Distribution and Occupancy Status of Alien Barnacles in South Korea

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ABSTRACT

The barnacles have free-swimming larval life in the sea and then sessile life from juvenile to adulthood. This feature allows them to enter various marine ecosystems through the bottom of the ship and ship hulls, which has the potential to cause disturbances in the marine ecosystem. In this study, the distribution and occupied area (%) of four alien and one indigenous barnacle species in 14 ports of South Korea were monitored. At each port, ten acrylic attachment plates (30x30cm) were installed, which were submerged from May 2017 to October (warm season), and from November 2017 to April 2018 (cold season). The occupancy ratio of all five species was 11.17% in the summer and 7.59% in the winter, showing a higher occupancy in summer. *Balanus trigonus*, an indigenous species, appeared in all regions except Incheon area, with the highest occupancy ratio was observed in the southern sea mainly including Busan, Yeosu and Gwangyang. In the case of four invasive species, *Perforatus perforatus*, *Amphibalanus eburneus*, and *A. improvisus* in the East Sea, *A. amphitrite*, *P. perforatus*, *A. eburneus* and *A. improvisus* in the South Sea, and *A. amphitrite* and *A. improvisus* in the West Sea, distributed respectively. As a result of nonparametric multidimensional scale method, significant differences occurred in the species composition of the East Sea and the South Sea, and the East Sea and the West Sea in both summer and winter periods, and the results well explained by the water temperature and salinity.

Introduction

- The barnacles is the most well-known organisms among the human-mediated species worldwide.
- They can disrupt ecosystems through spatial competition with indigenous species.
- However, Research investigating the distribution and seasonal differences of barnacles across Korea during the same time period are insufficient.
- It is known that the size and growth of barnacles are most affected by water temperature and salinity.
- In this study, we investigated the distribution of 4 exotic barnacles and 1 indigenous species targeted by season at a national scale and investigated the relationship between environmental factors related to water temperature and salinity and their distribution.

Materials and Method

1. Test species

Table 1. The abbreviations, Origin, and year of invasion of the test barnacle species in the present study

Species	Abbr.	Origin	Year of in vasion	Reference
Amphibalanus amphitrite	AMP	Unknown	1979	Kim and Kim, 1980
Perforatus perforatus	PER	Western Europe, Northwest Coast of Africa, M editerranean Sea	2000	Kim And Hong, 2010
Amphibalanus eburneus	EBU	North Atlantic Ocean		Kim, 1992
Amphibalanus improvisus	IMP	East North America	1990s	Kim, 1992
Balanus trigonus	TRI	**Native species**		

2. Sampling site

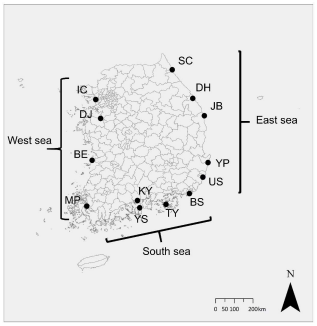


Figure 1. Map of the East, South, and West sea showing the 13 sampling sites surveyed for the occupied area of five barnacle species. Information of each sampling site were shown in Table S1.

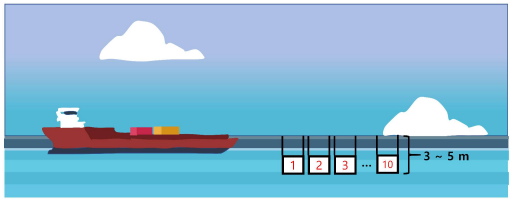
Table 2. Abbreviation, geographical coordination, and sea area of sampling site (port name)

Sampling site (port name)	Abbreviati on	Latitude	Longitude	Sea area
Sokcho	SC	38.210563	128.595372	East sea
Donghae	DH	37.491075	129.125603	
Jukbyeon	JB	37.055053	129.423896	
Yangpo	YP	35.878019	129.519859	
Ulsan	US	35.511124	129.386146	
Busan	BS	35.099024	129.038604	South sea
Tongyeong	TY	34.827298	128.435231	
Guangyang	KY	34.923204	127.696575	
Yeosu	YS	34.742078	127.755551	
Mokpo	MP	34.783600	126.388623	West sea
Bieung	BE	35.935197	126.527395	
Dangjin	DJ	36.986826	126.746202	
Incheon	IC	37.462473	126.620434	

3. Sampling design

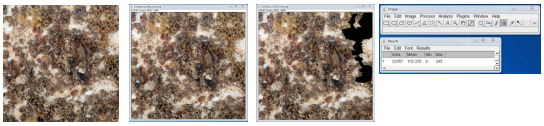
At each sampling site, ten acrylic attachment plate (30x30cm) which barnacle species can attach and inhabit were installed at a depth of 3 to 5m from the sea level at low tide.

The installed attachment plates were submerged and exposed for six months each in two seasons (warm and cold season).
Warm season: May to October 2017, including mainly spring and summer,
Cold season: November 2017 to April 2018, including autumn and winter.



After six mounth, the surface of attachment plates were photographed using a vertically fixed digital camera.

The occupied area of each test species and total area of the attachment plate were measure based on the number of pixel using the ImageJ program (Schneider, 2012).



The barnacle occupied area (%) was calculated as the ratio of the occupied area area of target species to the total area of the attachment plate.

4. Statistical analysis

- The default inverse distance weighting method (IDW) (r 'gstat' package; Pebesma, 2004) – extrapolation of temperature and salinity.

- non-metric multidimentional scaling (NMDS) with permutation multivariate analyses of variance (r 'vegan' package) evaluate the relationships among distribution and abundance of barnacle, environmental factors, and sea areas

Results

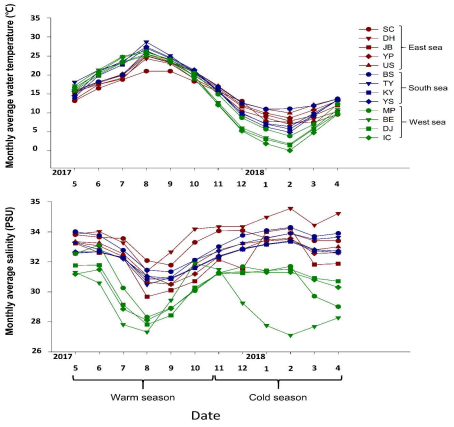


Figure 2. Monthly average water temperature and average salinity of each sampling sites from May 2017 to April 2018. The sampling sites were divided into three categories (east sea, south sea, west sea) according to their location and sampling dates were divided into two categories (warm season and cold season).

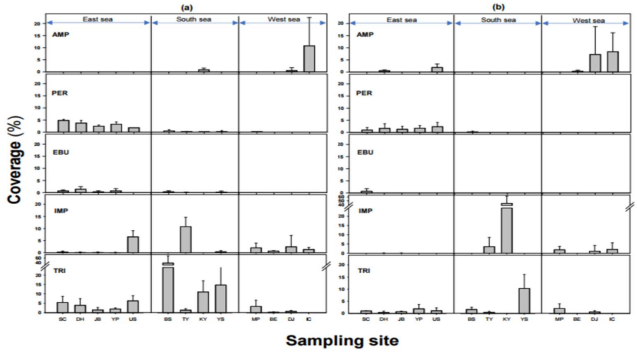


Figure 3. Mean occupied area of five barnacles at 13 sampling sites in east, south, west sea. Error bars means standard deviation. The attachment plates were exposed in water at a depth of 2 to 5 m of each sampling site from May 2017 to October 2017 (warm season; (a)) and from November 2017 to April 2018 (cold season; (b)). the occupied area (%) was calculated by the area occupied by each species in the total area of the attachment plate at the last month of exposure duration

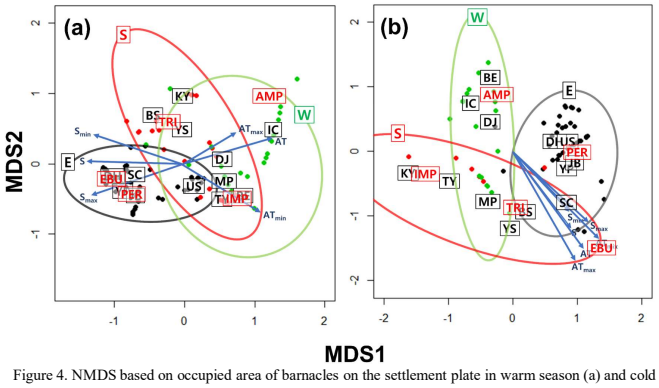


Figure 4. NMDS based on occupied area of barnacles on the settlement plate in warm season (a) and cold season (b) with the superimposition of the confidence ellipses (for α=0.05), relative to east sea (Black), south sea (red), west sea (green). Text with black and red box indicate sampling site and barnacle species, respectively. Arrows represent the significant variables related with water temperature and salinity as determined by the function "envfit" (P<0.05).

Conclusion

- Water temperature and salinity were significantly involved in the distribution and habitats preference of the five barnacle species
- The habitat of the indigenous barnacles has been maintained on the in a wider distribution than the four alien species.
- However, the alien barnacle species may cause economic damage to ship operation and ecological disturbance to indigenous sessile organisms. therefore, continuous monitoring is required.
- These barnacle community data of this study can be used as basic data that can set standards in terms of the ecological status of the barnacle in the marine ecosystem.