

# Morphological Descriptions of Four Oligotrich Ciliates (Ciliophora: Oligotrichia) from Southern Coast of Korea

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## ABSTRACT

For the purpose of taxonomical description of marine oligotrich ciliates, water samples were collected from the southern coast of Korea (Masan Bay and Jangmok Bay). Ciliate cells were identified based on protargol impregnated specimens. As a result, four oligotrich ciliates were identified and redescribed: *Rimostrombidium conicum* (Kahl, 1932), *Omegastrombidium kahli* Song et al., 2009 and *Spirotontonia turbinata* (Song and Bradbury, 1998), and *Spirotontonia grandis* (Suzuki and Han, 2000). Of them, *R. conicum*, *O. kahli*, and *S. turbinata* are newly recorded and *S. grandis* is recorded for the second time in Korea, while the last one is redescribed to compare its variations according to locality. In addition, their abundances were analyzed and discussed the changes in accordance with water temperature and salinity.

**Keywords:** *Rimostrombidium conicum*, *Omegastrombidium kahli*, *Spirotontonia grandis*, *Spirotontonia turbinata*, oligotrich ciliates, taxonomy, Korean coastal water

## INTRODUCTION

Ciliates have been recognized as important components in the marine microbial food webs and oligotrich ciliates usually occurred dominantly among the planktonic ciliate community (Froneman and Perissinotto, 1996; Quevedo and Anadón, 2000). According to Lynn (2008), the oligotrichs were divided into two subclasses; the Oligotrichia (oligotrichs sensu stricto) and the Choreotrichia, while the halteriid were affiliated with the stichotrichs. To date, about 1,490 species of oligotrichs (sensu lato) have been described worldwide but the validity is not confirmed. Of them, about 120 oligotrichids and 80 aloricate choreotrichids (not including tintinnids) have been recorded, only about 60% have been described, or redescribed using protargol staining method (Agatha, 2004a, 2004b, 2011; Agatha and Strüder-Kypke, 2007). Studies on marine planktonic ciliates have been carried out in Korea since 1980's, only 4 oligotrichids and 10 aloricate choreotrichids have been reported (Table 1) (Suzuki and Han, 2000; Jeong et al., 2004; Moon et al., 2004; Kim et al., 2005, 2008, 2010b; Ma and Choi, 2005; Lee et al., 2006).

The ecological roles of Korean oligotrichs (especially, lori-

cate tintinnids) have been investigated in many studies (Yoo and Park, 2001; Kim and Lee, 2003; Yang and Choi, 2003; Moon et al., 2004; Kim et al., 2007; Lee et al., 2007; Han and Lee, 2010; Lee and Kim, 2010). They are frequently collected and abundant in the surface layer of coastal water and easily identified due to their large size and conserved lorica (Yoo et al., 1988; Yoo and Kim, 1990). Aloricate oligotrichs are more abundant than loricate tintinnids in microzooplankton community (Vaqué et al., 1997; Ota and Taniguchi, 2003). However, most ecological studies do not include them because they are not easy to handle due to their limited taxonomic information, fragility and small size of body (Yoo and Park, 2001; Kim and Lee, 2003; Lee and Kim, 2010). The taxonomic information of these taxa in Korea is urgently needed to investigate other related studies. Therefore we describe here four aloricate oligotrichs with their abundance including water temperature and salinity.

## MATERIALS AND METHODS

### Sample collection

Ciliate samples were seasonally collected from Masan Bay

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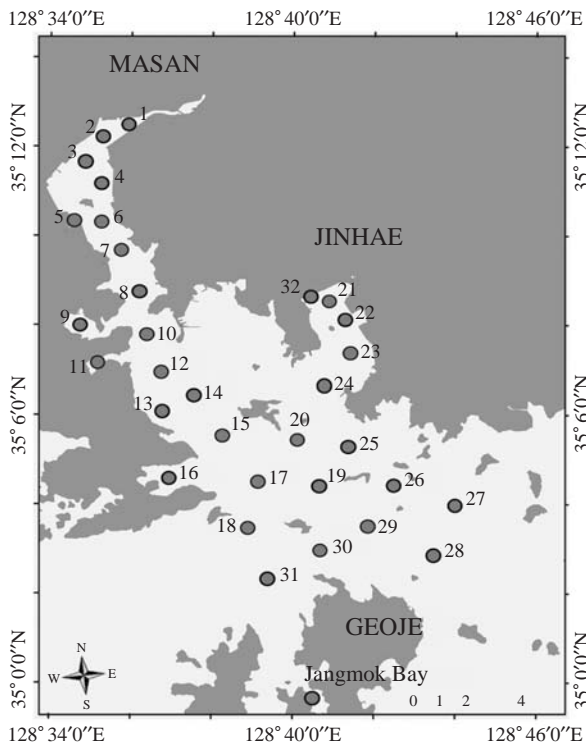
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**Table 1.** Number, habitat and references of oligotrich ciliates (Oligotrichida and Choreotrichida not including tintinnids) described taxonomically in Korea

Classification	No. of species	Habitat	References
Order Choreotrichida			
Suborder Strobiliidiina	2 genera 4 species	Freshwater	Moon et al., 2004
	1 species	Marine (coastal)	Jeong et al., 2004
	1 species	Marine (coastal)	Ma and Choi, 2005
	1 species	Marine (coastal)	Kim et al., 2005
	1 genus 2 species	Marine (coastal)	Lee et al., 2006
	1 genus 1 species	Marine (coastal)	Kim et al., 2010b
Suborder Tintinnina	10 genera 28 species	Marine (coastal)	Yoo et al., 1988
	16 genera 27 species	Marine (coastal)	Yoo and Kim, 1990
	1 genus 1 species	Marine (coastal)	Kim et al., 2010a
	1 species	Freshwater	Moon et al., 2004
Order Oligotrichida	1 species	Marine (offshore)	Suzuki and Han, 2000
	2 genera 2 species	Freshwater	Moon et al., 2004
	1 species	Coastal water	Kim et al., 2008



**Fig. 1.** Sampling sites located in the South Sea of Korea (M1-M32 stations from Masan Bay and 1 station from Jangmok Bay).

using Van Dorn sampler at 0.5 m depth of selected sampling sites (32 sites) from April 2006 to November 2008 (February, May, August, and November). In Jangmok Bay, ciliates were sampled by vertical towing from 5 m depth to surface using a 20 µm mesh plankton net (30 cm diameter) in June 2009 (Fig. 1). Samples were fixed immediately by Bouin's solution

(at final concentration 10%, v/v) in which most of the ciliates were well preserved. Water temperature and salinity were measured *in situ* using a portable T-S meter (556 MPS; YSI, USA).

**Morphological investigations**

In order to observe the morphological characteristics of ciliate cells, the fixed cells were stained and mounted using the quantitative protargol staining and the modified Wilbert's method (Wilbert, 1975; Montagnes and Lynn, 1987; Foissner et al., 1999). Ciliate cells were identified and counted under ×400-1,000 magnification using a light microscope (Zeiss Axioskop II, Goettingen, Germany).

**Terminology**

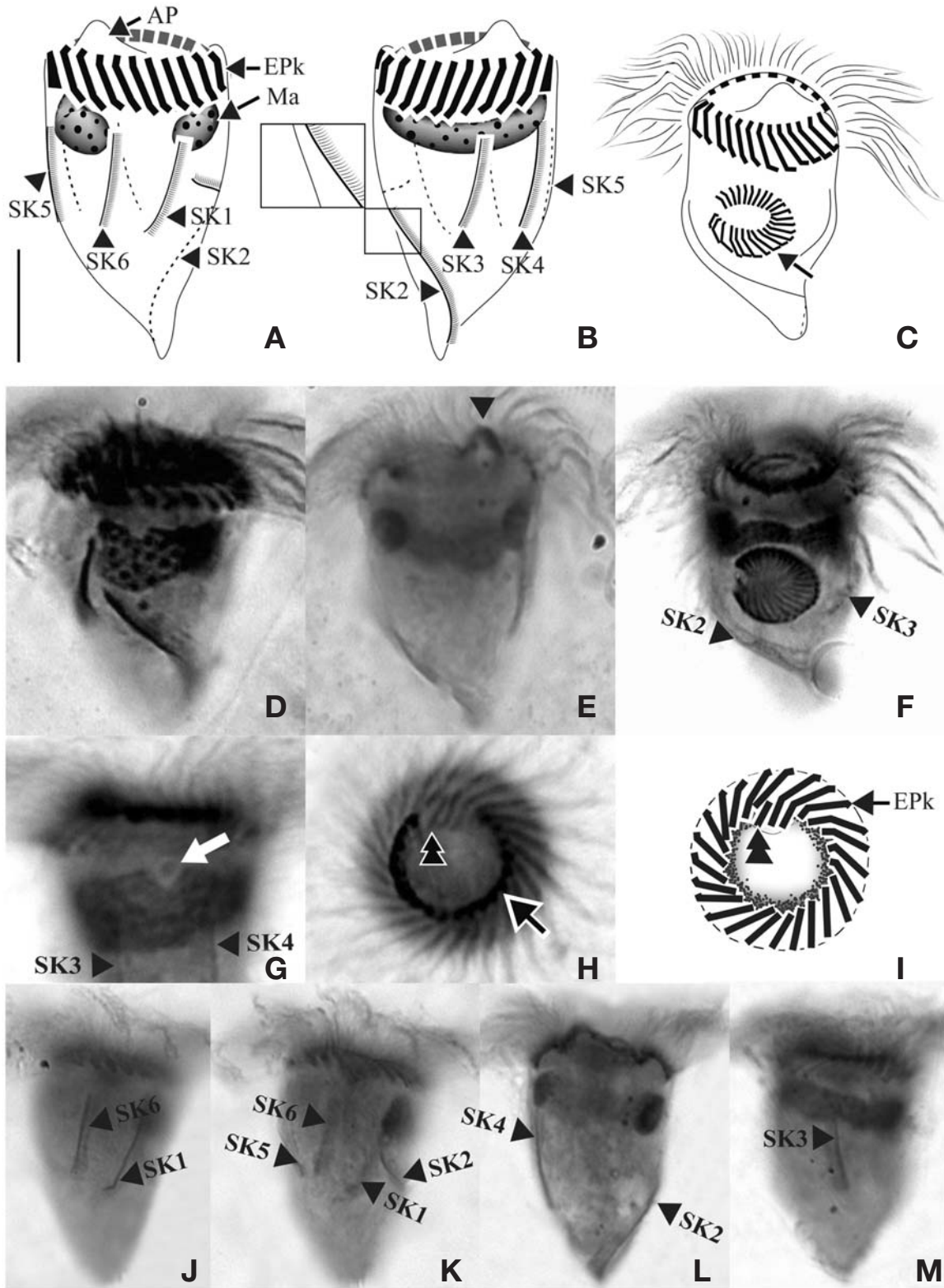
Terminology and classification for the ciliate taxonomy are according to Montagnes and Lynn (1991) and Agatha (2004a).

**RESULTS AND DISCUSSION**

- Class Oligotrichea Bütschli, 1889
- Subclass Oligotrichia Bütschli, 1889
- 1\* Order Choreotrichida Small and Lynn, 1985
- 2\* Suborder Strobiliidiina Jankowski, 1980
- 3\* Family Strobiliidiidae Kahl in Doflein and Reichenow, 1929
- 4\* Genus *Rimostrombidium* Jankowski, 1978
- 5\* *Rimostrombidium conicum* (Kahl, 1932)
- (Table 2, Fig. 2)

*Strobilidium conicum* Kahl, 1932: 506.

Korean name: 1\*폐구환소모충목, 2\*폐구환무각소모충아목, 3\*이종렬소모충과, 4\*단이종렬소모충속, 5\*원추단이종렬소모충



**Fig. 2.** *Rimostrombidium conicum* after protargol impregnation. A, Ventral view; B, Dorsal view; C, F, Oral primordium (OP) originating between SK2 and SK3 (arrow indicating OP in C); D, Left view; E, Black arrowhead indicating a conspicuous AP; G, White arrow indicating Mi; H, I, Apical view showing EPks, IPk and black circle (double arrowhead showing IPk in H and I, black arrow indicating black circle in H); J-M, SK arrangement. AP, apical protuberance. Scale bar: 10  $\mu$ m.

**Table 2.** Morphometrical characterization of *Rimostrombidium conicum* (R.c.), *Omegastrombidium kahli* (O.k.), *Spirotontonia turbinata* (S.t.), and *Spirotontonia grandis* (S.g.)

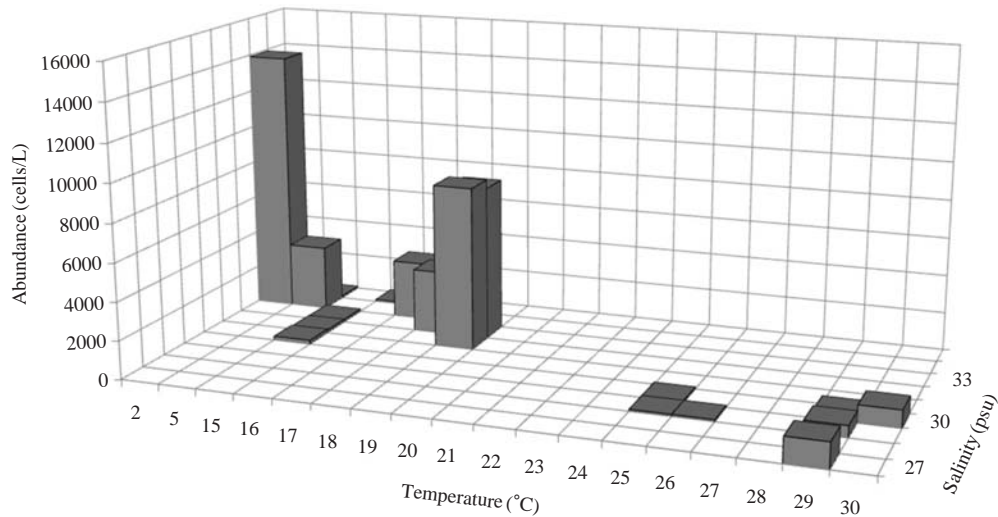
Characteristics	Species	Min	Max	Mean	SD	SE	CV	N
Cell length	R.c.	22.0	43.0	30.5	4.8	1.0	15.7	24
	O.k.	43	82.0	68.2	10.5	2.5	15.4	17
	S.t.	59.0	110.0	77.2	17.2	5.7	22.3	9
	S.g.	87.0	157.5	107.5	16.5	3.4	15.4	23
Cell width	R.c.	12.0	21.0	17.5	1.8	0.4	10.1	24
	O.k.	28	45.0	36.5	4.6	1.1	12.5	17
	S.t.	29.0	51.0	36.8	6.7	2.2	18.1	9
	S.g.	32.0	52.0	41.2	4.9	1.0	11.9	23
Cell length : width, ratio	R.c.	1.3	2.7	1.8	0.3	0.1	18.6	23
	O.k.	1.3	2.2	1.9	0.2	0.1	12.7	17
	S.t.	1.9	2.6	2.1	0.2	0.1	10.7	9
	S.g.	1.7	3.7	2.6	0.4	0.1	16.2	23
Anterior pole to buccal vertex, distance	S.t.	30.0	57.5	38.3	8.9	3.0	23.3	9
	S.g.	37.0	103.5	54.6	12.7	2.6	23.2	23
Cell length : anterior pole to buccal vertex, ratio	S.t.	1.7	2.5	2.0	0.3	0.1	12.5	9
	S.g.	1.3	2.4	2.0	0.3	0.1	14.0	23
EPk, number	R.c.	22	26	24	1.0	0.2	4.3	23
EPk, length	R.c.	4.0	5.0	4.6	0.4	0.1	8.1	7
AM, number	O.k.	44	58	51.7	4.3	1.6	8.3	7
	S.t.	13	15	14	0.5	0.2	3.8	8
	S.g.	13	15	14	0.6	0.1	4.3	22
AM, length	S.t.	18.0	20.0	19.0	1.4	1.0	7.4	2
	S.g.	12.0	20.0	18.0	3.0	1.1	16.7	7
VM, number	O.k.	6	13	8.9	2.3	0.9	26.4	7
	S.t.	15	20	17	2	1	10	9
	S.g.	23	34	28	3.1	0.7	11.3	23
pTM, number	O.k.	2	2	2	0.0	0.0	0.0	7
GK, number of whorl	S.t.	2	3	2.4	0.4	0.1	16.0	9
	S.g.	3	3	3	0.0	0.0	0.0	23
Dikinetids of GK, number (per 10 $\mu$ m)	S.t.	10	14	12	1.5	0.6	13.2	6
	S.g.	14	19	15	1.5	0.4	9.8	14
Probably fibers, number per 10 $\mu$ m	S.t.	6	10	9	1.6	0.7	18.1	6
	S.g.	5	9	7	1.5	0.5	21.3	11
SK 1, length	R.c.	10.0	15.0	11.7	1.4	0.3	12.1	22
SK 2, length	R.c.	19.0	28.0	21.5	2.8	1.0	12.9	8
SK 3, length	R.c.	8.0	13.0	9.5	1.4	0.3	15.0	26
SK 4, length	R.c.	9.0	18.0	12.4	2.3	0.5	18.4	24
SK 5, length	R.c.	8.0	16.0	11.5	1.8	0.4	15.8	24
SK 6, length	R.c.	9.0	15.0	10.9	1.6	0.3	–	23
Ma, number	O.k.	35	62	45.1	8.1	2.9	17.9	8
	S.t.	50	60	55	5.0	2.9	9.1	3
	S.g.	37	84	65	14.0	3.2	21.5	19
Ma, diameter	O.k.	2.0	5.5	3.3	1.0	0.3	30.9	9
	S.t.	3.0	3.5	3.2	0.3	0.2	9.1	3
	S.g.	3.0	4.0	3.4	0.4	0.1	12.9	19
Mi, diameter	R.c.	1.5	2.0	1.8	–	–	–	2

Data based on protargol impregnated specimens. Measurements in  $\mu$ m.

Min, minimum; Max, maximum; Mean, arithmetic mean; SD, standard deviation; SE, standard error; CV, coefficient of variation; N, number of specimen.

*Rimostrombidium conicum* Petz and Foissner, 1992: 160;  
Agatha and Riedel-Lorjé, 1998: 14.

**Diagnosis.** Body asymmetrically conical shaped; cell size 22-43  $\mu$ m in length and 12-21  $\mu$ m in width after protargol preparation; 22-26 EPks; one separated IPk; 6 SKs, SK2 longer



**Fig. 3.** Abundances of *Rimostrombidium conicum* at different temperatures (°C) and salinities (psu) in Masan Bay.

than the other kineties, and spirally extending to posterior cell end, SK1, 3, 4, 5, and 6 not extending to posterior end and slightly curved or straight; one Ma C- or horseshoe-shaped and horizontally located underneath EPZ.

**Morphological description of Korean population.** Body asymmetrically conical shaped with conspicuous protuberance at anterior pole of cell, bluntly tapering in posterior region. Body size 22-43  $\mu\text{m}$  in length and 12-21  $\mu\text{m}$  in width (average  $31 \times 18 \mu\text{m}$ ,  $n=24$ ) after protargol impregnation (Fig. 2A, B, D, E).

EPZ closed and surrounding anterior end of cell, consisting of 22-26 polykinetids (average 24,  $n=23$ ). Two elongated EPks extending into eccentric oral cavity. One IPk lying into oral cavity and separated from EPks. A black circle observed below anterior part of EPZ, having gap into oral cavity ("C" shaped position), probably fibres (Fig. 2H, I).

Six SKs composed of short cilia. Except for SK2, SKs not extending to posterior pole of cell and having similar lengths: SK1, 12  $\mu\text{m}$ ; SK3, 10  $\mu\text{m}$ ; SK4, 12  $\mu\text{m}$ ; SK5, 12  $\mu\text{m}$ ; and SK6, 11  $\mu\text{m}$  on average. SK2 longer than the other kineties (average 22  $\mu\text{m}$  in length,  $n=8$ ), slightly sinistrally spiraled and extended to posterior pole of cell. SK1 and SK6 less or not sinistrally curved than SK3-5 slightly dextrally curved or longitudinal (Fig. 2J-M).

Single Ma C- or horseshoe-shaped and contained numerous globular nucleoli, horizontally located underneath EPZ with ventrally opening. One ellipsoidal Mi positioned on dorsal side of Ma (Fig. 2G).

Oral primordium developing between SK2 and SK3 *de*

*novo* (Fig. 2C, F).

**Occurrence and ecological characteristics.** Maximum abundance (13,900 cells/L) of this species was observed at M4 site in Masan Bay in February 2008, where water temperature of 2.13°C and salinity of 34.21 psu were recorded. This species showed highest abundance in cold water (2-5°C) but also occurred at high temperatures ( $\geq 15^\circ\text{C}$ ) in low abundances (100-8,600 cells/L) (Fig. 3).

**Comparison with other populations.** German population was collected from the brackish and coastal waters of the North Sea and with maximum abundance of 100,000 cells/L in August while the maximum abundance of Korean population occurred in February (about 13,900 cells/L) (Agatha and Riedel-Lorjé, 1998). The morphology of Korean population is similar to German population (e.g., cell size, shape, number of SKs and EPks, shape, and location of Ma), except for the arrangement of somatic kineties. SK1 of German population is the longest (vs. SK2 the longest in Korean population). German population has dextrally spiral SK2 which does not reach a posterior pole (vs. SK2 extending to posterior pole in Korean population) (Agatha and Riedel-Lorjé, 1998).

<sup>1</sup>\*Order Oligotrichida Bütschli, 1889

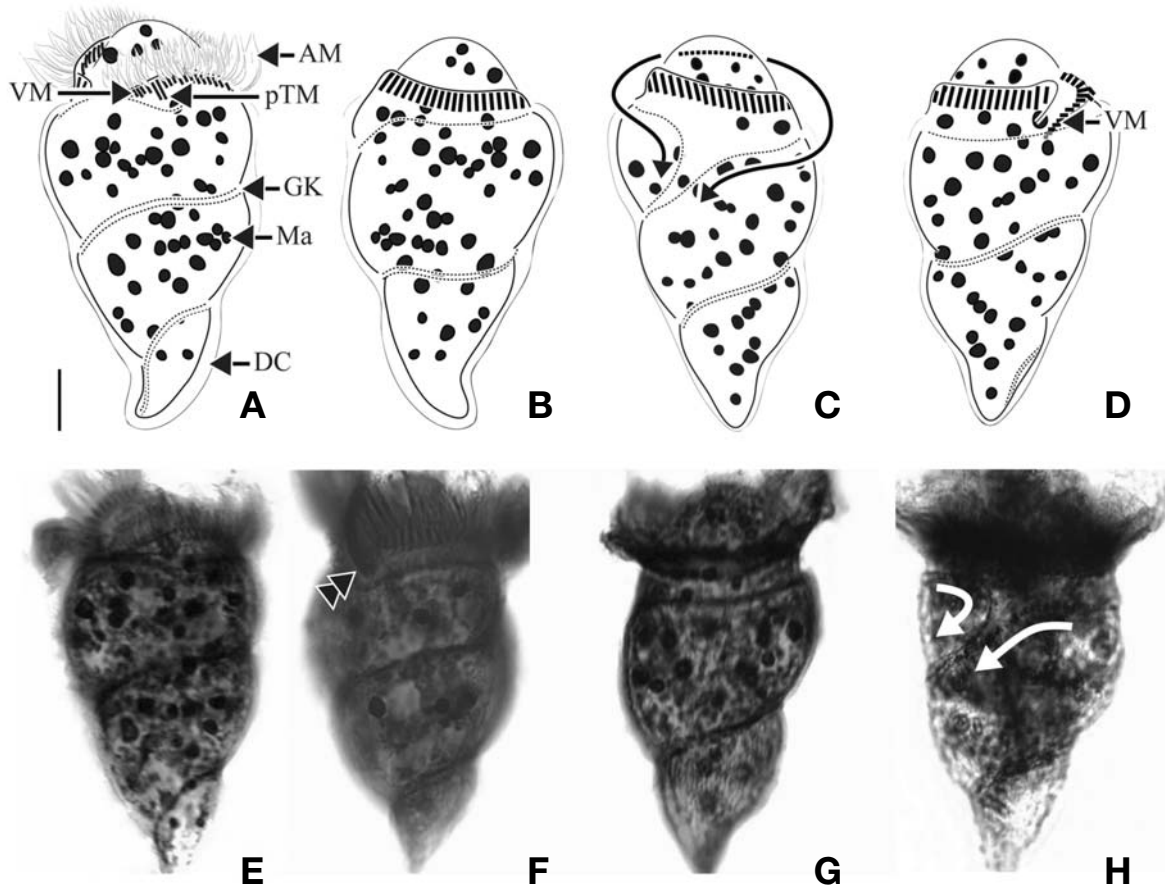
<sup>2</sup>\*Family Strombidiidae Fauré-Fremiet, 1970

<sup>3</sup>\*Genus *Omegastrombidium* Agatha, 2004

<sup>4</sup>\**Omegastrombidium kahli* Song et al., 2009  
(Table 2, Fig. 4)

*Omegastrombidium kahli* Song et al., 2009: 336-337.

Korean name: <sup>1</sup>\*개구환소모충목, <sup>2</sup>\*민소모충과, <sup>3</sup>\*오메가열소모충속, <sup>4</sup>\*다핵오메가열소모충



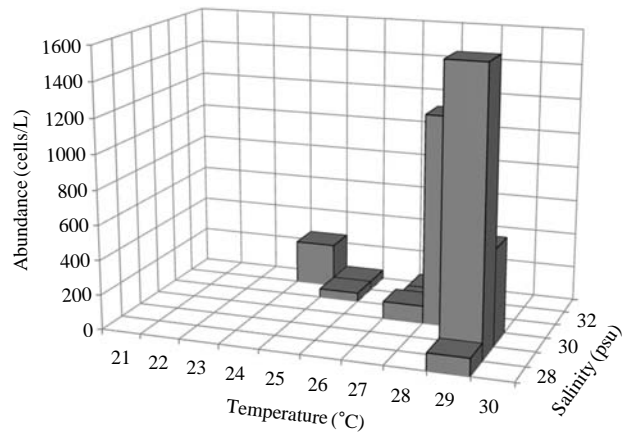
**Fig. 4.** *Omegastrombidium kahli* after protargol impregnation. A, E, F, Ventral view (double arrowhead in F indicating pTM); B, G, Dorsal view; C, H, Left view (white arrows in H indicating direction of GK); D, Right view. DC, distended cell surface. Scale bar: 10  $\mu$ m.

**Diagnosis.** Body obconical with screw-like appearance; cell size 43-82  $\mu$ m in length and 28-45  $\mu$ m in width after protargol preparation; 44-58 AM, 6-13 VM, and 2 pTM; dextrally spiral GK, performing about 2 whorls; 35-62 ellipsoidal Ma, about 2-5.5  $\mu$ m in diameter.

**Morphological description of Korean population.** Body dextrally screwed cone- or turban shell-shaped with conspicuous apical protrusion (AP) at anterior pole. Cell size 43-82  $\mu$ m in length, and 28-45  $\mu$ m in width (average 68  $\times$  37  $\mu$ m, n=17) after protargol impregnation. Transparent distended cell surface (DC) covered from GK to posterior end of cell (Fig. 4A-D).

Oral polykinetids surrounding anterior pole with ventral opening, divided into AM and VM. Approximate 44-58 AM (average 52, n=7) and 6-13 VM (average 9, n=7). Two pTM positioned between AM and VM and obviously longer than AM and VM (Fig. 4A, F).

GK originated at anterior part of body, both ends facing on left side of anterior part and turning approximately 1.5-2 whorls (with dextrally spiraling) and then terminating at pos-



**Fig. 5.** Abundances of *Omegastrombidium kahli* at different temperatures ( $^{\circ}$ C) and salinities (psu) in Masan Bay.

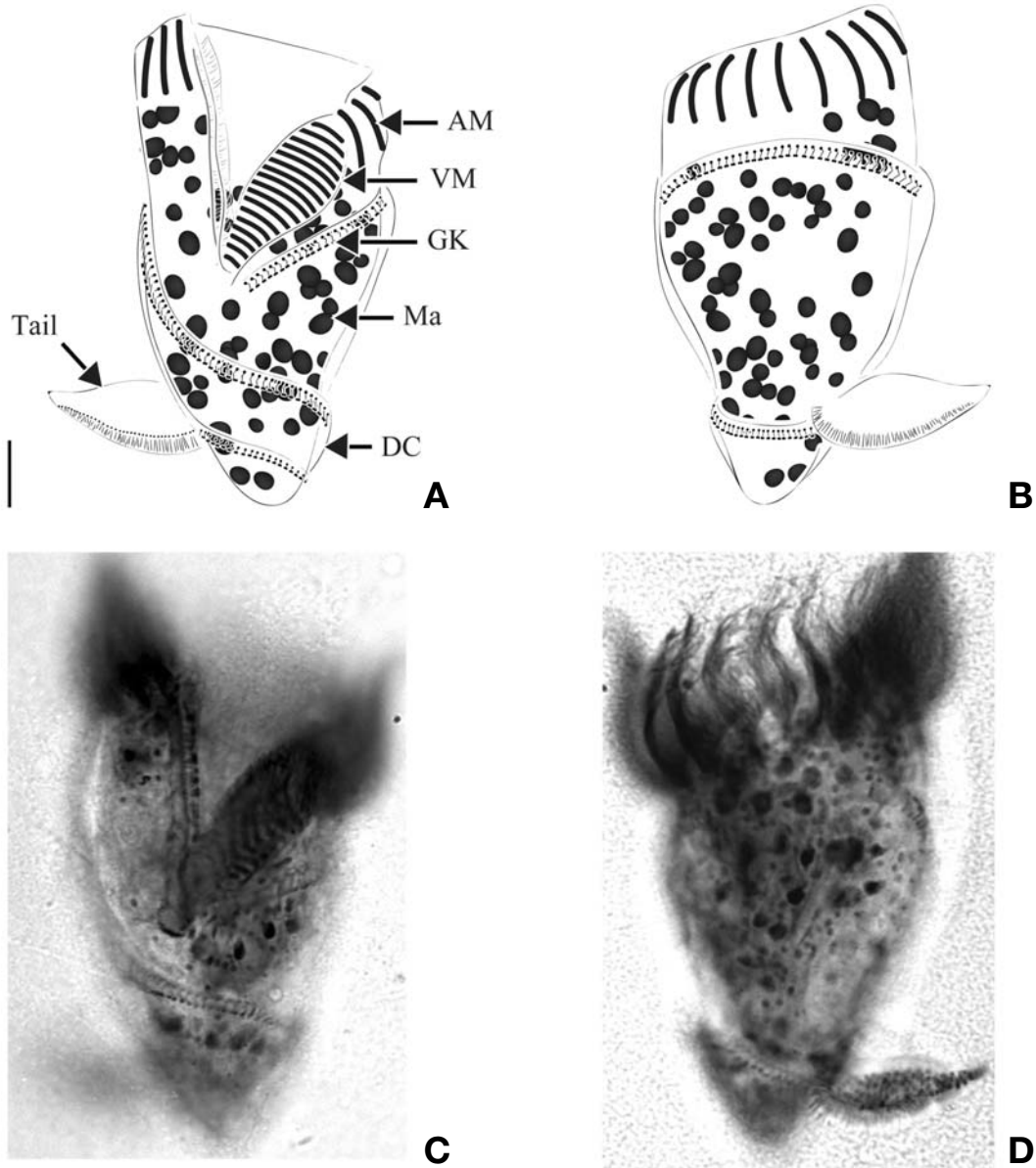
terior end on right lateral side (Fig. 4C, D). GK on ventral side obliquely extended to right side while GK on dorsal side positioned horizontally (Fig. 4A, B). No ventral kinety found.

About 35-62 (average 45, n=8) ellipsoidal Ma (2-5.5  $\mu\text{m}$  in diameter), scattered throughout cell.

**Occurrence and ecological characteristics.** Maximum abundance (ca. 1,600 cells/L) of this species was observed at M4 site in August, 2007 where water temperature of 29.13°C and salinity of 28.69 psu were recorded respectively. This species was strictly found at high temperatures (24-29°C) period (Fig. 5).

**Comparison with Chinese population.** *Omegastrombidium kahli* was recently recorded by Song et al. (2009). Korean population is the second record. Two populations are similar

in morphology: marine species collected from coastal water in salinity about 30 psu; cell shape; the number of AM and VM; the presence and number of pTM, and the shape and number of Ma. However, cell size of Korean population is smaller than Chinese population (43-82  $\times$  28-45  $\mu\text{m}$  of Korean population vs. 60-80  $\times$  40-50  $\mu\text{m}$  of Chinese population). Number of Ma of Korean population is larger than that of Chinese population (35-62 vs. 20-30). Chinese population is vague about the appearance of an AP but Korean population shows a conspicuous protrusion at anterior end of the cell after protargol impregnation.



**Fig. 6.** *Spirotontonia turbinata* after protargol impregnation. A, C, Ventral view; B, D, Dorsal view. DC, distended cell surface. Scale bar: 10  $\mu\text{m}$ .

<sup>1</sup>\*Family Tontoniidae Agatha, 2004

<sup>2</sup>\*Genus *Spirotontonia* Agatha, 2004

<sup>3</sup>\**Spirotontonia turbinata* (Song and Bradbury, 1998)  
(Table 2, Fig. 6)

*Spirotontonia turbinata* Song et al., 2009: 334.

**Diagnosis.** Body inverted triangle-shaped with tail on dorsal side of posterior cell end; body size, 59-110  $\mu\text{m}$  in length and 29-51  $\mu\text{m}$  in width after protargol impregnation; 13-15 AM and 15-20 VM; sinistrally spiral GK (about 2.5 whorls); no VK; ellipsoidal Ma, size 3-3.5  $\mu\text{m}$  in diameter, and 50-60 in number.

**Morphological description of Korean population.** Body obconical to inverted triangle with bluntly pointed posterior end, slightly leftward inclined anterior portion of body. Body size, 59-110  $\mu\text{m}$  in length and 29-51  $\mu\text{m}$  in width (average  $77 \times 37 \mu\text{m}$ ,  $n=9$ ). Tail located above the second whorl of GK on dorsal side, easily detached from body during process of handling or staining. A kinety consisting of densely spaced basal bodies with fibers on front of tail. Body covered with transparent DC between whorls of GK (Fig. 6A-D).

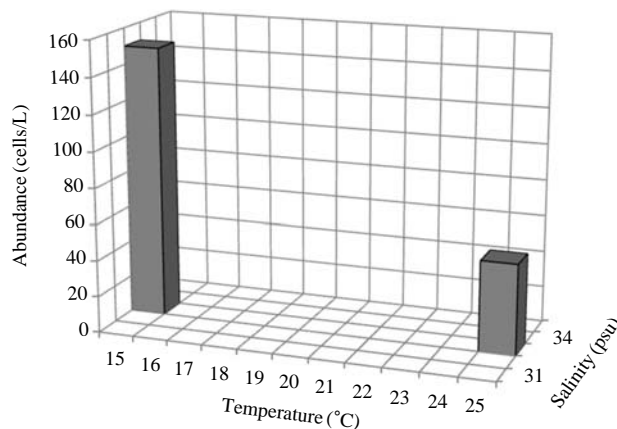
Buccal cavity open on ventral side, extending slightly to right and terminating approximately 1/2 of way down cell. AM and VM positioned like question-marked (“?”) on ventral side. About 13-15 AM (average 14,  $n=8$ ). VM extended along left side of buccal cavity and consisting of 15-20 membranelles (average 17,  $n=9$ ). A row of EM lying on inner wall of buccal lip on right inner side of oral cavity, consisting of densely arranged monokinetids (Fig. 6A, C).

Sinistrally spiral GK orientating on left side of buccal cavity, extending to left lateral side along posterior margin of VK then spirally turning down to posterior of body with about 2 whorls (average of GK per 10  $\mu\text{m}$ , 12). “L” shaped fibres located above GK and arranged along GK (average of F per 10  $\mu\text{m}$ , 9). No VK detected.

Ellipsoidal Ma scattered in whole of body, size 3-3.5  $\mu\text{m}$  in diameter (average 3  $\mu\text{m}$  in diameter,  $n=3$ ), 50-60 in number (average 55,  $n=3$ ).

**Occurrence and ecological characteristics.** This species were collected in November 2006 and in August 2008 from Masan Bay (water temperature of 15-23.27°C and salinity of 30.30-32.6 psu) and in June 2009 from Jangmok Bay (water temperature of 17.45-23.27°C and salinity of 30.30-31.51 psu). Maximum abundance of 150 cells/L showed at M20 and M30 sites in August 2006 where water temperature of 15°C and salinity of 32.6 psu were recorded respectively (Fig. 7).

**Comparison with other populations.** *Spirotontonia turbi-*



**Fig. 7.** Abundances of *Spirotontonia turbinata* at different temperatures (°C) and salinities (psu) in Masan Bay.

*nata* was initially reported from coastal of north China (Song and Bradbury, 1998). Unfortunately, water temperature and salinity were not recorded for the occurrence. Compared with Chinese population, Korean population has similar cell size and number of AM. However, there are some morphological differences between these two populations: the number of Ma (Korean population, 50-60 vs. Chinese population, 28-40), the number of VM (15-20 vs. 13-17), the number of GK whorls (2.5 whorls vs. 1.5 whorls), and the ratio of cell length to cell width (2.1 vs. 1.38).

<sup>4</sup>\**Spirotontonia grandis* (Suzuki and Han, 2000)  
(Table 2, Fig. 8)

*Tontonia grandis* Suzuki and Han, 2000: 989-994.

*Spirotontonia grandis* Agatha, 2004a: 298.

**Diagnosis.** Body obconical with screw-like appearance; size 87-157.5  $\mu\text{m}$  in length and 32-52  $\mu\text{m}$  in width after protargol impregnation; a conspicuously apical collar (AC) located at anterior pole; tail on dorsal side; 13-15 AM and 23-34 VM; sinistrally spiral GK of three whorls, oriented below buccal area and terminated at posterior end of dorsal side; no VK; 37-84 ellipsoidal Ma, about 3-4  $\mu\text{m}$  in diameter.

**Morphological description of Korean population.** Body screwed barrel in shape with AC at anterior pole, posterior of cell bluntly pointed. AC region truncate- or dome-shaped. Cell size 87-157.5  $\mu\text{m}$  in length and 32-52  $\mu\text{m}$  in width (average  $108 \times 41 \mu\text{m}$ ,  $n=23$ ) after protargol impregnation. Tail broad leaf shaped, located above the second whorl of GK on dorsal side, easily detached from body during handling in staining process. A short kinety positioned across front view of tail, consisting of densely spaced basal bodies and fibers

Korean name: <sup>1</sup>\* 꼬리소모충과, <sup>2</sup>\*나선체 꼬리소모충속, <sup>3</sup>\*원추나선체 꼬리소모충, <sup>4</sup>\*큰나선체 꼬리소모충

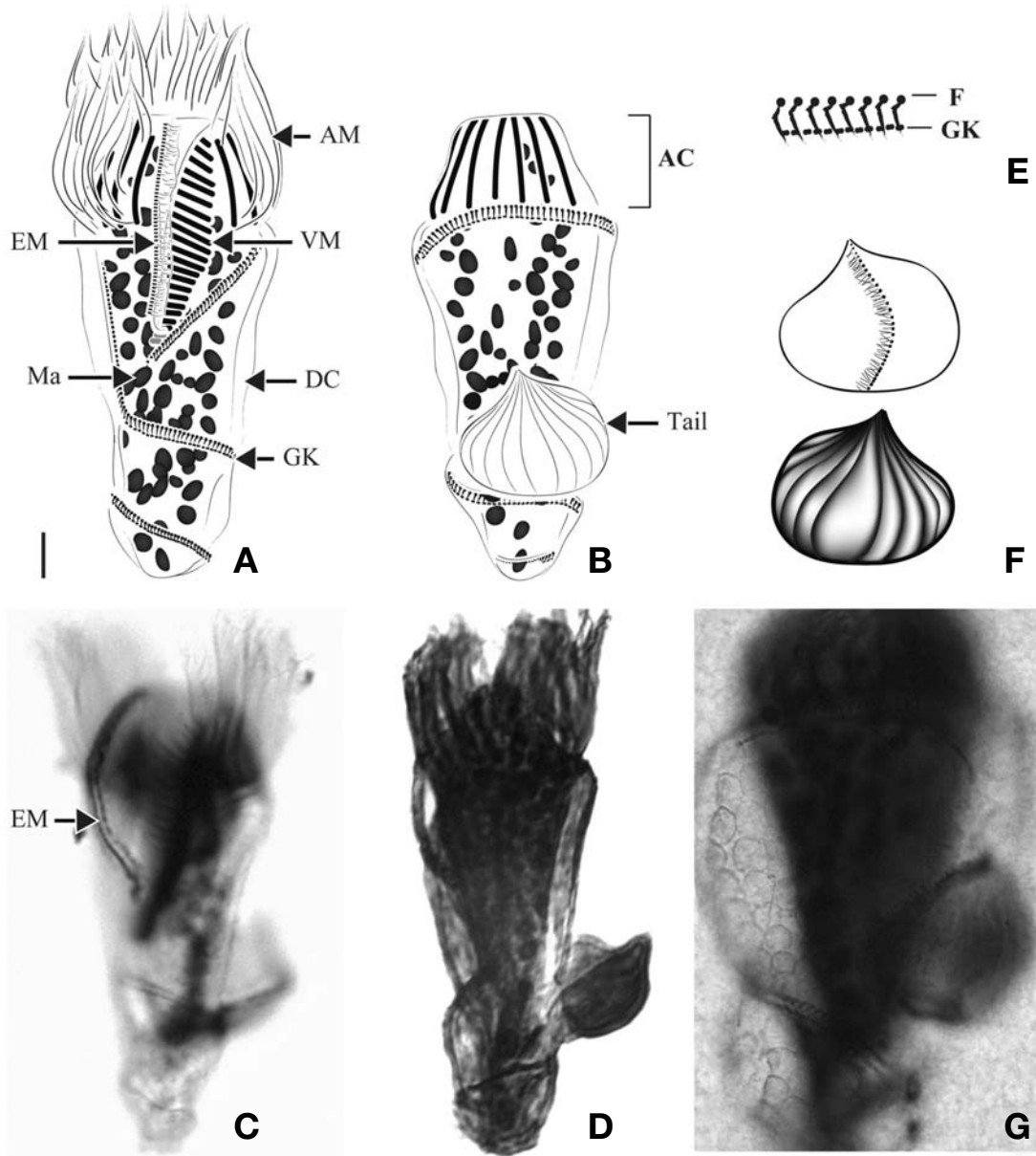


(Fig. 8F). Back view of tail wrinkled. Transparent DC covered between whorls of GK (Fig. 8A, B). Cortical platelets observed in several specimens, having elliptical shape and covering on DC surface (Fig. 8G).

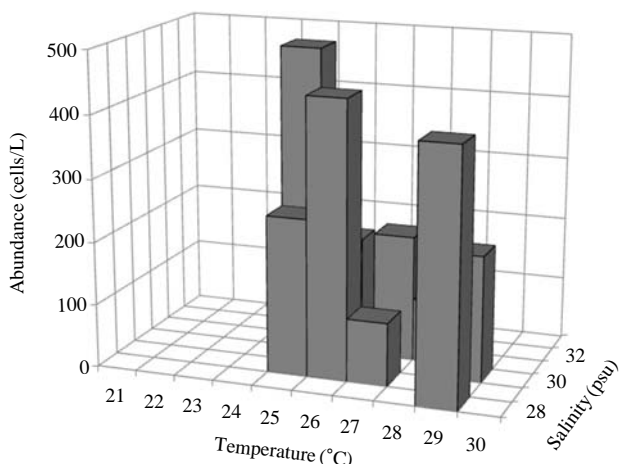
Buccal cavity open, extending obliquely to right and terminating about 1/2 of way down cell. AM surrounding AC region, consisting of 13 to 15 AM (average 14, n=22). VM extending along left side of buccal cavity, consisting of 23-34 membranelles (average 28, n=23). A row of EM lying on

inner wall of buccal lip on right side of buccal cavity, consisting of monokinetids.

Sinistrally spiral GK, with a total of three whorls, located below posterior part of buccal cavity, extending to left lateral side along posterior margin of VK and turning around dorsal side horizontally, then sharply going down to proximal part on ventral side and then spirally going down two whorls, finally terminating at posterior end of dorsal side. F (probably fibers) parallel arrangement above GK; "L"-shaped in



**Fig. 8.** *Spirotontonia grandis* after protargol impregnation. A, C, Ventral view; B, Dorsal view; D, Left view (B and D show that tail is located on the second whorl GK); E, Detail of GK arrangement with F (probably fibers); F, Detail of tail appearance, top is the front view and bottom is the back view with wrinkled surface; G, Plated-form on surface of DC. AC, apical collar; F, probably fibers; DC, distended cell surface. Scale bar: 10 μm.



**Fig. 9.** Abundances of *Spirotontonia grandis* at different temperatures (°C) and salinities (psu) in Masan Bay.

stained (the number of kinetids per 10 μm GK=15 and F=7 on average). No VK detected.

Oval or irregular shaped Ma scattered in whole of body, 3-4 μm in diameter (average 3 μm, n=19), and 37-84 in number (average 65, n=19).

**Occurrence and ecological characteristics.** This species were collected from Masan Bay in August 2006-2008 and Jangmok Bay in June 2009. During the survey period, this species was found only in summer at high water temperature (>17°C). In Jangmok Bay, this species and *S. turbinata* were simultaneously observed at the temperature range of 17.45-23.27°C and salinity of 30.30-31.51 psu. Maximum abundance (1,100 cells/L) of this species was observed at M27 site in Masan Bay in August 2006 where water temperature of 25.78°C and salinity of 29.50 psu were recorded respectively (Fig. 9).

**Comparison with other populations.** *Spirotontonia grandis* was recently described as a new species from the East China Sea and the Korea Strait (Suzuki and Han, 2000). This species was also recorded from the Irish Sea (Agatha, 2004c). Water temperature of 14.5-24.9°C and salinity of 30.7-34.5 psu were recorded when Chinese population was collected from the East China Sea in May, 1997 (Suzuki and Han, 2000). European population in the Irish Sea occurred in the hydrological environment of ~12°C and salinity of ~35 psu in May, 2002 (Agatha, 2004c). Compared with Chinese population and Korean population, European population shows larger size (146-189 μm in length of European population vs. 70-155 μm in length of Chinese population vs. 87-157.5 μm in length of Korean population) and has more Ma (82-113 vs. 55-88 vs. 37-84). It is assumed that Korean population is more similar to Chinese population than European population. Chinese and European populations were mentioned to have cortical

platelets. According to Suzuki and Han (2000), both plated-form and aplated-form (lacking the platelets) on surface of DC were found in Chinese population. However, there is no difference of other morphologic characteristics between these two forms. Korean population has also two forms in similar morphology.

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