Chapter 14
Benthic Animals

Jin-Woo Choi

Abstract The species composition and distribution of macrobenthic fauna in the East Sea (Japan Sea) are summarized and briefly introduced in this chapter from many investigations in both small scale local areas including coastal bays and shallow subtidal areas and large scale areas extending from shelf to bathyal and abyssal depths. There have been few studies on benthic organisms in the deep bottoms of the East Sea, and some recent investigations have not been completed or the target benthic fauna were restricted to a particular faunal group such as bivalves, polychaetes, sipunculids and pericarid crustaceans. Because both the faunal composition and the distribution of the benthic fauna are closely related to the sedimentary facies they inhabit, there were complex benthic faunal assemblages in the southwestern shelf area of the East Sea. The East Sea contains various benthic environments from shallow coastal zones to bathyal and abyssal depths and the distribution of macrobenthic fauna clearly represents the diversity of environmental factors related to the depth gradient. It is expected that when the water depth increased, the abundance and diversity of macrobenthic fauna decreased, although this conclusion is based on only a few fragmental fauna data. From the recent research by Russian investigators on bathyal and abyssal fauna, it can be concluded that there was no real abyssal fauna in the East Sea because they are different from fauna commonly found at near abyssal depths in the North Pacific Ocean. The macrobenthic fauna communities in the ocean dumping areas responded to the organic enrichment of sediments, and thus a few opportunistic species like *Capitella capitata* occurred in a temporally closed region of the dumping area for several years as well as in the present dumping area in the southwest of the East Sea.

Keywords Macrobenthic fauna · Community structure · Shelf and slope · Bathyal and abyssal · Ocean dumping · East Sea (Japan Sea)

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14.1 Introduction

Soft bottom benthic animals are an important component of the marine ecosystem. Benthic organisms are a food source for benthic fishes and large invertebrates, and they play important roles in ecosystems such as nutrient cycling, pollutant metabolism, and secondary production (Snelgrove 1998). Marine benthic organisms are mainly sessile or have no mobility and they have a relatively long life span integrating the effect of continuous environmental disturbances on them, thus they have been used as environmental indicators in many studies (Bilyard 1987; Dauer 1993; Borja et al. 2000). It is known that the body size of macrobenthic fauna become smaller with increasing water depth (Rex et al. 2000; Van Hoey et al. 2004). This decrease in body size in deep waters has been proposed to be related to primary productivity at the surface layer, total organic carbon (TOC), and particulate organic matter (POM), but the direct and important factors have not been clearly defined until the present time. In shallow benthic habitats, however, the species richness and abundance of macrobenthos has been closely related to the stability of sediments and the availability of food to the macrobenthos (Gray 1981). The distribution of macrobenthic fauna is likely determined mainly by sedimentary properties such as grain size and composition and organic content (Sanders 1958). The food supply to benthic environments will determine the composition of feeding types of macrobenthic fauna (Levinton 1972; Jumars and Fauchald 1977).

The benthic fauna described in this chapter only includes the soft-bottom animals inhabiting the continental shelf and slope and deep basin of the East Sea. Thus the sessile fauna on the hard bottoms and macroalgae are not included here. Among the three size categories of benthic fauna [macro- (>1 mm), meio- (0.062–1 mm), and microbenthos (<0.062 mm)], only macrobenthic fauna are dealt with here.

Most previous studies on the macrofauna in the East Sea were mainly focused on faunal composition and spatial distributions. Due to the limited research facilities, including research vessels and sampling gear operating for the deep water, there is no repeated time series monitoring data, and also limited faunal data from the deep basins of the East Sea. Thus most faunal data were collected from the shallow coastal regions.

There were some small and local scale investigations on the macrobenthic fauna or a specific fauna group along the coasts of the Korean Peninsula and far eastern Russia and an isolated ecosystem around a small island, Dokdo (Dok Island), in the middle of the East Sea. However, a series of large scale surveys in the Korean waters of the East Sea was started in 1982 and 5 succeeding surveys were conducted along the shelf and upper slope of the East Sea from 35°N to 37° 30′N until 1987 (Fig. 14.1). The final results of these surveys on the fauna groups of polychaetes (Choi and Koh 1988, 1990), mollusks (Je 1993), and ophiuroids (Shin and Koh 1993) were reported. There was a research report on the spatial distribution of macrobenthos in the slope area and a deep basin (Ulleung Basin) of the East Sea

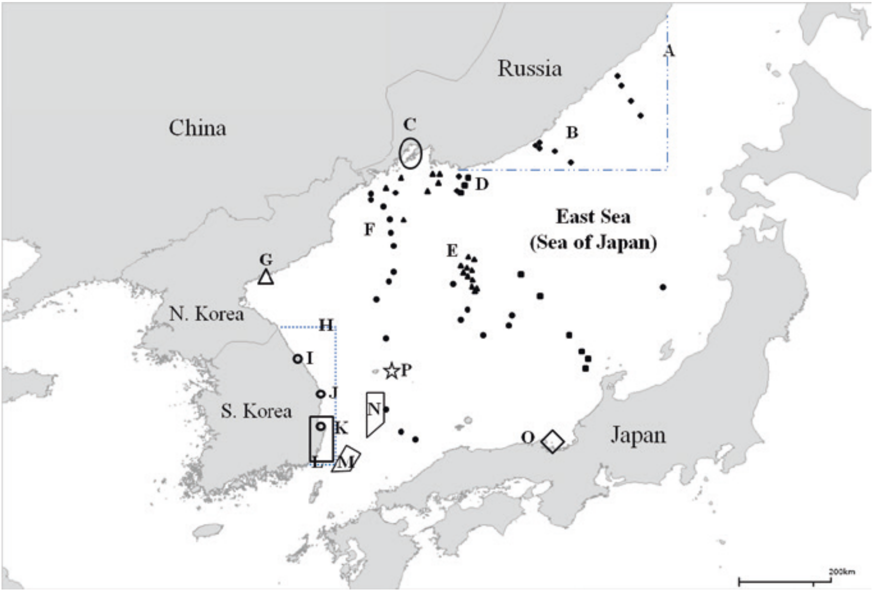

Fig. 14.1 Map showing the study areas of macrobenthic fauna in the East Sea. *A* Northern slope (Kharlamenko et al. 2013), *B* northern bathyal and abyssal (Kamenev 2013), *C* Amursky Bay (Belan 2003), *D* northern bathyal and abyssal (Kamenev 2013), *E* Japan Basin (Kamenev 2013), *F* northern shelf and slope (Kamenev 2013), *G* northern coast (KORDI 1999), *H* southern shelf and slope (Shin and Koh 1993), *I* Youngdong PP (Choi et al. 2000), *J* Uljin NPP (Yu et al. 2011; Shin per. comm.), *K* Youngil Bay (Shin et al. 1992), *L* southern shelf (Choi and Koh 1988), *M* dumping area (Donghaejeong) (KORDI 2008), *N* dumping area (Donghaebyung) (KORDI 2009), *O* Wakasa Bay (Antonio et al. 2010), *P* Dokdo (Choi et al. 2002; Park et al. 2002; Ryu et al. 2012)

(KORDI 1997). Also there was a small scale survey including the shelf area and the slope area around Dokdo in the East Sea (Choi et al. 2000).

Recently Russian benthologists carried out several benthic surveys during the Russian-German joint expedition Sea of Japan Biodiversity Studies (SoJaBio) on the spatial distribution and trophic relations of macro- and megabenthic fauna (>5 cm) in the northwestern part of the East Sea in August–September 2010 (Belan 2003; Alalykina 2013; Brandt et al. 2013; Kamenev 2013; Golovan et al. 2013; Maiorova and Adrianov 2013). These results will be used to compare with the benthic fauna occurring in the southwestern part of the East Sea. However, there are few studies on the trophic relationships among macrofauna in the soft bottom sediments of the East Sea (Antonio et al. 2010; Kharlamenko 2013).

There are two ocean dumping areas located at the deep central part of the Ulleung Basin (Donghaebyung dumping area) and at the southwestern shallow shelf (Donghaejeong dumping area) of the East Sea designated by the Korean government in 1992. The dumped materials were composed of feces of animals, and wastes from homes and industrial companies which contained high concentrations of nitrogen and phosphate, heavy metals, and polycyclic aromatic hydrocarbons

(PAHs) (Hong and Shin 2009). The amount of ocean dumping has increased during the period from 1992 to 2006. Thus the southern part of the Donghaebyung dumping area in the Ulleung Basin (UB) has been temporarily closed since 2006 due to the high organic enrichment and heavy metal contamination. Recently the Korean government decided to decrease gradually the amount of waste dumping and to cease completely ocean dumping in 2014. The intensive monitoring of benthic environmental conditions including the macrobenthos in the Donghaejeong and Donghaebyung dumping areas started in 2007 and 2009, respectively. Here the impacts of ocean dumping on the macrobenthic fauna were briefly described by focusing on changes in benthic community structures found at different water depths and sedimentary facies.

14.2 Local Scale Macrofauna Distributions

14.2.1 Southwestern Coasts

There were a few studies on the macrobenthic faunal communities in the southwestern coasts of the East Sea, that is, along the east coast of the Korean Peninsula (Fig. 14.1). These studies have focused on the distribution of macrobenthos around the discharge outfalls of power plants constructed along the coastal line in order to determine the influence of the discharged warm water on the benthic fauna and flora. However, there was an investigation on the macrobenthic faunal communities in a semi-enclosed bay, Youngil Bay, and the harbor area within the bay. An electric generating power plant, the Youngdong Power Plant, using coal as the fuel materials, is located near Gangneung city (37° 45′N) on the east coast of Korea. A seasonal investigation on the macrobenthic fauna was conducted at 14 stations in the coastal area including the discharge outfall of the power plant from April 1993 to February 1994 (Choi et al. 2000). The study area is located on the east coast of the Korean Peninsula where there are well developed sandy beaches along the coast, and thus the study area consists of sandy sediments out to a water depth of 50 m.

A total of 109 and 70 macrobenthic fauna species were collected in summer and winter, respectively. The mean density was in the range of 1995 and 631 ind. m^{-2} in summer and winter, respectively. Polychaete worms accounted for the majority of individuals and mollusks contributed to the biomass of the macrobenthic communities. Dominant species were *Spiophanes bombyx*, *Prionospio* sp., *Alvenius ojianus*, *Wecomedon* sp., *Urothoe* spp.

Based on cluster analysis of the abundance of macrobenthos, the study area was divided into two station groups by water depth (Fig. 14.2). The typical dominant species in the offshore area were *S. bombyx* and *A. ojianus*. They occurred during all seasons. However, the dominant species of the inner shallow area were *Scoloplos armiger*, *Mactra chinensis*, *Corophium* sp., and *Urothoe* spp. Their abundance changed from season to season, especially in autumn and winter possibly due to river discharge and warm water discharge from the power plant.

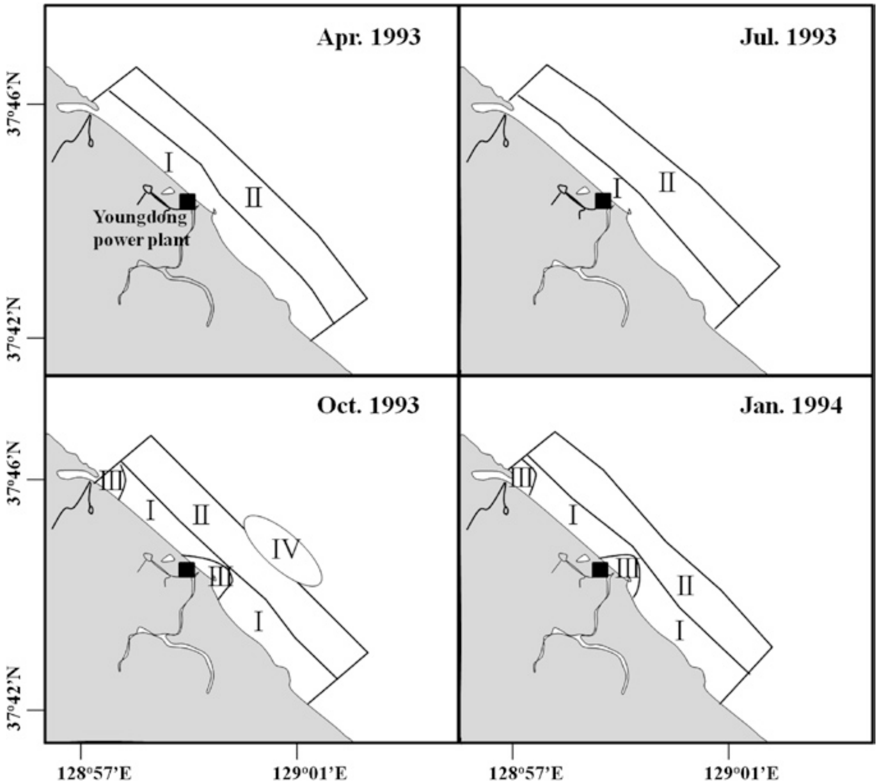

Fig. 14.2 Map showing the distribution of macrobenthic communities in the sandy sediments along the coast line of the east coast of the Korean peninsula. Station Group I: *Scoloplos-Mactra* community, Station Group II: *Spiophanes* community during spring and summer (from Choi et al. 2000)

The second case study of the small scale surveys conducted along the south-western coasts of the East Sea is from the subtidal region around the outfall of the warm water discharge of the nuclear power plant in Uljin province of Korea. There was an ecological survey of the macrobenthic polychaete communities on the subtidal soft-bottom around the discharge outfall of the Uljin Nuclear Power Plant (UNPP) in 2008 (Shin, personal communication).

A total of 84 polychaete species occurred and the average density was 2378 ind. m^{-2}. The typical dominant species were *Spiophanes bombyx*, *Magelona* sp., *Praxillella affinis*, and *Lumbrineris longifolia*. The high macrobenthic density was primarily due to the very high population density of *Spiophaes bombyx* which is known as a typical polychaete worm in sandy sediments. There were three polychaete assemblages in the study area (Fig. 14.3). While there was no single species characteristic of the shallower coastal area at less than 5 m depth, a *Spiophanes* assemblage occupied the coastal area where water depths ranged from 5 to 30 m, and a *Magelona* assemblage existed in the offshore area deeper than 30 m.

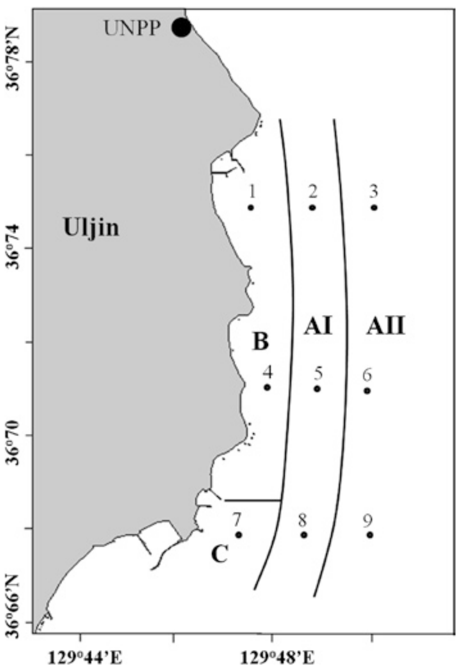

Fig. 14.3 The distribution of macrobenthic polychaete worms around the discharge outfall of the Uljin nuclear power plant (AI: *Spiophanes* community, AII: *Magelona* community) (created by J.-W. Choi)

This distribution pattern of polychaete assemblages indicates that there is little disturbance in the benthic environment around the UNPP except for the near shore coastal area.

A seasonal ecological survey was conducted from August 2007 to May 2008 to determine the effects of the warm water discharge from the UNPP (Yu et al. 2011). The macrobenthic fauna around the UNPP were divided into two regional assemblages with similar faunal composition according to water depth shallower and deeper than 30 m. The shallow coastal fauna assemblage was composed of some opportunistic fauna such as *Urothoe convexa*, *Mandibulophoxus mai*, *Felaniella sowerbyi*, and *Rhynchospio* sp. near the warm water discharge outfall. The deeper offshore fauna assemblage was characterized by polychaetes like *Magelona japonica*, *Spiophanes bombyx*, *Scoletoma longifolia*, and *Chaetozone setosa* which have been present since 1987, before the construction of the UNPP.

The third example of a small scale benthic survey was from a unique sheltered bay, Youngil Bay, along the east coast of Korea. An ecological study was carried out to determine the distribution patterns of the benthic polychaete worms in 1991 (Shin et al. 1992). A total of 72 polychaete species was found and the mean density was 1485 ind. m^{-2}. *Spiophanes bombyx*, *Pseudopolydora* sp. *Lumbrineris longifolia*, *Maldane cristata*, and *Polydora* sp. were the major contributors to the abundance of the polychaete worms in Youngil Bay. *Capitella capitata*, a well-known organic pollution indicator, occurred in the harbor region and the estuarine region of the bay. Based on a multivariate analysis, three station

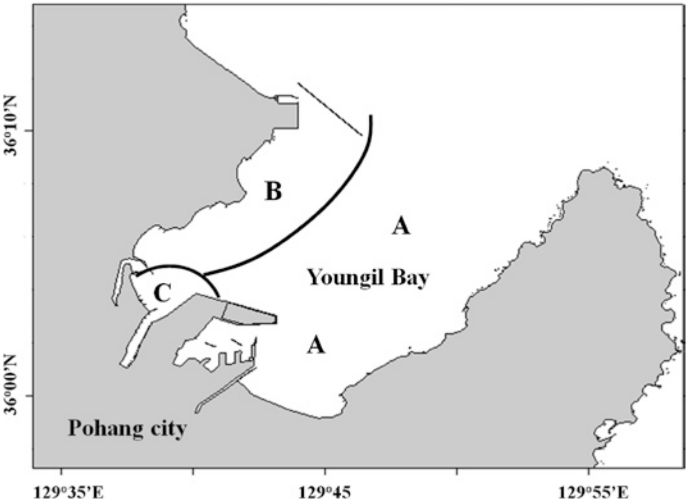

Fig. 14.4 The spatial distribution of polychaete communities in Youngil Bay during 1991. **a** *Maldane-Praxillella* assemblage, **b** *Spiophanes-Nephty*s assemblage, **c** *Pseudopolydora-Polydora-Capitella* assemblage (from Shin et al. 1992)

groups with similar species composition of polychaete worms were identified (Fig. 14.4). A *Maldane-Paxillella* assemblage occupied the southern half of the bay (A), a *Spiophanes-Nephtys* assemblage existed in the northern half (B), and a *Pseudopolydora-Polydora-Capitella* assemblage was located in the harbor and estuarine area (C). This distribution pattern of polychaete communities seemed to be influenced by the sedimentary facies under the current flow pattern in Youngil Bay and organic loads from Pohang City and seaport.

14.2.2 Northwestern Coasts

There was a marine environmental survey report on the macrobenthic fauna around the expected construction site of a Nuclear Power Plant in Shinpo City of North Korea (KORDI 1999). The sampling was conducted seasonally at 13 stations located around the discharge outfall of the power plant in 1998 (Fig. 14.1). A total of 244 species including 79 molluscan species, 75 polychaete species and 61 crustacean species was collected. The mean density and biomass was 2458 ind. m^{-2} and 121 g wet m^{-2}, respectively. The most abundant benthic fauna were *Mryiochele oculata* (23.5 %), *Nuculoma tenuis* (14.6 %), *Axinopsida subquadrat* (13.8 %), *Lumbrineris nipponica* (10.9 %), *Prionospio malmgreni* (4.1 %), and *Alvenius ojianus* (3.2 %). The dominant species among 45 megabenthos collected by Agassiz trawl were *Ophiura sarsi* and *Asterias amurensis*. The maximum biomass of megabenthos was estimated to be 9 kg wet $trawl^{-1}$.

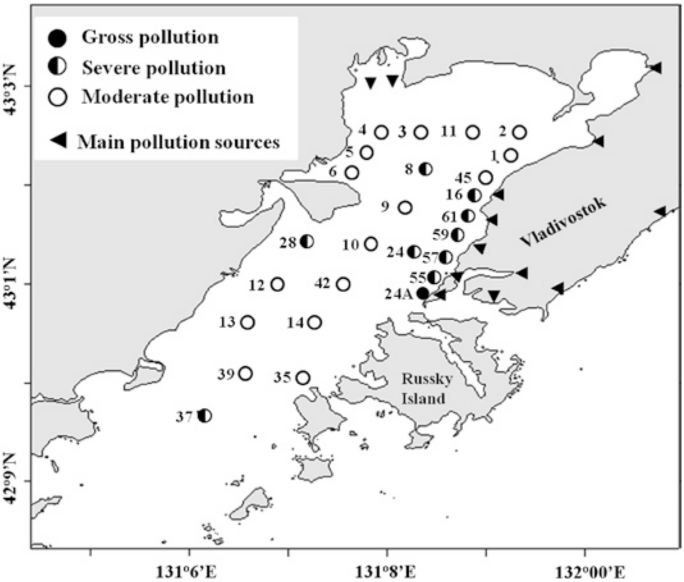

Fig. 14.5 Pollution level of *bottom* sediments and distribution of benthic communities in Amursky Bay during 1986–1989 (from Belan 2003)

There was another important local survey on the macrofauna assemblages at the northwestern coast of the East Sea, that is, in Amursky Bay, Russia. Belan (2003) investigated a contamination gradient, and assessed the effect of pollution on the macrobenthic fauna using quantitative and qualitative benthic parameters in Amursky Bay. He collected macrobenthic fauna at 30 stations from four survey cruises between 1986 and 1989. Significant changes in the number of taxonomic groups, density and ecological indices were observed between severe and moderate contamination levels. *Tharyx pacifica*, *Dorvillea japonica*, *Dipolydora cardalia*, *Capitella capitata*, and a phoronid, *Phoronopsis harmeri* were selected as the most contaminant insensitive species whereas *Maldane sarsi*, *Lumbrinereis* sp., and *Scoloplos armiger* were assigned as contaminant sensitive species. From the results of cluster analysis and n multidimensional scaling (MDS) ordination, two macrobenthic fauna assemblages were identified in Amursky Bay in response to the pollution gradient (Fig. 14.5).

14.2.3 Dokdo (Dok Island)

There was a unique isolated benthic ecosystem around Dokdo in the middle of the East Sea. The macrobenthic faunal assemblages are under the influence of the Tsushima Warm Current entering into the East Sea through the Korea Strait.

The surface sediments of the shelf and upper slope area were composed of sand particles with sponge spicules whereas those in the slope were composed of mud. An ecological survey on the macrobenthic fauna and their habitat conditions was conducted on the soft-bottom around Dokdo in September 1999 and May 2000. The macrobenthic fauna in the shelf and slope area were collected using a van Veen grab and a box corer, respectively.

The macrobenthos occurring on the slope were represented by 15 faunal groups in 8 phyla and the most abundant faunal group consisted of polychaete worms which accounted for 81 % of the slope fauna and 85 % of the shelf fauna. The mean faunal densities of the slope and shelf were 2028 and 456 ind. m^{-2}, respectively. The dominant species on the slope were *Exogone verugera* (41 %), *Cossura longocirrata* (8 %), *Tharyx* sp. (7 %), *Scalibregma inflatum* (5 %), *Aedicira* sp. (5 %), *Arricidea ramosa* (4 %), and *Sigambra tentaculata* (4 %). However, the dominant species in the shelf area were different from those in the slope area. They were *Chone* sp. (49 %), *Tharyx* sp. (18 %), *Ophelina acuminata* (7 %), *Chaetozone setosa* (4 %), *Glycera* sp. (3 %), and *Aedicira* sp. (2 %). The trophic composition of the macrobenthos differed between the slope and shelf areas, that is, surface deposit feeding worms were dominant in the slope area whereas filter feeders were dominant in the shelf area. According to cluster analysis and nMDS ordination (Fig. 14.6), the spatial distribution of macrobenthos in the slope area around Dokdo was related to sediment properties such as grain size and composition and organic content. Most macrobenthos inhabited the top 2 cm sediment layer of the slope area.

There is little published literature dealing with macro- and megabenthic fauna on the rocky hard-bottoms around Dokdo despite many investigations (Park et al. 2002; Ryu et al. 2012). Park et al. (2002) reported on densities and biomass of the subtidal hard-bottom megabenthic fauna (Fig. 14.7). Megabenthos were related to water depth and topographic conditions, and thus in the area shallower than 10 m, a turbo shell *Batillus cornutus* and a mussel *Mytilus coruscus* were dominant species with their distinct vertical distributions (Fig. 14.8). However, hard-bottoms at depths deeper than 10 m showed a diverse fauna distribution pattern depending on bottom topography, and a sea cucumber *Stichopus japonicus* was its dominant fauna. *B. cornutus*, *M. coruscus*, and *S. japonicus* were three commercially useful fauna on the hard-bottoms of Dokdo. The estimated amount of total biomass of these three species were 6.54, 3.89, and 8.92 tones, respectively. Abalones were rare and their biomass was very small.

Ryu et al. (2012) reported on the topographic distributions of macrofauna on the shallow rocky shores around Dokdo during August 2007–June 2008. A total of 98 macrofaunal species, including 21 newly recorded species which are all known from the Korean and Japanese waters, were collected at Dokdo. Among them, mollusks and crustaceans comprised more than 70 % of the total species at each station. Thus by 2008, 403 macrofaunal species were identified on the rocky shores of Dokdo. The fauna composition and distribution of invertebrates were related to the topographical characteristics of each habitat. A North American isopod *Idotea metallica*, first described at Helgoland Island in the German North Sea in 1994, was collected again in this survey. *I. metallica* had already been found at

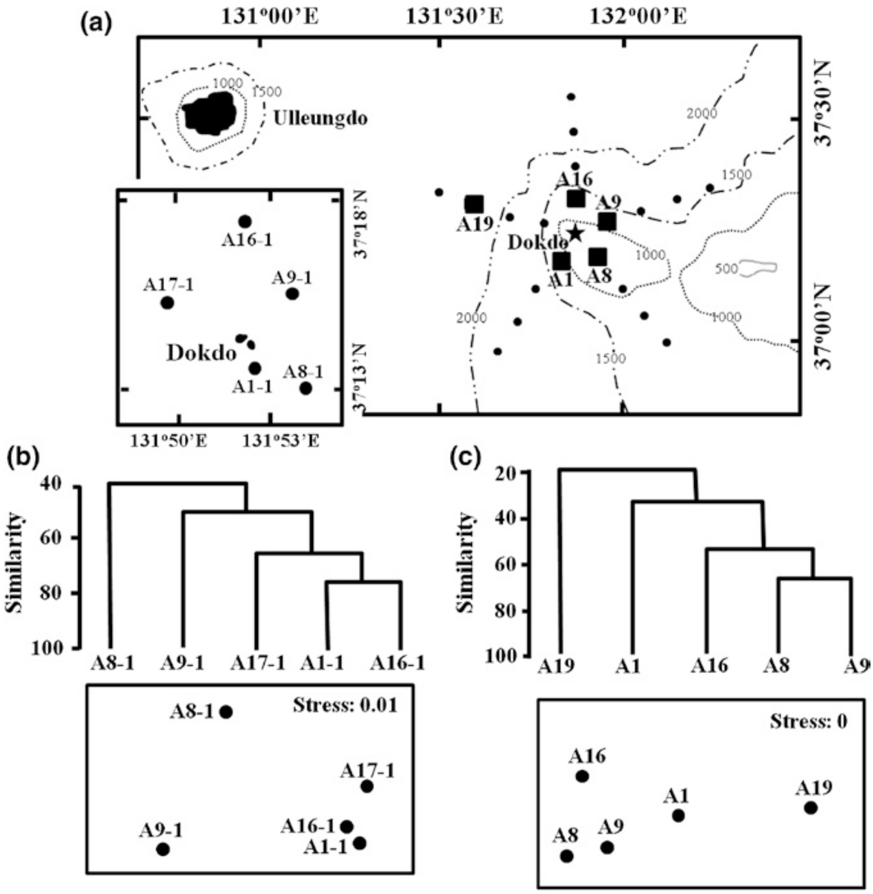

Fig. 14.6 Map showing the sampling stations for macrobenthos around Dokdo (**a**), and the dendrograms and nMDS plots indicating the fauna similarity between stations on the shelf area (**b**) and the slope area (**c**) of the East Sea (from Choi et al. 2002)

Dokdo in 1909. The Dokdo marine ecosystem seems to be highly dynamic in biodiversity, and Dokdo itself may play a role as a good settling site for warm-water invasive species entering the East Sea through the East China Sea.

14.3 Large Scale Macrobenthic Fauna Communities

14.3.1 Southwestern Shelf Area

The macrobenthic polychaete communities on the continental shelf area in the southwestern part of the East Sea were investigated through 4 April survey cruises from 1982 to 1984, and 1987. The surface sediment of this study area was

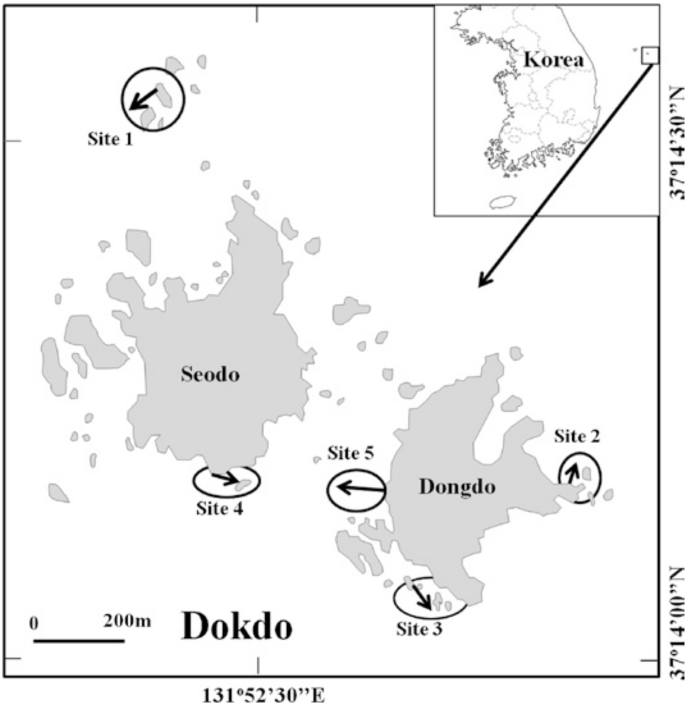

Fig. 14.7 The locations of sampling sites around Dokdo. The *arrows* indicate the direction of sampling from intertidal to subtidal region (from Park et al. 2002)

composed of various sedimentary facies from mud to muddy sand. Thus there existed many different macrobenthic fauna assemblages in the shelf area according to the sedimentary facies (Fig. 14.9). The shallow coastal region sustained 4 polychaete assemblages: a *Nothria* assemblage in the most northern part near Pohang city with fine sediments, a *Magelona*-*Maldane* assembalge off Gampo, an *Ophelina* assemblage in the middle coastal area off Ulsan city, and a *Nothria* assemblage in the southern section near Busan city. These coastal polychaete assemblages contained fewer than 10 species per station and showed a relatively low species diversity (H′ = 1.22–1.52). The offshore shelf area also contained 4 assemblages: a *Terebellides*-*Aglaophamus* assemblage in the deep northern area of very fine sediments, a *Myriochele* assemblage and a *Spiophanes* assemblage in the central area of sandy sediments, and a *Ninoe* assemblage in the southern offshore area composed of a sandy bottom. The offshore polychaete assemblages showed a relatively greater species richness and higher diversity than coastal ones (H′ = 1.90–2.26). However, the offshore region consisting of sandy sediment showed very low population densities. Some dominant species showed a preference for a specific sediment type, and this phenomenon could be detected by the feeding modes of dominant species. It seemed that the complicated distribution of various polychaete assemblages was determined by both the gradient of sedimentary properties and bottom temperature (Choi and Koh 1988).

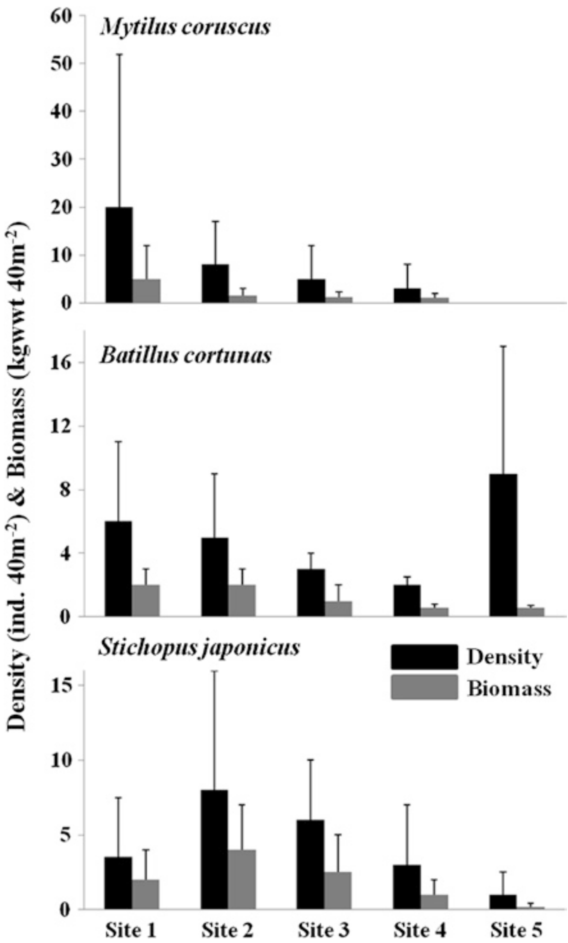

Fig. 14.8 Spatial variation in the density and biomass of three commercial species at each survey site around the Dokdo shown in Fig. 14.7 (from Park et al. 2002)

14.3.2 Southwestern Shelf and Slope Area

In the continental shelf and slope of the southwestern part of the East Sea, there was a study of the species composition and distribution patterns of the polychaete communities (Choi and Koh 1990). The polychaete worms were collected using a van Veen grab at 65 stations covering 15,000 km^2 from 35° 30′N to 37° 50′N on three sampling cruises in April 1985 and April and October 1987. The surface sediment showed five sedimentary facies. Fine sediments such as silt and clay prevailed on the slope area of the East Sea and the Hupo Basin, whereas mixed sediments like muddy sand and sand facies existed on the Hupo Bank and the shelf area off Jeokbyun.

A total of 112 polychaete species from 36 families were collected. The overall mean density of polychaete worms was 300 ind. m^{-2} and the species richness

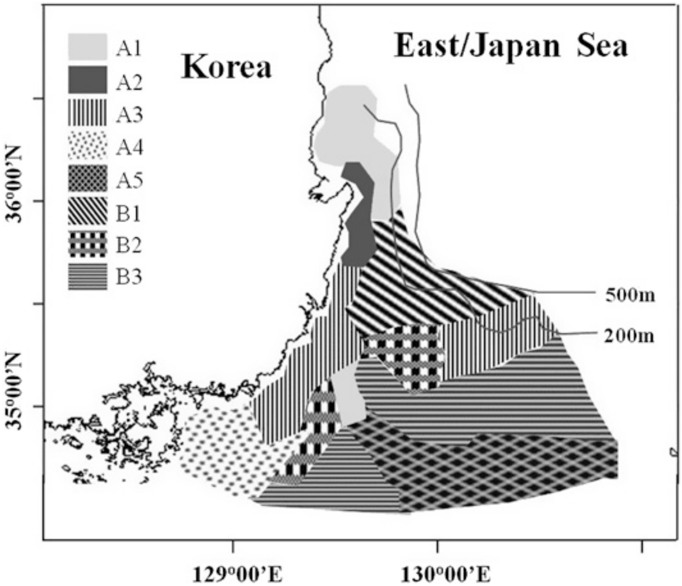

Fig. 14.9 The spatial distribution of macrobenthic polychaete communities in the southwestern shelf area of the East Sea (A1: *Nothria* assemblage, A2*: Magelona-Maldane* assemblage, A3: *Ophelina* assemblage, A4: *Nothria* assemblage, A5: *Ninoe* assemblage, B1: *Terebellides-Ampharete* assemblage, B2: *Myriochele* assemblage, B3: *Spiophanes* assemblage) (Redrawn from Choi and Koh 1988)

was about 15 species 0.2 m^{-2}. Dominant polychaete species were *Chaetozone setosa* (13.3 %), *Aglaophamus malmgreni* (6.7 %), *Ampharete acrtica* (5.9 %), *Terebellides horikoshii* (5.5 %), *Tharyx* sp. (4.8 %), and *Magelona pacifica* (7.2 %). Boreal and cold water polychaetes were major contributors to the polychaete communities in this area. Most dominant species had specific depth ranges from the shelf area to the upper slope and middle slope depth. A significant change in the mean polychaete density and species richness was found at a water depth of approximately 600 m (Fig. 14.10).

The distributional pattern of some dominant brittle stars was investigated in the East Sea (Shin and Koh 1993). They were *Amphiodia craterodometa*, *Amphioplus macraspis*, *Ophiura leptotenia*, and *Ophiura sarsi*. These brittle stars had specific distribution patterns in response to the water depth, that is, *Amphiodia craterodometa* was dominant on the shelf area, and *Ophiura sarsi* was abundant on the upper slope area in the depth range from 200 to 300 m, and *Ophiura leptotenia* was a dominant species on the middle and lower slope area deeper than 300 m (Fig. 14.11). This distribution pattern of brittle stars in the East Sea seemed to be related to the rapid decrease of water temperature (less than 1.0 °C below 200 m) with increasing water depth along the slope area.

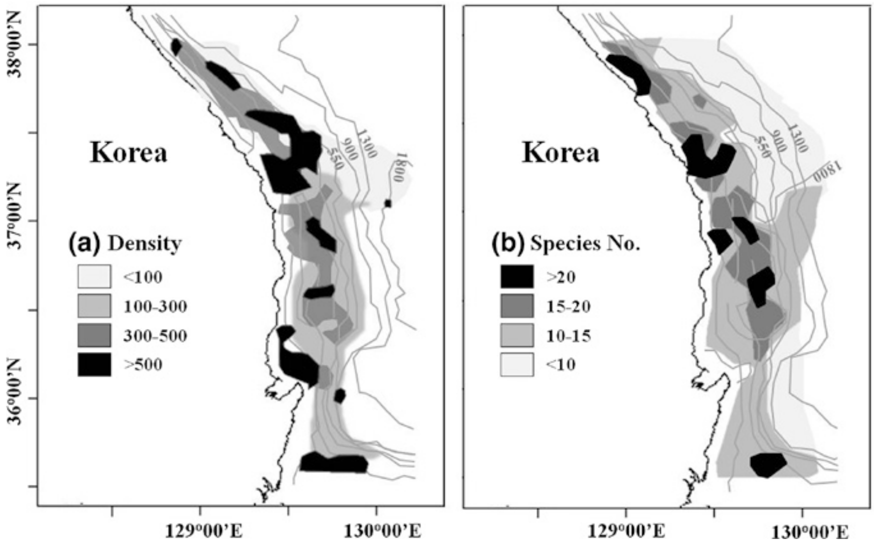

Fig. 14.10 Spatial distribution of density (**a**) and species number (**b**) of macrobenthic fauna in the continental shelf and slope area of the southwestern East Sea (Redrawn from Choi and Koh 1990)

14.3.3 Western Slope Area

Quantitative sampling of the deep sea macrobenthic fauna on the slope and UB in the East Sea was conducted in 1996. A large box corer was used, instead of a grab sampler, to determine the vertical distribution of macrofauna and a mesh screen of 300 μm was used to increase the sampling efficiency (KORDI 1997). The sediments from all sampling stations were composed of fine particles and the sedimentary facies was mud. The benthic animals collected in this deep bottom region were classified into 10 phyla, and polychaetes comprised the greatest abundance of the faunal groups, accounting for 43 % of total individuals. Nematodes (30 %), mollusks (14 %), and crustaceans (10 %) were also major faunal groups in this area. There were few echinoderms in these samples and their proportion was less than 1 % of the total faunal abundance.

Unfortunately, no fauna were identified to the species level. The fauna composition of this deep bottom region was very similar to that of the shallow soft bottom benthic communities except for the nematodes. A high proportion of polychaetes in the fauna of deep bottom communities was previously reported (Blake and Grassle 1994; Blake and Hilbig 1994). In the case of the Atlantic Ocean, polychaetes comprised 58 and 47 % of the total number of species and abundance of individuals, respectively. The overall density of the macrobenthos was 2655 ind. m^{-2}, ranging from 44 ind. m^{-2} in UB to 17,511 ind. m^{-2} at the station near Ulleungdo (Ulleung Island). The density of macrobenthos decreased from stations near the east coast of Korean Peninsula to UB at the latitude of 37°N (Fig. 14.12).

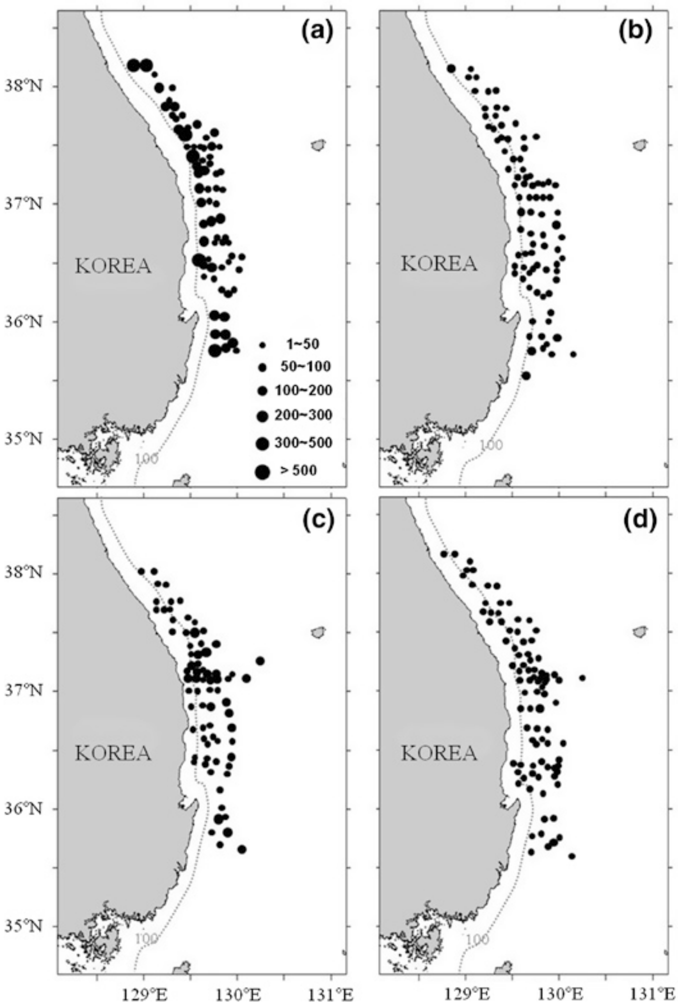

Fig. 14.11 The spatial distribution of four dominant brittle star species in the continental shelf and slope areas of the southeast coast of Korean Peninsula in the East Sea (**a** *Ampiodia craterodometa*, **b** *Amphioplus macraspis*, **c** *Ophiura leptoctenia*, **d** *Ophiura sarsi*) (Redrawn from Shin and Koh 1993)

From the vertical sections of sediment samples collected by a box corer, we can obtain the vertical distribution of macrofauna in the bathyal depths of stations like UB. More than 55 % of the total macrobenthic fauna was distributed in the surface sediment layer (0–2 cm) and more than 80 % of benthic animals were concentrated within 4 cm of the surface sediment layer (Fig. 14.13). At 8 cm below the sediment surface, only long-bodied polychaetes occurred. This vertical distribution pattern was found also on the deep slope benthic communities off Cape Lookout

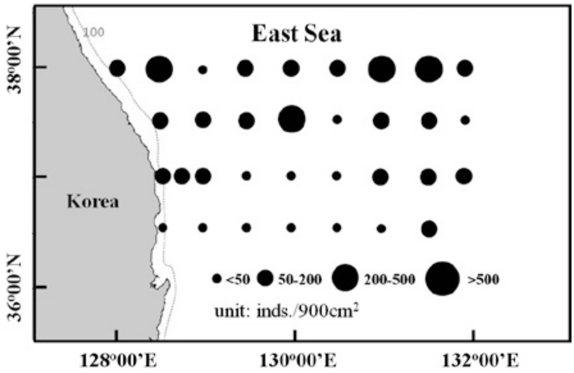

Fig. 14.12 Map showing the sampling stations and density of macrobenthos collected by a box corer (30 cm × 30 cm) in the Southwestern East Sea extended from the southeast coast of Korea to Ulleung Basin

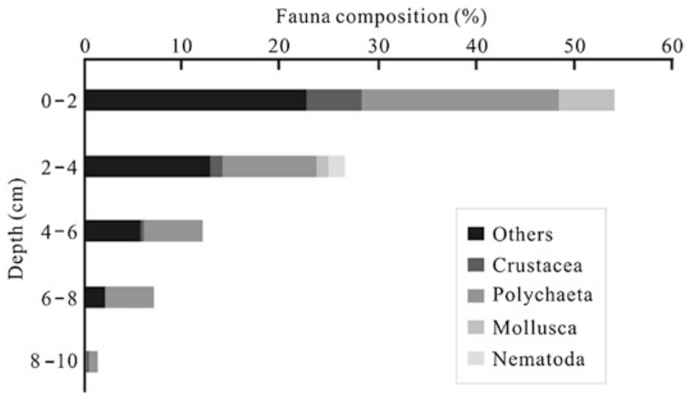

Fig. 14.13 The vertical distribution of macrobenthos occurring in the Ulleung Basin of the East Sea

in the Atlantic Ocean (Blake 1994). Major faunal groups also showed the same trend in vertical distribution as polychaetes, but crustaceans and mollusks were limited to the upper 4 cm layer, whereas polychaetes and nematodes appeared in relatively deeper sediment depths.

Megabenthos in the slope area of the southwestern part of the East Sea and UB were collected at 10 stations using an Agassiz trawl (KORDI 1997). The most abundant species were *Ophiura sarsi*, *Ctenodiscus crispatus*, and *Chinoecetes japonicus*. Thus the faunal composition of deep bottom megabenthos in the East Sea was dominated by echinoderms and decapods. A similar faunal composition of megabenthos was also reported for the slope area of the Atlantic Ocean where echinoderms accounted for 34 % of total individuals and other major contributors were cnidarians (24 %) and demersal fish (21 %) (Hecker 1994). A maximum density of 412 ind. trawl^{-1} and biomass of 4.0 kg trawl^{-1} were found at stations in the slope off Hupo Bank. The maximum biomass of *C. japonicus* was estimated to be 4.0 g m^{-2}. The estimated density of megafauna in the southwestern part of the East Sea collected from the Agassiz trawl survey was 0.4 ind. m^{-2} which is comparable to those found for the slope of the Atlantic Ocean, estimated in the ranges from 0.10 to 5.59 ind. m^{-2}.

14.3.4 North Bathyal and Abyssal Area

Kamenev (2013) studied the species composition and distribution of bivalves in bathyal and abyssal depths (465–3435 m) of the East Sea (Fig. 14.1). Twenty six species were collected during five cruises. The deep-water bivalve fauna of the East Sea were characterized by an impoverished shelf fauna and consisted of eurybathic species that extend from the shelf to the bathyal and abyssal zones. Most of bivalve species have a wide geographic distribution and inhabit cold water regions of the Northern Atlantic, Northern Pacific, and Arctic Ocean. Only five species were endemic to the East Sea. The species diversity of bivalves decreased with the increase of water depth. At depths below 3000 m, only *Dacrydium vitreum*, *Delectopecten vencouverensis*, and *Thyasira* sp. were found. The lack of typical abyssal species of bivalves in the deep East Sea seemed to be connected to the isolation of this water body from the Pacific abyssal depths.

Alalykina (2013) reported that a total of 92 polychaete species in 28 families were collected from the SoJaBio expedition, and dominant species were *Laonice* sp., *Ophelina cylindricaudata*, *Arcteobia spinelytris*, *Ampharete* sp., and *Chaetozone* sp.1. The most abundant polychaete families were Spionidae, Opheliidae, Polynoidae, Ampharetidae, and Cirratulidae. There was a depth related distribution pattern in polychaete assemblages such that the upper bathyal area of the East Sea had higher polychaete diversity than the abyssal area, likely because the fauna assemblages in the bathyal area might be in a zoogeographic zone that overlaps with the shelf area. The dominance of polychaete worms in the fauna of the bathyal and abyssal bottoms of the East Sea was similar with that found in deep bottoms world-wide (Brandt et al. 2013). Maiorova and Adrianov (2013) reported that 8 sipunculid species were recently found in the Russian coastal areas of the East Sea from the SoJaBio expedition. Until now, a total of 31 sipunculid species have been found in the East Sea. Among them, *Phascolosoma agassizii*, *P. scolops*, *Themiste nigra*, and *T. hexadactyla* were distributed in the shallow area (0–50 m), while *Golfingia margaritacea*, *G. vulgaris*, *Nephasoma capilleforme*, *N. wodjanizkii*, and *P. strombus* occurred at depths from 50 to 1000 m, especially *G. margaritacea* which was found at the deepest depth of 1699 m. Identification keys were provided for all sipunculids in the East Sea including Russian, Japanese, and Korean coasts.

Golovan et al. (2013) also investigated the diversity and distribution of peracarid crustaceans in the bathyal and abyssal depths of the East Sea (Fig. 14.1). In total, 146 species from 85 genera and 42 families were collected. The diversity and species richness and abundance of most peracarid species were highest at the shallowest slope stations (450–550 m) and decreased with depth, however, several opportunistic species such as *Eurycope spinifrons* (Isopoda), *Chauliopleona hanknechti*, and *Paratyphlotanais japonicus* (Tanaidacea) increased below the slope. They suggested that these opportunistic species may have recently colonized the geologically young pseudo-abyssal habitats of the East Sea.

There was only one study on trophic relationships among macrobenthic fauna in the bathyal and abyssal depths of the East Sea (Kharlamenko et al. 2013). They used stable isotope techniques ($TL = (\delta^{15}N_{consumer} - \delta^{15}N_{base})/\delta^{15}N + TL_{base}$, Post 2002) to estimate the trophic levels from primary producers to top predators. They selected the selective deposit feeder *Megayoldia* sp. as the baseline species with trophic level of 2. Suspended particulate organic matter (POM) and bottom sediment organic matter (SOM) were assigned to the basement of a food web, and primary consumers were categorized as surface deposit feeders and selective deposit feeders, for example, the foraminiferan *Elphidium* sp. and a protobranch bivalve *Megayoldia* sp. The third trophic group was occupied by the scaphopod *Fustiaria nipponica*, the ophiuroid *Ophiura leptoctenia*, and the crinoid *Heliometra glacialis*. The fourth trophic level of the continental slope benthic community in the East Sea was comprised of the large crab *Chionocetes japonicus*, the shrimp *Eualus biungus*, the septibranch bivalve *Cardiomya beringensis*, and the sea star *Ctenodiscus crispatus*. Antonio et al. (2010) reported the trophic relationships among benthic fauna from the estuarine coastal area to the offshore shelf area of Wakasa Bay in the southeastern part of the East Sea using stable isotopes. They defined the community structure and assigned the trophic levels from these faunal data. Benthic microalgae were an important energy source in the shallow coastal area, and their proportion decreased in the offshore area. The main food sources in the offshore shelf area changed to marine POM and phytoplankton.

14.4 Ocean Dumping Areas

There are two ocean dumping areas in the East Sea, The Donghaebyung dumping area in UB and the Donghaejeong dumping area in the southwestern shelf area. These ocean dumping areas were designated as receiving areas for the disposal of sewage sludge and wastes from land beginning in 1992 and scheduled to be closed by 2014. The amount of disposed wastes was 20,800 m^3 for ten years from 1993 to 2003. Thus some intensified ecological surveys were required in the ocean dumping areas in order to manage and maintain the marine ecosystem properly.

Two benthic fauna surveys were conducted to monitor and assess the ecological impact of ocean dumping such as the abundance and biological diversity of macrobenthos in the Donghaejeong area (1616 km^2) during June 2007 and 2010 (Fig. 14.1).

Macrozoobenthos collected during the 2007 and 2010 surveys comprised a total of 202 and 274 species in 8 animal phyla, and the mean faunal densities were 922 and 1337 ind. m^{-2}, respectively (KORDI 2008, 2010). Polychaete worms were the most dominant faunal group accounting for 51 % of the total abundance in the benthic community, with 92 and 152 species in 2007 and 2010, respectively. Total species number of the major benthic faunal groups in the reference area was very similar to that in the waste dumping area. However, in the case of mean density, the dumping area showed higher density than the reference area, especially for polychaete worms. Some faunal groups like crustaceans and echinoderms showed higher densities in the reference area.

The spionid *Spiophanes kroyeri* and the maldanid *Maldane cristata* were the most abundant fauna in the ocean dumping area with mud and muddy sand facies. These polychaete worms were also known as dominant species in surveys from the 1980s. Before waste dumping, a *Spiophanes kroyeri* assemblage mainly occupied the broad offshore area including the Donghaejeong dumping area, and an *Ophelina acuminata* assemblage was found in a coastal area. A *Myriochele* assemblage and a *Terebellides-Aglaophamus* assemblage occupied the region between the coastal and offshore shelf areas (Choi and Koh 1988). Several pollution indicative species were found at sites in the dumping area during the intensified survey in 2007 (Table 14.1). The indicators of organic enrichment were *Paraprionospio coora*, *Dorvillea* sp., *Polydora ligni*, *Spiochaetopterus* sp., *Euchone analis*, etc. These species were not found in the previous studies conducted during the 1980s before the waste dumping in the shelf area of the East Sea (Choi and Koh 1988). However, the abundance of these indicative species was very low and was not comparable to abundances in the semi-enclosed coastal bays of Korea. The study area sustained three different macrobenthic communities whose mean densities increased twice during the 20 years from the 1980s to 2007. The health of macrobenthic communities was assessed using several benthic indices such as Benthic Pollution Index (Seo et al. 2012) and was estimated to be below normal or indicative of slightly disturbed condition.

There is another marine dumping area (the Donghaebyung area) located in the central area of the Ulleung Basin at a distance of 125 km from Pohang City located at the southeast coast of Korea Peninsula (Fig. 14.1). The total designated area is about 3700 km^2 covering water depths of 200–2000 m. The macrobenthic faunal assemblages in this dumping area have been investigated in order to assess the benthic environmental health status in 2009 (KORDI 2009).

The macrobenthic fauna were collected at 25 stations using a box corer (covering 0.2 m^2) in May 2009, sieved through a 1 mm mesh screen. A total of 35 species occurred: the mean density and biomass were 525 ind. m^{-2} and 3.7 g wet m^{-2}, respectively. The Donghaebyung dumping area showed lower values of species richness, faunal density, and biomass compared with those from the Donghaejeong dumping area located in the southwestern shelf region of the East Sea. Within the dumping area, however, there was an increase in species richness and abundance of the macrobenthic fauna in the previously dumped region of the Donghaebyung dumping area compared with those in the present dumping region as well as the reference area (Fig. 14.14). Dominant species were *Thyasira tokunagai* (50.6 %), *Capitella capitata* (10.1 %), *Chaetozone* sp. (6.3 %), and

Table 14.1 Dominant macrofauna occurring in the dumping area and the reference area of the Donghaejeong dumping area in the East Sea

Dumping area			Reference area		
Species name	Density	%	Species name	Density	%
(a) 2007					
Spiophanes sp.	122	21.7	*Ennucula niponica*	75	21.1
Musculus senhausia	113	20.1	*Maldane cristata*	37	10.3
Maldane cristata	69	12.3	*Ophelina acuminata*	32	9.0
Thyasira tokunagai	17	3.1	*Ophiura* sp.	28	7.8
Ophelina acuminata	16	2.9	*Modiolus margaritaceus*	25	7.0
Ampelisca sp.	16	2.9	*Byblis japonicus*	18	5.1
Nothria sp.1	13	2.3	*Chaetozone setosa*	11	3.2
Ophiura sp.	10	1.8	*Spiophaneskroyeri*	11	3.2
(b) 2010					
Spiophanes kroeyeri	295	22.4	*Aoroides* sp.	190	14.0
Madane cristata	156	11.8	*Yoldiella philippiana*	150	11.0
Aoroides sp.	82	6.3	*Ophiura sarsi*	75	5.5
Ophiura sarsi	75	5.7	*Lumbrineris* sp.	73	5.4
Ampelisca sp.	48	3.6	*Ampelisca* sp.	65	4.8
Spiochaetopterus costarum	25	1.9	*Ampharete arctica*	46	3.4

Yoldiella philippiana (9.4 %) (Table 14.2). *T. tokunagai* was considered to be an opportunistic species with small body size and a short life span and reproductive maturation (Seo et al. 2013), thus this species can occupy any vacant habitat space after a strong disturbance. Although *T. tokunagai* occurred as a dominant species in the entire dumping area, *T. tokunagai* and *C. capitata* showed their high densities in temporarily closed part of the Donghaebyung dumping area since 2006 (Fig. 14.15). In conclusion, the ocean dumping in the East Sea resulted in the organic enrichment of surface sediments and changes in the community structure of macrobenthic fauna due to their responses to this long-term disturbance with the overall increase of faunal density and changed faunal composition by newly adding opportunistic fauna and reducing previously inhabited equilibrium species.

14.5 Summary and Further Study

In this chapter, the macrobenthic fauna assemblages in the East Sea investigated in both small and large scale areas were introduced. However, there are a few studies of the benthic organisms in the deep bottom regions of the East Sea. Moreover, these were incomplete or only limited to a particular target fauna like bivalves, polychaetes, and pericarid crustaceans. Because benthic faunal composition and distribution is closely related to the sedimentary facies where they reside, the benthic fauna assemblages found in the southwestern shelf area of the East Sea

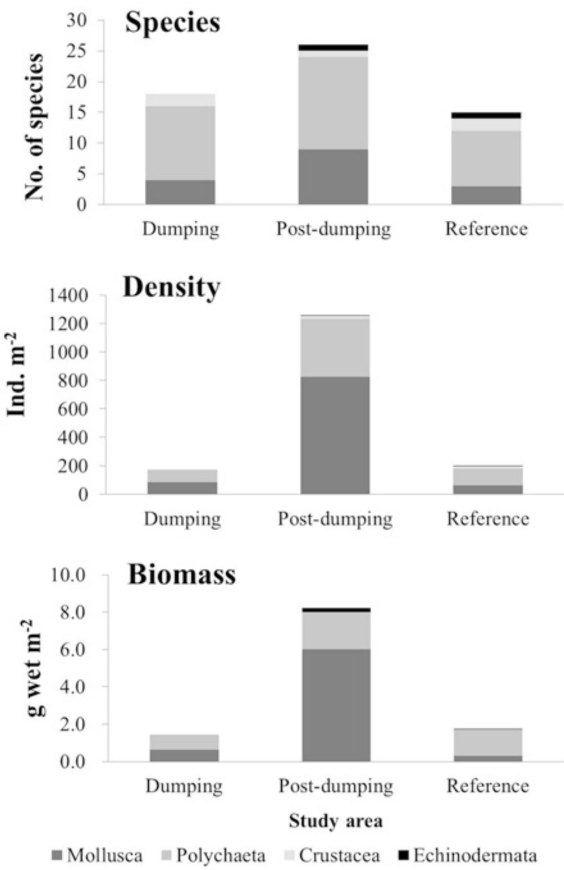

Fig. 14.14 Species number, density, and biomass of macrofauna occurring in the dumping area and the reference area of the Donghaebyung dumping area in the East Sea during May 2009

were complex. The East Sea contains various benthic environments from shallow coastal areas to the bathyal and abyssal depths, for which the distribution of macrobenthic fauna represents the diversity of environmental factors related to the depth gradient. It was clear that when the water depth increased, the abundance and diversity of macrobenthic fauna decreased, despite having only a small fragmented faunal dataset on which to base this conclusion.

The faunal data covering the macrobenthic communities were obtained from investigations conducted more than 20 years ago, making it difficult to compare the recent fauna data and old data sets directly to detect the temporal change in faunal composition for any specific location (Table 14.3). In order to detect changes in macrobenthic faunal assemblages attributable to global warming, such as the increase of sea water temperature, it would be necessary to investigate the faunal composition simultaneously at various local regions at the same latitude. In the East Sea, there was a specific faunal composition reflecting benthic

Table 14.2 Dominant macrofauna occurring in the dumping area and the reference area of the Donghaebyung dumping area in the East Sea during May 2009 (*density* ind. m^{-2})

Sampling area	Species name	Density	%
Dumping area	*Thyasira tokunagai*	130	43.4
	Yoldiella philippiana	65	21.9
	Aglaophamus malmgreni	26	8.7
	Capitella capitata	23	7.7
	Sigambra tentaculata	19	6.4
	Ophelina acuminata	19	6.2
Post-dumping area (dumping ceased in 2006)	*Thyasira tokunagai*	692	58.8
	Chaetozone sp.	169	14.4
	Capitella capitata	146	12.4
	Sigambra tentaculata	51	4.4
	Hyperiid sp.	25	2.1
	Yoldiella philippiana	23	2
Reference area	*Thyasira tokunagai*	1324	50.6
	Capitella capitata	264	10.1
	Yoldiella philippiana	246	9.4
	Chaetozone sp.	244	9.3
	Sigambra tentaculata	164	6.3
	Aglaophamus malmgreni	95	3.6

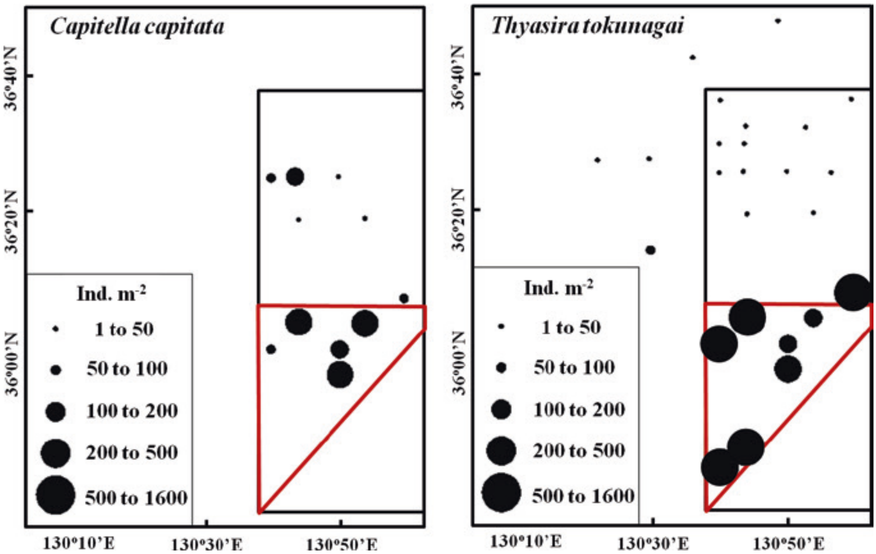

Fig. 14.15 The spatial distribution of dominant macrofauna occurring in the Donghaebyung dumping area in the East Sea during May 2009. The region enclosed with *red* color is the post-dumping region closed in 2006

Table 14.3 The dominant species of macrobenthic faunal communities in the coastal regions and bathyal and abyssal regions of the East Sea (created by J.-W. Choi)

Study area	Coasts	Bathyal and abyssal area	
Southern East Sea	Gangneung	Southwestern slope	
	Spiophanes bombyx	*Chaetozone setosa*	*Amphiodia craterodometa*
	Prionospio sp.	*Aglaophamus malmgreni*	*Amphioplus macraspis*
	Alvenius ojianus	*Ampharete acrtica*	*Ophiura leptotenia*
	Wecomedon sp.	*Terebellides horikoshii*	*Ophiura sarsi*
		(Polychaeta)	(Ophiuroidea)
	Uljin	Dokdo	
	Spiophanes bombyx	*Exogone verugera*	
	Magelona sp.	*Cossura longocirrata*	
	Praxillella affinis	*Tharyx* sp.	
	Lumbrineris longifolia	*Scalibregma inflatum*	
	Youngil Bay	Ulleung Basin	
	Spiophanes bombyx	*Ophiura sarsi*	
	Pseudopolydora sp.	*Crenodiscus crispatus*	
	Lumbrineris longifolia	*Chinoecetes japonicus*	
	Maldane cristata	(Ophiuroidea)	
	Polydora sp.		
Northern East Sea	Shinpo	Russian coast	
	Mryiochele oculata	*Dacrydium vitreum*	*Eurycope spinifrons*
	Nuculoma tenuis	*Delectopecten vencouverensis*	*Chauliopleona hanknechti*
	Axinopsida subquadrat	*Thyasira* sp.	*Paratyphlotanais japonicus*
	Lumbrineris nipponica	(Bivalvia)	(Crustacea)
	Amursky Bay		
	Tharyx pacifica	*Golfingia margaritacea*	
	Dorvillea japonica	(Sipuncula)	
	Dipolydora cardalia		
	Capitella capitata		

environmental conditions such as grain size and composition, sediment enrichment, and warm water discharge at small scales, but there was also a large scale distributional pattern of macrobenthic fauna reflecting a water depth gradient in bathyal and abyssal basins.

The macrobenthic fauna are closely associated with large demersal fishes or benthic decapods as important food organisms. However, there are few studies on the trophic structures or food webs of macrobenthic assemblages in the East Sea. Thus, it is necessary to investigate the functional aspects of the benthic macrofauna such as the secondary production, the amount of resources, their life cycles, and the pelagic-benthic coupling as well as the trophic structures. In order to effectively conduct these kinds of studies, international co-operation and communication among scientists are strongly recommended. In the ocean dumping areas, the community structure of macrobenthic fauna was changed by increasing opportunistic species and also excluding the previously existed native species there. Therefore, it has been decided to stop the ocean dumping from 2014 and after that a long-term monitoring will be needed to understand the natural restoration and recovery of benthic environment from ocean dumping.

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