

## Floristic and Taxonomic Accounts of the Genus *Strombomonas* (Euglenophyceae) from Korean Fresh Waters

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This paper deals with descriptions, illustrations and key to identify eight taxa of the genus *Strombomonas* collected from 29 sites of Korean fresh waters. Of these, five taxa are recorded for the first time in Korean euglenoid flora: *S. rotunda*, *S. scabra* var. *ovata*, *S. subcurvata*, *S. verrucosa* var. *borysthensis*, *S. verrucosa* var. *obovata*. Three taxa are cosmopolitan, whereas *S. napiformis* var. *brevicollis*, *S. rotunda*, *S. subcurvata*, *S. verrucosa* var. *borysthensis*, *S. verrucosa* var. *obovata* are the rare taxa in the world.

**Key Words:** Euglenophyceae, flora, fresh water, Korea, *Strombomonas*, taxonomy

### INTRODUCTION

The genus *Strombomonas* includes members with pliable envelope without spines or ornamentation. This genus is also characterized by having a wide apical pore and tail-cone with a gradual transition into the main body of the envelope (Deflandre 1926, 1930; Conrad and Van Meel 1952; Pringsheim 1953; Leedale 1967).

*Strombomonas* from Korea has been studied by the botanists and hydrobiologists in some local areas (Kim and Chung 1993; Kim *et al.* 1995; Park and Chung 1996). Most of the previous information is not accompanied with drawings and descriptions. Only two works contain a brief documentation and iconography (Chung and Kim 1992, 1993), that needs intensive work on flora and taxonomy of Korean *Strombomonas* for understanding further systematics and diversity.

The purpose of this study was to give the floristic and taxonomic accounts, and to understand biodiversity of *Strombomonas*. We provided the detailed descriptions and illustrations using specimens from various waters throughout the whole country. We treated here eight taxa belonging to seven species.

### MATERIALS AND METHODS

A total of 36 water samples were collected from June 1995 to July 1997 in 29 waters throughout Korea. Collections and observations of samples are described in details by Kim *et al.* (1998). The voucher specimens of this study have been deposited as liquid samples, slides, iconographs, and photographs in the herbarium of Chungnam National University, Daejeon, Korea.

### RESULTS AND DISCUSSION

A total of eight taxa of the genus *Strombomonas* were collected in the fresh waters of Korea and were in details described and illustrated. Although three taxa are common in the world (Conrad and van Meel 1952; Huber-Pestalozzi 1955; Tell and Conforti 1986; Philipose 1988), five taxa are apparently rare in the world flora of *Strombomonas*: *S. napiformis* var. *brevicollis*, *S. rotunda*, *S. subcurvata*, *S. verrucosa* var. *borysthensis*, *S. verrucosa* var. *obovata*.

In the present study, five taxa are recorded for the first time in Korea: *S. rotunda*, *S. scabra* var. *ovata*, *S. subcurvata*, *S. verrucosa* var. *borysthensis*, *S. verrucosa* var. *obovata*. Chung and Kim (1992, 1993) recorded 12 taxa in Yeongnam area, of which three taxa are redescribed here. However, the rest nine taxa were not collected in this study. A total of 17 taxa in *Strombomonas* are listed to the Korean euglenoid flora.

Most of Korean *Strombomonas* species appear to occur in the turbid waters such as swamps and urban draina-

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ges. Although the population size was small, *S. urceolata* bloomed with above 2,500 cells ml<sup>-1</sup> in urban drainage basins. These locations received a lot of organic or inorganic materials due to human activities, herbicides or industrial pollutants. These results agree with previous reports that *Strombomonas* often occurs in waters with high concentration of ammonium and nitrite salts (Lackey 1968; Rojo and Alvarez Cobelas 1993).

### The genus *Strombomonas* Deflandre

Arch. Protistenkd. 69: 551-614. 1930

Unicellular flagellates, enclosed in envelope (lorica). Lorica surface smooth, punctate and sometimes wrinkled, roughly covered with verrucae, scrobiculae and warts. Collar without demarcation at base. Chloroplasts parietal, discoid, with or without pyrenoids. Paramylon grains numerous, oval to rod-shaped. Stigma and flagellar swelling present. Flagellum same or longer than lorica length. Movement swimming and rotating. Naked cells non-rigid, wriggling and creeping.

### Key to the species

1. Cells ovoid to ellipsoid with broadly rounded or bluntly projected end .....2
1. Cells broadly ellipsoid to fusiform with distinct caudus .....5
  2. Loricae spirally recurved with bluntly projected end .....*S. subcurvata*
  2. Loricae flat with broadly rounded end .....3
3. Surface densely scabrous .....*S. scabra* var. *ovata*
3. Surface verrucose .....4
  4. Chloroplast doubly sheathed .....*S. verrucosa* var. *borysthensis*
  4. Chloroplast without pyrenoid .....*S. verrucosa* var. *obovata*
5. Chloroplast with double sheathed pyrenoid .....*S. rotunda*
5. Chloroplast without pyrenoid .....6
  6. Cells fusiform, caudus long with 19-27  $\mu$ m .....*S. maxima*
  6. Cells ovoid to broadly ellipsoid, caudus short with 7-15  $\mu$ m .....7
7. Collar with flared rim .....*S. napiformis* var. *brevicollis*
7. Collar with smooth rim .....*S. urceolata*

### 1. *Strombomonas maxima* (Skvortzow) Deflandre (Figs 7, 16)

Arch. Protistenkd. 69: 584. Figs 63-65. 1930

Synonyms: *Trachelomonas maxima* Skvortzow 1925. *T.*

*acuminata* var. *major* Skvortzow 1925.

Description: Lorica 81-96  $\mu$ m long, 30-37  $\mu$ m broad, fusiform with broadly swollen lateral sides, longitudinally or irregularly wrinkled and covered with irregular granules; in front conically narrowed into collar, in posterior end narrowly rounded with slender and sharply pointed conical cauda (19-27  $\mu$ m long). Flagellum aperture with straight and cylindrical collar (9-13  $\mu$ m high, 7-11  $\mu$ m wide), irregularly and obliquely flared at rim. Chloroplasts discoid without pyrenoid. Paramylon grains oval to rod shaped, 4-5  $\mu$ m long. Nucleus 14-19  $\mu$ m wide. Flagellum one half to same to lorica length.

Occurrence in Korea: It was previously recorded in Kyeongnam (Chung and Kim 1992). Nine local populations were collected: Lake (Bomunho Kyeongju, 22 APR 1997). Roadside ditch (Sucksung Buyeo, 15 DEC 1996). Swamp (Daepyeong Hamahn, 6 JUN 1997; Sajipo Changnyeong, 5 JUN 1997; Uncheonmot Kwangju, 29 DEC 1996). Urban drainage (Gapcheon Daejon, 25 JUN 1995; Kumhogang Daegu, 31 AUG 1997; Mihocheon Cheongju, 4 JAN 1997; Samcheoncheon Cheonju, 26 MAY 1997, 29 JUN 1997).

World distribution: It was originally recorded in Venezuela by Skvortzov (1925) under the name of *Trachelomonas maxima* and in Africa (Egypt), Asia (Japan), and Europe (France).

Taxonomic considerations: *S. maxima* was described by Deflandre (1930) based on the extremely large cell dimension and the wrinkled surface of lorica. Lorica of Korean specimens was densely punctate and granulate.

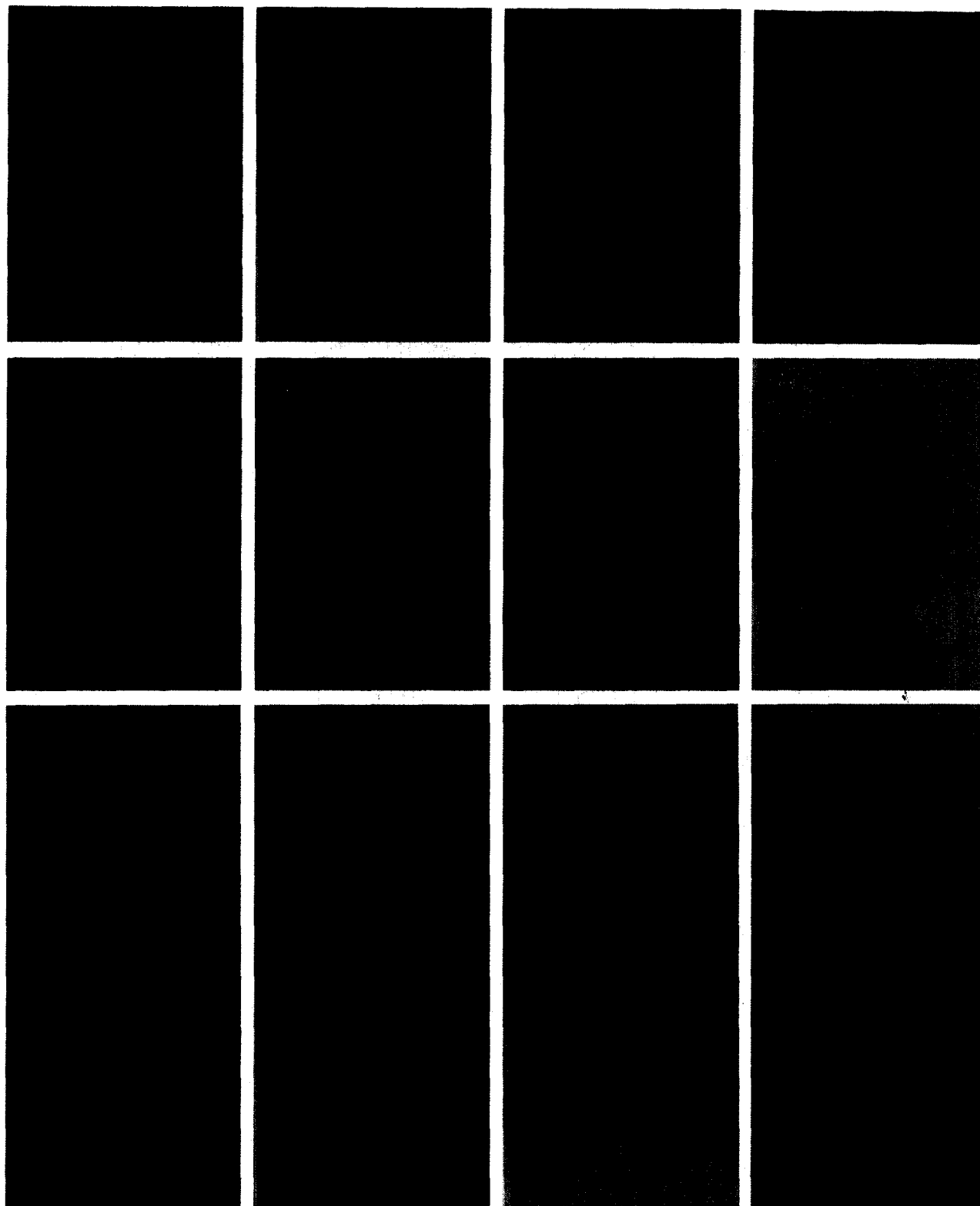
### 2. *Strombomonas napiformis* (Playfair) Deflandre var. *brevicollis* (Playfair) Deflandre (Figs 8, 12)

Arch. Protistenkd. 69: 591. Figs 83-84. 1930

Synonym: *Trachelomonas napiformis* Playfair var. *brevicollis* Playfair 1921.

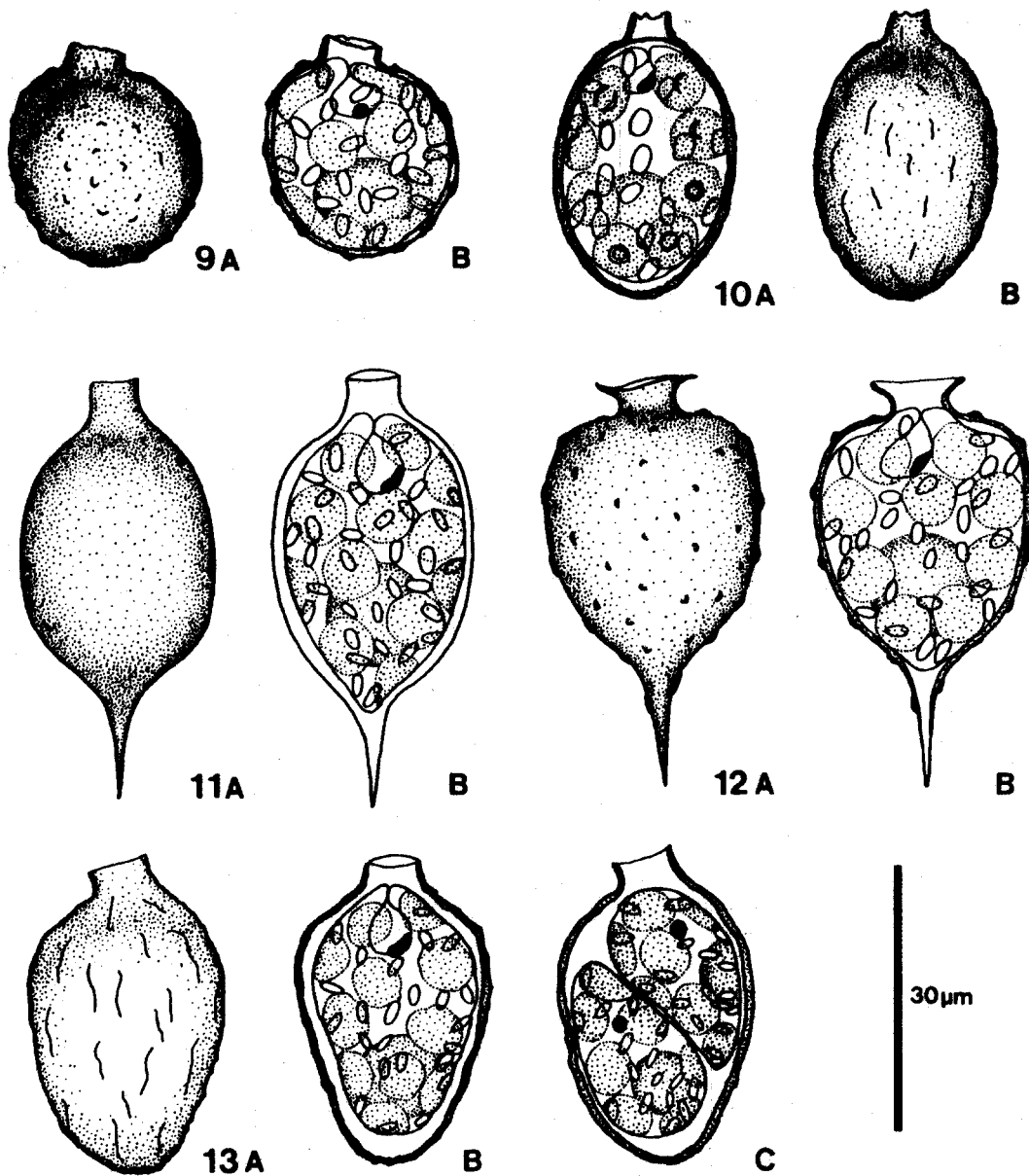
Description: Lorica 47-54  $\mu$ m long, 23-27  $\mu$ m broad, obovoid with broadly swollen lateral sides, minutely punctate and covered with rough or irregular granules; Cell rounded with collar at front, conically narrowed with slender and sharply pointed conical cauda (10-15  $\mu$ m long). Flagellum aperture with straight and cylindrical collar (4-7  $\mu$ m long, 7-11  $\mu$ m wide), obliquely flared vase-shaped at rim. Chloroplasts discoid without pyrenoids, 6-9 in number, 5-6  $\mu$ m long. Paramylon grains oval to rod shape, 3-5  $\mu$ m long. Nucleus 10-16  $\mu$ m wide. Flagellum one half to same to lorica length.

Occurrence in Korea: It was previously recorded in Kyeongnam (Chung and Kim 1993). Seven local popula-



**Figs 1-8.** Habit of Korean members of the genus *Strombomonas*.

**Fig. 1.** *S. scabra* var. *ovata*. **Fig. 2.** *S. verrucosa* var. *obovata*. **Fig. 3.** *S. subcurvata*. **Fig. 4.** *S. rotunda*. **Fig. 5.** *S. verrucosa* var. *borysthensis*. **A.** Cell in the field. **B.** Surface view. **Fig. 6.** *S. urceolata*. **A.** Cell showing even margined mouth. **B.** Cell in the field. **Fig. 7.** *S. maxima*. **A.** Cell in the field. **B.** Longitudinally wrinkled surface of lorica. **Fig. 8.** *S. napiformis* var. *brevicollis*. **A** and **B.** Cells in the field.



**Figs 9-13.** Morphology of Korean members of the genus *Strombomonas*.

**Fig. 9.** *S. verrucosa* var. *borysthensis*. A. Verrucose surface of lorica. B. Cell in the field. **Fig. 10.** *S. scabra* var. *ovata*. A. Scabrous surface of lorica. B. Cell with doubly paramylon sheathed chloroplasts. **Fig. 11.** *S. urceolata*. A. Smooth surface of lorica. B. Cell in the field. **Fig. 12.** *S. napiformis* var. *brevicollis*. A. Verrucose surface of lorica and flagellum pore flared like a vase. B. Cell in the field. **Fig. 13.** *S. verrucosa* var. *obovata*. A. Scabrous surface of lorica. B. Cell in the field. C. Cell division within lorica.

tions were collected: Lake (Seoho Suwon, 15 FEB 1997). River (Kumgang Shintanjin, 30 DEC 1995). Swamp (Jiahm Wanju, 29 JUN 1997; Jinnal Hamahn, 6 JUN 1997). Urban drainage (Jeju Jeju, 15, JAN 1997; Kwangjucheon Kwangju, 4 APR 1997; Samcheoncheon Cheonju, 15 SEP 1996, 24 OCT 1996, 25 JUL 1997).

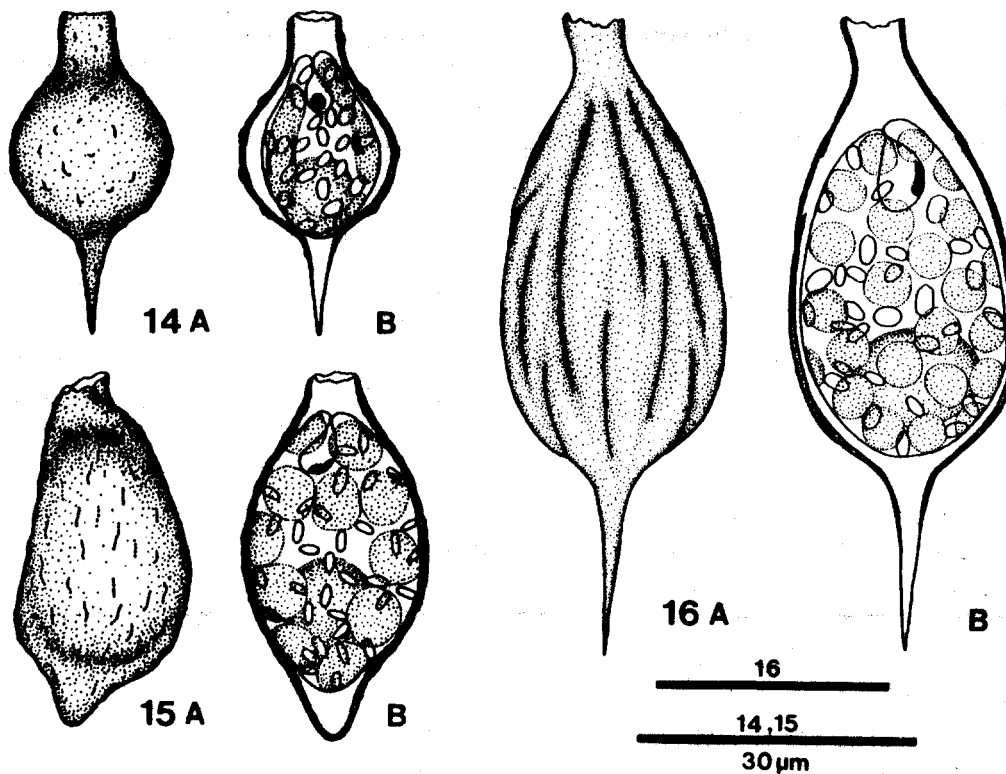
**World distribution:** It is a rare species recorded in Australia under the name of *Trachelomonas brevicollis* by Playfair (1921). In Asia, it was recorded in India and Malaysia.

**Taxonomic considerations:** Deflandre (1930) combined *Trachelomonas brevicollis* to *Strombomonas* on the basis of the feature of collar. The collar of Korean specimens has rather short neck like a vase.

**3. *Strombomonas rotunda* (Playfair) Deflandre (Figs 4, 14)**

Arch. Protistenkd. 69: 593. Fig. 88. 1930

**Synonyms:** *Trachelomonas gibberosa* var. *rotunda* Playfair 1915. *T. rotunda* Playfair 1921. *T. rotunda sensu*



Figs 14-16. Morphology of Korean members of the genus *Strombomonas*.

Fig. 14. *S. rotunda*. A. Verrucose surface of lorica. B. Cell with doubly paramylon sheathed chloroplasts. Fig. 15. *S. subcurvata*. A. Scabrous surface of recurved lorica. B. Cell in the field. Fig. 16. *S. maxima*. A. Rugose and wrinkled surface of lorica. B. Cell in the field.

Deflandre 1926. *T. fortii* Skvortzov 1926.

Description: Lorica 29-35  $\mu\text{m}$  long, 13-17  $\mu\text{m}$  broad, fusiform with transversely ellipsoidal midregion, smooth or slightly warted, with relatively large and straight collar, narrowed into fairly stout and sharply pointed caudae (8-10  $\mu\text{m}$  long) at posterior end. Flagellum aperture with straight and cylindrical collar (collar 5-8  $\mu\text{m}$  high, 4-6  $\mu\text{m}$  wide), smooth or obliquely flared at rim. Chloroplasts discoid with doubly sheathed pyrenoid, 6-12 in number. Paramylon grains oval to rod shape, 3-5  $\mu\text{m}$  long. Nucleus 8-10  $\mu\text{m}$  wide. Flagellum one half to same to lorica length.

Occurrence in Korea: Seven local populations were collected here: Reservoir (Woncheon Suwon, 20 APR 1997). Roadside ditch (Guryongpo Pohang, 22 APR 1997). Swamp (Daepyeong Hamahn, 6 JUN 1997; Uncheonmot Kwangju, 10 NOV 1996; Upo Changnyeong, 5 JUN 1997). Urban drainage (Mushimcheon Cheongju, 6 OCT 1996; Samcheoncheon Cheonju, 25 JAL 1997). It is recorded for the first time in Korea.

World distribution: It is a rare species recorded in Australia (Playfair 1921) and in India (Philipose 1988). This is the third report in the world.

Taxonomic considerations: *S. rotunda* was described by Deflandre (1930) based on the peculiar cell form. The lorica feature of Korean specimen show that the cells should be distinguished from related members. The cell dimension is larger than that of previous studies (Deflandre 1930; Philipose 1988; Conforti and Joo 1994). In addition to the smooth surface forms, the slightly warted lorica was observed in Korean specimens.

#### 4. *Strombomonas scabra* (Playfair) Tell et Conforti var. *ovata* (Playfair) Tell et Conforti (Figs 1, 10)

Bibl. Phycol. 75: 172. Fig. 398. 1986

Synonym: *Trachelomonas scabra* Playfair var. *ovata* Playfair 1915.

Description: Lorica 30-36  $\mu\text{m}$  long, 16-20  $\mu\text{m}$  broad, ovoid with swollen lateral sides, densely scabrous with short and thick warts or papillae in surface; anterior portion gradually narrowed into collar, posterior end broadly or conically narrowed into blunt apex. Flagellum pore with short cylindrical collar (4-6  $\mu\text{m}$  high, 3-4  $\mu\text{m}$  wide), obliquely narrowed and slightly flared at rim. Chloroplasts discoid with double-sheathed pyrenoid, 7-11 in number. Paramylon grains oval to rod shape, 3-5  $\mu\text{m}$

long. Nucleus 11-15  $\mu\text{m}$  wide. Flagellum one and one half to two times to lorica length.

Occurrence in Korea: Six local populations were collected: Fish farm (Pyeongjang Iksan, 26 MAY 1997). Pond (Duckjinmot Cheonju, 15 SEP 1996). Reservoir (Andongho Andong, 25 DEC 1996; Yonghwa Iksan, 26 MAY 1997). Swamp (Jinnal Hamahn, 6 JUN 1997; Yeosan Yeosan, 26 MAY 1997). This is the first report in Korea.

World distribution: It is common and ubiquitous. It was recorded in Australia by Playfair (1915) under the name of *Trachelomonas scabra*. It was also recorded in Asia (Malaysia) and America (Argentina, USA).

Taxonomic considerations: This variety was described by Tell and Conforti (1986) based on the cell form and scabrous surface of lorica. The morphology of Korean specimens accords well with the protologue.

#### 5. *Strombomonas subcurvata* (Proschkina-Lawrenko) Deflandre (Figs 3, 15)

Arch. Protistenkd. 69: 605. Figs 125-126. 1930

Synonym: *Trachelomonas subcurvata* Proschkina-Lawrenko 1925.

Description: Lorica 35-45  $\mu\text{m}$  long, 17-24  $\mu\text{m}$  broad, subovoid, spirally recurved to sigmoid with swollen lateral sides, irregularly scrobiculated with granules or warts; cell gradually narrowed into collar in front, at backward narrowed and bluntly projected. Flagellum pore with straight and cylindrical collar (3-6  $\mu\text{m}$  high, 4-6  $\mu\text{m}$  wide), widened toward pore and denticulate at rim. Chloroplasts discoid without pyrenoid, 8-14 in number. Paramylon grains oval to rod shape, 3-5  $\mu\text{m}$  long. Nucleus 10-15  $\mu\text{m}$  wide. Flagellum one half to same to lorica length.

Occurrence in Korea: Seven local populations were collected: Lake (Kyeongpoho Kangneung, 21 APR 1997), Reservoir (Gogun Jindo, 20 JAN 1997). Swamp (Daepyeong Hamahn, 6 JUN 1997; Sidong Hamahn, 6 JUN 1997; Upo Changnyeong, 5 JUN 1997; Yeosan Yeosan, 26 MAY 1997). Urban drainage (Samcheoncheon Cheonju, 27 JAN 1997). It is recorded for the first time in Korea.

World distribution: It is a rare species recorded in Soviet Union by Proschkina-Lawrenko (1924) under the name of *T. subcurvata*. It was also reported in India (Philipose 1988).

Taxonomic considerations: *S. subcurvata* was combined from *T. subcurvata* and described by Deflandre (1930) based on the spirally recurved habits. Korean specimens are peculiar in having a bluntly protruded posterior end without a distinct collar.

#### 6. *Strombomonas urceolata* (Stokes) Deflandre (Figs 6, 11)

Arch. Protistenkd. 69: 586. Figs 70-71, 73. 1930

Synonyms: *Trachelomonas urceolata* Stokes 1887. *T. urceolata sensu* Playfair 1915, 1921. *T. urceolata* Stokes sec. Playfair et Deflandre 1926. *T. urceolata* var. *hyalina* (Swirenko) Skvortzov 1925. *T. affinis* var. *levis* Lemmermann *sensu* Drezepolski 1925.

Description: Lorica 36-48  $\mu\text{m}$  long, 19-25  $\mu\text{m}$  broad, broadly ellipsoid with slightly swollen or nearly straight and parallel at lateral sides, nearly smooth or slightly granulate in surface; Cell broadly rounded with collar in front, conically narrowed and projected into straight and sharply pointed conical cauda (7-9  $\mu\text{m}$  long). Flagellum aperture with straight and cylindrical collar (3-5  $\mu\text{m}$  high, 5-6  $\mu\text{m}$  wide), truncate or slightly flared at rim. Chloroplasts discoid without pyrenoid, 8-13 wide, Paramylon grains oval to rod shape, 3-5  $\mu\text{m}$  long. Nucleus 9-13  $\mu\text{m}$  wide. Flagellum on half to same to lorica length.

Occurrence in Korea: It was previously recorded in Kyeongnam (Chung and Kim 1992). Six local populations were collected: Lake (Bomunho Kyeongju, 22 APR 1997). Swamp (Sajipo Changnyeong, 5 JUN 1997; Sidong Hamahn, 6 JUN 1997; Yeosan Yeosan, 26 MAY 1997). Urban drainage (Mihocheon Cheongju, 6 OCT 1996, 4 JAN 1997; Samcheoncheon Cheonju, from 15 SEP to 30 NOV 1996).

World distribution: It is common and ubiquitous. It was recorded in Asia (Cambodia, India, Soviet Union), Australia and Europe (France, Poland).

Taxonomic considerations: *S. urceolata* is characterized by ellipsoidal lorica with nearly smooth surface.

#### 7a. *Strombomonas verrucosa* (Daday) Deflandre var. *borystheniensis* (Roll) Deflandre (Figs 5, 9)

Arch. Protistenkd. 69: 568. Fig. 17. 1930

Synonyms: *Trachelomonas borystheniensis* Roll 1928. *S. borystheniensis* (Roll) Popova 1955.

Description: Lorica 24-31  $\mu\text{m}$  long, 19-24  $\mu\text{m}$  broad, ovoid with swollen lateral side, irregularly covered with short and thick warts or papillae, rounded at both ends. Flagellum aperture with low cylindrical collar (2-4  $\mu\text{m}$  high, 6-8  $\mu\text{m}$  wide), obliquely cut and undulated at rim. Chloroplasts discoid with doubly sheathed pyrenoid, 7-12 in number. Paramylon grains oval to rod shape, 3-5  $\mu\text{m}$  long. Nucleus 8-11  $\mu\text{m}$  wide. Flagellum two to three times to lorica length.

Occurrence in Korea: Seven local population were collected here: Fish farm (Pyeongjang Iksan, 26 MAY 1997). Lake (Bomunho Kyeongju, 22 APR 1997). Pond (Susungmot Daegu, 25 DEC 1996). Reservoir (Yonghwa Iksan, 26 MAY 1997). Swamp (Jinnal Hamahn, 6 JUN 1997; Sidong Hamahn, 6 JUN 1997; Yeosan Yeosan, 26 MAY 1997). This is the first report in Korea.

World distribution: It is a rare species in the world, and is recorded in India and Soviet Union.

Taxonomic considerations: This variety was combined from *T. borystheniensis* as a member of *S. verrucosa* complex by Deflandre (1930) based on the cell form and lorica surface.

**7b. *Strombomonas verrucosa* (Daday) Deflandre var. *obovata* Philipose (Figs 2, 13)**

Proc. Indian Acad. Sci. 98 (5): 375-376. Figs 50 d-f. 1988

Description: Lorica 33-37  $\mu\text{m}$  long, 17-21  $\mu\text{m}$  broad, obovoid with swollen lateral sides, slightly wavy and verrucose in surface; Cell gradually narrowed into collar in front, broadly rounded at posterior end. Flagellum aperture with low cylindrical collar (2-4  $\mu\text{m}$  high, 6-8  $\mu\text{m}$  wide), broadly opened and slanted in apex. Chloroplasts discoid without pyrenoid, 8-12 in number. Paramylon grains oval to rod shape, 3-5  $\mu\text{m}$  long. Nucleus 10-13  $\mu\text{m}$  wide. Flagellum one and one half to two times to lorica length.

Occurrence in Korea: Seven local populations were collected: Lake (Bomunho Kyeongju, 22 APR 1997). Reservoir (Haenam Haenam, 10 NOV 1996; Yonghwa Iksan, 26 MAY 1997). Swamp (Jiahm Wanju, 29 JUN 1997; Sidong Hamahn, 6 JUN 1997; Upo Changnyeong, 5 JUN 1997; Yeosan Yeosan, 26 MAY 1997). It is recorded for the first time in Korea.

World distribution: It is a rare species recorded in India (Philipose 1988). This is the second report in the world.

Taxonomic considerations: This variety was described as a member of *S. verrucosa* complex by Philipose (1988) based on the obovoid cell forms from Indian strains. The morphology of Korean specimens accord with the illustrations, although the collar height is somewhat variable.

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