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Dynamics and Seasonal Succession of Dinoflagellate Community in Masan Bay, Korea

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馬山灣의 渦鞭毛藻類 群集의 動態와 季節的 遷移

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The dynamics and seasonal succession of dinoflagellate community, and their correlations with environmental parameters were investigated during the period from April, 1986 to March, 1987 at 6 selected stations in Masan Bay, Korea.

The dinoflagellate standing crops varied extensively with months and stations: ranging from 44 to 2,798,900 cells/*l* at surface layer and from 52 to 165,714 cells/*l* at bottom layer, respectively. The distribution of standing crops by size class of dinoflagellate species showed that a group of 20-40 μm size class was predominant throughout the present survey, since the most of dominant species have belonged to the size category. Among dominant species, *Gyrodinium fissum* was most dominant throughout the year in all sampling stations, particulary in June. *Scripsiella trochoidea* was predominant in May, *Protoperidinium bipes* and *Prorocentrum minimum* from June to September, *Prorocentrum triestinum, P. micans* and *Ceratium fusus* from September to December, and *Heterocapsa triquetra* from December to April.

The stepwise multiple regression analysis between dinoflagllate and environmental parameters revealed that salinity, nitrate-N, pH, and transparency were correlated with the variations of standing crops of dinoflagellate.

본 研究는 馬山灣 일대의 渦鞭毛藻類 群集의 構造와 動態 및 季節的 遷移 그리고 環境要因과의 相互關係를 把握하고자 1986년 4월부터 1987년 3월까지 일년 동안 選定된 6개 定點에서 매월 실시하였다. 渦鞭毛藻類의 現存量의 分布는 표층에서 44-2,798,900 cells/*l*, 저층에서 52-165,714 cells/*l*로서 층별, 월별, 정점별 차이가 매우 크게 나타났으며 대발생(500,000 cells/*l*)의 양상은 표층의 4월부터 8월까지로써 춘·하계에 집중되어 있으며 정점별로는 외만보다 내만의 정점에서 더욱 두드러지게 나타났다. 出現種의 세포 크기에 의한 現存量의 분포를 조사한 결과 대부분의 우점종이 20-40 μm 크기로 대표할 수 있었으며 이들 종류들은 내만에 더욱 우점하는 특이한 경향을 나타내었다. 出現種 중 우점종은 6屬, 9種이며, 優占種의 季節的인 遷移는 *Gyrodinium fissum*이 년중 전 계절에 걸쳐 우점하였으며 5월에 *Scrippsiellat trochoidea*가, 6월에서 9월까지 *Prorocentrum minimum, Protoperidinium bipes*가 9월에서 12월까지 *Ceratium fusus, Prorocentrum micans, Prorocentrum triestinum*이 12월에서 4월까지 *Heterocapsa triquetra*가 우점하는 천이의 양상을 나타내었다. 渦鞭毛藻類의 現存量의 변화와 분석된 環境要因과의 相關關係를 段階式 重回歸式에 의해 分析한 결과 pH, 鹽分, 透明度, 窒酸鹽-窒素 등이 영향을 미치는 것으로 나타났다.

INTRODUCTION

Dinoflagellates are one of the most important members of primary producers in marine ecosystem. They are occasionally noticed as red tide causative organisms, since their blooms injure seriously to fisheries and even human-beings by its toxin. So, it is important to investigate the community structure and dynamics of dinoflagellates for clarifying the causative organisms of red tide as well as the primary production of coastal waters. Masan Bay, which is located in the southern part of the Korean Peninsula, has been known to be the most important spawning and nursing ground of fish and shellfish for past years. Recently, it becomes, however, notorious for the eutrophications, and red tide is common due to the establishment of new industrial complex around the bay since 1970's.

Most earlier investigations of red tide in the studied area have been dealing with its impact on fisheries (Park and Kim, 1967). In recent years, studies on the taxonomy and the ecology of dinoflagellates have received ever increasing attention in Masan Bay and there has been increasing documentation of taxonomical studies (Yoo, 1982; Han and Yoo, 1983a, b; Yoo and Lee, 1986). Meanwhile, ecological studies were also carried out a part of phytoplankton research program (Cho, 1978, 1981; Lee and Kwak, 1986). Population dynamics of dinoflagellate were studies as well (Yoo, 1984; Yoo and Lee, 1985). The physiological ecology of genus *Prorocentrum* (Kim, 1986a, b), and the trophodynamic pathway from dinoflagellate to tintinnid have also been reported (Yoo and Lee, 1987).

Despite their ecological importance, our knowledge on the biology of dinoflagellate, *i.e.*, population dynamics, are still rather limited in Masan Bay. The objectives of the present study are 1) clarifying the population dynamics of dinoflagellate community and 2) investigating the impact of environmental parameters on their seasonal succession.

MATERIALS AND METHODS

Field investigations were carried out monthly during the period from April, 1986 to March, 1987 at six selected stations in Masan Bay (Fig. 1). Each station was located with same distance from st. 1 (most inner part of the bay) to st. 6

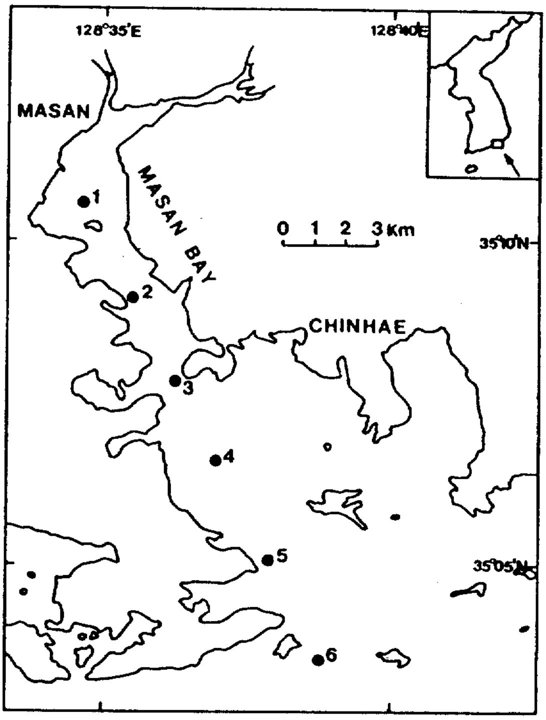

Fig. 1. Sampling stations in Masan Bay.

(most outer).

Samples, collected with van Dorn water sampler at surface (0.5 m beneath surface layer) and bottom layer (0.5 m above bottom layer), were fixed with 5% neutralized formalin on board. Analyses of samples in laboratory were followed methods described by Yoo and Lee (1986). Water temperature (°C), salinity (‰), transparency (m), pH, dissolved oxygen (mg/*l*), NO_3-N (μg-at/*l*), NO_2-N (μg-at/*l*), NH_4-N (μg-at/*l*), and PO_4-P (μg-at/*l*) were measured simultaneously (Parsons *et al.*, 1984).

The stepwise multiple regression analysis between environmental parameters and dinoflagellate standing crops was performed by the SYSTAT package for the statistical analysis. In series of steps for data processing, the dependent variable is the standing crops (cell/*l*) of dinoflagellate, which is converted in natural logarithm, and the independent variables are the nine environmental parameters, viz. temperature, salini-

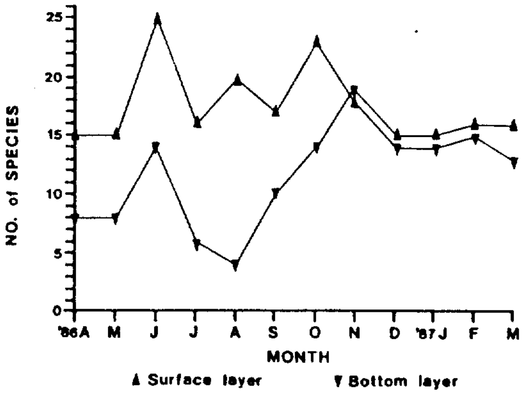

Fig. 2. Monthly variations of number of species of dinoflagellate during the period from April, 1986 to March, 1987 in Masan Bay.

ty, transparency, pH, dissolved oxygen, nitrate, nitrite, ammonium and phosphate.

RESULTS AND DISCUSSION

Species composition

A total of 53 taxa of dinoflagellate, representing 18 genera and 53 species was identified and classified by systematic treatment of Schiller (1933, 1937), Abe (1967a, b) and Dodge (1982) (Appendix 1).

The monthly variations of number of dinoflagellate species were greater at surface layer than those at bottom layer except winter season (Fig. 2). The total number of species was highest at the surface layer of st. 2 in June and lowest at the bottom layer of st. 6 in August, showing the inner stations (st. 2, 3) included the more number of species in outer stations (st. 4, 5, 6). Especially from July to September, the number of species at bottom layer was very lower due to deterioration of its environmental conditions. But such variations of dinoflagellate distributions by layers and stations were different from those of diatom in this area. Lee (1984) reported that there were little differences in the monthly distributions of diatom between vertical layers through the year. It suggests that the pattern of the occurrence of dinoflagellates seems to be quite different from that of diatom (Yoo and Lee, 1976; Yoo and Lee, 1979).

During the survey, the phytoplankton communities comprised diatoms, silicoflagellates, and euglenoids as well as dinoflagellates. The composition ratio showed that diatoms, dinoflagellates, and other flagellates were 63.1%, 32.9%, and 4.0%, respectively. The composition ratio of dinoflagellates, in phytoplankton communities varied by areas in Korean waters. Choi and Shim (1986) reported that 31 species of dinoflagellates comprised 13.6% of phytoplankton in Kyeonggi Bay in Yellow Sea, while 72 spp. of dinoflagellates accounted for 30.9% of phytoplankton in the southwestern part of Japan Sea (Shim, *et al.*, 1985). The differences between above mentioned areas seemed to be due to the hydrographic characteristics which perhaps might affect on the composition ratio of phytoplankton communities. In the present study area, Park (1982) observed that diatoms are more dominant than dinoflagellates just before the occurrence of red tide, and dinoflagellate bloom followed, comprising more than 50% in terms of species composition of phytoplankton during the red tide. According to Lee *et al.* (1981), the composition proportions of dinoflagellates and diatoms were 17.3% and 81.6%, respectively. Although there was a little variation with periods of observation. The occurrence of dinoflagellate comprising 11 families, 18 genera and 52 species were recorded in Masan Bay before this study. The number of dinoflagellate species shows increasing tendency year by year (Park and Kim, 1967; Cho, 1978; Park, 1979; Cho, 1979; Park, 1980; Yoo, 1980; Cho, 1981; Lee *et al.*, 1981; Yoo, 1982; Han and Yoo, 1983a, b; Yoo and Lee, 1985). In our observations, the number of species of dinoflagellate have increased yearly; from 22 species in 1979-1980 to 53 species in 1986-1987 of this study period.

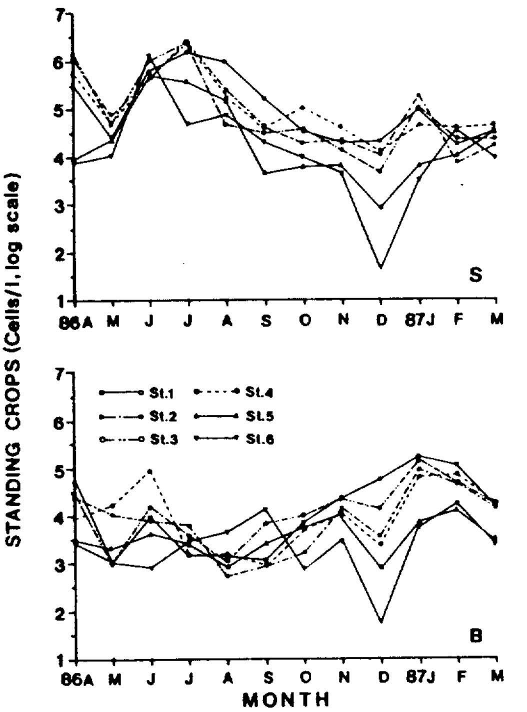

Fig. 3. Monthly variations of dinoflagellate standing crops during the period from April, 1986 to March, 1987 in Masan Bay (S; surface layer, B; bottom layer).

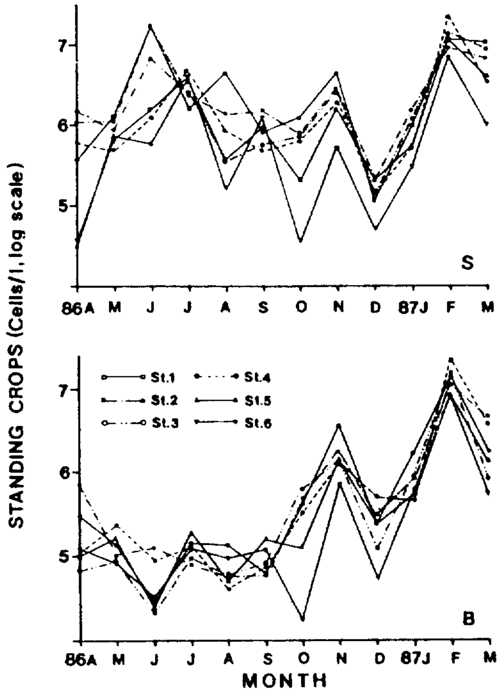

Fig. 4. Monthly variations of phytoplankton standing crops during the period from April, 1986 to March, 1987 in Masan Bay (S; surface layer, B; bottom layer).

Monthly variation and distribution of standing crops

Standing crops of dinoflagellates varied extensively, ranging from 44 to 2,789,900 cells/*l* at surface layer and from 52 to 165,714 cells/*l* at bottom layer (Fig. 3). It increased from April to August and after then decreased at surface layer, but showed very low densities at bottom layer. The difference between stations reveals that dinoflagellate standing crops were higher in the inner part of the bay than in the outer one. On the other hand, total phytoplankton standing crops ranged from 33,510 to 22,911,612 cells/*l* at surface layer; from 17,221 to 2,149,421 cells/*l* at bottom layer (Fig. 4). The fluctuation of phytoplankton is correlated well with diatom's variation, because diatom comprised 90% of total phytoplankton standing crops throughout the year except from April to July, at this time dinoflagellate reversely comprised more than 90%.

Standing crops of dinoflagellate were fractionated in each size class of 20 μm interval at each station. Size criterion of each species was cell length, which is the mean value from the direct measurement (Table 1). The cell length of dinoflagellate occurred during this study ranges from 20 to 1,000 μm, most of species belonging to size class of $<100\,\mu$m except genus *Noctiluca* and *Ceratium*. The total standing crop of each size class is summed and represented the percentage of total standing crops (Fig. 5). Size class of 20-40 μm is the highest from 64.6% to 92.6% at all stations due to high standing crops of genus *Gyrodinium*. At station 1, the genus *Prorocentrum*, belonging to size class of less than 20 μm, was predominant with 24.5%. Size

Table 1. List of dinoflagellates at a different size in Masan Bay.

<20	*Katodinium rotundatum*
	Prorocentrum balticum
	Prorocentrum minimum
20-40	*Amphidinium crassum*
	Ceratium kofoidii
	Diplopsalis lenticula
	Gonyaulax grindleyi
	Gonyaulax spinifera
	Gymnodinium nagasakiense
	Gyrodinium fissum
	Heterocapsa triquetra
	Prorocentrum dentatum
	Prorocentrum triestinum
	Protogonyaulax fratercula
	Protoperidinium bipes
	Protoperidinium brevipes
	Protoperidinium cerasus
	Protoperidinium minutum
	Scrippsiella trochoidea
40-60	*Dinophysis acuminata*
	Dinophysis infundibulus
	Dinophysis rotundata
	Gonyaulax triacantha
	Gonyaulax verior
	Gymnodinium sanguineum
	Prorocentrum micans
	Protoperidinium avellana
	Protoperidinium excentricum
	Protoperidinium pellucidum
	Protoperidinium punctulatum
	Protoperidinium subinerme
	Zygabikodinium lenticulatum
60-80	*Dinophysis fortii*
	Gonyaulax diegensis
	Gonyaulax digitale
	Oxyphysis oxytoxoid
	Protoperidinium conicum
	Protoperidinium granii
	Protoperidinium leonis
	Protoperidinium marielebouriae
	Protoperidinium oblongum
	Protoperidinium pallidum
	Protoperidinium thorianum
80-100	*Dissodinium pseudolenticula*
	Protoperidinium curtipes
	Protoperidinium divergens
100<	*Ceratium furca*
	Ceratium fusus
	Ceratium macroceros
	Ceratium trichoceros
	Noctiluca scintillans
	Polykrikos schwartzii
	Protoperidinium depressum

(unit = μm)

class of <40 μm represented more than 89% from st. 1 to st. 4, while st. 5 and 6 showed less than 80%. So it turns out that small dinoflagellate, *i.e.*, genus *Gyrodinium*, *Prorocentrum*, *Heterocapsa* predominated mainly the inner bay, while large species were widely distributed in the outer bay than in the inner bay. Yoo and Lee (1985) reported that dinoflagellate of the size class of 20-60 μm were more abundant than those of other size classes, because the 40-60 μm size class of *Gymnodinium sanguineum* and *Prorocentrum micans* were most predominant at that time. In this study, the 20-40 μm size class was most dominant, because the dominant species was belonging to the size class of below 40 μm.

Seasonal succession of dominant species

Table 2 shows the temporal and spatial distribution of dominant species. All dominant species, *i.e., Ceratium fusus, Gyrodinium fissum, Heterocapsa triquetra, Prorocentrum micans, Prorocentrum minimum, P. triestinum, Protoperidinium bipes, P. pellucidum* and *Scrippsiella trochoidea* were dominant at surface layer, while *Gyrodinium fissum, Heterocapsa triquetra,* and *Prorocentrum minimum* only at bottom layer. The geneus *Gyrodinium* was dominant at all stations; *Heterocapsa triquetra, Prorocentrum micans, P. minimum* and *Protoperidinium pellucidum* in inner station (st. 1,2,3,4); *Ceratium fusus* and *Scrippsiella trochoidea* at

Table 2. Dominant species of dinoflagellates during the study period.

	Species	Surface												Bottom											
		A	M	J	J	A	S	O	N	D	J	R	M	A	M	J	J	A	S	O	N	D	J	F	M
ST 1	*Ceratium fusus*																								
	Gyrodinium fissum				*									*											
	Heterocapsa triquetra	*									*												*		
	Prorocentrum micans			*																					
	Prorocentrum minimum					*																			
	Prorocentrum triestinum						*																		
	Protoperidinium bipes			*																					
	Protoperidinium pellucidum			*																					
	Scrippsiella trochoidea																								
ST 2	*Ceratium fusus*																								
	Gyrodinium fissum				*																				
	Heterocapsa triquetra	*									*												*		
	Prorocentrum micans			*																					
	Prorocentrum minimum					*																			
	Prorocentrum triestinum																								
	Protoperidinium bipes			*																					
	Protoperidinium pellucidum			*																					
	Scrippsiella trochoidea																								
ST 3	*Ceratium fusus*																								
	Gyrodinium fissum			*	*																				
	Heterocapsa triquetra	*									*												*		
	Prorocentrum micans																								
	Prorocentrum minimum																								
	Prorocentrum triestinum																								
	Protoperidinium bipes			*																					
	Protoperidinium pellucidum			*																					
	Scrippsiella trochoidea																								
ST 4	*Ceratium fusus*																								
	Gyrodinium fissum				*																				
	Heterocapsa triquetra	*																					*		
	Prorocentrum micans																								
	Prorocentrum minimum					*										*									
	Prorocentrum triestinum																								
	Protoperidinium bipes			*																					
	Protoperidinium pellucidum			*																					
	Scrippsiella trochoidea																								
ST 5	*Ceratium fusus*					*																			
	Gyrodinium fissum			*	*																				
	Heterocapsa triquetra																								
	Prorocentrum micans																								
	Prorocentrum minimum																								
	Prorocentrum triestinum			*																					
	Protoperidinium bipes			*																					
	Protoperidinium pellucidum																								
	Scrippsiella trochoidea																								
ST 6	*Ceratium fusus*					*																			
	Gyrodinium fissum			*																					
	Heterocapsa triquetra																								
	Prorocentrum micans																								
	Prorocentrum minimum																								
	Prorocentrum triestinum																								
	Protoperidinium bipes																								
	Protoperidinium pellucidum																								
	Scrippsiella trochoidea			*																					

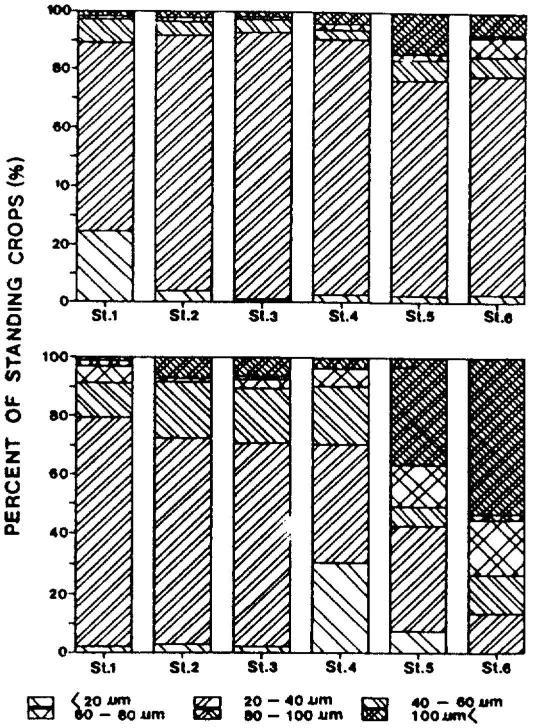

Fig. 5. Percent of dinoflgaellates standing crops a different stations during the period from April, 1986 to March, 1987 in Masan Bay.

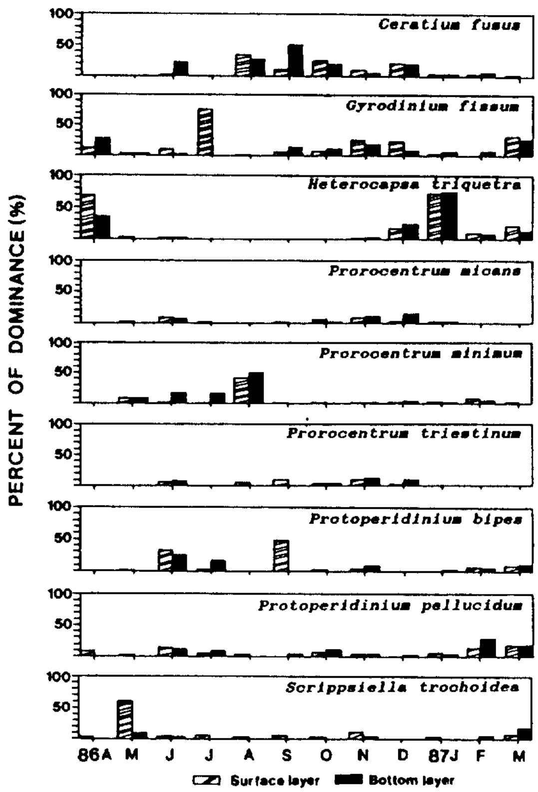

Fig. 6. Seasonal succession of the dominant species during the period from April, 1986 to March, 1987 in Masan Bay.

outer stations (st. 5,6). Station 1 included much more dominant species than station 6, so dominant species mainly predominated at inner stations. Lee and Kwak (1986) reported that *Gymnodinium nagasakiense* was predominant in the summer, and *Prorocentrum micans* and *Skeletonema costatum* occurred together frequently in the red tide outbreak. Dinoflagellates, however, were more predominant than diatoms in this area since 1980's, which reveals that diatom blooms has been changing to dinoflagellate blooms or phytoflagellate blooms recently. Park *et al.* (1989) also indicated that the characteristics of red tide in Korean waters is recently changed from diatom to phytoflagellates, especially *Prorocentrum* spp. of dinoflagellates or *Heterosigma akashiwo* of Raphidophyceae with large scale blooms. In Japan, Iwasaki (1989) reviewed that recent studies on phytoplankton blooms were focused from diatoms to following flagellates, Raphidophyceae: *Heterosigma, Chattonella;* Dinophyceae: *Gymnodinium, Prorocentrum, Alexandrium,* and *Dinophysis.*

Fig. 6 shows the pattern of succession in dinoflagellate community. *Gyrodinium fissum* was predominant throughout the year; *Scrippsiella trochoidea* in May; *Protoperidinium bipes* from June to September; *Prorocentrum minimum* from July to August; *Prorocentrum micans* and *Prorocentrum triestinum* from September to December; *Ceratium fusus* from August to December; *Heterocapsa triquetra* from December to April. There are some differences in succession patterns of phytoplankton communities according to the observation periods in this study area. Lee *et al.* (1981) reported

Table 3. Multiple correlation between dinoflagellate standing crops and environmental parameters during the surveyed period in Masan Bay.

	All Area n = 132 $r^2 = 0.489$		Surfacc Layer n = 72 $r^2 = 0.533$		Bottom Layer n = 72 $r^2 = 0.328$	
Parameter	N. coef.	%	N. coef.	%	N. coef.	%
Water Temp.			0.311	27.8	-0.573	79.1
Salinity	-0.259	26.0				
Transparency	-0.140	14.0	-0.359	32.0	-0.224	28.1
pH	0.402	40.3	0.229	20.5		
Nitrite-N			0.108	9.7		
Nitrate-N	0.196	19.7				
Phosphate-P			0.112	10.0		

n; Sample size.
r^2; Determination coefficient.
N. coef.; Normalized coefficient.
% Importance = N. coef./Sum of the absolute value of the N. coef. × 100.
Probability = 0.000
MODEL DINO = CONSTANT + TEM + SAL + TRA + PH + DO + NO_2 + NO_3 + NH_4 + PO_4.

that *Gonyaulax* sp., *Heterocapsa* sp., *Prorocentrum* sp. and *Gymnodinium* sp. were dominant when red tide occurred from May to October, and the red tide of dinoflagellate and diatom occurred complicatedely. Cho (1978, 1979) observed *Gonyaulax* sp. blooming in 1979 and *Ceratium fusus* blooming in August of 1978 in Chinhae bay. According to Yoo and Lee (1985), *Gymnodinium sanguineum* and *Prorocentrum micans* bloomed massively from spring to summer in this area. The pattern of succession during this survey, however, is different from those of other year at the point of *Gyrodinium* blooming. It is also notable that genus *Gymnodinium*, *Gonyaulax* and *Alexandrium* occurred in less abundance and genus *Prorocentrum* bloomed from spring to autumn. This finding suggested that the population dynamics of dinoflagellate might be more complexively changed year by year.

Correlations between dinoflagellate community and environmental parameters

The results of the stepwise multiple regression analysis with the total standing crops of dinoflagellates and environmental parameters are summerized in Table 3. The environmental parameters which affected the dinoflagellate dynamics are pH, salinity, nitrate (NO_3-N), transparency orderly at all stations, representing 48.9% of importance ($r^2 = 0.489$, determination coefficient). At each layer, transparency, temperature, pH, phosphate, nitrite orderly affected the dinoflagellate standing crops, representing 53.3% of importance ($r^2 = 0.533$) at surface layer, while at bottom layer temperature, transparency affected in 32.8% of importance ($r^2 = 0.328$).

Yoo and Lee (1980) indicated that environmental parameters for affecting on diatom, in the same area were phosphate, transparency, chlorophyll-a, water temperature and salinity. Ahn (1986) also reported that chlorophyll-a concentration in this area was related with pH and light intensity at surface layer, while bacteria and fungi biomass was affected by water temperature at the both of surface and bottom layers. According to Yang (1989), phosphate may be growth stimulators in the study area, because anoxic condition liberates phosphate during the phytoplankton blooms in summer seasons. In this study, temporal and spatial distribution of dinoflagellate community were correlated with water temperature at surface and bottom layers, and transparency, while nitrogen and phosphate sources affected only that of surface layer. Thus the salinity, pH, transparency, nitrogen and phosphate may be mainly related with the variation of dinoflagellate community, viz., the various sources from land run off affect the concentration of nitrogen and phosphate, and salinity as a growth stimulators. As a result, dinoflagellate dynamics may show the variations with the fluctuations of pH and transparency forming to blooms.

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Appendix 1. Systematic list of Dinoflagellates in Masan Bay, Korea

Phylum DINOPHYTA
Class DINOPHYCEAE Fritsch, 1929
Order Prorocentrales Lemmermann
Family Prorocentraceae Stein
Genus Prorocentrum Ehrenberg, 1833
Prorocentrum balticum (Lohmann) Loeblich III, 1970
P. dentatum Stein, 1883
P. micans Ehrenberg, 1833
P. minimum (Pavillard) Schiller, 1993
P. triestinum Schiller, 1918

Order Dinophysiales Lindemann
Family Dinophysiaceae (Bergh) Stein
Genus *Dinophysis* Ehrenberg, 1839
Dinophysis acuminata Claparede & Lachmann, 1959
D. fortii Pavillard
D. infundibulus Schiller
D. rotundata Claparede & Lachmann, 1859

Family Oxyphysaceae Sournia, 1984
Genus *Oxyphysis* Kofoid, 1926
Oxyphysis oxytoxoides Kofoid, 1926

Order Gymnodiniales Lemmermann
Family Gymnodiniaceae (Bergh) Lankaster
Genus *Amphidinium* Claparede & Lachmann, 1959
Amphidinium crassum Lochmann, 1908

Genus *Gymnodinium* Stein, 1878
Gymnodinium nagasakiense Takayama & Adachi, 1984
G. sanguineum Hirasaka, 1922

Genus *Gyrodinium* Kofoid & Swezy, 1921
Gyrodinium fissum Kofoid & Swezy, 1921

Family Polykrikaceae Kofoid & Swezy
Genus *Polykrikos* Butschli, 1873
Polykrikos schwarzii Butschli, 1873

Family Lophodiniaceae Tafall
Genus *Katodinium* Fott, 1957
Katodinium rotundatum (Lohmann) Loeblich, 1965

Order Noctilucales Haeckel
Family Noctilucaceae Kent
Genus *Noctiluca* Suriray ex Lamarck, 1816
Noctiluca scintillans (Macartney) Kofoid, 1920

Order Peridiniales Haeckel, 1894
Family Peridiniaceae Ehrenberg, 1832
Genus *Heterocapsa* Stein, 1883
Heterocapsa triquetra (Ehrenberg) stein, 1883

Genus *Diplopsalis* Bergh, 1882
Diplopsalis lenticula Bergh, 1882

Genus *Zygabikodinium* Loeblich & Loeblich III, 1970
Zygabikodinium lenticulatum (Paulsen) Loeblich & Loeblich III, 1970

Genus *Scrippsiella* Balech, 1959
Scrippsiella trochoidea (Stein) Loeblich III, 1976

Genus *Protoperidinium* Bergh, 1882
Protoperidinium avellana (Meunier) Balech, 1974
P. bipes (Paulsen) Balech, 1974
P. brevipes (Paulsen) Balech, 1974
P. Cerasus (Paulsen) Balech, 1973
P. conicum (Gram) Balech, 1974
P. curtipes (Jorgensen) Balech, 1974
P. depressum (Bailey) Balech, 1974
P. divergens (Ehrenberg) Balech, 1974
P. excentricum (Paulsen) Balech, 1974
P. granii (Ostenfeld) Balech, 1974
P. leonis (Pavillard) Balech, 1974
P. marielebouriae (Paulsen) Balech, 1974
P. minutum (Kofoid) Loeblich III, 1969
P. oblongum (Aurivillius) Parke & Dodge, 1976
P. pallidum (Ostenfeld) Balech, 1973
P. pellucidum Bergh, 1882
P. punctulatum (Paulsen) Balech, 1974
P. subinerme (Paulsen) Loeblich III, 1969
P. thorianum (Paulsen) Balech, 1973

Family Gonyaulacaceae Lindemann, 1928
Genus *Gonyaulax* Diesing, 1866
Gonyaulax diegensis Kofoid, 1911
G. digitale (Pouchet) Kofoid, 1911
G. grindleyi Reinecke, 1967
G. spinifera (Claparede & Lachmann) Diesing, 1866
G. triacantha Jorgensen, 1899
G. verior Sournia, 1973

Genus *Alexandrium* Halim 1960, emend. Balech
Alexandrium fratercula (Balech) Balech, 1985

Family Ceratiaceae Lindemann
Genus *Ceratium* Schrank, 1793
Ceratium furca (Ehrenberg) Claparede & Lachmann, 1858
C. fusus (Ehrenberg) Dujardin, 1841
C. kofoidii Jorgensen, 1911
C. macroceros (Ehrenberg) Vanhoffen, 1897
C. trichoceros (Ehrenberg) Kofoid, 1908

Order Blastodiniales
Family Dissodiniaceae
Genus *Dissodinium* Klebs in Pascher 1916
Dissodinium pseudolunula Swift ex Elbrachter & Drebes, 1978