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Redescription of *Gonostomum algicola* and *G. gonostomoida* (Ciliophora: Spirotrichea: Sporadotrichida) Unknown from Korea

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ABSTRACT

Two rare ciliates from soil under the oak tree and mosses in the top of mountain in Korea were identified as *Gonostomum algicola* Gellért, 1942 and *G. gonostomoida* (Hemberger, 1985), respectively. There is little information on their morphological features, therefore their detailed redescriptions are needed. The description was based on the observation of living and protargol impregnated specimens, and biometric analysis. Their diagnostic characteristics are as follows. *Gonostomum algicola*; 88-113 × 30-40 μm *in vivo*, colourless cortical granules, 20-31 adoral membranelles, two fronto-terminal cirri, five fronto-ventral cirri, no mid-ventral cirri, two transverse cirri, two to three micronuceli. *Gonostomum gonostomoida*; 60-121 × 21-40 μm *in vivo*, no cortical granules, 27-34 adoral membranelles, no fronto-terminal cirri, two fronto-ventral cirral rows with each row bearing three cirri, midventral cirral row with 11-14 cirri, two to three transverse cirri, one to six micronuceli. So far, total three species within the genus *Gonostomum* have been recorded from Korea by the present study.

Key words: *Gonostomum algicola*, *Gonostomum gonostomoida*, terrestrial, morphology, Korea

INTRODUCTION

The species belonging to genus *Gonostomum* are common in terrestrial but rare in freshwater and marine ecosystems. Up to now, more than 17 species have been reported worldwide and only one species, *G. affine* (Stein, 1859), was recorded in Korea (Maeda and Carey, 1984; Shin and Kim, 1995; Berger, 1999 and 2001; Vd'acny and Tirjakova, 2006). Since the establishment of genus *Gonostomum* in 1878 by Sterki, its taxonomic position has been controversial as it was proposed to be in different families, Oxytrichidae (Borror, 1972; Hemberger, 1982; Berger, 1999), Holostichidae (Corliss, 1979), Gonostomatidae (Small and Lynn, 1985) or Trachelostylidae (Lynn, 2002; Lynn and Small, 2000). The present work presents the redescriptions of Korean populations of the species, *G. algicola* Gellért, 1942 and *G. gonostomoida* (Hemberger, 1985) which were not recorded from Korea previously. We investigated the morphological and biometrical characterizations, and variation of these species, and compared the characteristics of Korean and other populations of these species and some related species.

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MATERIALS AND METHODS

Specimens were collected from soil under the oak tree and mosses in the top of mountain in Korea during the period from November 2003 to May 2004. The laboratory cultures were maintained at room temperature in the commercial mineral water provided with dried wheat grains for supplying fungal and bacterial nutrients of ciliates. The characteristics of living specimens were observed under microscope equipped with the bright field and DIC (40-1,000 ×) and their images were captured by digital camcorder and camera. The infraciliature was observed by using the modified protargol impregnation method (Wilbert, 1975; Shin and Kim, 1995). The biometrical analysis was performed according to Sokal and Rohlf (1973). The scheme of classification by Lynn and Small (2000) was adopted.

RESULTS AND DISCUSSION

Phylum Ciliophora Doflein, 1901
Class Spirotrichea Bütschli, 1889
Order Sporadotrichida Fauré-Fremiet, 1961
Family Trachelostylidae Small and Lynn, 1985
Genus *Gonostomum* Sterki, 1878

Gonostomum algicola Gellért, 1942 (Figs. 1, 2 and Tables 1, 2)

Gonostomum algicola Gellért 1942, p. 23; Maeda and Carey, 1984, p. 12, fig. 5; Foissner et al., 2002, p. 799, fig. 174.

Trachelostyla candensis Buitkamp and Wilbert, 1974, p. 208, fig. 6.

Material examined. The living specimens collected from mosses in the top of Cheonhwang Mt. in Tongyeong, Korea (128°15′10″E and 34°37′57″N), on 14 May 2004, were cultured at the laboratory, and 25 living and 25 protargol impregnated specimens were observed and biometrically analyzed respectively. Their data were summarized in Table 1.

Description. Body size 88-113 × 30-40 μm *in vivo*, ratio of length to width usually 3 : 1 and 2.5 : 1 (after staining), body inflexible and noncontractile, long ellipsoid in shape, anterior and posterior end narrowly rounded. Cytoplasm colourless, containing small colourless fat globules (2-5 μm) around posterior end, and many food vacuoles (7-10 μm). Colourless cortical granules (CGs) irregularly distributed on dorsal surface. Contractile vacuole (CV) approximately 10-15 μm in diameter, located in mid-body during diastole with long collecting canals and splitted into three small vacuoles. Movement slow and jerky, usually crawling on bottom or swimming in water. Adoral zone of membranelles (AZM) about 40% of body length, 25 adoral membranelles, each about 8-12 μm wide. Pharyngeal fiber about 15-20 μm, undulating membranes (UM) in *Gonostomum* pattern: paroral (PM) and endoral (EM) parallel to each other with endoral anterior to paroral. 23 right marginal cirri (RMC), 19 left marginal cirri (LMC), On average three frontal cirri (FC), two fronto-terminal cirri (FTC), five fronto-ventral cirri (FVC), one buccal cirri (BC), two transverse cirri (TC). Two to four caudal cirri (CC) on dorsal side of posterior end, three dorsal kineties (DKs), kinety 1 slightly shortened anteriorly. Two oval macronuclei (Ma), size 6-20 × 5-11 μm after protargol impregnation, with two to three spherical micronuclei (Mi).

Distribution. Korea, Africa, North America, Europe.

Remarks. Since the establishment of this species by Gellért (1942) from the algal layer on the tree in Hungary, Foissner et al. (2002) redescribed and neotypified it from the mineral soil in Namibia. Most characteristics of our specimens agree with those of the original description (Gellért, 1942) and redesciption by Foissner et al. (2002): size (78-108 μm vs. 60-100 μm vs. 52-95 μm respectively). short adoral zone of membranelles (about 40% vs. 45% vs. 40% respectively), pattern and number of frontoventral cirri [5 vs. 5 vs. 5 (4-8) respectively] and pattern and number of frontoterminal cirri [2 (1-2) vs. 1 vs. 2 (2-3) respectively]. However, there are some differences: the number of caudal cirri [2 vs. 4 (seems to be 2) vs. 3 respectively] and the number of transverse cirri (2 vs. 2 vs. 1 respectively). This species differs from the congeners (*G. affine*, *G. franzi*, *G. gonostomoida* and *G. strenua*), as summerized in Table 2, by (i) the number of macronucleus (11 in *G. franzi*), (ii) the pattern and number of frontoventral cirri [12 (11-15) in *G. strenua*, 27-51 (4 rows) in *G. franzi* and about 5 in *G. affine*, *G. algicola* and *G. gonostomoida*], (iii) the presence of midventral cirri in *G. gonostomoida*, (iv) the number of transverse cirri (about 2 in *G. algicola* and *G. gonostomoida*, about 4 in *G. affine* and about 6 in *G. strenua*) (Buitkamp and Wilbert, 1974; Foissner, 1982; Hemberger, 1985; Song, 1990; Berger, 1999; Foissner et al., 2002).

Gonostomum gonostomoida (Hemberger, 1985) (Figs. 3, 4 and Tables 1-3)

Trachelocharta gonostomoida Hemberger, 1985, p. 400, fig. 3.

Gonostomum gonostomoida: Berger, 1999, p. 392, fig. 124.

Material examined. The living specimens collected from soil under the oak tree in Ulsan, Korea (129°27′07″E and 35°36′59″N), on 14 November 2003, were cultured at the laboratory, and 19 living and 10 protargol impregnated specimens were observed and biometrically analyzed respectively. Their data were summarized in Table 1.

Description. Body size 60-121 × 21-40 μm *in vivo*, ratio of length to width usually 3 : 1 and 2.5 : 1 (after staining), body flexible but noncontractile and long ellipsoid in shape, anterior end rounded, posterior end narrowly rounded and right posterior margin emarginate. Cytoplasm colourless, containing small colourless fat globules (1.5-3 μm) around posterior end, cortical granules (CGs) absent. Colourless ellipsoidal structure (2-3 μm), very likely mitochondria, numerous and located at underneath pellicle. Contractile vacuole (CV) approximately 9 μm in diameter, located in mid-body during diastole with a long collecting canal and splitted into two small vacuoles. Movement rapid and crawling on bottom or swimming in water for culture. Adoral zone of membranelles (AZM) about 50% of body length, 31 adoral membranelles about 7-10 μm wide. Pharyngeal fiber about 10-17 μm, undulating membranes (UM) in *Gonostomum* pattern: paroral (PM) and endoral (EM) parallel to each other with endoral anterior to paroral. 17 right marginal cirri (RMC) and 15 left marginal cirri (LMC); two marginal cirral rows not overlapped at the posterior end. On average enlarged three frontal cirri (FC), one buccal cirri (BC), two fronto-ventral cirral (FVC) rows with each row bearing three cirri, midventral cirral (MVC)

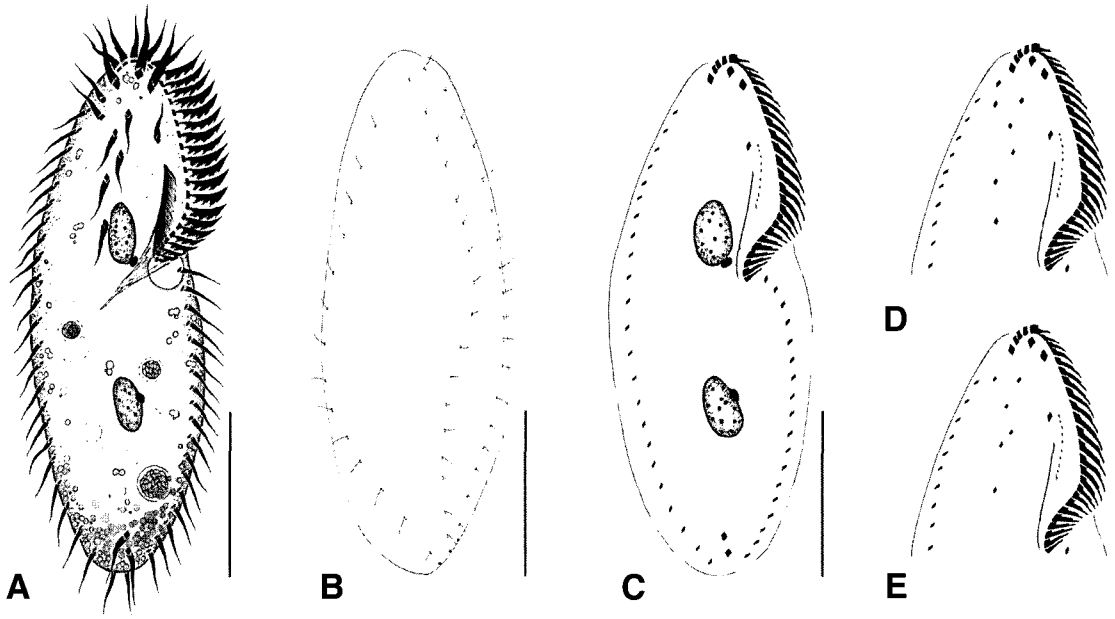

Fig. 1. *Gonostomum algicola* Gellért, 1942. A, living specimen, ventral view; B, dorsal kineties, dorsal view; C, infraciliature without FVC and FTC after protargol impregnation and nuclear state, ventral view; D, E, the variation of FTC and FVC in anterior end, ventral view. Scale bars=30 μm (A-E).

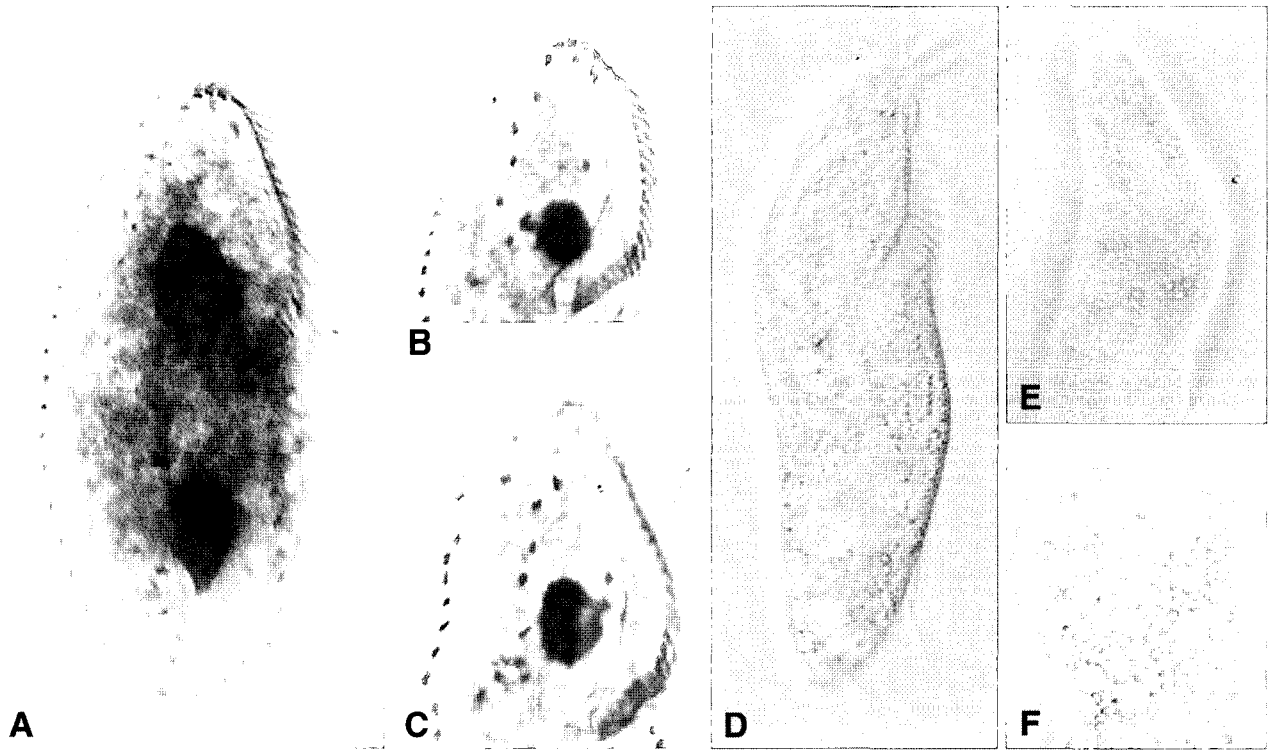

Fig. 2. Photograph of protargol impregnation and live specimen in *Gonostomum algocola*. A, the body shape and arrangement of LMC, RMC and Ma, ventral view; B, C, the variation of FC, FVC, ventral view; D, Body shape and arrangement of AZM and Ma nodules, ventral view; E, the arrangement of cortical granules, dorsal view; F, the states of fat globules in posterior end, ventral view.

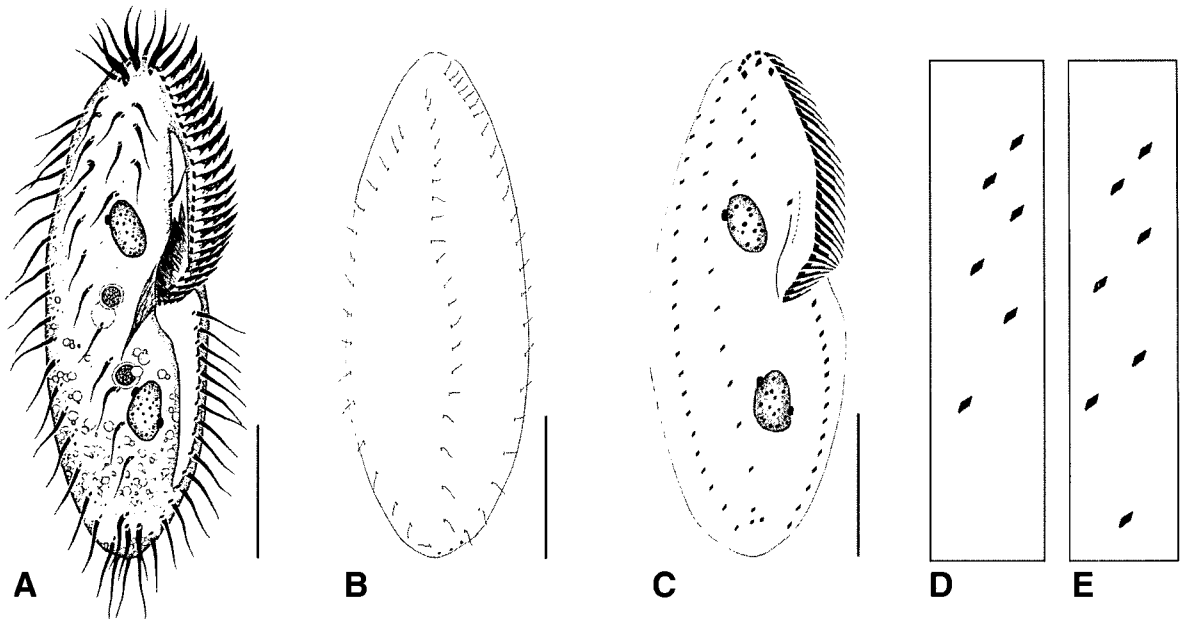

Fig. 3. *Gonostomum gonostomoida* (Hemberger, 1985) Berger, 1999. A, living specimen, ventral view; B, dorsal kineties, dorsal view; C, infraciliature after protargol impregnation and nuclear state, ventral view; D, E, the variation pattern of FVC row. Scale bars=30 μm (A-E).

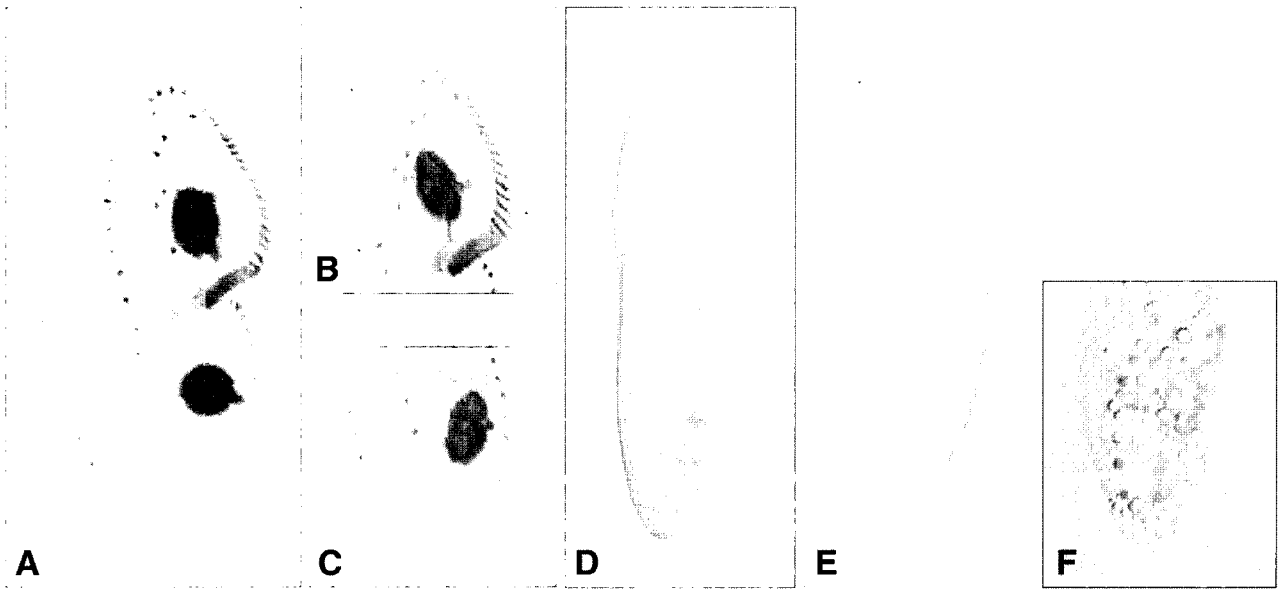

Fig. 4. Photograph of protargol impregnation and live specimen in *Gonostomum gonostomoida*. A, body shape and arrangement of FVC, MVC, LMC, RMC and Ma, ventral view; B, the arrangement of AZM, FC, FVC, ventral view; C, the arrangement of LMC and RMC rows and TC in posterior end, ventral view; D, body shape and arrangement of AZM and Ma nodules, ventral view; E, the arrangement of CV with collecting canals, ventral view; F, the states of fat globules in posterior end, ventral view.

row with 11-14 cirri and three transverse cirri (TC). Three conspicuous caudal cirri (CC) and three dorsal kineties (DKs) on dorsal side. Two oval macronuclei (Ma) after protargol impregnation 8-16 × 6-9 μm, with three to five spherical micronuclei (Mi) nearby.

Distribution. Korea, Germany.

Table 1. Biometric characterization of *Gonostomum algicola* (upper line) and *G. gonostomoida* (lower line). Abbreviation: L (live), S (Stained), SD (standard deviation), SE (standard error), CV (coefficient of variation in %) and n (population size)

Characters	Methods	Mean	Med	Min	Max	SD	SE	CV	n
Body length (μm)	L	101.1	102	88	113	6.9	1.4	6.8	25
		86.8	88	60	121	14.2	3.3	16.3	19
	S	91.6	91	78	108	6.6	1.3	7.2	25
		106.5	108	85	124	11.3	3.6	10.6	10
Body width (μm)	L	35.0	35	30	40	3.5	0.7	10.0	25
		29.8	30	21	40	4.4	1.0	14.8	19
	S	37.6	39	26	45	5.2	1.0	13.8	25
		44.1	46	30	55	8.7	2.8	19.7	10
Ratio of body length to body width	L	2.9	2.9	2.6	3.3	0.2	0.0	6.6	25
		3.0	3.0	2.1	4.2	0.6	0.1	19.2	19
	S	2.5	2.4	2.0	3.3	0.4	0.1	15.9	25
		2.5	2.6	1.8	3.0	0.4	0.1	15.5	10
Length of AZM (μm)	L	38.6	38	30	49	5.9	1.2	15.4	25
		42.5	40	30	58	7.3	1.7	17.1	1
	S	39.9	40	35	44	2.2	0.4	5.6	25
		54.1	54	50	58	2.7	0.9	5.0	10
Ratio of body length to AZM length	L	2.7	2.6	2.2	3.3	0.4	0.1	13.3	25
		2.1	2.1	1.8	2.6	0.2	0.0	9.6	19
	S	2.3	2.3	2.0	2.8	0.2	0.0	8.8	25
		2.0	1.9	1.6	2.2	0.2	0.1	9.0	10
Number of AM	S	24.6	25	20	31	2.9	0.6	11.6	25
		30.5	30	27	34	2.4	0.7	7.8	10
Length of UM (μm)	S	27.2	26	21	35	4.1	0.9	15.3	22
		21.7	22	18	23	1.6	0.5	7.2	10
Number of Ma	S	2.0	2	2	2	0.0	0.0	0.0	25
		2.0	2	2	2	0.0	0.0	0.0	10
Length of anterior Ma (μm)	S	11.6	10	7	20	4.2	0.8	36.4	25
		12.1	13	8	16	3.1	1.0	25.7	10
Width of anterior Ma (μm)	S	8.0	8	6	11	1.1	0.2	14.1	25
		7.9	8	6	9	1.0	0.3	12.6	10
Distance between Ma nodules (μm)	S	21.6	21	18	27	2.6	0.5	11.8	25
		28.0	25	13	48	10.0	3.2	35.6	10
Length of posterior Ma (μm)	S	10.0	8	6	18	3.4	0.7	34.0	25
		11.9	12	8	17	3.1	1.0	26.4	10
Width of posterior Ma (μm)	S	7.0	7	5	12	1.2	0.2	17.8	25
		8.0	8	6	10	0.9	0.3	11.8	10
Number of Mi	S	2.2	2	2	3	0.4	0.1	17.3	25
		3.1	3	1	6	1.4	0.4	44.2	10
Length of Mi (μm)	S	2.1	2	2	3	0.3	0.1	15.6	25
		2.5	2	2	3	0.5	0.2	21.1	10
Number of RMC	S	22.6	23	20	24	1.2	0.3	5.5	24
		19.4	19	18	21	0.9	0.3	4.7	8
Number of LMC	S	18.8	19	15	22	1.7	0.3	8.9	24
		15.0	15	14	16	0.8	0.3	5.0	8
Number of FC	S	3.0	3	3	3	0.0	0.0	0.0	25
		3.0	3	3	3	0.0	0.0	0.0	10
Number of FTC (*G. algicola*)	S	1.9	2	1	2	0.3	0.1	15.8	21
Number of MVC (*G. gonostomoida*)	S	13.1	13	11	14	1.1	0.4	8.1	7
Number of FVC	S	5.0	5	5	5	0.0	0.0	0.0	25
		6.4	7	4	7	1.1	0.4	17.6	7
Number of BC	S	1.0	1	1	1	0.0	0.0	0.0	25
		1.0	1	1	1	0.0	0.0	0.0	7
Number of TC	S	2.0	2	2	2	0.0	0.0	0.0	19
		2.7	3	2	3	0.5	0.2	18.0	7
Number of CC	S	2.3	2	2	3	0.4	0.1	19.9	16
		3.0	3	3	3	0.0	0.0	0.0	5
Number of DK	S	3.0	3	3	3	0.0	0.0	0.0	20
		3.0	3	3	3	0.0	0.0	0.0	6

Table 2. Comparisons of *G. algicola* and *G. gonostomoida* with their most similar congeners

Characters \ Species	*G. affine*	*G. algicola*	*G.algicola*	*G. franzi*	*G. gonostomoida*	*G. gonostomoida*	*G. strenua*
Length of body (μm)	43-112	91 (78-108)	71 (52-95)	100-130	107 (85-124)	110-200	88-119
Number of AM	33 (22-40)	25 (20-31)	20 (19-22)	25 (24-27)	30 (27-34)	33	30 (26-33)
Number of Ma	2	2	2	11 (8-17)	2	2	2
Number of Mi	2 (1-4)	2 (2-3)	2 (1-3)	2	3 (1-6)	2	2
Number of RMC	20 (14-28)	23 (20-24)	18 (15-24)	No mention	19 (18-21)	23 (18-27)	26 (23-29)
Number of LMC	15 (8-21)	19 (15-22)	13 (10-16)	No mention	15 (14-16)	14 (12-15)	18 (17-21)
Number of FTC	2-3	2 (1-2)	2 (2-3)	Absent	Absent	Absent	4 (4-6)
Number of FVC	5-6	5	5 (4-8)	4 rows (27-51)	2 rows (6-7)	2 rows (5-7)	12 (11-15)
Number of MVC	Absent	Absent	Absent	Absent	13 (11-14)	17 (17-18)	Absent
Number of TC	4 (0-7)	2	1	4 (1-7)	3 (2-3)	2	6 (4-7)
Number of CC	3 (1-4)	2 (2-3)	3	3	3	3	3
CGs	Present	Present	Present	Absent	Present	No mention	Present
Data sources	Berger, 1999	present work	Foissner et al., 2002	Foissner, 1982	present work	Hemberger, 1985	Song, 1990

Table 3. Comparisons between the present species and *Trachelochaeta gonostomoida* sensu Hemberger, 1985

Characters \ Species	*Gonostomum gonostomoida*	*Trachelochaeta gonostomoida*
Length of body (μm)	85-124	110-200
Width of body (μm)	30-55	30-50
Ratio of body length to body width	2-4 : 1	3-4 : 1
Ratio of body length to AZM length	2-3 : 1	2-3 : 1
Number of AM	30 (27-34)	33
Number of BC	1	1
Number of RMC	19 (18-21)	23 (18-27)
Number of LMC	15 (14-16)	14 (12-15)
Number of MVC	13 (11-14)	17 (17-18)
Number of TC	3 (2-3)	2
Number of CC	3	3
Number of DK	3	3
Number of Ma	2	2
Number of Mi	3 (1-6)	2
Data sources	Present work	Hemberger, 1985

Remarks. G. gonostomoida was originally found in the Germany by Hemberger (1985) under name of *Trachelochaeta gonostomoida.* Berger (1999) transferred this species into the genus *Gonostomum* mainly because of the shape of AZM and UM. Most characteristics of our specimens agree with those of the original description (Table 2): short adoral zone of membranelles (about 40% vs. 40% respectively), number of adoral membranelles [28 (27-34) vs. 33 respectively], the number of transverse cirri [3 (2-3) vs. 3 respectively], the numbers of caudal cirri, dorsal kinety, macronuclei and micronuclei [3 (1-6) vs. 2 respectively]. However, the body size of German population was slightly bigger than Korean population: 110-200 μm × 30-50 μm vs. 60-121 μm × 21-40 μm. Therefore, the number of cirri in cirral row of German population are slightly more than those of Korean population, especially, in the number of midventral cirri [17 (17-18) vs. 13 (11-14)], right marginal cirri [(23 (18-27) vs. 19 (18-21)]. Very similar to the case of *G. algicola* in Korean and Namibian populations (Table 2). The body size of Korean population was slightly bigger than that of Namibian population. Therefore, the number of cirri in cirral row of Korean population were slightly more than those of Namibian population, especially, in the number of right and left marginal cirri.

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