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Community structure of marine benthic invertebrates recruited on artificial substrates in the Korean coast

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Abstract: In this study, the community structure of marine benthic invertebrates was examined to evaluate the differences between the west, south, and east coasts of Korea and to identify the indicator species representing each region. Acrylic attachment plate sets were installed in Jeongok, Mokpo, Tongyeong, Yangpo, and Gangreung, and the invertebrate fauna thus captured were identified. Monitoring was performed in each area from March 2017 to May 2018. Water depth, temperature, and salinity at each location were measured to determine the potential influence of abiotic factors on the community structure. As a result, the mean depth of plates installed and the water temperature were significantly different in each area. A total of 32 invertebrate species were identified in all localities, and the most significant difference in the species compositions was found between Mokpo and Gangreung. The community structure differed significantly with a change in the plate depth, and a larger number of indicator species appeared on shallower plates. Finally, we determined the community structure of benthic invertebrates in different geographical regions of the Korean ocean by characterizing the dominant invertebrate taxa and the indicator species at each site.

Keywords: benthos, diversity, monitoring, coastal ecosystem

INTRODUCTION

Benthic invertebrates are vital members of the coastal ecosystem, playing a significant role in the energy flow within the environment (Levinton *et al.* 1984). They often provide an excellent model to study the community structure of marine ecosystems due to their distinct life cycles, exhibiting clearly defined planktonic larval and sessile adult stages. The larvae can thrive passively floating in the water column and undergo maturation and metamorphose into sessile forms after they adhere to a suitable substrate (Anil *et al.* 1995; Lambert 2019). In their sessile form as adults, they are unable to avoid unfavorable conditions and thus adapt to the changes in environmental conditions over time, thereby reflecting the association between environmental factors and the organism (Reiss and Kröncke 2005). The ecological fitness of a given invertebrate is indicated by the occurrence, density, abundance, and spatial distribution and is highly dependent on the various conditions within the habitat, such as the competition for the space (Rossi and Snyder 2001), food availability (Svensson and Marshall 2015), predation risk (Rogers *et al.* 2016), anthropological activity (Bevilacqua *et al.* 2006), and environmental conditions such water temperature and salinity (Kennish *et al.*

2004; Kuklinski *et al.* 2013; Schröder *et al.* 2015). The responses to these factors are the measure of successful settlement of each species, evaluating the changes in the community structure that consequently allow the determination of the succession pattern of the benthic invertebrate community (Reynoldson and Metcalfe-Smith 1992).

Artificial substrates have been used as a useful tool allowing the evaluation of the settlement and succession of benthic invertebrates community by facilitating the manipulation and standardizing the habitat condition over time (Perkol-Finkel and Beneyahu 2005; Lozano-Cortés and Zapata 2014). It is found that the benthic invertebrates community can vary in mortality, recruitment success, and species composition, depending on the type of substrate (Fraschetti *et al.* 2007; Chase *et al.* 2016). Due to such utility, many studies have emplyed the artificial substrate to figure out the species-specific substarate (Mellina and Rasmussen 1994; Saunders and Metaxas 2009; Tracy and Reyns 2014), variation of community sturucture due to the depth of substrate (Glasby and Connell 2001), and the immersion time (Segal *et al.* 2012).

The three water bodies surrounding the Korean peninsula, namely the East Sea, Korea strait, and Yellow Sea, are characterized by different current dynamics and physical properties (Yang and Kim 1990; Na *et al.* 1991; Seong *et al.* 2010). The varying environmental conditions in different geographical areas provide heterogeneous environmental conditions for marine organisms, attracting a diverse range of invertebrate species with various adaptabilities and habitat preferences. Regionally focused studies on invertebrates will help determine species composition, dominant species, seasonal variation in species occurrence, and spatial distribution, accounting for the community structure change in each sea region. Studies on the seasonal variation in the species composition of the subtidal sandy bottom of Gangreung in the East Sea have revealed a substantial change in the community assemblage between spring and winter seasons (Choi *et al.* 2000). A study on the species composition and density of the benthic invertebrate fauna in Jinhae Bay of Korea strait reported 237 species of bivalves, gastropods, annelids, arthropods, and echinoderms (Paik and Yun 2000). Dominant invertebrate 378 species over 5 years in 21 stations of Chonsu Bay of the Yellow Sea were determined (Park *et al.* 2006). A number of studies have contributed significantly to the knowledge of the local fauna that act as signifiers of the ecosystem health, whereas there are still limited published data focused on the standardized and quantified experimental comparison between sea regions despite the significant heterogeneity.

We conducted a monitoring survey on benthic invertebrate fauna inhabiting Korean waters to evaluate the difference in the progression of community structure in the multiple regions under the same experimental conditions. A 15-month long investigation was done at several localities, representing all surrounding Korean waters using acrylic attachment plates, which is a commonly employed artificial substrate used to attract various sessile invertebrates (Glasby and Connell 2001; Blum *et al.* 2007; Tracy and Reyns 2014). In this survey, we primarily aimed to evaluate the geographical differences in the invertebrate diversity in the selected areas arising due to the depth of the plate installation, change in water temperature, and salinity, as well as characterize the dominant taxa as an indicator species in each local community. Finally, we collected the records of water temperature, salinity, and depth of installed plates from the field and the online database to assess the relationship between the change of community structure and the physical properties.

MATERIALS AND METHODS

1. Study area and data collection

Surveying was carried out from March 2017 to May 2018 in five yacht marinas located at Jeongok and Mokpo (Yellow Sea), Tongyeong (Korea strait), and Yangpo and Gangreung (East Sea) in Korea. Columns were set up at each yacht marina (Fig. 1). Four acrylic plates (30 × 30 cm each) were used to construct a set of attachment plates (Fig. 2A), and two plate sets were installed at each column, to which benthic invertebrates could adhere at two different depths of 3 and 5 m from sea level, respectively (Fig. 2B–D). SCUBA assisted plate photography was carried out at each monthly survey to visually record the monthly recruitment change of benthos at the study sites over time using a camera (G7X, Canon, Japan) The plates were checked to be permanently immersed and the depth were estimated at each instance using a dive computer (Suunto EON Steel, Finland). A water temperature data logger (UTBI-001; Onset, USA) was installed at each site to automatically record temperature at hourly intervals at the depths of both the upper and lower plates. Salinity (PSU) was measured using a multiparameter meter (Pro Plus; YSI, USA) mounted at the front of each column. We also acquired salinity data from the Korean real-time ocean observation information system (KOOFS).

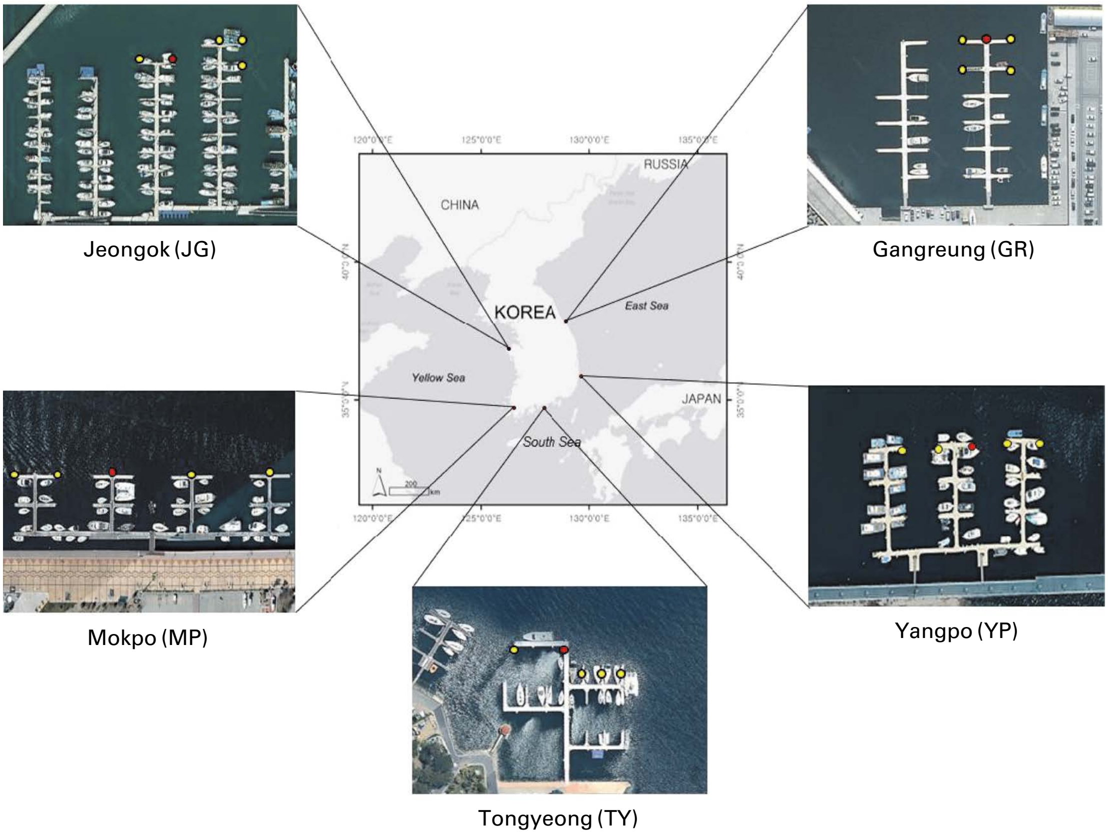

Fig. 1. A map showing the five harbors selected as study regions in Korea. Yellow circles indicate the columns where the attachment plates are installed.

2. Species identification and data analyses

The benthic invertebrate species were identified in the plate photographs captured at the study areas based on the existing literature on Korean marine invertebrate fauna (Rho 1977; Kim 1998; Seo 2010; Park 2011). All the photographs were pooled for the subsequent image analyses. The coverage rate of each plate was analyzed based on the pixel data that were generated from the plate photographs using ImageJ 1.52a (Schneider *et al.* 2012). Through this analysis, the occupancy area (%), expressed as the coverage ratio of the plates by each species to the total area of the attachment plate was estimated. Independent sample *t*-test and analysis of variance (ANOVA) using SPSS version 12.0 (SPSS Institute, Chicago, IL, USA) were carried out to verify the statistical significance of inter- and intra-regional differences in both the upper and lower plates, average water temperature, and salinity. PC-ORD ver. 7 (Grandin 2006) was used for the subsequent multivariate statistical analyses. Nonmetric multidimensional scaling (NMDS) analysis was performed to examine the trends of 13 surveys with the relationship of multiple variables including species numbers, coverage rate, mean depth, temperature, and salinity. Additionally, NMDS analysis was used to evaluate the difference in the scatter plot between upper and lower plates in each area according to the variables. Multiple response permutation procedure (MRPP) was used to evaluate the difference in the macroinvertebrate community in each locality based on the variables, species numbers, coverage rate, mean depth, temperature, and salinity (Mielke 1979). This analysis is a nonparametric test to assess the significant difference between two or more groups of sampling units that does not require distributional assumptions typical of parametric tests. Dominant species of each area were analyzed using indicator species analysis (ISPN) (Hill *et al.* 1975). We excluded any species that appeared in less than 5% occupancy area in the analysis to minimize statistical errors (Clarke 1993).

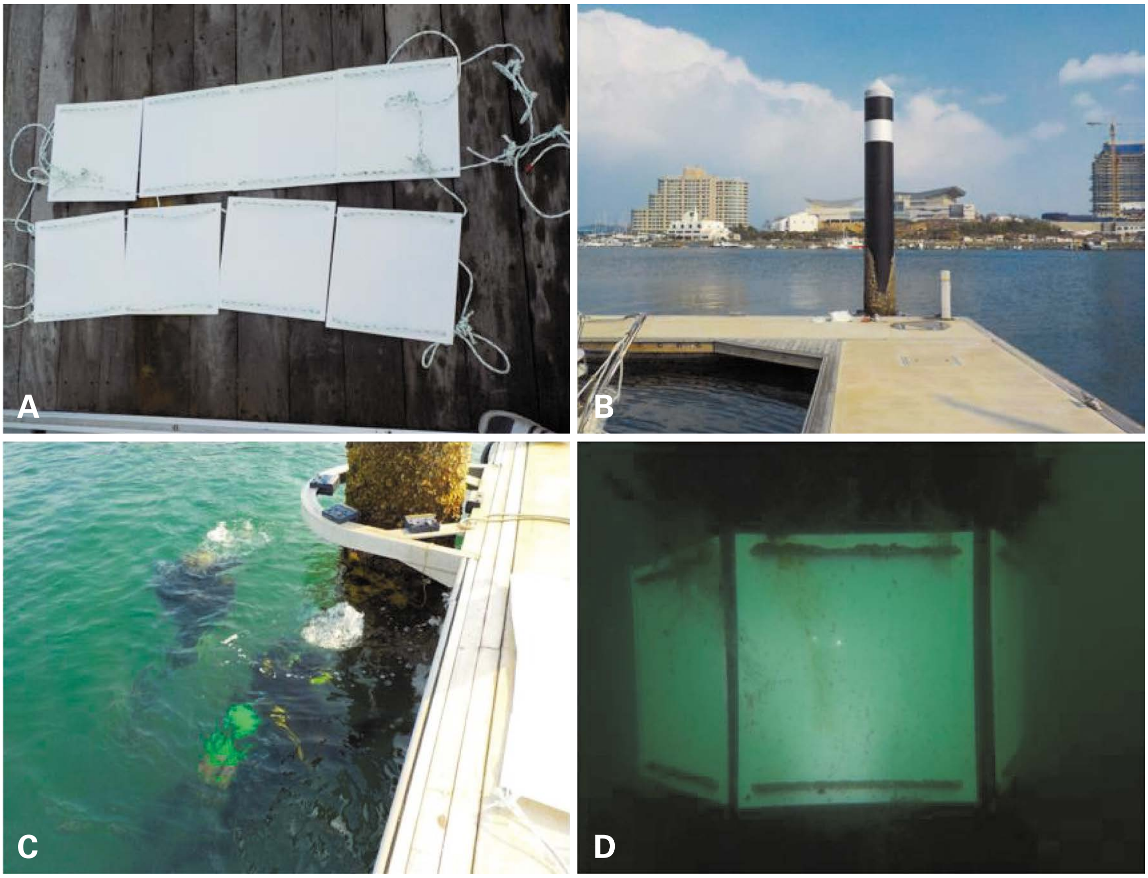

Fig. 2. Artificial substrate plates installed for the monitoring survey. A. 30×30 cm acrylic plates at Mokpo; B. The column where plates were installed in Tongyeong; C. The divers installing the plates in Mokpo; D. A plate fixed in the water column.

Table 1. Mean depth, mean monthly water temperature, and salinity at the sites of installation of artificial plates installed on columns in five areas during the investigation period

Area	Mean depth (m)		Mean temperature (°C)		Mean salinity (PSU)	
	Upper plate	Lower plate	Upper plate	Lower plate	YSI	KOOFS
Jeongok	3.03	4.84	13.8±9.0	13.5±8.9	30.8	30.2
Mokpo	3.47	6.57	15.2±7.3	14.8±7.1	30.6	30.8
Tongyeong	3.23	5.83	16.1±6.2	15.7±6.0	32.9	32.8
Yangpo	2.81	5.76	16.1±5.0	15.8±5.0	33.2	33.4
Gangneung	1.64	4.05	14.3±5.8	14.8±6.71	33.0	34.2

YSI: multiparameter meter (Pro Plus; YSI, USA); KOOFS: Korean real-time ocean observation information system

RESULTS

1. Environmental factors

The mean depth, mean monthly water temperature, and salinity of the study areas were summarized (Table 1). The upper and lower plates at Mokpo showed the greatest mean depth of installation, while the lowest mean depth was seen at Gangreung. The highest mean water temperatures over the course of 15 months were recorded in Yangpo, whereas the lowest mean water temperatures were seen in Jeongok. The highest mean salinities were seen in Yangpo. Overall,

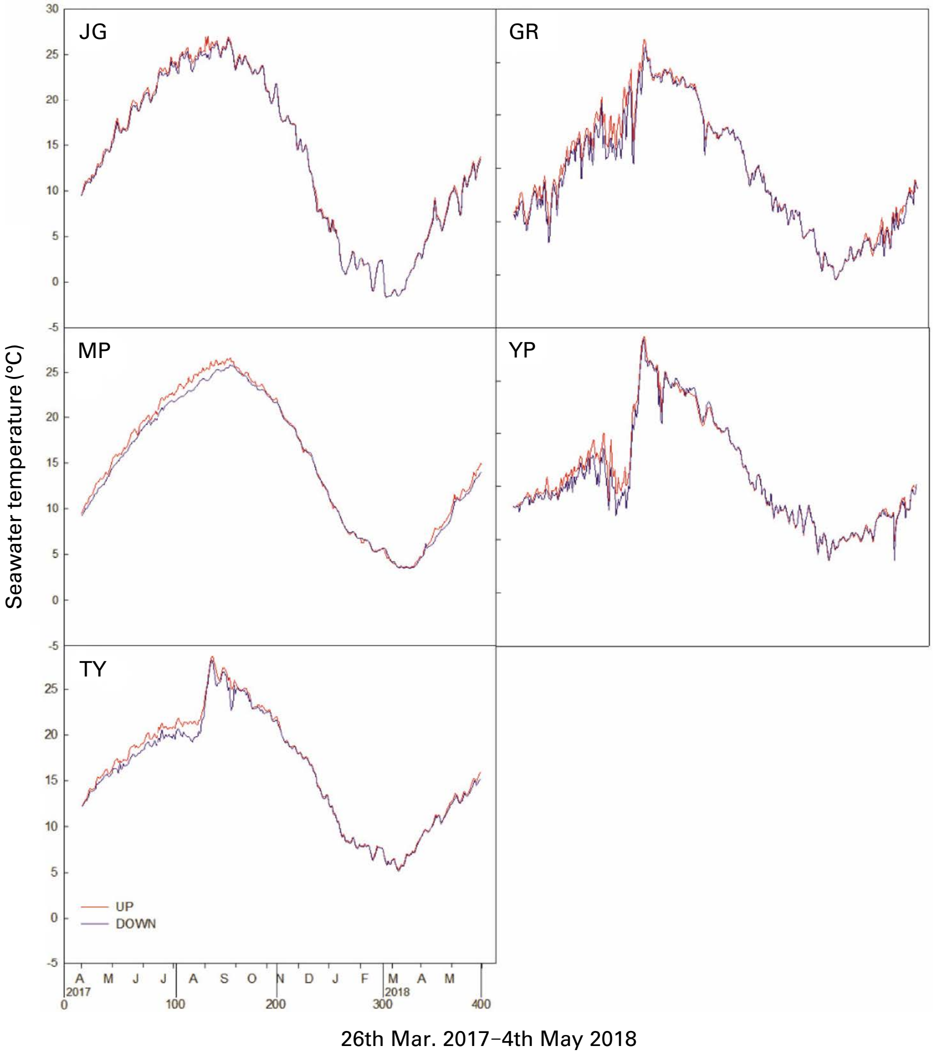

Fig. 3. Changes in water temperature conditions during the survey. JG, Jeongok; MP, Mokpo; TY, Tongyeong; YP, Yangpo; GR, Gangreung.

the fluctuations in water temperature at all sampling locations were similar; most sites showed the highest temperatures (>25°C) between August and September and the lowest temperatures (<5°C) were seen between February and March (Fig. 3). The independent sample *t*-test revealed that the difference in the mean depth of upper and lower plates of each area is statistically significant ($p < 0.0001$). However, the mean monthly water temperature at both upper and lower plates over 15 months did not significantly differ at any of the localities ($p = 0.2361$). The test detected that the on-site measurements and KOOFS records did not significantly differ in the mean salinity at all localities ($p = 0.0858$) (Table 1). ANOVA revealed that the mean depth between upper ($F = 7.279$, $p < 0.0001$) and between lower plates ($F = 10.501$, $p < 0.0001$) significantly differed. The test detected water temperature ($F = 16.228$, $p < 0.0001$), and salinity ($F = 5.63$, $p < 0.0001$) were statistically different.

2. Invertebrate fauna in all study areas

Thirty-two benthic invertebrates belonging to nineteen families, ten orders, seven classes, and six phyla appeared across the plate matrices installed in all five locations during the study period. All the species identified were listed in Table 2. The taxon with the largest number of species was class Ascidiacea (phylum Chordata), represented by 11 species (39.3%), followed by class Gymnolaemata (phylum Bryozoa), represented by seven species (25%) (Fig. 4A).

Table 2. A list of species collected in the five study areas

Phylum	Class	Species	JG	MP	TY	YP	GR
Porifera	Demospongiae	1. *Halichondria* (*Halichondria*) *bowerbanki* Burton, 1930	○	○	○	○	
		2. *Haliclona* sp.					○
Cnidaria	Anthozoa	3. *Anthopleura anjunae* Den Hartog & Vennam, 1993	○	○	○	○	○
	Hydrozoa	4. *Ectopleura crocea* (Agassiz, 1862)	○	○	○	○	○
Mollusca	Bivalvia	5. *Mytilus galloprovincialis* Lamarck, 1819	○	○	○	○	○
		6. *Magallana gigas* (Thunberg, 1793)	○	○	○	○	○
Arthropoda	Thecostraca	7. *Amphibalanus improvisus* (Darwin, 1854)	○	○	○	○	○
		8. *Balanus trigonus* Darwin, 1854	○	○	○	○	○
		9. *Megabalanus rosa* Pilsbry, 1916			○	○	
		10. *Perforatus perforatus* (Bruguière, 1789)				○	○
Bryozoa	Gymnolaemata	11. *Bugula neritina* (Linnaeus, 1758)	○	○	○	○	○
		12. *Bugulina californica* (Robertson, 1905)*		○			
		13. *Caberea lata* Busk, 1852			○	○	
		14. *Celleporaria brunnea* (Hincks, 1884)		○	○	○	○
		15. *Iodictyum axillare* (Ortmann, 1890)			○	○	
		16. *Schizoporella unicornis* (Johnston in Wood, 1844)	○		○	○	
		17. *Tricellaria occidentalis* (Trask, 1857)	○	○	○	○	○
		18. *Watersipora subtorquata* (d'Orbigny, 1852)	○	○	○	○	○
Chordata	Ascidiacea	19. *Ascidia sydneiensis* Stimpson, 1855	○	○			
		20. *Ascidiella aspersa* (Müller, 1776)	○	○	○	○	
		21. *Botryllus schlosseri* (Pallas, 1766)	○	○	○	○	
		22. *Ciona robusta* Hoshino & Tokioka, 1967	○	○	○	○	
		23. *Ciona savignyi* Herdman, 1882	○	○	○	○	○
		24. *Didemnum vexillum* Kott, 2002	○	○	○	○	
		25. *Halocynthia aurantium* (Pallas, 1787)*			○	○	
		26. *Halocynthia roretzi* (Drasche, 1884)	○	○		○	
		27. *Herdmania momus* (Savigny, 1816)*				○	
		28. *Molgula manhattensis* (De Kay, 1843)	○	○			
		29. *Rhodosoma turcicum* (Savigny, 1816)*				○	
		30. *Styela clava* Herdman, 1881	○	○	○	○	○
		31. *Styela plicata* (Lesueur, 1823)		○	○	○	○
		32. *Symplegma reptans* (Oka, 1927)				○	

Class Thecostraca (phylum Arthropoda) was represented by four species (14.3%), and class Demospongiae (phylum Porifera) and Bivalvia (phylum Mollusca) were represented by two species (7.1%), respectively. Class Anthozoa and Hydrozoa (phylum Cnidaria) showed the lowest abundance with one recognized species, respectively. The taxon showing the highest mean coverage rate across all plates was class Bivalvia with 30.3% coverage rate. Class Thecostraca and Ascidiacea showed the coverage rate with 18.6 and 18.5%, respectively (Fig. 4B). The species *Ascidia sydneiensis* and *Molgula manhattensis* (class Ascidiacea) appeared solely in Jeongok and Mokpo. *Haliclona* sp. (class Demospongiae) and *Symplegma reptans* (class Ascidiacea) were found exclusively in Gangreung and Yangpo, respectively. Among all areas, Yangpo showed the greatest species richness with 25 recorded species, followed by Tongyeong (22 species), Mokpo (21 species), Jeongok (20 species), and Gangreung (15 species) (Table 2).

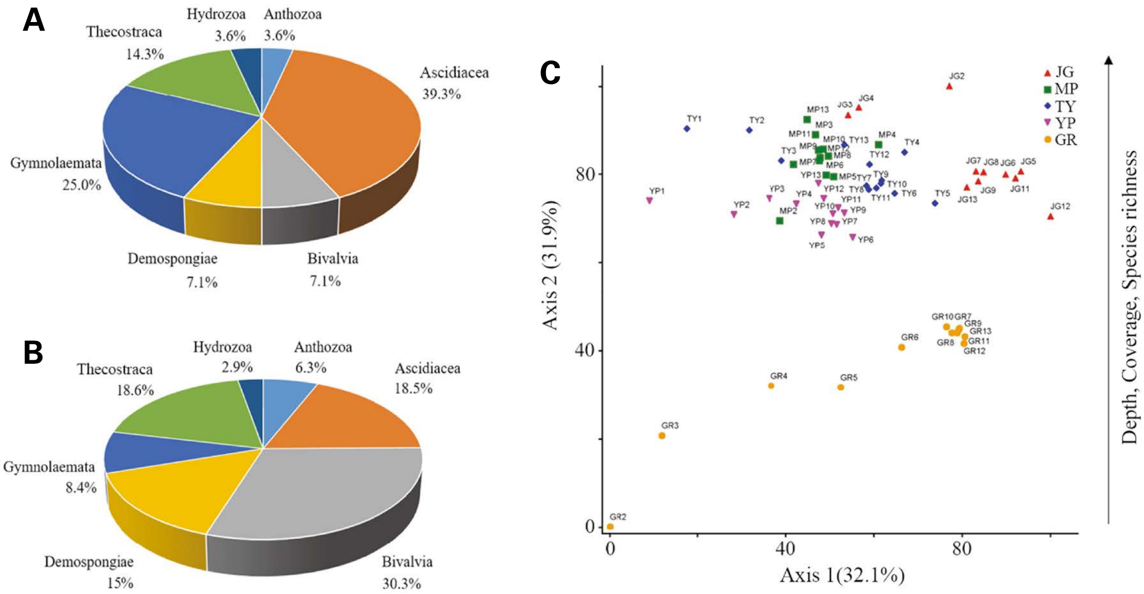

Fig. 4. Species composition and inter-regional differences in the invertebrate community. A. A pie chart of species composition; B. A pie chart of the coverage rate of taxa; C. Nonmetric multidimensional scaling (NMDS) of marine benthic communities in the survey. Each dot represents the attachment plate in the area. JG, Jeongok; MP, Mokpo; TY, Tongyeong; YP, Yangpo; GR, Gangreung.

3. Inter-regional differences in the community structures

The NMDS analysis based on all area datasets described the major clustering with the first two axes carrying 64% (Axis 1 = 32.1%; Axis 2 = 31.9%) of the total variance (Fig. 4C). We found that two of the five localities were distinguishable along the Axis 2 of scatter plot according to the depth, species composition, and coverage rate. The plates installed at Gangreung were distinct from others with a score of 0 to 60 along Axis 2. Plates installed at Yangpo were moderately distinguished based on the clustering with scores between 60 and 80 along Axis 2. MRPP analysis (Table 3) revealed that all localities significantly differ from each other ($p < 0.05$), and Mokpo and Gangreung were the most distantly related ($A = 0.2694$; $p < 0.05$). The ISPN analysis based on the overall dataset determined the indicator species in each region. Jeongok was represented by two indicator species, *Schizoporella unicornis* and *Tricellaria occidentalis* (class Gymnolaemata). Mokpo showed eight indicator species of *Mytilus galloprovincialis* (class Bivalvia), *Watersipora subtorquata* (class Gymnolaemata), *A. sydneiensis*, *Ciona robusta*, *Didemnum vexillum*, *Halocynthia roretzi*, *M. manhattensis*, and *Styela clava* (class Ascidiacea). Tongyeong showed three species, *Anthopleura anjunae* (class Anthozoa), *A. sydneiensis*, and *Styela plicata* (class Ascidiacea). Yangpo was characterized by seven indicator species, *Ectopleura crocea* (class Hydrozoa), *Halichondria* (*Halichondria*) *bowerbanki* (class Demospongiae), *Celleporaria brunnea*, and *Iodictyum axillare* (class Gymnolaemata), *Perforatus perforatus* (class Thecostraca), and *Botryllus schlosseri* (class Ascidiacea). Gangreung was represented by one indicator species, namely *Haliclona* sp. (class Demospongiae).

Table 3. Multi response permutation procedure (MRPP) analysis to detect regional differences in species composition

Group compared	Test statistic (T)	Chance-corrected within group agreement (A)	p-value
JG vs MP	−10.0136	0.164545	<0.0001
JG vs TY	−9.99942	0.137781	<0.0001
JG vs YP	−12.0109	0.200092	<0.0001
JG vs GR	−11.4473	0.240421	<0.0001
MP vs TY	−9.13065	0.123537	<0.0001
MP vs YP	−10.2296	0.145456	<0.0001
MP vs GR	−12.3074	0.269437	<0.0001
TY vs YP	−6.20837	0.075941	<0.0001
TY vs GR	−12.7058	0.254398	<0.0001
YP vs GR	−12.0607	0.230723	<0.0001

Abbreviations: JG, Jeongok; MP, Mokpo; TY, Tongyeong; YP, Yangpo; GR, Gangreung

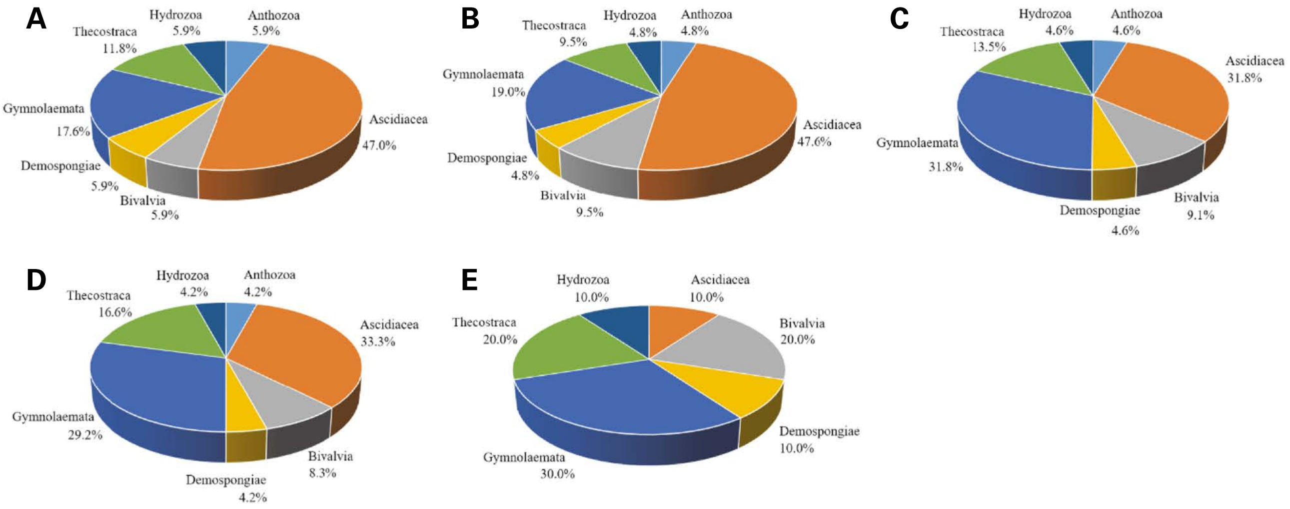

Fig. 5. A pie chart of species composition in each area. A. Jeongok; B. Mokpo; C. Tongyeong; D. Yangpo; E. Gangreung.

4. Community structure in the upper and lower plates of each study site

1) Jeongok

Of a total of 20 species identified on plates installed at Jongeok (Table 2), 17 showed a frequency greater than 5% in the upper and lower plates. These belonged to fourteen families, nine orders, seven classes, and six phyla. The most dominant taxon was class Ascidiacea (47.0%) with *A. aspersa, B. schlosseri, C. robusta, Ciona savignyi, D. vexillum, H. roretzi, M. manhattensis,* and *S. clava,* followed by class Gymnolaemata (17.6%) with *S. unicornis, T. occidentalis,* and *W. subtorquata* (Fig. 5A). MRPP results indicated that the community structures of the upper and lower plates were statistically distinguishable from each other ($p < 0.05$) (Table 4). ISPN results determined two indicator species on the upper plate and one on the lower plate (Table 5).

2) Mokpo

Of a total of 21 species identified on plates installed at Mokpo (Table 2), 17 showed a frequency greater than 5% in the upper and lower plates. These belonged to fifteen families, ten orders, seven classes, and six phyla. The most dominant taxon was class Ascidiacea (47.6%) with *A. aspersa, A. sydneiensis, B. schlosseri, C. robusta, C. savignyi, D. vexillum, H. roretzi, M. manhattensis, S. clava,* and *S. plicata,* followed by class Gymnolaemata (19.0%) with *Bugula neritina, C. brunnea, T. occidentalis,* and *W. subtorquata* (Fig. 5B). MRPP results indicated that the community structures of the upper and lower plates were statistically distinguishable from each other ($p < 0.05$) (Table 4). ISPN determined eight indicator species on the upper plate and one on the lower plate (Table 5).

Table 4. Multi response permutation procedures analysis to detect differences in the invertebrate community between upper and lower plates at the study sites

Area	Test statistic (T)	Chance-corrected within group agreement (A)	p-value
JG	−3.9986260	0.05949248	0.0017
MP	−6.5730716	0.08737436	<0.0001
TY	−0.51097878	−0.00645842	0.6426
YP	−6.9782517	0.08909128	<0.0001
GR	−6.6672387	0.13323406	0.0001

Abbreviations: JG, Jeongok; MP, Mokpo; TY, Tongyeong; YP, Yangpo; GR, Gangreung

3) Tongyeong

Of a total of 22 species identified on plates installed at Tongyeong (Table 2), all 22 showed a frequency greater than 5% in the upper and lower plates. These belonged to sixteen families, ten orders, seven classes, and six phyla. The most dominant taxa were class Ascidiacea (31.8%) with *A. aspersa, B. schlosseri, C. robusta, C. savignyi, D. vexillum, S. clava,* and *S. plicata,* and class Gymnolaemata (31.8%) with *B. neritina, C. brunnea, Caberea lata, I. axillare, T. occidentalis, S. unicornis,* and *W. subtorquata* (Fig. 5C). MRPP results indicated that the community structures of the upper and lower plates were not statistically distinguishable from each

Table 5. A list of indicator species at the five study sites based on Indicator species analysis (ISPN)

Area	Species	Upper & Lower	Indicator value (IV)	*p*-value
JG	*Tricellaria occidentalis*	Upper	90.1	0.0002
	Balanus trigonus	Upper	70	0.0290
	Ascidiella aspersa	Lower	72.3	0.0034
MP	*Anthopleura anjunae*	Upper	52.3	0.0348
	Ascidia sydneiensis	Upper	60.8	0.0108
	Didemnum vexillum	Upper	79.9	0.0010
	Styela clava	Upper	68.7	0.0110
	Magallana gigas	Upper	57.7	0.0396
	Mytilus galloprovincialis	Upper	99.9	0.0002
	Tricellaria occidentalis	Upper	43	0.0432
	Watersipora cucullata	Upper	66.3	0.0452
	Ascidiella aspersa	Lower	83.8	0.0004
TY	*Ciona savignyi*	Upper	19.6	0.0588
	Mytilus galloprovincialis	Upper	46.4	0.0028
YP	*Botryllus schlosseri*	Upper	79.9	0.0006
	Ciona robusta	Upper	46.2	0.0176
	Didemnum sp.	Upper	90.8	0.0002
	Styela plicata	Upper	76.9	0.0002
	Mytilus galloprovincialis	Upper	88.9	0.0002
	Bugula neritina	Upper	90.5	0.0002
	Tricellaria occidentalis	Upper	44.8	0.0460
	Perforatus perforates	Upper	91.4	0.0002
	Balanus trigonus	Lower	83.9	0.0006
GR	*Styela clava*	Upper	66.7	0.0016
	Magallana gigas	Upper	64.6	0.0348
	Mytilus galloprovincialis	Upper	88	0.0002
	Haliclona sp.	Upper	76	0.0002
	Perforatus perforatus	Upper	85	0.0002
	Balanus trigonus	Lower	61.2	0.0672

Abbreviations: JG, Jeongok; MP, Mokpo; TY, Tongyeong; YP, Yangpo; GR, Gangreung

other ($p=0.6426$) (Table 4). ISPN results determined one indicator species on the upper plate exclusively (Table 5).

4) Yangpo

Of a total of 25 species identified on plates installed at Yangpo (Table 2), 24 showed a frequency greater than 5% in the upper and lower plates. These belonged to sixteen families, ten orders, seven classes, and six phyla. The most dominant taxon was class Ascidiacea (33.3%) with *A. aspersa, A. sydneiensis, B. schlosseri, C. robusta, C. savignyi, D. vexillum, S. clava, S. plicata,* and *S. reptans,* followed by class Gymnolaemata (29.2%) with *B. neritina, C. brunnea, C. lata, I. axillare, T. occidentalis, S. unicornis,* and *W. subtorquata* (Fig. 5D). MRPP results indicated that the community structures of the upper and lower plates were statistically distinguishable from each other ($p<0.05$) (Table 4). ISPN determined eight indicator species on the upper plate and one on the lower plate (Table 5).

5) Gangreung

Of a total of 15 species identified on plates installed at Yangpo (Table 2), 10 showed a frequency greater than 5% in the upper and lower plates. These belonged to nine families, seven orders, six classes, and six phyla. The most dominant taxon was class Gymnolaemata (30.0%) with *B. neritina, C. brunnea,* and *W. subtorquata,* followed by class

Thecostraca (20.0%) with *B. trigonus*, *P. perforates*, and class Bivalvia (20.0%) with *M. galloprovincialis* and *M. gigas* (Fig. 5E). MRPP results indicated that the community structures of the upper and lower plates were statistically distinguishable from each other ($p < 0.05$) (Table 4). ISPN revealed five indicator species on the upper plate exclusively (Table 5).

DISCUSSION

MRPP results indicated that the invertebrate communities in four out of the five regions differed significantly in the upper and lower attachment plates, with the exclusion of Tongyeong. ISPN results from Tongyeong, however, revealed a difference in the indicator species. The depth of the plates was a significant factor influencing the characteristics of community structure. Notably, water temperature cannot be considered as a determining factor for changes in community structure with depth since the temperature-depth gradient was statistically negligible under our experimental conditions. This result is in agreement with previous studies on the physical properties of Korean waters (Choi *et al.* 2000; Park *et al.* 2006) reported a scarce difference in the water temperature between the surface and water at shallow depths. Alternatively, we assume that change in light penetration with depth might influence on the community structure given that ISPN analysis indicated that the upper attachment plates in all study locations tend to show a greater number of indicator species than lower plates. It can be supported by Seo *et al.* (2010), who reported that the invertebrate communities could vary significantly due to change in light availability at depths of 1, 5, and 10 m deep in the tidal zone of the Korean coast. Indeed, the light penetration is considered to be one of the physical factors affecting vertical distribution of marine life, and there are numerous reports that light transmittance varies according to the depth, affecting marine photosynthetic algae (Gattuso *et al.* 2006; Gómez *et al.* 2009) and diatoms (Colijn and van Buurt 1975), which are a major component of the diets of various marine invertebrates. Thus, further study is required to determine our hypothesis on the effect of the light to the community structure.

We found that there were geographical differences in the seasonal variation of water temperature and salinity, which can be an important factor in explaining the characteristics of the invertebrate communities in each area. The highest species richness were observed at Mokpo, Yangpo, Tongyeong, Jeongok, and Gangreung in descending order, which can be attributed to the relatively lower water temperatures seen in regions at the lower latitudes. This trend corresponds to the general notion of temperature-dependence species emergence that the species richness of the community tends to increase during the seasons when water temperature rises and decrease when the temperature falls (Kennish *et al.* 2004; Kuklinski *et al.* 2013; Schröder *et al.* 2015). We, therefore, assume water temperature is also a decisive factor that causes geographical disparity in the regional species composition.

In the faunal survey, we identified the characteristics of invertebrate fauna not only in each area but also across regions. Tongyeong, which lies at the oceanic intersection of the Yellow and East Seas, showed intermediate characteristics, including species that appeared in both the Yellow Sea and East Sea areas simultaneously. On the contrary, Jeongok and Mokpo, which are situated in the Yellow Sea were clearly distinguishable from Gangreung and Yangpo in the East Sea, based on the appearance of unique species. In the case of former two localities, frequent exposure to the air as a result of tidal movements can significantly affect the benthic organism in the tidal zone, which is the defining geographical characteristic governing the unique community structure. This is, however, quite opposite to the east coast, in which characteristic of tidal movements much weaker than west. Our statistical analysis on the indicator species revealed that Tongyeong, Jeongok, and Gangreung exhibited a smaller number of indicator species than Mokpo and Yangpo which was due to the unique geographical characteristics in each region. A number of bryozoans, for instance, were determined as indicator species at Jeongok, Mokpo, and Yangpo since most recorded bryozoan species preferred the relatively warm currents of the low latitude regions (Saunders and Metaxas 2008; Denley *et al.* 2019).

In conclusion, we have successfully identified the changes in marine invertebrate communities in Korean waters by performing a monitoring survey over a period of 15 months using artificial substrate plates. We clarified the relationship between the community and the environmental factors such as depth of plate installation and water temperature, and finally determined the dominant fauna in each region that will serve as useful fundamental data for performing sea-region-specific faunal research. The indicator species of each area is expected to play a significant role in monitoring the possible influence of environmental change caused by industrial development and pollution.

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