Korean Journal of Malacology, Vol. 22(1): 63-86, June 30, 2006

Bivalve Mollusks in Yeongil Bay, Korea. 2. Faunal Analysis

Konstantin A. Lutaenko[1], Jong-Geel Je[2] and Sang-Ho Shin[2]

[1]*Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok 690041, Russia*
[2]*Korea Ocean Research & Development Institute, Ansan, Seoul 425-600, Korea*

ABSTRACT

A list of species of bivalve mollusks, their local distributions and relative abundance in Yeongil Bay were analysed. Species richness ranging from 1 to 37 species was low (less than 10) in some stations at the entrance and in the central part of the bay. Fifteen species (*Acila insignis, Nucula tenuis, Yoldia notabilis, Mytilus galloprovincialis, Arca boucardi, Axinopsida subquadrata, Felaniella usta, Mactra chinensis, Raeta pulchella, Nitidotellina hokkaidoensis, Theora fragilis, Alvenius ojianus, Callithaca adamsi, Ruditapes philippinarum* and *Laternula anatina*) were most frequently encountered, and seven of them were most abundant numerically (per sample): *Th. fragilis* in the inner bay, *A. insignis, N. tenuis,* and *A. ojianus* in the outer bay, and *C. adamsi, A. subquadrata, R. pulchella* in both parts. Local distributions of common species were described and presented in plotted data, and three distribution patterns were recognized. Biogeographical analysis shows that a majority of species (55%) belongs to the subtropical group, tropical-subtropical species (16%) play a relatively significant role, and the percentage of boreal (temperate) and boreal-arctic species is 18% which characterizes the whole fauna as subtropical. Zonal-biogeographical composition and number of species in families in Yeongil Bay are compared with those of some Japanese (Wakasa and Mutsu) and Russian (Peter the Great, Possjet and Amursky) bays of the East Sea. The absence of a number of typical warm-water embaymental mollusks in Yeongil Bay found in the north further East Sea and Japan, and the similar zonal-biogeographical structure of the inner and outer bay faunas are explained by active water exchange due to the openness of the bay, relatively low summer temperatures, and presence of upwelled cold waters.

Keywords: Korea, East Sea, Bivalve mollusks, Ecofaunal analysis, Biogeography.

Received March 28, 2006; Accepted May 27, 2006
Corresponding author: Lutaenko, Konstantin A.
Tel: +7 (4232) 3177-111 e-mail: lutaenko@mail.primorye.ru
1225-3480/22107

INTRODUCTION

This papers is the second part of the account of the bivalve molluscan fauna of Yeongil Bay, southwestern East Sea (Lutaenko *et al.*, 2003). In the first part of the paper, we described material and methods, previous research, regional setting, compared species richness of the Yeongil Bay fauna with neighboring areas of Russia and Japan and provided with an annotated list of the species found along with illustrations. In this part, we analyze list of species, their local distribution, relative abundance and biogeography.

LOCAL SPECIES RICHNESS AND ITS DISTRIBUTION

In all, 98 species, 75 genera and 36 families of bivalve mollusks were found in Yeongil Bay (Table 1). According to the data presented in the first part of the paper (Lutaenko *et al.*, 2003), this species number is comparable with that in some small bays of the Japanese coast of the East (Japan) Sea such as Tsukumo and Mano Bays, or Russian bays such as Possjet and Vostok Bays (northwestern East Sea).

Table 1. List of species of bivalve mollusks found in Yeongil Bay with zonal-biogeographical characteristics and bathymetric ranges.

Species	Biogeographical characteristics	Bathymetric range
Acila insignis	subtropical	19.5-
Nucula paulula	Subtropical	25
N. tenuis	Boreal-arctic	20.5-
Yoldia notabilis	Lowboreal	8.5-
Mytilus galloprovincialis	Circumboreal	6.5-
M. coruscus	Subtropical	-
Septifer virgatus	Tropical-subtropical	-
S. keenae	Subtropical	25
Modiolus auriculatus	Tropical-subtropical	25
M. kurilensis	Subtropical-boreal	-
Vilasina decorata	Subtropical-lowboreal	25
Lithophaga cf. *curta*	Subtropical	25
Arca boucardi	Subtropical-lowboreal	6.5-
Acar plicatum	Tropical-subtropical	25
Anadara kagoshimensis	Subtropical	-
Porterius dalli	Subtropical	25
Empleconia cumingii	Subtropical	25
Glycymeris aspersa	Tropical-subtropical	25
G. cf. *rotunda*	Subtropical	2-
G. cf. *yessoensis*	Lowboreal	25-
Limaria hakodatensis	Subtropical	-
Limatula kurodai	Subtropical	25
Crassostrea gigas	Subtropical-lowboreal	-
C. nippona	Subtropical	-
Chlamys swiftii	Lowboreal	-
Pecten albicans	Subtropical	50-
Mizuhopecten yessoensis	Lowboreal	25-
Chama sp.	-	30
Pillucina pisidium	Subtropical	8.5-
Axinopsida subquadrata	Circumboreal	19.5-
Cycladicama lunaris	Subtropical	8.5-
C. cumingii		8.5-
Felaniella usta	Subtropical-lowboreal	8.5-
Phlyctiderma japonicum	Subtropical	8.5-
Borniola sp.	-	8.5
Montacutona sp.	-	8.5-
Nipponomysella oblongata	Subtropical	18.5-
N. cf. *subtruncata*	Subtropical	7
N. obesa	Subtropical	13.5-
Cardita leana	Subtropical	13.5-

Table 1. (continued)

Species	Biogeographical characteristics	Bathymetric range
Cyclocardia ferruginea	Subtropical-lowboreal	50-
Megacardita coreensis	Subtropical	25
Salaputium cf. *unicum*	Subtropical	25
Nipponocrassatella sp.	-	21
Indocrassatella cf. oblongata	Subtropical	21
Astarte hakodatensis	Subtropical	25-
Astarte sp.	-	25
Clinocardium cf. californiense	Widely distributed boreal	25-
Fulvia mutica	Subtropical	8.5-
Mactra chinensis	Subtropical-lowboreal	1-
Spisula sachalinensis	Lowboreal	-
Mactromeris polynyma	Widely distributed boreal	25
Tresus keenae	Subtropical	1
Raeta pulchella	Tropical-subtropical	6.5-
Solen cf. *strictus*	Subtropical	-
S. krusensterni	Subtropical-lowboreal	14-
Siliqua pulchella	Subtropical	6.5-
Cadella lubrica	Lowboreal	22.5-
Moerella jedoensis	Subtropical	19-
M. rutila	Subtropical	8.5
Moerella sp.	-	19.5
Nitidotellina hokkaidoensis	Subtropical	6.5-
N. minuta	Tropical-subtropical	7-
N. pallidula	Tropical-subtropical	13.5-
Macoma tokyoensis	Subtropical	12-
M. incongrua	Subtropical-lowboreal	-
M. nipponica	Subtropical	25
M. sectior	Subtropical	8.5
M. irus	Subtropical	-
Theora fragilis	Tropical-subtropical	8.5-
Alvenius ojianus	Subtropical	6.5-
Corbicula japonica	Brackish-water	-
Mercenaria stimpsoni	Lowboreal	8.5-
Callithaca adamsi	Lowboreal	6.5-
Protothaca jedoensis	Subtropical	-
Callista brevisiphonata	Lowboreal	25-
Saxidomus purpurata	Subtropical	1-
Dosinia japonica	Subtropical	24.5-
Ruditapes philippinarum	Subtropical-lowboreal	1-
Gomphina melanaegis	Subtropical	6.5
Irus macrophyllus	Tropical-subtropical	2-

Table 1. (continued)

Species	Biogeographical characteristics	Bathymetric range
I. mitis	Tropical-subtropical	1
Petricolirus aequistriatus	Subtropical	·
Mya cf. japonica	Widely distributed boreal	8.5
Paramya recluzii	Subtropical	8.5
Cryptomya busoensis	Subtropical	8.5
Anisocorbula venusta	Subtropical-lowboreal	21–
Hiatella arctica	Boreal-arctic	19.5
Barnea manilensis	Subtropical	8.5–
Zirfaea subconstricta	Tropical-subtropical	8.5
Laternula anatina	Tropical-subtropical	12–
Lyonsia ventricosa	Subtropical	22.5
L. nuculanoformis	Lowboreal	27.5
Agriodesma navicula	Widely distributed boreal	·
Myadora japonica	Subtropical	25
Myadora reeveana	Subtropical	25
Myadoropsis transmontana	Subtropical	7–
Cuspidaria hindsiana	Tropical-subtropical	25

Distribution of species richness in Yeongil Bay itself is shown in Fig. 1. Species richness ranges from 1 (station 65, intertidal collecting site near Daedongbae where only *Mytilus galloprovincialis* was found, and station 57, depth 24 m, gravel) to 37 species (station 58, depth 25 m, coarse-grained sand with numerous shells). Stations located at the entrance to the bay (stations 52-57) as well as some stations in the central part (Fig. 1) are characterized by a rather low species richness (1 to 9 species) as well some stations in the central part (Fig. 1). Species richness was less than 10 at 19 stations (of 31 sampling sites as a whole), and only at two stations more than 20 species were collected. Perhaps, no trend exists for species richness/sediment type relationships. Species richness of beach (drifted) shell accumulations varies between 11 (Limgok) and 15 (Pohang).

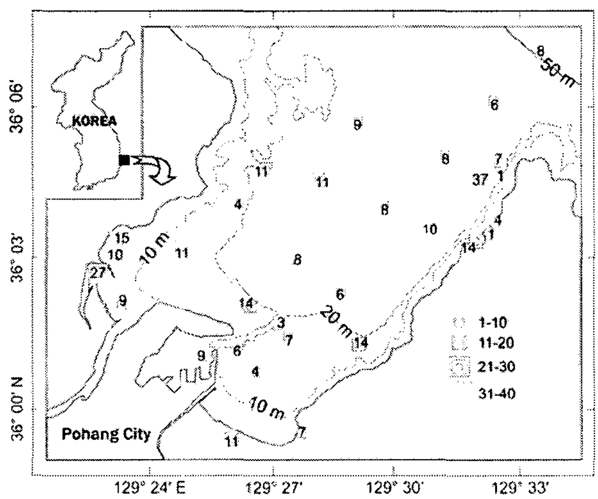

Fig. 1. Species richness of bivalve mollusks (number of species) at different collecting stations in Yeongil Bay (as for map of the stations, see Part 1 of the present paper).

ECOFAUNAL CHARACTERISTICS

Despite the qualitative collecting, we will attempt to discuss some ecological features of the bivalve molluscan fauna in Yeongil Bay and compare those with other bay faunas in the East/Japan Sea and the neighboring areas (Pacific coast of Japan and South Sea of Korea). According to frequency of occurrence (at least, more than five stations) and abundance of individuals in samples, the most common species in the bay in 1997 were as follows: *Acila insignis* (found at seven stations), *Nucula tenuis* (six stations), *Yoldia notabilis* (ten stations), *Mytilus galloprovincialis* (ten stations), *Arca boucardi* (eight stations), *Axinopsida subquadrata* (nine stations), *Felaniella usta* (six stations), *Mactra chinensis* (eight stations), *Raeta pulchella* (seventeen stations), *Nitidotellina hokkaidoensis* (six stations), *Theora fragilis* (ten stations), *Alvenius ojianus* (twelve stations), *Callithaca adamsi* (twenty stations), *Ruditapes philippinarum* (six stations) and *Laternula anatina* (nine stations). Because almost the same sampling efforts were made at all stations, we can say that numerically (per sample) most abundant mollusks were *A. insignis, N. tenuis, A. subquadrata, R. pulchella, Th. fragilis, A. ojianus* and *C. adamsi* (Fig. 2-7). For these and some other species we plotted maps of their local distributions in Yeongil bay (Fig. 8-13).

A majority of enumerated species are common

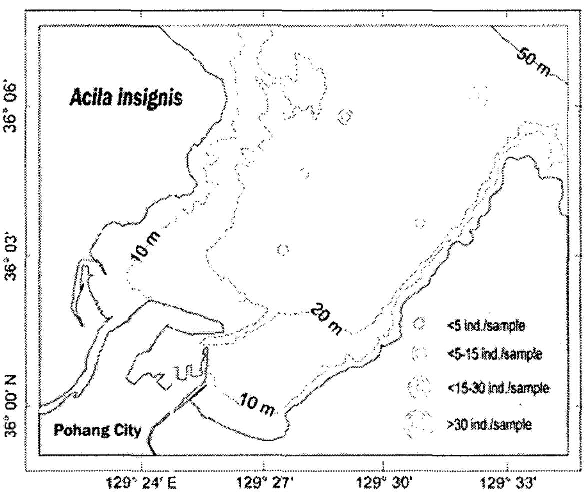

Fig. 2. Relative abundance of shells and live specimens (per sample) of *Acila insignis* (Nuculidae) in Yeongil Bay in August 1997.

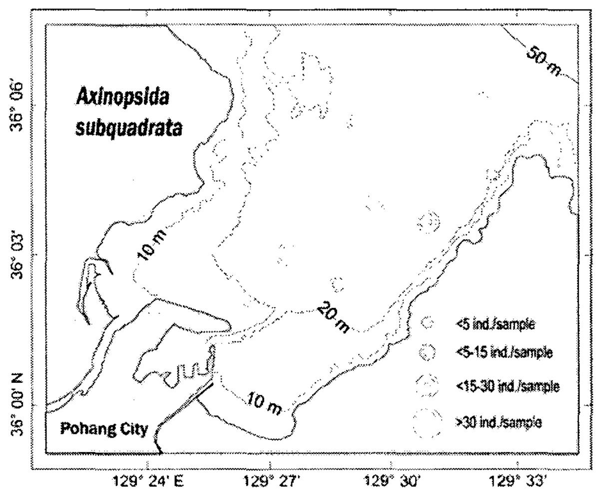

Fig. 4. Relative abundance of shells and live specimens (per sample) of *Axinopsida subquadrata* (Thyasiridae) in Yeongil Bay in August 1997.

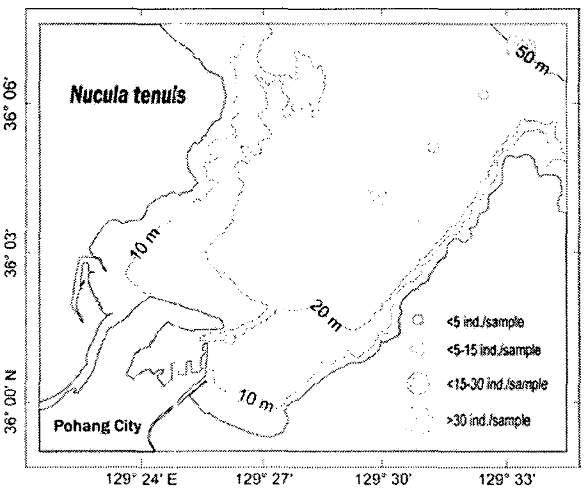

Fig. 3. Relative abundance of shells and live specimens (per sample) of *Nucula tenuis* (Nuculidae) in Yeongil Bay in August 1997.

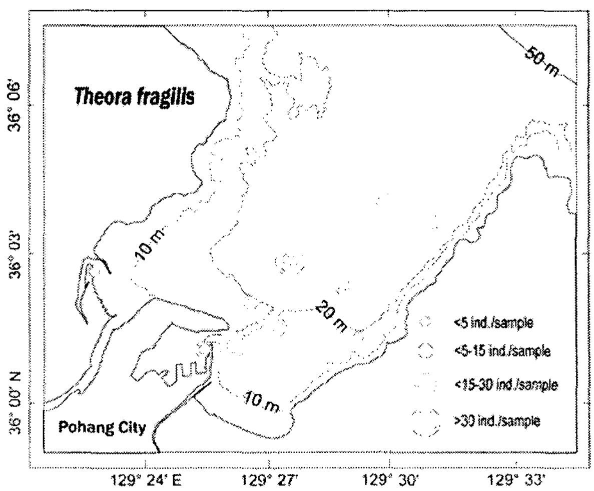

Fig. 5. Relative abundance of shells and live specimens (per sample) of *Theora fragilis* (Semelidae) in Yeongil Bay in August 1997.

infaunal bivalves inhabiting muddy or sandy bottoms of embayments in the East Sea. Muddy bottom dwellers tend to inhabit the central and south-eastern parts of Yeongil Bay with a predominance of mud and muddy sand (stations 35-43, 53-55, 59, 60). Three local distribution patterns of these species can be distinguished. Some concentrate mostly in the inner part (*Yoldia notabilis, Theora fragilis, Laternula anatina*), other species inhabit the entire bay area, being found in the inner, middle and outer parts (*Acila insignis, Axinopsida subquadrata, Alvenius ojianus, Callithaca adamsi, Raeta pulchella*), and one dominant species is collected only in the outer and outermost, rather deep areas (stations 54-55, depth 35-52 m) (*Nucula tenuis).* Two species that occurred more rarely, *Clinocardium californiense* and *Mizuhopecten yessoensis*, were also found only in the outermost part of Yeongil Bay (Fig. 9). This phenomenon can be attributed to the boreal nature of these species distributed mostly in temperate latitudes of the Pacific Ocean; *Nucula tenuis* belongs to the boreal-arctic complex. Therefore, not only sediment characteristics, but also temperature conditions govern the distribution of certain species in the bay. These examples also demonstrate the effect of the submergence of boreal animals into deeper areas in the southern parts of their geographic ranges.

The spatial distributions of the rest of species seem to be determined by their substrate preferences and the mode of life. Epifaunal *Arca boucardi* is encountered along the coastline (except for the southernmost part of the bay), in areas occupied mostly by sandy sediments often intermixed with gravel; the same pattern is found for infaunal *Felaniella usta* (Fig. 9) and, to some extent, rock-boring *Barnea manilensis* (Fig. 13) distributed only along the western coast. Psammophilous *Mercenaria stimpsoni, Mactra chinensis, Ruditapes philippinarum, Siliqua pulchella* and *Fulvia mutica* occur only near sandy beaches (stations 34, 48, 49, 61-63) or in the area of coarse-grained sand and gravel (stations 56-58).

Many species in our samples were represented by empty shells. This is explained by the method of collecting: a small-dredge captured only superficial sediments and did not permit collecting deep-burrowing live bivalves. Habe (1956b) found that in the bays of Japan the composition of modern thanatocoenoses (death assemblages of animals that recently died or their remains) of molluscan shells is quite similar to that of living communities at the same place. The rather high fidelity of death

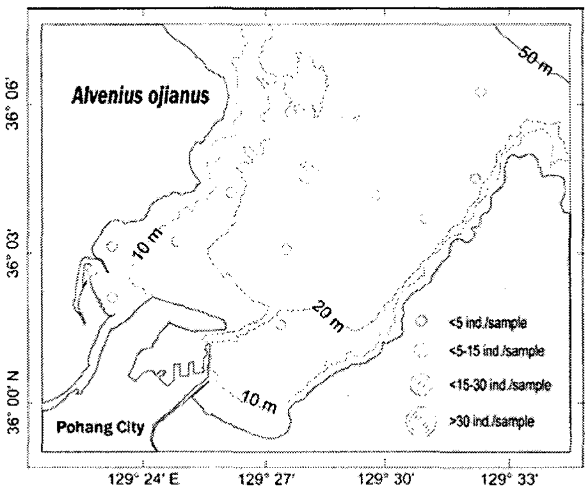

Fig. 6. Relative abundance of shells and live specimens (per sample) of *Alvenius ojianus* (Kelliellidae) in Yeongil Bay in August 1997.

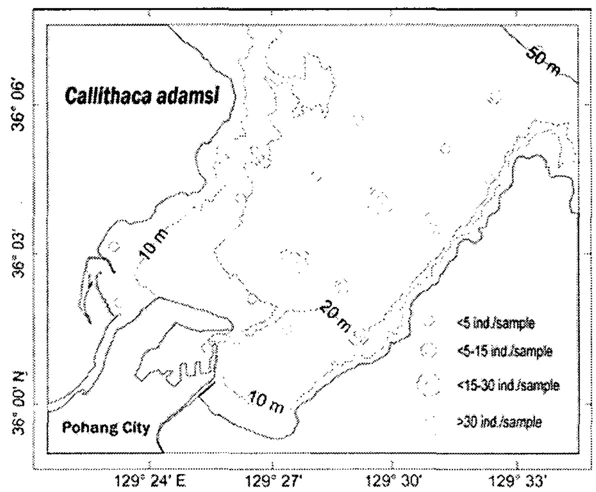

Fig. 7. Relative abundance of shells and live specimens (per sample) of *Callithaca adamsi* (Veneridae) in Yeongil Bay in August 1997.

Table 2. Dominant and common species of bivalve mollusks in bays of Japan and Russian waters of the East/Japan Sea.

Locality	Dominant and common species	Reference
Ariake Bay, Kyushu	*Theora lubrica* [=*Th. fragilis*], *Paphia undulata, Raeta pulchella, Veremolpa micra, Myadora fluctuosa, Abrina kanamurai, Alveniua ojianus, Modiolus comptus, Crassatellites nanus, Chlamys asperulata, Ostrea denselamellosa, O. futamiensis, Crassostrea gigas, C. irregularis, Oxeperas bernardi, Monia umbonata*	Habe, 1959; Habe and Tanaka, 1959
Usuki Bay, eastern Kyushu	*Pitar chordatum, Striarca interplicata, Oblimopa forskalii, Oxyperas bernardi, Veremolpa minuta, Modiolus agripetus* [=*M. auriculatus*]	Shuto, 1973
Wakasa Bay, East/Japan Sea side of Honshu	*Modiolus margaritaceus, Carditella hanzawai, Bathyarca kyurokusimana, Laevicirce soyoae, Crenulilimopsis oblonga, Variocorbula rotalis*	Ito, 1990
Toyama Bay, East/Japan Sea side of Honshu	Euneritic zone (0-20-30 m): *Barbatia stearnsii, Limopsis japonica, Neopycnodonte musashiana, Pitar chordata, Fabulina nitidula* [=*Nitidotellina hokkaidoensis*], *Myadora fluctuosa*	Fujii, 1987
Tsukumo Bay, Noto Peninsula, East/Japan Sea side of Honshu	Inner bay area: *Anodontia stearnsiana, Pecten albicans, Laevicardium undatopictum, Fulvia hungerfordiana, Raetellops pulchella* [=*Raeta pulchella*], *Theora lubrica* [=*Th. fragilis*], *Moerella iridescens, Nitidotellina minuta, Macoma tokyoensis*; outer bay area: *Oblimopa japonica, P. albicans, Pillucina yamakawai, Leptaxinus oyamai, L. undatopictum, Costellipitar chordatum, Nitidotellina nitidula* [=*N. hokkaidoensis*], *N. minuta*	Habe, 1973
Nanao Bay, Noto Peninsula, East/Japan Sea side of Honshu	*Nucula paulula, Theora lubrica* [=*Th. fragilis*], *Paphia undulata, Microcirce gordonis*	Habe, 1956a
Tanabe Bay, Kii Peninsula, Pacific side of Honshu	*Fulvia hungerfordi, Theora lubrica* [=*Th. fragilis*], *Microcirce dilecta, Pillucina neglecta, Alvenius ojianus, Fabulina minuta* [=*Nitidotellina minuta*], *Modiolus nipponica, Dosinia angulosa, Paphia undulata, Macoma awajiensis, Nucula paulula*	Habe, 1960
Mikawa Bay, central Pacific side of Honshu	*Nucula paulula, Microcirce dilecta, Theora fragilis, Raetellops pulchella* [=*Raeta pulchella*], *Alvenius ojianus, Veremolpa micra, Paphia undulata, Musculista senhousia, Pillucina pisidium*	Nobuhara *et al.*, 1991
Ofunato Bay, Pacific side of Honshu	*Theora lubrica* [=*Th. fragilis*], *Alvenius ojianus, Raeta pulchlla, Axinopsida subquadrata, Thyasira tokunagai, Clinocardium californiense, Callithaca adamsi*; at the entrance of the bay: *Ennucula tenuis* [=*Nucula tenuis*], *Acila insignis, Lasaea nipponica, Fabulina minuta* [=*Nitidotellina minuta*]	Habe, 1955a
Possjet Bay, northwestern East/Japan Sea, Russian coast	Semi-enclosed bays: *Pillucina pisidium, Arca boucardi, Crenomytilus grayanus, Chlamys farreri nipponensis, Venerupis japonica* [=*Ruditapes philippinarum*], *Musculista senhousia, Macoma incongrua, Macoma sicca* [=*M. contabulata*], *Anadara broughtonii, Theora lubrica, Alvenius ojianus, Axinopsida subquadrata, Anisocorbula venusta, Raeta pulchella, Laternula limicola*; open part of the bay: *C. grayanus, Modiolus difficilis* [=*M. kurilensis*], *Acila insignis, Ennucula cyrenoides* [=*Nucula ovatotruncata*], *P. pisidium, Macoma orientalis* [=*M. scarlatoi*], *Mercenaria stimpsoni, Felaniella usta, Siliqua alta, Turtonia minuta, Peronidia venulosa* [=*Megangulus venulosus*], *Patinopecten yessoensis* [=*Mizuhopecten yessoensis*], *Spisula sachalinensis, Mactra sulcataria* [=*M. chinensis*], *Macoma calcarea, Callista brevisiphonata, Serripes groenlandicus, Callithaca adamsi, Panope japonica* [=*Panopea abrupra*]	Scarlato *et al.*, 1967; Golikov and Scarlato, 1967; Klimova, 1980; Komendantov and Orlova, 1990
Nakhodka Bay, northwestern East/Japan Sea, Russian coast	*Macoma scarlatoi, Axinopsida subquadrata, Clinocardium californiense, Raeta pulchella, Callithaca adamsi, Liocyma fluctuosa, Theora fragilis*	Lutaenko, 1999
Amursky Bay, northwestern East/Japan Sea, Russian coast	*Nucula ovatotruncata, Nucula tenuis, Yoldia notabilis, Yoldia seminuda, Musculus laevigatus, Serripes groenlandicus, Axinopsida subquadrata, Dosinia penicillata, Liocyma fluctuosa, Callithaca adamsi, Alvenius ojianus, Macoma calcarea, Macoma incongrua, Macoma scarlatoi, Macoma tokyoensis, Theora lubrica, Raeta pulchella, Potamocorbula amurensis, Mya uzenensis, Mya japonica*	Lutaenko, 2002, 2003

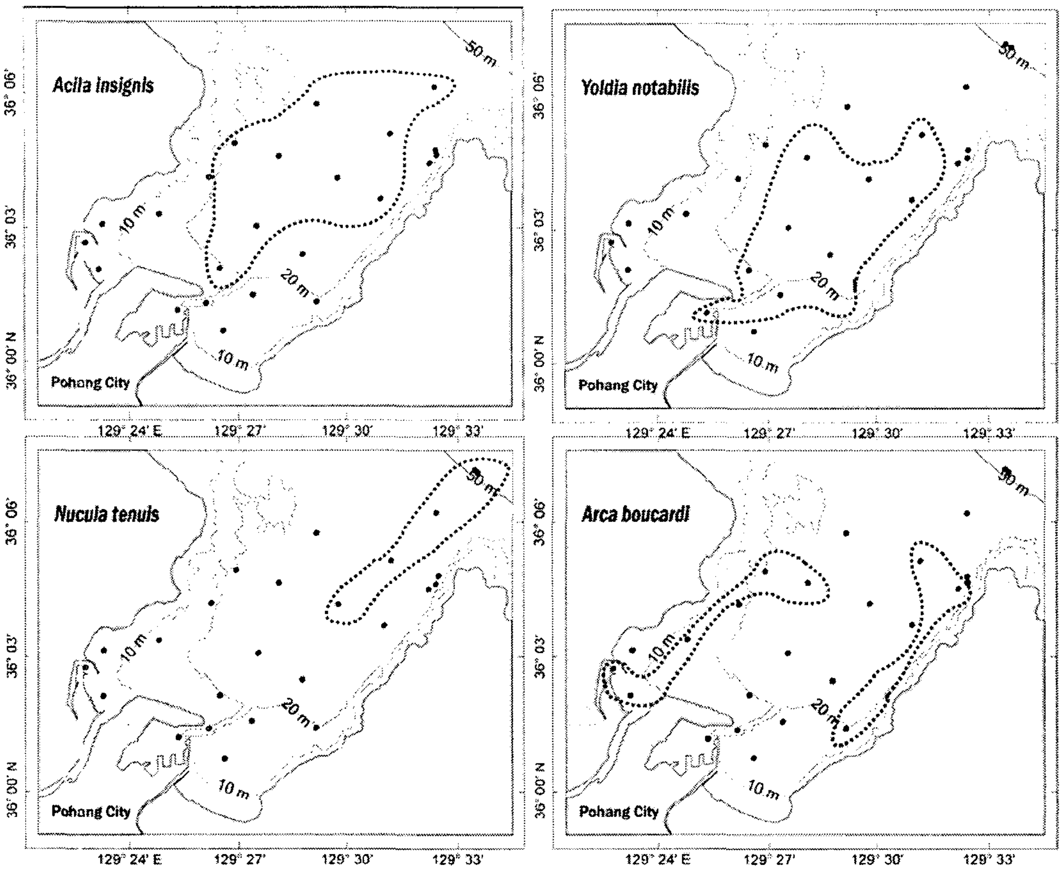

Fig. 8. Local distributions of *Acila insignis* (Nuculidae), *Yoldia notabilis* (Yoldiidae), *Nucula tenuis* (Nuculidae) and *Arca boucardi* (Arcidae) in Yeongil Bay.

assemblages to source live communities with respect to species richness and taxonomic composition appears to be a general rule for shallow marine environments (Kidwell and Bosence, 1991; Lutaenko and Oleynik, 1992). Transportation of shell remains seems not remarkable even near high-energetic bay mouths (Habe, 1956b); the same conclusion was drawn for beach thanatocoenoses (Lutaenko, 1994). Therefore, we can consider local distribution of molluscan shells as more or less accurately reflecting the distribution of live mollusks. The distribution of mollusks in Yeongil Bay represented in many cases by empty shells shows a characteristic pattern related to bottom sediments type and/or temperature conditions at different depths.

Numerous studies of the molluscan faunas of bays carried out by Japanese workers and some Russian faunal/ecological studies in the northwestern East/Japan Sea allow us to compare Yeongil Bay and other areas with respect to dominant and common species (Table 2). Habe (1956b) established that species composition of thanatocoenoses of bivalve mollusks in Japan are similar regardless of their geographical locations with several exceptions. According to this author, the important indicators of bay conditions are (1) *Nucula paulula, Microcirce gordonis, Veremolpa minuta, Sydlorina yamakawai* and *Laevicardium undatopictum* (inhabit chiefly outer bay areas), (2) *Theora lubrica* (= *Th. fragilis*), *Raeta pulchella, Fulvia hungerfordi, Paphia undulata, Veremolpa micra* and *Alvenius ojianus* (inhabit inner bay areas), (3) *Brachidontes senhousia* (= *Musculista*

Table 3. Dominant and common species of bivalve mollusks in different localities along the southern and eastern coasts of Korea.

Locality	Dominant and common species	Reference
Masan Bay	*Theora fragilis, Raetellops pulchella* [=*Raeta pulchella*]	Hong and Lee, 1983
Aenggang Bay	*Theora fragilis, Alvenius ojianus*	Lim *et al.*, 1999
Yoja Bay	*Theora fragilis, Scapharca subcrenata* [=*Anadara kagoshimensis*], *Moerella iridescens, Paphia undulata*	Lim *et al.*, 1991
Chinhae Bay	*Theora fragilis, Raetellops pulchella* [=*Raeta pulchella*], *Macoma tokyoensis, Periglypta cf. puerpera, Acila divaricata, Yoldia johanni, Scapharca broughtonii* [=*Anadara broughtonii*]	Lim *et al.*, 1992 Lim and Hong, 1997
Deukryang Bay	*Atrina pectinata, Fulvia mutica, Paphia undulata, Saxidomus purpurata, Scapharca broughtonii* [=*Anadara broughtonii*], *Sinonovacula constricta, Tegillarca granosa* [=*Anadara granosa*], *Ostrea denselamellosa, Chlamys farreri farreri, Musculista senhousia*	Ma *et al.*, 1995; Kim and Hur, 1998
Pusan area (including Suyeong Bay and Pusan Harbour)	*Fabulina* sp., *Macoma* sp., *Acila mirabilis, Tapes philippinarum* [=*Ruditapes philippinarum*], *Laternula limicola, Soletellina olivacea* [=*Nuttallia olivacea*], *Macoma incongrua, Brachidontes senhousia* [=*Musculista senhousia*]	Yi, 1975; Lee, 1976; Hong *et al.*, 1982
Ulsan Bay	*Theora lata* [=*Theora fragilis*], *Musculista senhousia, Macoma tokyoensis, Nucula paulula, Raetellops pulchella* [=*Raeta pulchella*]	Yi *et al.*, 1982 (as inferred from Table 1)
Onsan Bay	*Mytilus edulis* [=*Mytilus trossulus*], *Crassostrea gigas, Septifer virgatus, Lasaea undulata, Ostrea circumpicta*	Rho *et al.*, 1997
Kangnung area	*Alvenius ojianus, Mactra chinensis, Mytilus edulis galloprovincialis*	Choi *et al.*, 2000

senhousia), *Macoma incongrua* and *Pillucina pisidium* (live in innermost bay areas in southern Japan), and (4) *Ennucula tenuis* (=*Nucula tenuis*), *Thyasira tokunagai, Acila insignis* and *Axinopsida subquadrata* (inhabit bays in northern Japan). Elements of all four types of molluscan assemblages of Japan are found in Yeongil Bay. The assemblage *Callithaca adamsi-C. californiense-Axinopsida subquadrata-Mizuhopecten yessoensis-Nucula tenuis -Acila insignis* is idicative for the outer bay area, while the inner part is dominated by the assemblage *Yoldia notabilis-A. insignis-Alvenius ojianus-Th. fragilis-Callithaca adamsi-Laternula anatina-Raeta pulchela-Nitidotellina hokkaidoensis-Macoma tokyoensis*. Spatial overlapping of local ranges of some species tending to inhabit the entire area of the bay is related to rather intensive water exchange between the bay and the open sea. Therefore, in Yeongil Bay we can recognize only two ecological areas characterized by the above-mentioned assemblages (outer and inner bay), while in Japanese bays the areas based on spatial distribution of molluscan assemblages can be classified into six types (outer bay, outer part of middle bay, middle part of middle bay, inner part of middle bay, inner bay, innermost part of inner bay) (Habe, 1956b). It should be noted that a number of warm-water, subtropical and tropical- subtropical (in zonal-geographical terminology) species have not been found in Yeongil Bay. These mollusks inhabit chiefly the innermost parts of inner bays not only in southern Japan, but also in northern Japan and the north-western East/Japan Sea. As an example, we can enumerate *Musculista senhousia, Trapezium liratum* (a common species in oyster communities), *Macoma contabulata, Mactra veneriformis, Dosinia penicillata* and *Barnea dilatata*. These mollusks are found in Peter the Great Bay (Scarlato, 1981; Lutaenko, 2002, 2003) located further north of North Korea. These and some other species (*Meretrix lusoria, Meretrix petechialis, Cyclina sinensis*) are common on muddy and sandy tidal flats of Japan (*e.g.* Kondo, 1987; Tanabe and Arimura, 1987) and constitute the major portion of benthic communities on tidal flats of western Korea (Choi, 1969, 1971; Lee *et al.*, 1983; Hong and Park, 1998) and on the southern coast of Korea (Suyeong, Ulsan, Deukryang Bays, *etc.*) (Table 3). Thus, *Musculista senhousia,* a mud mussel, form mass settlements in Mokpo coastal area with annual mean density of 8,215 individuals/m^2 and annual mean biomass of 1,966.43 g/m^2 (Lim and Park, 1998b); in Inchon coastal area, 10.5 individuals/m^2 (Koh *et al.*, 1997) and even further northward, in Possjet Bay (-42° N, northwestern East/Japan Sea, near the Russian-North Korea border) this species attains a density of 500-750 individuals/m^2 in *Zostera marina* community (Golikov and Scarlato, 1967). *M. senhousia* also penetrates to some warmed-up, southern areas of the Sea of Okhotsk where in Busse Lagoon (-46-47° N, Sakhalin Isl.) it participates in the community of *Ahnfeltia tobuchiensis* with a maximum density of 450 individuals/m^2 (Golikov and Scarlato, 1985). *M. senhousia* was also recorded on the rather cold-water Pacific coast of Hokkaido (Akkeshi Bay) (Habe, 1955b; as *Brachidontes senhousia*). In the light of these data, it is surprising why this species was not found in Yeongil Bay.

Another faunal and ecological feature of Yeongil Bay is a low frequency of occurrence of some, chiefly subtropical, infaunal mollusks which are rather common in southern bays of Korea and in

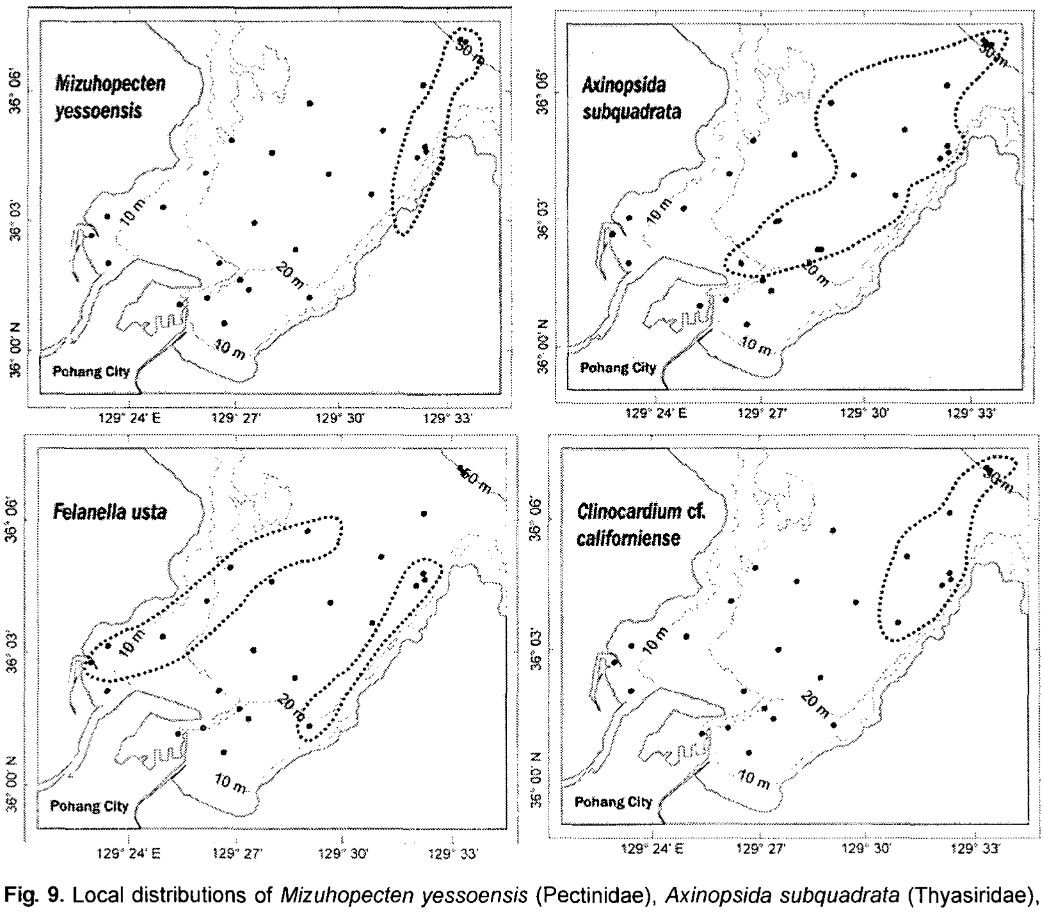

Fig. 9. Local distributions of *Mizuhopecten yessoensis* (Pectinidae), *Axinopsida subquadrata* (Thyasiridae), *Felaniella usta* (Ungulinidae) and *Clinocardium* cf. *californiense* (Cardiidae) in Yeongil Bay.

semi-enclosed bays of Japanese and Russian coasts of the East/Japan Sea (*e.g.*, *Anadara kagoshimensis, Macoma incongrua* and *Solen strictus*). Habe (1955b) noticed that *M. incongrua* is one of the commonest species in bays of Japan, and it is very common in Possjet Bay (maximum density of 9 individuals/0.1 m^2) and Amursky Bay in Primorye (Golikov and Scarlato, 1967; Lutaenko, 2003) as well as in Busse Lagoon in southern Sakhalin Island (maximum density up to 40 individuals/m^2) (Golikov and Scarlato, 1985). However, in Yeongil Bay it was found with a low density of 0.08 individual/0.1 m^2 (Koh and Kang, 1998). *A. kagoshimensis* is usually found in the South and West Seas of Korea (*e.g.* Yoo, 1977; as *Arca subcrenata*) where it is an important edible species, but it became extinct in the northwestern East/Japan Sea in the Late Holocene (Lutaenko, 1993); in Japan, this species is most abundant and cultured in the Ariake Sea and Tokyo Bay (Yamamoto and Habe, 1958). *Anadara broughtonii*, an allied species presently distributed further northward, was not found in our samples although it is also common on the southern coast of Korea and inhabits Ulsan Bay (Yoo *et al.*, 1977; Kwon and Cho, 1986; Kim and Hur, 1998). In the northwestern East/Japan Sea, *A. broughtonii* commonly inhabits semi-enclosed bays and inner parts of bays reaching a maximum density of 5 individuals/m^2 (Gabaev and Olifirenko, 2001). However, the absence of this species in Yeongil Bay may be caused by our sampling technique, short-term sampling and/or low abundance caused by local population harvesting. *S. strictus* is abundant on some

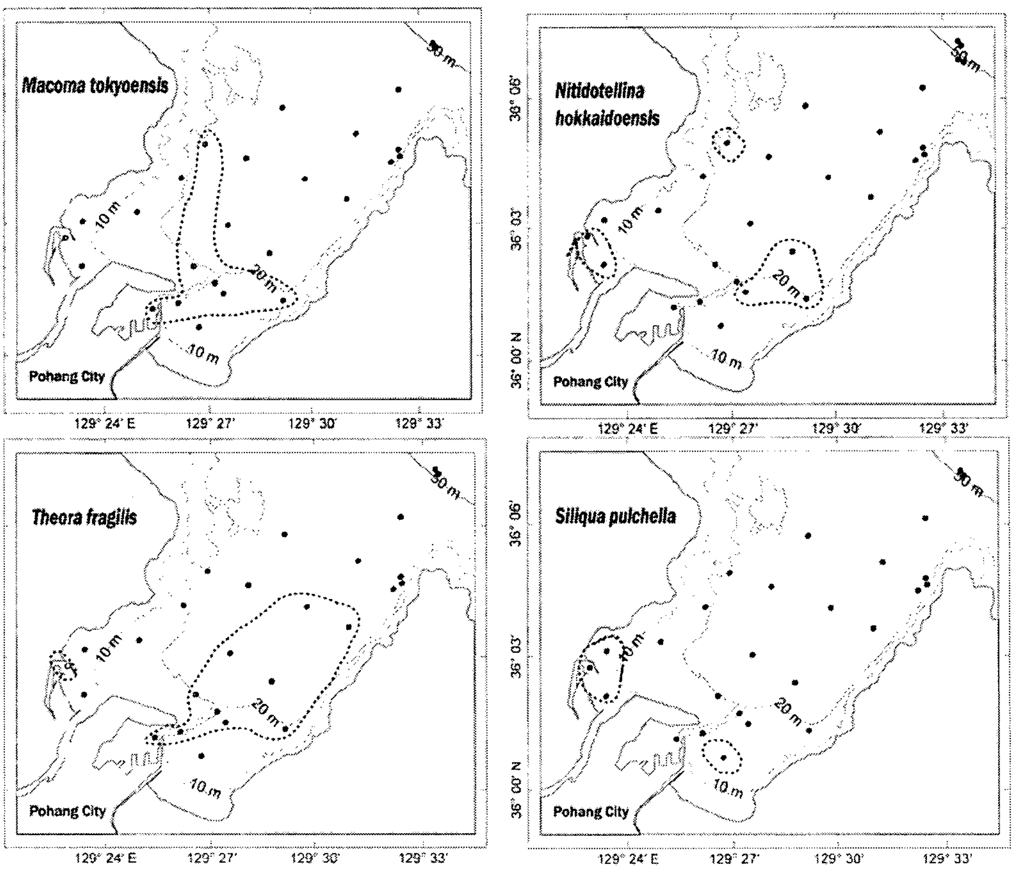

Fig. 10. Local distributions of *Macoma tokyoensis, Nitidotellina hokkaidoensis* (Tellinidae), *Theora fragilis* (Semelidae) and *Siliqua pulchella* (Pharidae) in Yeongil Bay.

macrotidal flats in western Korea (mean density of 126 individuals/m^2) (Hong and Park, 1994), and was found in Possjet and Ussuriysky Bays in Russian Primorye (Razin, 1934; Golikov and Scarlato, 1967) but seems to be absent in eastern Hokkaido and along the Pacific coast of northern Honshu washed by a cold current (Habe, 1955b; Tsuchida and Kurozumi, 1995; Tsuchida, 1998); its northernmost limit is Hakodate (Tsugaru Strait, southern Hokkaido) and Mutsu Bay (northern Honshu) (Yamamoto and Habe, 1959).

As was mentioned above, the inner part of Yeongil Bay is characterized by presence of *Theora fragilis* and *Raeta pulchella* along with other species. These mollusks are adapted to extreme environments and are often found on black reducing mud where the bottom water lacks dissolved oxygen in the summer stagnation period (Habe, 1956b). Formation of such populations bears cyclic character and juveniles are recruited several times during the stratification period: *Th. fragilis* is a short-lived species; however, in the Seto Inland Sea most of the juveniles found at hypoxic stations died out immediately after settlement and never grew up to the adult size (Kagawa, 1986). In Waitemata Harbour (New Zealand), this anthropogenically introduced species can rapidly colonize disturbed and muddy habitats and is perhaps the most pollution-tolerant mollusk in this harbour (Hayward, 1997). In Hakata Bay (northern Kyushu), the spatial dynamics of populations of *Th. fragilis* and *Musculista senhousia* can differ greatly depending on season: the center of mollusk distribution shifted from the inner waters of the bay to the middle waters

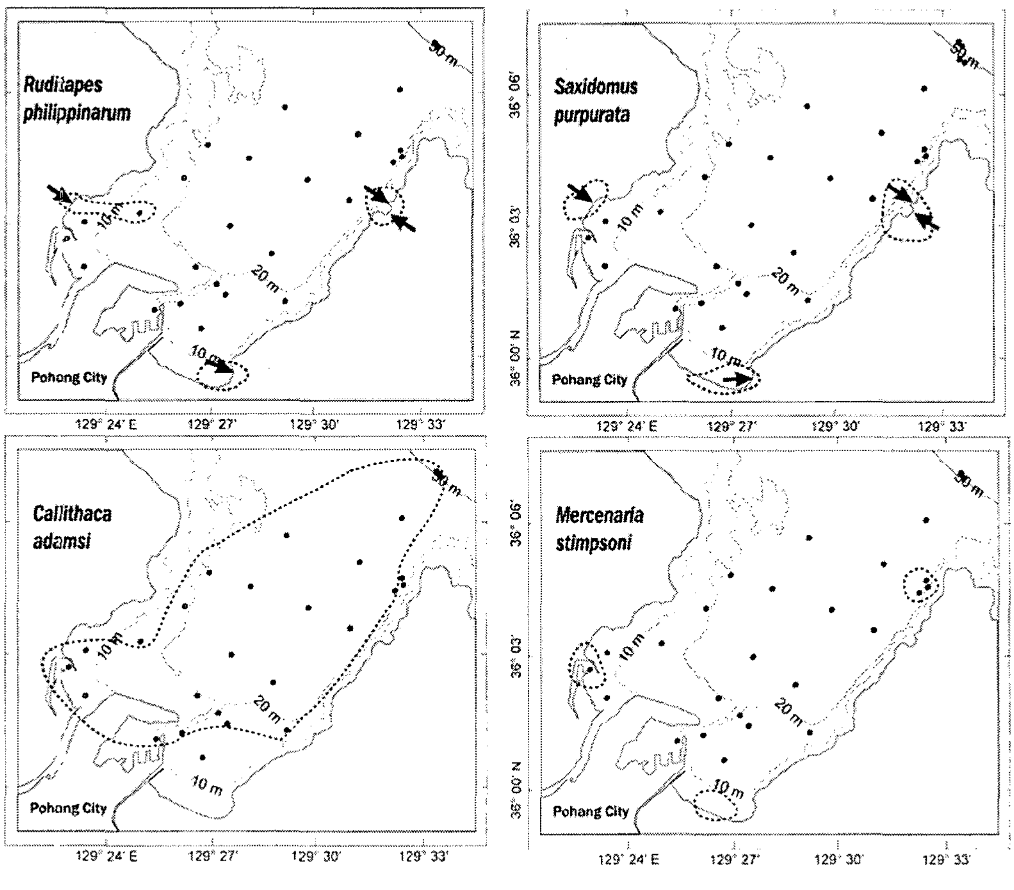

Fig. 11. Local distributions of *Ruditapes philippinarum, Saxidomus purpurata, Callithaca adamsi* and *Mercenaria stimpsoni* (Veneridae) in Yeongil Bay.

during the summer stratification period when dissolved oxygen of the bottom water diminished; the center returned to the inner waters when dissolved oxygen increased (Hamano *et al.*, 1986).

Theora fragilis is a very common species in Korean bays where its presence is considered as indicative of organic pollution (*e.g.* in North Port of Inchon; Hong *et al.*, 1994). In Chinhae Bay, two peaks of spat settlement were observed, one in summer and another in winter with maximum in summer; the density of population is highest at the mouth of the bay (up to 2,116 individuals/m^2 in summer) but it rapidly declined in fall after mass mortality (Lim *et al.*, 1995). Spatial distribution and abundance of *Th. fragilis* in this bay is largely controlled by sediment organic carbon content and the dissolved oxygen of the bottom water: population density increases with increasing organic carbon content and after recovery from oxygen deficiency of the bottom water, the local distributional area expanded towards the inner part of the bay in winter (Lim *et al.*, 1995). In the Yongsan River estuary, *Th. fragilis* was one of a few invertebrate dominant species (up to 1330 individuals/m^2) in the innermost estuarine bay where summer hypoxia developed; however, *Raeta pulchella* and *Th. fragilis* predominated also in the central transitory area of the estuarine bay but with relatively low density as compared to that of the innermost area (Lim and Park, 1998a). In Chonsu Bay (West Sea), *Th. fragilis* was the dominant species in August reaching 433 individuals/m^2 (Lee and Park, 1998) however, this bay is semi-enclosed with a tidal flat and a mean tidal range of about 4.7 m, and no summer stratification/oxygen deficiency phenomena occur here.

In the northern East Sea, *Theora fragilis* plays a significant role in soft-bottom communities of semi-enclosed inlets of Possjet Bay with a density of up to 140 individuals/m^2 (Golikov and Scarlato, 1967), and also is very abundant in muddy bottom of the innermost part of Amursky and Nakhodka Bays (Lutaenko, 1999; 2003).

In Yeongil Bay, *Theora fragilis* occupies the inner part of the bay being especially abundant (more than 30 individuals/sample, up to 39 individuals/sample) at two stations (Fig. 5, 10). Since the shell of this bivalve is very thin and fragile and during the dredging and washing procedures many shells were merely destroyed, it is very likely that the true numerical abundance of mollusks in samples was much higher. Our collecting coincided with the time of mass spat settlement in bays of the southern coast of Korea. However, it is not known if that mass mortality takes place in Yeongil Bay: its bottom waters in June-August are rather cold (7-9℃) due to upwelling (Son, 1977). It might be suggested that the spatial distribution and abundance of *Th. lubrica* in Yeongil Bay are determined by sediment type (mud and muddy sand) and sediment organic carbon content.

Due to a the limited number of stations in Yeongil Bay, the peculiarities of bathymetric distributions of mollusks can be treated only tentatively. We selected some common species frequently collected in the study area; the complete listing of depth ranges for each species is given in Table 1. Comparative data for some species inhabiting Yeongil Bay and found in other areas of the East Sea can be extracted from the paper by Lutaenko (1999).

Analysing the upper bathymetric limits of such species as *Acila insignis* (19.5-35.5 m), *Yoldia notabilis* (8.5-52 m), *Felaniella usta* (8.5-25 m), *Theora fragilis* (8.5-28 m) and some others, we can assume that in the northern areas of the East Sea, *e.g.*, Peter the Great Bay, they inhabit more shallow waters, *i.e.*, they shift their upper limits into upper 1-4 m deep. This might be associated with differential summer heating of coastal waters in Peter the Great Bay and Yeongil Bay: some embaymental areas in the former bay can warm up to 28℃, while maximum bottom temperatures in the latter bay in 1973-1978 reached only 19℃ (Yoo and Park, 1979). So, warm-water and relatively warm-water (lowboreal) mollusks can go up in the north-western East Sea, while they live deeply in Yeongil Bay although further bathymetric data are needed to prove this conclusion. On the other hand, *A. insignis* was found in Wakasa Bay only in depths below 58 m, and *Felaniella usta* - deeper than 41 m (Ito, 1990). The same trend is also drawn for *Arca*

Table 4. Number of species in families of bivalve mollusks from different bays of the East/Japan Sea and neighboring Mutsu Bay.

Family	Yeongil Bay (present study)	Wakasa Bay (Ito, 1990)	Peter the Great Bay (combined data)	Mutsu Bay (Yamamoto, Habe, 1958, 1959)
Nuculidae	3	5	3	1
Yoldiidae	1	3	10	2
Mytilidae	8	10	18	13
Arcidae	3	10	2	7
Parallelodontidae	1	1	0	1
Limopsidae	1	5	0	1
Glycymerididae	3	1	1	1
Limidae	2	6	2	2
Ostreidae	2	1	1	2
Pectinidae	3	10	6	4
Chamidae	1	2	0	1
Lucinidae	1	8	1	4
Thyasiridae	1	4	4	2
Ungulinidae	4	6	2	4
Lasaeidae	5	16	3	5
Carditidae	3	8	3	2
Crassatellidae	3	2	0	0
Astartidae	2	2	3	0
Cardiidae	2	8	5	2
Mactridae	5	7	5	4
Solenidae	2	2	2	2
Pharidae	1	0	1	0
Tellinidae	12	14	20	19
Semelidae	1	7	1	1
Kelliellidae	1	1	1	1
Veneridae	10	20	12	13
Petricolidae	1	1	0	1
Myidae	3	2	4	2
Corbulidae	1	7	2	2
Hiatellidae	1	2	6	2
Pholadidae	2	0	3	2
Laternulidae	1	1	1	2
Lyonsiidae	3	1	3	2
Myochamidae	3	1	0	0
Cuspidariidae	1	6	3	0

Remarks: Non-marine family Corbiculidae is excluded.

boucardi (found in Yeongil Bay in depth range of 6.5–30 m), *Nucula hokkaidoensis* (6.5–23 m), *Callithaca adamsi* (6.5–52 m) and *Laternula anatina* (12–23 m): their upper bathymetric limits lie deeper in Wakasa Bay, as compared to Yeongil Bay (41–139 m; 30-40 m; 87–161 and 50–62 m, respectively) (Ito, 1990). *Laternula anatina* found in Yeongil Bay in the depth range of 12-23 m was recorded from off Hino-Misaki (eastern East Sea) at a depth of 58-59 m (Tsuchida and Hayashi, 1994). It is no surprise that warm-water species are found deeper along the Japanese coast of the East Sea due to the warming effect of the Tsushima Current, however, why they do not inhabit the upper subtidal zone (0–30 m) is not clear.

BIOGEOGRAPHY

Biogeographically, Korean waters of the East Sea belong to two regions: boreal (north of East Korean

Bay) and subtropical (south of that bay) (Scarlato, 1981). J. Briggs (1995) believes that the southern part of the Korean Peninsula (along the eastern coast northward to Yeongil Bay, according to Fig. 78, l.c.) is characterized by the warm-temperate Japan Region biota, while the northern Korean coast belongs to the cold-temperate Oriental Province; the latter biota exists in three segments: along the Chinese coast including the entire Yellow Sea, eastern Korea and northern Honshu. Chinese workers (Tchang *et al.*, 1963) regard Yellow Sea, Korean and Russian coasts of the East Sea as belonging to the Far Eastern Subregion of the temperate North Pacific Region. Kafanov (1991) considers the Korean coast (south to Pusan) as belonging to the North Pacific (boreal) Region, and preliminarily called this area as the East Korean Province. Nishimura (1965), summarizing distributional data on different groups of organisms in the East Sea, mentions four zoogeographical points (lines) along the Korean coast set by previous workers: Wonsan, Yeongil Bay and two lines around Korea Strait and Pusan. The bioclimatic zoning scheme of Kafanov and co-authors (2000) shows a boundary between the mild-temperate and warm-temperate zones in the region slightly north of Yeongil Bay. Ophiuran biogeography suggests that the zoogeographic boundary line exists on the Korean coast to the northeast of Yeongil Bay (Shin and Koh, 1993). Thus, it seems that Yeongil Bay is situated in the intermediate zone between the temperate (boreal) and the subtropical zones, and its fauna may contain a number of warm-water (tropical-subtropical and

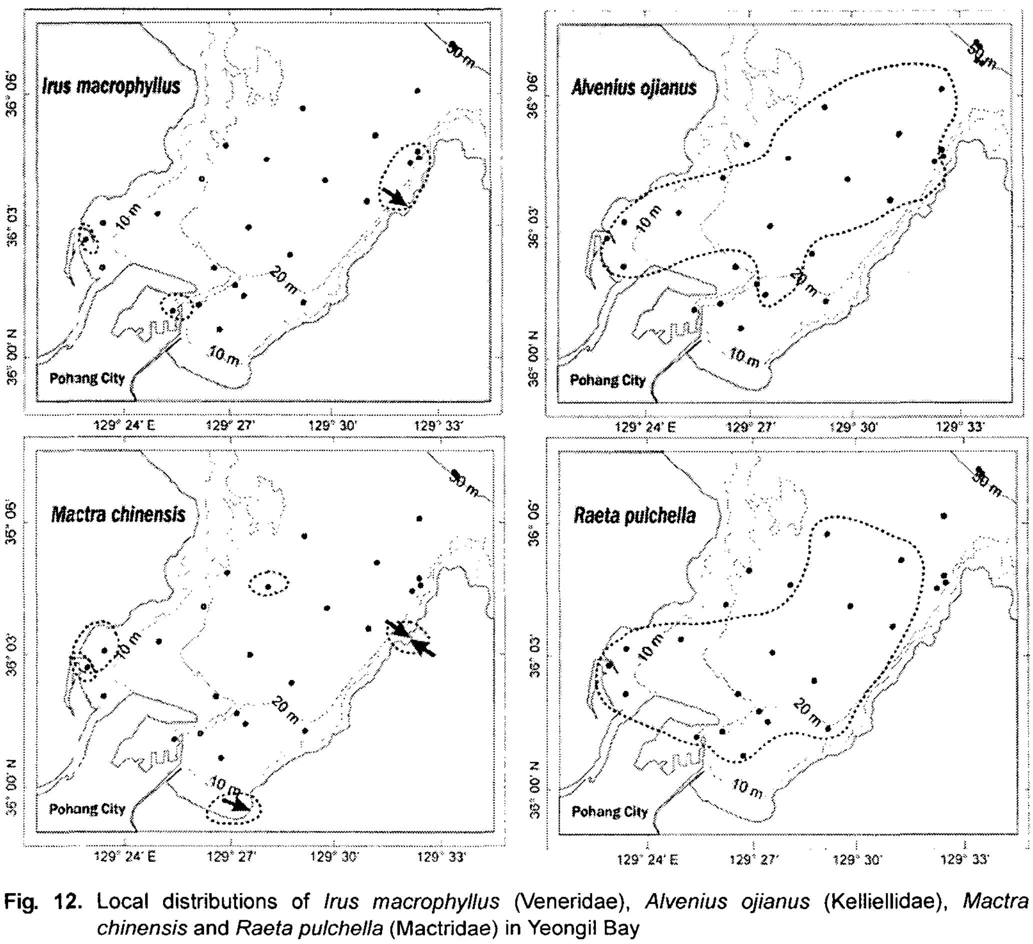

Fig. 12. Local distributions of *Irus macrophyllus* (Veneridae), *Alvenius ojianus* (Kelliellidae), *Mactra chinensis* and *Raeta pulchella* (Mactridae) in Yeongil Bay

subtropical) elements as well as some cold-water and boreal ones. To reveal the zoogeographic nature of the bay molluscan fauna, we analyzed its zonal-biogeographical composition. This approach is widely accepted in the Russian biogeographical literature (Scarlato, 1981).

Species collected in Yeongil Bay were assigned to six zonal-geographical groups: 1, tropical-subtropical (distributed southward to the Philippines, Vietnam and Indonesia), 2, subtropical (distributed southward to Taiwan and the northern part of the South China Sea), 3, subtropical-lowboreal (limited both to subtropical seas and the East Sea, southeastern Sakhalin and southern Kuril Islands), 4, lowboreal (limited to the East Sea from Peter the Great Bay, northern Korea and northern Honshu to southwestern Sakhalin, Aniva and Terpenya Bays and the southern Kuril Islands), 5, widely distributed boreal (limited within the East Sea and Hokkaido to Bering Strait along the Asian coast and along the northern American coast southward to California) and circumboreal (limited mainly to temperate latitudes, both of Atlantic and Pacific Oceans, but partly to subtropical and arctic zones), and 6, boreal-arctic (limited both to the temperate zone of the Pacific Ocean and to the Arctic and partly to the temperate Atlantic).

In all, 91 species were taken into consideration; six species identified to the genus level (*Chama* sp., *Borniola* sp., *Montacutona* sp., *Nipponocrassatella* sp., *Astarte* sp. and *Moerella* sp.) and one brackish-water species (*Corbicula japonica*) were excluded from the

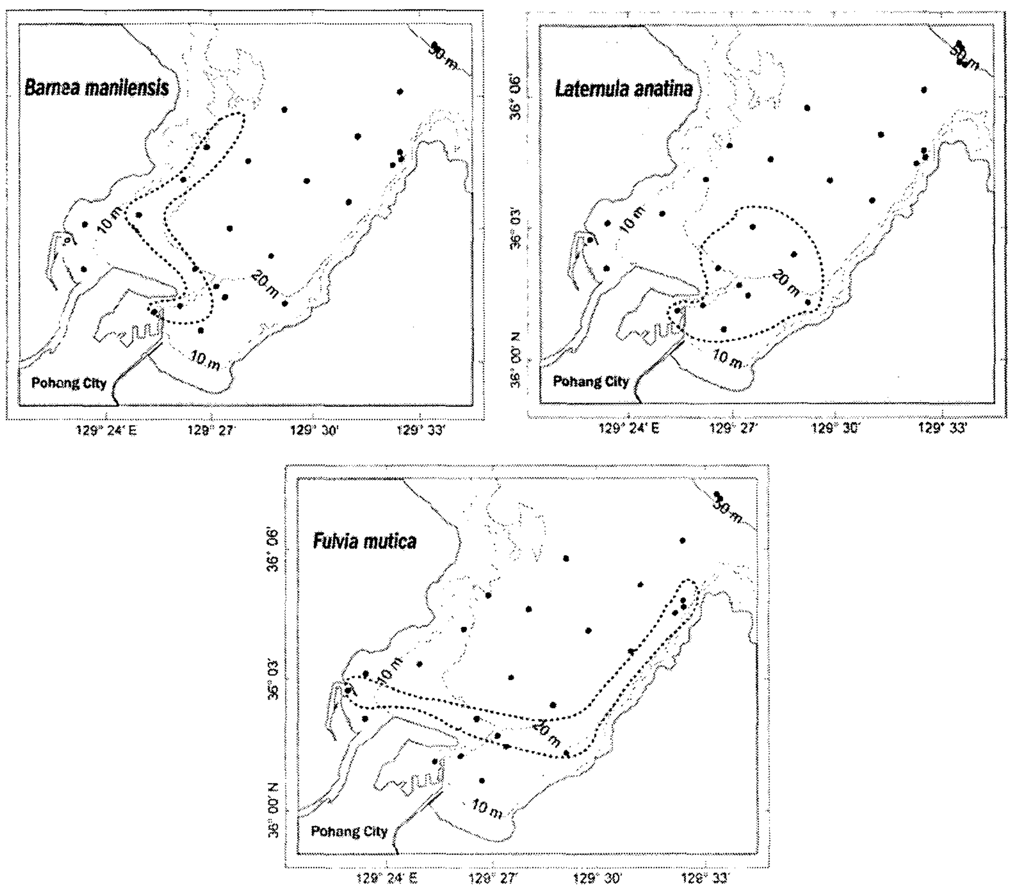

Fig. 13. Local distributions of *Barnea manilensis* (Pholadidae), *Laternula anatina* (Laternulidae) and *Fulvia mutica* (Cardiidae) in Yeongil Bay

biogeographical analysis. A majority of species found in Yeongil Bay (49 species, or 55%) belong to the subtropical group, and tropical-subtropical mollusks also play a significant role (15 species, or 16%). Taking into account that the rest of warm-water species (subtropical-lowboreal) make up 11% (10 species), the total share of thermophilous species (tropical-subtropical + subtropical + subtropical-lowboreal) is 82%, and only 18% of the fauna are boreal and boreal-arctic species (Fig. 14).

For comparison, let us consider the zonal-geographical structure of the bivalve molluscan fauna in bays of the northwestern East Sea, *e.g.*, Possjet Bay (Scarlato, 1981) and Amursky Bay (Lutaenko, 2003). These bays are characterized by strong summer/winter contrasts: in summer, sea surface temperature in semi-enclosed bays can reach 28-30℃ (Biryulin *et al.*, 1970; Grigoryeva, 2000), while in winter it can fall as low as -1.9℃ and coastal areas are covered by ice during 4-4.5 months in the year. Thus, nearly arctic conditions occur in coastal waters in winter and subtropical, in summer. Among 97 species of bivalve mollusks found in Possjet Bay, 37 species are subtropical and subtropical-lowboreal (36.2%), 32 lowboreal (33%) and 28 widely distributed boreal and boreal-arctic (28.8%) (Fig. 15). In Amursky Bay, the biogeographical structure of the molluscan fauna is similar to that of Possjet Bay: the proportion of subtropical and subtropical-boreal mollusks is 33% (38 species), while lowboreal (26 species, or 23%) and widely distributed boreal and circumboreal (24 species, or 21%) are dominant and make up altogether 44 % of the molluscan fauna (Fig. 15). Thus, in general, warm-water mollusks in Yeongil Bay predominate over boreal ones, amounting up to 82%, while in bays of the northwestern East Sea boreal species hold a dominant position (44-50%) with a significant presence of cold-water (boreal-arctic) species, 11-20%. This allows us to characterize the Yeongil Bay molluscan fauna as subtropical. However, in its taxonomic composition, the fauna is significantly impoverished due to the unfavourable oceanographic regime of the coastal waters and the narrow shelf adjacent to Yeongil Bay. The impoverishment can be easily seen when we compare the number of species from warm-water families in Wakasa Bay lying at nearly the same latitude on the opposite side of the East Sea (Table 4). Remarkable richness in the number of species in Wakasa Bay is observed in the families Arcidae, Limidae, Pectinidae, Lasaeidae, Cardiidae, Veneridae and Corbulidae. In Mutsu Bay (northern Honshu), the species richness in those families is close to the Yeongil Bay fauna (Table 4). However, the high number of species in the families Yoldiidae and Mytilidae in Peter the Great Bay, as compared to Yeongil and Wakasa Bays, is related to the presence of many boreal and/or boreal-arctic mollusks; and the high number of species in the Tellinidae in Peter the Great Bay and Mutsu Bay (20 and 19, respectively) as compared to Yeongil (12) and Wakasa (14) Bays can be explained by the mixed character of the fauna of the northern East Sea where boreal and subtropical species meet, in same localities but in different bathymetric horizons (in the northern East Sea, the family Tellinidae is especially rich in representatives of the genus *Macoma*, but in Yeongil Bay, half of the tellinid richness refers to *Moerella* and

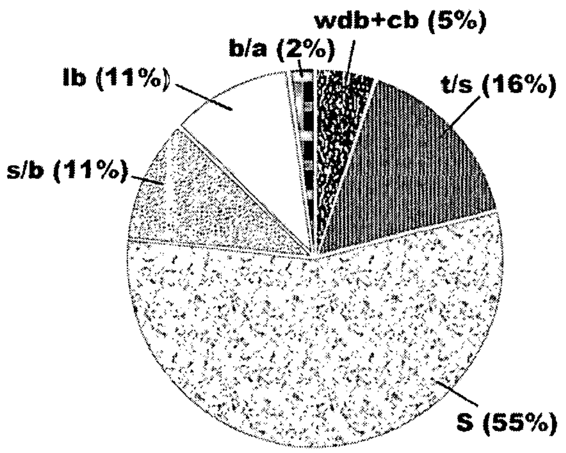

Fig. 14. Zonal-geographical composition of the bivalve molluscan fauna in Yeongil Bay. (t/s: tropical-subtropical species; s: subtropical species; s/b: subtropical-boreal (mostly subtropical-lowboreal) species; lb: lowboreal species; b/a: boreal-arctic species; wdb + cb; widely distributed boreal + circumboreal species)

Nitidotellina which are not at all found in Peter the Great Bay).

In the adjacent regions of the Gangwon and Gyeongsangbuk Provinces lying further north of Yeongil Bay, the molluscan fauna, judging by limited data on beach thanatocoenoses (Lutaenko *et al.*, 2002), differs by presence of some species of miscellaneous biogeographic nature - *Chlamys farreri* (Jones et Preston, 1904), *Anomia chinensis* Philippi, 1849, *Megangulus venulosus* (Schrenck, 1862), *Gari californica* (Conrad, 1849), *Soletellina atrata* Deshayes, 1857, *Protothaca euglypta* (Sowerby III, 1914), *Irus ishibashianus* Kira, 1959, *Penitella kamakurensis* (Yokoyama, 1922) and *Panope abrupta* (Conrad, 1849). The lack of these mollusks in Yeongil Bay cannot be explained by the relatively cold conditions of the upper shelf waters in areas located further north as these species are rather warm-water except for lowboreal *M. venulosus* and *P. euglypta* and circumboreal *G. californica*. The surprising thing is

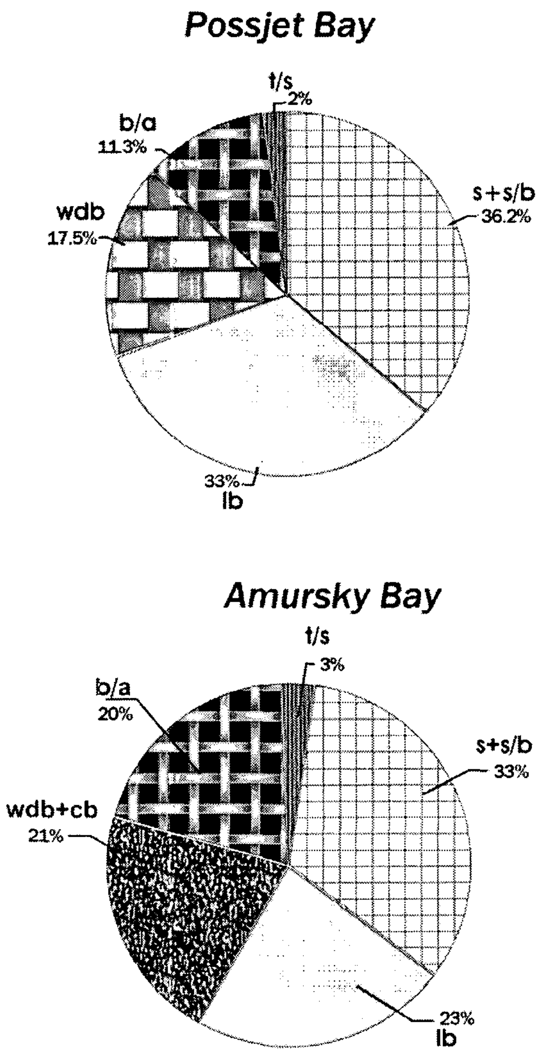

Fig. 15. Zonal-geographical compositions of the bivalve molluscan faunas in the north-western East Sea: Possjet Bay (according to Scarlato, 1981) and Amursky Bay (according to Lutaenko, 2003). For abbreviation explanations, see Fig. 14.

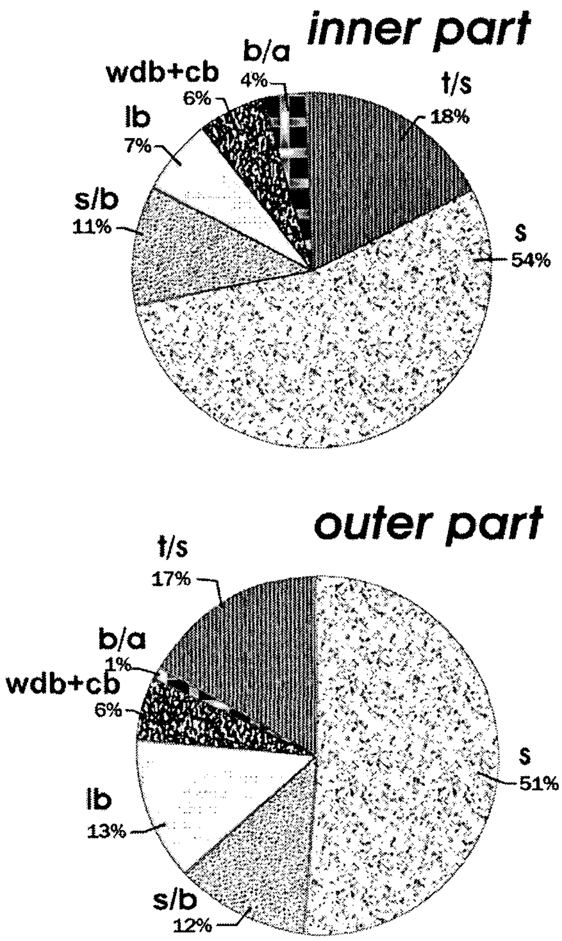

Fig. 16. Zonal-geographical compositions of the bivalve molluscan faunas in the inner and outer parts of Yeongil Bay. For abbreviation explanations, see Fig. 14.

Table 5. Main spawning seasons of some warm-water bivalve mollusks in Korea as related to seawater temperatures.

Species/Family/Biogeographical characteristics	Spawning season	Seawater temperature	Area	Reference
Anadara granosa (Arcidae), tropical-subtropical	July-August (begins in late July at about 20°C)	23-24° C	Beolkyo, southern coast of Korea	Lee, 1997b (as *Tegillarca granosa*)
Anadara kagoshimensis (Arcidae), subtropical	August	21-25.5°C and over	Sunchon Bay, southern coast of Korea	Lee, 1998 (as *Scapharca subcrenata*)
Anadara broughtonii (Arcidae), subtropical	August -maximum occurrence of larvae	27°C	Southern coast of Korea and Ulsan	Yoo *et al.,* 1977
Musculista senhousia (Mytilidae), subtropical-lowboreal	August-September	—	Mokpo, West Sea	Lim and Park, 1998b
Dosinia japonica (Veneridae), subtropical	June-early August	At above 20°C	Piin Bay, West Sea	Chung *et al.,* 1997 (as *Dosinorbis* (*Phacosoma*) *japonicus*)
Meretrix lusoria (Veneridae), tropical-subtropical	July-August (begins in June at above 22° C)	27-28°C	Simpo (near Kunsan), West Sea	Lee, 1997a
Mactra veneriformis (Mactridae), subtropical	July-August	At above 22°C	Kunsan, West Sea	Chung and Ryou, 2000
Solen strictus (Solenidae), subtropical	June-July	At above 20°	Pusan, East Sea; Gunsan, West Sea	Chung *et al.,* 1986
Solen grandis (Solenidae), tropical-subtropical	June-July	At above 20°C	Kunsan, West Sea	Chung and Kim, 1989

that members of the Psammobiidae have not at all been found in Yeongil Bay.

Additional evidence in support of the conclusion about the subtropical character of the Yeongil Bay molluscan fauna is the presence in this bay of five truly thermophilous families not found in the northwestern East Sea - Parallelodontidae, Chamidae, Crassatellidae, Petricolidae and Myochamidae. All these families are present in Wakasa Bay (Ito, 1990) but disappear in Hokkaido (*e.g.*, Akkeshi Bay - Habe, 1955b). However, they are recorded for northern Honshu (Mutsu Bay; except for Crassatellidae) where, surprisingly, some tropical families are found as well (Pinnidae, Spondylidae, Trapezidae) (Yamamoto and Habe, 1958, 1959)[1]. *Porterius dalli,* the only parallelodontid in the northern Pacific, penetrates further north of Hokkaido, to Sakhalin, inhabiting coastal waters of small Moneron Island washed by the outermost branch of the warm Tsushima Current (Kafanov and Lutaenko, 1994).

As was mentioned above, two areas - outer and inner - can be recognized in Yeongil Bay as is evidenced by the distribution of molluscan assemblages. In bays of the northern East Sea, these areas are clearly differentiated by their biogeographic composition (Golikov and Scarlato, 1967; Scarlato, 1981; Lutaenko, 2003). For instance, in Possjet and Amursky Bays, warm-water taxa predominate in semi-closed inlets and inner, shallow parts of the bays. In Possjet Bay, the proportion of subtropical and subtropical-lowboreal species in semi-closed inlets reaches 46.4%, while in open areas it is only 12.5%; lowboreal mollusks have a leading role in open areas - 43.8%, the proportion of boreal-arctic mollusks here is much higher (17.2%) than in semi-closed areas (4.3%) (Scarlato, 1981). In the outer part of Amursky Bay,

1) At the same time, fish and ascidian faunas in Mutsu Bay show low percentage of southern species (Nishikawa, 1992).

boreal (widely distributed boreal + lowboreal) species predominate (47%) with a high proportion of boreal-arctic species (20%), while in the inner part subtropical and subtropical-lowboreal mollusks prevail - 57% (in the outer part, their proportion reaches only 31%) (Lutaenko, 2003). This pattern is connected with the heterogeneity of summer temperatures in bays, which allows the warm-water taxa to concentrate in semi-closed inlets and inner parts under favourable conditions for spawning.

Among 97 molluscan species found in Yeongil Bay (without *Corbicula japonica*), 23 species were collected only in the inner part, and 40 were found only in the outer part; the dividing line between the inner and outer parts was set roughly between station groups 34-41, 47-49, 61-63 (inner part) and the rest of stations (outer part). Thus, 34 species, or 35% of the total list, are common for both parts indicating significant differences in the species composition between inner and outer bay. The number of species collected in the inner part is lower (57 species) when compared to outer part of Yeongil Bay (73 species). It is remarkable that out of 40 species found only in the outer part, a half (18 species) was dredged from one and the same station (station 58).

Among mollusks of the inner part, subtropical species are predominant (29 species, or 54%), while temperate and cold-water species (lowboreal + widely distributed boreal + circumboreal + boreal-arctic) make up only 17% (Fig. 16). The share of the latter group of species is slightly higher (20%) in the outer part of the bay although the general zonal-geographical structure of the faunas is very similar for both parts of the bay (Fig. 16). We note the only difference is presence of lowboreal species concentrating mostly in the outer part (9 species, 13% against 6 species, 7% in the inner part). We believe that 13 out of the 23 species found only in the inner part can be truly restricted in the local distribution by the inner part (*Anadara kagoshimensis, Phlictyderma japonicum, S.* cf. *strictus, S. pulchella, Moerella rutila, Moerella pallidula, Macoma incongrua, Macoma sectior, Irus mitis, Petricolirus aequistriatus, Paramya recluzii, Cryptomya busoensis* and *Zirfaea subconstricta*), while others can also be found in the outer part when more collections are taken. Anyway, regardless of the difference in species composition of the molluscan fauna between the inner and outer parts of Yeongil Bay with only 35% species in common, their zonal-biogeographical compositions are similar clearly indicating that temperature is not responsible for this discrepancy. It seems that the confinement of some species to muddy and sandy bottoms occupying the greater portion of the inner bay can account this phenomena. Yeongil Bay is an open bay with active water exchange which makes no difference in biogeographical composition when considering its subdivisions into outer and inner parts. This is proved by the absence of typical inner bay faunal elements (*Musculista senhousia, Trapezium liratum, Mactra veneriformis, Dosinia penicillata*), as was pointed out above.

The absence of the above-mentioned species is closely related to summer temperatures which are critical for their successful reproduction. According to Scarlato (1981, p. 121), eurythermic tropical-subtropical species such as *Trapezium liratum, Dosinia angulosa* (misidentification of *D. penicillata*) and *Solen corneus,* can survive in the temperature range of -1℃ and 28-29℃ but their optimum temperatures are between 23 and 25℃; optimum temperatures, in turn, indirectly point to temperatures required for reproduction. It seems that SSTs summer maximum value in Yeongil Bay is 25℃, but cold water inflow occurs often from May to August with stagnation of cold waters for 10-20 days during this period (see Part 1 of this paper), the main spawning season of warm-water mollusks in Korea (Table 5). Moreover, bottom temperatures did not exceed 19℃ in summer (Yoo and Park, 1979). This stable cold-water inflow explains why some warm-water, tropical-subtropical[2] mollusks living

2) Some researchers doubt if mollusks living in temperate waters but extending their southern limits of distribution to tropical waters can be termed as tropical or tropical-subtropical. Briggs (1995) calls them "eurythermic tropicals" and mentions that "this group, although it ranges broadly in the tropics, also habitually occupies the

further north, in Russian waters of the East Sea where maximum summer temperatures reach 28-30℃, are not found in Yeongil Bay. However, bivalve fauna of Yeongil Bay as a whole is subtropical.

ACKNOWLEDGEMENTS

We are grateful to Dr. Min Huh (Chunnam National University), Dr. Lee Eui-Hyeong (Korea University, Seoul) and Dr. Eugene I. Schornikov (Institute of Marine Biology, FEB RAS, Vladivostok) for invitation of the first and third authors to take part in the coastal expedition in August 1997, and generous support. Dr. Kazutaka Amano (Joetsu University of Education, Joetsu) kindly sent us a collection of Astartidae, Ungulinidae, Mactridae and Myidae from Japan for comparative purposes and helped with identification of other species as well as did Dr. T. Kase (National Science Museum, Tokyo). Prof. Byung Lae Choe (Sung Kyun Kwan University, Suwon), Prof. Sung Yun Hong (Pukyong National University, Pusan), Dr. Heung-Sik Park (KORDI) and Dr. Joong-Ki Park (Seoul National University, Seoul) kindly provided us with literature. Photographs of shells were taken by Mr. Aleksander A. Omelyanenko (IMB). English text was kindly improved by Ms. Tatyana Koznova (IMB) to whom my special thanks. This study was partly supported by grants from the Russian Foundation of Basic Researches (RFFI) nos. 96-05-64-86, 00-04-49013 and Far East Branch of the Russian Academy of Sciences (DVO-1) "Reaktsia Morskoy Bioty na Izmenenya Prirodnoy Sredy i Klimata" and "Metodologiya Monitoringa Morskogo Bioraznoobraziya".

REFERENCES

Biryulin, G.M., Biryulina, M.G., Mikulich, L.V. and Yakunin, L.P. (1970) Summer modifications of waters in Peter the Great Bay. *Transactions of the Far East Regional Hydrometeorological Institute* (*Vladivostok*), **30**: 286-299. [in Russian]

Briggs, J.C. (1995) Global Biogeography (Developments in Palaeontology and Stratigraphy 14). 452 p. Elsevier, Amsterdam.

warm-temperate zones that lie next to the tropics" (l.c., p. 210).

Choi, J.-W., Je, J.-G., Lee, J.-H. and Lim, H.-S. (2000) Distributional pattern of macrobenthic invertebrates on the shallow subtidal sandy bottom near Kangrung, east coast of Korea. *The Sea* (*Journal of the Korean Society of Oceanography*), **5**(4): 346-356.

Choi, K.-C. (1969) Studies on the structure of tidal flat ecosystem for increasing commercial clam yield. *Korean Journal of Limnology*, **2**(3-4): 1-21.

Choi, K.-C. (1971) Ecological studies of the clams, *Meretrix lusoria* and *Cyclina sinensis* for increasing seed clam yield. *Korean Journal of Limnology*, **4**(1-2): 9-19.

Chung, E.-Y., Kim, H.-B. and Lee, T.-Y. (1986) Annual reproductive cycle of the jackknife clams, *Solen strictus* and *Solen gordonis*. *Bulletin of the Korean Fisheries Society*, **19**(6): 563-574.

Chung, E.-Y. and Kim, Y.-G. (1989)A study on sexual maturation of razor clam, *Solen grandis* Dunker in the west coast of Korea. *Yellow Sea Research*, **2**: 39-49.

Chung, E.-Y., Kim, B.-G. and Seo, Y.-H. (1997) Maturation and spawning of the Japanese Dosinia, *Dosinorbis* (*Phacosoma*) *japonicus* in the coastal waters of western Korea. *Korean Journal of Malacology*, **13**(1): 43-54.

Chung, E.-Y. and Ryou, D.-K. (2000) Gametogenesis and sexual maturation of the surf clam *Mactra veneriformis* on the west coast of Korea. *Malacologia*, **42**(1-2): 149-163.

Fujii, S. (1987) The molluscan fauna from Toyama Bay in the Japan Sea. *Journal of the College of Liberal Arts, Toyama University* (*Natural Science*), **20**(1): 17-31.

Gabaev, D.D. and Olifirenko, A.B. (2001) Growth, stocks and production of the *Anadara, Scapharca broughtoni*, in Peter the Great Bay, Sea of Japan. *Oceanology*, **41**(3): 422-430. [in Russian]

Golikov, A.N. and Scarlato, O.A. (1967) Molluscs of the Possjet Bay (the Sea of Japan) and their ecology. *Proceedings of the Zoological Institute, USSR Academy of Sciences*, **42**: 5-154. [in Russian]

Golikov, A.N. and Scarlato, O.A. (1985) Shell-bearing gastropods and bivalves of the shelf of south Sakhalin and their ecology. *Explorations of the Fauna of the Seas*, **30**(38): 368-487. [in Russian]

Grigoryeva, N.I. (2000) Thermohaline conditions of the spawning of the oyster *Crassostrea gigas* in Possjet Bay (Sea of Japan). *Bulletin of the Russian Far East Malacological Society*, **4**: 52-58. [in Russian]

Habe, T. (1955a) Deposits of shell remains in Ofunato Bay, Iwate Pref., northern Japan. *Venus*, **18**(4): 244-251. [in Japanese]

Habe, T. (1955b) Fauna of Akkeshi Bay. XXI. Pelecypoda and Scaphopoda. *Publications of the Akkeshi Marine Biological Station*, **4**: 1-31.

Habe, T. (1956a) Benthic communities and molluscan thanatocoenoses of the Nanao Bay. A Special Publication of the Japan Sea Regional Fisheries

Research Laboratory on the 3rd Anniversary of its Founding, 59-64. [in Japanese]

Habe, T. (1956b) Studies on the shell remains in bays. *Contribution to Physiology and Ecology, Kyoto University*, **77**: 1-31. [in Japanese]

Habe, T. (1959) Pelecypod shell remains of Ariake Bay. *Records of the Oceanographic Works in Japan, Spec.* No. **3**: 69-74.

Habe,T. (1960) Pelecypod shell remains in Tanabe Bay, Wakayama Prefecture. *Records of the Oceanographic Works in Japan, Spec.* No. **4**: 39-51.

Habe, T. (1973) The molluscs of Tsukumo Bay, Noto Peninsula. *Annual Reports of the Noto Marine Laboratory*, **13**: 13-23. [in Japanese]

Habe, T. and Tanaka, Y. (1959) The molluscan fauna of Ariake Bay - I. *Report on the Investigation of the Ariake Sea, Seikai Regional Fisheries Research Laboratory*, **5**: 9-18. [in Japanese]

Hamano, T., Kouya, T., Shimoyama, S. and Matsuura, S. (1986) The dynamics of the molluscan community in the soft bottom of Hakata Bay, Japan, with special reference to the summer stratification period. *Benthos Research,* **29**: 1-8. [in Japanese]

Hayward,B.W. (1997) Introduced marine organisms in New Zealand and their impact in the Waitemata Harbour, Auckland. *Tane (Journal of the Offshore Islands Research Group)*, **36**: 197-223.

Hong, J.S. and Lee, J.H. (1983) Effects of pollution on the benthic macrofauna in Masan Bay, Korea. *Journal of the Oceanological Society of Korea,* **18**: 169-179.

Hong, J.-S. and Park, H.-S. (1994) Growth and production of macrobenthic fauna on a macrotidal flat, Inchon, Korea. I. Growth of the razor clam, *Solen (Solen) strictus* (Bivalvia, Solenidae) from Chokchon tidal flat. *Bulletin of the Korean Fisheries Society,* **27**(6): 549-559.

Hong, J.-S. and Park, H.-S. (1998) Molluscan death assemblages and their ecological implications on a tidal flat, Inchon, Korea. *The Sea (Journal of the Korean Society of Oceanography)*, **3**(2): 94-102.

Hong, J.-S., Seo, I.-S., Yoo, J.-W. and Jung, R.-H. (1994) Soft-bottom benthic communities in North Port, Inchon, Korea. *Nature Conservation,* **88**: 34-50.

Hong, S.Y., Han, U.J. and Paik, E.I. (1982) Marine macrobenthos distribution and the substrate conditions of Suyeong Bay. *Publications of the Institute of Marine Sciences, National Fisheries University of Busan,* **14**: 1-21.

Ito, K. (1990) Distribution of molluscan shells in Wakasa Bay, Japan Sea. *Bulletin of the Japan Sea National Fisheries Research Institute,* **40**: 79-211. [in Japanese]

Kafanov, A.I. (1991) Bivalve Molluscs and Faunistic Biogeography of the Northern Pacific. 195 p. FEB, USSR Academy of Sciences, Vladivostok. [in Russian]

Kafanov, A.I., Volvenko, I.V., Fedorov, V.V. and Pitruk, D.L. (2000) Ichthyofaunistic biogeography of the Japan (East) Sea. *Journal of Biogeography,* **27**: 915-933.

Kagawa, T. (1986) Fluctuation patterns of macrobenthic fauna during the stratification period in the eastern part of Hiuchi-Nada, Seto Inland Sea. *Benthos Research,* **29**: 9-15. [in Japanese]

Kidwell, S.M. and Bosence, D.W.J. (1991) Taphonomy and time-averaging of marine shelly faunas. *In*: Taphonomy. Releasing the Data Locked in the Fossil Record (ed. by Allison, P.A. and Briggs, D.E.G.), pp. 115-209. Plenum Press, N.Y. & London.

Kim, C.W. and Hur, S.B. (1998) Distribution of the bivalve resources in Deukryang Bay. *Journal of Aquaculture,* **11**(2): 249-260.

Klimova, V.L. (1980) Bottom fauna of Possjet Bay. *In*: Coastal Plankton and Benthos of the Northern Part of the Sea of Japan (ed. By Kussakin, O.G.), pp. 20-31. FESC USSR Academy of Sciences, Vladivostok [in Russian]

Koh, B.-S., Lee, J.-H. and Hong, J.-S. (1997) Distribution patterns of the benthic macrofaunal community in the coastal area of Inchon, Korea. *The Sea (Journal of the Korean Society of Oceanography)*, **2**(1): 31-41.

Koh, C.-H. and Kang, S.-G. (1998) Sample size determination for the estimation of population density of marine benthos on a tidal flat and a subtidal area, Korea. *Journal of the Korean Society of Oceanography,* **33**(3): 113-122.

Komendantov, A.Yu. and Orlova, M.I. (1990) Further study of macrozoobenthos of Gladkaya River (the Possjet Bay of the Japan Sea). *Proceedings of the Zoological Institute, USSR Academy of Sciences,* **218**: 161-174. [in Russian]

Kondo, Y. (1987) Burrowing depth of infaunal bivalves - observation of living species and its relation to shell morphology. *Transactions and Proceedings of the Palaeontological Society of Japan, N.S.*, **148**: 306-323.

Kwon, W.-S. and Cho, C.-H. (1986) Culture of the ark shell, *Anadara broughtonii* in Yoja Bay. *Bulletin of the Korean Fisheries Society,* **19**(4): 375-379.

Lee, J.-H. (1976) A study of the benthic fauna along the Busan coast, Korea. *Publications of the Institute of Marine Sciences, National Fisheries University, Busan,* **9**: 49-70.

Lee, J.-H., Hong, J.-S. and Yi, S.K. (1983) Studies on the benthic fauna in Garolim Bay, Korea. *Journal of the Oceanological Society of Korea,* **18**(2): 111-116.

Lee, J.-H. and Park, H.-S. (1998) Community structures of macrobenthos in Chonsu Bay, Korea. *Journal of the Korean Society of Oceanography,* **33**(1-2): 18-27.

Lee, J.H. (1997a) Histological studies on the gametogenesis and reproductive cycle of the hard clam, *Meretrix lusoria. Korean Journal of Malacology,* **13**(2): 131-141.

Lee, J.H. (1997b) Studies on the gonadal development and gametogenesis of the granulated ark, *Tegillarca* *granosa (Linne)*. *Korean Journal of Malacology*, **13**(1): 55-64.

Lee, J.H. (1998) A study on sexual maturation of the ark shell, *Scapharca subcrenata* Lischke. *Korean Journal of Malacology*, **14**(2): 91-102.

Lim, H.S., Je, J.-G., Choi, J.-W. and Lee, J.-H. (1991) Distribution pattern of the macrozoobenthos at Yoja Bay in summer. *Ocean Research*, **13**(2): 31-46.

Lim, H.-S., Choi, J.-W., Je, J.-G. and Lee, J.-H. (1992) Distribution pattern of macrozoobenthos at the farming ground in the western part of Chinhae Bay, Korea. *Bulletin of the Korean Fisheries Society*, **25**(2): 115-132.

Lim, H.-S. and Hong, J.-S. (1997) Ecology of the macrozoobenthos in Chinhae Bay, Korea. 2. Distribution pattern of the major dominant species. *Journal of the Korean Fisheries Society*, **30**(2): 161-174.

Lim, H.-S., Hong, J.-S. and Je, J.-G. (1995) Abundance and distribution pattern of the semelid bivalve, *Theora fragilis* A. Adams in Chinhae Bay, Korea. *Korean Journal of Malacology*, **11**(1): 21-34.

Lim, H.-S., Park, H.-S., Choi, J.-W. and Je, J.-G. (1999) Macrobenthic community of the subtidal soft bottom of Aenggang Bay in the southern coast of Korea. *The Sea (Journal of the Korean Society of Oceanography)*, **4**(1): 80-92.

Lim, H.-S. and Park, K.-Y. (1998a) Community structure of the macrobenthos in the soft bottom of Yongsan River estuary, Korea. 2. The occurrence of summer hypoxia and benthic community. *Journal of the Korean Fisheries Society*, **31**(3): 343-352.

Lim, H.-S. and Park, K.-Y. (1998b) Population ecology of the mud mussel *Musculista senhousia* (Bivalvia: Mytilidae) on the mud tidal flat in Mokpo coastal area, southwest coast of Korea. 1. Distribution and growth. *Korean Journal of Malacology*, **14**(2): 121-130.

Lutaenko, K.A. (1993) Subfamily Anadarinae (Bivalvia: Arcidae) of the Russian Far East coast. *Korean Journal of Malacology*, **9**(1): 27-32.

Lutaenko, K.A. (1994) Beach molluscan thanatocoenoses in Possjet Bay, Sea of Japan: comparison between open and sheltered beaches. *Benthos Research*, **47**: 1-12.

Lutaenko, K.A. (1999) Additional data on the fauna of bivalve mollusks of the Russian continental coast of the Sea of Japan: middle Primorye and Nakhodka Bay. *Publications of the Seto Marine Biological Laboratory*, **38**(5/6): 255-286.

Lutaenko, K.A. (2002) Bivalve molluscan fauna of Amursky Bay (Sea of Japan/East Sea) and adjacent areas. Part 1. Families Nuculidae - Cardiidae. *Bulletin of the Russian Far East Malacological Society*, **6**: 5-60. [in Russian]

Lutaenko, K.A. (2003) Bivalve molluscan fauna of Amursky Bay (Sea of Japan/East Sea) and adjacent areas. Part 2. Families Trapezidae-Periplomatidae. Ecological and biogeographical characteristics of the fauna. *Bulletin of the Russian Far East Malacological Society*, **7**: 5-84. [in Russian]

Lutaenko, K.A., Je, J.-G. and Shin, S.-H. (2002) Report on bivalve mollusks from beach death assemblages in Gangwon and Gyeongsangbuk Provinces, Korea (East Sea). *Korean Journal of Malacology*, **18**(1): 27-40.

Lutaenko, K.A., Je, J.-G. and Shin, S.-H. (2003) Bivalve mollusks in Yeongil Bay, Korea. 1. Introductory part and annotated list of species. *Ocean and Polar Research*, **25**(2): 155-182.

Lutaenko, K.A. and Oleynik, A.E. (1992) Actuopaleontology and formation of fossil record incompleteness. *Proceedings of the [Russian] Academy of Sciences, Series Biological*, **4**: 582-589. [in Russian]

Ma, C.-W., Hong, S.-Y. and Lim, H.-S.(1995). Macrobenthic fauna of Deukryang Bay, Korea. *Journal of the Korean Fisheries Society*, **28**(5): 503-516.

Nishikawa, T. (1992) The ascidians of the Japan Sea. III. *Publications of the Seto Marine Biological Laboratory*, **35**(6): 303-334.

Nishimura, S. (1965) The zoogeographical aspects of the Japan Sea. Part 1. *Publications of the Seto Marine Biological Laboratory*, **13**(1): 35-79.

Nobuhara, T., Kubota, Y., Itoigawa, J. and Matsuoka, K. (1991) Molluscan thanatocoenoses in Mikawa Bay, central Japan. Part 1. Bivalvia. *Science Reports of the Toyohashi Museum of Natural History*, **1**: 13-32. [in Japanese]

Razin, A.I. (1934) Marine commercial molluscs of the southern part of the Maritime Province of the Soviet Far East. *Bulletin of the Pacific Scientific Institute of Fisheries*, **8**: 1-110. [in Russian]

Rho, B.J., Choe, B.L., Song, J.-I., Park, K.S., Lee, I.-S. and Park, J.-K. (1997) An analysis of invertebrate community at the tidal and subtidal zone in Onsan Bay with regard to the effect of pollution. *Korean Journal of Environmental Biology*, **15**(1): 79-88.

Scarlato, O.A. (1981) Bivalve mollusks of temperate latitudes of the western portion of the Pacific Ocean. *Opredeliteli po Faune SSSR, Izdavayemye Zoologicheskim Institutom AN SSSR*, **126**: 1-479. [in Russian]

Scarlato, O.A., Golikov, A.N., Vassilenko, S.V., Tzvetkova, N.L., Grusov, E.N. and Nesis, K.N. (1967) Composition, structure and distribution of bottom biocenoses in the coastal waters of the Possjet Bay (the Sea of Japan). *Explorations of the Fauna of the Seas*, **5**(13): 5-61. [in Russian]

Shin, H.C. and Koh, C.-H. (1993) Distribution and abundance of ophiuroids on the continental shelf and slope of the East Sea (southwestern Sea of Japan), Korea. *Marine Biology*, **115**: 393-399.

Shuto, T. (1973) Molluscan thanatocoenoses in Usuki Bay, east Kyushu. *Science Reports of the Tohoku*

University, 2nd Series (Geology), Spec. **6** (Hatai Memorial Vol.): 15-27.

Son, S.J. (1977) A study on the characteristics of cold water in Young Il Bay. *Bulletin of the Fisheries Research and Development Agency*, **18**: 23-28.

Tanabe, K. and Arimura,E. (1987) Ecology of four infaunal bivalve species in the Recent intertidal zone, Shikoku, Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **60**: 219-230.

Tchang, S., Tsi, C.-Y., Zhang, F.-S. and Ma, S.-T. (1963). A preliminary study of the demarcation of marine molluscan faunal regions of China and its adjacent waters. *Oceanologia et Limnologia Sinica*, **5**(2): 124-138.

Tsuchida, E. (1998) Characteristics of upper-sublittoral molluscs of Nemuro-Bay, eastern Hokkaido Japan, collected by the R/V Tansei-Maru. *Bulletin of the Hokkaido National Fisheries Research Institute*, **62**: 83-105. [in Japanese]

Tsuchida, E. and Kurozumi, T. (1995) Fauna of marine mollusks of the sea around Otsuchi Bay, Iwate Prefecture. (5) Bivalvia-2. *Otsuchi Marine Research Center Reports*, **19**: 13-42. [in Japanese]

Tsuchida, E. and Hayashi, I. (1994) Characteristics of lower-sublittoral and bathyal molluscs in the western area (sic) of the Sea of Japan. *Bulletin of the Japan Sea National Fisheries Research Institute*, **44**: 81-129. [in Japanese]

Yamamoto, G. and Habe, T. (1958) Fauna of shell-bearing mollusks in Mutsu Bay. Lamellibranchia (1). *Bulletin of the Marine Biological Station Asamushi*, **9**(1): 1-20.

Yamamoto, G. and Habe, T. (1959) Fauna of shell-bearing mollusks in Mutsu Bay. Lamellibranchia (2). *Bulletin of the Marine Biological Station Asamushi*, **9**(3): 85-122.

Yi, S.K. (1975) Studies on the intertidal macrofauna community at Yong-ho Bay, Busan, Korea. Bulletin of the Korean Fisheries Society, 8(3): 133-149.

Yi, S.K., Hong, J.-S. and Lee,J.H. (1982) A study on the subtidal benthic community in Ulsan Bay, Korea. *Bulletin of the Korea Ocean Research and Development Institute*, **4**(1-2): 17-26.

Yoo, S.K. (1977) Biological studies on the propagation of important bivalves. 5. Morphological characteristics of the ark shell, *Anadara subcrenata. Bulletin of the National Fisheries University of Busan*, **17**(1,2): 71-78.

Yoo, S.K., Park, K.Y. and Yoo, M.S. (1977) Biological studies on arkshell culture. I. Distribution of drifting larvae of the arkshell, *Anadara broughtonii* Schrenck. *Journal of the Oceanological Society of Korea*, **12**(2): 75-81.

Yoo, S.K. and Park, K.Y. (1979) Distribution of drifting larvae of scallop, *Patinopecten yessoensis*, in the Yeong-il Bay. *Journal of the Oceanological Society of Korea*, **14**(2): 54-60.