

## DISTRIBUTION AND ABUNDANCE OF CHOANOFLLAGELLATES IN GREAT-WALL BAY, KING GEORGE ISLAND, ANTARCTICA IN AUSTRAL SUMMER

Bo CHEN

*Polar Research Institute of China, 451 Shangchuan Road, Shanghai 200129, China*

**Abstract:** Eleven species of seven genera of loricate choanoflagellates were found in Great-Wall Bay, King George Island, west Antarctica during the sampling period from January 22 to February 8, 1991. Among them, *Pleurasiga orculaeformis* aff. was a new record in Antarctic waters. Choanoflagellates was an abundant taxa in Great-Wall Bay. Their total abundance ranged from  $5.1 \times 10^3$  to  $5.3 \times 10^4$  cells/l. The spatial distribution of choanoflagellate species and abundance showed heterogeneous patterns. The maximum concentration of chlorophyll *a* and the highest abundance of choanoflagellates were located at depths of 20 m and 30 m respectively. Choanoflagellates usually showed a tendency to follow the variations of chlorophyll *a* concentration in their vertical abundance. Regression analysis on the basis of 40 data sets showed that there was a positive correlation between abundance of choanoflagellates and chlorophyll *a* concentration in this season. The four dominant species of choanoflagellates, *Bicosta spinifera*, *Crinolina aperta*, *Diaphanoeca multiannulata* and *Parvicorbicula circularis*, were distributed widely from the surface to the bottom in Great-Wall Bay. They were counted for more than 90% of total choanoflagellates in all layers. *B. spinifera* was up to about 41% of the mean value of surface abundance of total choanoflagellates. *D. multiannulata* reached the highest abundance of  $2.2 \times 10^4$  cells/l at 20 m depth on January 25.

### 1. Introduction

Choanoflagellates, which bear an extracellular siliceous lorica (Acanthoecidae), are considered to be a conspicuous and abundant component of the Antarctic marine nanoplankton (e.g. MARCHANT, 1985). The potential importance of the group of these protozoa has been established not only as a food source for Antarctic krill, *Euphausia superba* (MEYER and EL-SAYED, 1983; MARCHANT and NASH, 1986; TANOUE and HARA, 1986), but also as an important consumer of a significant fraction of bacterial production (MARCHANT, 1985; BUCK and GARRISON, 1988). Some quantitative data revealed that choanoflagellates had a substantial abundance in Antarctic waters, e.g. in the Weddell Sea their abundance was on the order of  $10^3$ – $10^5$  cells/l (SILVER *et al.*, 1980; BUCK and GARRISON, 1983, 1988), while it was on the order of  $10^4$ – $10^6$  cells/l at inshore sites in Prydz Bay in summer (MARCHANT and PERRIN, 1990). Their important ecological role and status in the Antarctic microbial food webs and marine ecosystems were consequently inferred.

But the investigation areas and the quantitative data on choanoflagellates from Antarctic waters, especially in Antarctic coastal neritic waters, are still very limited. The purpose of the present study was to understand the regional features of species composition, spatial distribution patterns and abundance of choanoflagellates. As for the specific trophic level of choanoflagellates, the present study also analyzed the relationship between choanoflagellate abundance and chlorophyll *a* concentration so as to understand whether there exists a coupling correlation between them in austral summer in the Antarctic neritic water: Great-Wall Bay, King George Island, west Antarctica.

## 2. Materials and Methods

### 2.1. Collection of samples

Samples of choanoflagellates were collected from Great-Wall Bay, King George Island, Antarctica during the Seventh Chinese Antarctic Research Expedition (CHINARE-VII, 1990/1991) from January 22 to February 8, 1991.

Ten stations (Stns. 1–10) were selected to take surface water samples for the observation of choanoflagellate horizontal distribution (Fig. 1). For the vertical

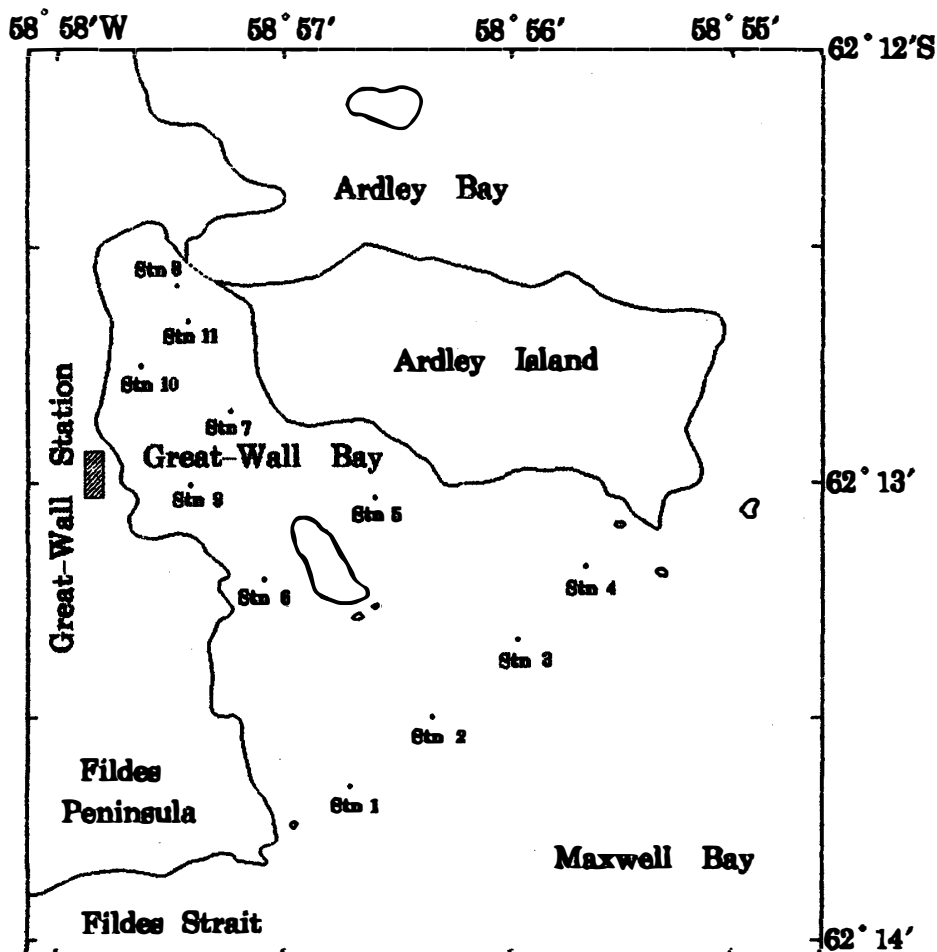


Fig. 1. Sampling stations of choanoflagellates in Great-Wall Bay.

distribution, water samples were taken from five layers: 0, 5, 10, 20, 30 m with a 5 l plastic water bottle (Model HQC-5) at Stn. 11, which has a maximum depth of 35 m in the Bay. Temperature, salinity, pH of surface water samples and air temperature were recorded simultaneously.

## 2.2. Processing of samples

From each water sample 2–3 l were prefiltered through a 20  $\mu\text{m}$  nylon mesh to eliminate macro- and micro-plankton, and then one to two litres aliquot of the filtrate was filtered by a 0.45  $\mu\text{m}$  HA filter to a final volume of 10–20 ml. After adding drops of 25% glutaraldehyde solution directly into the filter apparatus to a final concentration of about 2.5%, the concentrated sample with fixative was kept for 10 min. Then distilled water was used to rinse the sample on the filter three times and concentrated to less than 5 ml by filtration. A drop of the concentrated sample was placed on a cleaned cover slip and fixed for 1 min with  $\text{OsO}_4$  vapor. The fixed samples were taken back to China to observe the fine structure for identification of the species on a Hitachi S-520 SEM.

For quantitative count, one litre aliquot was filtered with a 0.45  $\mu\text{m}$  HA filter. Samples on the filters were fixed for 1 min with  $\text{OsO}_4$  vapor, dried in air and taken back to China. A 3 mm diameter circle of the filter was cut out, coated with Au and examined on the SEM. Choanoflagellate cells were counted at low magnification, usually 1000–1500 times, until more than 300 individuals were attained (NISHIDA, 1986). Only loricas containing a protoplast were used to calculate abundance. The filtration and fixation were finished within 8 hours after sampling.

## 2.3. Measurement of chlorophyll *a*

Chlorophyll *a* was determined after filtration of two litres seawater (0.45  $\mu\text{m}$  Millipore HA filters), previous addition of  $\text{MgCO}_3$ , and extraction in 90% acetone. After 24 hours, spectrophotometric determinations were carried out. Chlorophyll *a* concentrations were calculated according to JEFFREY and HUMPHREY (1975).

# 3. Results

Eleven species of seven genera of choanoflagellates were found in Great-Wall Bay during the sampling period from January 22 to February 8, 1991 (Table 1). The horizontal and vertical distributions of choanoflagellate species in Great-Wall Bay showed specific patterns. *Bicosta spinifera*, *Crinolina aperta*, *Diaphanoeca multiannulata* and *Parvicorbicula circularis* were distributed widely at all stations and in all layers (Tables 2, 3). But *Acanthocorbis unguiculata* was found only in the upper 5 m, *Calliacantha natans* only in the upper 10 m, and *Calliacantha simplex* only in the upper 20 m (Table 3). Analysis of surface water samples revealed that the diversity of choanoflagellate species in the inner part of the Bay was higher than that in the outer part (Table 2). Only one specimen of *Pleurasiga* sp. was detected in a surface sample at Stn. 11 and two empty loricas

Table 1. Choanoflagellates found in Great-Wall Bay.

<i>Acanthocorbis unguiculata</i> (THOMSEN) HARA and TAKAHASHI 1984
<i>Bicosta spinifera</i> (THRONSEN) LEADBEATER 1978
<i>Calliacantha natans</i> (GRONTVED) LEADBEATER 1978
<i>Calliacantha simplex</i> MANTON and OATES 1979
<i>Crinolina aperta</i> (LEADBEATER) THOMSEN 1976
<i>Diaphanoeca multiannulata</i> BUCK 1981
<i>Diaphanoeca pedicellata</i> LEADBEATER 1972
<i>Parvicorbicula circularis</i> THMOSEN 1976
<i>Parvicorbicula socialis</i> (MEUNIER) DEFLANDRE 1960
<i>Pleurasiga orculaeformis</i> SCHILLER aff.
<i>Pleurasiga</i> sp.

Table 2. Horizontal distribution of species of choanoflagellates recorded from surface water samples on January 25, 1991. (\* Only one specimen was found.)

Stations	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.6	Stn.7	Stn.8	Stn.9	Stn.10	Stn.11
<i>A. unguiculata</i>							+	+		+	+
<i>B. spinifera</i>	+	+	+	+	+	+	+	+	+	+	+
<i>C. natans</i>							+	+		+	+
<i>C. simplex</i>							+		+		
<i>C. aperta</i>	+	+	+	+	+	+	+	+	+	+	+
<i>D. multiannulata</i>	+	+	+	+	+	+	+	+	+	+	+
<i>D. pedicellata</i>			+	+	+		+		+	+	+
<i>P. circularis</i>	+	+	+	+	+	+	+	+	+	+	+
<i>P. socialis</i>						+	+		+	+	+
<i>P. orculaeformis</i> aff.											++
<i>Pleurasiga</i> sp.											++

Table 3. Vertical distribution and abundance (cells/l) of total choanoflagellates and individual species in Great-Wall Bay recorded from Stn. 11 on January 25, 1991. (- : no individual was found, \* : only one specimen was found.)

Depth (m)	0	5	10	20	30
Choanoflagellates	$1.4 \times 10^4$	$1.7 \times 10^4$	$3.8 \times 10^4$	$4.9 \times 10^4$	$2.6 \times 10^4$
<i>A. unguiculata</i>	$3.1 \times 10^2$	$<10^2$	-	-	-
<i>B. spinifera</i>	$8.4 \times 10^3$	$7.8 \times 10^3$	$8.1 \times 10^3$	$5.1 \times 10^3$	$4.6 \times 10^3$
<i>C. natans</i>	$<10^2$	$<10^2$	$<10^2$	-	-
<i>C. simplex</i>	$<10^2$	$<10^2$	$<10^2$	$<10^2$	-
<i>C. aperta</i>	$1.6 \times 10^3$	$5.2 \times 10^3$	$1.5 \times 10^4$	$7.8 \times 10^3$	$1.4 \times 10^3$
<i>D. multiannulata</i>	$4.3 \times 10^2$	$<10^2$	$4.2 \times 10^3$	$2.2 \times 10^4$	$1.1 \times 10^4$
<i>D. pedicellata</i>	$3.8 \times 10^2$	$2.4 \times 10^2$	$<10^2$	$2.0 \times 10^3$	$<10^2$
<i>P. circularis</i>	$2.7 \times 10^3$	$3.8 \times 10^3$	$1.0 \times 10^4$	$1.2 \times 10^4$	$8.8 \times 10^3$
<i>P. socialis</i>	$1.2 \times 10^2$	$<10^2$	$<10^2$	$<10^2$	$3.4 \times 10^2$
<i>P. orculaeformis</i> aff.	*		*		
<i>Pleurasiga</i> sp.	*				

of *Pleurasiga orculaeformis* aff., which has not previously been reported in Antarctic waters, were found in two water samples from the surface and the 10 m layer respectively at Stn. 11 (Table 3).

Table 4. Chlorophyll *a* concentration, abundance of choanoflagellates, temperature, salinity and pH value of surface water during sampling period from January 22 to February 8, 1991. (\* Air temperature data were measured at Great-Wall Station.)

Range of chlorophyll <i>a</i> (mg/m <sup>3</sup> )	0.96–2.61
Mean of chlorophyll <i>a</i> (mg/m <sup>3</sup> )	1.72
Range of choanoflagellates (cells/l)	$5.1 \times 10^3$ – $2.6 \times 10^4$
Mean of choanoflagellates (cells/l)	$1.3 \times 10^4$
Air temperature (°C)*	–2.0~+4.0
Water temperature (°C)	0.5–3.0
Salinity	21–25
pH	8.13–8.46

At the surface, the total abundance of choanoflagellates ranged from  $5.1 \times 10^3$  (Stn. 1) to  $2.6 \times 10^4$  cells/l (Stn. 10) with an average of  $1.3 \times 10^4$  cells/l. The concentration of chlorophyll *a* was from 0.96 (Stn. 1) to 2.61 mg/m<sup>3</sup> (Stn. 7) and the mean value was 1.72 mg/m<sup>3</sup> during the sampling period. Temperature, salinity and pH of surface water are shown in Table 4. In the vertical profile, the maximum abundance of total choanoflagellates was  $5.3 \times 10^4$  cells/l, which was recorded at the depth of 30 m on February 2 at Stn. 11 (Fig. 2). It is noteworthy that both the maximum concentration of chlorophyll *a* and the highest abundance of choanoflagellates were located at depths of 20 and 30 m respectively, not at the surface. In general, the vertical abundance of total choanoflagellates showed a tendency to follow the variations of chlorophyll *a* concentration (Figs. 2, 3). Choanoflagellate abundance was closely associated with chlorophyll *a* concentration. The regression equation derived on the basis of 40 data sets is as follows:

$$Y = 1.919E-2 - 0.416X + 1.108X^2 - 0.247X^3. \quad (r=0.87)$$

The regression line shown in Fig. 4 reveals that there was a positive correlation between the choanoflagellate abundance and chlorophyll *a* concentration in Great-Wall Bay in this season.

Four dominant species were counted for more than 90% of total loricate choanoflagellates in every layer (Fig. 5). *B. spinifera* was the most abundant species at the surface. Its abundance was up to about 41% of the mean value of surface total choanoflagellate abundance during the sampling period. *D. multianulata* reached the highest abundance of individual species ( $2.2 \times 10^4$  cells/l) in the 20 m layer on January 25 (Table 3).

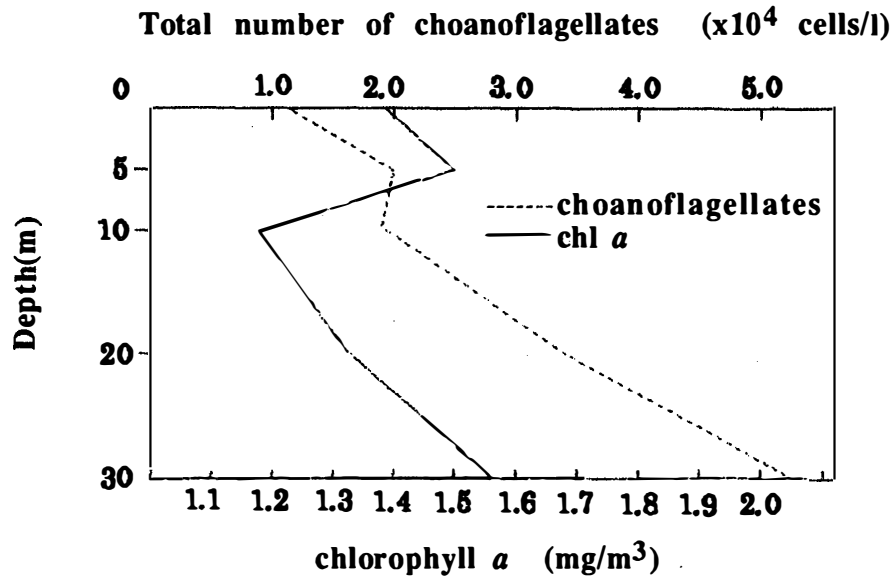


Fig. 2. Vertical distribution of chlorophyll *a* and abundance of choanoflagellates recorded at Stn. 11 on February 2, 1991.

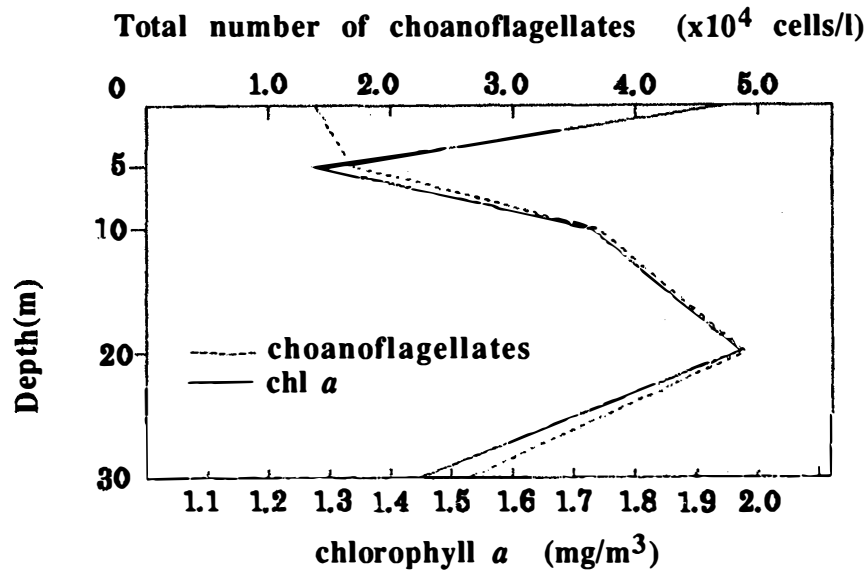


Fig. 3. Vertical distribution of chlorophyll *a* and abundance of choanoflagellates recorded at Stn. 11 on January 25, 1991.

#### 4. Discussion

This is the first report on species composition and abundance of loricate choanoflagellates in Great-Wall Bay, and the first study on choanoflagellates in the region of the South Shetland Islands as well. *Pleurasiga oraculaeformis* aff. was a new record in Antarctica. The specimen of *P. oraculaeformis* aff. from Great-Wall Bay (illustrated in: CHEN Bo, 1993, Fig. 16) has the same lorica

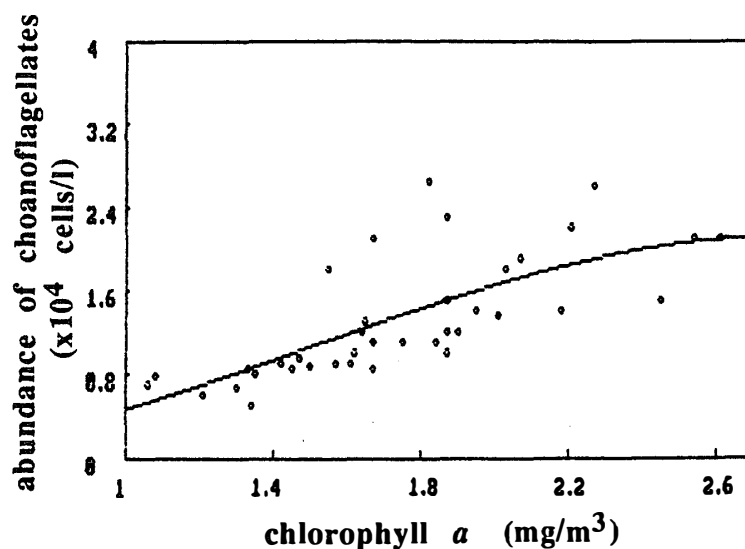


Fig. 4. Relationship between chlorophyll *a* concentration and abundance of choanoflagellates in Great-Wall Bay in austral summer.

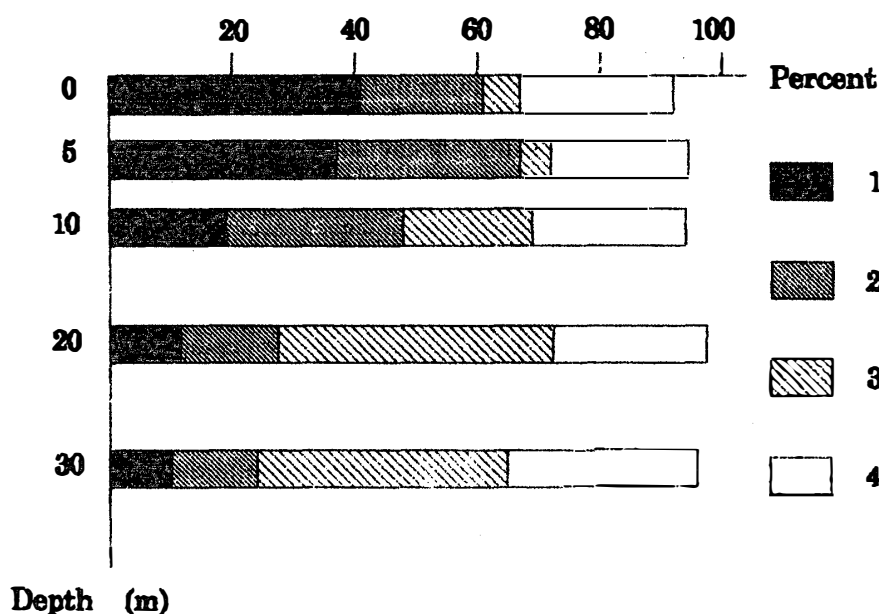


Fig. 5. Mean percentages of four species abundance at Stn. 11 during the sampling period. (1=*Bicosta spinifera*; 2=*Crinolina aperta*; 3=*Diaphanoeca multiannulata*; 4=*Parvicorbicula circularis*)

characters as the specimen from the Isefjord of Denmark, which was described and illustrated by THOMSEN (1976). The other ten species found from Great-Wall Bay have been reported in the other Antarctic waters (Table 5). Except for *D. multiannulata*, *Pleurasiga orculaeformis* aff. and *Pleurasiga* sp., all eight other species are cosmopolitan in geographical distribution (BUCK and GARRISON, 1988; MARCHANT and PERRIN, 1990). Most of the species recorded are common in Antarctic oceanic or neritic waters. But *Acanthocorbis unguiculata* has not been reported from other Antarctic areas except from Prydz Bay and a fjord in the

Table 5. Species of loricate choanoflagellates from Great-Wall Bay distributed in other Antarctic waters.

Investigation regions	Terre Adélie (DEFLANDRE, 1960)	65°50'S, 155°16'E (HARA and TANOUE, 1984)	Lützow-Holm Bay (TAKAHASHI, 1981)	Weddell Sea and Scotia Sea (BUCK, 1981; BUCK and GARRISON, 1983, 1988; GARRISON and BUCK, 1989; SILVER <i>et al.</i> , 1980; THOMSEN and LARSON, 1992)	75°E (HARA <i>et al.</i> , 1986)	Coastal Prydz Bay*	Oceanic Prydz Bay*
<i>Acanthocorbis unguiculaia</i> (THOMSEN) HARA and TAKAHASHI 1984					+		+
<i>Bicosia spinifera</i> (THRONSEN) LEADBEATER 1978			+	+	+		+
<i>Calliacantha natans</i> (GRØNTVED) LEADBEATER 1978			+	+	+		+
<i>Calliacantha simplex</i> MANTON and OATES 1979				+	+		+
<i>Crinolina aperta</i> (LEADBEATER) THOMSEN 1976			+	+	+		+
<i>Diaphanoeca multiannulata</i> BUCK 1981			+	+	+		+
<i>Diaphanoeca pedicellata</i> LEADBEATER 1972				+	+		+
<i>Parvicorbicula circularis</i> THOMSEN 1976				+	+		+
<i>Parvicorbicula socialis</i> (MEUNIER) DEFLANDRE 1960	+	+	+	+	+		+
<i>Pleurasiga orculaeformis</i> SCHILLER aff.							
<i>Pleurasiga</i> sp.			+	+			

\*Species in Prydz Bay reported by MARCHANT (1985), MARCHANT and PERRIN (1986, 1990), MARCHANT *et al.* (1987).



Vestfold Hills (MARCHANT, 1985; MARCHANT *et al.*, 1987). *Pleurasiga* sp., which was similar to the species reported from Lützow-Holm Bay by TAKAHASHI (1981) and from the ice-edge zone in the Weddell Sea by BUCK and GARRISON (1988), has not been reported from any other Antarctic region.

Although loricate choanoflagellates often showed considerable uniformity in the species distribution (MARCHANT and PERRIN, 1990), especially in the upper water column (BUCK and GARRISON, 1988), there was a heterogeneous pattern of species spatial distribution in Great-Wall Bay. In species horizontal distribution, the inner part contained more abundant species than the outer part (Table 2). In the vertical profile, the four dominant species were distributed widely in all layers. They were counted for more than 90% of total choanoflagellates in every layer (Fig. 5). But choanoflagellates other than the four dominant species occurred in low abundance. *A. unguiculata*, *C. natans* and *C. simplex* were mainly distributed in the upper layer, and their abundance was much lower (Table 3). The highest abundance of total choanoflagellates, the maximum density of individual species, and the maximum chlorophyll *a* concentration were located at depth of 20 or 30 m (Figs. 2, 3). This depth was close to the bottom (35 m). These differences of spatial distribution of choanoflagellate species and abundance may be due to the difference of water mass structure and environmental factors of their habitats such as temperature and nutrient contents. Unfortunately, no more data on environmental factors under surface water habitats were obtained. Therefore it was difficult to analyze the relationships between choanoflagellate spatial distributions and environmental factors. So more detailed studies in the region are needed. However, it is noteworthy that melted snow water entering the shallow Bay could cause great change of water conditions, especially at the surface. And also, choanoflagellates and the water conditions in the outer part of the Bay may be influenced by the swift current from Fildes Strait and the water conditions of Maxwell Bay.

Choanoflagellates were relatively abundant in Great-Wall Bay in summer. Their total abundance in the present study ranged from  $5.1 \times 10^3$  to  $5.3 \times 10^4$  cells/l. This falls within the range of values previously reported from other Antarctic waters (SILVER *et al.*, 1980; BUCK and GARRISON, 1983, 1988; FRYXELL *et al.*, 1984; MARCHANT, 1985; MARCHANT and PERRIN, 1990). On the one hand, choanoflagellates are consumers of bacteria and cyanobacteria, and they also ingest nano- and pico-autotrophs and detritus including particulate organic matter (LAVAL, 1971; LEADBEATER and MORTON, 1974; FENCHEL, 1982; MARCHANT, 1985; SHERR, 1988). Chlorophyll *a* concentration as an important indicator of autotrophic biomass obviously affects the choanoflagellate abundance and vertical distribution in Great-Wall Bay. The positive correlation between choanoflagellate abundance and chlorophyll *a* concentration indicates that choanoflagellates are closely associated with primary production. Therefore the development of choanoflagellates is dependent on primary production directly or indirectly. On the other hand, there is a potential importance of choanoflagellates as a food source for Antarctic krill, *Euphausia superba* (MEYER and EL-SAYED, 1983; MARCHANT and NASH, 1986; TANOUE and HARA, 1986). Their high abundance in

Great-Wall Bay suggests that the significance of choanoflagellates in Antarctic neritic ecosystems can not be ignored. In fact, the total abundance (order of  $10^3$ – $10^4$  cells/l) and the highest density of individual species (order of  $10^4$  cells/l) in Great-Wall Bay approached the level of the ocean and ice-edge zone in the Weddell Sea (SILVER *et al.*, 1980; BUCK and GARRISON, 1983, 1988). The present study suggests that the choanoflagellates as an important component of Antarctic neritic waters play an important role in the flow and transformation of energy and materials in Antarctic neritic ecosystems as well as Antarctic pelagic ecosystems.

### Acknowledgments

This study was supported by the State Antarctic Committee of P. R. China. I sincerely thank members of the Seventh Chinese Antarctic Research Expedition (CHINARE-VII, 1990/91) for their assistance in sampling.

### References

- BUCK, K. R. (1981): A study of choanoflagellates (Acanthoecidae) from the Weddell Sea, including a description of *Diaphanoeca multiannulata* n. sp. J. Protozool., **28**, 47–54.
- BUCK, K. R. and GARRISON, D. L. (1983): Protists from the ice-edge region of the Weddell Sea. Deep-Sea Res., **30**, 1261–1277.
- BUCK, K. R. and GARRISON, D. L. (1988): Distribution and abundance of choanoflagellates (Acanthoecidae) across the ice-edge zone in the Weddell Sea, Antarctica. Mar. Biol., **98**, 263–269.
- CHEN, Bo (1993): Choanoflagellates from Great-Wall Bay, Antarctica. Antarct. Res. (Chin. Ed.), **5**(3), 27–39.
- DEFLANDRE, G. (1960): Sur la présence de *Parvicorbicula* n. g. *socialis* (MEUNIER) dans le plancton de l'Antarctique (Terre Adélie). Rev. Algol., **5**, 183–189.
- FENCHEL, T. (1982): Ecology of heterotrophic micro-flagellates. IV. Quantitative occurrence and importance as bacterial consumers. Mar. Ecol. Prog. Ser., **9**, 35–42.
- FRYXELL, G. A., THERIOT, E. C. and BUCK, K. R. (1984): Phytoplankton, ice algae and choanoflagellates from AMERIEZ, the southern Atlantic and Indian Oceans. Antarct. J. U. S., **19**, 107–109.
- GARRISON, D. L. and BUCK, K. R. (1989): Protozooplankton in the Weddell Sea, Antarctica: Abundance and distribution in the ice-edge zone. Polar Biol., **9**, 341–351.
- HARA, S. and TANOUE, E. (1984): Choanoflagellates in the Antarctic Ocean, with special reference to *Parvicorbicula socialis* (MEUNIER) Deflandre. Mem. Natl Inst. Polar Res., Spec. Issue, **32**, 1–13.
- HARA, S., TANOUE, E., ZENIMOTO, M., KOMAKI, Y. and TAKAHASHI, E. (1986): Morphology and distribution of heterotrophic protists along 75° E in the Southern Ocean. Mem. Natl Inst. Polar Res., Spec. Issue, **40**, 69–80.
- JEFFREY, S. W. and HUMPHREY, G. (1975): New spectrophotometric equations for determining chlorophylls *a*, *b*, *c*<sub>1</sub> and *c*<sub>2</sub> in higher plants, algae and natural phytoplankton. Biochem. Physiol. Pflanz., **167**, 191–194.
- LAVAL, M. (1971): Ultrastructure et mode de nutrition du choanoflagelle *Salpingoeca pelagica* sp. nov. Comparaison avec les choanocytes des spongiaires. Protistologica, **7**, 325–336.
- LEADBEATER, B. S. C. and MORTON, C. (1974): A microscopical study of a marine species of *Codosiga* James-Clark (Choanoflagellate) with special reference to the ingestion of bacteria. Biol. J. Linn. Soc., **6**, 337–347.

- MARCHANT, H. J. (1985): Choanoflagellates in the Antarctic marine food chain. Antarctic Nutrient Cycles and Food Webs, ed. by W. R. SIEGFRIED *et al.* Berlin, Springer, 271–276.
- MARCHANT, H. J. and NASH, G. V. (1986): Electron microscopy of gut contents and faeces of *Euphausia superba* DANA. Mem. Natl Inst. Polar Res., Spec. Issue, **40**, 167–177.
- MARCHANT, H. J. and PERRIN, R. A. (1990): Seasonal variation in abundance and species composition of choanoflagellates (Acanthoecidae) at Antarctic coastal sites. Polar Biol., **10**, 499–505.
- MARCHANT, H. J., VAN DEN HOFF, J. and BURTON, H. R. (1987): Loriccate choanoflagellates from Ellis Fjord, Antarctica including the description of *Acanthocorbis tintinnabulum* sp. nov. Proc. NIPR Symp. Polar Biol., **1**, 10–22.
- MEYER, M. A. and EL-SAYED, S. Z. (1983): Grazing of *Euphausia superba* DANA on natural phytoplankton populations. Polar Biol., **1**, 193–203.
- NISHIDA, S. (1986): Nannoplankton flora in the Southern Ocean, with special reference to siliceous varieties. Mem. Natl Inst. Polar Res., Spec. Issue **40**, 56–68.
- SHERR, E. (1988): Direct use of high molecular weight polysaccharide by heterotrophic flagellates. Nature, **335**, 348–351.
- SILVER, M. W., MITCHELL, J. G. and RINGO, D. (1980): Siliceous nanoplankton II. Newly discovered cysts and abundant choanoflagellates from the Weddell Sea, Antarctica. Mar. Biol., **58**, 211–217.
- TAKAHASHI, E. (1981): Loriccate and scale bearing protists from Lützow-Holm Bay, Antarctica. Species of the Acanthoecidae and the Centrohelida found at a site selected in the fast-ice. Nankyoku Shiryô (Antarct. Rec.), **73**, 1–22.
- TANOUE, E. and HARA, S. (1986): Ecological implications of fecal pellets produced by the Antarctic krill *Euphausia superba* in the Antarctic Ocean. Mar. Biol., **91**, 359–369.
- THOMSEN, H. A. (1976): Studies on marine choanoflagellates. Fine-structural observations on some silicified choanoflagellates from the Isefjord (Denmark), including the description of two new species. Norw. J. Bot., **23**, 33–51.
- THOMSEN, H. A. and LARSEN, J. (1992): Loriccate choanoflagellates of the Southern Ocean with new observations on cell division in *Bicosta spinifera* (THRONDSSEN, 1970) from Antarctica and *Saroeca attenuata* THOMSEN, 1979, from the Baltic Sea. Polar Biol., **12**, 53–63.

(Received April 1, 1993; Revised manuscript received August 6, 1993)