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Baseline

Biodiversity hotspot for marine invertebrates around the Dokdo, East Sea, Korea: Ecological checklist revisited

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ABSTRACT

We extensively reviewed the macrozoobenthos around Dokdo, Korea, by analyzing metadata collected over the past 50 years. The Dokdo macrozoobenthos was represented by 578 species belonging to 243 families from 12 phyla, where four major phyla (or classes) collectively accounted for 86% to total. Mollusks, arthropods, and cnidarians were semi-equally occurred in intertidal and subtidal areas, while polychetes dominated the subtidal zone. The northern most region of Dokdo had the greatest biodiversity (173 species). The taxonomic distinctness analysis (delta +) indicated a close association between species by region, although the number of species varied greatly. About half of the species did not occur cross the locations (n = 20), indicating strong habitat preferences of Dokdo macrofaunal assemblages. Overall, the diversity of Dokdo was greater than that of Ulleung Island (east coast), but comparable to that of the well-developed tidal flats in the western Korean waters, highlighting its status as a biodiversity hotspot.

The Dokdo is an island in the East Sea of Korea, which is located in the easternmost territory of Korea, and a region of public concern because of the scientific merit and economic value that has been revealed over the last 50 years. The Dokdo (37° 13.9′ N, 131° 52.3′ E) is situated 217 km from the mainland and 87 km from Ulleung Island (Fig. 1). Dokdo collectively encompasses two large volcanic islands (Dongdo and Seodo) with 89 small islets and rocks. The island was designated as natural monument No. 336 by the Cultural Heritage Administration of Korea in 1982, with public access being restricted (Cultural Heritage Administration, http://www.cha.go.kr).

This far remote volcanic island of Dokdo has unique characteristics, exhibiting all processes of geographical seamount formation between the period of 4.6 and 2.5 Mya (Sohn and Park, 1994; Kim et al., 2013). The evolution of Dokdo involves dynamic sedimentary processes which could result in a variety of habitats, including gravel shores, marine plateaus, and coastal terraces (Sohn and Park, 1994; Ryu et al., 2012). Because of the influences of two major currents, the Tsushima Warm Current and the North Korea Cold Current, the sea around Dokdo is rich in nutrient sources (Chang et al., 2015). Altogether, the dynamic geological and environmental conditions generally support diverse and abundant plankton and benthos, as well as commercially important fishery resources (Je et al., 1997; Choi et al., 2002; Park et al., 2002).

While Dokdo is expected to contain rich and well-preserved biodiversity, scientific publications remain limited due to difficulty accessing the island, which is 217 km distant from mainland Korea. Here, we aimed to provide more recent numbers on the taxonomic diversity of marine invertebrates around Dokdo, while also integrating information on biogeography and system ecology (i.e., distribution and habitat preferences). Previous publications focused on the taxonomy of marine invertebrates, whereas, here, we also reviewed ecological studies, to enhance our understanding of the ecology of Dokdo taxa.

In brief, we aimed to 1) provide the most up-to-dated count of Dokdo taxa through a metadata analysis, with thorough taxonomic re-identification, 2) characterize species composition and regional distribution in intertidal and subtidal communities, and 3) determine the general ecological quality of the well-preserved status of the benthic communities. This information will help us determine how the diversity of marine invertebrates around Dokdo compares with that of well-

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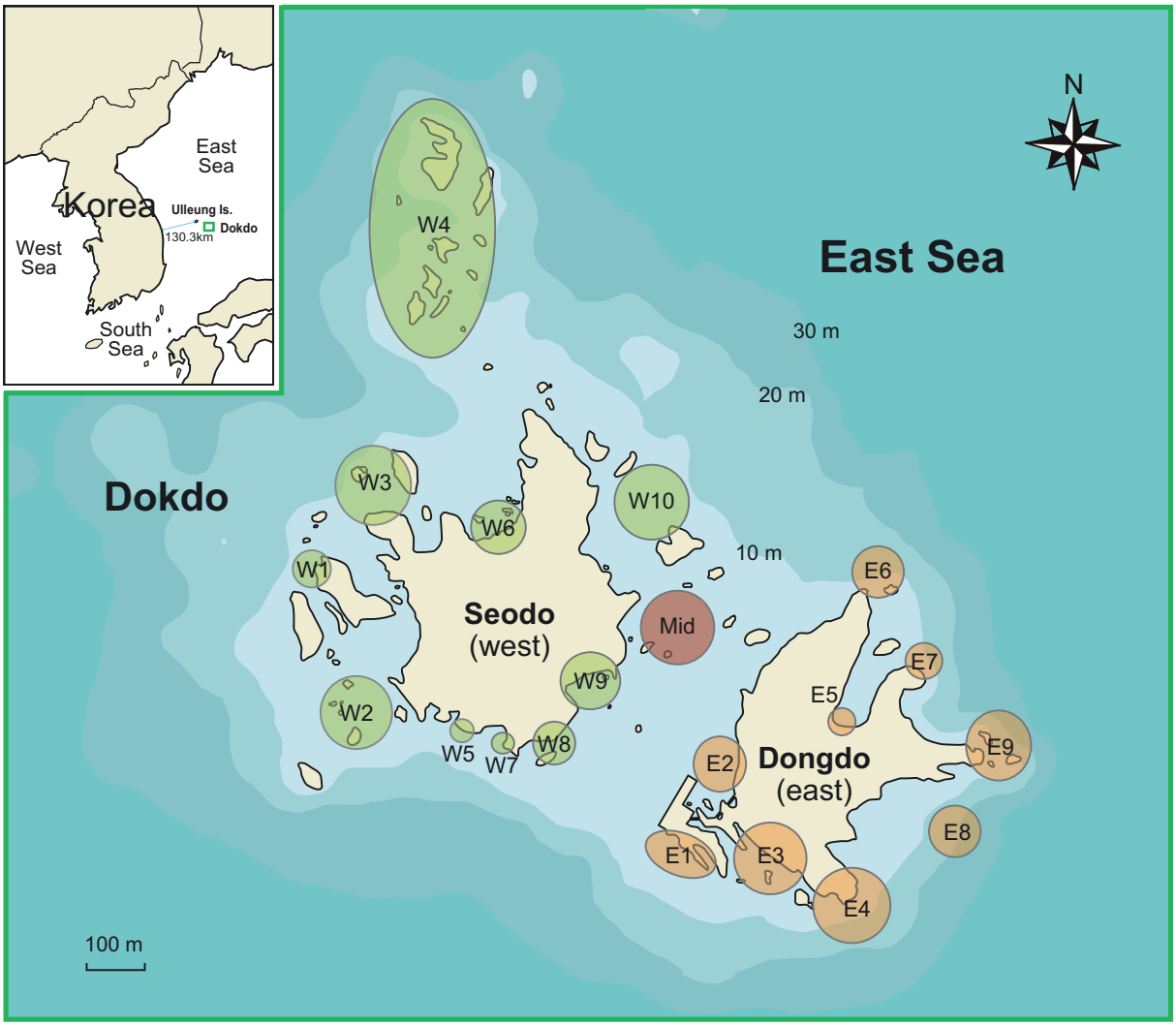

Fig. 1. Map showing the sampling regions reported by previous studies around Dokdo, Korea, over the last half century (1960–2013); sampling regions of W1–W10 and Mid were located around Seodo (west), while E1–E9 were located around Dongdo (east). For details on sampling, see Table 1.

developed tidal flats along the west coast of Korea and nearby Ulleung Island in the East Sea of Korea.

To produce a complete and up-to-dated ecological checklist of macrozoobenthos reported around Dokdo, we analyzed the historical development of studies to obtain information on species occurrence, composition, and distribution patterns based on metadata reported over the last 50 years (1960–2013). A total of 41 documents are carefully selected to provide up-to-dated list of Dokdo invertebrate taxa, including 1) peer-reviewed journal articles, 2) peer-reviewed governmental report or encyclopedia, and 3) dissertation relating to macrozoobenthos assemblages. Of note, we reconfirmed the species identification during the meta-data analysis, thus presented ecological checklist would warrant the correct scientific information followed by data interpretation. Information about habitat types and geological locations was used to identify the spatial distribution of marine invertebrates around Dokdo, which strengthened the significant use of ecological data in checklist (Table 1).

To assess the spatial distribution of taxa around Dokdo, we established 20 sampling regions across the two islands of Seodo and Dongdo based on information provided in the various publications (Fig. 1). The Seodo group (west: W1–W10 & Mid) contained 11 regions, including the northern limit of the boundary (W4: Mul-Gae-Ba-Wi) and the central region (Mid: Chot-Dae-Ba-Wi). The Dongdo group (east: E1–E9) contained nine regions, including the main wharf (E2), the old wharf (E7), and the eastern limit of the boundary (E9: Dok-Lip-Mun-Ba-Wi).

To provide the most precise and up-to-dated information for the reported taxa, we re-identified all of the species that had been reported by thorough comparisons with the database of the World Register of Marine Species (http://www.marinespecies.org). As a result, we obtained a final inventory of 578 marine invertebrate species belonging to 243 families from 12 phyla, excluding all specimens only identified above the family level. This list of macrozoobenthos around Dokdo included the species occurrence and distribution across two habitat types (viz., intertidal and subtidal areas), as well as throughout the 20 regional localities between the Seodo and Dongdo islets (Fig. 1). To compare the biodiversity across the 20 regional localities, a taxonomic distinctness index (delta +) was calculated using species occurrence data (Clarke and Warwick, 1998). We also included some environmental variables (i.e., bottom type, species density, and biomass), if available, to improve our description of the faunal assemblages in the ecosystem.

A Korean taxonomist first inventoried the invertebrate assemblages of Dokdo in the 1950s, producing the first publication in 1960 (Kim, 1960, refer to Table 1). The author investigated the brachyuran and anomuran crabs of Ulleung Island and Dokdo, recording one hermit crab, *Eupagurus similis* (Ortmann, 1892) = presently *Pagurus similis* (Ortmann, 1892), and one crab, *Pachygrapsus crassipes* (Randall,

Table 1
Summary of the sampling information and reported marine invertebrates in Dokdo of Korea, corresponding references given.

Article type	Sampling				# of species	Macrofaunal composition				References
#	Year	Site	# of locations	Habitat type		Mollusca	Arthropoda	Annelida	Others	
Peer-reviewed articles										
1	1958	Dokdo	1	Intertidal	2		2			Kim, 1960
2	1958	Dokdo	1	Subtidal	3				3	Rho and Kim, 1966
3	1976	Dokdo	n.s.	Intertidal	16	7	8		1	Kim, 1978
4	1981	Dokdo	n.s.	Intertidal, subtidal	42	19	17		6	Kim and Choe, 1981
5	1981	Dongdo, Seodo	4	Intertidal, subtidal	22	15	5		2	Hong, 1981
6	1992	Dongdo, Seodo	?	Intertidal, subtidal	22	22				Son and Hong, 1992
7	1989	Dongdo, Seodo	2	subtidal	9	9				Choe and Lee, 1994
8	1995	Dongdo, Seodo	2	Intertidal, subtidal	7		7			Kim et al., 1996
9	1995	Dongdo, Seodo	2	Intertidal, subtidal	17	17				Choe et al., 1996
10	1996	Dongdo, Seodo	2	Intertidal, subtidal	8	4	3		1	Je et al., 1997
11	1993–1999	Dongdo, Seodo	8	Intertidal, subtidal	15				15	Park and Song, 2000
12	1999	Dokdo	1	Intertidal	9	7	2			Cha et al., 2002
13	1997–1999	Dongdo, Seodo	11	Intertidal, subtidal	22		22			Oh, 2001
14	2000	Dongdo, Seodo	5	Subtidal	13	6			7	Park et al., 2002
15	1999–2000	around Dokdo	5	Subtidal	48			48		Choi et al., 2002
16	2004	Dongdo, Seodo	8	Intertidal, subtidal	25	25				Son et al., 2004
17	2002–2004	Dongdo, Seodo	8	Intertidal, subtidal	16				16	Choi et al., 2006
18	1999–2004	Dongdo, Seodo	8	Subtidal	13		13			Hong et al., 2006
19	2006–2008	Dongdo, Seodo	8	Subtidal	29	29				Hong et al., 2008
20	2007–2008	Dongdo, Seodo	9	Intertidal, subtidal	97	45	24	11	17	Ryu et al., 2012
21	2012	Dongdo	1	Intertidal, subtidal	34	12	5	11	6	Kang et al., 2013
Illustrated encyclopedia										
1	n.s.	Dokdo	1	Intertidal	2		2			Kim, 1973
2	1958	Dokdo	1	Subtidal	2				2	Shin, 1996
3	n.s.	Dongdo, Seodo	n.s.	Intertidal, subtidal	110	44	10	4	52	KORDI, 2008
4	n.s.	Dongdo, Seodo	n.s.	Intertidal, subtidal	117	54	20	4	39	NFRDI, 2009
Governmental report										
1	1996–1997	Dongdo, Seodo	5	Intertidal, subtidal	60	60				Je et al., 1998
2	1997	Dongdo, Seodo	n.s.	Intertidal, subtidal	32			32		Paik, 1998
3	1999	Dongdo, Seodo	15	Intertidal, subtidal	209	47	42	55	65	DRPA, 1999
4	1997–1999	Dongdo, Seodo	5	Intertidal, subtidal	55			55		Lee, 2000
5	2001	Seodo	2	Intertidal, subtidal	59	31	14		14	Lee et al., 2001
6	2003	Dongdo, Seodo	3	intertidal, subtidal	36	13	10	8	5	DURI-GJU, 2004
7	2005–2006	Dongdo, Seodo	3	Intertidal, subtidal	89		56		33	Kim and Kim, 2006
8	2005–2006	Dongdo, Seodo	3	Intertidal, subtidal	96	61		29	6	Lee and Seo, 2006
9	2007	Dongdo, Seodo	7	Intertidal, subtidal	90	44	25	7	14	Ryu et al., 2007
10	2008	Dongdo, Seodo	7	Intertidal, subtidal	70	40	14	1	15	DREO, 2008
11	2007–2008	Dongdo, Seodo	9	Intertidal, subtidal	96	44	25	10	17	DIRA, 2008
12	2008	Dongdo, Seodo	6	Intertidal, subtidal	128	51	31	17	29	NFRDI, 2008
13	2009	Dongdo, Seodo	n.s.	Intertidal, subtidal	97	45	25	11	16	RIUD-KNU, 2009
14	2009	Dongdo, Seodo	7	Intertidal	31	23	4		4	DREO, 2009
15	2010	Dongdo, Seodo	7	Intertidal	31	20	5		6	DREO, 2010
16	2011	Dongdo, Seodo	7	Intertidal	41	28	8	1	4	DREO, 2011

n.s.: not specified.

1840) around Dokdo. Subsequently, Rho and Kim (1966) recorded 25 species of echinoderms belonging to 17 families from 34 localities in the coastal waters of Korea, of which three echinoid species, *Hemicentrotus pulcherrimus* (Agassiz, 1863), *Heliocidaris crassispina* (Agassiz, 1863), and *Echinometra mathaei* (Blainville, 1825) were recorded around Dokdo.

During the period 1970s to early 1980s, only four studies were performed around Dokdo (Kim, 1978; Kim and Choe, 1981; Hong, 1981) and one reference illustrating the records of decapod from Dokdo was documented (Kim, 1973). Of note, the first investigation for the benthic invertebrates in the bottom water environment was conducted by SCUBA diving (Hong, 1981). This work was also the first in which a marine ecologist discussed faunal distribution patterns cross four vertical zones; namely, the supralittoral, mediolittoral, infralittoral, and circalittoral. In anyhow, the lack of studies during these periods might have been due to natural obstacles (distance or weather) and/or politics of strictly limited access to the public during the given years.

However, during the course of the 1990s, studies of marine invertebrates around Dokdo noticeably increased with respect to both research topic and scale, and was paralleled by a timely increase in governmental support. One representative work by Son and Hong (1992) cataloged 40 species of mollusks around Dokdo belonging to 18 families from four the main classes of Polyplacophora, Gastropoda, Bivalvia, and Cephalopoda. Subsequently, Paik (1998) collected underwater sediment samples using SCUBA, at depths of up to 10 m, and listed the first polychete species in the region, documenting 32 species belonging to 31 genera of 17 families. This work included a discussion of their biogeographical distribution.

Until the late 1990s, most studies focused on the taxonomy of marine invertebrate taxa around Dokdo, with studies since the 2000s increasingly focusing on ecological aspects. For example, Park et al. (2002) and Choi et al. (2002) analyzed the benthic community to link species composition and distribution to environmental conditions in the study area.

Since the mid-2000s, various research projects supported by central and local governments were launched to monitor the macrozoobenthic community structure of Dokdo (DREO, 2008; DREO, 2009; DREO, 2010; DREO, 2011; NFRDI, 2008; NFRDI, 2009). These efforts helped to improve our understanding about the marine invertebrates of Dokdo, including polychetes (Lee, 2000), crustaceans (e.g. hermit crabs, Oh,

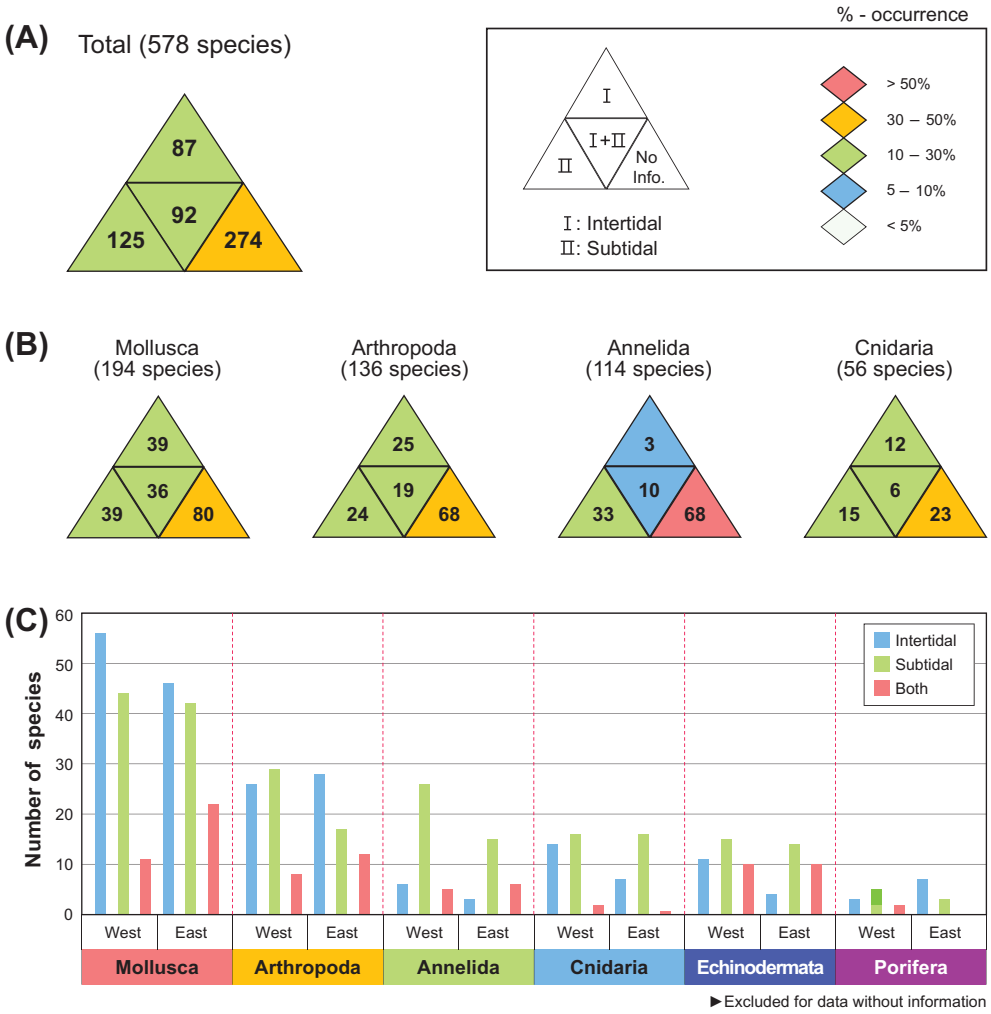

Fig. 2. Occurrence of macrozoobenthos species in different habitats; namely, intertidal, subtidal, and both combined; (A) for all 578 species, (B) for the four major phyla of Mollusca, Arthropoda, Annelida, and Cnidaria, and (C) in a regional comparison of Seodo (west) and Dongdo (east) islands of Dokdo for the six major phyla.

2001; decapods, Hong et al., 2006; Hong et al., 2008), and mollusks (Son et al., 2004). More recently, Ryu et al. (2012) updated the list of Dokdo taxa, obtaining 403 species. The authors also added 21 newly reported taxa (98 species in 7 phyla reported) from their own work. Overall, Ryu et al. (2012) produced the most comprehensive review of macrozoobenthos on Dokdo, discussing various ecological characteristics, including species composition and habitat type, in addition to the occurrence, distribution, and biodiversity of fauna.

We only listed the macrozoobenthos species around Dokdo that could be distinguished to the species (or subspecies) level, after careful reconfirmation. A total of 578 species or subspecies of 409 genera belonging to 243 families from 12 phyla were identified (Fig. 2A). These species were primarily composed of four major groups: Mollusca (n = 194 spp.), Arthropoda (n = 136 spp.), Annelida (n = 114 spp.), and Cnidaria (n = 56 spp.), collectively accounting for ca. 86% of all invertebrate species (Fig. 2B). The remaining phyla included Echinodermata (n = 29 spp.), Porifera (n = 20 spp.), and others (n = 29 spp.), which consisted of a small number of species, including Chordata (almost ascidians), Bryozoa, Platyhelminthes, and Ctenophora.

Of note, out of the main animal groups, the phylum Mollusca primarily contained gastropods (65%), bivalves (24%), polyplacophores (9%), and cephalopods (2%). The phylum Arthropoda primarily contained crustaceans (ca. 96%), of which 73 species (53%) were decapods including shrimps, hermit crabs, and crabs.

To determine the habitat preferences for the marine invertebrate taxa listed around Dokdo, occurrence based distributions were examined by counting the distributions of the different taxa across intertidal and subtidal habitats. The results were compiled as pyramid diagrams (Fig. 2A–B). Overall, the distribution of the invertebrates around Dokdo in terms of habitat preference showed low variation across taxa, except for Annelida, for which most species occurred in subtidal areas. A relatively large proportion of co-occurrence across the intertidal and subtidal areas reflected the common distribution of widespread taxa in the dynamic environmental conditions of the study area. Of note, mollusk species were equally distributed across intertidal and subtidal areas, in which they exhibited the greatest co-occurrence, with a low degree of habit preference.

No clear habitat preference was detected when assessing the regional distribution of marine invertebrates around Dokdo, with comparable numbers of species occurring across the Seodo and Dongdo islets. However, the diversity of certain taxa was slightly greater around Seodo (west) compared to Dongdo (east), especially for Mollusca and Annelida.

Out of the 20 regions around the Seodo and Dongdo islets of Dokdo surveyed during the previous studies, region W4 (Mul-Gae-Ba-Wi) contained the most diverse macrozoobenthos. This region contained 173 species, dominated by the mollusks (52 species), followed by arthropods (48) and annelids (25) (Fig. 3A). These three taxa collectively occupied over 70% of total number of macrozoobenthos species. Compared to other regions, this region was quite flat, with comparatively easy access for intertidal sampling and was suitable for SCUBA sampling in the subtidal areas.

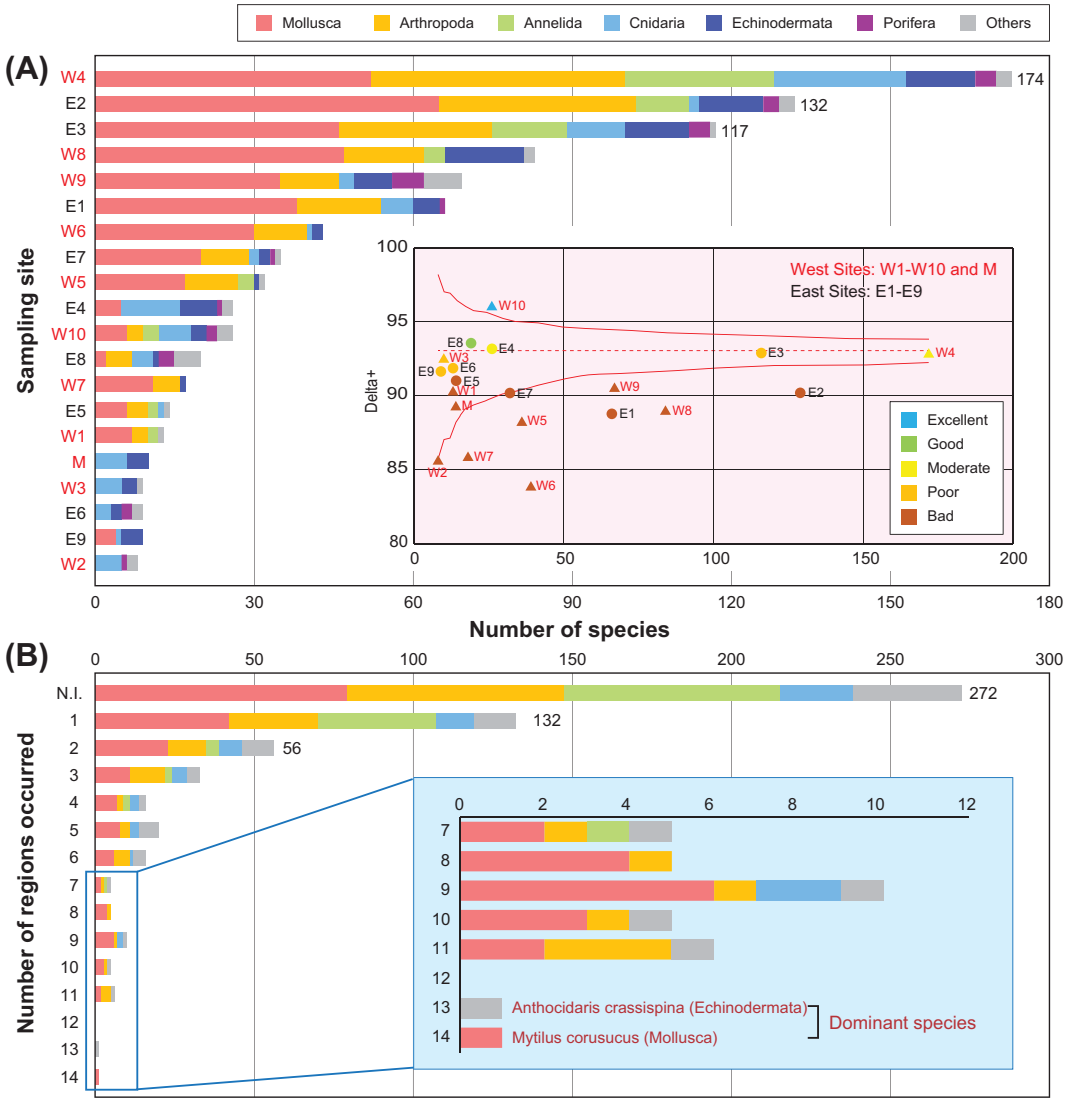

Fig. 3. Regional distribution of macrozoobenthos species in Dokdo; (A) Number of occurred species in Seodo (west) and Dongdo (east) islands of the Dokdo by 6 major phyla and others; delta + indicating benthic ecological quality also given, (B) (B) Number of co-occurred regions by 6 major phyla and others, The inset shows the most common species being dominated in > 7 regions of 20 total.

In addition to region W4, the macrozoofaunal diversity was investigated in the subtidal areas of two of the of East regions (E2 and E3). Region E2 supported relatively high diversity, containing 132 species, of which over 75% were mollusks and arthropods. Region E3 also supported a high diversity of benthic animals, with 117 species. Mollusks and arthropods were also the dominant taxa, representing ca. 64% of total species.

This relatively high species diversity in E2 and E3 might be attributed to the well-developed intertidal zones, which, while small in size, provided easy access for sampling invertebrates. In contrast, all other regions, which contained much smaller habitats, supported < 90 species (maximum 83 species in region W3, minimum 8 species in region W2). In particular, the lack of intertidal habitats in regions W2 and W3 of Seodo and regions E6 and E9 of Dongdo supported very low species diversity, with < 10 species (8, 9, 9, and 9 species, respectively). Of note, the regional diversity of macrozoobenthos apparently influenced by both the geographical feature of sampling sites (say spatial size in intertidal zone) and the degree of sampling quality being underestimated by limitations on sampling conditions.

To understand the characteristics of regional occurrence and distribution, we examined the distribution pattern across the 20 regions. Unexpectedly, over 130 of the total 578 species occurred in just one of the 20 regions (Fig. 3B). Site information was not given for 272 species; following the exclusion of these species, the 130 species found in the single region accounted for about half of species. Thus, Dokdo appears to lack of commonly occurring typical species that are widely distributed.

Fewer commonly distributed species were detected, with the number of co-occurring species rapidly decreasing as the number of regions increased. For example, 56 species co-occurred at in two regions, with just 33 species occurring across three regions. Collectively, a total of 221 macrozoobenthos species occurred within the three regions, while the remaining 85 species were distributed across just four regions. However, species composition did not greatly differ across these regions, which might be due to random sampling across surveys (or localities). At least 13 species appeared to co-occur in > 10 regions (six mollusks, four arthropods, and three others), which are considered as typical common invertebrates around Dokdo. Of note, two of the dominant species around Dokdo were found. Specifically, *Heliocidaris crassispina* (Agassiz, 1864) from the phylum Echinodermata co-occurred in 13 regions, while *Mytilus coruscus* (Gould, 1861) from the phylum Mollusca co-occurred in 14 regions.

Based on the analyses of the occurrence, distribution, and abundance of species, we narrowed down the typical (i.e., common) taxa

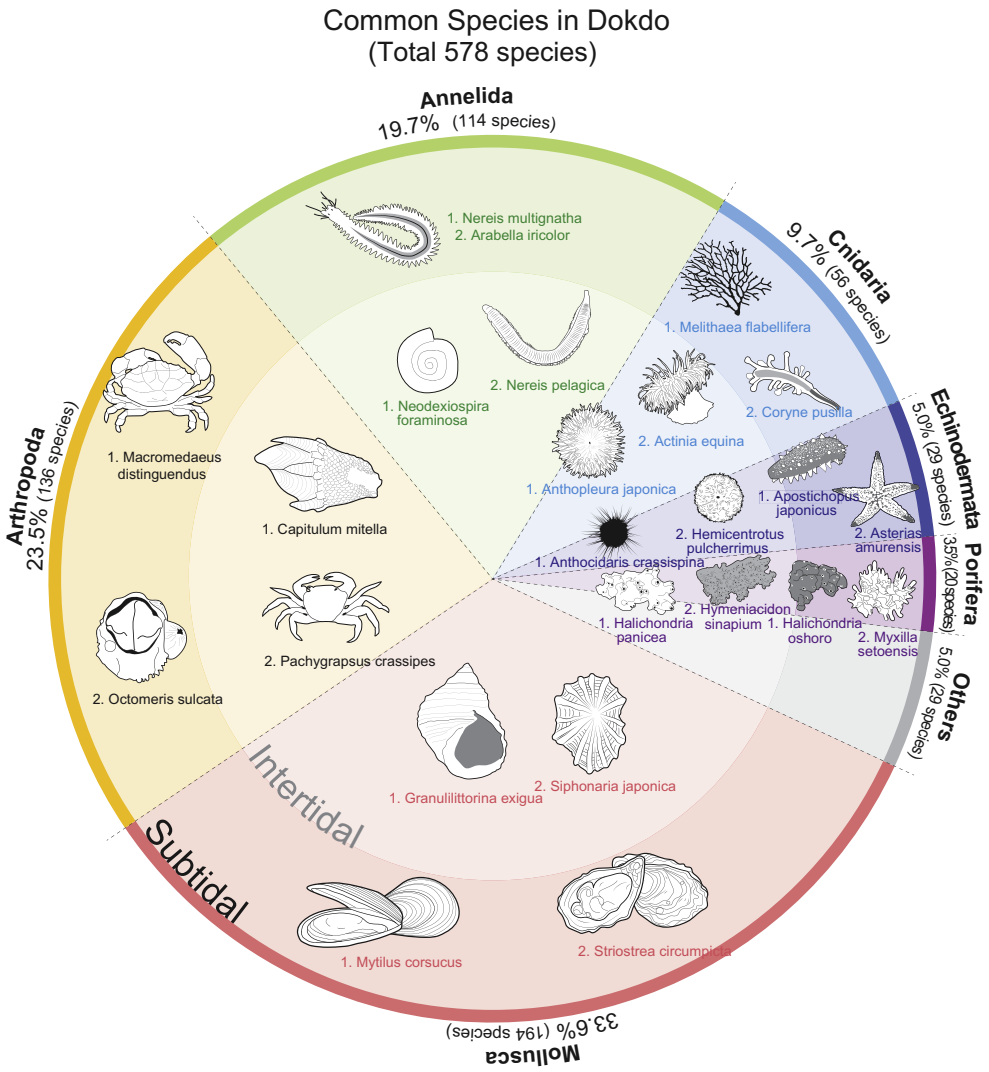

Fig. 4. A simple illustrated description of the common invertebrate taxa found in the intertidal and subtidal areas of Dokdo. The proportion of corresponding taxa and the top two dominant species in each habitat are provided for comparison.

found around Dokdo to identify the representative species of the region, if any. Fig. 4 represents a pictorial diagram showing the representative common species of benthic invertebrates at the phylum level from the intertidal and subtidal areas of Dokdo. In other words, this figure shows the most recorded species from the 20 regions around Dokdo, including Dongdo and Seodo and the adjacent islets, with morphological characteristics also being shown.

The Phylum Mollusca was the predominant taxon with 194 species, of which two gastropods, *Granulilittorina exigua* (Dunker, 1860) and *Siphonaria japonica* (Donovan, 1824), were the most common species in the intertidal zone and two bivalves, *Mytilus coruscus* (Gould, 1861) and *Striostrea circumpicta* (Pilsbry, 1904), were the most common species in the subtidal area. The Phylum Arthropoda was dominated by *Capitulum mitella* (Linnaeus, 1758) of the stalked barnacles and *Pachygrapsus crassipes* (Randall, 1840) of the grapsid crabs in the intertidal zone, and was dominated by *Macromedaeus distinguendus* (De Haan, 1835) of the xanthid crabs and *Octomeris sulcata* Nilsson-Cantell, 1932 of the barnacles in the subtidal zone.

The Phylum Annelida was the third dominant group, containing 114 benthic polychetes. The most common species were *Neodexiospira foraminosa* (Moore and Bush, 1904) on hard rock bottoms, *Nereis pelagica* (Linnaeus, 1758) in the intertidal zone, and *Nereis multignatha* (Imajima and Hartman, 1964) and *Arabella iricolor* (Montagu, 1804) in the subtidal zone. These commonly occurring species found in Dokdo generally belonged to widely distributed species that are found throughout the coastal waters of Korea (Ryu et al., 2012; Park et al., 2014).

The increasing impacts of various human activities, including global warming, rising sea levels, and the invasion of alien species, cause major stresses on long-term ecological changes in the marine benthic ecosystem (Schückel et al., 2015). To monitor such long-term ecological changes, fundamental knowledge and understanding of our seas and associated ecosystems are required. Although extensive scientific efforts have long been practiced to identify and document coastal and marine invertebrates, their significance and implications in terms of science-based policy implementation remain poorly acknowledged.

To effectively manage marine bio-resources in a sustainable manner, the integrated accumulation of species checklists would be essential as a fundamental step; however, such efforts at documenting and analyzing metadata seem to be far beyond individual excellence (Ryu et al., 2012; Park et al., 2014). Thus, upon the opportunity of updating the ecological checklist of Dokdo macrozoofauna, we extended our viewpoint towards regional comparisons of Dokdo to closely situated Ulleung Island (representing east coast of Korea) and western Korean waters. To our knowledge, the presently reviewed meta-data of macrozoobenthos on Korean coastal waters would be considered as most up-to-dated checklist for marine invertebrate species.

First, we compiled and analyzed the taxonomic metadata for

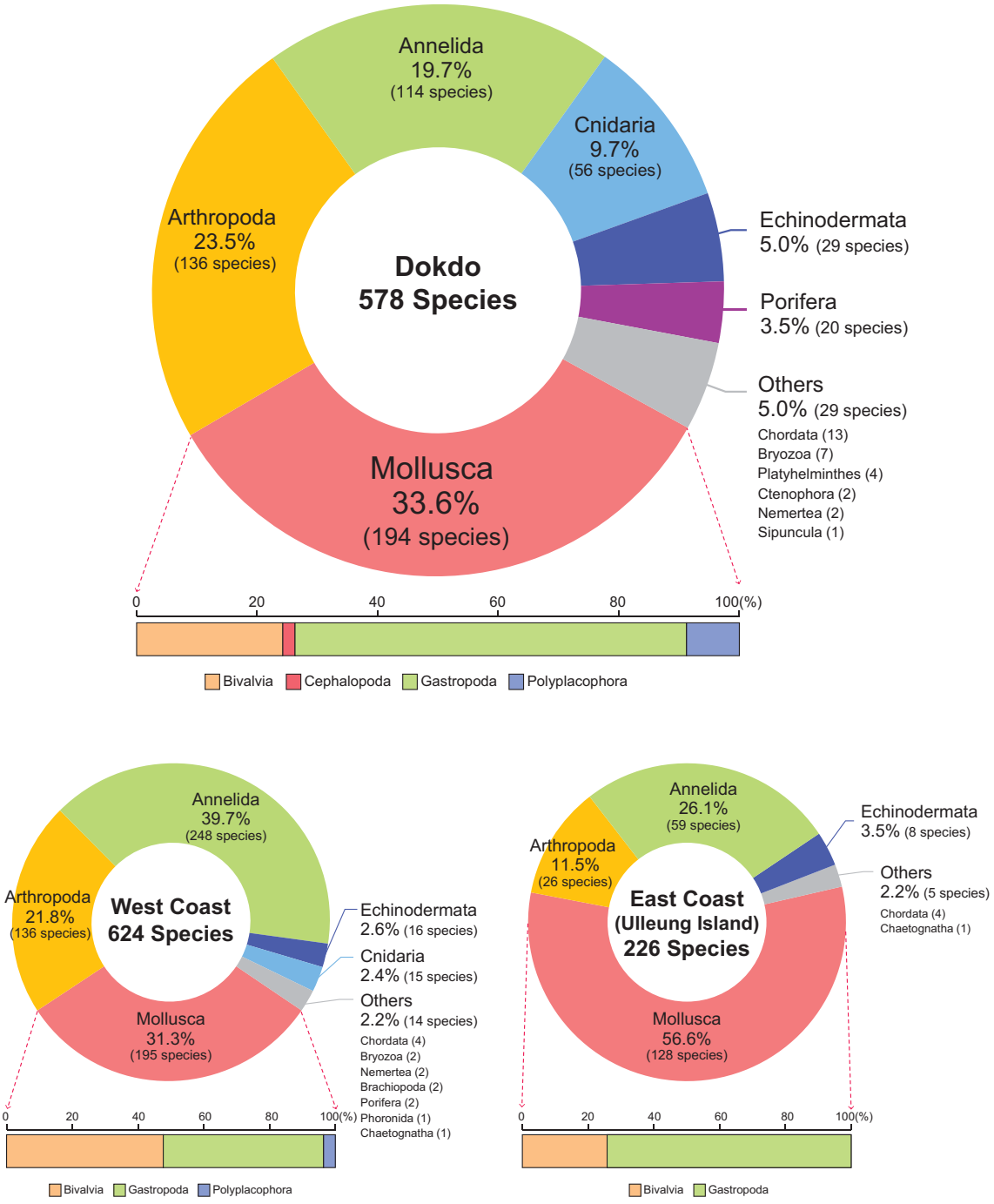

Fig. 5. Composition of the macrozoobenthos recorded in Dokdo (present review), the tidal flats along the west coast of Korea, and Ulleung Island on the east coast of Korea, providing the total number of invertebrate taxa and their species composition to the phylum level.

macrozoobenthos reported in the coastal areas of the Ulleung Island (Fig. 5). The island is situated closer to Dokdo compared to the east coast of the Korean Peninsula, and has a similar environment to Dokdo. A total of 226 invertebrates have been reported around Ulleung Island since the mid-1980s, which represent just 40% of the numbers detected around Dokdo. However, research effort is also comparatively lower in Ulleung Island, which may account for the lower numbers (13 references available from Ulleung Island: Cha et al., 2002; Choe et al., 1994; Choe and Lee, 1994; Choe and Yoon, 1990a, Choe and Yoon, 1990b; Choe and Yoon, 1992; Kim et al., 1993; Kim and Kim, 1991a; Kim and Kim, 1991b; Kim and Kim, 1991c; Paik, 1986; Park, 1988; Sim and Kang, 2004). The composition of macrofauna across the two islands did not seem to be comparable across invertebrate taxa. However, the proportion of macrofauna was identical across the two islands, in the order of Mollusca, Annelida, and Arthropoda. These results indicate that the faunal assemblages of the two islands were generally similar.

Next, a recent review by Park et al. (2014) revealed that a total of 624 marine invertebrates have been collectively reported in the well-developed tidal flats along the west coast of Korea over the last 40 years (Fig. 5). Not surprisingly, the most abundant taxon in the Korean tidal flats was the Phylum Annelida (39.7%), followed by Mollusca (31.3%) and Arthropoda (21.8%). A similar number of marine invertebrate taxa was documented around Dokdo (total of 578 species); however, the species composition slightly differed to that of the Korean tidal flats. For example, the phylum Annelida (19.7%) was less dominant com-

pared to Mollusca (33.6%) around Dokdo, whereas Cnidaria (9.7%) was more dominant. These differences might be explained by the corresponding habitat characteristics; namely, the obvious contrast in bottom sediment faces between Dokdo and the west coast of Korea.

In conclusion, our study provided the most up-to-dated numbers of marine invertebrates in the far remote island of Dokdo, Korea, based on a metadata analysis of > 40 publications over the last half century. A total of 578 species were recorded in Dokdo compared to 624 species found in the coastal tidal flats of Korea, which represent a well-known diversity hotspot globally. The regional distribution of marine invertebrates across the two main islands of Seodo and Dongdo revealed site-specific habitat preferences in the tidal regime. Only a small number of species were widely distributed (i.e., common) throughout Dokdo, which might reflect the dynamic environmental conditions across the region and localities. The top three phyla were Mollusca, Annelida, and Arthropoda, which accounted for most marine invertebrates in the waters of Korea, including Dokdo (ca. 80%). The phyla Cnidaria and Porifera were also important taxa on Dokdo, with > 13% occupation. Overall, the marine invertebrate taxa reported to occur around Dokdo showed a similar species composition to Ulleung Island, east coast of Korea due to the close geographical setting, but quite different from those found in western Korean coastal waters being dominated by soft bottom communities.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.marpolbul.2017.03.068.

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