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Distribution of Tintinnids in the Southern Korean Waters, the East Sea, and the East China Sea in the Summer of 1998

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1998년 하계 한국 남해, 동해 및 동중국해에 출현하는 유종섬모충류의 분포

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1998년 하계에 한국 남해, 동해 그리고 동중국해에 출현하는 유종섬모충류의 분포를 조사하였다. 총 20종류가 출현하였으며 동중국해에서 9종, 남해에서 9종 그리고 동해에서 13종이 각각 기록되었다. Quantitative Protargol Staining (QPS) 방법에 의해 정량 및 정성분석한 결과 현존량은 0-240 cells · l^{-1}의 범위를 보였으며 chlorophyll *a* 분포와 역관계를 보였다. 동중국해에서 *Dadayiella ganymedes, Eutintinnus tubulosus*, 남해에서 *Amphorides quadrilineata*, 동해에서 *Amphorellopsis acuta, Amphorides quadrilineata, Salpingella* sp.이 우점종으로 출현하였다. 출현종의 대부분은 온수종이었으며, 남해와 동해는 주로 외양성인 종류가 분포하는 반면 동중국해에서는 연안종의 분포가 우세하였다.

The distribution of tintinnids was studied in the East China Sea, the southern Korean waters and the East Sea (the Sea of Japan) in the summer of 1998. A total of 20 species of tintinnids occurred: 9 species in the East China Sea, 9 species in the southern Korean waters, and 13 species in the East Sea were recorded, respectively. Quantitative and qualitative analyses by the QPS (Quantitative Protargol Stain) method revealed that the standing stocks of tintinnids ranged from 0 to 240 cells · l^{-1} and showed a reverse relation with the distribution of chlorophyll *a*. Dominant species were *Dadayiella ganymedes* and *Eutintinnus tubulosus* sp. in the East China Sea, *Amphorides quadrilineata* in the southern Korean waters, and *Amphorellopsis acuta, Amphorides quadrilineata*, and *Salpingella* sp. in the East Sea. Most species occurred during this investigation were warm-water species. Oceanic tintinnids were mainly found in the southern and eastern Korean waters while neritic species in the East China Sea.

Key words : tintinnids, planktonic ciliates, plankton distribution, the East China Sea, Korean waters, the East Sea.

INTRODUCTION

Phytoplankton biomass and productivity are dominated by nanoplankton (Malone, 1980) and picoplankton (Stockner and Antia, 1986; Stockner, 1988). Planktonic ciliates are recognized to be major consumers of nano- and picoplankton (Fenchel, 1987). Namely, they are efficient transferrer from the primary production to higher trophic levels. The ciliates are divided into two groups, tintinnids (loricate ciliates) and oligotrichs (naked ciliates). Tintinnids are the best known group of marine ciliates and recognized as indicator species of different water masses due to their hard loricae (Kato and Taniguchi, 1993). Several studies have shown the food of tintinnids to include bacteria (Hollibaugh *et al.*, 1980), diatoms and dinoflagellates (Heinbokel and Beers, 1979; Stoecker *et al.*, 1981, 1983, 1984), and other smaller protozoans. Strong positive correlations between phytoplankton and tintinnid abundances have been found (Kimor and Golandsky, 1977; Sorokin, 1977). Some tintinnids, especially genus *Favella*, are specialized predators on small, bloom-forming dinoflagellates (Stoecker *et al.*, 1984). These tintinnids are important in the population dynamics of some dinoflagellates, including some red-tide-forming species in Korean waters (Yoo and Lee, 1987).

The rapid industrial growth on Chinese inlands and the massive flow of Chanjean River (Yangtze River) lead to the eutrophication of neighboring waters of the East China Sea. And it sometimes causes the lower salinity phenomenon around Cheju Island especially in summer. The flow is known to affect the southern and even the eastern Korean waters. A study on tintinnid distribution is considered as a best approach which can indicate the flow of water mass in the open ocean like the East China Sea and the neighboring waters of Korea. In our country, taxonomical studies on tintinnids have been done in Chinhae Bay and Youngil Bay (Yoo *et al.*, 1988; Yoo and Kim,

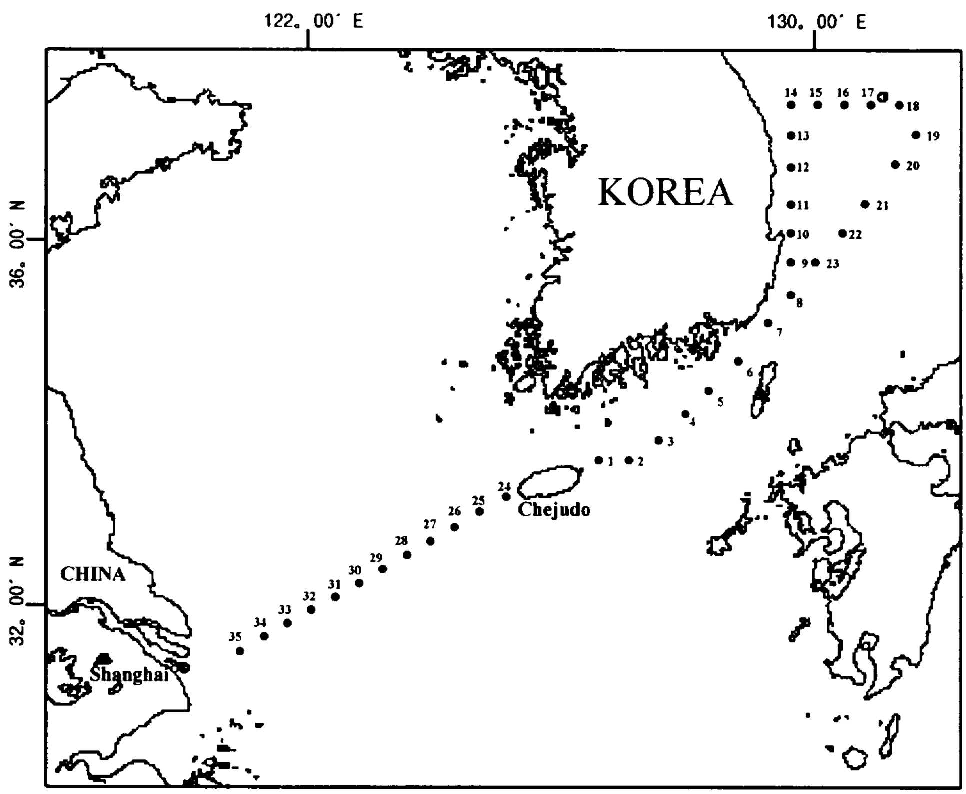

Fig. 1. A map showing the sampling stations in the study area.

1990). There, however, are few ecological studies focused on distribution or dynamics in Korean waters. This study has been carried out to clarify the effect of the flow route from the mouth of Chanjean River to the East Sea (the Sea of Japan) with regard to plankton distribution.

MATERIALS AND METHODS

Sampling was done in the East China Sea (St. 24 - 35) on 28 to 30 June 1998, and in the southern Korean waters (St. 1 - 7) and in the East Sea (St. 8 - 23) from 26 August to 5 September 1998 on a cruise aboard using the R/V Ara-ho of Cheju National University (Fig. 1). Water samples were collected using Niskin water bottle at 0, 10, 30, and 50m and then fixed immediately in 7% (v:v) Bouin's fixative. For high reliability of species identification and counting, the fixed samples were stained by QPS (Quantitative Protargol Stain) method (Montagnes and Lynn, 1987). Tintinnids were identified and counted using a light microscope under a difference interference contrast (DIC). Identification and systematics of tintinnids were done based on Kofoid and Campbell (1929, 1939), Campbell (1942), Hada (1932a, b, c; 1935, 1937, 1938) and Sano (1975). For phytoplankton biomass, chlorophyll *a* were measured by the standard method of APHA *et al.* (1994) and calculated with ㎍ chl-*a* · l^{-1}.

RESULTS AND DISCUSSION

Species composition

A total of 20 species of tintinnids occurred during the sampling period. Nine species in the East China Sea, 9 species in the southern Korean waters, and 13 species in the East Sea were recorded, respectively (Table 1). Tintinnids from Korean waters were first described 27 species in Chinhae Bay (Yoo *et al.*, 1988) and then serially reported 52 species in Youngil Bay (Yoo and Kim, 1990). As these prior investigations were accomplished over one or more years, the larger number of species was observed comparing with the samples for this study collected only during the summer from June to August.

Tintinnids occurred in the study area can be divided as neritic or oceanic species according to ecological distribution (Kim, 1986). Three oceanic species were included in the East China Sea, whereas 9 oceanic species existed in the southern Korean waters, and 10 in the East Sea (Table 1). In particular, the smallest number of oceanic species was recorded in the East China Sea. The genera *Tintinnopsis*, *Stenosemella*, *Helicostomella*, and *Favella* which have been found to be neritic, or restricted to relatively shallow waters (Pierce and Turner, 1993) were detected only in the sea. This results reveals that neritic tintinnids are largely distributed in the East China Sea, where Chanjean River and coastal waters from inland China affect this sea. Tintinnids, however, actually comprise a larger number of oceanic species than neritic species. Yoo and Kim (1990) also suggested that the larger number of oceanic species was distributed in Youngil Bay located in the East Sea than in Chinhae Bay in the southern Korean waters.

Based on the distribution to water temperature, tintinnids can be also grouped as cold- or warm-water species. From this study, cold- and warm-water species included 2 and 18 species, respectively (Table 1). There were one cold- and 8 warm-water species in the East China Sea, one cold- and 8 warm water species in the southern Korean waters, and one cold- and 12 warm-water species in the East Sea. Tintinnid species distributed in tropical and temperate waters display higher species composition. Namely, the warm-water species

Table 1. Occurrence list of tintinnids in the southern Korean waters, the East Sea and the East China Sea in the summer of 1998

Species Name	ECS (St.24-35)	South (St.1-7)	East (St.8-23)	Chinhae[1] Bay	Youngil[2] Bay	N/O	C/W
Acanthostomella norvegica		*	*		*	O	C
Amphorellopsis acuta			*	*	*	O	W
Amphorides amphora		*	*	*	*	O	W
Amphorides minor		*	*		*	O	W
Amphorides quadrilineata		*	*		*	O	W
Amphorides sp.		*	*	*	*	O	W
Ascampbelliella urceolata		*			*	O	W
Condonellopsis morchella			*		*	N	W
Dadayiella ganymedes	*	*			*	O	W
Epiplocyloides reticulata			*		*	O	W
Eutintinnus tubulosus	*		*	*	*	N	W
Eutintinnus sp.	*		*	*	*	N	W
Favella sp.	*			*	*	N	W
Helicostomella sublata	*			*	*	N	C
Rhabdonella poculum			*		*	O	W
Salpingella subconica		*	*		*	O	W
Salpingella sp.	*	*	*	*	*	O	W
Stenosemella sp.	*			*	*	N	W
Tintinnopsis beroidea	*			*	*	N	W
Tintinnopsis gracilis	*			*	*	O	W
Number of species	9	9	13	11/(27)[1]	20/(52)[2]		

1: Yoo *et al.* (1988) reported a total of 27 species from Chinhae Bay
2: Yoo and Kim (1990) reported a total of 52 species from Youngil Bay
N/O: Neritic species / Oceanic species
C/W: Cold water species / Warm water species

is more diverse than cold-water one. Furthermore, because the sampling in studying sites was limited to the warm season and to 50m depth above the thermocline, the higher composition of warm-water species in this results can be easily understood. In general, the cold-water species are mainly found below 20° C (Hada 1960). Two cold-water species, *Helicostomella subulata* and *Acanthostomella norvegica*, recorded from this study revealed the different distribution in comparison with other reports. *Helicostomella subulata* was detected in the East China Seas. This species was frequently observed in neritic area and cold season (Yoo et al., 1988; Yoo and Kim, 1990). *Acanthostomella norvegica* was detected in the southern Korean waters and the East Sea. This species is described as the most reliable indicator species of cold current from the Oyashio water (Kato and Taniguchi, 1993) and as the only tintinnid showing a bipolar distribution (Pierce and Turner, 1993).

Standing stocks

The maximum standing stocks showed 240 cells · l^{-1} at 30 m depth in the East China Sea. The range of standing stocks from the southern Korean waters was 0 to 120 cells · l^{-1} with the average of 37 cells · l^{-1}. The maximum was recorded at the surface and the 10 m depth of St. 1 and 2. The standing stocks between sampling stations in the

Table 2. Distribution of dominant tintinnids at each sea during the study period

Species Name	ESC (St.24-35)	South (St.1-7)	East (St.8-23)	N/O	C/W
Amphorellopsis acuta			*	O	W
Amphorides quadrilineata		*	*	O	W
Dadayiella ganymedes	*			N	W
Eutintinnus tubulosus	*			N	W
Salpingella sp.			*	O	W

N/O: Neritic species / Oceanic species
C/W: Cold water species / Warm water species

East Sea were quite different. The standing stocks varied from 0 to 240 cells · l^{-1}, showing the maximum at the 30 m depth of St. 20.

Dominant species were selected on the basis of abundance with more than 60 cells · l^{-1} from all the stations. The species included are as follows: *Amphorellopsis acuta*, *Amphorides quadrilineata*, *Dadayiella ganymedes*, *Eutintinnus tubulosus*, and *Salpingella* sp. (Table 2). Distribution patterns are quite different in each sea. Warm-neritic species dominated in the East China Sea, whereas warm-oceanic species were predominant in both the southern Korean waters and the East sea.

Relationship with phytoplankton abundance

Fig. 2 shows the fluctuation of chlorophyll *a* and tintinnid abundance in the southern and eastern waters. Chlorophyll *a* means phytoplankton biomass in these stations. The chlorophyll *a* represented the range of 0.10~0.90 μg · l^{-1} (mean 0.38 μg · l^{-1}) and 0.00~0.70 μg · l^{-1} (mean 0.19 μg · l^{-1}) in the southern Korean waters and the East Sea, respectively. The fluctuation of phytoplankton and tintinnids is likely to be related, which means they show a reverse distribution in both waters based on cell abundance. Stations having high phytoplankton abundance show relatively lower tintinnid abundance and vice versa. This suggests that the tintinnid might affect phytoplantkon abundance with respect to the relationship of prey-predator. There are only a few studies on the feeding relationships between these taxa in the culture system (Heinbokel and Beers, 1979; Stoecker *et al.*, 1981, 1983, 1984), but rare in nature. Thus, some *in situ* observation data concerning the food chain between various taxa should be collected continuously to understand the microbial loop and the energy transfer in marine ecosystems.

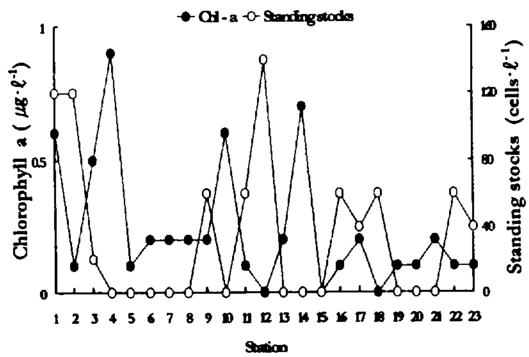

Fig. 2. **Distribution of chlorophyll *a* and standing stocks of tintinnids on the surface layer in the southern Korean waters and the East Sea in the summer of 1998.**

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Explanation of Plate

PLATE I

1. *Tintinnopsis beroidea* (length 60㎛)
2. *Tintinnopsis gracilis* (length 135㎛)
3. *Codonellopsis morchella* (length 85㎛)
4. *Helicostomella subulata* (length 70㎛)
5. *Acanthostomella norvegica* (length 26㎛)
6. *Rhabdonella poculum* (length 85㎛)
7. *Epiplocyloides reticulata* (length 75㎛)
8. *Ascampbelliella urceolata* (length 35㎛)

PLATE II

1. *Amphorides amphora* (length 160㎛)
2. *Amphorides minor* (length 90㎛)
3. *Amphorides quadrilineata* (length 135㎛)
4. *Amphorellopsis acuta* (length 110㎛)
5. *Dadayiella ganymedes* (length 103㎛)
6. *Eutintinnus* sp. (length 100㎛)
7. *Salpingella subconica* (length 140㎛)
8. *Salpingella* sp. (length 100㎛)

PLATE I

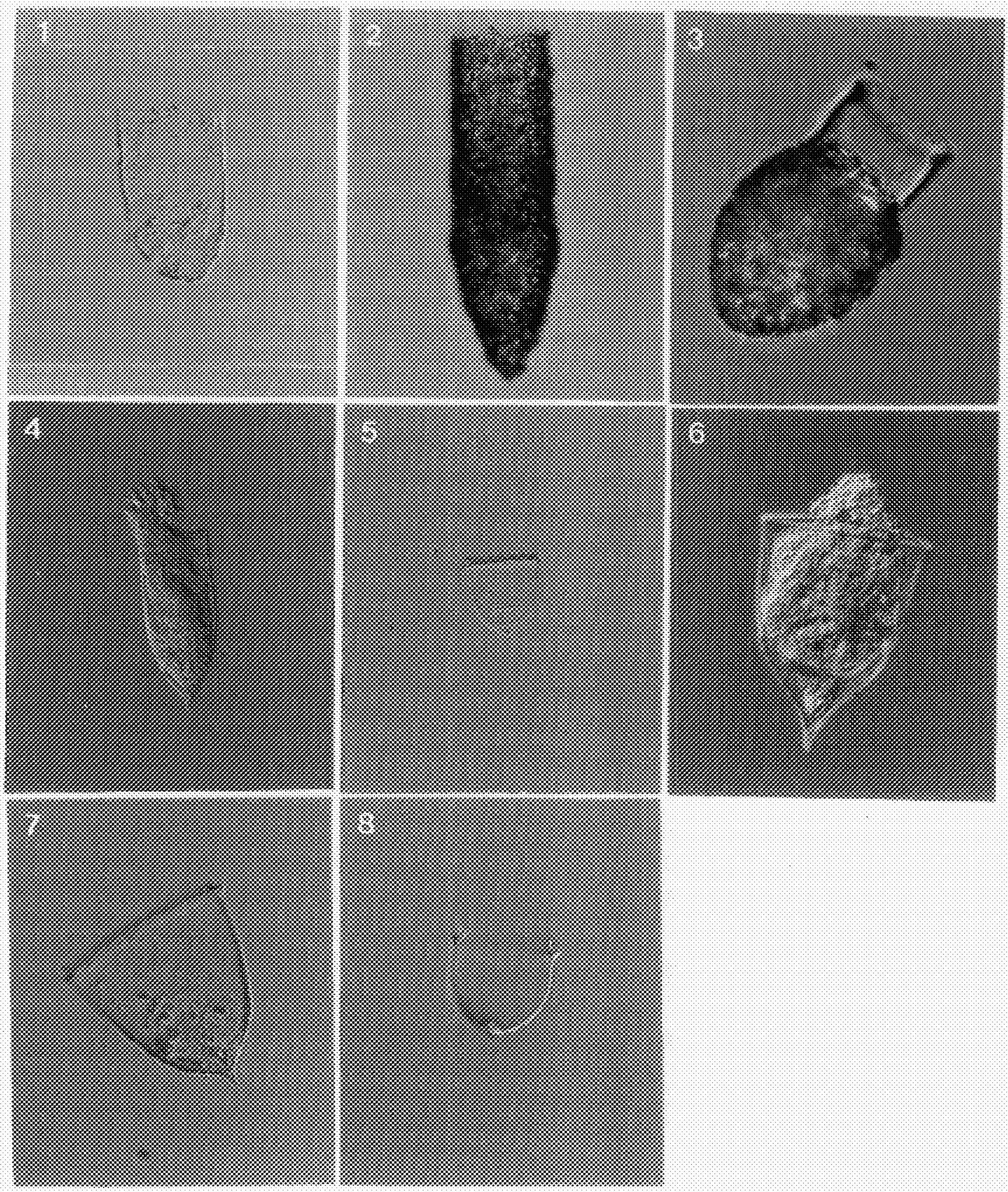

PLATE Ⅱ