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Seasonal Fluctuation of Zooplankton Community in Asan Bay, Korea

Keun-Hyung CHOI and Chul PARK
Department of Oceanography, Chungnam National University,
Taejon 305-764, Korea

About three fourths of total variability of zooplankton in Asan Bay was associated with season and the difference between inner bay and outer bay was relatively small. However, the differences in percent compositions of major taxa at inner bay and outer bay increased gradually with time, suggesting the change of ecosystem in this bay due to the human exploitation such as reclamation. Seasons of maximum abundances were different among the taxa but consistent for each taxon throughout the three survey years. *Calanus sinicus* and *Acartia bifilosa* showed maximum abundance in spring. *Sagitta crassa, Paracalanus parvus, A. pacifica, Tortanus spinicaudatus, Corycaeus affinis* and Decapoda larva were most abundant in summer. *Labidocera euchaeta* and Bivalve larva appeared most abundantly in fall. But in winter no taxon showed maximum. In general, low abundance with many species in fall, low abundance and few taxa in winter, increase in both number of taxa and abundance in spring, and high abundance and many taxa in summer were observed. A hypothesis for the observed patterns was suggested although more evidences were needed to support this.

Introduction

The human exploitation of coastal areas(e.g. reclamations and constructions of many industrial complexes) was known to cause the hydrologic conditions of the adjacent shallow waters changed in some degree, and in turn any of the components of coastal ecosystem would be changed whether those changes were negative or positive(Gabriel et al., 1975; Moon and Choi, 1991). Continued investigations on the hydrologic conditions and each component of the ecosystem are necessary for the monitoring of those changes. However, studying every environmental factors and components of the ecosystem is not easy.

On the contrary, since plankton communities, which may be influenced first by the changes in hydrologic conditions, are basis for the higher trophic levels, monitoring any changes in plankton community can be more informative for the changes in ecosystem(Lee, 1970; Reid, 1975; Lee and Ramster, 1977). In this respect, we focused on zooplankton distribution in Asan Bay where construction of many industrial complexes and reclamation were under way.

Asan Bay is a spawning and nursery ground for various commercial fishes. Previous studies around the Asan Bay include Park(1990), Park et al. (1991), and Moon et al.(1993). Park(1990) has shown the importance of the replicate sampling, of understanding seawater movement in deciding the sampling sites, and of the day-night differences in zooplankton catches in this active tidal mixing bay. Moon et al.(1993) reported the distribution of nutrients, chlorophyll a, and particulate organic matters in this bay.

Following Park et al.(1991) which showed zooplankton species composition and abundance distri-

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bution in this bay, here we report the seasonal variations in major components of zooplankton from the data obtained each season for three consecutive years. Community analyses and comparison between the inner bay and outer bay are also done in this study.

Materials and Methods

Seasonal zooplankton samples were collected in Asan Bay, Korea(Fig. 1) for three years from fall of 1989 till summer of 1992. An open/closing "Bongo" net(mouth diameter 60㎝) fitted with 0.333 and 0.505㎜ mesh size nets on each side was used. It was towed obliquely at certain depths or whole water column. Tow speed and duration were about 1*m*/sec and 7~8minutes, respectively. Only one or three sampling sites were selected due to the strong tidal current in this bay. Three replicate samples were intended for each sampling unit.

In the first year(fall, 1989-summer, 1990) sampling was done only at Station 2 during Nov. 11~12, 1989, Feb. 27~28, May 26~27, and Aug. 5~6, 1990. The net was towed during both day and night at depths of 0~5 and 5~10*m*(water depth, about 15*m*) obliquely. The time lag between the day and night sampling was kept to be about 12.5 hours to make the tidal phase be as equal as possible so that the distance between the centers of the moving water parcels sampled at day and night was minimized. It was not only because the day-night difference could be interpreted in terms of locality unless the same water mass was sampled, but also because it was practically diffcult to deploy a marker buoy in this bay of shallow and active tidal mixing. This effort for the sampling the same water mass was effective in this area(Park, 1990). The period around dusk was avoided to minimize variation caused by the vertical migration of zooplankton (Park et al., 1991).

Examining the data from the first year samples, we changed the sampling scheme in the second and third year. That is, sampling was done at three stations(Fig. 1) only during the daytime and the net was towed obliquely for whole water column (water depths, 7~8*m* at Station 1, about 25*m* at Station 3). It was for the comparison between the inner and outer bay and eliminating the effect of the vertical migration of zooplankton from the sources of variability. Sampling dates were Nov. 4, 1990, Feb. 21, May 5, Aug. 13, Nov. 12, 1991, Feb. 18, May 18, and Aug. 18, 1992.

Samples were fixed and preserved with buffered formalin(pH 8, 4%). A Folsom Plankton Splitter was used to split the samples into subsamples of countable size. Each subsample containing about 1000~1500 individuals by subsampling was counted under a dissecting microscope with identification to possible lowest taxon.

Analysis of variance(ANOVA) was done for the detection of any significant differences among the stations, seasons, and interaction of these two with total abundances, and abundances of the major taxa. The abundance data were transformed to $\log_{10}$ (abundance + 1) when homoscedasticity assumption for the ANOVA was considered to be violated. Violation of this assumption was examined by the plot of residuals against the predicted values. To examine the relationship among the major taxa, correlation coefficients of abundances and percent composition were obtained and cluster analysis based on percent composition was done. Factor anlyses was done for examining the variance structure. STATGRAFICS(1986) was used for data processing.

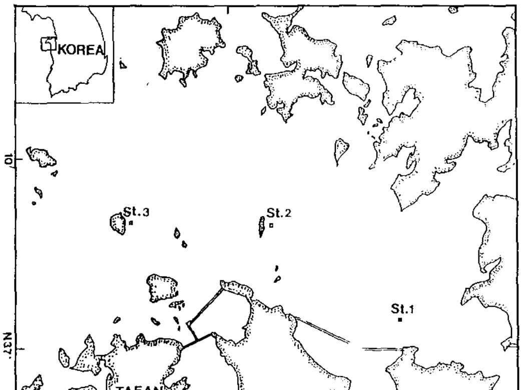


Fig. 1. Map showing Asan Bay and sampling sites.

Results

Environmental conditions

Seawater temperatures and salinities measured at the same time with the collection of zooplankton were summarized in Table 1. Seasonal temperature fluctuations showed the typical pattern in temperate seas. Temperature differences among the stations within the same season were negligible with the biggest of 1.3℃(winter, 1991). It was expected from the fact that the distances between the two adjacent stations were about the same with or a little greater than the estimated distances travelled by the water parcel sampled at one station for one tidal period. (According to the Office of Hydrographic Affairs (1992), average tidal current was about 2.0 Knot and tidal period was about 12.5 hours.) Although average temperatures varied from 14.3℃ (1st year) to 14.8℃(2nd year), and then to 12.9℃ (3rd year), it was difficult to impose any statistical meaning on year-to-year variation due to the small number of the measurements.

Seasonal and year-to-year salinity variations were minor in this area with the range of 29.1~31.8‰. However, there was a tendency of small salinity increase from Station 1 (inner bay) toward Station 3 (outer bay) though it might not be statistically significant. These results suggested that the effect of freshwater input was weak. Sporadic opening of the sluice of the Asan Barrage seemed to be the only cause of salinity variation other than the rainfall in this area (Moon et al., 1993).

Total abundance and number of taxa observed

From the total of 199 samples (only from 0.333 ㎜ mesh net) 62 taxa were identified. *Noctiluca scintillans* was not included not only because of its large variation in abundances due to the clogging effect of the net but also because of its taxonomic position, Dinoflagellate.

The numbers of taxa observed in each season were given in Table 2 with the number of replicate samples in parenthesis. There was no significant difference in the numbers of the taxa observed with regard to stations(ANOVA, P>0.05). But the difference with season was significant(ANOVA, P< 0.02). Usually total numbers of taxa observed were larger in summer and fall, then sharply reduced in winter, and gradually increased again in spring.

Seasonal total abundances at each station were shown in Fig. 2. With regard to the stations(second and third year data only), total abundance at the inner bay stations was usually greater than that at the outer bay station(ANOVA, p<0.02). When examined for each season, there was no difference in total abundance among the stations in fall and winter. In spring, total abundances were much larger at the inner bay stations. However, total abundances in summer were not consistent between the second and third survey years. That is, it was the biggest at the midbay station in the second year while it was the biggest at the inner bay station in the third year(Fig. 2).

When all the data from three stations were pooled, total abundances were small in fall and winter, and greatly increased in spring and summer. Maximum appeared at inner and outer bay stations in spring, but it appeared at midbay station in summer. Total abundances and the numbers of taxa appeared in each season were summarized in Fig. 3.

Table 1. Sea water temperature and salinity in Asan Bay, Korea (F: Fall, W: Winter, Sp: Spring, Sm: Summer).

Year		'89	'90				'91				'92		
Season		F	W	Sp	Sm	F	W	Sp	Sm	F	W	Sp	Sm
Temperature (℃)	St.1					17.3	1.2	15.5	23.1	12.3	2.2	14.0	24.4
	St.2	13.4	4.2	14.5	25.0	18.2	2.4	15.6	23.8	12.4	2.1	12.9	23.5
	St.3					18.4	2.5	15.6	24.2	12.6	2.4	12.9	23.5
Salinity (‰)	St.1					30.0	30.5	29.1	30.9	30.7	31.6	31.1	30.7
	St.2	30.4	30.6	30.7	–	30.2	30.9	30.3	31.2	30.9	31.7	31.3	31.0
	St.3					30.3	31.0	30.4	31.4	31.2	31.8	31.4	31.3

Table 2. Total number of zooplankton taxa observed in Asan Bay, Korea with the number of replicate samples in parenthesis (F: Fall, W: Winter, Sp: Spring, Sm: Summer).

Year	'89	'90				'91				'92		
Season	F	W	Sp	Sm	F	W	Sp	Sm	F	W	Sp	Sm
St.1					31	13	17	27	29	19	24	26
					(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
St.2	42	24	28	38	29	13	17	32	25	18	20	27
	(14)	(12)	(17)	(12)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
St.3					29	13	17	30	29	21	21	31
					(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Total	42	24	28	38	33	16	22	35	35	23	26	34
	(14)	(12)	(17)	(12)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)

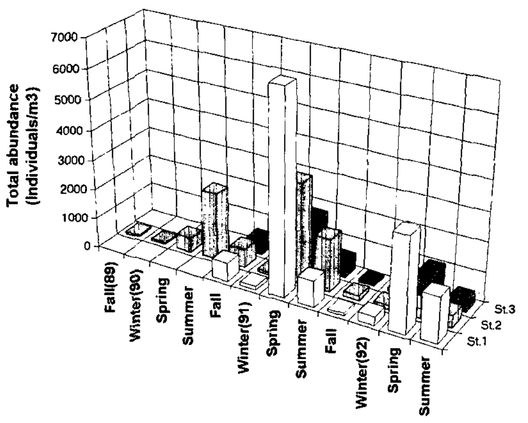


Fig. 2. Distribution of mean total abundance of zooplankton at each sampling site during the survey.

Year-to-year variation in total abundance(pooled data of 4 seasons) is shown in Fig. 4. This trend was the same whether the data from different stations were pooled or not. Although year-to-year variation in total abundances was statistically marginal ($p<0.05$) with the high abundance in the second survey year, it was difficult to say about annual variation due to the small number of samples, three years.

Distribution of the major taxa

With the data from the second and third survey years, statistical significance of differences in abundances among the seasons, stations, and interactions between these two were examined by analysis of variance(ANOVA) for 9 major taxa of which average percent compositions were greater than 1 %. *Evadne tergestina* and *Acartia pacifica* were not included though average percent compositions were >1% because their occurrences were mainly confined in summer. ANOVA model used was:

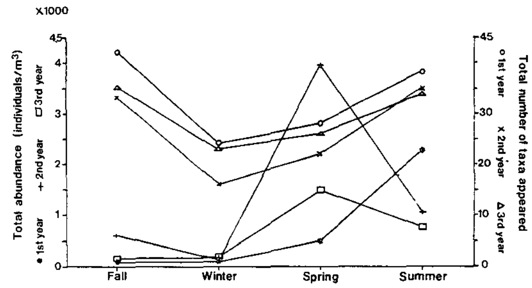


Fig. 3. Seasonal variation of total number of taxa appeared and mean total abundance within each survey year.

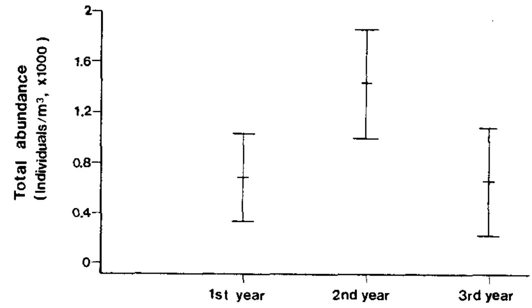


Fig. 4. Mean of total zooplankton abundance at each year with the confidence intervals (95%).

$Y_{ijk} = u + a_i + b_j + (ab)_{ij} + e_{ijk}$.

where Y_{ijk} was the abundance of a taxon from ith season, jth station, and kth replicate tow. u was the overall mean, a_i was the effect of ith season($i=1,2,3$, and 4 for spring, summer, fall, and winter), b_j was the effect of jth station($j=1,2$, and 3 for Station 1,2, 3). $(ab)_{ij}$ was the interaction between ith season and jth station, and e_{ijk} was error associated with ith season, jth station, and kth replicate tow($k=1,2,3$). Results of ANOVA were given in Table 3.

Like total abundance, abundances of major taxa showed marked abundance variation with seasons and stations. Interactions between season and station were significant in more than half cases(Table 3). Seasonal variations in abundances were significant in most cases but spatial differences within the season were hard to conclude due to the significant interactions between the season and station. This significance of interaction could be interpreted as spatial shift of the centers of distribution with seasons. Details of spatial and temporal changes in abundance of each taxon follow with Figures 5a-i. As shown in those figures, abundance variations were found to be much larger with respect to season than with regard to stations and survey years. Six taxa, *Sagitta crassa, Calanus sinicus, Paracalanus parvus, Acartia bifilosa, Corycaeus affinis*, and Decapoda larva occurred throughout the whole survey period at all stations, and five taxa, Bivalve larva, *C. sinicus, Labidocera euchaeta, A bifilosa,* and *Tortanus spinicaudatus,* showed the same pattern of yearly variation with total abundance.

Bivalve larva(Fig. 5a): This taxon showed high abundances during the summer and fall and low abundances during the winter. But abundances during the abundant seasons decreased with survey year and no appearance in the summer of the third survey year was observed. Seasonal difference in abundance with respect to stations was clear in the third year as shown in ANOVA result (Table 3) and Fig. 5a. However, the pattern of spatial shift of the center of distribution with season was not easy to detect due to the small number of sampling events. In the sense that this taxon might be impo-

Table 3. Summary of ANOVA results with the model given in the text. No significant difference in abundances with respect to the effect of concern at $\alpha=0.05$ level is noted as NS and significant difference as p-value. Log transformation is indicated with *.

Taxon	Sampling time	Season	Station	Interaction between season & station
Bivalve larva	2nd year	$p<0.01$	NS	NS
	3rd year	$p<0.01$	$p<0.04$	$p<0.01$
S. crassa	2nd year	$p<0.01$	NS	NS
	3rd year	$p<0.01$	$p<0.01$	$p<0.01$
C. sinicus	2nd year	$p<0.01$	NS	NS
	3rd year	$p<0.01$	NS	$p<0.02$
P. parvus	2nd year*	$p<0.01$	$p<0.01$	$p<0.01$
	3rd year	NS	NS	NS
L. euchaeta	2nd year	$p<0.01$	NS	$p<0.01$
	3rd year	$p<0.01$	NS	NS
A. bifilosa	2nd year	$p<0.01$	$p<0.01$	$p<0.01$
	3rd year*	$p<0.01$	$p<0.01$	$p<0.01$
T. spinicaudatus	2nd year	$p<0.01$	$p<0.02$	$p<0.01$
	3rd year	$p<0.04$	NS	NS
C. affinis	2nd year*	$p<0.01$	$p<0.01$	$p<0.01$
	3rd year	$p<0.01$	NS	NS
Decapoda larva	2nd year*	$p<0.01$	NS($p<0.06$)	$p<0.03$
	3rd year	$p<0.01$	$p<0.01$	$p<0.01$

rtant commercially in this region, the detection of this pattern and annual fluctuation was desired with continued sampling for longer period.

Sagitta crassa (Fig. 5b): In all three years the abundance decreased from fall to winter, and recovered in spring, and then reached at maximum in summer. Spatial difference was not significant in the second year but significant in the third year with higher abundances at inner bay station. When the data from Station 2 were used, there was no significant year-to-year variation. But when the data from other stations were pooled together annual increase of this species was observed. In other words, annual increase was reflected in abundance at inner bay station only.

Calanus sinicus (Fig. 5c): Like *S. crassa*, this taxon showed consistent seasonal pattern in abundance through the three survey years. Unlike *S. crassa*, however, maximum abundance appeared in spring and spatial difference in each season was not significant (Table 3). Year-to-year variation was the same pattern with that of total abundance shown in Fig. 3.

Paracalanus parvus (Fig. 5d): Seasonal fluctuation of the abundance of this taxon, of which the name was in controversy (as *P. indicus*), was the same pattern with that of *S. crassa* except that the maximum summer peak was not observed in the third survey year. Abundances in the first summer (683 ind. m^{-3}) and the second summer (850 ind. m^{-3}) were larger than those in the third summer (16 ind. m^{-3}) by more than an order of magnitude. On the contrary, the summer peak was the highest in the third year in case of *S. crassa*. Abundance differences of *P. parvus* among the stations was not significant in that year.

Labidocera euchaeta (Fig. 5e): The abundance was maximum in fall throughout the three survey years like Bivalve larva. But unlike Bivalve larva winter abundance was larger than those of spring and summer in all three years. No significant station to station difference was found in case of this species.

Acartia bifilosa (Fig. 5f): This species, formerly misidentified as *A. omorii* by Park et al.(1991), was one of the most abundant taxa in this bay as noted by the scale of the vertical bar in Fig. 5f. Seasonal distribution pattern was similar to that of *C. sinicus* with the peak abundance in spring. The difference between these two taxa was that *A. bifilosa* was the more abundant at inner bay station while *C. sinicus* did not show any difference among the stations.

Tortanus spinicaudatus (Fig. 5g): This taxon showed maximum abundance in summer like *Sagitta crassa* and *Paracalanus parvus*. But unlike those species this species totally disappeared in winter. Spatially this species was more abundant at the inner bay station as in case of *A. bifilosa*, though statistically not significant in case of the third survey year.

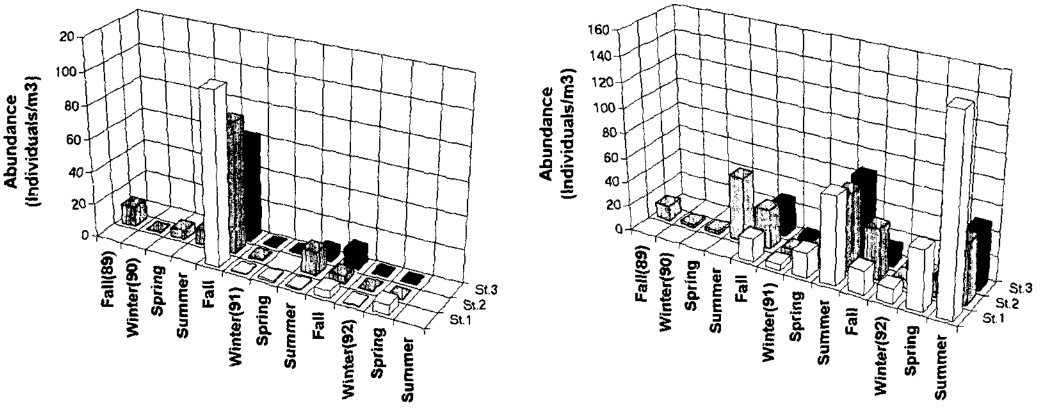
Corycaeus affinis (Fig. 5h): It appeared through the whole survey periods at all stations. Year-to-year variation was small with the summer maximum abundance within a year. Spatial shift of the center of the distribution with season was observed in the second survey year but not in the third year.

Decapoda larva (Fig. 5i): The abundance was extremely low during fall and winter. Then it gradually increased in spring and reached at maximum in summer. Year-to-year variation was not significant, but summer abundance at the midbay station decreased gradually in contrast to the gradual increase at the inner bay station.

Seasonal variations of these major taxa were summarized in Table 4. *Acartia pacifica* was included in the table though its abundance was not mentioned above. It was because its abundance was important in summer with percent composition of 17.4% (Table 5) in spite of total disappearance during winter and spring. *C. sinicus* and *A. bifilosa* showed maximum abundances in spring while Bivalve larva and *L. euchaeta* were at maximum in fall. Other taxa, *S. crassa, P. parvus, A. pacifica, T. spinicaudatus, C. affinis,* and Decapoda larva, were most abundant in summer. In winter, all the major taxa showed low abundances or absence.

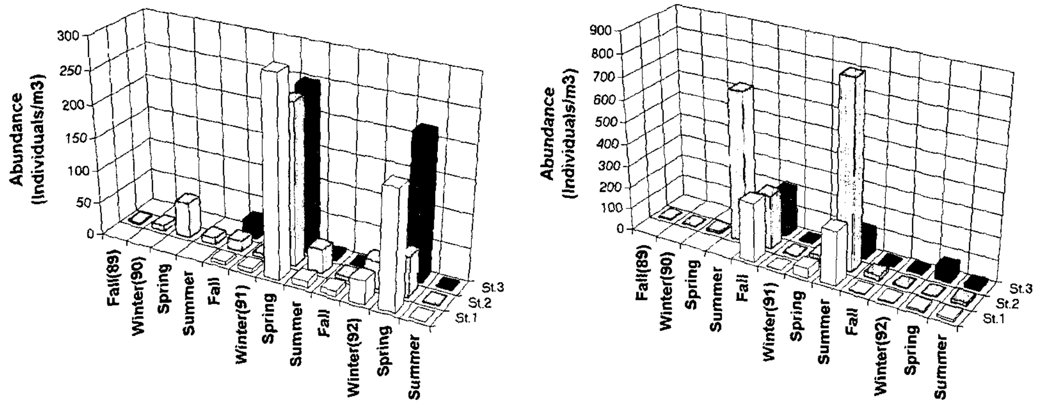
Percent composition and species association

Percent compositions of the major taxa are given in Table 5. During summer and fall when zooplankton was abundant, percent compositions were relatively evenly distributed. In winter and spring si-



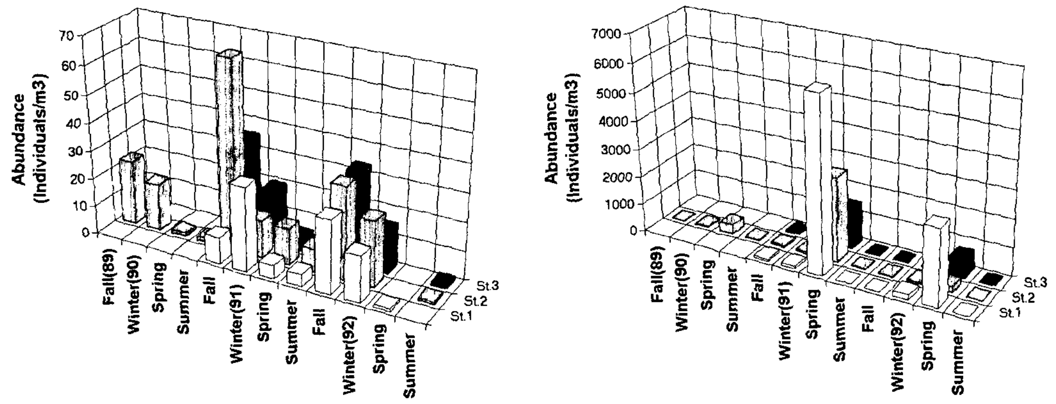
(a) **Bivalve larva**

(b) ***Sagitta crassa***



(c) ***Calanus sinicus***

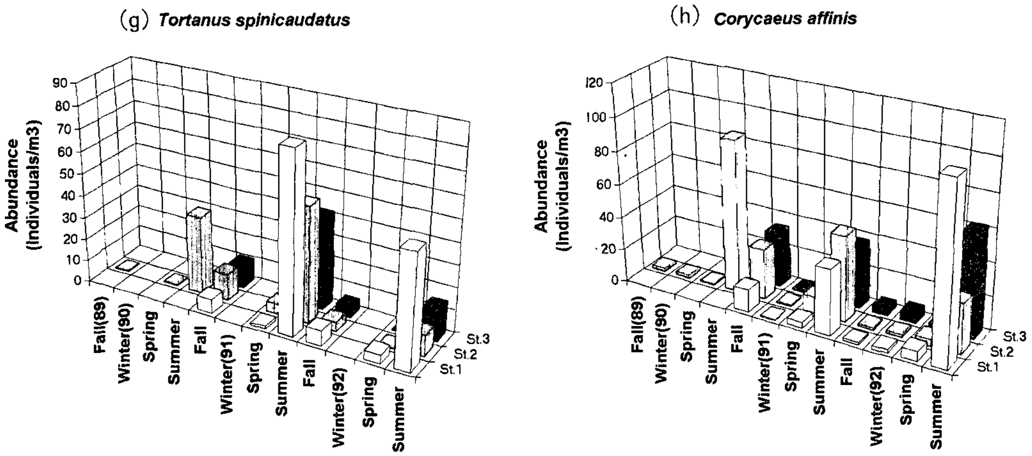
(d) ***Paracalanus parvus***



(e) ***Labidocera euchaeta***

(f) ***Acartia bifilosa***

Fig. 5. a~f. Distribution of mean zooplankton abundances of major taxa.



(g) *Tortanus spinicaudatus*

(h) *Corycaeus affinis*

(i) **Decapoda larva**

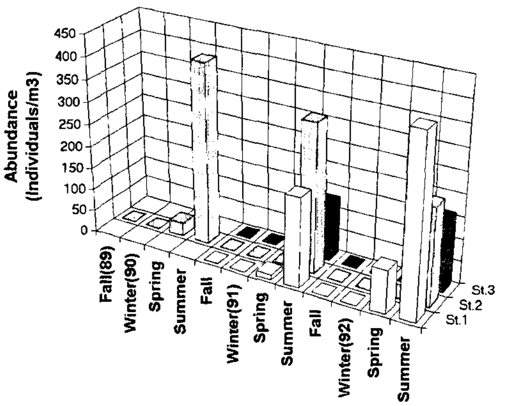


Fig. 5. g~i. Distribution of mean zooplankton abundances of major taxa.

Table 4. Seasonal abundance of zooplankton in Asan Bay, Korea.
***=maximum, **=moderately abundant, *=a few, blank=none.

Taxon	Spring	Summer	Fall	Winter
Bivalve larva	*	**	***	*
S. crassa	**	***	**	*
C. sinicus	***	*	*	**
P. parvus	**	***	**	*
L. euchaeta	*	*	***	**
A. bifilosa	***	*	**	**
A. pacifica		***	*	
T. spinicaudatus	**	***	**	
C. affinis	*	***	**	*
Decapoda larva	**	***	*	*

Table 5. Percent composition (%) of major zooplankton in Asan Bay, Korea. Data are pooled from all three survey years.

Taxon	Fall	Winter	Spring	Summer
Bivalve larva	13.1	<<1	<<1	<<1
S. crassa	7.7	4.7	0.6	6.5
C. sinicus	3.2	14.4	7.7	<<1
P. parvus	35.7	2.3	1.2	24.8
L. euchaeta	10.6	14.5	<<1	<<1
A. bifilosa	10.8	57.4	86.6	0.7
A. pacifica	<<1	–	–	17.4
C. affinis	4.0	1.5	<<1	5.4
Decapoda larva	<<1	<<1	0.9	23.7

ngle taxon, *Acartia bifilosa*, occupied more than half of the total abundance (in numbers). It was 57.4% in winter and 86.6% in spring. This may indicate that the ecological stability is higher in summer and fall than in winter and spring from the concept of evenness.

Meanwhile, it could be seen that differences in percent composition between Station 1 and Station 3 gradually increased with time (Table 6). It may indicate that ecosystem in this bay is under process of change probably due to the exploitation of the coastal environment such as reclamation. For the monitoring of the possible changes, however, more information based on long-term data aquisition is required.

Pearson correlation coefficients among the major

Table 6. Comparison of percent composition of major zooplankton. Only more than 10% of total abundance at any of the two stations 1 and 3 are listed (F: Fall, W: Winter, Sp: Spring, Sm: Summer).

Year		'90	'91				'92		
Season		F	W	Sp	Sm	F	W	Sp	Sm
Bivalve larva	St.1	16.6				5.2			
	St.3	12.7				13.2			
S. crassa	St.1				3.0	22.6			10.2
	St.3				11.8	14.9			12.0
C. sinicus	St.1						12.6	5.7	
	St.3						24.9	21.2	
P. parvus	St.1	43.1			28.4				
	St.3	42.1			21.2				
L. euchaeta	St.1		22.6			30.1	5.9		
	St.3		20.1			39.6	14.1		
A. bifilosa	St.1	12.4	66.7	92.5			62.7	86.0	
	St.3	10.3	64.3	80.7			39.2	66.9	
A. pacifica	St.1				9.8				47.2
	St.3				15.6				8.9
C. affinis	St.1								7.0
	St.3								15.4
Decapoda larva	St.1				23.1				26.4
	St.3				23.4				39.8

taxa based on both abundances and percent compositions were examined (Table 7). Those taxa occurred most abundantly in the same season showed positive correlations. (e.g. *C. sinicus* and *A. bifilosa,* both showed maximum abundance in spring, were positively correlated both in numbers (r=0.80) and in percent composition (r=0.67).) On the other hand, there were negative or no significant correlations between the major taxa that occurred abundantly in different seasons, in general. From the clustering based on percent composition, Fig. 6 was obtained. This clustering was compatible with the summary in Table 4, though not perfectly matched.

Factor analysis based on the correlation coefficients of abundances showed the importance of seasonal change (Table 8). The first three factors explained about 75% of total variability. Those taxa occurred mostly in summer were highly associated with the first factor which explained about 43% of total variability. *C. sinicus* and *A. bifilosa,* most abundant in spring, were highly associated with the second factor. Bivalve larva and *L. euchaeta,* showing maximum abundance in fall, showed relative high factor loadings on factor 3. These results indicate that seasonal variation was the major source of zooplankton variation in this bay.

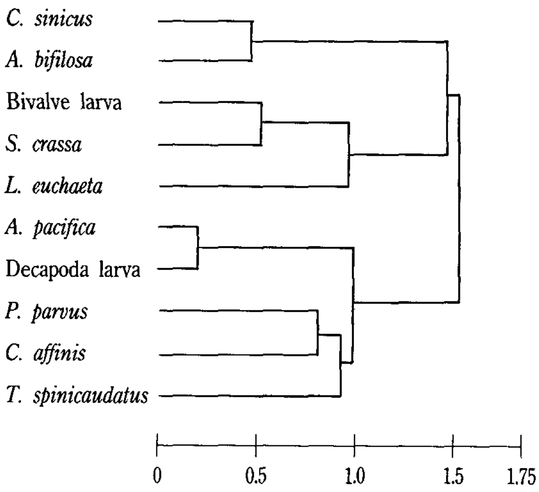


Fig. 6. Euclidian distance between clusters, average linkage.

Table 7. Pearson correlation coefficients of the abundances(upper-right diagonal) and percent composition (lower-left diagonal) of 10 major taxa. NS stands for no significance at $\alpha=0.05$ level.

	Bivalve *larva*	*S. crassa*	*C. sinicus*	*P. parvus*	*L. euchaeta*	*A. bifilosa*	*A. pacifica*	*T. spinicaudatus*	*C. affinis*	Decapoda *larva*
Bivalve larva		NS	NS	0.1847	0.3478	NS	NS	NS	NS	NS
S. crassa	0.5948		NS	0.3261	NS	NS	0.7778	0.7922	0.7401	0.7050
C. sinicus	NS	NS		NS	-0.1941	0.8038	NS	-0.1821	-0.1855	NS
P. parvus	NS	NS	NS		NS	NS	0.3766	0.4802	0.6381	0.5249
L. euchaeta	0.5771	0.7045	NS	NS		NS	-0.2211	-0.1859	-0.1980	-0.3065
A. bifilosa	NS	-0.6429	0.6741	-0.5968	NS		NS	NS	NS	NS
A. pacifica	NS	NS	-0.5750	NS	NS	NS		0.5747	0.6209	0.7033
T. spinicaudatus	NS	NS	-0.5690	NS	NS	-0.6737	NS		0.7563	0.6760
C. affinis	NS	NS	-0.5672	NS	NS	-0.7660	0.8592	NS		0.7587
Decapoda larva	NS	NS	-0.5698	NS	NS	NS	0.9905	NS	0.8161	

Discussion

Most of previous studies on the distribution of zooplankton in the Western coastal areas of Korea were based on the data obtained by vertical or horizontal towing of nets without replicate sampling (Hwang and Choi, 1993; Park, 1990 and references therein). Thses sampling schemes, considering the ecological and behavioral charateristics of zooplankton such as vertical migration and patchy distribu-

Table 8. Factor pattern and proportion of variance explained by each factor resulting from the factor analysis.

Taxon	Factor 1	Factor 2	Factor 3	Factor 4
Bivalve larva	0.0308	-0.4474	0.7446	0.0978
S. crassa	0.8664	0.0959	0.0780	-0.4035
C. sinicus	-0.2744	0.8420	0.3421	-0.0004
P. parvus	0.6350	-0.0481	0.3151	0.5904
L. euchaeta	-0.2581	-0.5478	0.4920	-0.4219
A. bifilosa	-0.2223	0.8261	0.4039	-0.1193
A. pacifica	0.8135	0.0981	-0.0935	-0.2646
T. spinicaudatus	0.8595	0.0357	0.0532	-0.0970
C. affinis	0.9001	0.0241	0.1138	0.1030
Decapoda larva	0.8794	0.1164	-0.0593	0.0478
Proportion(%)of variance explained by each factor	43.3	19.3	12.1	8.1

tion, were considered not sufficient for the unbiased estimates of biomass (Wiebe and Holland, 1968; Park, 1989, 1990; Park et al., 1989). For this reason, oblique towing at certain depth strata or whole water depth with at least three replicate samples were intended in this study. Also the number of stations selected in the second and third survey year was restricted to 3 because of the active water movement by tide (Park, 1989). In this sense we assume that sampling error was minimized enough so that the sources of variations shown in the present study could be considered as year-to-year variation, seasonal variation, and spatial variation within each season.

Total numbers of taxa observed varied with seasons. Similar trends were also shown in nearby bays with similar taxonomic levels of identification (Kim and Huh, 1983; Shim and Yun, 1990; Suh et al., 1991). Total abundances were also about the same orders with (Suh et al., 1991) or a little lower than the previous report (Kim and Huh, 1983) from the bays of west coast of Korea, although complete comparisons were difficult due to the differences in sampling scheme.

On the contrary, phytoplankton biomass in this bay (in terms of chlorophyll a, Moon et al., 1993) was reproted to be much lower than that in nearby Chunsu bay (Shim and Shin, 1989; Shin et al., 1990). In addition, Moon et al.(1993) suggested that phytoplankton in this bay was physiologically not in good condition. About the same biomass of zooplankton and lesser phytoplankton biomass with unfavorable physiological condition may imply that zooplankton in this bay depends their food on nonliving particulate organic matters to some extent. Food content of zooplankton needs to be studied to elucidate this possibility. Without this kind of study, it is difficult to figure out the reasons for the seasonal, and local variation with season in zooplankton in this bay. Simple contrast of the zooplankton variation with seasonal fluctuation in environmental factors such as temperature can not offer any meaningful explanations on the reasons of seasonal variation in zooplankton distribution. In this sense, details on mechanism of seasonal variation of zooplankton remain for further study and the present study is confined in reporting the patterns as shown in Table 4.

Total abundance in the second survey year was about twofold of that in the first and third survey year (Fig. 3). Single species, *A. bifilosa,* was almost responsible for this variation (Fig. 5f). In this sense knowledge on the biology of this species was required to understand the impact of environmental changes on ecosystem of this bay caused by human exploitation such as reclamation. Evidence of change in this bay ecosystem was added by the fact that the differences in percent compositions of major taxa at inner bay station and outer bay station became greater as time passed (Table 6).

Percent compositions in fall were relatively evenly distributed (Table 5). In winter dominance of one taxon, *A. bifilosa*, appeared and this dominance became more marked in spring. Then in summer, the percent compositions distributed evenly again. This pattern of change in percent composition, along with the seasonal fluctuation of abundances, made the following scenario possible. Relatively stable zooplankton community in fall showed high diversity but low abundance (Fig. 3 and Table 5) probably due to the low concentration of biogenic materials (Moon et al., 1993). As the environment became worse with low temperature and low phytoplankton biomass in winter (Moon et al., 1993), zooplankton abundance remained low and dominance of a few taxa appeared. When the environmental conditions were getting better with seasonal warming and phytoplankton bloom in spring, well-adapted taxon, *A. bifilosa,* abruptly increased resulting in high abundance and low diversity. Then in summer, many zooplanktons depending on phytoplankton as well as non-living detritus (despite decrease in biomass of phytoplankton), greatly flourished and maximum in abundance within year and relatively high evenness resulted. In fall, abundance decreased with the exploitation of food, but high diversity remained. To test this scenario, however, studies on feeding behavior, growth, and life cycle of each taxon as well as phytoplankton dynamics are needed. It is because, for example, we do not know yet whether the spring increase of *A. bifilosa* was a result of immigration to the bay system or of growth from the diapause stage within the bay.

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아산만 동물플랑크톤 군집의 계절변화

최근형 · 박 철
충남대학교 해양학과

아산만 동물플랑크톤 변이의 약 3/4 가량이 계절에 따른 변이로 파악되었으며 만의 안쪽과 바깥쪽의 차이는 상대적으로 매우 작았다. 그러나 만의 안쪽과 바깥쪽에서의 주요종의 조성율 차이가 시간의 경과에 따라 점차 커지고 있어 방조제 건설 등에 따른 변화가 진행되고 있는 것 같았다. 조사 기간 3년 동안 종별로 가장 많이 출현하는 계절이 서로 달랐으나 각종이 가장 많이 출현하는 계절은 3년 계속 일치하고 있었다. *Calanus sinicus*와 *Acartia bifilosa*는 봄철에, *Sagitta crassa, Paracalanus parvus, Acartia pacifica, Tortanus spinicaudatus, Corycaeus affinis* 및 Decapoda larva는 여름철에, *Labidocera euchaeta*와 Bivalve larva는 가을철에 가장 많이 출현하였고 겨울철에 가장 많이 나타난 종은 없었다. 대체로 가을철에는 많은 종류가 적게 출현하고, 겨울철에는 종수와 양이 모두 적었고, 이들은 모두 봄에 증가하기 시작하여 여름철에는 많은 종이 모두 다량 출현하는 변화양상 이었다. 지지하는 증거는 불충분하지만 이러한 변화양상에 대한 가설을 제기하였다.