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Spring and Summer Zooplankton Community near Tongyeong and Namhaedo in the South Sea of Korea

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통영-남해도 주변해역의 봄-여름 동물플랑크톤 군집

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Abstract

The monthly variations of zooplankton community were investigated at 12 stations near Tongyeong and Namhaedo in the South Sea of Korea from April to July, 2012. Zooplankton samples were collected by a plankton net (RN80) from near the bottom to the surface. Zooplankton community consisted of 97 taxa, and the mean abundance ranged from 213 inds.m^{-3} in July to 426 inds.m^{-3} in April. Copepods constituted 38.98% of zooplankton abundance, and included 39 species. *Calanus sinicus, Corycaeus affinis, Paracalanus parvus* s.l., copepodids, *Evadne nordmonni, Podon leuckarti,* cirriped nauplii, *Muggiacea* sp., *Diphyes* sp., and *Zonosagitta bedoti* were dominant species. Of these, *Calanus sinicus* was the most abundant throughout the study period, being constituted 18.6% of total zooplankton abundance. The density variations of dominant species between stations and months were correlated with the environmental factors. Zooplankton community varied with by sampling months, being influenced by monthly oceanographic variations.

Key words: Abundance, Zooplankton community, Warm month, South Sea of Korea

Ⅰ. Introduction

Zooplankton play a crucial role in energy transfer in the marine ecosystem. They feed on bacteria, phytoplankton, detritus, and even nektonic organisms, serving as a basic food source for larval and juvenile fishes as well as carnivorous invertebrates (Fielding et al., 2007; Mackas & Tsuda, 1999). The pattern of zooplankton community is greatly influenced by the hydrographic conditions where they exist, and have been suggested to be biological indicators for water masses which affect marine ecosystem differently (Jang et al., 2012; Morioka, 1985; Park et al., 1998; Shim & Lee, 1986). Thus, the knowledge of zooplankton community is fundamental for understanding the plankton ecology, fisheries management and the mechanism by which physical

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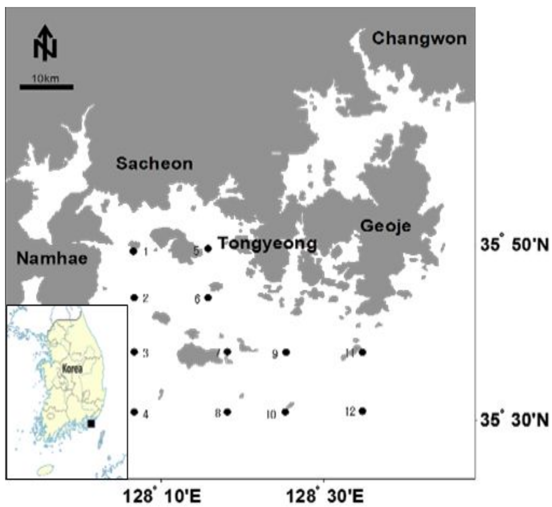
and biological process build marine ecosystems.

The South Sea of Korea is influenced by the Tsushima Warm Current, which is branched from the Kuroshio Current (Kondo, 1985). The warm current provides ideal nurseries, permanent habitats, and migration routes for many fish and shellfish (Chung & Yang, 1991; Lee, 2003). In this area, the abundance and distribution of zooplankton are sensitive to seasonal changes in different water masses (Jang et al., 2012), particularly by the Tsushima Warm Current (Kondo, 1985; Moon et al., 2010). The zooplankton community is characterized by the seasonal vertical distribution of copepod and water mass characteristics (Kang & Hong, 1995). In the southern coastal waters of Korea, zooplankton abundance is higher in winter than in summer, and is attributable to seasonal changes in temperature and salinity (Jang et al., 2012; Moon et al., 2010). Zooplankton diversity is high around the inner regions during summer, but it is relatively low in the outer regions in fall (Kim, 1984).

Tongyeong and Namhaedo of the South Sea of Korea is located at the pathway of the Tsushima Warm Current. The sea comprises numerous islands, which are highly productive. This area has also been known to be less polluted, comparing to the southern coastal waters of Korea (Lee, et al., 2001). The aims of this study were to investigate zooplankton community near Tongyeong and Namhaedo during warm months and to understand zooplankton community structure for changing environment conditions.

Ⅱ. Material and Methods

Zooplankton and physical environmental data were monthly collected at 12 stations near Tongyeong and Namhaedo in the South Sea of Korea from April to July 2012 ([Fig. 1]). At each station, the plankton net, RN80 (80 cm diameter net mouth; 330 μm mesh size) was deployed and retrieved once in a oblique fashion. A flow-meter was mounted in the net mouth to register the volume of water filtered during sampling. Temperatures and salinities were measured at sea surface (1 m depth) and sea bottom (40-50 m depth) using a handheld YSI 600XL (Multi-Parameter Water Quality Sonde). Samples were preserved in 5% buffered formalin aboard the ship and transported to laboratory. In the Laboratory, prior to determination of zooplankton biomass, the percentage of zooplankton and non-zooplankton were estimated with naked eyes. Large gelatinous taxa were removed to avoid bias of zooplankton biomass through scanning.



[Fig. 1] Location of sampling stations near Tongyeong and Namhaedo in the South Sea of Korea.

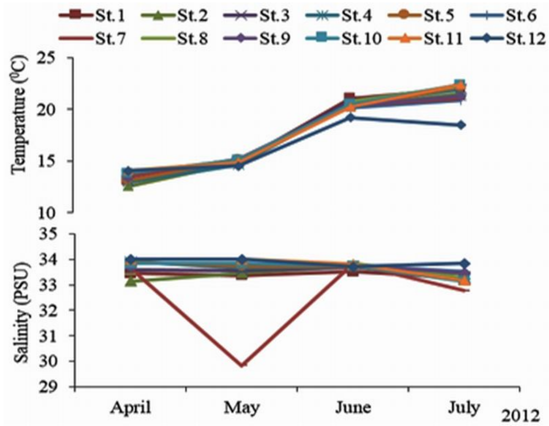
Displacement volume of total plankton was used as a proxy for biomass. Displacement volume was estimated by subtracting the volume of decanted liquid from the sample-liquid starting volume. Displacement volume was then converted to standing stock (ml.m^{-3}) by dividing by the volume of water filtered. Detailed species composition was determined by splitting samples with a Motoda type splitter to achieve the total count of 300-500 individuals under the microscope. All species in the splits were identified and enumerated to the lowest taxa, if possible. Densities (inds.m^{-3}) were calculated using the filtered volumes.

The zooplankton diversity was calculated by the given method of Shannon & Weaver (1949): $H = -\Sigma\ (ni/N) \times \log_2 (ni/N)$ − where, ni = the number of individuals of each species and N = total number of individuals. Community patterns were explored by the Primer (Version 6.1.12) to reveal patterns in zooplankton communities. Two dimensional and non-metrics of the multi-dimensional scaled (MDS) ordination plot of sampling by Bray-Curtis Cluster analysis, and SIMPER analysis were used to test the difference of zooplankton community between groups.

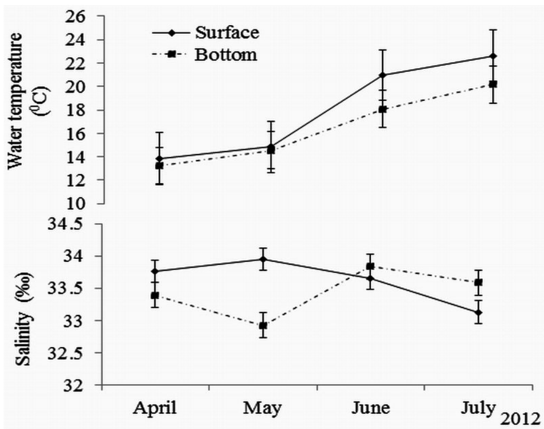
Ⅲ. Results

1. Environmental conditions

Sea water temperatures varied with sampling months and stations. Temperature increased during the sampling period from 12.6°C to 22.4°C. Temperature was lowest in April, and highest in July ([Fig. 2]). The sea surface temperature was slightly higher than the bottom water temperature and both varied monthly ([Fig. 3]). Salinity varied slightly by sampling months and stations with the range of 32.8 ~ 34.0 psu except the station 7 in May (29.8 psu) ([Fig. 2]).



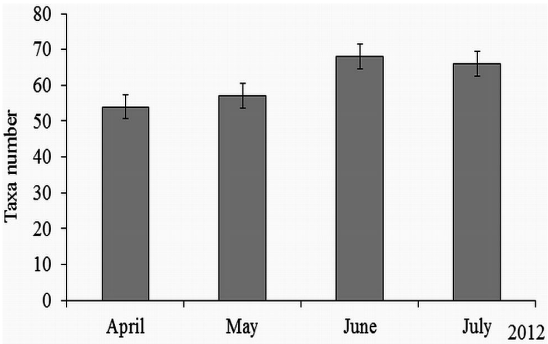
[Fig. 2] Monthly variation of temperature and salinity near Tongyeong and Namhaedo in the South Sea of Korea.



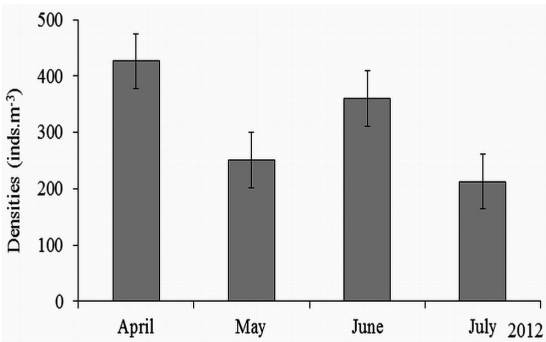
[Fig. 3] Monthly variation of temperature and salinity at the surface and bottom near Tongyeong and Namhaedo in the South Sea of Korea

2. Monthly variation of zooplankton community

A total of 97 taxa of 10 phyla of zooplankton was identified during the study period. The number of taxa was lowest in April (54 taxa), increased slightly in May, highest in June (68 taxa), and then decreased in July (66 taxa) ([Fig. 4]). Zooplankton density decreased gradually from April to July ([Fig. 5]).



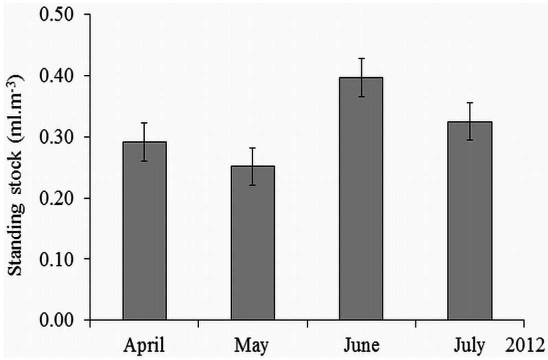
[Fig. 4] Monthly variation of zooplankton taxa near Tongyeong and Namhaedo in the South Sea of Korea



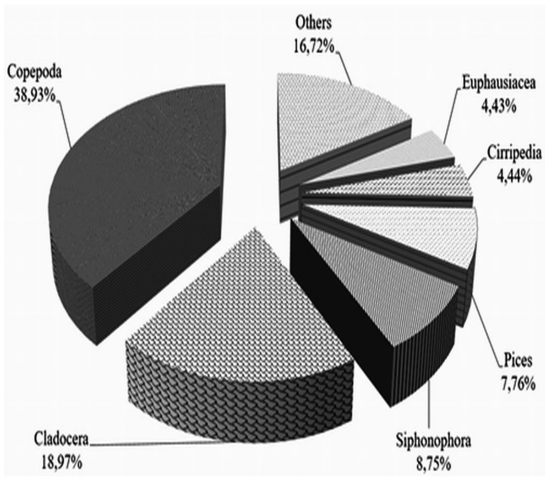
[Fig. 5] Monthly variation of zooplankton abundance near Tongyeong and Namhaedo in the South Sea of Korea

Mean zooplankton density ranged from 213 to 426 inds.m^{-3}. Zooplankton biomass (ml.m^{-3}) ranged from 0.25 to 0.49 ml.m^{-3}. Monthly biomass was highest in June and lowest in May ([Fig. 6]).

The major zooplankton groups at all stations during the study period were copepods, cladocerans, siphonophorans, euphausiids, and cirripeds ([Fig. 7]). The most dominant group was copepods at all stations. 37 taxonomic categories of copepods were identified.

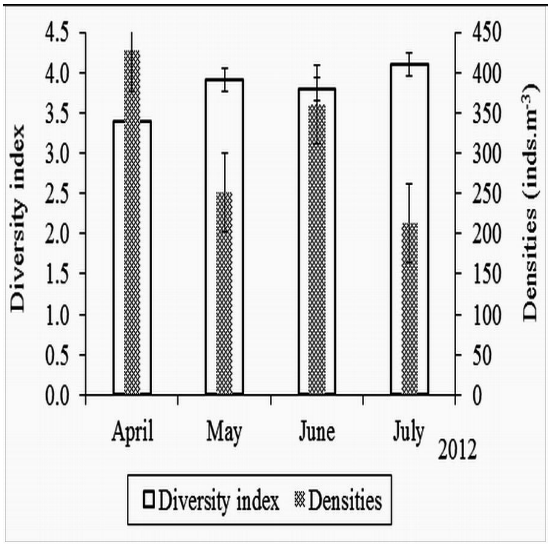


[Fig. 6] Monthly variation of zooplankton standing stock near Tongyeong and Namhaedo in the South Sea of Korea



[Fig. 7] Composition of zooplankton abundance near Tongyeong and Namhaedo in the South Sea of Korea

The diversity index of zooplankton was lowest in April (3.4) and highest in July (4.1) ([Fig. 8]). There were four major hierarchical clusters at 50% similarity by month (stress value = 0.17). Zooplankton densities at stations in June and July was strongly driving the pattern that separated from April and May, which had more similar abundance ([Fig. 10]).



[Fig. 8] Monthly variation of the species diversity and densities of zooplankton occurred near Tongyeong and Namhaedo in the South Sea of Korea

The most dominant species of zooplankton in the study period were *Calanus sinicus*, followed by *Corycaeus affinis*, *Paracalanus parvus* s.l., copepodid, *Evadne nordmonni*, *Podon leuckarti*, cirriped nauplius, *Muggiacea* sp., *Diphyes* sp., and *Zonosagitta bedoti* (<Table 1>, [Fig. 9]).

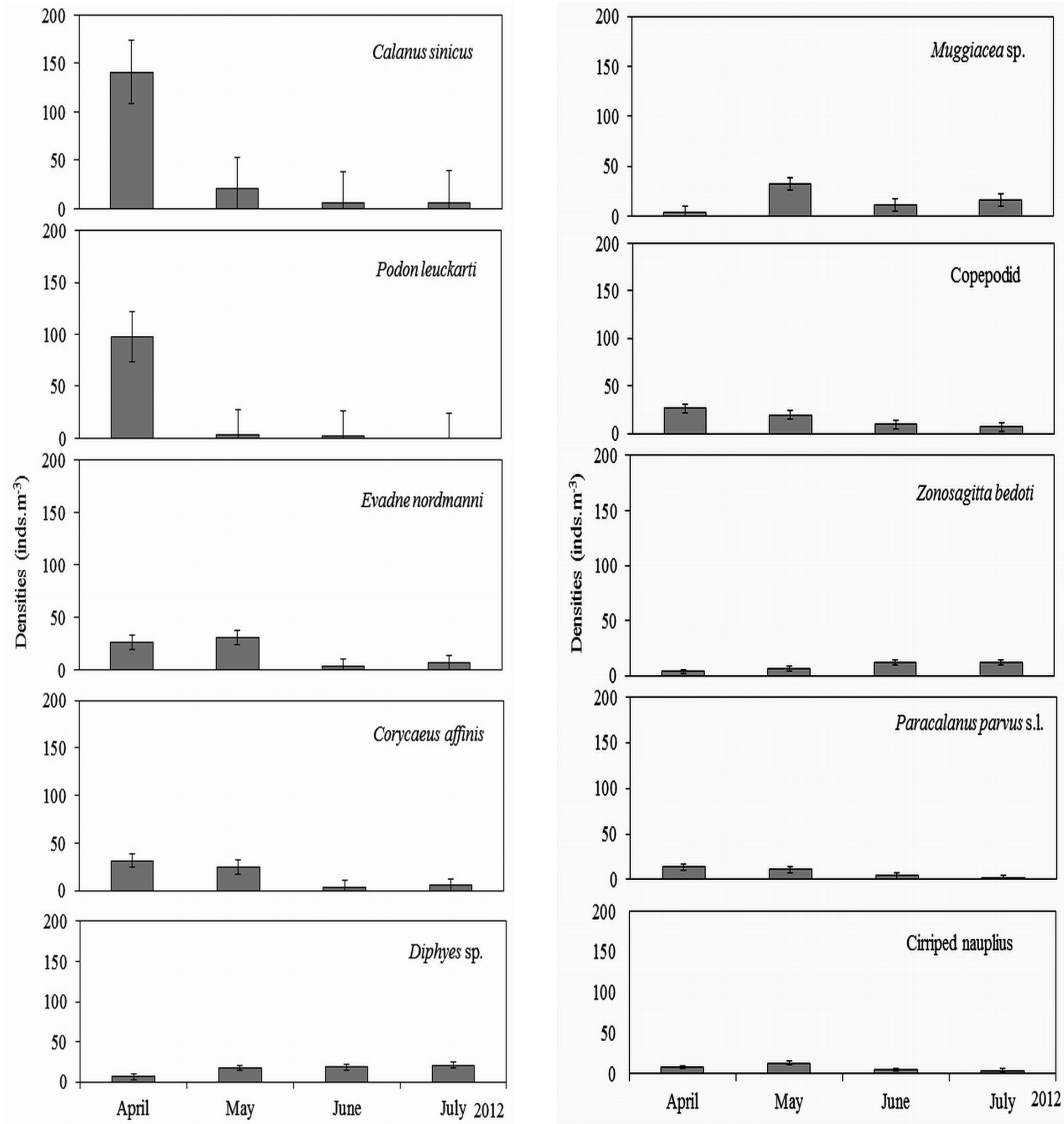
Densities of *Calanus sinicus* were highest with a range from 6 to 141 inds.m^{-3}. Those of *Podon leukarti* ranged from 0 to 97 inds.m^{-3}. Those of *Evadne nordmanni* ranged from 3 to 32 inds.m^{-3}. Those of *Corycaeus affinis* ranged from 4 to 32 inds.m^{-3}. Those of copepodite stages ranged from 7 to 26 inds.m^{-3} (9.0%). Those of cirriped nauplii were lowest, ranged from 4 to 13 inds.m^{-3} (<Table1>).

Densities of upper 10 dominant taxa varied by sampling month ([Fig. 9]). Densities of *Calanus sinicus*, *Corycaeus affinis*, *Paracalanus parvus* s.l., copepodid, *Evadne nordmanni*, *Podon leuckarti*, and cirriped nauplius declined gradually from April to July. However, densities of *Diphyes* sp., *Muggiacea* sp., and *Zonosagitta bedoti* increased slightly from April to July ([Fig. 9]).

<Table 1> Density and relative proportion of the dominant zooplankton taxa near Tongyeong and Namhaedo in the South Sea of Korea

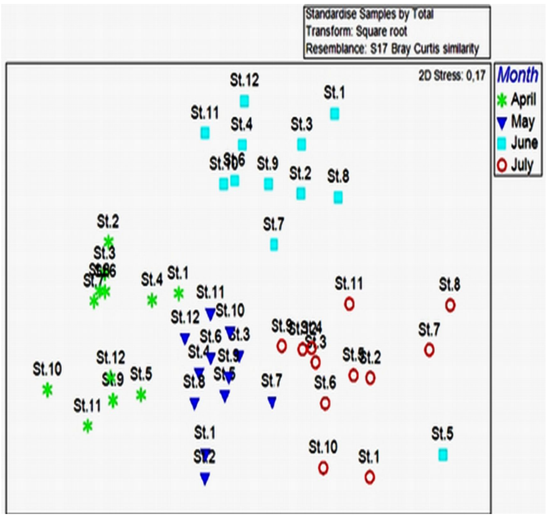
Rank	Species	Avr	Min	Max	SD	%
1	*Calanus sinicus*	43.2	5.8	140.9	65.5	25.1
2	*Podon leuckarti*	25.6	0.1	97.4	47.8	14.9
3	*Evadne nordmanni*	16.8	3.4	30.8	13.6	9.7
4	*Corycaeus affinis*	16.4	3.5	31.6	14.0	9.5
5	*Diphyes* sp.	15.8	6.4	21.0	6.4	9.2
6	*Muggiacea* sp.	15.7	3.1	32.5	12.4	9.1
7	Copepodid	15.4	6.8	26.4	9.1	9.0
8	*Sagitta bedoti*	8.6	3.6	12.1	4.2	5.0
9	*Paracalanus parvus* s.l.	7.4	1.4	13.5	5.7	4.3
10	Cirriped nauplius	7.3	4.0	12.7	3.9	4.3

Avr = Average density (inds.m^{-3})
SD = Standard deviation



[Fig. 9] Monthly variation of dominant taxa near Tongyeong and Namhaedo in the South Sea of Korea.

Densities of *Podon leuckarti*, *Calanus sinicus*, *Corycaeus affinis* and sea surface temperature were negatively correlated (r = -0.450; -0.453; -0.467; respectively; $p < 0.05$) (<Table 2>), but were not significantly correlated with salinity ($p > 0.05$). Density of *Zonosagitta bedoti* was positively correlated to sea surface temperature (r = 0.335; $p < 0.05$), but there was no significant relationship with salinity (r = 0.035; $p > 0.05$). There were no significant relationship between other dominant species and density, sea surface temperature, and salinity.



[Fig. 10] Two-dimensional non-metric MDS ordination plot of sampling date based on densities of zooplankton near Tongyeong and Namhaedo in the South Sea of Korea

<Table 2> Correlation between temperature and salinity and the abundance of dominant taxa (Pearson correlation analysis) near Tongyeong and Namhaedo in the South Sea of Korea

Parameters	Temperature		Salinity	
	r	p	r	p
Abundance				
Calanus sinicus	-0.453	0.002	0.057	0.710
Podon leuckarti	-0.450	0.007	0.023	0.882
Corycaeus affinis	-0.467	0.001	0.126	0.411
Copepodid	-0.103	0.500	0.135	0.376
Evadne nordmanni	0.008	0.959	-0.132	0.387
Paracalanus parvus s.l.	-0.003	0.985	0.230	0.129
Cirriped nauplius	0.069	0.653	0.076	0.622
Muggiacea sp.	-0.076	0.619	-0.503	0.000
Diphyes sp.	0.176	0.247	-0.288	0.056
Zonosagitta bedoti	0.355	0.017	0.035	0.819

Ⅳ. Discussion

Zooplankton community and distribution pattern are characterized by the oceanographic features off Korean peninsula. In general, zooplankton abundance is low with many species in fall, low abundance and few taxa in winter, increases in both number of taxa and abundance in spring and summer (Choi & Park, 1993). The seasonal variations in zooplankton community in the southern coastal waters of Korea are attributable to seasonal changes in temperature and salinity (Moon et al., 2010). Total numbers of taxa increased from cold to warm months were consistent with the distribution of zooplankton composition in others Korean sea water (Choi & Park, 1993; Moon et al., 2010).

Zooplankton community in the South Sea of Korea is seasonally less variable in diversity and abundance while that in the East Sea and Yellow Sea is relatively highly variable (Hwang & Choi, 1993; Kim, 1984; Park & Choi, 1997; Park et al., 1998). In the Yellow Sea, the most abundant zooplankton was copepods which accounted for 60 to 87% of the total abundances (Kang & Kim, 2008). The distributional patterns of the dominant copepods were associated with their respective preferences for environmental and biological parameters in the Yellow Sea (Choi & Park, 2013; Hwang & Choi, 1993; Shim & Park, 1982; Yoo, 1991). In the East Sea, zooplankton community varies with a characteristic of warm, cold, and coastal waters (Morioka, 1985; Park et al., 1998; Shim & Lee, 1986). The front zone between warm and cold waters divides zooplankton distribution with the front (Park et al., 1998). The abundance of zooplankton generally was highest in spring, lowest in winter (Morioka, 1985), and high in the coastal and northern areas (Kang et al., 2002; Park & Choi, 1997).

The warm month contributes to the high diversity and low abundance of zooplankton in the East Sea and in the South Sea of Korea (Kang et al., 1996; Park & Choi, 1997). The lowest diversity index was observed in February, while highest in July (Kang et al., 1996). These changes of zooplankton diversity and abundance is probably influenced by the Tsushima Warm Current. Our results were coincided with patterns of the southern coastal area of Korea (Kim, 1984; Lee et al., 2004).

Copepods are a dominant group in zooplankton communities in the southern waters of Korea (Kim et al., 1993; Moon et al., 2010). Seasonal variation of copepod abundance shows bimodal peaks of zooplankton abundance in the Masan Bay in April and October (Lee, 1972), while other areas in southern waters in general tend to show unimodal peak in fall (Kang & Lee, 1991; Kim et al., 1993). The monthly changes of copepod abundances in our study were similar to those of previous studies.

Some species preferring warmer waters occur in a colder season with low abundances while other species preferring colder waters do in a warmer season with high abundances (Park & Choi, 1997). The relative abundances of *Podon leuckarti, Calanus sinicus,* and *Corycaeus affinis* decreased when temperature was high (Kang & Kim, 2008; Lee, et al., 2001). This result was similar to the patterns of *Calanus sinicus* occurring in the southern Yellow Sea that they remained high abundance in cold bottom water during summer (Wang et al. 2003). The variations in abundance of dominant species between stations and months were correlated with the environmental conditions during the sampling period.

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