On the Trophic Correlation between Tintinnids and Dinoflagellates in Masan Bay, Korea*

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The correlation between tintinnid and dinoflagellate by means of seasonal variation of standing crops was investigated at two selected stations in Masan Bay, well-known as a red tide zone in southern coastal waters of Korea, during the period from January 1981 to December 1982.

The most dominant dinoflagellates mainly belonged to 20-60 μm of size class, and *Gymnodinium* and *Prorocentrum* were predominant from spring to summer season. Of tintinnid, *Favella* spp. were most dominant and associated with dinoflagellate blooms at the same season.

Especially, *Favella* spp. were most positively correlated with 40-60 μm size class of dinoflagellate, and also represented higher multiple corrleation with outer station (St. 2), comprising relatively large species of *Gymonodinium* and *Protogonyaulax*, than with inner station (St. 1), dominated by *Prorocentrum* blooms. Thus, the interspecific food selection by size and morphology between tintinnid including *Favella* and dinoflagellate is recognized and it is considered to be an important factor influenecing on the prey-predator relationship in lower trophic level in the surveyed area.

Introduction

Microzooplankton comprises a large portion of total zooplankton abundance and biomass in coastal waters and takes an important role in lower trophic level of planktonic food web as secondary producer (Beers and Stewart, 1971; Porter *et al.*, 1985). Therefore, it has been noticed that the abundance of microzooplankton feeding mainly dinoflagellates, such as tintinnid, might have influence on red tide population dynamics, although there are close correlation between tintinnids and dinoflagellates.

Assuming that the food chain in lower trophic level is one of the factors influencing on the decay of dinoflagellate blooms, the tintinnid may be a specialized predator of dinoflagellate or may require certain species in its diet. Therefore, the fact has been already verified with *in vivo* and *in vitro* experiments (Gold, 1970; Heinbokel and Beers, 1979; Stoecker *et al.*, 1983; Watras *et al.*, 1985; Rassoulzadegan and Sheldon, 1986), as well as in the field (Sanders, 1987).

The Masan Bay is one of the typical embayment with its fringed coastline and shallow bottom in southern coast of Korea and it is most important breeding and nursing ground for many commercial fishes and shellfishes in the past years. Recently, the outbreaks of red tide have appeared frequently in the southern coastal waters of Korea, among which Masan Bay has been well known as multiple red tide zone (Park, 1980, 1982; Yoo, 1984). Consequently, the heavy damages on the fishery production have been occurred in this area.

The extensive studies on the red tide problem have been carrying out to investigate the mechanisms of dinoflagellate blooms in Chinhae Bay,

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including Masan Bay, by many authors since 1970s, But it has focused merely on taxonomic accounts of causative organisms as well as population dynamics of the community (Cho, 1978, 1981; Lee *et al.*, 1981; Yoo, 1982; Han and Yoo, 1983a, b; Yoo and Lee, 1985, 1986; Lee and Kwak, 1986).

As a part of red tide researches the correlation between causative organisms of red tide and microzooplankters have received ever increasing attentions in this area. Evidently, the tintinnids of the genus *Favella* are often associated with dinoflagellate blooms and it is observed that *Favella ehrenbergii* preys on the dinoflagellate and coincides in abundance with dinoflagellates in Masan Bay (Kim, 1986).

In spite of their importance in coastal food webs there are still many gaps in our knowledge on the correlation between these two taxa, as prey-predator relationships, in coastal waters of Korea. Thus, the purpose of present study is to clarify the interspecific food selection according to its prey size and the correlation between prey and predator in the lower trophic level by means of seasonal fluctuation of standing crops between tintinnids and dinoflagellates in Masan Bay.

Materials and Methods

Samplings were made monthly at two selected stations in Masan Bay during the period from *January 1981 to December 1982* (Fig. 1).

The samlpes of dinoflagellate were collected using van Dorn water samlper, while tintinnid using *Marutoku type plankton net* (mouth diameter 45*cm*, mesh aperture 100*µm*) from surface layer.

Analyses of samples in laboratory were followed the methods described by Yoo (1984) and Kim (1986). All counts of dinoflagellate were then converted into cell per liter, as well as tintinid into indiviual per cubic meter of sea water.

The linear correlation and multiple regression analyses were performed using the statistical package SYSTAT.

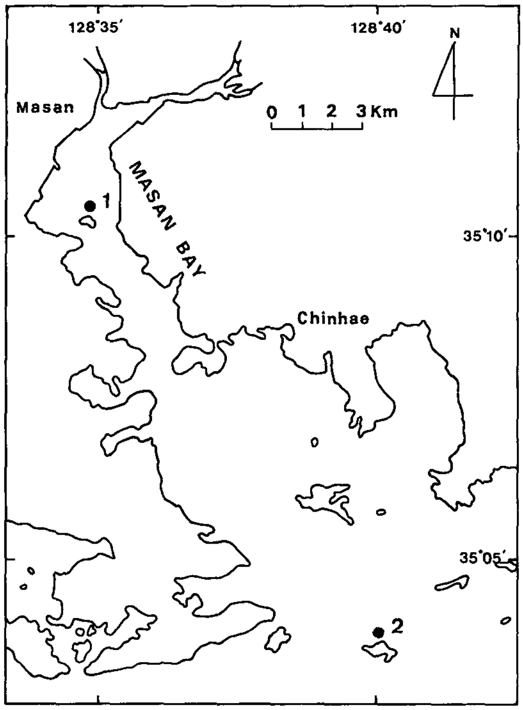

Fig. 1. Sampling stations in Masan Bay.

Results

1. Dinoflagellate population

A total of fourty-three species of dinoflagellates was identified during the study period.

For the dinoflagellate population, as the prey, the size ranged from <20 to 100 *µm* and it can be divided into six groups by size class in 20 *µm* interval.

Of these the most dominant genera were *Gymnodinium* and *Prorocentrum*. However, the dominant species, representing more than 25% of standing crops in blooms, counted a total of nine species of which *Gymmnodinium nagaskiense*, *G. sanguieum*, *Prorocentrum micans* and *P. minimum* were dominant species and it mainly belonged to 20-60 *µm* size fraction (Table 1).

For the genus of *Gymnodinium* it dominated throughout the years and it was characteristic that *G. nagasakiense* dominated in 1981, while *G. sanguineum* in 1981-1982. Moreover, genus *Poro-*

Table 1. The seasonal occurrence and frequency of dominant species of microzooplanklon in Masan Bay

St. 1	1981												1982											
Species	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
DINOFLAGELLATE																								
Gymnodieium nagasakiense									**															
Gymnodinium sanguineum					**						*				**	**				**	**	**	**	
Heterocapsa triquetra															*									
Prorocentrum micans								**										**						
Prorocentrum minimum						**	**												*					
Prorocentum triestinum											*								**		*			
Prorocentrum dentatum																								
Protogonyaulax fratercula																								
Protoperidinium bipes										*														
Scrippsiella trochoidea																	*							
TINTINNIDA																								
Codonellopsis nipponica																**								
Favella ehrenbergii						*		**	**		*								*					
Favella taraikaensis		**		**	**	**									**		**						**	

St. 2	1981												1982											
Species	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
DINOFLAGELLATE																								
Gymnodinium nagaskiense							**	**	*															
Gymnodium sanguineum			*													**	**			**				
Heterocapsa triquetra																								
Prorocentrum micans																								
Prorocentum minimum																								
Prorocentrum triestinum																								
Prorocentum dentatum																		*						
Protogonyaulax fratercula									**						**									
Protoperidinium bipes										**														
Scrippsiella trochoidea																								
TINTINNID																								
Codonellopsis nipponica			**		**	**								**	**	**								
Favella ehrenbergii									**															
Favella taraikaensis				**	**			*								*	**							

*;>25%, **;>50%.

centrum dominated from spring to summer seasons through 1981-1982.

In spatial distribution of the species the inner station (St. 1) and the outer station (St. 2) of the bay showed slight differences between species and size. The dominant species were mainly composed of smaller group (<20-40 μm), such as *Prorocentrum minimum*, *P. triestinum* and *Heterocapsa triquetra* at St. 1. On the other hand larger dinoflagellate (40-60μm), such as *Gymnodinium sanguineum* and *Protogonyaulax fratercula* were dominant at St. 2. Therefore, dinoflagellate abundance and blooms showed in different patterns by seasons and areas.

2. Tintinnid population

A toal of twenty eight species of tintinnids were identified during the study period.

For the tintinnid population, as the predator, the size ranged mostly in 100 μm. The dominant genera were *Codonellopsis* and *Favella*. Of these only three species were really important: *Codonellopsis nipponica*, *Favella ehrenbergii* and *F. taraikaensis*.

C. nipponica was dominant throughout the year except fall season. Moreover, two species of genus *Favella* occurred predominantely between spring to summer seasons (*F. taraikasensis*) and summer to fall seasons (*F. ehrenbergii*), respectively.

However, the species composition of tintinnid was similar at both, inner and outer, stations.

3. Dinoflagellate bloom and tintinnid abundance

The monthly variation of standing crops of dinoflagellate at St. 1 is shown in Fig. 2. The multiple blooming peaks (over 10^5 *cell*/l) appeared from

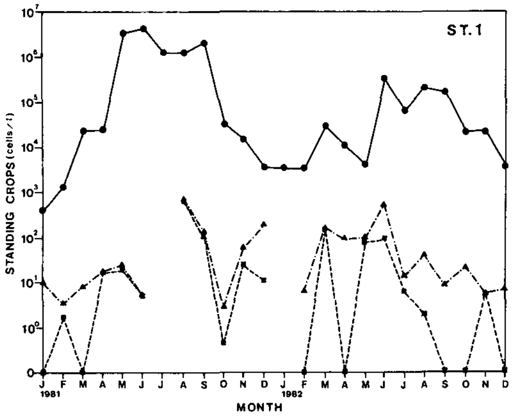

Fig. 2. Seasonal variation of dinoflagellate/tininnid abundance at St. 1 in Masan Bay (circle; dinoflagellate, triangle; tintinnid, rectangle; *Favella* spp.).

May to September in 1981 and and June to September in 1982. Besides, the tintinnid abundance varied through spring to fall seasons. In most cases the abundance of tintinnid, mainly with genus *Favella*, associated with larger size dinoflagellate, while it was not related with blooms of genus *Prorocentrum*.

At St. 2 dinoflagellate blooms were not frequently occurred, hence the blooms were observed two times from July to August in 1981 as well as only one time in May 1982(Fig. 3). It was peculiar that monospecific blooms of genus *Gymnodinium* were occurred in this area during the study period. Especially, *Favella taraikaensis* abundance was closely associated with dinoflagellate bloom in May 1982.

4. The correlation analyses of populations

The correlation matrice and multiple regression

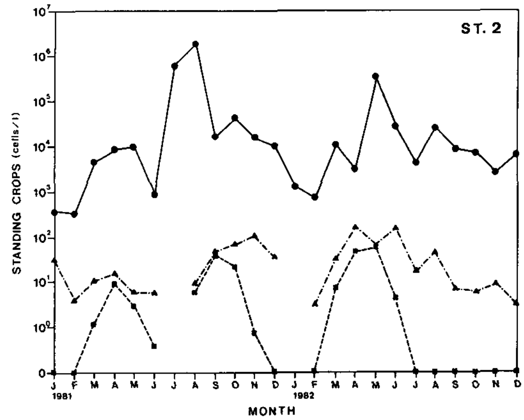

Fig. 3. Seasonal variation of dinoflagellate/tininnid abundance at St. 2 in Masan Bay (circle; dineflagellate, triangle; tintinnid, rectangle; *Favella* spp.).

between dinoflagellate abundance by size fraction and *Favella* species densities are presented in Table 2. Significant correlation ($p<0.05$) are interpreted as indicating factors which may be important in determining food selectivity between two populations.

Table 2. Correlation matrices and multiple correlation coefficients(R) between *Favella* and dinoflagellate size class

St. 1	N=22 ; R=0.640			
	Dinofalgellate size class (μm)			
	<20	20-40	40-60	Total
Favella	−0.037	0.080	0.272	0.146
<20		0.003	−0.003	0.735
20-40			0.078	0.420
40-60				0.563

St. 2	N=22 ; R=0.712			
	Dinoflagellate size class (μm)			
	<20	20-40	40-60	Total
Favella	−0.193	−0.037	0.648	0.076
<20		−0.117	−0.105	−0.124
20-40			0.155	0.985
40−60				0.323

N; sample size,
Total; total abundanace of dinoflagellate.

The multiple coefficients were 0.640 (St. 1) and 0.712 (St. 2), respectively, and it showed the significance between *Favella* sp. and dinoflagellate size class.

In correlation matrices *Favella* abundance was positively correlated with 40-60 μm size fraction of dinoflagellate at both stations; St. 1(r = 0.272) and St. 2 (r = 0.648), respectively. It showed that the outer station (St. 2) was highly correlated with tintinnid and dinoflagellate association in comparison to the inner station.

Discussion

During the study period the most dominant dinoflagellate species by size fractions are included in the range of 20-60 μm, comprising mainly of the causative organisms of red tide (Yoo and Lee, 1985). Consequently, the dinoflagellate blooms have occurred frequently during the spring-summer seasons which caused mainly by *Prorocentrum* and *Gymnodinium* spp. (Lee *et al.*, 1981; Yoo, 1984; Lee and Kwak, 1986).

Of tintinnids *Favella* sp. is most dominant in abundance and are mainly associated with dinoflagellate blooms at the same season (Kim, 1986). As well as in coastal waters it has been also observed that the large-sized tintinnid commonly cooccurred with dinoflagellate blooms in a small estuary (Stoecker *et al.*, 1983).

Moreover, *Favella* sp. is a selective predator on dinoflagellates, but it shows food selectivity on dinoflagellates as suitable prey (Stoecker *et al.*, 1981, 1984). In the present study *Favella* sp. with 70-95 μm of oral lorica diameter may be more highly associated with 40-60 μm size fraction of dinoflagellate than others. Especially, dominant dinoflagellates at St. 2 are composed of relatively large species including *Gymnodinium* and *Protogonyaulax*, whereas it is composed of smaller species including mainly *Prorocentrum* at St. 1. This results are consistent that *Favella* sp. selectively prefer larger dinoflagellate with very different size (Stoecker *et al.*, 1981), and prey on *Gymnodinium* sp, *Gonyaulax* sp. or *Heterocapsa* sp. as good food rather than *Prorocentrum* sp. in Masan Bay (Fig. 4).

Stoecker *et al.* (1984) reported that the association between planktonic ciliates and their phytoplankton prey should result in ciliate growth rates and grazing impact on phytoplankton population. However, *Favella* sp. was not closely correlated with total abundance of dinofladellate in the present study. It is suggested that *Favella* sp. recognizes with specific size class and shows food selectivity on dinoflagellate species suitable to prey. Thus, *Favella* abundance may be associated with the blooming of dinoflagellate when it is matched with prey-predator relationships.

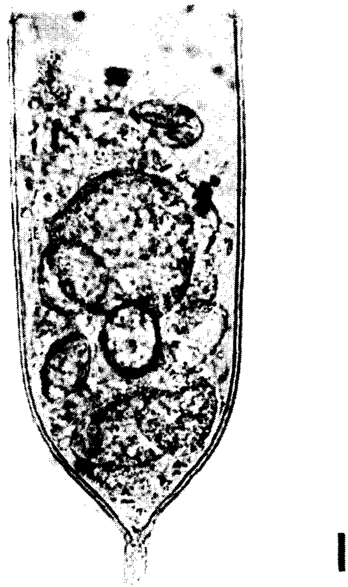

Fig. 4. *Favella ehrenbergii* feeding on dinoflagellates (scale bar = 10μm).

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마산만의 유종섬모충류와 와편모류간의 포식-피포식 상관관계에 대하여

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(1987년 2월 20일 수리)

적조의 다발해역으로 알려진 마산만 일대의 2개 정점에서 1981년 1월부터 1982년 12월까지 유종섬모충류와 와편모류의 현존량을 월별로 조사하여 이들 변동과 포식—피포식 상관관계를 조사하였다.

와편모류의 우점종은 주로 20-60 μm의 크기로서 *Gymnodinium*, *Prorocentrum* 속 등이었으며, 특히 봄에서 여름에 결쳐 대발생을 보였다. 한편 유종섬모충류는 *Favella*가 압도적으로 우점하였으며 이들은 같은 시기에 현존량의 상관관계를 나타내었다.

이들의 중상관분석의 결과로 *Favella*는 와편모류중 40-60 μm 크기의 종류들과 높은 정의 상관관계를 나타냈으며, *Prorocentrum* 등이 우점한 정점 1보다는 *Gymnodinium*, *Protogonyaulax* 등 크기가 큰 종류들이 우점한 정점 2에서 더 높은 중상관관계를 보였다.

이로서 유종섬모충류와 와편모류간에는 크기 및 형태에 의한 먹이 선택성을 인정할 수 있었으며 이들은 연안역의 저차생산단계에서 포식·피포식 상관관계를 통하여 중요한 역활을 맡고 있다고 사료된다.