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Pierre Bartoli, Rodney Bray, David Gibson. Three poorly known and rarely reported Bucephalid species (Digenea) in fishes from the Western Mediterranean fishes. *Systematic Parasitology*, 2005, 62 (2), pp.135-149. 10.1007/s11230-005-5489-4. hal-00095600

HAL Id: hal-00095600

<https://hal.science/hal-00095600v1>

Submitted on 24 Jan 2023

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Three poorly known and rarely reported bucephalid species (Digenea) in fishes from the Western Mediterranean

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Abstract

Three poorly known bucephalid species are described from off Corsica, in the Western Mediterranean Sea. *Bucephalus gorgon* (Linton, 1905) (syn. *B. introversus* Manter, 1940) from *Seriola dumerili* is reported for only the third time in the Mediterranean Sea. *Prosorhynchoides arcuatus* (Linton, 1900) from *Sarda sarda* is reported for the first time from the Mediterranean Sea. *P. tergestinum* (Stossich, 1883) n. comb. (originally in *Gasterostomum* von Siebold 1848; has also been in *Bucephalopsis* Diesing, 1855 and *Bucephalus* von Baer, 1827) from *Gobius geniporus* is reported for only the second time.

Introduction

This is second of a series of papers dealing with the Bucephalidae from fish from the Scandola Nature Reserve, Corsica (Western Mediterranean) (Bartoli & Bray, 2005).

Materials and methods

Fish were collected live off the Natural Reserve of Scandola, Corsica (Western Mediterranean) and autopsied immediately after death. The digeneans collected were studied while still living and later in permanent preparations. Individuals were fixed in Bouin's fluid between a slide and a cover-glass under a light pressure, stained in acetic carmine and mounted in Canada balsam. Studies were conducted using a microscope with DIC optics and illustrations were made with the aid of a drawing apparatus. Measurements are given as the range in micrometres, with the mean in parentheses. Only ovigerous specimens were taken into account for measurements. Voucher specimens

have been deposited in the Natural History Museum, London.

Family Bucephalidae Poche, 1907

Subfamily Bucephalinae Poche, 1907

Genus *Bucephalus* von Baer, 1827

***Bucephalus gorgon* (Linton, 1905) Eckmann, 1932**
Syns *Gasterostomum gorgon* Linton, 1905; *Nannoenterum gorgon* (Linton, 1905) Linton, 1940; *Bucephalus introversus* Manter, 1940

Host: *Seriola dumerili* (Risso), Carangidae.

Locality: Off Scandola Nature Reserve, Corsica, France (41°25'N; 8°38'E).

Sites: Pyloric caeca (preferred site), stomach and duodenum.

Number of fish examined: 9.

Prevalence: 22.2%. *Intensity*: 41.5. *Abundance*: 9.2

Material studied: Thirty-five adult specimens. In most specimens, the rhynchus was located as usual at the anterior extremity of the body, but in 6 specimens the anterior extremity including the rhynchus was retracted into the body.

Voucher specimens: BMNH Reg. No. 2005.2.28. 1–5.

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Description

Specimens with rhynchus not retracted (Figures 1–4; Table 1)

General morphology (Figure 1A–B). Body elongate, with parallel margins; anterior extremity truncate; posterior extremity rounded.

Tegument. Entire body surface spined, densely anteriorly, less dense posteriorly. Spines thin, scale-like, with transversely elongate bases; appearing sharp at body margin.

Rhynchus. Rhynchus sucker-like, muscular, oval, with terminal aperture, crowned by series of fleshy retractable tentacles. Twenty-eight of 30 specimens studied had tentacles retracted (retracted tentacles resemble papillae). Three categories of extension can be seen (Figure 2A–C) which are, according to terminology of Corkum (1967):

- 2 conspicuous primary tentacles, emanating from each anterior corner of ventral aperture of rhynchus;
- 5 smaller secondary tentacles, 1 on mid-dorsal line, 2 latero-dorsal and 2 latero-ventral;
- 11–14 small papillae, at bases of 7 tentacles (see above), often retracted; number difficult to estimate.

Digestive system. Mouth on ventral surface, slightly posterior to middle of body. Prepharynx not seen. Pharynx subspherical, usually anterior to ovary (81.5%; n = 27) [contiguous with ovary (68.2%) or separated by caecum (31.8%)]; more rarely (18.5%), posterior to ovary [contiguous with ovary (100%)]. Oesophagus short. Caecum usually oriented anteriorly (74.1%), sometimes posteriorly (25.9%). Oral and oesophageal glands not detected.

Male reproductive system. Testes 2, oval, entire, posterior to middle of body, dextral (100%), often contiguous (72.4%) or slightly separated by uterine loops (27.6%); anterior testis contiguous with ovary (55.2%) or slightly separated (44.8%). Cirrus-sac thin-walled, cylindrical, rectilinear (Figure 3), sinistral (100%); its proximal extremity at level of posterior testis (24.2%), anterior testis (72.4%) or ovary (3.4%). Seminal vesicle elongate, more than twice as long as wide. Seminal duct absent. Pars prostatica cylindrical, rectilinear, lined by thick layer of anuclear structures,

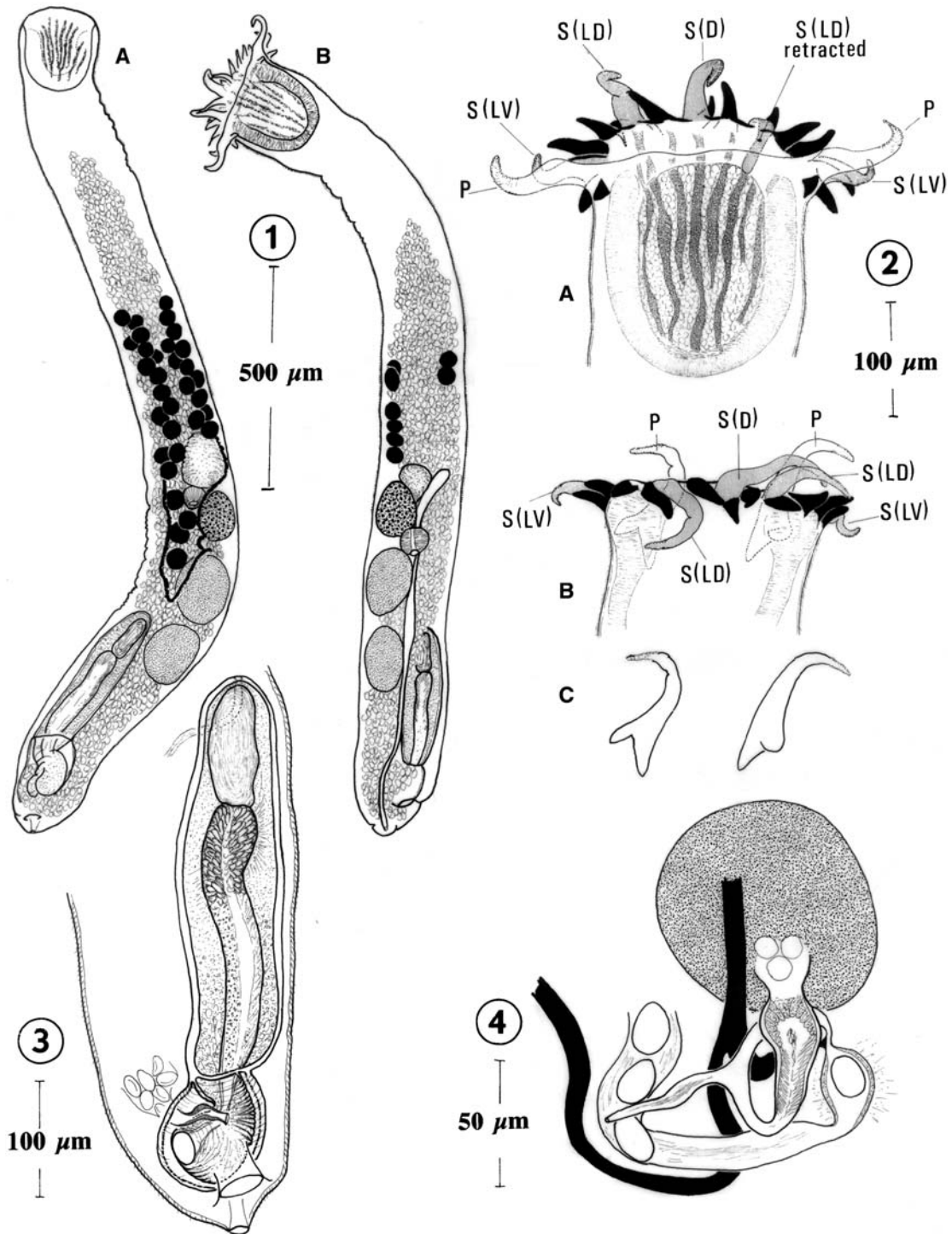
surrounded by prostatic cells. Ejaculatory duct passes through distal extremity of cirrus-sac and genital lobe. Genital lobe with irregular expansions, projects into genital atrium. Genital atrium thin-walled, wide, devoid of surrounding gland-cells. Genital pore ventral, subterminal, wide.

Female reproductive system. Ovary spherical to oval, entire, just posterior to middle of body, dextral (100%), in contact with posterior margin of caecum (100%). Oöcapt swollen, emerges from posterior margin of ovary (Figure 4). Oviduct tubular, thick-walled, ciliated, directed posteriorly. Laurer's canal thin-walled, devoid of external gland-cells, rectilinear, oriented transversely, post-ovarian, opens dorsally just posterior to ovary. Oötype and Mehlis' gland poorly developed. Proximal part of uterus contains sperm, acts as uterine seminal receptacle. Uterine loops extend well into pre-vitelline field. Distal part of uterus differentiated as weakly developed metraterm; opens into genital atrium near distal extremity of cirrus-sac. Eggs thin-shelled, operculate. Vitelline follicles in 2 longitudinal fields of subglobular follicles; dextral field 12–14 (13) (80% have 13); sinistral field 16–20 (19) (75% have 19) (n = 20), almost twice length of dextral. Vitelline ducts in dorsal parenchyma of body; sinistral much longer than dextral, forming conspicuous loop before joining vitelline reservoir (Figure 1A). Vitelline reservoir inconspicuous. Vitelline duct joins oviduct just before oötype.

Excretory system. Excretory vesicle I-shaped, reaches anterior level of ovary (Figure 1B). Excretory pore terminal.

Specimens with retracted rhynchus (Figure 5AB; Table 1)

In the stomach and the pyloric caeca of 1 fish, 6 specimens exhibiting a rhynchus withdrawn into the anterior extremity of the body were found along with 'normal' specimens. These 6 specimens have the anterior part of their body enlarged and truncate. The retracted rhynchus, abutted against the anterior uterine loops, retains its usual structure with 7 retracted tentacles. Some characters of these 6 specimens are similar to those of specimens having their rhynchus located terminally: the size of the rhynchus and eggs; the relative arrangement of the gonads; and the extent of the uterine loops, cirrus-sac and excretory vesicle. Some other



Figures 1–4. *Bucephalus gorgon* (Linton, 1905) from the pyloric caeca of *Seriola dumerili*, off Scandola Nature Reserve, Corsica. Specimens with their rhynchus not retracted. 1. General morphology. A. Dorsal view of a specimen with rhynchus with retracted tentacles; B. Ventral view of a specimen with rhynchus with expanded tentacles (its dorsal vitelline follicles are hidden by uterine loops). 2. Rhynchus. A. Ventral view; B. Dorsal view. C. Details of the primary tentacles of the Figure 2B. 3. Cirrus-sac, distal uterus and genital atrium enclosing the genital lobe (ventral view). 4. Proximal female genitalia (dorsal view). Abbreviations: P, primary tentacle; S, secondary tentacle; D, dorsal; LD, latero-dorsal; LV, latero-ventral.

Table 1. Measurements of ovigerous *Bucephalus gorgon* specimens with a normal rhynchus compared with specimens with a retracted rhynchus, all from the stomach and the pyloric caeca of *Seriola dumerili* from Scandola, Corsica.

Specimens with: n	Normal rhynchus 10	Retracted rhynchus 6
Body length	1,562–2,750 (1,974)	2,085–2,844 (2,497)
Body width at level of ovary	178–241 (208)	237–343 (290)
Rhynchus	186–230 × 160–208 (210 × 173)	192–230 × 134–205 (214 × 174)
Tentacles:		
– primary	109–125 (116)	–
– secondary (mid-dorsal)	84–106 (95)	–
– secondary (latero-dorsal)	71–96 (80)	–
– secondary (latero-ventral)	46–70 (63)	–
– papillae	27–50 (36)	–
Pharynx	44–64 × 54–64 (52 × 61)	70–77 × 70–93 (72 × 80)
Digestive caecum	95–160 × 50–112 (127 × 81)	128–176 × 74–96 (151 × 84)
Oesophagus	27–64 (45)	54–112 (81)
Anterior testis	133–262 × 90–144 (171 × 111)	182–246 × 141–170 (220 × 159)
Posterior testis	109–214 × 90–122 (143 × 103)	160–224 × 122–192 (190 × 153)
Ovary	85–147 × 70–108 (119 × 92)	141–214 × 99–160 (164 × 125)
Cirrus-sac	272–428 × 86–99 (364 × 93)	576–736 × 122–147 (654 × 131)
Thickness of cirrus-sac wall	4–7 (6)	4–8 (6)
Seminal vesicle	74–118 × 32–48 (99 × 38)	122–166 × 36–96 (145 × 62)
Pars prostatica	224–336 × 32–51 (275 × 40)	224–464 × 48–80 (344 × 62)
Genital atrium	96–192 × 90–125 (145 × 103)	144–208 × 74–144 (179 × 118)
Length of right vitelline cluster	267–445 (341)	165–537 (442)
Length of left vitelline cluster	412–889 (580)	527–933 (765)
Number of right vitelline follicles	12–14 (13)	12–13 (13)
Number of left vitelline follicles	16–20 (19)	16–21 (18)
Diameter of vitelline follicles	35–50 (41)	50–74 (61)
Eggs (uncollapsed) (n = 50)	21–24 × 13–15 (22 × 14)	21–22 × 13–14 (22 × 13)
Distance from anterior end of body to:		
– anterior limit of uterus	254–635 (399)	(#) 305–445 (392)
– anterior limit of right vitelline field	540–1,016 (726)	(#) 559–838 (674)
– anterior limit of left vitelline field	577–972 (733)	(#) 603–921 (710)
– anterior extremity of caecum	794–1,330 (1,042)	(#) 700–1,270 (1,044)
– pharynx	838–1,700 (1,144)	(#) 603–1,460 (1,163)
– anterior testis	978–1,746 (1,280)	(#) 1,016–1,632 (1,335)
– ovary	889–1,480 (1,137)	(#) 825–1,378 (1,172)
Pharynx to posterior end of body	614–1,054 (806)	1,143–1,416 (1,278)
Body width %*	7.3–15.0 (10.8)	(#) 9.0–13.5 (11.7)
Space anterior to pharynx %*	53.6–63.6 (57.7)	(#) 28.9–55.3 (46.0)
Previtelline region %*	31.5–45.0 (37.0)	(#) 23.8–31.7 (26.9)
Cirrus-sac length %*	12.8–22.4 (15.5)	(#) 21.8–32.2 (26.4)
Cirrus-sac length %**	33.4–53.9 (45.6)	47.3–57.4 (51.2)
Post-testicular region %*	17.7–21.8 (19.6)	(#) 26.5–36.8 (29.4)

(#) Distance from apparent anterior end of body.

*As % of body length.

**As % of length of body posterior to pharynx.

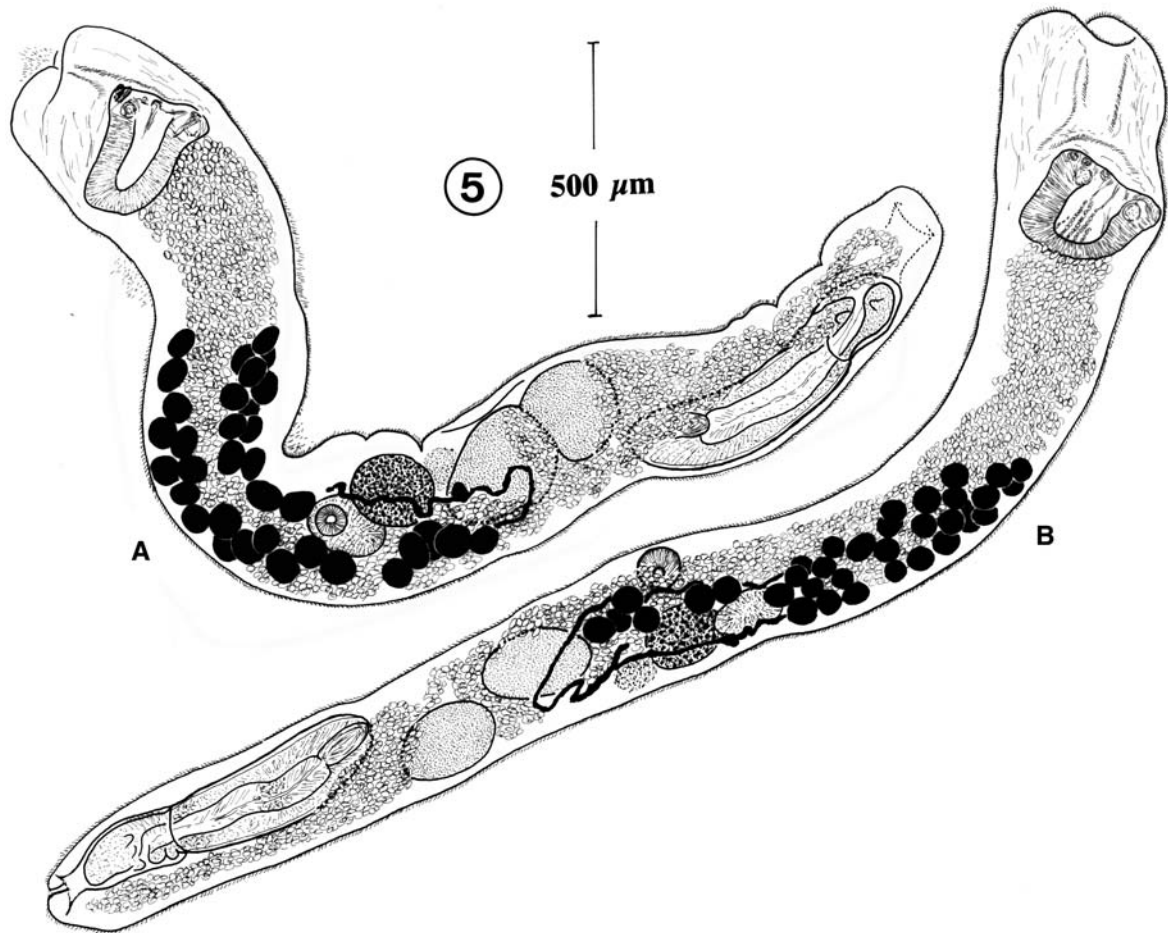


Figure 5. *Bucephalus gorgon* (Linton, 1905) from the pyloric caeca of *Seriola dumerili*, off Scandola Nature Reserve, Corsica. A-B: specimens with rhynchus retracted in the forebody. (Dorsal views).

characters are markedly different: the larger body-size, pharynx, gonads, Mehlis' gland and cirrus-sac; and the oblique testes.

Type-host and locality: *Seriola lalandi*, off Beaufort, North Carolina, USA.

Records: 1. Linton (1905); 2. Linton (1940); 3. Manter (1940)¹; 4. Bravo-Hollis & Sogandares-Bernal (1953)¹; 5. Oshmarin (1965); 6. Parukhin (1966)¹; 7. Corkum (1967); 8. Nahhas & Powell, 1971; 9. Fischthal (1982), Fischthal et al. (1982); 10. Luque & Oliva (1993)¹, 11. Montero et al. (2002); 12. Present study.

Descriptions: 1, 2, 3, 5, 7, 10, 12.

Definitive hosts: Carangidae: *Carangoides otrynter* (4—as *Citula dorsalis*), *Caranx hippos* (3), *Pseudo-*

caranx dentex (9—as *Caranx*); *Seriola lalandi* (1, 2, 3—as *dorsalis*, 10—as *mazatlana*), *S. dumerili* (3, 7, 9, 11, 12), *S. nigromaculata*[?] (5), *S. zonata* (7, 8), *Seriola* sp. (3), *Seriolina nigrofasciata* (6—as *Seriola nigrophasciata*).

Distribution: Off Beaufort, North Carolina (1); off Woods Hole, Massachusetts (2); Gulf of Mexico (7, 8); Eastern Mediterranean (off Israel) (9); Western Mediterranean: Balearic Sea (11), off Corsica (12); Pacific off Colombia (3), Pacific off Mexico (3, 4), off Chile (10), Gulf of Vietnam (5), South China Sea (6).

Discussion

In describing *Gasterostomum gorgon*, Linton (1905, p. 364) mentioned “an anterior sucker [i.e. a rhynchus] surrounded by a crown of about

¹As *Bucephalus introversus*.

eighteen tentacles”; in most cases, the anterior end of his specimens was withdrawn (his figure 241; incorrectly oriented). Eckmann (1932) placed this species in *Bucephalus* von Baer, 1827. Linton (1940) redescribed the species with an anterior sucker provided with about 20 tentacles, the specimens being “all macerated” (p. 37) and moved the species to *Nannoenterum* Ozaki, 1924. Velasquez (1959, p. 138) examined the material of Linton (1940) and replaced this species in *Bucephalus* as *B. gorgon* (Linton, 1940 [sic]), either assuming that the species described by Linton in 1905 and in 1940 were different or as a *lapsus*. Corkum (1967), as well as Nahhas & Powell (1971), Fischthal (1982) and Fischthal et al. (1982), retained the name of *B. gorgon* (Linton, 1905).

The original description of Linton (1905) is fragmentary while the ‘somewhat diagrammatic’ figures are probably of macerated worms and worms with the rhynchus withdrawn. The redescription of Linton (1940) is slightly more detailed, but with schematic figures exclusively of the rhynchus with its tentacles. The first useful figures of the body and rhynchus were provided by Corkum (1967), but details of the structure of the genital and excretory systems, as well as metrical data, are still missing. Nevertheless, the description of the specimens from Corsica fits well

with those of Linton (1940) and of Corkum (1967) (see Table 2).

The rhynchus of *B. gorgon* consists of seven large retractile tentacles, each of them provided with one or two small basal processes. The small distal prongs observed in the tentacles of some species, such as *Bucephalus varicus* Manter, 1940, are absent in *B. gorgon*. Seven large tentacles appear to be the basic number among *Bucephalus* species. The retraction of the rhynchus observed in some specimens may be an indicator of a moribund condition. In our material, all specimens with a non-retracted rhynchus were clearly alive and moving, whereas the six large (old?) specimens with a retracted rhynchus were motionless. Three of these six specimens had a disorganised, lacunar parenchyma, the tegument was shedding its spines and the vitelline follicles were more or less disintegrated. The retracted rhynchus could be observed in macerated specimens.

The first report of *B. gorgon* from *S. dumerili* in Mediterranean waters was by Fischthal (1982) and Fischthal et al. (1982) from off the Mediterranean coast of Israel. Recently, Montero et al. (2002) listed this species from *S. dumerili* in the Balearic Sea. It is probable that the bucephalid species collected by Grau et al. (1999) from the digestive tract of *S. dumerili* in the Balearic Sea and

Table 2. Comparative measurements of *Bucephalus gorgon* according to the literature.

n	Linton (1905) 1	Linton (1940) 5	Corkum (1967) ?	Fischthal et al. (1982) 60	Present study 10
Body:					
– length	1.650	2,380–3,130 (2,900)		615–3,230	1,562–2,750 (1,974)
– width	360	290–420 (360)			178–241 (208)
Rhynchus:					
– length		210–280 (240)			186–230 (210)
– width	360	180–220 (200)			160–208 (173)
Tentacles:		“tentacle”: 150			
– primary			104		109–125
– secondary			73		46–70
– papillae			42		27–50
Anterior extremity to:					
– vitellarium		560–910 (740)			540–1,016 (726)
– uterus		10–560 (310)			254–635 (399)
– pharynx		1,570–1,680			838–1,700
Diameter of pharynx		60			50–112
Number of follicles		13 + 17			13 + 19
Eggs	22 × 14	18–21 × 10–12			21–24 × 13–15

identified as *Bucephalus polymorphus* von Baer, 1827 corresponds to *B. gorgon*. *B. polymorphus* is a parasite of freshwater fishes, with freshwater lamellibranchs acting as its first intermediate hosts.

Oshmarin (1965) described *B. gorgon* from ‘*Seriola nigromaculata*’ (not listed by Froese & Pauly, 2004) from the Gulf of Vietnam. The illustration suggests that this Pacific Ocean form is, indeed, very similar to the Atlantic concept of *B. gorgon*.

Two other species of *Bucephalus* have been described from *Seriola* spp: (1) *B. introversus* Manter, 1940 from *Seriola lalandi* Valenciennes (as *S. dorsalis* (Gill)) and *S. dumerili*, off the Pacific coast of Colombia and Mexico (Manter, 1940); and (2) *B. paraheterotentaculatus* Velasquez, 1959 from *Seriolina* (as *Seriola*) *nigrofasciata* (Rüppell) off the Philippines (Velasquez, 1959).

B. introversus was described by Manter (1940) on the basis of two kinds of specimens. This author stated that in “... almost all specimens the anterior end was introverted into the anterior part of the body ...” and gave some measurements of four specimens with the anterior end everted. Comparison of the description of *B. introversus* of Manter (1940) with that reported in here for *B. gorgon*, shows them to be very similar (Table 3). Strangely, Manter (1940) never made reference to *B. gorgon* as described by Linton (1905) from the same host fish species. It is our opinion that *B. introversus* is a synonym of *B. gorgon*. Most other records appear to be of the same species, but that of Caballero y C. et al. (1956), from the centropomid *Centropomus pectinatus* Poey, is not considered conspecific here and should be further investigated.

B. paraheterotentaculatus differs from *B. gorgon* in that the mouth is located more posteriorly (at about the level of the anterior end of the cirrus-sac), and it has a posteriorly oriented caecum, overlapping gonads, a much smaller rhynchus, confluent vitelline follicles forming an arch anteriorly with a larger dextral field, and a long excretory vesicle extending to the rhynchus.

Genus *Prosorhynchoides* Dollfus, 1929

Syns *Bucephalopsis* Diesing, 1855; *Neobucephalopsis* Dayal, 1948; *Bucephaloides* Hopkins, 1954

Prosorhynchoides arcuatus (Linton, 1900) Love & Moser, 1983

Syns *Gasterostomum arcuatus* Linton, 1900; *Bucephalopsis arcuatus* (Linton, 1900) Eckmann, 1932; *Bucephaloides arcuatus* (Linton, 1900) Velasquez, 1959; *Bucephalopsis callicotyle* Kohn, 1962; *Bucephaloides callicotyle* (Kohn, 1962) Corkum, 1968

Host: *Sarda sarda* (Bloch), Scombridae, Perciformes.

Locality: off Scandola Nature Reserve, Corsica, France (41°25'N; 8°38'E).

Site: Pyloric caeca.

Number of fish examined: 1. *Intensity*: several hundreds.

Material studied: 36 adult specimens.

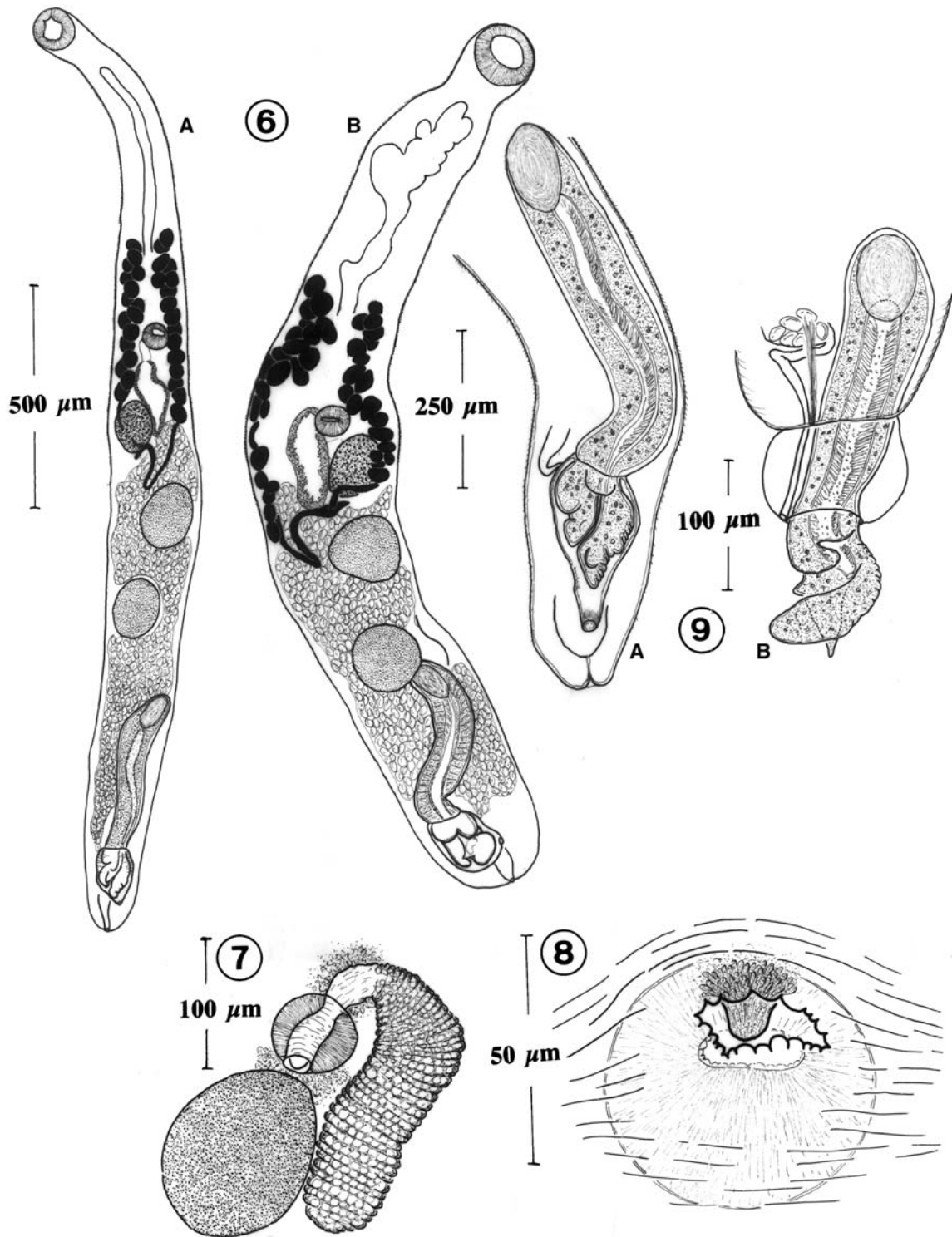
Voucher specimens: BMNH 2005.2.16.1–6.

Description (Figures 6–10; Table 4)

General morphology (Figure 6A,B). Body more or less cylindrical, elongate; some specimens arched

Table 3. Comparative measurements of ovigerous specimens with non-retracted rhynchus of *Bucephalus introversus* and *B. gorgon*.

	<i>B. introversus</i>	<i>B. gorgon</i>
Source	Manter (1940)	Present study
Host(s)	<i>Seriola</i> spp., <i>Caranx hippos</i>	<i>Seriola dumerili</i>
Sites	Stomach	Stomach and pyloric caeca
Locality	Off Colombia and Mexico	Off Scandola (Corsica)
n	4	10
Body length	1,202–1,707	1,562–2,750
Body width	225–285	178–241
Rhynchus	length: 170–345	length: 186–230
Anterior end to mouth	817–1,035	838–1,700
Pharynx width	37–61	54–64
Eggs	22–26 × 12–15 (24 × 14)	21–24 × 13–15 (22 × 14)



Figures 6–9. *Prosorhynchoides arcuatus* (Linton, 1900) from the pyloric caeca of *Sarda sarda*, off Scandola Nature Reserve, Corsica. 6. General morphology. A. Ventral view; B. Dorsal view. 7. Digestive system (ventral view). 8. Oral papilla and oral gland-cells (ventral view). 9. Cirrus-sac, distal uterus and genital atrium. A. Genital lobe protruding into genital atrium – usual condition (ventral view); B. Genital atrium everted; genital lobe projected outside through the genital pore (dorsal view).

Table 4. Comparative measurements of *Prosorhynchoides arcuatus* and *P. tergestinum*.

Host Site n	<i>P. arcuatus</i> <i>Sarda sarda</i> Pyloric caeca 10	<i>P. tergestinum</i> <i>Gobius geniporus</i> Mid-intestine 1
Body length	955–1,745 (1,412)	546
Maximal body width	181–252 (220)	272
Rhynchus	73–103 × 85–109 (86 × 93)	101 × 137
Pharynx	49–59 × 47–65 (53 × 51)	71 × 79
Digestive caecum	110–182 × 57–88 (147 × 70)	161 × 115
Oesophagus	47–87 (63)	0
Anterior testis	81–155 × 79–123 (115 × 100)	96 × 90
Posterior testis	63–150 × 82–130 (105 × 100)	104 × 90
Ovary	74–111 × 71–110 (97 × 85)	103 × 66
Cirrus-sac	280–442 × 54–71 (355 × 66)	232 × 46
Thickness of cirrus-sac wall	4–8 (5)	
Seminal vesicle	51–98 × 23–58 (69 × 37)	79 × 47
Pars prostatica	174–261 × 35–65 (212 × 52)	175 × 40
Genital atrium	60–110 × 73–114 (94 × 89)	85 × 65
Length of right vitelline cluster	165–362 (294)	161
Length of left vitelline cluster	285–495 (377)	126
Number of vitelline follicles	30–34 (32)	–
Diameter of vitelline follicles	27–40 (31)	–
Eggs (uncollapsed) (n = 30)	16–19 × 10–13 (17 × 11)	17–19 × 9–12 (19 × 11)
From anterior end of body to:		
– anterior limit of uterus	520–972 (783)	77
– anterior limit of vitellarium	350–580 (482)	144–221
– proximal extremity of caecum	496–978 (809)	300
– mouth	448–830 (676)	155
– anterior testis	550–1,022 (845)	224
– ovary	476–890 (730)	162
From mouth to posterior end of body	507–946 (736)	410
Maximum body width %*	12.1–21.8 (16.2)	49.8
Pre-oral region %*	44.6–53.8 (48.0)	28.4
Previtelline region %*	32.8–36.6 (34.3)	33.4
Cirrus-sac length %*	21.0–35.1 (25.8)	42.5
Cirrus-sac length %**	38.5–65.0 (49.6)	56.6
Post-testicular region %*	16.8–28.7 (23.0)	25.3

*As % of body length.

**As % of length of body posterior to pharynx.

when fixed; maximum width at level of ovary or anterior testis.

Tegument. Entire surface of body spinose and finely folded (transverse rows of thin furrows), between anterior extremity and ovarian level, and particularly in anterior part of this region; spines very dense, strongly developed, acuminate, flattened, with transversely enlarged bases; posterior

to ovarian level, spines smaller, less dense, and absent posterior to level of cirrus-sac.

Rhynchus. Rhynchus sucker-like, round, ventro-terminal, devoid of special spines, lobes and gland-cells.

Digestive system. Mouth on ventral surface, usually near middle of body; anterior lip with prom-

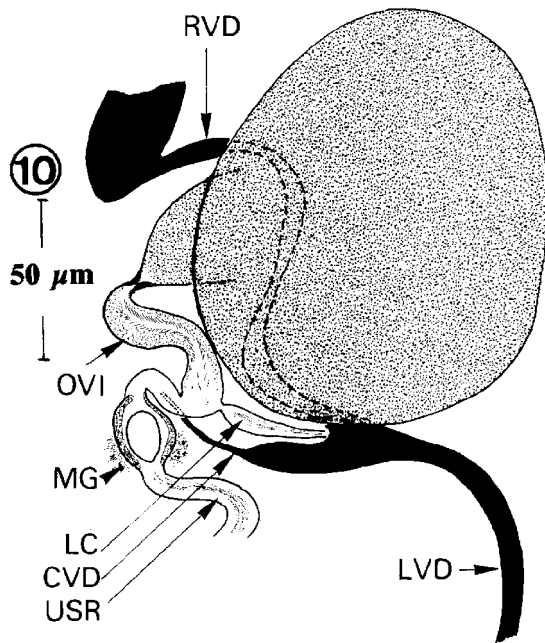


Figure 10. *Prosorhynchoides arcuatus* (Linton, 1900) from the pyloric caeca of *Sarda sarda*, off Scandola Nature Reserve, Corsica. Proximal female genitalia (ventral view). Abbreviations: CVD, common vitelline duct; LC, Laurer's canal; LVD, left vitelline duct; MG, Mehlis' gland; OVI, oviduct; RVD, right vitelline duct; USR, uterine seminal receptacle.

inent conical outgrowth (oral papilla) protruding over oral opening, with oral gland-cell ducts opening on tip (Figures 7, 8). Pharynx spherical. Oesophagus distinct, thin-walled. Caecum cylindrical, posteriorly oriented, reach posteriorly as far as level of middle of ovary or further; wall thick and transversely folded; gastrodermis with large non-chromophilic convex cells (Figure 7). Oesophageal and oral gland-cells numerous, very small, not easily detected.

Male reproductive system. Testes 2, spherical to oval, entire, in anterior part of posterior half of body, widely separated from ovary by uterus (86.1%; $n = 36$) or rarely contiguous (13.9%). Testes widely separated from each other by uterine loops (91.4%) or rarely contiguous (8.6%); anterior testis dextral (50%), more rarely median (38.9%) or sinistral (11.1%); posterior testis dextral (42.9%), median (40%) or sinistral (17.1%). Cirrus-sac conspicuous, thin-walled, cylindrical, rectilinear or slightly curved, depending of state of contraction, often sinistral (44.4%), sometimes median (30.6%) or dextral (25%), with proximal extremity

at level of posterior testis (i.e. in contact) (52.8%) or more posterior (i.e. separated) (47.2%). Seminal vesicle ovoid, less than twice as long as wide. Seminal duct absent. Pars prostatica cylindrical, often rectilinear, more rarely curved, lined with thick layer of anuclear structures, surrounded by prostatic cells. Ejaculatory duct passes through distal extremity of cirrus-sac which forms genital lobe projecting into genital atrium for 88.9% of specimens (Figure 7A); in 11.1% of specimens, genital atrium is everted and genital lobe is protruded through genital pore (Figure 7B). Genital lobe with 2 pointed, irregular lobes. Genital atrium thin-walled, wide, devoid of surrounding gland-cells. Genital pore ventral, subterminal.

Female reproductive system. Ovary spherical to oval, entire, in middle of body, dextral (88.9%) or median (11.1%), contiguous with right side of caecum (89.5%) or its distal extremity (10.5%). Oöcapt swollen, emerging from right side of ovary (Figure 10). Oviduct tubular, thick-walled, lined with posteriorly directed cilia. Laurer's canal thin-walled, devoid of external glandular cells, rectilinear, transversely oriented, post-ovarian, opens dorsally just posterior to ovary. Oötype thick-walled; Mehlis' gland poorly developed. Proximal part of uterus containing sperm, acts as uterine seminal receptacle. Uterine loops exclusively post-ovarian, fill most of post-ovarian part of body; distal part not differentiated as metraterm, opens into genital atrium near distal extremity of cirrus-sac. Eggs thin-shelled, operculate; abnormal eggs coexisting with normal ones in 33.3% of specimens. Vitelline follicles in 2 regular longitudinal rows, on either sides of pharynx, 13–18 (15) in dextral field, 16–19 (17) in sinistral field; total number 30–34 (32); sinistral field longer than dextral. Vitelline ducts run in dorsal parenchyma; sinistral duct longer than dextral, describes conspicuous loop before joining vitelline reservoir (Figure 6A–B). Vitelline reservoir posterior to ovary with unusually straight common vitelline duct joining oviduct just proximal to oötype.

Excretory system. Excretory vesicle I-shaped, sometimes with irregular bulges, very long, reaching to near rhynchus. Excretory pore terminal

Type-host and locality: *Sarda sarda*, off Woods Hole, Massachusetts, USA.

Records: 1. Linton (1900); 2. Linton (1901); 3. Linton (1905); 4. Linton (1940); 5. Kohn (1962)¹; 6. Nahhas & Cable (1964)²; 7. Nahhas & Short (1965)²; 8. Corkum (1968)³; 9. Overstreet (1969)²; 10. Yamaguti (1970)⁴; 11. Gomez, De Fabio & Rolas (1972)¹; 12. Greze et al. (1975)^{4,5}; 13. Szuks (1981)^{1,4}; 14. Bray (1984); 15. Wang (1985)⁴; 16. Wallet & Kohn (1987)¹; 17. Dimitrov (1989); 18. Gijon-Botella & Lopez-Roman (1989)¹; 19. Cohen, Kohn & Barth (1995); 20. Dyer, et al. (1998); 21. Present study.

Descriptions: 1, 4, 5, 10, 13, 14, 19, 21.

Definitive hosts: Carangidae: *Caranx hippos* (3). Scombridae: *Sarda sarda* (1, 12, 17, 21), *S. orientalis* (10); *Scomberomorus regalis* (3, 9), *S. cavalla* (6, 20), *S. guttatus* (15), *S. maculatus* (7); *Scomber scombrus* (4, 12). Sebastidae: *Helicolenus dactylopterus* (13). Trichiuridae: *Trichiurus lepturus* (4). Gadidae: *Gadus morhua* (4). Pomatomidae: *Pomatomus saltatrix* (5, 7, 8, 11, 13, 14, 16, 17, 18, 19). Carcharhinidae: *Carcharhinus obscurus* (2)

Distribution: Off Woods Hole (1, 2, 4); off Beaufort, North Carolina (3); off Florida (9); Gulf of Mexico (7, 8); off Curaçao and Jamaica (6); off Puerto Rico (20); off Brazil (5, 11, 16, 19); off South Africa (14); off Hawaii (10); Canaries (18); Black Sea (12); Western Mediterranean (21); off Mauritania (13); off Fujian, China (15); Black Sea off Bulgaria (17).

Discussion

Historical review

Gasterostomum arcuatum was originally described by Linton (1900) from the Atlantic bonito *Sarda sarda* off Woods Hole, Massachusetts, USA and later (Linton, 1901) from the dusky shark *Carcharhinus obscurus* (Lesueur) ('almost certainly' an accidental host according to Bray & Cribb (2003)) from the same area. Linton (1905) then reported this species from off Beaufort, North Carolina, USA from two other fish hosts, the cero *Scomberomorus regalis* (Bloch) (with a figure) and the crevalle jack *Caranx hippos* (L.). Eckmann (1932) placed the species in *Bucephalopsis* as *B. arcuata* [sic] (Linton, 1900). Nagaty (1937 p. 45) listed the

¹As *Bucephalopsis callicotyle*; ²as *Bucephaloides arcuatus*; ³as *Bucephaloides callicotyle*; ⁴as *Bucephalopsis arcuatus*; ⁵as *Bucephalus arcuatus*.

synonyms of *B. arcuatus*. Unaware of Eckmann's new combination, Linton (1940) retained this species in *Gasterostomum* and added three new host fishes for it, the mackerel *Scomber scombrus* L., the largehead hairtail *Trichiurus lepturus* L. and the cod *Gadus morhua* L. from off Woods Hole. The same year, Manter (1940) pointed out that the species reported by Linton (1905) from *Scomberomorus regalis* from Beaufort might not be *Bucephalopsis arcuatus* due to its large size and its relatively short cirrus-sac and added the great barracuda *Sphyraena barracuda* (Walbaum) from off Tortugas, Florida, as a further host for *B. arcuatus*. Sogandares (1959), Siddiqi & Cable (1960) and Sogandares-Bernal & Sogandares (1961) reported *B. arcuatus* from *Sphyraena barracuda* from off Panama and Puerto-Rico. Manter (1963) pointed out that the specimens from the barracuda that he found earlier (Manter, 1940), and those reported by Siddiqi & Cable (1960), had an excretory vesicle ending at the level of the pharynx, whereas it extends almost to the rhynchus in *B. arcuatus* (see Linton, 1900, figure 86), more widely separated vitelline fields, and a longer cirrus-sac. Manter (1963, p.229) considered the specimens from *Sphyraena barracuda* to be *Bucephaloides longicirrus* Nagaty, 1937, a parasite of *Sphyraena agam* from the Red Sea, basing his opinion on the truncate rhynchus, the location of the gonads, the extent of the vitellarium and uterus and the egg-size. Yamaguti (1970) described and figured *Bucephalopsis arcuatus* from the striped bonito *Sarda orientalis* (Temminck & Schlegel) from off Hawaii. Bray (1984) transferred *Bucephaloides arcuatus* to *Prosorhynchoides* unaware that this action had been taken the year earlier by Love & Moser (1983). Bray (1984) also synonymised *Bucephalopsis callicotyle* Kohn, 1962, from the bluefish *Pomatomus saltatrix* (L.) off Brazil, with *P. arcuatus*.

Identification of the Mediterranean specimens

Surprisingly, despite many reports of *Prosorhynchoides arcuatus* around the world, the morphological and metrical data available for this species are extremely fragmentary, apart from those given by Yamaguti (1970) for specimens from *Sarda orientalis* off Hawaii. The description and the measurements of Yamaguti (1970) agree with the data from the present study except for the number of vitelline follicles and the side of the body where the U-shaped vitelline duct runs. A

scanning electron microscopical study of specimens from *Pomatomus saltatrix* off Rio de Janeiro, Brazil by Cohen et al. (1995) is in general agreement with the present description except for the lack of an oral papilla, which obvious in all of our specimens, and the genital aperture which is protuberant and provided with a muscular sphincter, structures that are lacking in our specimens. The oral papilla of *P. arcuatus* is similar to that described by Manter & Van Cleave (1951) for *Bucephalopsis* (= *Prosorhynchoides*) *labiatus* (Manter & Van Cleave, 1951) from *Paralichthys californicus* (Ayres) and by Santos & Gibson (2002) for *Prosorhynchus crucibulum* (Rudolphi, 1819) from *Conger conger* (L.).

Distribution

Prosorhynchoides arcuatus is listed by Greze et al. (1975, p. 501) as present in the Black and Azov Seas in *Sarda sarda* (as *Bucephalopsis arcuatus*) and *Scomber scombrus* (as *Bucephalus arcuatus*), and Dimitrov (1989) reported *P. arcuatus* from *Pomatomus saltatrix* and *Sarda sarda* from the Bulgarian Black Sea coast. In the Mediterranean, *Sarda sarda* appears to have been investigated for digeneans only by Barbagallo & Drago (1903), who listed “*Distoma clavatum Rudolphi*” (a *species inquirendum*) found in their stomach of *Sarda sarda* from the Ionic Sea, eastern Mediterranean. In contrast, numerous studies have been conducted on the digenean fauna of *Scomber scombrus* and *S. japonicus* Houuttuyn at various places in the Mediterranean, but none have reported a bucephalid species. As a result, we report *Prosorhynchoides arcuatus* for the first time in the Mediterranean.

***Prosorhynchoides tergestinum* (Stossich, 1883) n. comb.**

Syns *Gasterostomum tergestinum* Stossich, 1883; *Bucephalopsis tergestina* (Stossich, 1883) Nagaty, 1937; *Bucephalus tergestinus* (Stossich, 1883) Yamaguti, 1958

Host: *Gobius geniporus* Valenciennes, Gobiidae.

Locality: Off Scandola Nature Reserve, Corsica, France (41°25'N; 8°38'E).

Sites: Mid-intestine.

Number of fish examined: 17.

Prevalence: 5.9%. *Intensity:* 1. *Abundance:* 0.06.

Negative hosts: 16 *Gobius paganellus* L. and 11 *G. cobitis* Pallas from the same locality.

Material studied: 1 adult specimen.

Voucher specimens: BMNH 2005.2.28.6.

Description (Figures 11, 12; Table 4)

General morphology (Figure 11A,B). Body pyriform, not elongate, widest at level of pharynx, narrowing in post-testicular field. Extremities rounded.

Tegument. Entire body-surface densely spined; spines scale-like.

Rhynchus. Rhynchus sucker-like, subterminal, large, circular, muscular, with wide cavity but small ventral aperture.

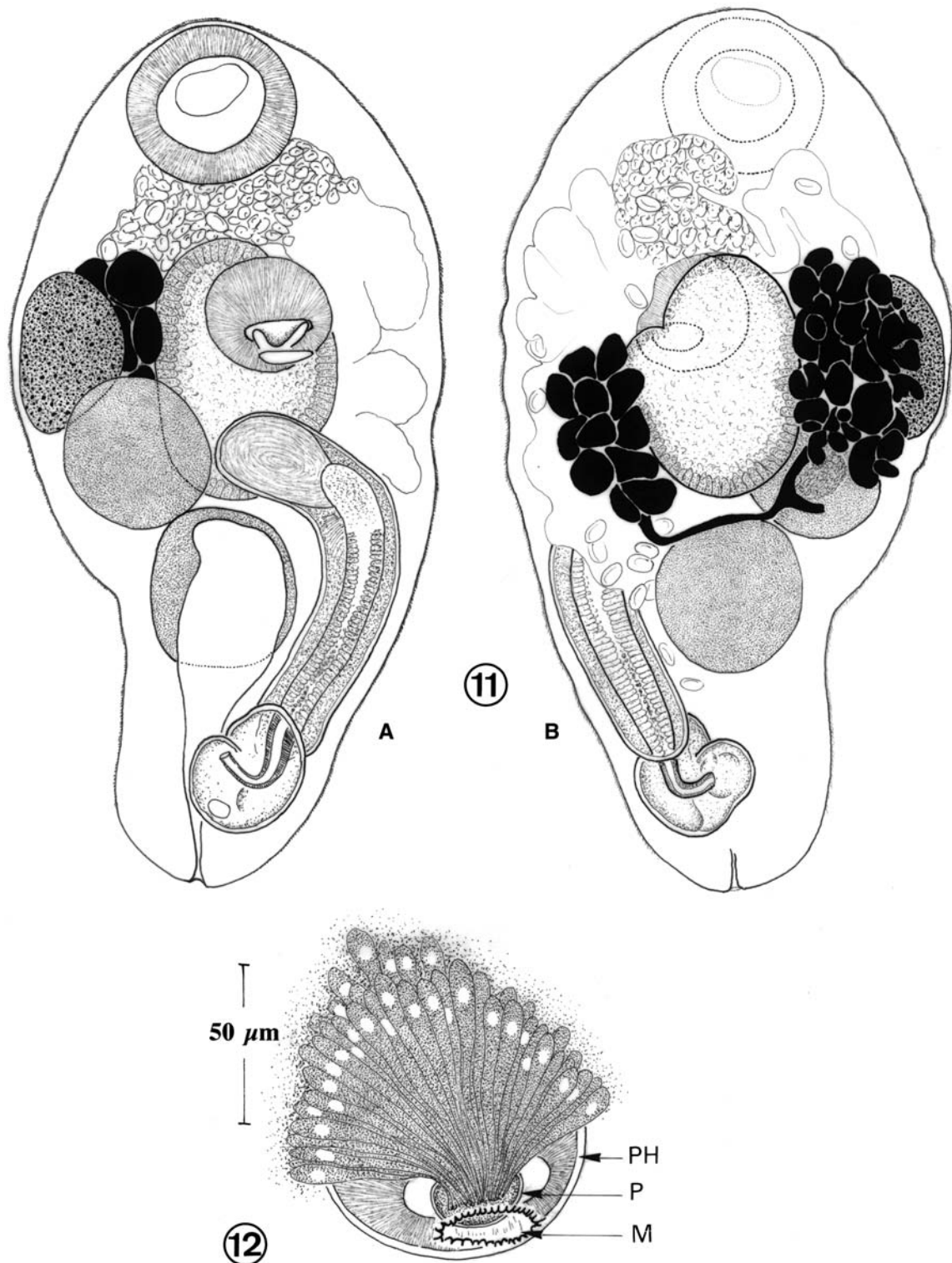
Cephalic gland-cells. Numerous discrete gland-cells among parenchymal cells of pre-vitelline field; ducts pass dorsally to rhynchus and open on its anterior lip.

Digestive system. Mouth on ventral surface, near anterior extremity of middle third of body. Prepharynx short. Pharynx transversely oval, large, with thick basal lamina; at level of ovary but separated from it. Oesophagus absent. Caecum sac-like, oval, dorsal to pharynx, posteriorly oriented. Gastrodermis with tall columnar cells. Oesophageal glands not detected.

Oral gland-cells. Numerous discrete gland-cells radiate in ventral parenchyma anterior to pharynx; ducts open at tip of oral papilla (Figure 12). Oral papilla conical, distinct, emerges from anterior wall of prepharynx and projects into prepharyngeal cavity.

Male reproductive system. Testes 2, contiguous, oblique, entire, spherical; anterior dextral, in ventral parenchyma, slightly overlaps ovary; posterior submedian. Cirrus-sac curved, sinistral; proximal extremity contiguous with left side of anterior testis. Seminal vesicle oval, entire (i.e. not twisted); length slightly more than twice width. Pars prostatica sub-rectilinear, curved at anterior extremity. Distal ejaculatory duct curved. Genital lobe weakly bi-lobed. Genital atrium thick-walled; surrounding gland-cells apparently missing. Genital tube absent. Genital pore sub-terminal.

Female reproductive system. Ovary pre-equatorial, dextral, anterior and dorsal to anterior testis, oval.



Figures 11–12. *Prosorhynchoides tergestinum* (Stossich, 1883) from the mid-intestine of *Gobius geniporus*, off Scandola Nature Reserve, Corsica. 11. General morphology of the same specimen (only some eggs are figured in the anterior uterine loops). A. Ventral view; B. Dorsal view. 12. Mouth, oral papilla and oral gland-cells (ventral view). Abbreviations: M, mouth; P, oral papilla; PH, pharynx.

Laurer's canal not detected. Mehlis' gland poorly developed, posterior to ovary, dorsal to anterior testis (Figure 11B). Anterior uterine loops at level of posterior extremity of rhynchus. Eggs numerous, all collapsed. Metraterm not detected. Vitelline follicles in 2 clusters, in dorsal parenchyma of mid-body, lateral to caecum at ovarian level; follicles closely packed, not clearly outlined, of variable shape and size; number difficult to count. Left vitelline duct only slightly longer than right.

Excretory system. Excretory vesicle I-shaped, wide, with its anterior extremity reaching anterior margin of posterior testis, in ventral parenchyma. Excretory pore terminal.

Type-host and locality: *Gobius niger* L. [first host listed], Adriatic Sea off Trieste.

Records: 1. Stossich (1883); 2. Stossich (1901; repeat of 1); 3. Present study.

Descriptions: 1, 2, 3 (and Nicoll, 1910, from specimens in Stossich's collection).

Definitive hosts: Gobiidae: *Gobius niger* (1; and *G. jozo* – according to Froese & Pauly, 2004, a synonym of *G. niger*); *G. geniporus* (3).

Distribution: Mediterranean: Adriatic Sea (1,2); Western Mediterranean (Corsica) (3).

Discussion

The present description of *P. tergestinum* is in close agreement with those of Stossich (1883, 1901) and Nicoll (1910). As reported by Stossich (1883), but unlike Nicoll (1910), the only specimen found reported in this study shows a wide digestive caecum extending anteriorly as well as posteriorly to the pharynx, an entire and oval seminal vesicle, and two vitelline clusters larger than the pharynx. This is a very rare species which has not been reported since the original record of Stossich in 1883.

Acknowledgements

Fieldwork on Corsica of PB was carried out under the auspices of the Comité Scientifique de la Réserve Naturelle de Scandola.

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