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Temporal and Spatial Variation in Species Composition and Abundances of Ichthyoplankton in Masan Bay

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ABSTRACT A total of 4 pelagic eggs and 24 larval fish species were collected in Masan Bay. *Engraulis japonicus* eggs predominated in pelagic eggs. Abundant larval fishes were *Omobranchus elegans, Scomber japonicus, Acanthogobius flavimanus, Hexagrammos otakii, Repomucenus* sp., *Scartella cristata* and Gobiidae sp., and these 7 species accounted for 78.5% in the total number of individuals. Temporal and spatial variation in both species composition and abundance of was large: the peak abundances of pelagic eggs and larval fishes occurred in July 2007, whilst these were lowest in February 2007. Higher abundance of ichtyoplankton were at station 5 than those of other stations. Temporal changes in the abundances of pelagic eggs and larval fishes corresponded with temperature. Pelagic eggs and larval fishes varied among stations between with shallower inner stations and deeper outer stations with physical characteristics such as depth and local topography.

Key words : Ichthyoplankton, temporal and spatial variation, Masan Bay

INTRODUCTION

Coastal habitats are well known to be important nursery areas for both larval and juvenile stages of marine fish species (Jenkins and Wheatley, 1998; Lazzari *et al.*, 1999; Guidetti, 2000; Paperno *et al.*, 2001; Kwak and Klumpp, 2004; Lanksburry *et al.*, 2005; Pattrick and Strydom, 2008). Many marine fish species spawn in or near coastal habitats such as bays and estuaries to provide the early life stages with favourable habitats for development. Many ichthyoplankton studies have been made in the coastal areas in the southern sea, Korea such as Changson channel (Kim, 1983), Nakdong River Estuary (Cha and Huh, 1988), Kwangyang Bay (Yoo and Cha, 1988; Cha and Park, 1994), Jinhae Bay (Yoo *et al.*, 1992), and Coastal off Tongyong (Park *et al.*, 2005).

Masan Bay have been known one of polluted area where environmental disturbances have occurred every year due to industrial complex around coastal areas since 1980's, however, construction of sewage treatment plant may give it to improve the water quality (Kim, 2003; Oh *et al.*, 2005). Oceanographic studies in Masan Bay has been focused on the sustainable management for target water quality to date (Lee and Park, 2003; Oh *et al.*, 2005), and little is known about ichthyoplankton compared with other regions in Korea, although some studies have been conducted on fish assemblages with using gill nets (Youm, 1997; Kwak and Huh, 2007).

The objective of this study was to examine the temporal and spatial variation in species composition and abundance of ichthyoplankton in Masan Bay and to determine the relationships between environmental factors and ichthyoplankton abundance.

MATERIALS AND METHODS

Masan Bay was a semi-closed bay and were located several small islands (Fig. 1). Pelagic eggs and larvae of fish were collected with a Bongo net (60 cm diameter, 0.33 mm mesh) at 10 stations in February, May, July, and September 2007. The net, fitted with a flowmeter, was towed horizontally at a speed of 2∼3 knot lasting 10 minutes from surface to 10 m depth, and then the volume of water filtered by the net was estimated.

Specimens were preserved immediately in 10% formalin after capture. The identification and counting pelagic eggs and larval fish species were carried out under a dis-

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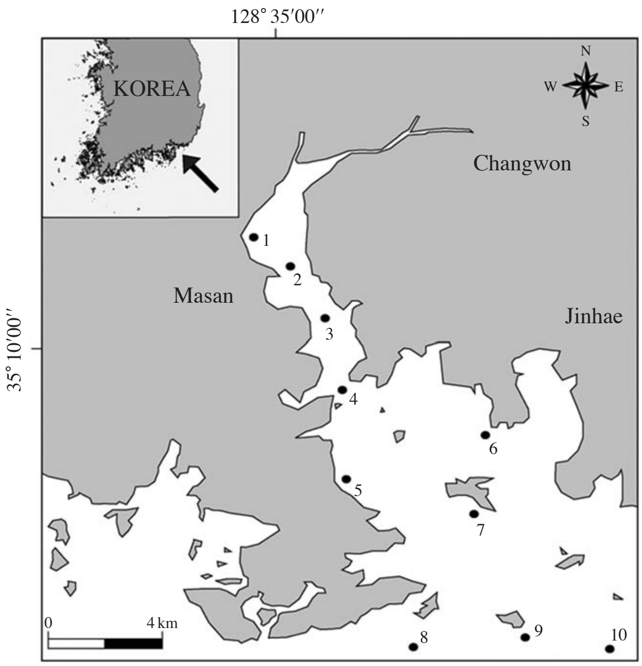

Fig. 1. Map showing the sampling sites.

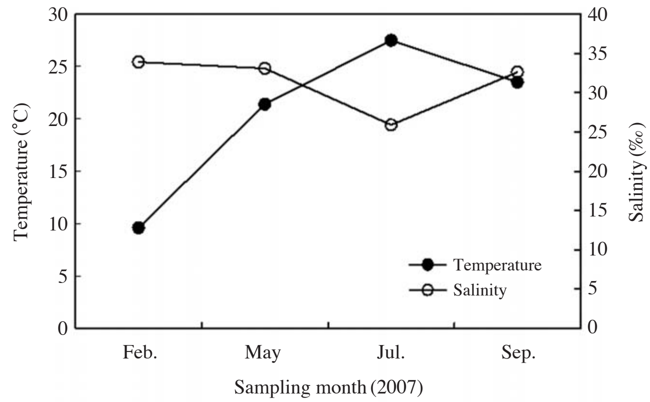

Fig. 2. Variations of temperature and salinity in Masan Bay in 2007.

Table 1. Species composition of pelagic eggs in Masan Bay in 2007 (unit: eggs/1,000 m^3)

Species	Feb.	May	Jul.	Sep.	Total
Engraulis japonicus	34	2,026	812	1,289	4,161
Unidentified sp. 1	69	2,277	727	14	3,087
Unidentified sp. 2	14	1,185	348	47	1,594
Unidentified sp. 3		1,233	99	49	1,381
Total	117	6,721	1,986	1,399	10,223

secting microscope in the laboratory. The species were identified according to Okiyama (1988), Lee *et al.* (1981), Kim *et al.* (1986), Masuda *et al.* (1984), and Kim *et al.* (2005). Water temperature and salinity were monitored on each sampling occasion.

The ichthyoplankton data were log-transformed ($\log_{10}(x+1)$) before analysing the data. Diversity (H') (Shannon and Weaver, 1949) was calculated as:

$$H' = -\sum P_i \times \log_2 P_i$$

where n is the number of individuals of each i species in a sample and N is the total number of individuals.

Association of 10 stations for larval fishes, Pianka's similarity index (Pianka, 1973), A_{ij} was calculated as:

$$A_{ij} = \frac{\sum (P_{ih} \times P_{jh})}{\sqrt{\sum P_{ih}^2 \times \sum P_{jh}^2}}$$

where A_{ij} is the similarity of species j on species i. P_{ih} is the proportion of individuals of a_i in a particular month h, P_{jh} is the proportion of individuals of a_j in a particular month h. Values for the similarity index may vary between 0, if no similarity occurs, and 1 for complete similarity. The Pianka's similarity index was subjected to an average linkage analysis.

A one-way ANOVA with orthogonal design was used to analyse variations in ichthyoplankton abundance and environmental factors with season. The relationships between ichthyoplankton abundance and environmental factors were analysed using Pearson's correlation coefficient.

Hierarchical cluster analyses based on the Bray-Curtis similarity based on %W were used for the classification and ordination of stations. Non-metric multi-dimensional scaling (NMDS) ordination was used to plot each stations as a point on an ordination plot, in terms of Bray-Curtis similarity. These were applied by the PRIMER software package.

RESULTS

1. Temperature and salinity

Temperature at the study site ranged from 9.6°C in February to 27.5°C in July 2007. Salinity was similar at around 33.5‰ except in rainy season in July (Fig. 2).

2. Ichthyoplankton species composition

A total of 10,223 pelagic eggs belonging to 4 species (including 3 unidentified fish species) were collected and *Engraulis japonicus* eggs (40.7%) dominant in the number of eggs (Table 1). A total of 12,674 larvae were caught, comprising 24 species (including Gobiidae). Numerically dominant larval fishes were *Omobranchus elegans* (19.6 %), *Scomber japonicus* (18.0%), *Acanthogobius flavimanus* (10.8%), *Hexagrammos otakii* (9.9%), *Repomucenus* sp. (9.8%), *Scartella cristata* (5.5%), and Gobiidae sp. (4.9%), together accounting for 78.5% of the catch (Table 2).

Table 2. Species composition of larval fish in Masan Bay in 2007 (unit: larvae/1,000 m^3)

Species	Feb.	May	Jul.	Sep.	Total
Omobranchus elegans			958	1,531	2,489
Scomber japonicus		861	1,361	55	2,277
Acanthogobius flavimanus		1,366			1,366
Hexagrammos otakii	1,141			113	1,254
Repomucenus sp.		47	654	543	1,244
Scartella cristata		568	94	34	696
Gobiidae sp.	59	66	500		625
Clupea pallasii	376				376
Sillago japonicus			342		342
Trachurus japonicus		24	185	102	311
Engraulis japonicus	129		56	106	291
Rudarius ercodes				238	238
Sebastes inermis	53			113	166
Pholis nebulosa		145			145
Syngnathus schlegelii		72	68		140
Plecoglossus altivelis	136				136
Parablennius yatabei				94	94
Sebastes pachycephalus				90	90
Stephanolepis cirrhifer				88	88
Platycephalus indicus			80		80
Sebastes schlegeli	75				75
Spratelloides japonicus		64			64
Girella punctata	58				58
Apogon lineatus			29		29
Total	2,027	3,213	4,327	3,107	12,674

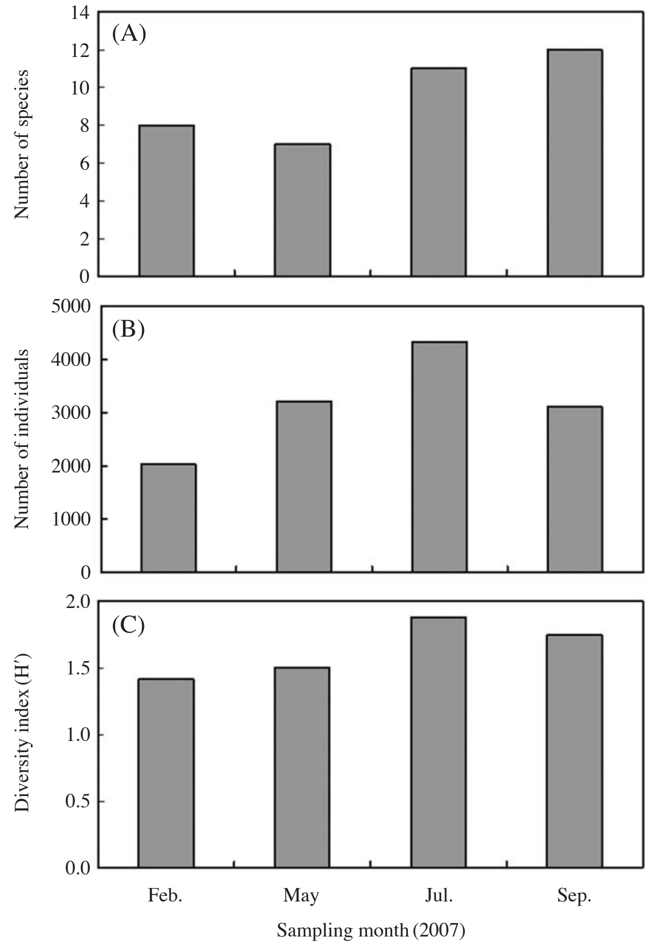

Fig. 3. Temporal variations in (A) number of species, (B) number of individuals, and (C) diversity index of larval fish in Masan Bay in 2007.

3. Temporal variation in abundance of ichthyoplankton

The abundance of pelagic eggs varied with seasons showing a peak in May 2007 (6,721 eggs/1,000 m^3). For larval fishes, the number of species (8～12 species) varied with seasons. Higher number of larval fish species were collected in September 2007 (Fig. 3A). Abundance varied significantly with seasons showing high abundance in July 2007 when *O. elegans, S. japonicus*, and *Repomucenus* sp., were dominant while catch rate was low in February 2007. The diversity index ranged from 1.41 to 1.88, and the highest value was in July 2007 (Fig. 3C). Correlation analysis between ichthyoplankton abundance and environmental factors showed that there was found significantly positive correlation between larval fish abundance and water temperature ($P < 0.05$).

4. Spatial variation in abundance of ichthyoplankton

A large difference in overall pelagic eggs abundance was observed among 10 stations. Overall, mean pelagic egg abundance were higher at station 5,6,7,9 (413～488 eggs/1,000 m^3) (Fig. 4). For larval fishes, abundances differed substantially between different stations. Higher mean larval fishes abundance was at station 1,5,9 (442～718 larvae/1,000 m^3) (Fig. 5). Larval fish density ranged from 24 to 218 larvae/1,000 m^3 except at the station 9 (847 larvae/1,000 m^3) in February 2007 and $<$400 larvae /1,000 m^3 were shown except at the station 5,7 (1,329 larvae/1,000 m^3 and 530 larvae/1,000 m^3) in May 2007. Higher abundance was at the station 1 (1,112 larvae/1,000 m^3) and the station 5 (1,006 larvae/1,000 m^3) when many *S. japonicus, T. japonicus* and Gobiidae sp. were present in July 2007. However, the highest density was at station 6 (596 larvae/1,000 m^3) with ranged from 80 larvae/1,000 m^3 to 428 larvae/1,000 m^3 in other stations in September 2007.

The dendrogram of larval fishes shows several groups (40% similarity) which identify the 10 stations in February, May, July and September (Fig. 6). Cluster analysis of four seasons data split into two or three group. These groups can be distinguished into inner stations and outer stations. Inner stations close to the land and higher numbers of *Engraulis japonicus* (in February), gobiid species including *A. flavimanus* (in May and July) and *Repomucenus* sp. (in September) were collected. However, outer stations located in mouth of bay and higher abundances of *H. otakii* (in February), *S. japonicus* (in May) and *O.*

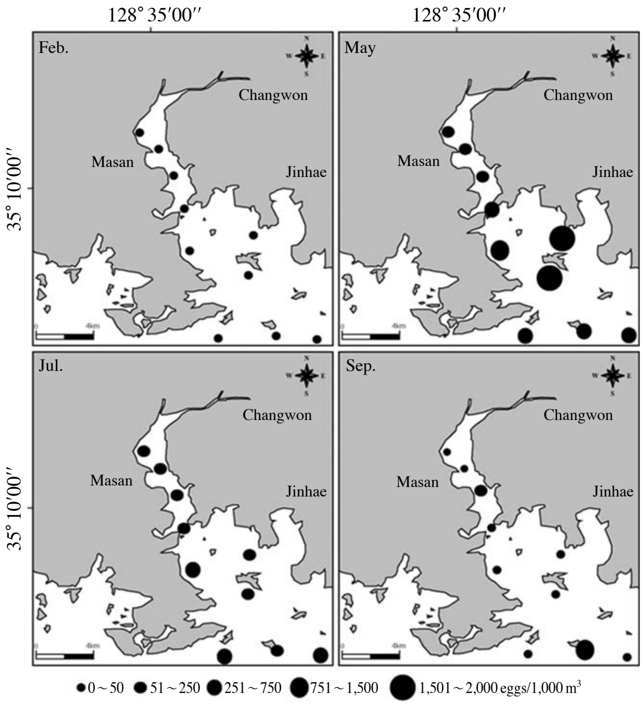

Fig. 4. Spatial variations in number of pelagic eggs in Masan Bay in 2007.

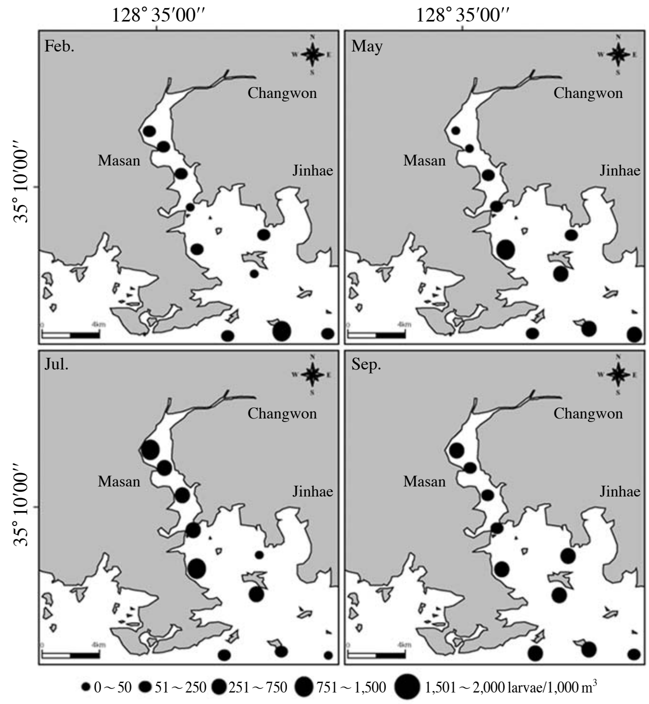

Fig. 5. Spatial variations in number of larval fish in Masan Bay in 2007.

elegans (in September) were occurred during study periods. The groupings set out in the dendrograms described above were also well represented in the MDS ordination plots for each stations in each seasons.

DISCUSSION

A total of 4 pelagic eggs and 24 larval fishes were recorded from Masan Bay. The dominant species was *E. japonicus* in pelagic eggs and *O. elegans, S. japonicus*, *A. flavimanus, H. otakii, Repomucenus* sp., *S. cristata*, and Gobiidae sp. in larval fish. Compared with studies of ichthyoplankton in the southern area nearby the study area (Table 3), 44 larval fishes in Changson channel (Kim, 1983), 8 pelagic eggs and 26 larval fishes Nakdong River Estuary (Cha and Huh, 1988), 10 pelagic eggs and 21 larval fishes in Kwangyang Bay (Cha and Park, 1994), and 74 larval fishes in th coastal off Tongyong (Park *et al.*, 2005) were occurred. These results indicated similar pattern was studies of Kwangyang Bay, and Nakdong River Estuary, and was fewer value than those of Changson channel and coastal off Tongyong despite of difference of study periods and interval of sampling.

Engraulis japonicus, *S. japonicus*, and *H. otakii* among ichtyoplanktons are of commercial and recreational importance. In particular, pelagic eggs of *E. japonicus* was dominated in the coastal areas of Korean peninsula include Jeju Island (Kim, 1983; Cha and Huh, 1988; Cha and Park, 1994; Oh, 2003; Lee and Go, 2006). Lim and Ok (1977) have reported that pelagic eggs of *E. japonicus* was widely occurred at the temperature between 9°C to 32°C.

For larval fish species, Gobiidae sp., *A. flavimanus, Repomucenus* sp. were dominated by most of other areas in the southern sea, and *O. elegans, H. otakii* were also common larval fishes in the Nakdong River Estuary and Kwangyang Bay (Cha and Huh, 1988; Cha and Park, 1994; Oh, 2003). *Repomucenus* sp. mainly inhabits on sandy mud substrate in the coastal area, and *O. elegans* and Gobiidae sp. were higher numbers in the crevice of rocky shore and tide pool in the coastal area (Mito, 1965; Takita, 1980, 1983; Kim *et al.*, 2005). These larval fishes including *S. japonicus* were higher numbers in July and September 2007 with 23.5~27.5°C in the study area. Such result are agreement with other studies of ichthyoplankton in the coastal area of southern sea such as Nakdong River Estuary, Kwangyang Bay, and coastal off Tongyoung (Cha and Huh, 1988; Oh, 2003; Park *et al.*, 2005).

Each dominant larval fishes exhibited their own distinct seasonal occurrence pattern and different time of peak abundance. Peak numbers of *H. otakii* and *Clupea pallasii* in February 2007, those of *A. flavimanus* and *S. cristata* were in May 2007, *O. elegans* and *S. japonicus* were in July 2007, *Repomucenus* sp. and *O. elegans* were

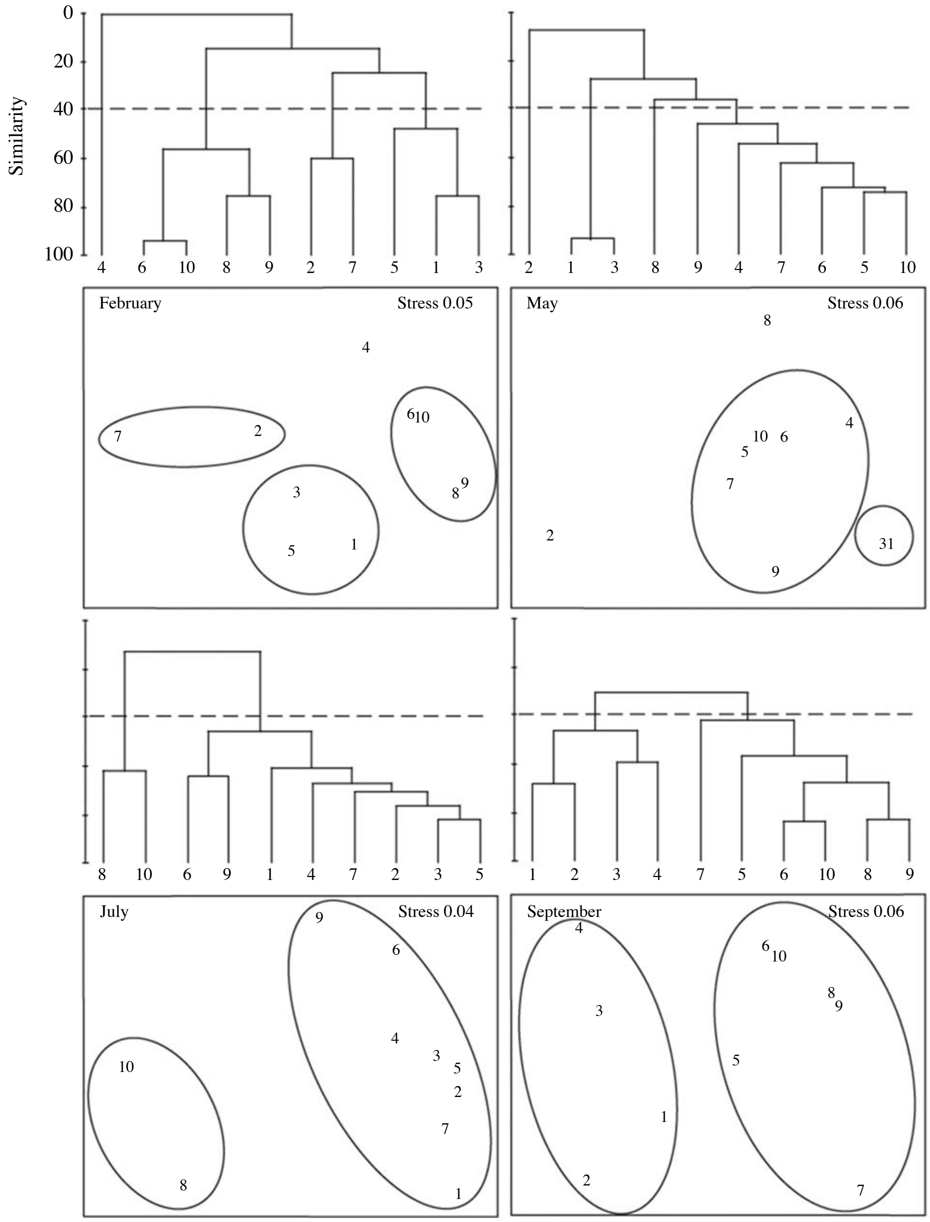

Fig. 6. Dendrogram and MDS illustrating the species associations of larval fish species in Masan Bay.

in September 2007. These results indicate that peak abundance was closely related with the spawning time. Peak recruitment and abundance of one species was separated several months from other species, with some overlap with another species. Hence Masan Bay is partitioned temporally by dominant larval fishes in this ways. Other studies have shown similar patterns of variable in ichthyoplankton in the coastal areas, Korea (Cha and Huh, 1988; Oh, 2003; Park *et al.*, 2005).

Temporal variation in both species composition and abundance of larval fishes appear to be considerable for ichthyoplankton. In Masan Bay, peak abundance of pelagic eggs was in May 2007, and those of larval fishes in July 2007 when temperature was relatively high. Several other studies have demonstrated a positive correlation between temperature and ichthyoplankton abundances (Cha and Huh, 1988; Cha and Park, 1994; Oh, 2003; Park *et al.*, 2005). A significantly greater abundance of larval fish in this period confirmed that larval fish was likely to be related to the abundances of food organisms with higher temperature for survival during the early life stages in the study area.

Spatial variation on in both species composition and abundance of larval fishes was also remarkable characteristics in Masan Bay. Different abundance and species contributed by grouping inner and outer site which iden-

Table 3. Comparisons of ichthyoplankton were surveyed in some areas close to this study area

Source	Present study	Park *et al.* (2005)	Cha and Park (1994)	Cha and Huh (1988)	Kim (1983)
Sampling periods	Jan. to Dec. 2006	Mar. 1998 to Feb. 1999	Feb. to Dec. 1990	Feb. 1987 to Jan., 1988	Jun. 1982 to May 1983
Study area	Masan Bay	Tongyoung	Kwangyang Bay	Nakdong River Estuary	Changson Channel
Number of stations	10	4	8	8	1
Intervals of sampling	Seasonal	Monthly	Bimonthly	Monthly	Monthly
Pelagic eggs					
Number of species	1 speices, 3 unidentified	–	1 family, 2 genus, 7 species	1 family, 4 genus, 2 species, 1 unidentified	–
Fish larvae					
Number of species	1 family, 1 genus, 22 species	4 family, 18 genus, 48 species, 4 unidentified	2 family, 3 genus, 16 species	2 family, 5 genus, 18 species, 1 unidentified	3 genus, 41 species
Dominant species	*Omobranchus elegans* (19.6)	*Engraulis japonicus* (48.9)	*Engraulis japonicus* (34.5)	*Engraulis japonicus* (38.6)	*Engrauli sjaponicus* (86.6)
(%N)	*Scomber japonicus* (18.0)	*Repomucenus* sp. (17.8)	Gobiidae (24.5)	Gobiidae (15.3)	*Acanthogobius flavimanus* (5.9)
	Acanthogobius flavimanus (10.8)	*Parablennius yatabei* (6.3)	*Konosirus puntatus* (12.8)	*Repomucenus* sp. (15.0)	*Endrias* sp. (1.7)
	Hexagrammos otakii (9.9)	*Acanthogobius* sp. (4.4)	*Argyrosomus argentatus* (8.0)	*Coilia* sp. (14.0)	*Sebastes inermis* (1.2)
	Repomucenus sp. (9.8)	*Tridentiger* sp. (3.2)	*Leiognathus nuchalis* (7.4)	*Hexagrammos otakii* (6.6)	*Leucopsarion petersi* (0.8)

tify the 10 stations with cluster analysis. Theses results may be explained difference of physical parameter such as depth and local topography in each stations. Inner stations were shallow sites and were located close to land, and it was easy for many larval fishes to settle down with slow current. Therefore most of larval fishes which inhabits on bottom area such as *A. flavimanus, Repomucenus* sp., *S. cristata*, and Gobiidae sp. were more abundant than those of other stations, deeper sites. Park *et al.* (2005) also demonstrated higher numbers of larval fishes were in shallow, moderate current, and input of fresh water in the coastal off Tongyoung. Hence we suggested that temporal and spatial variation in species composition and abundance of ichthyoplankton was correlated with temperature and physical characteristics such as depth and local topography.

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마산만에 출현하는 난자치어 종조성과 출현량의 시공간 변동

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요 약 : 조사기간 동안 총 4종의 부유성 어란과 24종의 자치어가 마산만에서 채집되었다. 어란의 우점종은 멸치 (*Engraulis japonicus*) 어란이었다. 그러나 자치어는 앞동갈베도라치 (*Omobranchus elegan*), 고등어 (*Scomber japonicus*), 문절망둑 (*Acanthogobius flavimanus*), 쥐노래미 (*Hexagrammos otakii*), 돛양태류 (*Repomucenus* sp.), *Scartella cristata*, 망둥어과 (Gobiidae sp.) 순으로 우점하였다. 이들 7종은 전체 출현개체수의 78.5%를 차지하였다. 어란과 자치어는 시공간적으로 큰 변동을 보였다. 어란과 자치어의 현존량은 2007년 7월에 가장 높았으며, 2007년 2월에 가장 낮았다. 그리고 난자치어는 다른 정점에 비해 정점 5에서 현존량이 높았다. 어란과 자치어 현존량의 시간적 변화는 수온에 영향을 받았다. 부유성 어란과 자치어는 수심, 지형 등과 같은 물리적 환경 요인에 따라 좀 더 얕은 만 안쪽 정점과 깊은 만 외곽 정점 간 군집 차이를 보였다.

찾아보기 낱말 : 난자치어, 시공간변동, 마산만