, were apparently introduced in Europe from other continents a few years ago. The genus *Anguillicola* is divided into two subgenera: *Anguillicola* (type species *A.* (*A.*) *globiceps*) and *Anguillicoloides* subgen. n. (type species *A.* (*A.*) *crassus*). All *Anguillicola* species are briefly described and illustrated. The paper is supplemented by a key to the identification of *Anguillicola* species.

The genus *Anguillicola* Yamaguti, 1935 of the monotypic family Anguillicolidae (Dracunculoidea) was established by Yamaguti (1935) for *A. globiceps* from the swimbladder of Japanese eels (*Anguilla japonica*) in Japan. Later two additional congeneric species were described: *A. australiensis* Johnston et Mawson, 1940 from *Anguilla reinhardtii* from Australia and *A. crassus* Kuwahara, Niimi et Itagaki, 1974 from *Anguilla anguilla* and *A. japonica* raised in eel farms in Japan. The species were distinguished principally by the form of the oesophagus, number of large unicellular rectal glands, and number of caudal papillae in the male (see Peters and Hartmann 1986). Until recently, all the three above mentioned species were considered to be limited in their distribution to East Asia and Australia and New Zealand.

The general interest in these pathogenic nematodes has increased considerably since *Anguillicola* appeared in Europe. In 1982, Paggi et al. reported *Anguillicola australiensis* from *Anguilla anguilla* from Lake Bracciano near Rome in Italy. At about the same time *Anguillicola* nematodes were recorded from eels from the open waters of the Weser-Ems River region in Northern Germany (Neumann 1985); since then, they have spread throughout many countries of Western, Northern and Central Europe with great rapidity. Although the nematodes from Western Europe (Holland, Belgium) were identified as *A. crassus* by Van Banning et al. (1985) and De Charleroy (1986), Peters and Hartmann (1986) state that those from Northern Germany cannot be unequivocally assigned to any of the known species. According to De Charleroy et al. (1987), the Belgian nematodes seem to be conspecific with *A. crassus*, but the authors mention that the redescription of *A. australiensis* based on Italian nematodes (Paggi et al. 1982) approximates very closely to that of the helminths found in Belgium. Consequently, they consider it possible that *A. crassus* and *A. australiensis* are one and

the same species. This uncertainty in species identification of European *Anguillicola* members is responsible to the fact that these highly pathogenic nematodes are frequently reported from Europe as only *Anguillicola* sp. (see e.g. Peters and Hartmann 1986, Molnár 1986, Køie 1987, Koops 1987).

In an attempt to resolve the problem of the species identity of European members of *Anguillicola*, we examined a number of the type and non-type specimens of all three previously recognized species in this genus. Some of the results obtained pertaining to the European members of *Anguillicola* have been published by Taraschewski et al. (1987), who showed clearly that there are actually two species occurring in eels in Europe. Since, however, some new and important data on the morphology of *Anguillicola* members of other continents were obtained during this study, it proved possible to undertake a revision of the whole genus. It is hoped that this will help in reliable species identification and will form the basis for future work on the biology of these interesting and economically important helminths. In addition to the previously recognized species, the materials at our disposal contained two new, hitherto undescribed *Anguillicola* species which are described in the present paper.

MATERIALS AND METHODS

The following *Anguillicola* specimens were studied:

A. globiceps — 3 ♂♂ + 2 ♀♀ from unknown host (*Anguilla japonica?*) from Japan (leg. Dr. H. Hirose);
— 1 ♂, 2 juv. ♀♀ + 11 larvae from unknown host (*Anguilla japonica?*) from China (leg. Prof. P. Q. Wang and Prof. H. S. Wu);

A. australiensis — type specimens (♂ + ♀) from *Anguilla reinhardtii* from South Australia (South Australian Museum, Adelaide, Coll. No. V 1392);

A. crassus — syntypes (♂ + ♀) from *Anguilla anguilla* from Japan (Shizuka Pref., 1972, leg. Dr. A. Kuwahara) (Meguro Parasitological Museum, Tokyo, Coll. No. MPM 19093);
— specimens (21 ♂♂ + 29 ♀♀) from cultured *Anguilla japonica* (Shizuka Pref., March 1979, leg. Dr. H. Hirose);
— 5 ♂♂ + 7 ♀♀ from unknown host (*Anguilla japonica?*) from China (leg. Prof. P. Q. Wang and Prof. H. S. Wu);
— numerous specimens from *Anguilla anguilla* from the Federal Republic of Germany (Ruhr Lake, River Weser, R. Elbe estuary, June—September 1986, leg. Dr. H. Taraschewski);

A. novaezelandiae — specimens (4 ♂♂ + 3 ♀♀ — types) from *Anguilla australis* from New Zealand (Matahina dam, 17 May 1978, leg. Dr. B. Jones);
— specimens (3 ♂♂ + 3 ♀♀) from *Anguilla anguilla* from Italy (Bracciano Lake, leg. Prof. L. Paggi);

A. papernai — specimens (2 ♂♂ + 4 ♀♀) from *Anguilla mossambica* from South Africa (21 September 1984, leg. Dr. I. Paperna).

The nematodes were mostly fixed in 70% ethanol or 4% formaldehyde. All the specimens were cleared and examined in glycerine. *En face* views were prepared according to Anderson's (1958) method. Drawings were made with the aid of a Zeiss microscope drawing attachment. All measurements are in mm.

RESULTS

Genus *Anguillicola* Yamaguti, 1935

Diagnosis: Anguillicolidae. Cuticle very finely spinose or aspinose, sometimes with marked, irregularly scattered excrescences of fibrous structure on anterior and posterior ends of body. Head end bearing four cephalic papillae and two lateral amphids. Buccal

capsule present, provided with row of small circumoral teeth. Oesophagus short and wide, consisting of anterior muscular and posterior muscular-glandular sections. Valvular apparatus well developed. Intestine dark, distended. Rectal glands large. Male: Spicules absent. Testis beginning near tail end; seminal vesicle well developed. Ductus ejaculatorius opening outside on prominent caudal process. Six pairs of sessile caudal papillae present. Female: Vulva opening on tip of prominent cone in posterior part of body. Uterus opposed. Ovoviviparous. Parasites of swimbladder of eels.
Type species: *A. globiceps* Yamaguti, 1935

Remark: Since the type species *A. globiceps* differs from the remaining *Anguillicola* species in some taxonomically very important features (structure of oesophagus, spinose cuticle), we consider it useful to separate the genus *Anguillicola* into two subgenera which, in our opinion, will reflect more accurately relationships among *Anguillicola* species.

I. Subgenus ***Anguillicola*** Yamaguti, 1935

Diagnosis: *Anguillicola*. Body filiform, cuticle very finely spinose throughout. Oesophagus conspicuously inflated at anterior end, its posterior part cylindrical.
Type species: *A.* (*A.*) *globiceps* Yamaguti, 1935

II. Subgenus ***Anguillicoloides*** subgen. n.

Diagnosis: *Anguillicola*. Body fusiform or filiform, cuticle aspinose. Anterior end of oesophagus lacking inflation, narrow; posterior part of oesophagus distinctly expanded.
Type species: *A.* (*A.*) *crassus* Kuwahara, Niimi et Itagaki, 1974

REVIEW OF *ANGUILLICOLA* SPECIES

I. ***Anguillicola (Anguillicola) globiceps*** Yamaguti, 1935 Fig. 1

Description: Body filiform. Epicuticle densely covered by minute spines. Head end rounded, buccal capsule very large, well sclerotized; some 80 small circumoral teeth present. Anterior end of oesophagus bulbously inflated, posterior part of oesophagus cylindrical. Valvular apparatus well developed. Three large and one small unicellular rectal glands present. Tail very short, usually blunt.
Male (5 specimens): Length of body 24.28—32.91, maximum width 0.952—1.115. Length of buccal capsule 0.068—0.109, its width 0.272—0.408, its maximum thickness 0.009—0.015. Length of oesophagus 1.25—1.50; length of its anterior bulb 0.408 to 0.544, width 0.476—0.707, maximum width of its posterior cylindrical part 0.258—0.299. Length ratio of oesophagus and body 1: 21.5—25.4. Distance of nerve ring and excretory pore from anterior extremity 0.571—0.775 and 1.27—1.37, respectively. Common cloacal duct opening on prominent process 0.068—0.109 long. Size of larger rectal glands 0.109—0.312×0.082—0.109, that of smaller one 0.068—0.081×0.030—0.041. Six pairs of caudal papillae present: 3 preanals and 3 postanals. Tail 0.095—0.244 long.
Female (2 specimens): Length of body of gravid females 37.31—37.81, maximum width 1.44—1.54. Length of buccal capsule 0.109—0.122, width 0.408, maximum thickness of its wall 0.009. Length of oesophagus 1.50; length of its anterior bulb 0.049, width 0.571—0.639, maximum width of its posterior cylindrical part 0.299—0.313. Length ratio of oesophagus and body 1: 24.9—25.3. Distance of nerve ring and excretory pore 0.748—0.762 and 1.56—1.59, respectively. Size of larger rectal glands 0.163—0.204 by

0.109—0.136, that of smaller one 0.068×0.041. Vulva elevated, situated 6.99—8.43 from posterior extremity, this representing approximately 1/5 of body length. Uterus not reaching anteriorly oesophageal region; uterus containing numerous eggs (size 0.078—0.081×0.069), developing embrya and fully formed, sheathed larvae some 0.180 long and 0.015 wide. Rectum thin hyaline tube, anus slightly elevated. Tail short, blunt, 0.122 long.

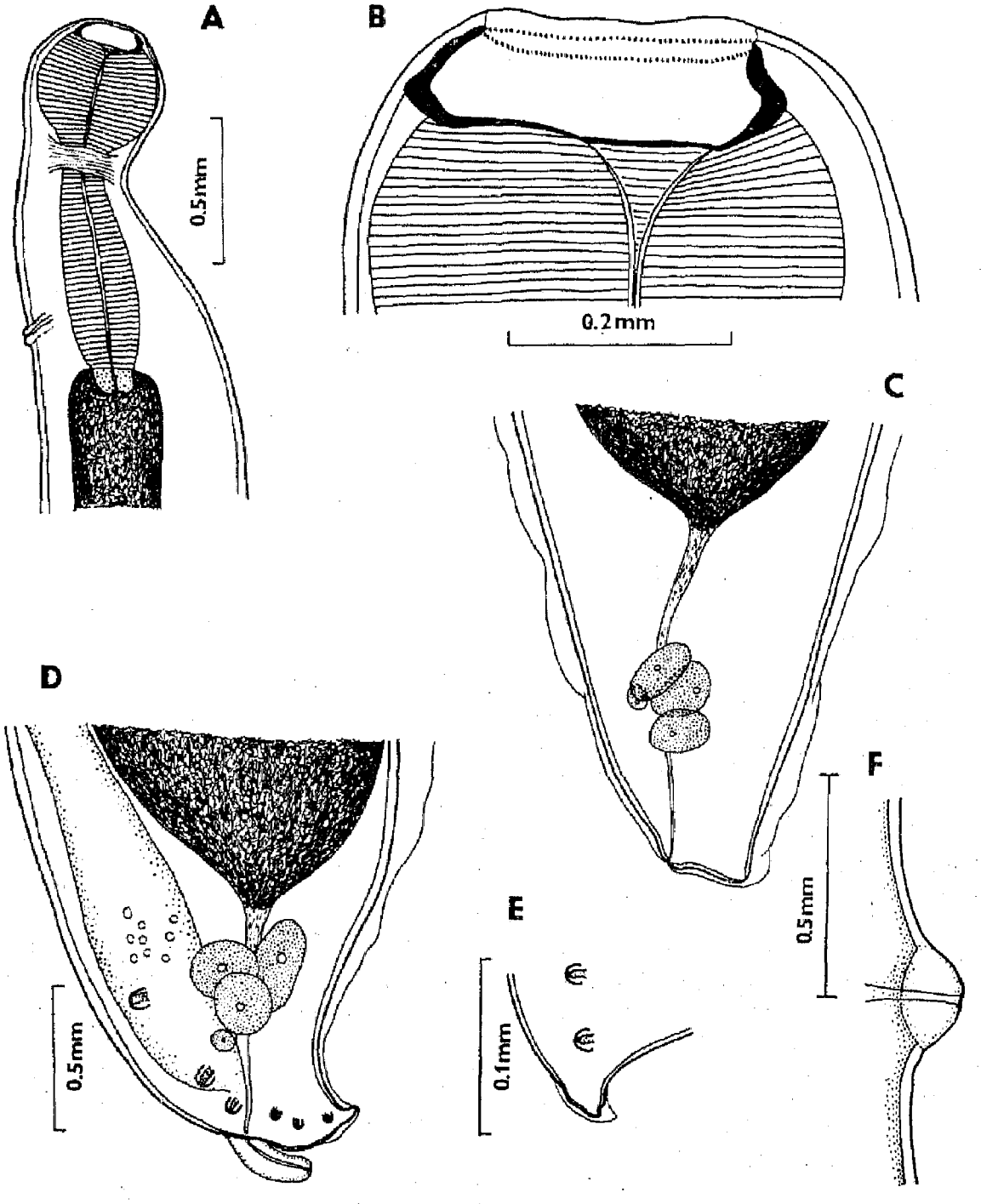

Fig. 1. *Anguillicola globiceps* Yamaguti, 1935. A — head end of male; B — buccal capsule of male; C — caudal end of gravid female; D — posterior end of male; E — tail tip of male; F — vulva.

Host: *Anguilla japonica* Temminck et Schlegel.
Localization: swimbladder.
Distribution: Japan (Central Honshu) and China (Fujian, Hubei and Henan Provinces).

Comments: — The morphology of the present specimens corresponds, more or less, to the original description of *A. globiceps* given by Yamaguti (1935); even though we did not succeed in obtaining the type specimens for study, it is clear that our nematodes belong to this species. Some slight differences concern only measurements that are apparently within the normal limits of intraspecific variability of this species.

Yamaguti (1935) provided a relatively very original description of *A. globiceps*, but he did not study the exact number of circumoral teeth in the buccal capsule which is, in our opinion, an important specific taxonomic feature in *Anguillicola* spp. Unfortunately, we were also unble to establish the exact number of these teeth from head end sections because of the limited number of borrowed specimens available; in lateral view it was possible to determine that the buccal capsule of the specimens of the present material was armed with some 80 teeth. According to Wang and Zhao (1980), *A. globiceps* possesses 76 teeth, but it is probable that there is some individual variability in the number of these teeth, as suggested by data on other congeneric species.

It has been mentioned above that *A. globiceps* differs considerably in its morphology from other congeneric species, principally in the structure of the oesophagus which is usually considered one of the most important features in nematode taxonomy. Other marked differences are the spinose epicuticle and the form of body. Therefore, we propose to place *A. globiceps* and the remaining *Anguillicola* species into two separate subgenera (see above).

A. globiceps was originally described by Yamaguti (1935) from Lake Hamana from Japan (Central Honshu); he mentions that this species is very common in *Anguilla japonica* in which heavy infections cause a considerable thickening of the host's swimbladder wall. Later this species was reported from Japan by Egusa et al. (1969), but in fact another species, *A. crassus* was misidentified as *A. globiceps* in this case (see Hirose et al. 1976). According to recent information from Dr. H. Hirose, in Japan this species is much less common in *A. japonica* than *A. crassus*. In 1956, Wu reported *A. globiceps* from pond-cultured *A. japonica* from China, but the accompanying drawings suggest that besides *A. globiceps*, *A. crassus* might also have been included in the material examined. *A. globiceps* was also reported by Wu (1984) from the same host species from the Liaoho River (China, Prov. Henan), but the drawing of the anterior end of the nematode (Fig. 17, p. 198) is more similar to *A. crassus* than *A. globiceps*. The *Anguillicola* material from China provided by Prof. P. Q. Wang and Prof. H. S. Wu contained both *A. globiceps* and *A. crassus*. According to Wang and Zhao (1980), *A. globiceps* is a common parasite of *Anguilla japonica* in the Chinese Provinces of Fujian and Hubei. It appears from the present data that *A. globiceps* is restricted in its distribution to the region of the Far East only, but its future accidental introduction in other geographical regions cannot be excluded.*

* Only recently, when this paper was accepted for publication, the recent publication of Ghittino (1985), reporting the record of *A. globiceps* in Italy, has come to the authors' attention. In our opinion, a re-examination of these specimens and the verification of their species appurtenance is quite necessary, because their identification was based on Dr. Molár's presumption that *A. globiceps* was the only valid species of *Anguillicola*.

2. *Anguillicola (Anguillicoloides) australiensis* Johnston et Mawson, 1940 Fig. 2

Description (based on type specimens): Large sized, brown coloured nematodes. Body filiform, relatively narrow for *Anguillicola;* epicuticle smooth, aspinose. Head end bulbously inflated, spherical, neck constriction in front of nerve ring marked; body tapering at posterior end to pointed tail. Buccal capsule small, thin-walled, its anterior edge armed with numerous minute circumoral teeth; number of teeth not established. Oesophagus expanded at its posterior half. Valvular apparatus of oesophagus well developed. Nerve ring situated somewhat below neck constriction, excretory pore near junction of oesophagus and intestine. Intestine thick-walled, dark, being first narrow, then becoming very broad, occupying almost whole width of body. Three conspicuously large oval unicellular rectal glands present, one dorsal and two subventral; additional small ventral rectal gland also present. Tail conical, pointed.

Male (1 specimen): Length of body 32.30, maximum width 0.911; length of inflated head end 0.163, its width 0.218; width of body at neck constriction 0.136. Buccal capsule 0.009 long and 0.030 wide; maximum thickness of its wall 0.003. Length of oesophagus 0.938, its maximum width 0.204; length of oesophageal valves 0.054. Length ratio of oesophagus and body 1: 34.4. Distance of nerve ring and excretory pore from anterior extremity 0.258 and 1.05, respectively. Testis reaching anteriorly slightly below end of oesophagus. Seminal vesicle well developed, size 0.816×0.476. Common cloacal duct opening on prominent process 0.075 long. Size of large rectal glands 0.313—0.340 by 0.190—0.299, of small one 0.122×0.082. Six pairs of caudal papillae present: 3 preanals, 1 adanal, and 2 postanals; adanal and first preanal pairs less distinct than others. Tail conical, 0.204 long.

Female (1 specimen): Length of body of nongravid female 27.25, maximum width 0.721; length of inflated head end 0.150, its width 0.204; width of body at neck constriction 0.095. Buccal capsule 0.009 long and 0.033 wide; maximum thickness of its wall 0.003. Length of oesophagus 0.898, its maximum width 0.177; length of oesophageal valves 0.054. Length ratio of oesophagus and body 1: 30.3. Distance of nerve ring and excretory pore from anterior extremity 0.272 and 0.789, respectively. Vulva elevated, prominent, situated in posterior part of body, 6.96 from posterior extremity, this representing approximately 1/4 of body length. Uterus still without eggs. Anterior ovary reaching anteriorly almost mid-length of oesophagus. Size of large rectal glands 0.245—0.272 by 0.231—0.245, of small one 0.068×0.054. Posterior end of body at rectal region gradually tapering to end of tail. Tail conical, relatively long (0.422), pointed.

Host: *Anguilla reinhardtii* Strd.
Localization: swimbladder.
Distribution: South Australia.

Comments: — This species was described by Johnston and Mawson (1940) from the long-finned eel, *Anguilla reinhardtii*, from Prospect Reservoir near Sydney, New South Wales, Australia. According to the original description, the gravid females of this species are 60—70 mm long and 1.5 mm wide, whereas the body of young females is 25—30 mm long and 0.5 mm wide; the male is 40 mm long and 1 mm wide. This corresponds, more or less, to our findings. In contrast to most other species of *Anguillicola* (except *A. globiceps*), *A. australiensis* seems to be characterized by a relatively long and narrow body. Although Johnston and Mawson (1940) reported only four pairs of caudal papillae in the male of this species, we found six pairs; it is possible that the above mentioned authors overlooked the adanal and first preanal pairs of papillae that are less distinct than others.

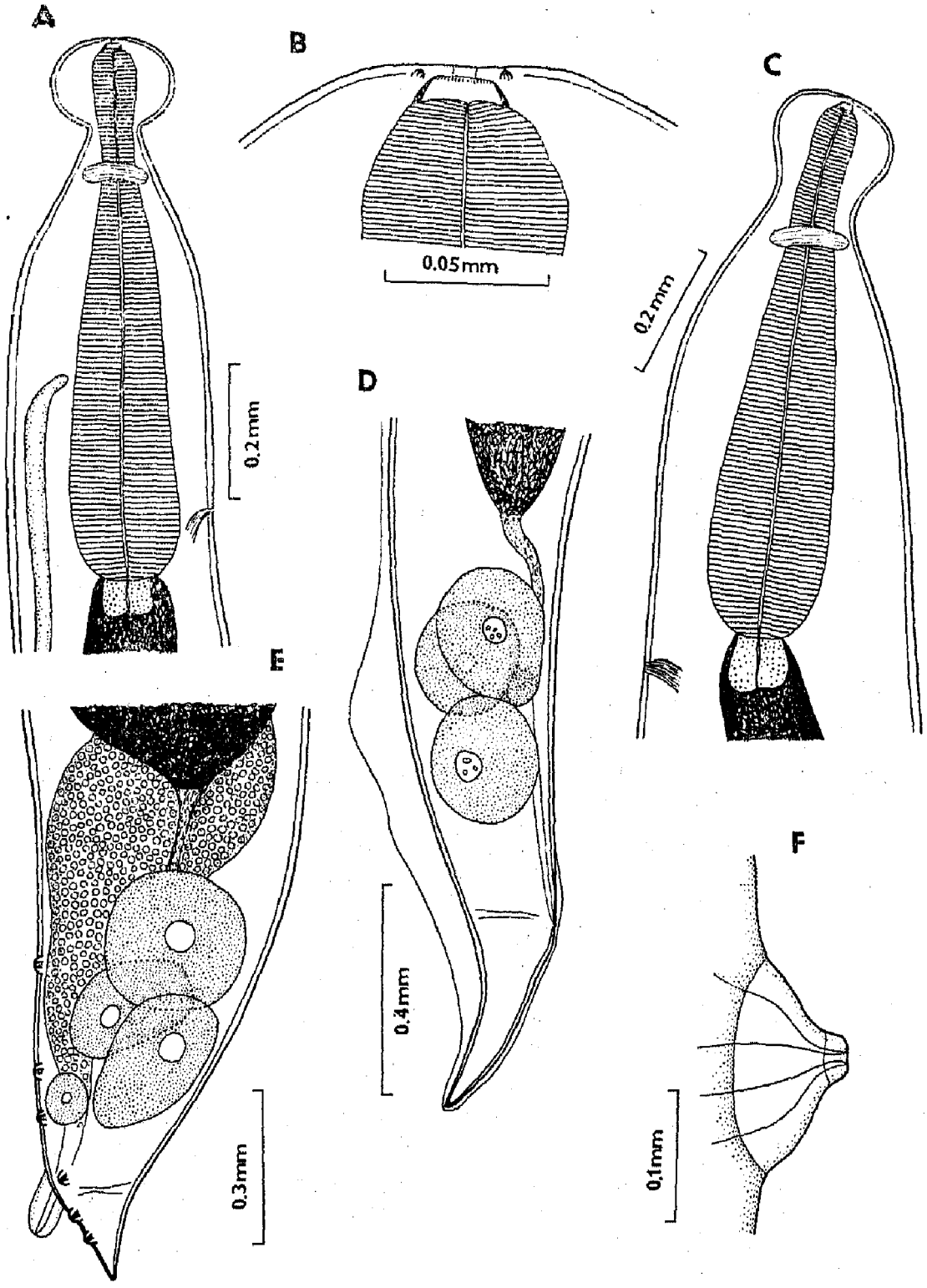

Fig. 2. *Anguillicola australiensis* Johnston et Mawson, 1940 — type specimens. A — head end of gravid female; B — buccal capsule of gravid female; C — head end of male; D — caudal end of female; E — posterior end of male; F — vulva.

A. australiensis has also been reported from *Anguilla dieffenbachii* and *A. australis* from New Zealand (Brunsdon 1956, Rid 1973, Hine 1978, Boustead 1982, Blair 1984) and from *A. anguilla* from Italy (Paggi et al. 1982, Sarti et al. 1985, Sarogli a et al. 1985). Although the nematodes from New Zealand have not been described and illustrated and we could not obtain the specimens relating to these records, we consider them conspecific with the newly collected specimens from *A. australis* from New Zealand and those from *A. anguilla* from Italy that are now described as a new species, *A. novaezelandiae* sp. n. The nematodes reported as *A. australiensis* by Hartmann (1987) from the FRG belonged probably to *A. crassus*.

3. *Anguillicola (Anguillicoloides) crassus* Kuwahara, Niimi et Itagaki, 1974 Figs. 3, 4

Description (based on non-type specimens from *A. japonica* from Japan): Body darkly coloured, fusiform, rather plump, tapering to both ends. Epicuticle almost

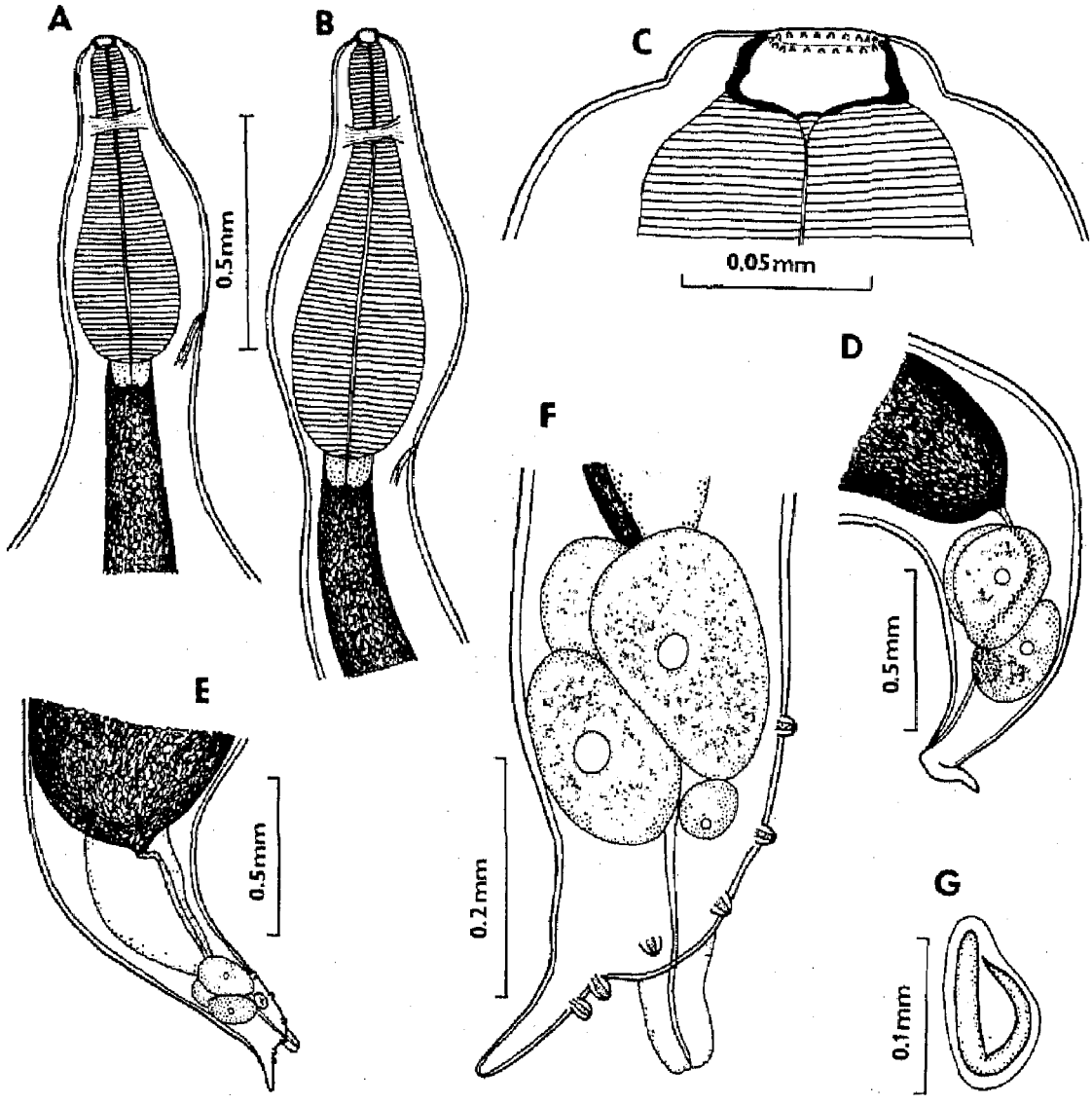

Fig. 3. *Anguillicola crassus* Kuwahara, Niimi et Itagaki, 1974 — type specimens. A, B — head end of male and female; C — buccal capsule of female; D — caudal end of female; E — posterior end of male; F — tail of male; G — larva from uterus.

smooth. Head end rounded. Mouth aperture circular, surrounded by four big dorsolateral and ventrolateral cephalic papillae and two small lateral amphids. Buccal capsule well sclerotized, its anterior rim bearing one row of 22 rather big circumoral teeth. Oesophagus strongly muscular, expanded at its posterior half. Valvular apparatus of oesophagus well developed. Nerve ring situated approximately at border of first and second thirds of oesophagus length, excretory pore near junction of oesophagus and intestine. Intestine dark, straight, broad, only its anterior end being usually narrowed. Three conspicuously large, oval unicellular rectal glands present; additional small ventral rectal gland also

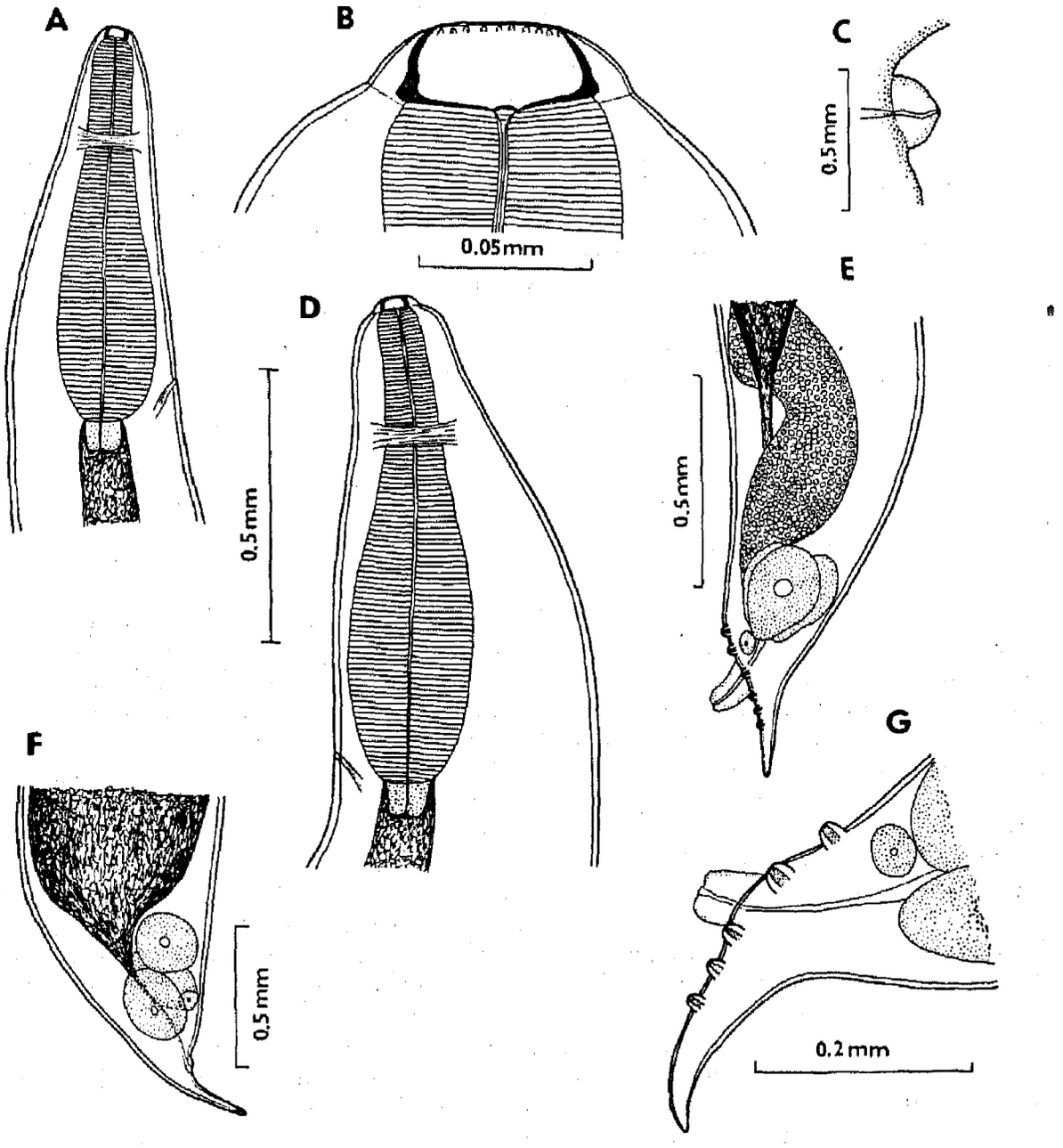

Fig. 4. *Anguillicola crassus* Kuwahara, Niimi et Itagaki, 1974 — non-type specimens from Japan. A — head end of male; B — buccal capsule of female; C — vulva; D — head end of gravid female; E — posterior end of male; F — caudal end of female; G — tail of male (specimen with only 5 pairs of caudal papillae).

present being frequently overlapped by large ones and, accordingly, indistinct. Tail conical, short.

Male (21 specimens): Length of body 6.54—21.76, maximum width 0.558—1.22. Buccal capsule 0.021—0.027 long and 0.048—0.63 wide; maximum thickness of its wall 0.003 to 0.006. Length of oesophagus 0.721—0.843, its maximum width 0.190—0.218; length of oesophageal valves 0.054—0.095. Length ratio of oesophagus and body 1: 9.1—25.8. Distance of nerve ring and excretory pore from anterior extremity 0.210—0.286 and 0.694—0.924, respectively. Seminal vesicle well developed, variable in size. Common cloacal duct opening on prominent process 0.048—0.090 long. Size of large rectal glands 0.122—0.394×0.082—0.204, of small one 0.042—0.109×0.027—0.068. Mostly six pairs of caudal papillae present: 2—3 preanals, 1 adanal, and 2—3 postanals. In one male only 5 papillae found (Fig. 4G). Tail conical, 0.109—0.240 long.

Female (29 specimens): Length of body of gravid females 13.08—44.74, maximum width 1.22—3.50. Buccal capsule 0.027 long and 0.057—0.063 wide; maximum thickness of its wall 0.006. Length of oesophagus 0.857—1.088, its maximum width 0.204—0.272. Length ratio of oesophagus and body 1: 15.3—40.3. Distance of nerve ring and excretory pore from anterior extremity 0.258—0.299 and 0.857—1.142, respectively. Vulva prominent, cone-shaped, situated in posterior part of body, 3.40—4.90 from posterior extremity, this representing approximately 1/4—1/10 of body length. Ovarian tubes reaching anteriorly to some distance below oesophagus end level and posteriorly to region in front of rectal glands. Uterus occupying most space of body, containing numerous eggs, developing embrya, and fully formed, sheathed larvae 0.244—0.258 long and 0.015 wide. Rectum hyaline tube, opening usually on well developed papilla-like projection; latter indistinct in some specimens. Tail conical, 0.272—0.299 long.

Hosts: *Anguilla anguilla* (L.) (type host) and *A. japonica* Temminck et Schlegel.
Localization: swimbladder.
Distribution: Japan, China and Europe.

Comments: — This species was first described by Kuwahara et al. (1974) from pond-cultured *Anguilla anguilla* and *A. japonica* from Japan (Hamamatsu, Shizuoka Pref., Honshu). The original description of *A. crassus* (erroneously named as *crassa*) was inadequate and inaccurate in some respects and this was the main reason for doubts about the species identification of conspecific *Anguillicola* nematodes recorded later from eels in Europe. Only recently, Taraschewski et al. (1987) carried out a detailed comparison of the morphology of the type (syntypes) and non-type specimens of *A. crassus* from Japan with *Anguillicola* specimens from three localities in West Germany; they concluded that all these nematodes belonged to one and the same species, *A. crassus*. Since the paper by Taraschewski et al. (1987) was submitted for publication, we have obtained additional numerous Japanese non-type specimens of *A. crassus* for study. An examination of these specimens showed much greater biometrical variability of *A. crassus* from Japan, which is similar to that found by Taraschewski et al. (1987) for European specimens (see Table 1).

It has already been mentioned by Taraschewski et al. (1987) that in spite of the considerable biometrical variability of *A. crassus* the size of the buccal capsule remains much the same (Table 1). According to these authors the character of the buccal capsule (size, shape, degree of sclerotization) seems to be one of the most important specific features of *Anguillicola;* the present study shows that in addition the position of the buccal capsule in relation to the nematode's anterior extremity and the number of circumoral teeth may be taxonomically important. The number of circumoral teeth in *A. crassus* was not established by Kuwahara et al. (1974) in the original description, but seems

Table I. Comparison of *Anguillicola crassus* from Japan and Europe

	Paratypes (own data)		Non-type specimens from Japan (new data)		European specimens (after Taraschewski et al. 1987)	
	♂	♀	♂♂	♀♀	♂♂	♀♀
Length of body	34.94	42.94	6.54 —21.76	13.08 —44.74	5.77 — 23.12	16.23 —36.72
Width of body	3.7	4.7	0.558— 1.22	1.22 — 3.50	0.340— 1.77	1.36 — 5.00
Length of buccal capsule	0.024	0.027	0.021— 0.027	0.027	0.021— 0.027	0.024— 0.027
Width of buccal capsule	0.048	0.054	0.048— 0.063	0.057— 0.063	0.048— 0.057	0.054— 0.063
Lenght of oesophagus	0.760	0.980	0.721— 0.843	0.857— 1.09	0.571— 0.816	0.775— 1.06
Width of oesophagus	0.260	0.330	0.190— 0.218	0.204— 0.272	0.135— 0.258	0.258— 0.381
Length ratio of oesophagus and body	1:43.3	1:43.7	1:9.1—25.8	1:15.3—40.3	1:10.1—29.2	1:20.9—34.6
No. of caudal papillae in male	6	—	6	—	6	—
Distance of vulva from posterior end	—	?	—	3.40 — 4.90	—	4.01 — 7.01
Length of tail	0.207	0.231	0.109— 0.240	0.272— 0.299	0.120— 0.286	0.136— 0.448
Hosts	*Anguilla anguilla*		*Anguilla japonica*		*Anguilla anguilla*	
Occurrence	Japan		Japan		F.R. Germany	

to be rather variable in this species. Wang and Zhao (1980) reported 25—26 big teeth in Far-eastern *A. crassus*, while only 21—25 teeth were found in the conspecific nematodes from Belgium (De Charleroy et al. 1987); according to Taraschewski et al. (1987) the specimens of *A. crassus* from West Germany possess 22—28 teeth; in one non-type specimen from Japan we found 22 teeth.

It has been mentioned that *A. crassus* was originally described from Japan by Kuwahara et al. (1974), but this species was found in Japan as early as in 1969 by Egusa et al., who had mistaken it for *A. globiceps* (see Hirose et al. 1976). Later, this species was also recorded from Japan by Hirose et al. (1976) and Egusa (1979); the latter author mentions that the introduced European eel, *Anguilla anguilla*, is, in Japan, much more susceptible to *A. crassus* infection than *A. japonica* (prevalence in cultured eels being several tens of per cent and occasionally nearly 100% in *A. anguilla* and 10—40 % in *A. japonica*). This species was also present in the *Anguillicola* material from China provided by Prof. P. Q. Wang and Prof. H. S. Wu. Recently *A. crassus* has been reported from Japan by Salati (1987).

In Europe, *A. crassus* was first recorded as *Anguillicola* sp. from eels (*Anguilla anguilla*) of the Weser-Ems River region in North Germany in 1982 (Neumann 1985, Mann 1986). According to Peters and Hartmann (1986) and Taraschewski et al. (1987), it now occurs frequently in other localities in the F. R. of Germany (river basins of the Elbe, Weser and Rhine) and in the water bodies of Berlin. It occurs also in Holland (Van Banning et al. 1985), Belgium (Belpaire et al. 1987, De Charleroy et al. 1987) and the record of *Aguillicola* sp. in eels in Denmark (Køie 1987) apparently relates to this species; recently it has been recorded also from eels in Italy (fish farm in the Po delta) (Canestri-Trotti 1987) and Great Britain (personal communication of Prof. C. R. Kennedy). It seems that *A. crassus* was introduced here only a few years ago and is now quickly spreading mainly throughout North-western and Central Europe.

4. *Anguillicola (Anguillicoloides) novaezelandiae* sp. n. Figs. 5, 6

Description (based on specimens from *A. australis* from New Zealand): Medium sized, darkly coloured nematodes. Epicuticle aspinose. Head end with slight neck constriction just in front of nerve ring. Buccal capsule small, feebly sclerotized, with minute circumoral teeth; exact number of teeth not established (32 in Italian specimens according to Paggi et al. 1982). Oesophagus expanded at its posterior half. Valvular apparatus of oesophagus well developed. Nerve ring situated immediately below neck constriction, excretory pore near junction of oesophagus and intestine. Intestine dark, almost straight, broad. Three conspicuously large oval unicellular rectal glands present; additional small rectal gland, often overlapped by large ones, also present. Tail conical, pointed.

Male (4 specimens; measurements of holotype in brackets): Length of body 5.54—8.57 (8.57), maximum width 0.476—0.680 (0.558), length of slightly enlarged head end 0.111—0.132 (0.120), its width 0.087—0.111 (0.093); width of body at neck constriction 0.078—0.099 (0.078). Buccal capsule 0.006 (0.006) long and 0.021 (0.021) wide, maximum thickness of its wall 0.002 (0.002). Length of oesophagus 0.476—0.530 (0.530), its maximum width 0.095—0.120 (0.109). Length ratio of oesophagus and body 1: 10.4 to 16.2 (1: 16.2). Distance of nerve ring and excretory pore from anterior extremity 0.159—0.165 (0.159) and 0.462—0.585 (0.585), respectively. Common cloacal duct opening on prominent process 0.087—0.096 (0.087) long. Size of large rectal glands 0.272—0.354×0.136—0.231 (0.272—0.340×0.136), that of small one 0.033—0.039 by 0.030—0.033 (0.039×0.030). Six pairs of caudal papillae present: 3 preanals, 1 adanal, and 2 postanals. Tail conical, 0.156—0.195 (0.156) long.

Female (3 specimens; measurements of allotype in brackets): Length of body 7.17 to 13.63 (13.63), maximum width 0.653—1.18 (1.18); length of sligthly enlarged head end 0.123—0.135 (0.132), its width 0.090—0.102 (0.102); width of body at neck constriction 0.063—0.078 (0.078). Buccal capsule 0.006—0.009 (0.009) long and 0.018—0.021 (0.021) wide; maximum thickness of its wall 0.002—0.003 (0.003). Length of oesophagus

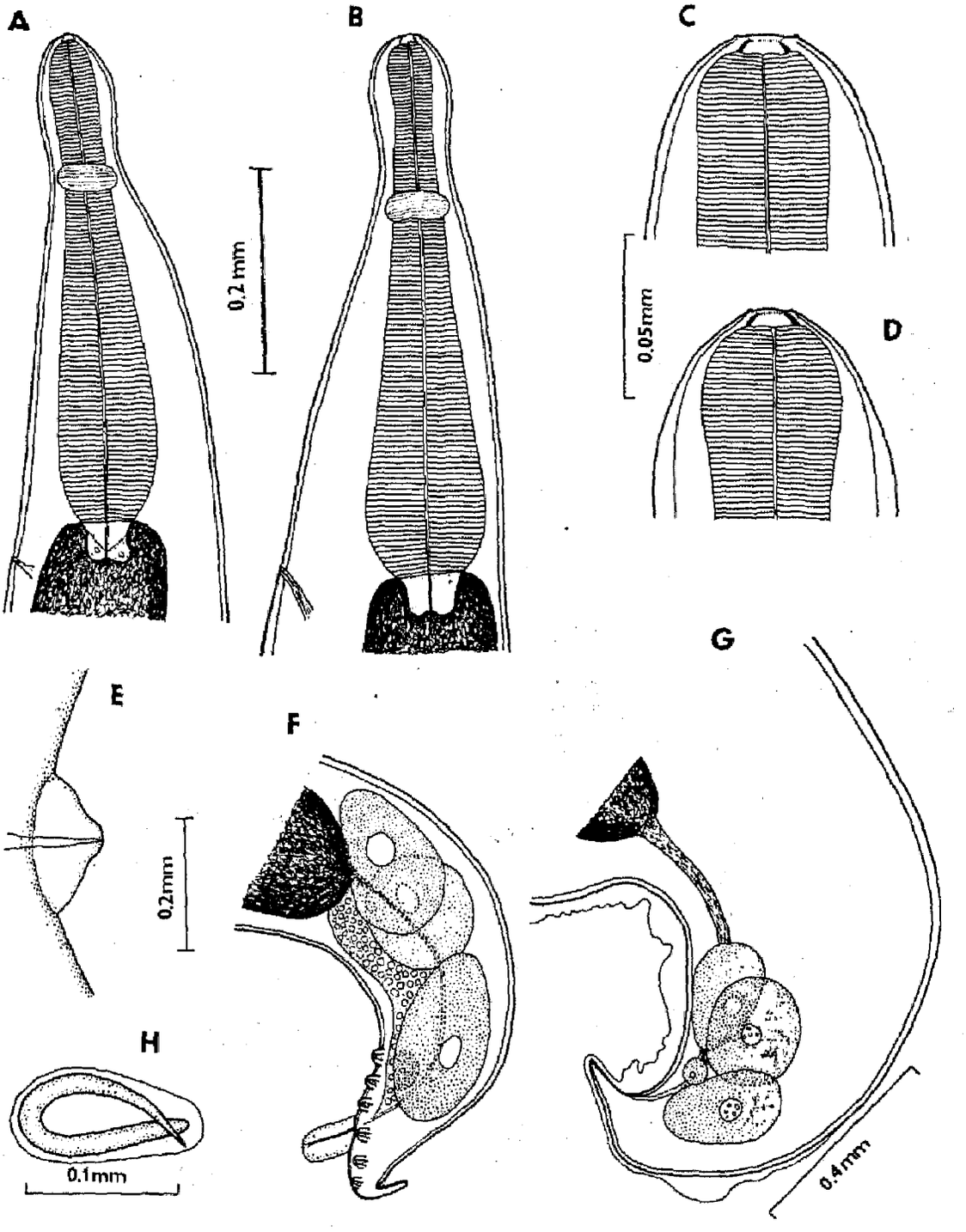

Fig. 5. *Anguillicola novaezelandiae* sp. n. from *A. australis* from New Zealand. A, B — head end of male and gravid female; C, D — buccal capsule of male and young female; E — vulva; F — posterior end of male; G — caudal end of female; H — larva from uterus.

0.544—0.625 (0.625), its maximum width 0.136—0.177 (0.150). Length ratio of oesophagus and body 1: 13.2—21.8 (1: 21.8). Distance of nerve ring and excretory pore from anterior extremity 0.165—0.195 (0.195) and 0.558—0.680 (0.680), respectively. Vulva elevated, prominent, situated in posterior part of body, 1.84—2.08 (2.08) from posterior extremity, this representing approximately 1/4—1/6 (1/6) of body length. Ovarial tubes not reaching anteriorly level of oesophagus. Uterus containing mostly eggs, several sheathed larvae, 0.249—0.255 (0.255) long and 0.015 (0.015) wide, present only near vulva of two larger females (body length 9.6 and 13.6). Size of large rectal glands 0.204—0.275 × 0.136—0.245 (0.272 × 0.217—0.245), small rectal gland indistinct. Tail conical, 0.186—0.225 (0.186) long, pointed.

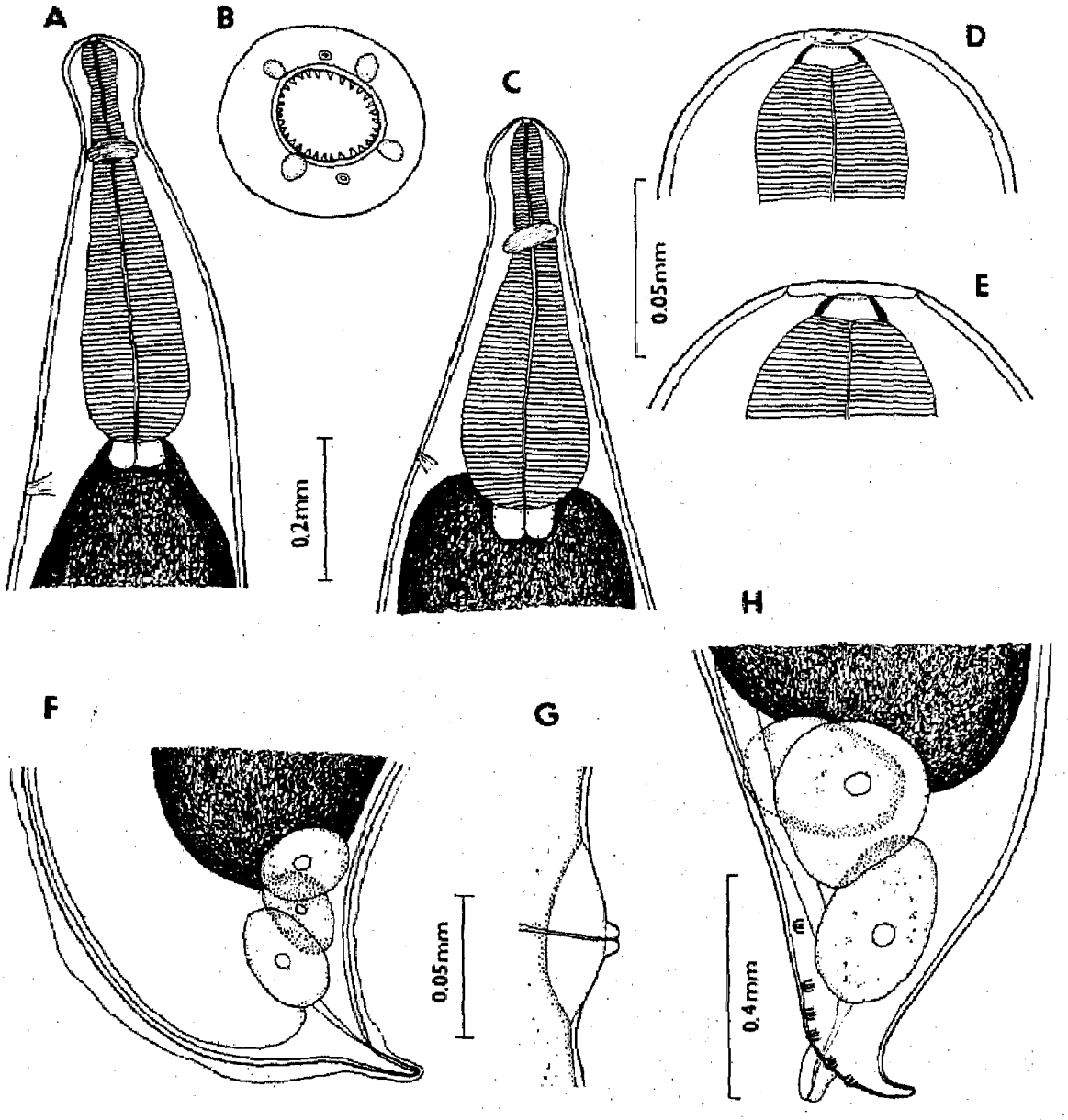

Fig. 6. *Anguillicola novaezelandiae* sp. n. — specimens from *A. anguilla* from Italy. A — head end of male; B — head end, apical view (re-drawn from Paggi et al. 1982); C — head end of female; D, E — buccal capsule of male and female; F — caudal end of female; G — vulva; H — posterior end of male.

Table. 2. Comparison of *Anguillicola novaezelandiae* sp.n. from New Zealand and Italy

	Specimens from New Zealand (own data)		European specimens (own data)	
	♂♂	♀♀	♂♂	♀♀
Length of body	5.54 —8.57	7.17 —13.63	11.63—14.92	24.82 —28.70
Max. width of body	0.476—0.680	0.653— 1.183	1.47— 1.56	2.00— 3.00
Length of buccal capsule	0.006	0.006— 0.009	0.007	0.007— 0.009
Width of buccal capsule	0.021	0.018— 0.021	0.024	0.024— 0.027
Length of oesophagus	0.476—0.530	0.544— 0.625	0.639—0.666	0.653— 0.843
Max. width of oesophagus	0.095—0.120	0.136— 0.177	0.136—0.163	0.204—0.245
Length ratio of oesophagus and body	1 : 10.4—16.2	1 : 13.2—21.8	1 : 18.2—22.8	1 : 37.0—38.0
No. of caudal papillae in male	6	—	6	—
Distance of vulva from posterior end	—	1.84 — 2.08	—	4.42 — 4.76
Length of tail	0.156—0.195	0.186— 0.225	0.190	0.204— 0.272
Hosts	*A. australis*		*A. anguilla*	
Occurrence	New Zealand		Italy	

Hosts: Short-finned eel, *Anguilla australis* Richardson (type host) and European eel, *A. anguilla* (L.); probably also in long-finned eel, *A. dieffenbachii* Gray.
Localization: swimbladder.
Type locality: Matahina dam, New Zealand (17 May 1975, coll. Dr. B. Jones); other localities: Lake Bracciano near Rome, Italy; probably also in other localities in New Zealand reported by Brunsdon (1956), Rid (1973), Hine (1978) and Boustead (1982).
Deposition of types: holotype (♂), allotype (♀) and paratypes (♂ + ♀) in Institute of Parasitology, Czechoslovak Academy of Sciences, České Budějovice (Cat. No. N-263).

Etymology: The specific name of this nematode species relates to the country of the origin of type specimens.
Comments: — *A. novaezelandiae* sp. n. is most similar to *A. australiensis* Johnston et Mawson, 1940. However, it differs from the latter species mainly in the shape of the head end which is bulbously inflated, almost spherical, and followed by a marked neck constriction in *A. australiensis*, whereas it is only slightly expanded in *A. novaezelandiae* sp. n.; the anterior ovary in *A. australiensis* females extends anteriorly to about the mid-length of the oesophagus, while it does not reach the end of oesophagus in *A. novaezelandiae* sp. n. Both the species differ also in the size and form of the body. While the body of *A. australiensis* is long (30—40 mm in males and 60—70 mm in gravid females) and relatively slender (at most 1.5 mm in gravid females), that of *A. novaezelandiae* sp. n. is much shorter (6—15 mm in males and 10—31 mm in gravid females) and wider (up to 3 mm in gravid females); the type *A. australiensis* female examined (27 mm long and 0.72 mm wide) was still non-gravid, without eggs in its uterus. The shape of the posterior end of the female body seems also to be different in these two species.

The specimens reported as *A. australiensis* by Paggi et al. (1982) from *A. anguilla* from Italy are somewhat larger than those from *A. australis* from New Zealand (see Table 2), but they are morphologically indistinguishable and, therefore, we consider them conspecific with *A. novaezelandiae* sp. n. It is probable that this new species was introduced in Italy along with the transfers of live eels *Anguilla australis* from New Zealand; a stock of *A. australis* was introduced into Lake Bracciano in 1975 (Welcomme 1981, Paggi et al. 1982).

According to the present data, *A. novaezelandiae* sp. n. is probably indigenous to New Zealand; from where it has recently been introduced to Italy (Paggi et al. 1982, Saroglia et al. 1985, Di Cave 1986, Sarti 1986). From New Zealand, another *Anguillicola* species, *A. australiensis*, has so far been recorded from *Anguilla dieffenbachii* and *A. australis* (Brunsdon 1956, Rid 1973, Hewitt and Hine 1972, Hine 1978, Boustead 1982); however, since no description or drawings of these parasites were provided, it may well be that they belonged in the fact to the species *A. novaezelandiae* sp. n. and that *A. australiensis* is restricted in distribution to the territory of Australia only.

5. *Anguillicola (Anguillicoloides) papernai* sp. n. Figs. 7, 8

Description: Body spirally coiled, darkly coloured (due to eel blood inside nematode's intestine), fusiform, rather plump, tapering to both ends; anterior end of body bottle-shaped, posterior one narrowed, conical. Epicuticle finely wrinkled, with network structure, aspinose, forming irregular fine transparent coating. Cuticle of anterior and posterior narrowed parts of body bearing several marked, up to 0.030 high, irregularly scattered dull papilla-like excrescences of fibrous structure; sometimes these formations indistinct on female posterior end. Head end rounded, being separated by slight constriction in front of nerve ring level; body of some specimens somewhat inflated in region of posterior half of oesophagus. Entire anterior narrowed part of body approximately twice as long as oesophagus. Four dorso- and ventro-lateral papillae and two small

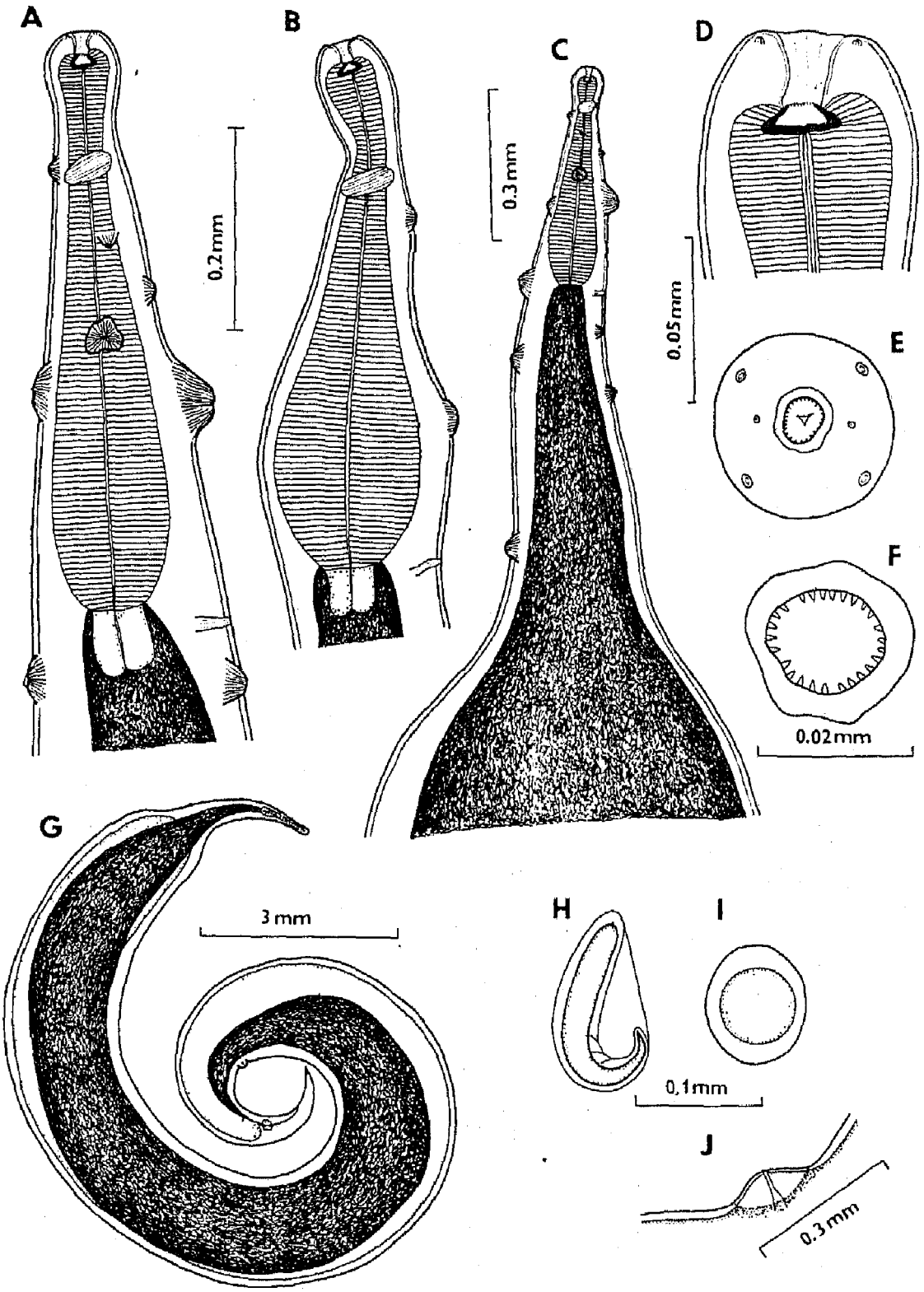

Fig. 7. *Anguillicola papernai* sp. n. from *A. mossambica* from South Africa. A, B — head end of gravid female and male; C — anterior end of female; D — buccal capsule of male; E — head end of female, apical view; F — buccal capsule of female, apical view; G — female, general view; H, I — larva and egg from uterus; J — vulva.

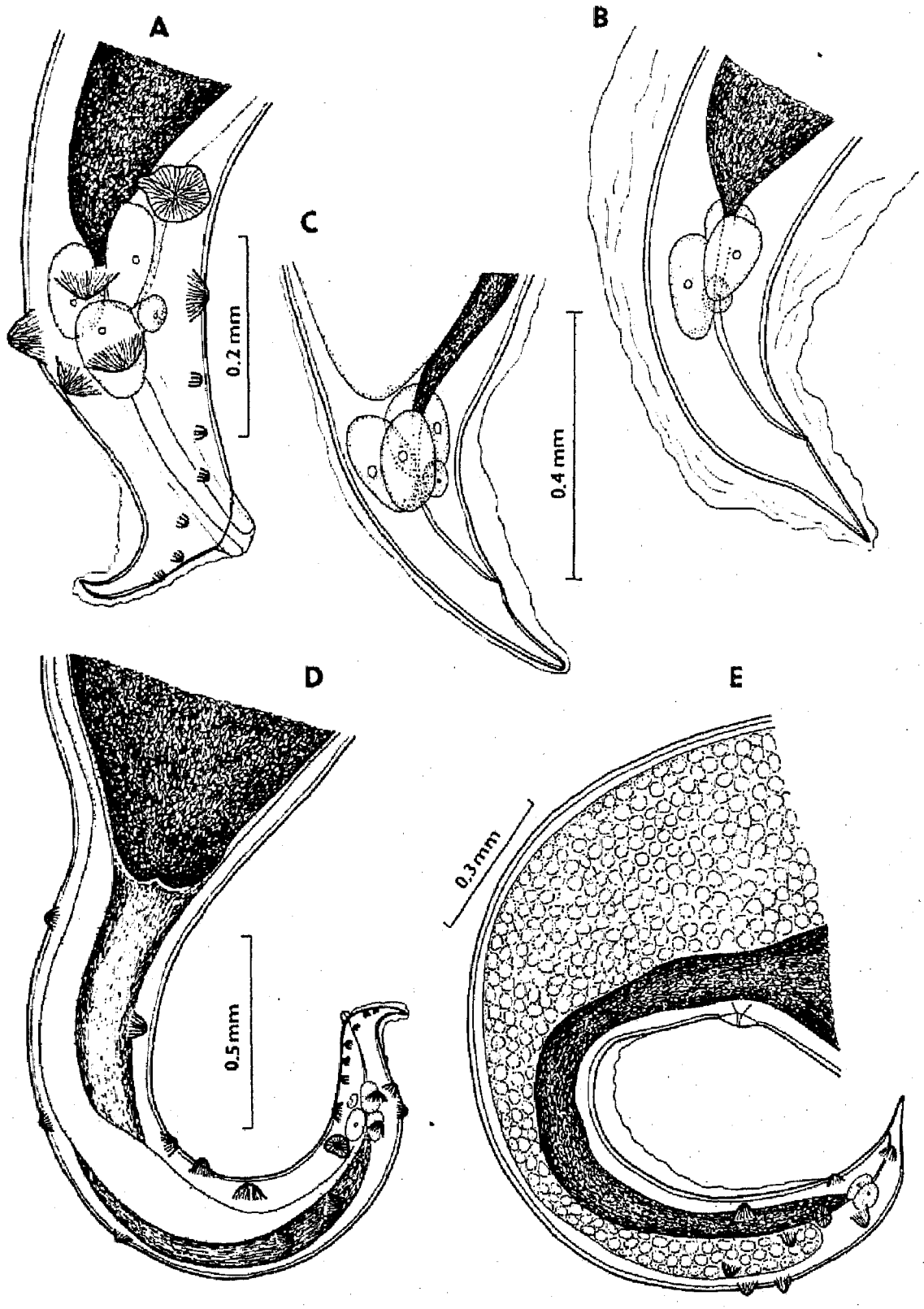

Fig. 8. *Anguillicola papernai* sp. n. from *A. mossambica* from South Africa. A — posterior end of male; B, C — caudal end of female; D — posterior end of male; E — posterior end of female.

lateral amphids present. Mouth conspicuously depressed, anterior margin of buccal capsule being 0.027—0.030 from anterior extremity; mouth opening circular. Buccal capsule well sclerotized, trapezium-shaped in lateral view, its anterior rim bearing one row of 26 circumoral teeth. Oesophagus strongly muscular, expanded at its posterior half; its lumen distinctly triangular. Valvular apparatus of oesophagus well developed. Nerve ring situated immediately below neck constriction, excretory pore near junction of oesophagus and intestine. Intestine dark, almost straight, broad, being narrowed at anterior and posterior ends only. Three conspicuously large oval unicellular rectal glands present, one dorsal and two subventral; additional small ventral rectal gland, often overlapped by large ones, also present. Tail conical, short.

Male (1 specimen and 1 fragment of another one; measurements of holotype in brackets): Length of body (12.99), maximum width (1.50); length of head end (0.109), of entire narrowed anterior part of body (1.22); width of body at head constriction (0.060), at end of narrowed anterior body part (0.272). Buccal capsule 0.011—0.012 (0.011) long and 0.030 (0.030) wide; maximum thickness of its wall 0.003—0.004 (0.004). Length of oesophagus 0.530—0.598 (0.530), its maximum width 0.150—0.163 (0.163). Length ratio of oesophagus and body (1: 24.5). Distance of nerve ring and excretory pore from anterior extremity (0.180) and (0.667), respectively. Testis reaching anteriorly to some distance below end of narrowed anterior part of body. Seminal vesicle well developed, rather long. Common cloacal duct opening on prominent process (0.048) long. Size of large rectal glands (0.105—0.120 × 0.054—0.057), that of small one (0.039 × 0.030). Six pairs of caudal papillae present: 3 preanals, 1 adanal, and 2 postanals. Tail conical, (0.141) long.

Female (4 specimens; measurements of allotype in brackets): Length of body of gravid females 15.78—28.29 (28.29), maximum width 1.64—2.18 (1.64); length of head end 0.081—0.099 (0.099), of entire narrowed anterior part of body 1.43—2.07 (1.64); width of body at head constriction 0.060—0.068 (0.063), at end of narrowed anterior body part 0.408—0.571 (0.408). Buccal capsule 0.009—0.012 (0.012) long and 0.030 (0.030) wide; maximum thickness of its wall 0.003—0.005 (0.005). Length of oesophagus 0.598—0.625 (0.625), its maximum width 0.135—0.177 (0.135). Length ratio of oesophagus and body 1: 24.2—45.3 (1: 45.3). Distance of nerve ring and excretory pore from anterior extremity 0.147—0.171 (0.147) and 0.692—0.695 (0.695), respectively. Vulva elevated, prominent, situated in posterior part of body, 3.20—3.74 from posterior extremity, this representing approximately 1/5—1/8 of body length. Postvulvar part of body markedly tapered. Ovarial tubes forming numerous coils in anterior half of body, anteriorly not reaching to narrowed part of body. Uterus occupying most space of body, containing numerous eggs (size 0.081—0.105 × 0.075—0.084), developing embrya, and fully formed, sheathed larvae 0.189—0.255 long and 0.018—0.021 wide. Uterus extending anteriorly to end of narrowed anterior body part and posteriorly reaching almost level of rectal glands. Rectum thin hyaline tube, anus not elevated. Size of large rectal glands 0.120—0.180 by 0.063—0.090 (0.150—0.180 × 0.090), that of small one 0.039—0.045 × 0.030—0.033 (0.045 × 0.033). Tail conical, its tip sharply pointed or somewhat rounded; length of tail 0.180—0.204 (0.180).

Type host: *Anguilla mossambica* Peters.
Localization: swimbladder.
Type locality: Amalynda fish farm near East London, Cape Province, Rep. of South Africa (21 September 1984; coll. Dr. I. Paperna).
Deposition of types: holotype (♂), allotype (♀) and 2 paratypes (♀♀) in Institute of Parasitology, Czechoslovak Academy of Sciences, České Budějovice (Cat. No. N-279); 3 paratypes (1 male frag. + 2 ♀♀) in National Animal Parasite Laboratory, Maryland, USA (Cat. No. 80007).

Etymology: This species is named in honour of Dr. Ilan Paperna, the Hebrew University of Jerusalem, who contributed greatly to the knowledge of fish parasites.

Comments: — The unique morphological features of *A. papernai* sp. n. by which this species differs distinctly from its congeners are the presence of marked cuticular excrescences on the anterior and posterior ends of the body and the location of the buccal capsule deeply inside the head end. This species is the first *Anguillicola* member known from Africa.

KEY TO THE SPECIES OF *ANGUILLICOLA*:

1 Epicuticle finely spinose. Oesophagus conspicuously inflated at anterior end, its posterior part cylindrical. Buccal capsule large, 0.068—0.109 × 0.272—0.408 mm in male and 0.109—0.122 × 0.408 mm in female, with about 80 very small circumoral teeth. Tail relatively short. In eels of East Asia (Japan, China) ... (subgen. *Anguillicola*) . . . . . ***A. globiceps***

— Epicuticle aspinose. Anterior end of oesophagus lacking inflation, narrow; posterior part of oesophagus distinctly expanded. Buccal capsule small or medium sized, less than 0.030 mm long and 0.070 mm wide; maximum number of circumoral teeth 32. Tail relatively long. In eels of East Asia, Australia, New Zealand, Africa or Europe ... (subgen. *Anguillicoloides*) 2

2 Buccal capsule medium sized, 0.021—0.027 mm long and 0.048—0.063 mm wide, with 21—28 rather big circumoral teeth. Head end not expanded, without distinct neck constriction. Body fusiform. East Asia and Europe ..... ***A. crassus***

— Buccal capsule small, at most 0.012 mm long and 0.033 mm wide; circumoral teeth very small. Head end bulbously inflated or at least slightly expanded with distinct neck constriction. Body fusiform or filiform. Australia, New Zealand, Africa or Europe 3

3 Body fusiform, anterior and sometimes also posterior ends of body with marked papila-like cuticular excrescences. Head end slightly expanded. Buccal capsule located deeply inside head end, with 26 minute teeth. Africa .... ***A. papernai*** sp. n.

— Body filiform of fusiform, cuticular excrescences on anterior and posterior ends of body lacking. Head end bulbously inflated or slightly expanded. Buccal capsule located near nematode anterior extremity. In eels of other geographical regions . . 4

4 Head end bulbously inflated. Anterior ovary in females extending to about mid-length of oesophagus. Body filiform, 30—40 mm long in males and 60—70 mm in gravid females. South Australia . . . . . ***A. australiensis***

— Head end slightly expanded. Anterior ovary in females not extending to end of oesophagus. Body fusiform, only 6—15 mm in males and 10—31 mm in gravid females. New Zealand and Europe (Italy) . . . . . ***A. novaezelandiae*** sp. n

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РЕВИЗИЯ РОДА *ANGUILLICOLA* YAMAGUTI, 1935 (NEMATODA: ANGUILLICOLIDAE) — ПАРАЗИТОВ ПЛАВАТЕЛЬНОГО ПУЗЫРЯ УГРЕЙ С ОПИСАНИЕМ ДВУХ НОВЫХ ВИДОВ — *A. NOVAEZELANDIAE* SP. N. И *A. PAPERNAI* SP. N.

Ф. Моравец и Г. Тарашевски

Резюме. На основе типовых экземпляров и других материалов сделали ревизию рода *Anguillicola*. Описаны два новых вида: *A. novaezelandiae* sp. n. от угрей *Anguilla australis* (типовой хозяин) из Новой Зеландии и *A. anguilla* из Италии (нематоды этого вида раньше приводились из Италии под названием *A. australiensis*) и *A. papernai* sp. n. от *Anguilla mossambica* из Южной Африки. В настоящее время к роду *Anguillicola* пирнадлежат пять следующих видов: *A. globiceps* Yamaguti, 1935, *A. australiensis* Johnston et Mawson, 1940, *A. crassus* Kuwahara, Niimi et Itagaki, 1974, *A. novaezelandiae* sp. n. и *A. papernai* sp. n. За последние пять лет были завезены в Европу из других континентов два вида рода *Anguillicola* — *A. crassus* и *A. novaezelandiae* sp. n. Род *Anguillicola* разделен на два подрода — *Anguillicola* (типовой вид *A.* (*A.*) *globiceps*) и *Anguillicoloides* subgen. n. (типовой вид *A.* (*A.*) *crassus*). Приведены короткие описания и рисунки всех видов р. *Anguillicola*, а также определительная таблица для идентификации видов этого рода.

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