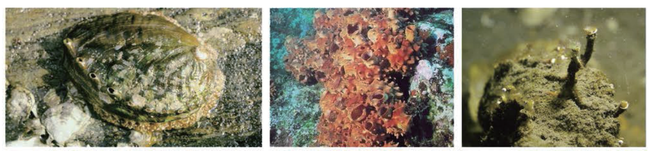

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Atlas of Marine Invasive Species in the NOWPAP Region

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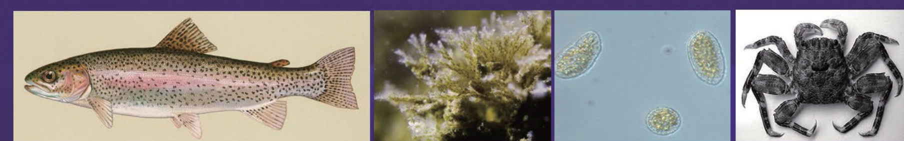

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Published in 2013 by NOWPAP DINRAC

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http://dinrac.nowpap.org

Acknowledgement

DINRAC would like to acknowledge the individual contribution of Dr. Konstantin LUTAENKO from A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences, for the preparation of the Atlas of Marine Invasive Species in the NOWPAP region. DINRAC is also grateful to Dr. Toshio Furota from Faculty of Science, Toho University, Ms. Satoko Nakayama from Tokyo Bay Ecosystem Research Center, Toho University, Dr. Kyoungsoon Shin from Ballast Water Center, Korea Institute of Ocean Science & Technology, Dr. Xu Jing from Institute of Environmental Ecology, Chinese Research Academy of Environmental Sciences for their efforts in preparing the Atlas. The comments made by the Regional Coordinating Unit of NOWPAP and National Focal Points of DINRAC are also highly appreciated.

Disclaimer

The views expressed in the Atlas of Marine Invasive Species in the NOWPAP region are those of the authors and do not necessarily reflect the position of NOWPAP Member States. These designations employed and the presentation of the material in this document do not imply the expression of any opinion, whatsoever on the part of UNEP concerning the legal status of any State, Territory, city and area, or its authorities, or concerning the delimitation of its frontiers or boundaries.

In the Atlas, “Korea” means Republic of Korea, “China” – People’s Republic of China, and “Russia” – Russian Federation. Regional distribution means distribution within NOWPAP region. Bibliography includes only most important works of regional relevance. Authors responsible for information presented are shown in brackets at the end of relevant pages and are abbreviated as follows: TF, SN – Toshio Furota and Satoko Nakayama; KL – Konstantin A. Lutaenko, KS – Kyoungsoon Shin, XJ – Xu Jing. KL is responsible for overall editing.

Acronyms and Abbreviations

AMBACS - the Aegean Sea, the Sea of Marmara, the Black Sea, the Sea of Azov, and the Caspian Sea

APN - Asia-Pacific Network for Global Change Research

ASP - Amnesic Shellfish Poisoning

COBSEA - Coordinating Body on the Seas of East Asia

DINRAC - Data and Information Network Regional Activity Center

DSP - Diarrheic Shellfish Poisoning

EEZ - the exclusive economic zone

EKWC - the East Korean Warm Current

IMO - International Marine Organization

KIOST - Korea Institute of Ocean Science & Technology

MIS - marine invasive species

NB - Nearshore Branch

NIER - National Institute of Environmental Research

NKCC - North Korean Cold Current

NOWPAP - Northwest Pacific Action Plan (The Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region)

PICES - North Pacific Marine Science Organization

PSP - Paralytic Shellfish Poisoning

YSWC - the Yellow Sea Warm Curren

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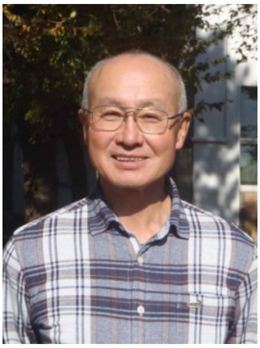

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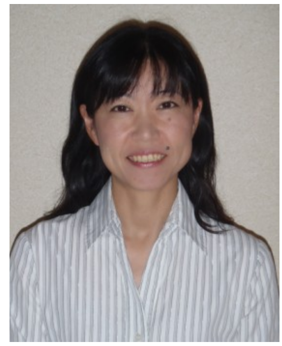

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CONTENTS

1. Introduction

Biological invasions in marine environment represent a serious ecological and economic menace leading to biodiversity loss, ecosystem unbalancing, fishery and tourism impairment, and other ecological and environmental consequences. The problem of marine biological invasions is closely related also to treatment of ballast waters and biofouling of ships and hydro-technical structures. Bio-invasions create so-called "novel" ecosystems containing new combinations of species that arise through human action, environmental change, and the impacts of the deliberate and inadvertent introductions of species from other regions (Hobbs et al., 2006).

Biological invasions in the sea consist of natural range expansion due to changing climates or currents and human-mediated introductions. The latter are usually unpredictable and independent of the natural barriers of space and time (Carlton, 1996). The important role of ballast waters in the unintentional introductions was revealed in the beginning of the 20th century: in the 1880s ship building technology changed, and the existence of bulk-headed, metal-walled spaces, combined with motor-driven pumps, permitted ships to begin to switch from carrying rocks for ballast to carrying water for ballast (Carlton, 1985). For the first time in the history of the ocean, large amounts of plankton-rich water were being transported across and between oceans (Carlton, 1996).

Taking into account the importance of the biological invasions as part of global environmental changes and their significance to the NOWPAP member countries, the NOWPAP DINRAC implemented a project on the marine invasive species (MIS) in the NOWPAP region in 2009-2010 with compilation of four national reports from China, Japan, Korea, and Russia and a regional overview (DINRAC, 2010). The regional overview and national reports were important contributions to understanding of the MIS problem in the North-East Asia along with other regional international projects/activities by COBSEA, PICES (e.g., Lee, Reusser, 2012a, b) and other relevant organizations.

Recommendations of the regional overview included compilation and publication of an atlas of the common and economically/environmentally important alien species in the NOWPAP region with their illustrations and basic data on the biology, regional distribution and relevant references. Such an atlas may serve as a preliminary identification guide and it may summarize to some degree our knowledge on the common MIS in the region. Similar atlases and guides were published, for instance, for the Mediterranean region (Zenetos et al., 2003) and intercontinental Eurasian seas – AMBACS (the Aegean Sea, the Sea of Marmara, the Black Sea, the Sea of Azov, and the Caspian Sea) (Zaitsev, Ozturk, 2001).

When compiling the present Atlas, the authors used the following criteria for selection of species and we included 1) most established, visible and abundant species; 2) species having important ecological and economic impact; 3) species with reliable identification (properly identified by experts in taxonomy). We did not consider potential, or expected MIS although there are some suggestions in the literature about possible introduction of certain species. The Atlas contains information about taxonomic and common names, regional distributions, possible origins and ways of introduction, impact and bibliographies of 79 species of marine organisms including 15 species of plants (macroalgae, vascular plants and phytoplankton) and 64 species of animals.

We should be aware that the NOWPAP region is a vast area lying in different geographical zones – from subtropical in the south to temperate (boreal) in the north, with conditions approaching to arctic environment in winter in the northern part. This is why some species are regarded as native in the northern part of NOWPAP region (e.g., *Saccharina japonica, Undaria pinnatifida, Mizuhopecten yessoensis, Panopea japonica, Oncorhynchus kisutch,* etc.) but they were introduced to China and, therefore, same species may be invasive only in some parts of the NOWPAP region. Another problem in compilation of the Atlas was taxonomic status of some species regarded as synonyms in modern revisions and databases. Whenever possible, leading author made comments about doubtful status of some species.

Exact distributions of many invasive species are not clearly known and perhaps are rapidly changing, so we used a simplified way of representation of their local/regional distributions by dots or lines based on various literature sources. In fact, the maps are the first attempt to trace distribution of most common MIS in the region and, therefore, should be very useful for future work. References given at the end of the species information pages are most important literature sources whereas more detailed data can be found in papers cited or relevant databases. In general, the Atlas is a quick guide to common MIS and we hope it can be used by scientists and practitioners in understanding and management of the coastal and marine environment of the NOWPAP region.

2. NOWPAP region

The Northwest Pacific region features coastal and island ecosystems with spectacular marine life and commercially important fishing resources. The region is also one of the most densely populated parts of the world, resulting in enormous pressures and demands on the environment. The geographical scope of NOWPAP covers the marine environment and coastal zones from about 33º to 52º N and from approximately 121º to 143º E (Fig. 1). The whole sea area of NOWPAP can be divided into western part (between China mainland, Korea and Japan) and eastern part (between Russia mainland, Korea and Japan) (Regional Overview…, 2007; 2010).

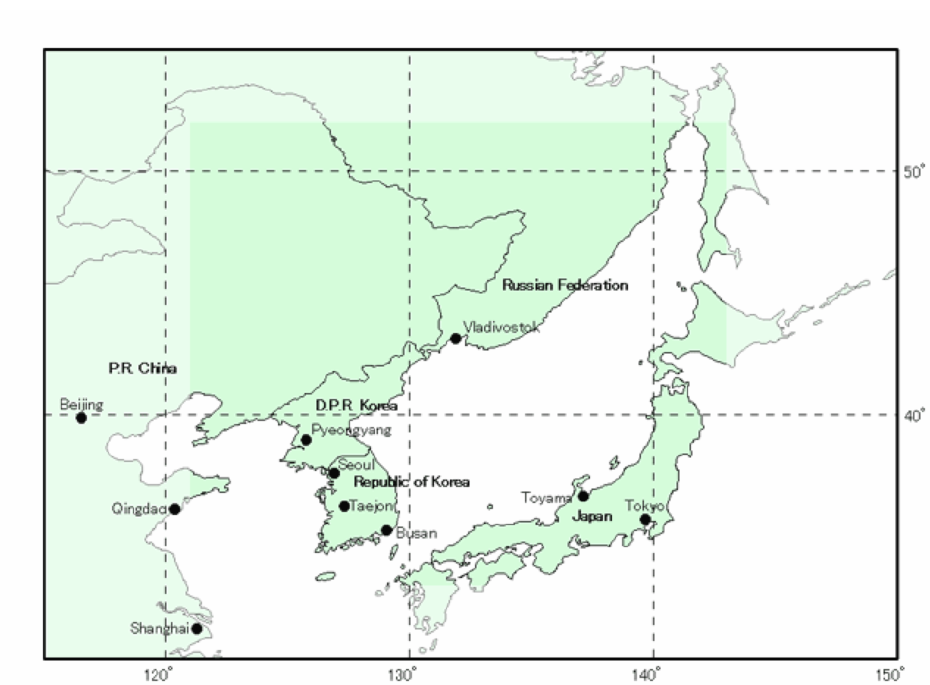

Fig. 1. Area of the NOWPAP region (http://cearac.nowpap.org/nowpap/coverage.html).

The eastern part of the NOWPAP region is a semi-enclosed sea. It has the southern entrance (Tsushima Strait) and the northern exits (Tsugaru Strait and Soya Strait). In Japan, there are 44 prefectures with reverine systems that flow into the NOWPAP region. Japan consists of four main islands. Japan has 29,751 km of shoreline from Hokkaido in the north to Okinotorishima Island in the south. A branch of the Kuroshio enters through Tsushima Strait, and then flows out the area passing the Tsugaru Strait located between Hokkaido and northernmost Honshu. Under these oceanographic conditions, there is a wide range of water masses, from tropical water in Okinawa archipelago and southern islands such as Chichijima archipelago in the Pacific Ocean to subarctic water in northern Hokkaido with large seasonal temperature fluctuations.

The Korean part of NOWPAP region includes inland and sea areas. Sea area extends from the coastline up to the exclusive economic zone (EEZ). Korea's coastline stretches to some 11,942 km. In terms of relative proportion, the coastal area accounts for 31,641 km^2 (about 32%) of the total territorial land area of 99,514 km^2. Some 2,550 km^2 are tidal flats, which account for about 2.3% of the total land area. The territorial sea covers some 71,000 km^2, while the EEZ covers about 447,000 km^2. There are 3,169 islands that are distributed around Korea's marine waters. Comparatively, the west coast is shallow while the east coast is deep (Regional Overview…, 2010).

To the south from Korean Peninsula, the semidiurnal tide is dominant (Ogura, 1933), and its current, about 75 cm/s, is similar to or stronger than other currents (Odamaki, 1989). The Yellow Sea Cold Water, the East China Water and Yellow Sea Warm Water enter through the Jeju Strait, where the speed of the eastward mean current is about 12.5 cm/s (Chang, Kim, 1995). The Tsushima Warm Current derived from the Kuroshio enters the water area between Korea and Japan through the Korea Strait, and the current of the Western Channel of the Korea Strait is approximately 50 cm/s or stronger (Lie, Cho, 1997; Kim, 1998; 2000).

It is known that the Tsushima Current splits into 3 branches after entering the water area between Korea and Japan through the Korea Strait between Korea and Japan in the south. The first one, called the Nearshore Branch (NB), flows along the Japanese coast which is topographically controlled (Yoon, 1982). The second branch, less clear, may exist along the slope near Japan. According to Kawabe (1982), it becomes prominent only in summer due to the increase of Tsushima Current volume transport. The third branch, called the East Korean Warm Current (EKWC), flows northward along the Korean coast and separates from the coast where it meets the southward flowing North Korean Cold Current (NKCC). The EKWC and NKCC, after separation from the coast, form a strong front which runs in the east-west direction. Along the front, large meanders develop associated with warm and cold eddies (Seung, Kim, 1993).

The Chinese part of the NOWPAP region mainly belongs to the Yellow Sea, which bordering Liaoning, Shandong and Jiangsu Provinces. The total area of these provinces accounts for 10.8% of the entire national territory of China.

The Yellow Sea is a semi-enclosed body of water surrounded by the Asian continent and Korean Peninsula, with wide continental shelves and long coastlines. Its mean depth is about 55 m. The oceanographic conditions of the Yellow Sea are strongly affected by the monsoon where the wind blows toward the north in summer and the south in winter. General current circulation in the Yellow Sea is divided into two different currents in summer and winter (Suk, 1989). The Yellow Sea Warm Current (YSWC) originating from the Kuroshio flows into the northwest of the central Yellow Sea in summer and remains outside of Jeju in winter. Coastal currents of the Yellow Sea include the Shandong Coastal Current, Yellow Sea Coastal Current, Jiangsu Coastal Current and West Korea Coastal Current. The Shandong Coastal Current, Yellow Sea Coastal Current and Jiangsu Coastal Current flowing into the south along the western border of the Yellow Sea are stronger due to the northwest monsoon in winter (Martin et al., 1993). In the Yellow Sea, two different circulations are observed. One is a clockwise circulation formed at the junction of Yellow Sea Warm Current and West Korea Coastal Current, which flows along the east side of the Yellow Sea, and the other is a smaller and semi-permanent counterclockwise circulation formed in the south-west of Jeju (Mao et al., 1993; Kum, 2000).

The Russian Federation's part of the NOWPAP region is located between the Asia coast, the Japanese Islands and the Sakhalin Island. It is situated between 34º26' and 51º41' N and between 127º20' and 142º15' E. It is connected with the Okhotsk Sea by the Nevelskoy and La-Perouse (Soya) straits in the north and northeast, with the Pacific by the Tsugaru Strait in the east. Far Eastern territories of Russia adjoining NOWPAP region are Primorsky and Khabarovsky regions (territories) and the Sakhalin Island. Overall shoreline length of the Russian part of the NOWPAP region sea is about 6,230 km.

The Russian continental coast of the NOWPAP region is clearly divided into two geomorphologic regions with different oceanography and environmental conditions. The northern region is characterized by a weakly indented coastline with open bays. Abrasional shores with rocky cliffs predominate along nearly the entire coastline, and accumulative areas with low marine terraces and sandy beaches occur in coastal concavities (Papunov, 1987). The northern shelf of the NOWPAP region is narrow (average 35 km), and occasionally narrows to only 10–11 km. The depth of the shelf edge varies from 100 to 200 m. Southern part of the Russian coast lies within large Peter the Great Bay with six ria-type embayments: Possyet, Amursky, Ussuriysky, Strelok, Vostok and Nakhodka bays. Temperature regime of Peter the Great Bay is characterized by contrasting conditions: in winter, coastal waters are approaching arctic conditions while in summer, waters of semi-enclosed shallow bays warm strongly (to 28º C in August).

Two cold currents wash the Russian continental coast of the NOWPAP region – Primorskoye and Schrenck's (= Liman Cold Current) currents (Yurasov, Yarichin, 1991). The main stream of the Primorskoye Current flows at a distance of 15–20 km from the coast along the marginal part of the shelf. Generally, cold currents in the sea are much weaker than warm currents (Hidaka, 1966). Salinity in open areas is 33–34 ‰ but it can decrease in bays for a short time during rains. Salinity in shallow waters of Peter the Great Bay depends significantly on river runoff and semi-enclosed bays and inner embaymental areas may have decreased salinity (Podorvanova et al., 1989).

3. Current status of the marine invasive species in the NOWPAP region

Marine invasive species introductions can be divided into intentional, via aquaculture and via shipping and ballast water transfer.

Shipping and ballast water release are the most important ways of introduction of marine organisms into the NOWPAP region. In Japan, Otani (2004) reported that rich marine invasive species were found on ship hull and in sea chests and he estimated that about 44% of exotic marine species in Japan were brought with hull fouling.

In Japan, when the country opened to trade with foreign countries after 1900, especially with Europe and America, many exotic sessile marine organisms unintentionally arrived to Japanese coastal waters with cross-ocean vessels. After the World War II, due to growth of the international trade, frequency of arrivals of the vessels to Japanese ports rapidly increased. Some of these vessels brought ballast waters that had been pumped in tanks of the vessel at the departure port, then the water was drained out to the sea at the arrival port. Since the ballast water contained large number of planktonic organisms, including larvae of fishes and invertebrates, chances of unintentional introduction of exotic marine organisms into Japanese waters largely increased. Furthermore, intentional and unintentional introduction of the exotic marine organisms associated with import of living marine aquaculture animals, such as fishes, clams and snails also increased the chance to establish new marine exotic populations. At the end of the 20th century, 33 species of marine exotic organisms had been listed up, and then up to date, new invasions of the exotic species continue (The Regional Overview and National Reports…, 2010).

Until now in Japanese coastal waters, 29 exotic brackish/marine plant species have been identified by the national report for the MIS published in 2010 (Furota, Nakayama 2010). After the 2010, we added one new exotic species, so, up to date, 30 exotic species have been identified. Process for the identification of the exotic species adopted the evaluation process proposed by the Committee for the Preservation of the Natural Environment, the Japanese Association of Benthology (Iwasaki et al., 2004). The committee cautiously evaluated information of non-indigenous marine and brackish water species through three aspects: the original habitat of the species, when and where it was found in Japan, and possible vector of the introduction.

Among 30 exotic brackish and marine species identified, 19 species are sessile. They may have been introduced with interoceanic trading ships (Iwasaki et al., 2004). Recently, ballast water and sea chest tended to have more responsibility for transoceanic introduction by the ships, since free-living organisms can easily survive in the ballast water and inside of the sea chest during long distance voyage (Otani, 2004). Furthermore, associating with increase of import of marine living aquaculture species such as Asari (Manila) clam *Ruditapes phlippinarum,* unintentional introduction of MIS species, that had been contaminated with imported species, has increased (Okoshi, 2004).

In Japanese coastal waters, the MIS populations tend to be abundant in eutrophicated enclosed bays near large urban cities, such as Tokyo Bay and Osaka Bay. Elimination of native marine organisms by deterioration of marine ecosystems caused by construction of artificial concrete hard surface and periodic mortality of native populations due to summer hypoxia may provide more opportunities for the MIS (Furota, Kinoshita, 2004).

Among plants, one phytoplankton species, five green macroalgae species, and one cordgrass species have been introduced in Japanese waters. The dinoflagellate phytoplankton species, *Heterocapsa circularisquama,* causes red tide in coastal waters. Sea lettuces, *Ulva* spp., sometimes overgrow on shoals and tidal flats in eutrophicated enclosed waters (Fig. 2, 3).

Fig.2. Overgrowth of the sea lettuce *Ulva* sp. in Yatsu tidal mudflat within Tokyo Bay (photo by T. Furota).

Fig.3. Mass mortality of the exotic hard clam, *Mercenaria mercenaria,* in Yatsu tidal flat, Tokyo Bay (photo by T. Furota).

Recently, the invasive cordgrass, *Spartina alterniflora* was found in Mikawa Bay. This cordgrass covers lower intertidal flat surface where it is exposed to the air, and native animals such as crabs, clams and polychaetes abundantly inhabit these areas (Fig.4). Growth of the cordgrass alters the sediment condition. Up to date, locations of the cordgrass populations are limited; however, special attention must be paid to its extermination to prevent the establishment of new population.

Fig.4. Invasive cordgrass *Spartina alterniflora* in a Japanese tidal flat. The cordgrass covers lower tidal flat surface, native reed *Phragmites communis* covers only upper tidal surface (Photo by E.Fujioka).

Until now, five barnacle species, one isopod, three crab species, three gastropod, six bivalve, one bryozoan species, three polychaete species and two tunicate species were found in Japanese waters as the MIS. Most of these exotic marine invertebrates are sessile species, and they easily hitchhike with vessels if they once attach to the ship hulls. Recently, free-living animals such as crabs and snails also are introduced directly in ballast waters and unintentionally with imported live aquaculture animals. Dense growth of exotic sessile animals causes biofouling of industrial water intakes, such as electric power plants, and aquaculture nets. On the other hand, recently introduced clam, *Mercenaria mercenaria*, has become important fishery object instead of native clams in eutrophicated enclosed bays where native clam populations have largely declined due to coastal development and bottom hypoxia.

Intentional introductions can also be shown on the example of China. In the 1980's, to protect beaches, promote sediment deposition, and open sea ranching, China introduced the English cordgrass

(*Spartina anglica*) from Denmark, the Netherlands and the United Kingdom to retain solid shore beaches. However, due to mismanagement, the English cordgrass spread out of the original introduction sites and became a threat to local biodiversity. In 1979, smooth cordgrass (*S. alterniflora*) originated from southeast coast of the USA was introduced to China for retaining solid shore beaches. Recently, smooth cordgrass has gradually evolved into the main MIS to the China's coastal areas and became a serious environmental and economic threat. China has introduced at least ten species of fish, two species of shrimp, nine species of shellfish, one species of echinoderms, four species of algae in mariculture. Failed introductions of alien marine organisms could be potential dangers to the marine environment of China.

In Japan, 21 exotic species were reported to be introduced intentionally for commercial selling or fishery studies and three species were unintentionally released with other commercial animal species. Since seed stock of fish and shellfish have been introduced to Japan from foreign countries, especially from China (including Taiwan area) and Korea, to cultivate in aquaculture systems, many exotic species may have escaped into natural marine environment. Furthermore, some species have been unintentionally released with such commercial animal species. Okoshi (2004, 2007) listed 22 animal species found in sacks of the imported Manila Clams *R. philippinarum* which were released at tidal flats in northern Honshu.

There are no data for intentional introductions of alien species to Korea and to the Russian part of the NOWPAP area. All aquaculture practices in the Russian NOWPAP area are based on local species, and there is no evidence of intentional release of marine organisms.

In Korea, there are many ports on the coastline despite the small country size. The indented coastline creates semi-closed topography with possibility for exotic species to spread quickly. Between 1960s and 1970s, when Korea was in the early stage of economic growth, the government, with the purpose of procuring protein resources, intentionally introduced domestic fish-raising (Park et al., 2005). In fact, according to the report from National Institute of Environmental Research (NIER, 1996), the estimated number of exotic fishes introduced to Korea was more than 223 among which nearly 200 alien species were introduced as pets, as well as for fishing and fish-raising (NIER, 1996).

Every year harmful algal blooms or harmful organisms such as jellyfish appear near Korea, Japan and China causing social and economic problems. Also, Korea, China, Japan and Russia are geographically close, and there are many regions with similar marine environments in those countries. So, when such harmful organisms migrate to different regions, there is a high possibility that they can easily adapt to the new environment. Thus, it is necessary to develop measures to cope with the problem by making a joint effort.

In Korea, a program of ballast water risk assessment was first developed by Korea Institute of Ocean Science & Technology (hereafter referred as “KIOST” formerly “KORDI”, Korea Ocean Research & Development Institute) in 2010. The program was established based on the GloBallast project initiated by International Maritime Organization (IMO) and conducted relative overall risk assessment. Furthermore, Korea also considers the species-specific risk assessment, environmental matching risk assessment and species’ biogeographical risk assessment which were outlined in G7 (Guidelines for risk assessment under regulation A-4) for assessing the risks in relation to granting an exemption in accordance with regulation A-4 (exemptions) of the Ballast Water Management Convention. The G7 guidelines suggest that environmental matching risk assessment should be used only in circumstances where the environments are at biological extremes, such as between purely freshwater and purely marine environments. In these circumstances, those species that can survive at both extremes should be individually assessed. On the contrary, species-based assessments should only be used within a single bio-province with the assumption that the majority of native species are shared. In these circumstances, the unknown species can be assumed to be native, reducing the number of species assessments required.

Currently, KIOST is building a MIS related database as a part of their research called Development of Port Environmental Risk Assessment

Technology. Also, Ministry of Oceans and Fisheries (hereafter referred as "MOF") is making a list of marine alien species and their characteristics as a part of their Study on Management of Invasive Species in Marine Ecosystem.

There are a few published reports on the extent of marine invasive species in the Korean part of the NOWPAP region (Seo, Lee, 2009). However, a lot of marine invasive species have already invaded the region. There are 41 species suspected to be invaders in Korean coastal waters (Kim, 1992; Gong, Seo, 2004; Kim et al., 2008; Seo, Lee, 2009). These species belong to seven major groups, namely bivalves, echinoderms, barnacles, tunicates, bryozoans, phytoplankton and fishes.

In Russia, the rate of species distribution by means of vessels depends primarily on the intensity of the maritime traffic and the availability of harbors appropriate for colonization (Zvyagintsev, 2003, 2005). In Peter the Great Bay, about 16000 ships enter ports and harbours every year, and among them about 8000 ships operate on international lines (Zvyagintsev, 2007). A majority of ships (more than 10000) go into the Vladivostok Port. Such an intensive traffic favors introductions of alien species through fouling communities and release of ballast waters.

In Russian waters of NOWPAP region, 37 marine invasive species were known by 2010 (The Regional Overview and National Reports…, 2010) but this number may increase up to 66 (Zvyagintsev et al., 2011).

One of the important consequences of the naturalization of invasive species in Russia - in Peter the Great Bay - is predominance of new inhabitants over native species which leads to alterations in the ecosystem structure and trophic relationships and occasionally to unbalancing of coastal ecosystems. Ovsyannikova (2008) showed that a successful naturalization of the invasive barnacle *Amphibalanus improvisus* led to displacement of indigenous species (Fig. 5). Numerous settlements of the Mediterranean mussel *Mytilus galloprovincialis* with high population density in Peter the Great Bay provides an example of ecosystem alterations through engineering activity of this mollusk. Predominance of the mussel may lead to suppression and displacement of other species. Increasing competition between native and alien species in general is an important ecological consequence of invasions.

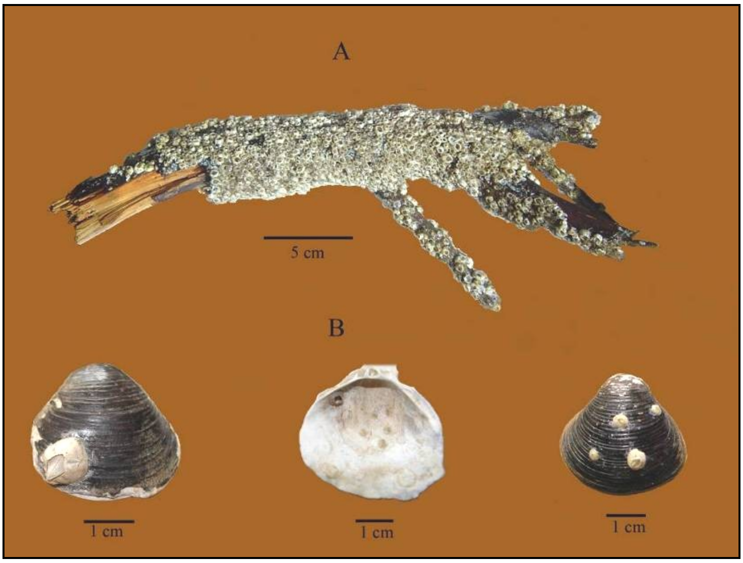

Fig.5. The appearance of *Amphibalanus improvisus* attached to a tree branch (**A**) and shells of the bivalve mollusk *Corbicula japonica* (**B**) in Amursky Bay (after: Ovsyannikova, 2008).

In Russia, biofouling of ships, piers, buoys and other hydrotechical structures consisting partly of invasive species has an important economic impact. The cost of cleaning ship hulls is very high. "Southern migrants"– fishes appeared in Peter the Great Bay – play an important role in local fishing and resulted in a positive economic effect of introduction of non-native species. The mussel *M. galloprovincialis* which became an abundant component of biofouling in Peter the Great Bay (Ivanova, Lutaenko, 1998) as well as barnacles may damage aquaculture installations but, at the same time, this mussel and its hybrids with local allied species *Mytilus trossulus* might be a perspective object of aquaculture. Conditionally pathogenic and toxicogenic mycelial fungi which are able to induce mycoses and mycotoxicosis of invertebrates and fishes were isolated from ballast waters of ships in Vladivostok Port (Zvyagintsev et al., 2009).

Sokolovsky et al. (2004) predict appearance of more subtropical fish species in Peter the Great Bay with global warming and intensification of warm currents in the NOWPAP region except the Yellow Sea. Zvyagintsev et al. (2009) believe that ascidian *Polyandrocarpa zorritensis*, barnacle *Balanus glandula*, polychaetes of the genus *Polydora* and bivalve mollusk *Perna viridis* are potential marine benthic invasive species into Peter the Great Bay. Zvyagintsev (2003) regarded as potential invaders species that are in the first stage of introduction and small-scale development. Some of these species have been introduced from subtropical waters; some did come from temperate and cold waters of the Pacific and even the Northern Atlantic. Another group of potential invasive species are related to migrations induced by global warming and current system modifications. Coastal warming and introduction of new species may also favor aquaculture and fisheries.

In Russian waters, in comparison with the late 1960s and early 1970s, the species richness of phytoplankton in Amursky Bay increased markedly and a greater number of bloom-forming species was recorded; some of them can be invasive species but it is diffucult to prove as there was no long-term monitoring in the area (Orlova et al., 2009). Selina et al. (2009) mentioned that appearance of the dinoflagellate *Scrippsiella spinifera* in Possyet Bay in 1999 might be related to the introduction with warm waters from the coast of Japan. Another dinoflagellate *Gyrodinium instriatum*, new for Russian waters of Russia and found in Peter the Great Bay, probably, penetrated to the bay with ballast waters (Orlova et al., 2003). The diatom *Cerataulina dentata* was recorded for the first time in Peter the Great and previously was known in tropical-subtropical regions (Stonik, Orlova, 1998).

The impact of algal blooms might be related to fish and shellfish poisoning in this area. Some microalgae have ability to produce potential toxins that can find their way through the food chain to humans, causing a variety of gastrointestinal and neurological illnesses, such as Paralytic Shellfish Poisoning (PSP), Diarrheic Shellfish Poisoning (DSP) and Amnesic Shellfish Poisoning (ASP). Although there have been no reports of shellfish poisoning incidents in Russia as yet, the presence of various toxin-producing species have been recorded in Russian waters;

shellfish poisoning in Russia could become a major threat in the future, particularly due to the expansion of the aquaculture industry and appearance of invasive plankton species.

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4. Main marine invasive species in the NOWPAP region

4.1. Plants and phytoplankton

Saccharina japonica (Areschoug) Lane, Mayes, Druehl et Saunders, 2006

Common name: Kelp.

Taxonomy: Ochrophyta, Phaeophyceae, Laminariales, Laminariaceae.

Fig. 6. *Saccharina japonica*.

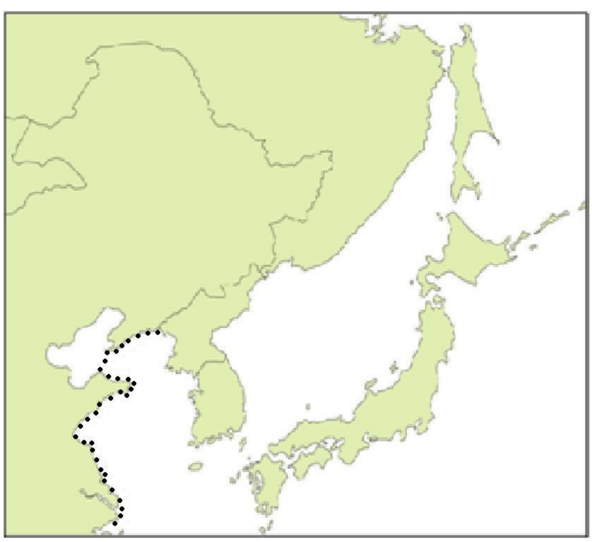

Fig. 7. Distribution of *Saccharina japonica* in China.

Regional distribution: China: most coastal areas, including Huanghai Sea.

Possible origin: Japan.

Possible way of introduction: Intentional introduction for aquaculture.

Habitat: Marine areas at about 2 m deep, with summer seawater temperatures not exceeding 20° C for a prolonged period.

Impact: China is the largest kelp producer, and S. *japonica* brings great economic benefits. On the other hand, this species also occupies niches and biotopes of native species，and this may lead to suppression and displacement of other species.

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(XJ)

Macrocystis pyrifera (Linnaeus) C. Agardh, 1820

Common name: Giant kelp.

Taxonomy: Ochrophyta, Phaeophyceae, Laminariales, Laminariaceae.

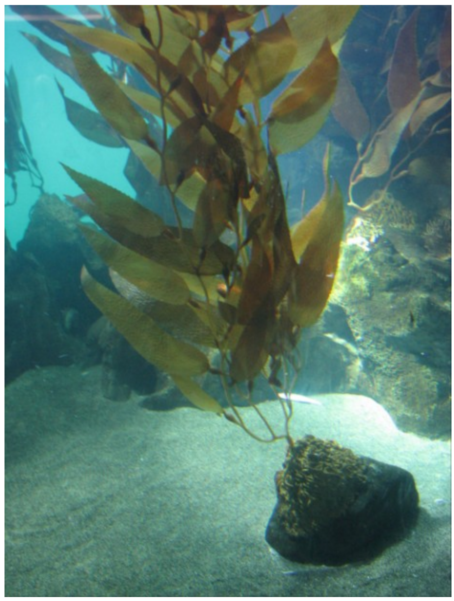

Fig. 8. *Macrocystis pyrifera.*

Fig. 9. Distribution of *Macrocystis pyrifera* in China.

Regional distribution: China: Coastal areas from Dalian to Changdao Island.

Possible origin: Mexico.

Possible way of introduction: Intentional introduction for aquaculture.

Habitat: Shallow waters (5-25 m deep).

Impact: This species improves the coastal environment, providing food and habitat for marine organisms. It changes the structure, function and biodiversity of the marine ecosystem.

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(XJ)

Undaria pinnatifida (Harvey) Suringar, 1873

Common name: Asian kelp.

Taxonomy: Ochrohyta, Phaeophyceae, Laminariales, Alariaceae.

Fig. 10. *Undaria pinnatifida.*

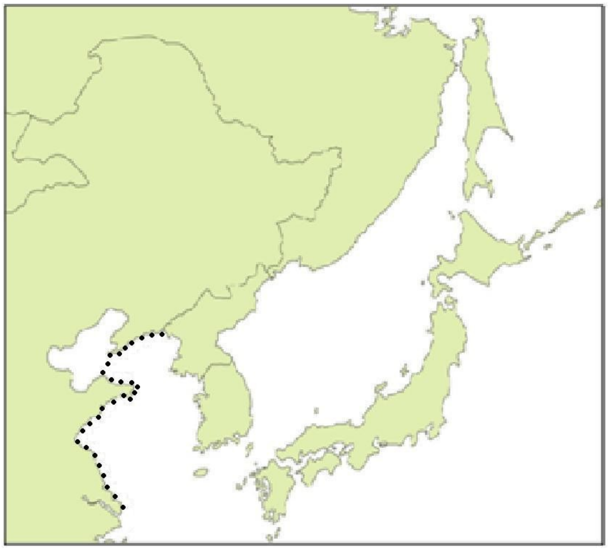

Fig. 11. Distribution of *Undaria pinnatifida* in China.

Regional distribution: **China:** coastal areas of Liaoning, Shandong and Jiangsu provinces (cited after: http://zlg.kepu.gov.cn).

Possible origin: Japan.

Possible way of introduction: Intentiuonal introduction for aquaculture.

Habitat: *U. pinnatifida* inhabits intertidal zone down to a depth of 15–20 m. It grows on hard substrata such as rocks and reefs.

Impact: *U. pinnatifida* brings great economic benefits, while filial generation of kelps may lead to genetic changes of both native and alien marine species in China.

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(XJ)

Desmarestia ligulata (Stackhouse) Lamouroux, 1813

Common name: Color changer.

Taxonomy: Ochrophyta, Phaeophyceae, Desmarestiales, Desmarestiaceae.

Fig. 12. *Desmarestia ligulata*.

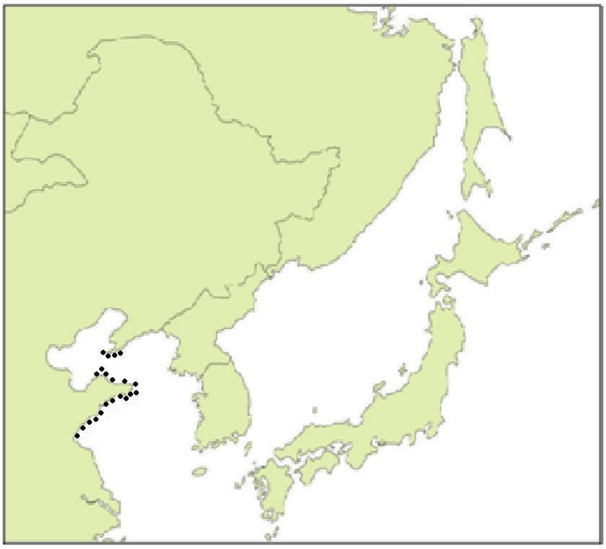

Fig. 13. Distribution of *Desmarestia ligulata* in China.

Regional distribution: China: Dalian, Lushun, and Shandong provinces.

Possible origin: Japan.

Possible way of introduction: Possibly dispersed with the introduction of *Undaria pinnatifida*(Harvey)Suringar, 1873.

Habitat: Rocks and shells in the low intertidal down to the upper subtidal zones in moderately sheltered to fully exposed coastal areas. This species often lives in kelp forest of other species.

Impact: Acid is excreted when this algae is dying, and it may lead to mortality of other algae and marine organisms.

Bibliography:

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Xu H. and Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 99.

(XJ)

Cutleria multifida (Turner) Greville, 1830

Common name: Flat wipe-seaweed;

Japanese name: Hiramuchimo.

Taxonomy: Ochrophyta, Phaeophyceae, Cutleriales, Cutieriaceae.

Fig. 14. *Cutleria multifida* from Japan (photo by T. Horiguchi).

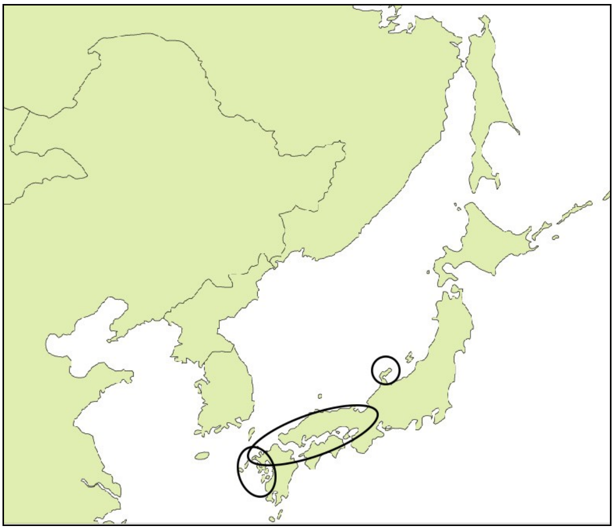

Fig. 15. Distribution of *Cutleria multifida* in Japan.

Regional distribution: Japan: western Kyusyu, Ehime Pref., Hiroshima Pref., Mie Pref., Noto Peninsula (western Honshu).

Possible origin: Europe.

Possible way of introduction: Ship hull-fouling.

Habitat: Embayment waters.

Impact: Unknown.

Bibliography:

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(TF, SN)

Ulva fasciata Delile, 1813

Common name: Ribbon sea lettuce.

Japanese name: Ribon Aosa.

Taxonomy: Chlorophyta, Ulvophyceae, Ulvales, Ulvaceae.

Fig. 16. Overgrowing area of sea-lettuce (*Ulva* sp.) on Yatsu tidal flat at the innermost of Tokyo Bay, Japan.

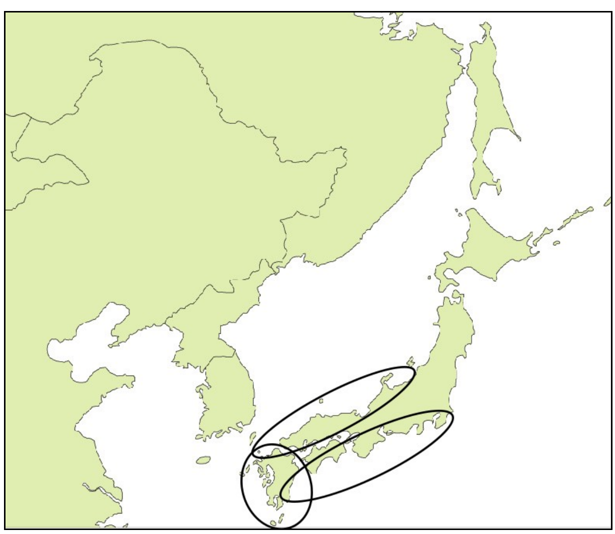

Fig. 17. Distribution of *Ulva fasciata* in Japan.

Regional distribution: Japan: Pacific coast of central to southern Honshu, southern coast of the NOWPAP area, and Okinawa Archipelago.

Possible origin: Southwest Pacific?

Possible way of introduction: ballast water, ship hull-fouling.

Habitat: Rocky shore.

Impact: unknown.

Comments:

Based on a genetic analysis, three exotic sea-lettuce species have been identified in Japanese waters (Kawai et al., 2007). Morphological identification, however, is very difficult.

This species may be a synonym of *Ulva lactuca* Linnaeus; two other species are *Ulva armoricana* P. Dion, B. de Reviers et G. Coat, 1998 (a possible synonym of *Ulva rigida* C. Agardh, 1823) and *Ulva scandinavica* Bliding, 1969 (a possible synonym of *Ulva rigida* C.Agardh, 1823) (www.algaebase.org; comments by KL).

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(TF, SN)

Spartina alterniflora Loisel, 1807

Common name: Smooth cordgrass; saltmarsh cordgrass.

Japanese name: Higata-ashi.

Taxonomy: Magnoliophyta, Liliopsida, Poales, Poaceae.

Fig. 18. *Spartina alterniflora* in China.

Fig. 19. *Spartina alterniflora* in Japan.

Fig. 20. Distribution of *Spartina alterniflora* in China and Japan.

Regional distribution: **China:** coastal areas from Liaoning to Jiangsu Province;

Japan: Mikawa Bay, Ariake Bay.

Possible origin: unknown (native range – Atlantic coast of North America).

Possible way of introduction: **a**quaculture; ballast water.

Habitat: intertidal zone and estuarine tidal flats.

Impact: *Spartina alterniflora* occupies niches of native species, destroys habitat and threatens local biodiversity. They also clog waterways, affecting water exchange and cause red tide. Competition with native marsh reed.

Bibliography:

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http://chubu.env.go.jp/pre_2011/data/1006a_1.pdf

(TF, SN, XJ)

Spartina anglica C.E. Hubbard, 1968

Common: Common cordgrass.

Taxonomy: Angiospermae, Graminales, Poaceae.

Fig. 21. *Spartina anglica* in China.

Fig. 22. Distribution of *Spartina anglica* in China.

Regional distribution: China: coastal areas of Jiangsu Province.

Possible origin: United Kingdom.

Possible way of introduction: Aquaculture.

Habitat: It grows on mud-flats and in salt marshes, estuarine wetlands, shorelines, etc., near the high tide mark.

Impact: Common cordgrass may destroy habitat for coastal living, and clog waterways, affecting water exchange.

Bibliography:

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Xu H., Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 422–423.

(XJ)

Pseudo-nitzschia calliantha Lundholm, Moestrup et Hasle, 2003

Taxonomy: Ochrophyta, Bacillariophyceae, Bacillariales, Bacillariaceae.

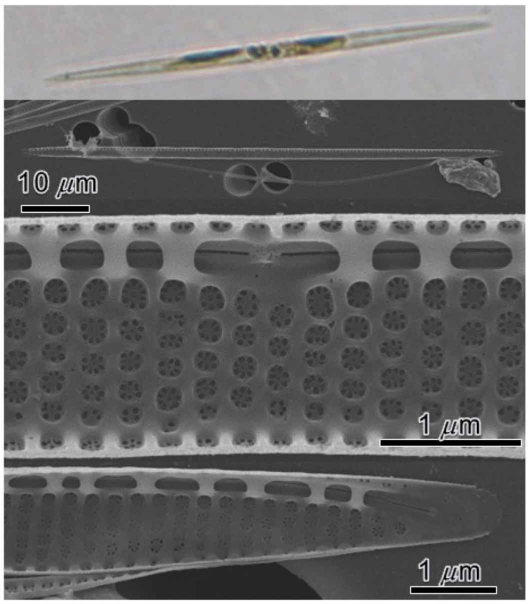

Fig. 23. *Pseudo-nitzschia calliantha.*

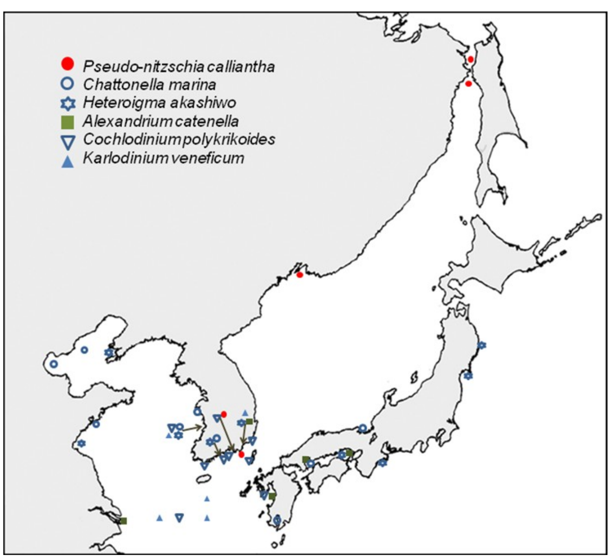

Fig. 24. Distribution of six phytoplankton species within NOWPAP area.

Regional distribution: Korea: Tongyeong, Maemul-do;

Russia: Peter the Great Bay, Sakhalin Island;

China: Hong Kong.

Possible origin: Tropical and temperate region (type locality: Ejby, Zealand, the Isefjord, Denmark).

Possible way of introduction: Via shipping.

Impact: Unknown.

Bibliography:

Orlova T.Y., Stonik I.V., Aizdaicher N.A., Bates S.S., Le´ger C. and Fehling J. 2008. Toxicity, morphology and distribution of *Pseudo-nitzschia calliantha, P. multistriata* and *P. multiseries* (Bacillariophyta) from the northwestern Sea of Japan. *Botanica Marina.* V. 51. P. 297–306.

Stonik I.V., Orlova T.Y. and Begun A.A. 2008. Potentially toxic diatoms *Pseudo-nitzschia fraudulenta* and *P. calliantha* from Russian waters of East/Japan Sea and Sea of Okhotsk. *Ocean Science Journal,* V. 43. P. 25–30.

Park J.-G., Kim E.-G. and Im W.A. 2009. Potentially toxic *Pseudo-nitzschia* species in Tongyeong coastal waters, Korea. *The Sea.* V. 14. P. 163–170.

(KS)

Chattonella marina (Subrahmanyan) Hara et Chihara, 1982

Taxonomy: Ochrophyta, Raphidophyceae, Chattonellales, Chattonellaceae.

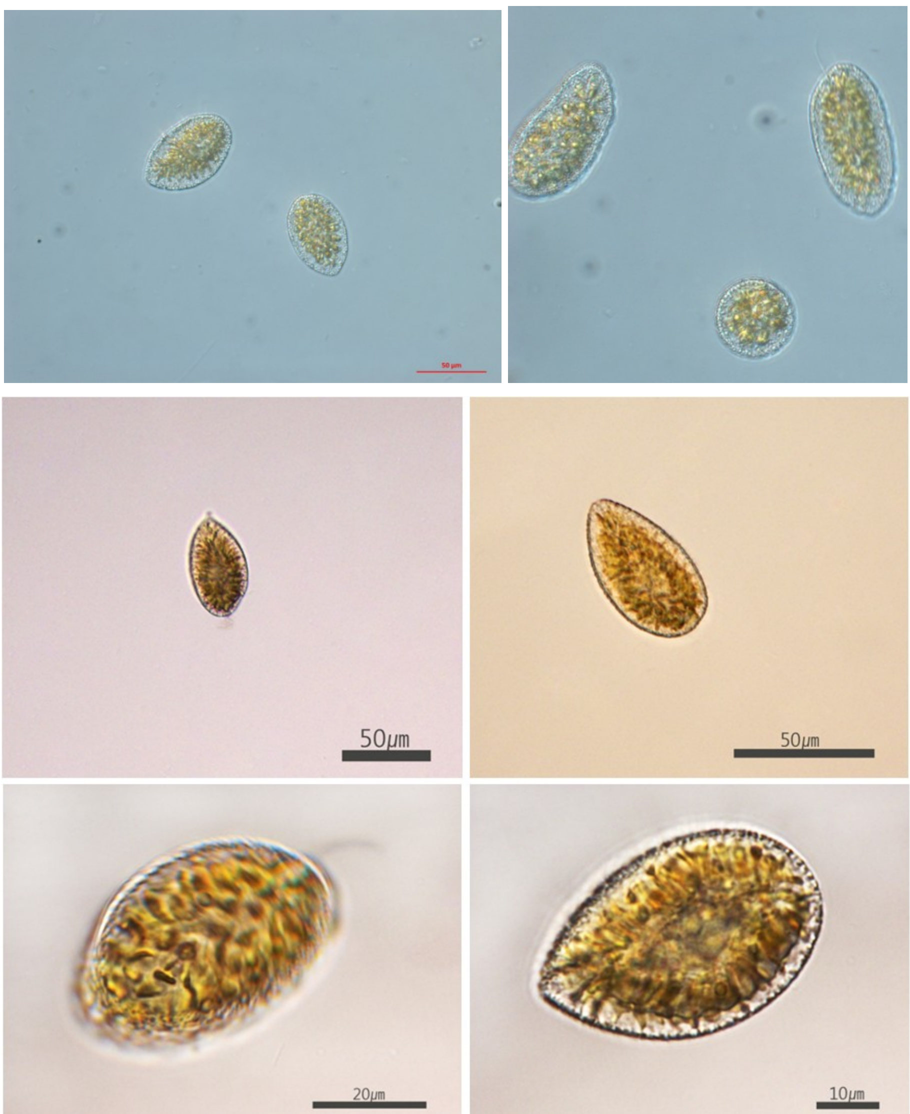

Fig. 25. *Chattonella marina.*

Regional distribution: Korea: Gunsan, Cheonsu Bay, Yeosu;

Japan: Kagoshima, Seto inland Sea, Maizuru Bay; China: Tianjin, Qinhuangdao Bay, Qingdao, Hong Kong.

Possible origin: Japan? (type locality: Malabar Coast) (see Fig. 24).

Possible way of introduction: Via shipping.

Habitat: Neritic regions including estuarine systems.

Impact: Invasive alien species causing mortality of fish. Gill damage. Decrease in heart rate of fish caused by brevetoxins, resulting in reduced flow of oxygen to the gills.

Bibliography:

Endo M., Onoue Y. and Kuroki A. 1992. Neurotoxin-induced cardiac disorder and its role in the death of fish exposed to *Chattonella marina. Marine Biology.* V. 112. P. 371–376.

Onoue Y. and Nozawa K. 1989. Separation of toxins from harmful red tides occurring along the coast of Kagoshima Prefecture. **In:** T. Okaichi, D.M. Anderson and T. Nemoto (Eds.). *Red Tides, Biology, Environmental Science, and Toxicology.* Amsterdam: Elsevier. P. 371–374.

Hara Y. and Chihara M. 1982. Ultrastructure and taxonomy of *Chattonella* (class Raphidophyceae) in Japan. *Japanese Journal of Phycology.* V. 30. P. 47–56.

Noh I.-H., Oh S.-J., Park J-S., Shin H.-H. and Yoon Y.-H. 2009. Growth kinetics on the nutrient of the harmful algae *Chattonella marina* and *C. ovata* (Raphidophyceae) isolated from the South Sea of Korea. *Korean Journal of Fisheries and Aquaculture Science.* V. 42. P. 674–682.

(KS)

Heterosigma akashiwo (Y. Hada) Y. Hada ex Y. Hara et M. Chihara, 1967

Taxonomy: Ochrophyta, Raphidophyceae, Chattonellales, Chattonellaceae.

Fig. 26. *Heterosigma akashiwo.*

Regional distribution: Korea: Jinhae Bay, Yeosu, Gunsan;

Japan: Seto Inland Sea, Gokasho Bay, Sanriku coast, Onagawa Bay;

China: Dalian Bay, Haizhou Bay, Hong Kong (see Fig. 24).

Possible origin: Japan? (type locality: Seto Inland Sea).

Possible way of introduction: Via shipping.

Habitat: Shallow water mostly within 10 m of the surface.

Impact: Invasive alien marine species. Mortality of finfish.

Bibliography:

Hada Y. 1967. Protozoan plankton of the Inland Sea, Setonaikai I. The Mastigophora. *Bulletin of the Suzugamine Women's College, Natural Science.* V. 14. P. 1–26.

Hara Y. and Chihara C. 1987. Morphology, ultrastructure and taxonomy of the raphidophycean alga *Heterosigma akashiwo. Botanical Magazine, Tokyo* V. 100. P. 151–163.

Honjo T. 1993. Overview on bloom dynamics and physiological ecology of *Heterosigma akashiwo.* **In:** T.J. Smayda and Y. Shimizu (Eds.). *Toxic Phytoplankton Blooms in the Sea.* Amsterdam: Elsevier. P. 33-41.

Smayda T.J. 1998. Ecophysiology and bloom dynamics of *Heterosigma akashiwo* (Raphidophyceae). **In:** M. Anderson, A.D. Cembella & G.M. Hallegraeff (Eds.). *Physiological Ecology of Harmful Algal Blooms.* Berlin, Heidelberg: Springer-Verlag. P. 113–131.

(KS)

Alexandrium catenella (Whedon et Kofoid) E. Balech, 1985

Taxonomy: Dinophyta, Dinophyceae, Gonyaulacales, Goniodomataceae.

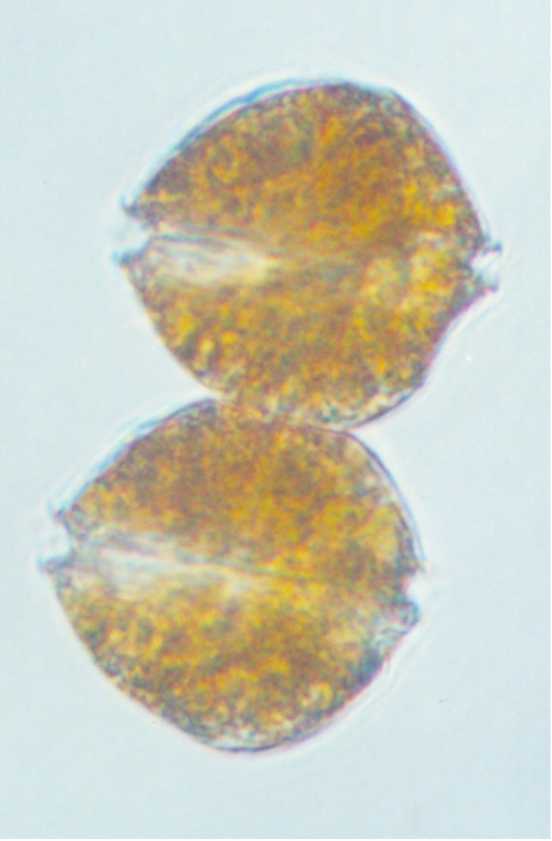

Fig. 27. *Alexandrium catenella.*

Regional distribution: **Korea:** Jinhae Bay;

Japan: Seto Inland Sea, Yamakawa Bay, Harima-Nada Sea;

China: Hong Kong, Changjiang estuary (see Fig. 24).

Possible origin: Neritic regions including estuarine systems.

Possible way of introduction: Via shipping.

Habitat: Neritic regions including estuarine systems.

Impact: Producer of paralytic shellfish poisoning toxins and fish mass mortality causative substance.

Bibliography:

Balech E. 1985. The genus *Alexandrium or Gonyaulax* of the *tamarensis* group. **In:** D.M. Anderson, A.W. White and D.G. Baden (Eds.) *Toxic Dinoflagellates.* New York: Elsevier. P. 33–38.

Ogata T. and Kodama M. 1986. Ichthyotoxicity found in cultured media of *Protogonyaulax* spp. *Marine Biology.* V. 95. P. 217–220.

Kim C.-H., Sako Y. and Ishida Y. 1993. Variation of toxin production and composition in axenic cultures of *Alexandrium catenella* and *A. tamarense. Nippon Suisan Gakkaishi.* V. 59. P. 633–639.

(KS)

Cochlodinium polykrikoides Margalef, 1961

Taxonomy: Dinophyta, Dinophyceae, Gymnodiniales, Gymnodiniaceae.

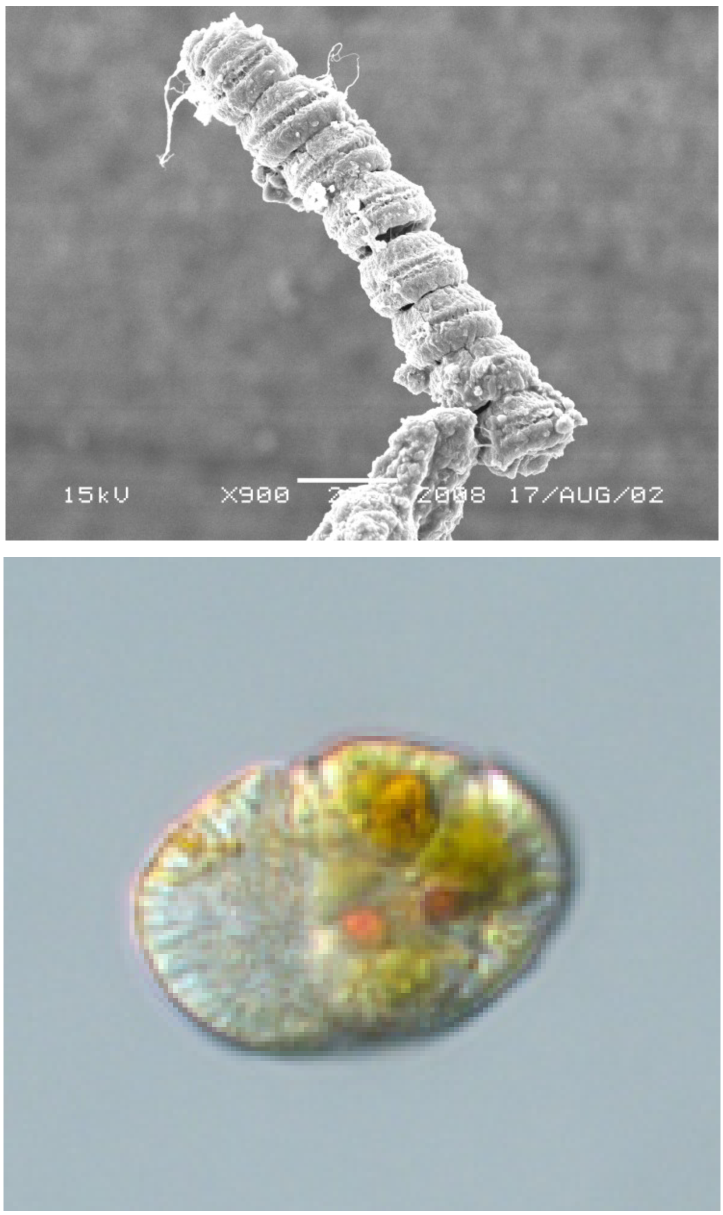

Fig. 28. *Cochlodinium polykrikoides.*

Regional distribution: **Korea:** Tongyeong, Busan, Goheung, Namhae, Wan-do, Gunsan;

Japan: Tsushima Island, Nagasaki, Yatsushiro Sound;

China: Quanzhou Bay, Hong Kong, Guangdong, East China Sea (see Fig. 24).

Possible origin: Oceanic regions.

Possible way of introduction: Via shipping.

Habitat: Oceanic regions.

Impact: Serious fishkiller. Toxic to juvenile fish.

Bibliography:

Kim H.G. 1998. *Cochlodinium polykrikoides* blooms in Korean coastal waters and their mitigation. **In:** B. Reguera, J. Blanco, M. L. Fernández and T. Wyatt (Eds.). *Harmful Algae.* Santiago de Compostela: Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO. P. 227–228.

Matsuoka K., Iwataki M. and Kawami H. 2008. Morphology and taxonomy of chain-forming species of the genus *Cochlodinium* (Dinophyceae). *Harmful Algae.* V. 7. P. 261–270.

Park T.-G., Kang Y.-S., Park Y.-T., Bae H.-M. and Lee Y. 2009. Detection of fish killing dinoflagellates *Cochlodinium polykrikoides and Karlodinium veneficum* (Dinophyceae) in the East China Sea by Real-time PCR. *Algae*. V. 24. P. 105–110.

(KS)

Karlodinium veneficum (Ballantine, 1956) J. Larsen, 2000

Taxonomy: Dinophyta, Dinophyceae, Gymnodiniales, Kareniaceae.

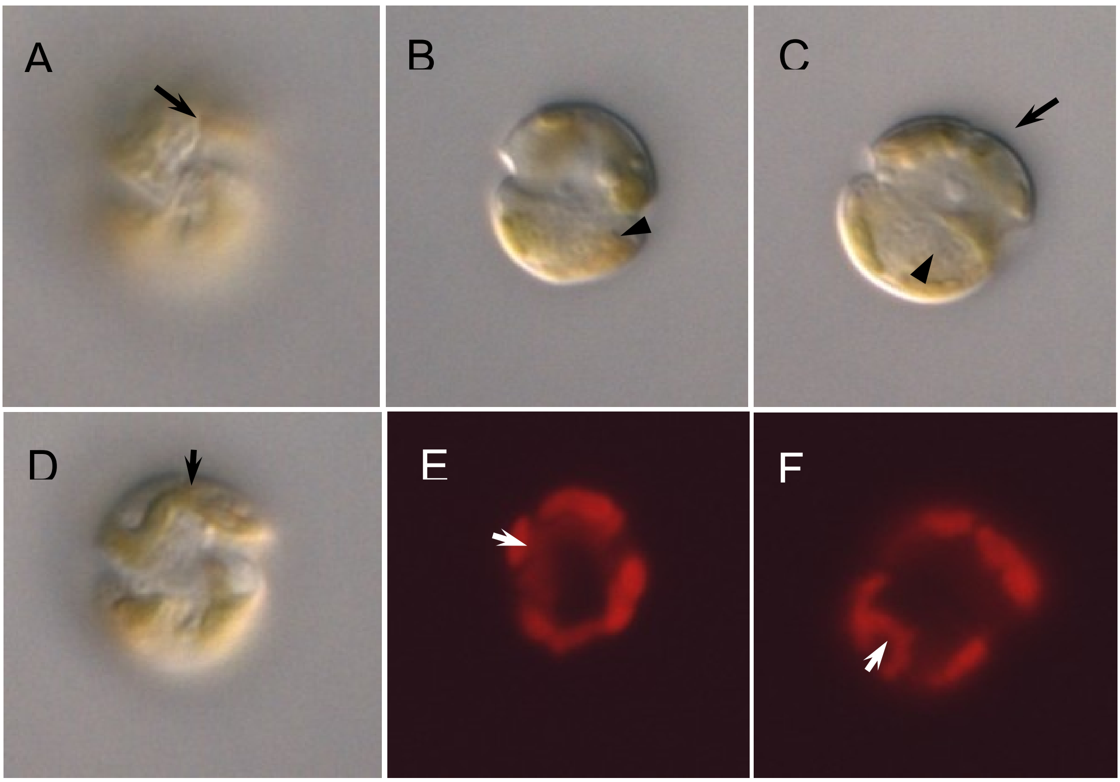

Fig. 29. *Karlodinium veneficum.*

Regional distribution: Korea: Gunsan, Jinhae Bay, Yellow Sea;
China: Quanzhou Bay, Hong Kong, Guangdong, East China Sea (see Fig. 24).

Possible origin: Cold waters.

Possible way of introduction: Via shipping.

Habitat: Cold waters.

Impact: Toxic to a range of marine invertebrates and fish. This species produces so-called karlotoxins that exhibit a broad-spectrum lytic effect on membranes from very diverse cell types.

Bibliography:

Park T.-G., Kang Y.-S., Park Y.-T., Bae H.-M. and Lee Y. 2009. Detection of fish killing dinoflagellates *Cochlodinium polykrikoides* and *Karlodinium veneficum* (Dinophyceae) in the East China Sea by real-time PCR. *Algae*. V. 24. P. 105–110.

Park J.-G. Kim S.H. and Kim K. 2009. Occurrence of an ichthyotoxic dinoflagellates *Karlodinium veneficum* bloom in a newly constructed coastal lake, Saemangeum, Korea. *Yellow Sea*. V. 10. P. 10–18.

Wang H., Lu D., Huang H., Göbel J., Dai X. and Xia P. 2011. First observation of *Karlodinium veneficum* from the East China Sea and the coastal waters of Germany. *Acta Oceanologica Sinica*. V. 30. P. 112–121.

(KS)

Heterocapsa circularisquama Horiguchi, 1995

Taxonomy: Dinophyta, Dinophyceae, Peridiniales.

Fig. 30. *Heterocapsa circularisquama* in Japan.

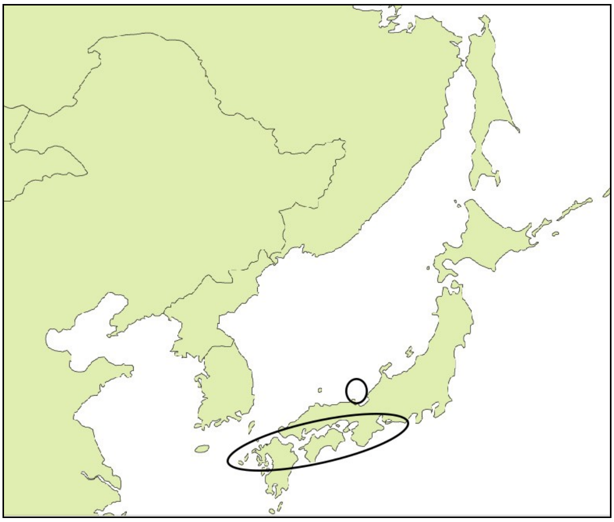

Fig. 31. Distribution of *Heterocapsa circularisquama* in Japan.

Regional distribution: Japan: Western main Japanese islands and Ohama Bay, estern Japan.

Possible origin: Southwest Pacific?

Possible way of introduction: Ballast water.

Habitat: Embayment waters.

Impact: Mortality of cultured mollusks and fishes.

Bibliography:

Horiguchi T. 1995. *Heterocapsa circularisquama* sp. nov. (Peridinales, Dinophyceae): a new marine dinoflagellate causing mass mortality of bivalves in Japan. *Phycological Research.* V. 43. P. 129–136.

Iwataki M. and Matsuoka K. 2009. Transportation of harmful dinoflagellates. **In:** The Plankton Society of Japan and the Japanese Association of Benthology (eds.). *Marine Aliens Introduced by Human Activities and Their Impacts on Ecosystems and Industries.* Hatano: Tokai University Press. P. 108–119. [in Japanese].

(TF, SN)

4.2. Animals

Ficopomatus enigmaticus (Fauvel, 1923)

Common name: Crab-inhabited tube-worm;

Japanese name: Kani-yadori Kanzashi: Crab hosted Kanzashi-worm (Kanzashi=Japanese classic hiarpine).

Taxonomy: Annelida, Polychaeta, Canalipalpata, Serpulidae.

Fig. 32. Crab inhabited tube-worm, *Ficopomatus enigmaticus.*

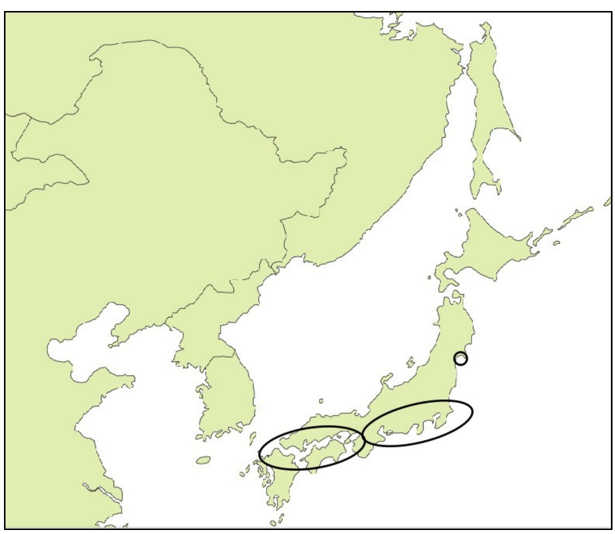

Fig. 33. Distributional region of *Ficopomatus enigmaticus* in Japan.

Regional distribution: **Japan:** Miyagi Prefecture, Pacific coast from Ibaraki Prefecture to Mikawa Bay, Seto Inland Sea, Shimane Prefecture and northern Kyushu, Ishigaki Island.

Possible origin: Australia.

Possible way of introduction: Ship hull-fouling, ballast water.

Habitat: Shallow hard substrata in estuarine waters. A species of the small xanthid crab occasionally inhabits its tube.

Impact: Bio-fouling on oyster culture, compete with native serpulid species.

Bibliography:

Iwasaki K., Kimura T., Kinoshita K., Yamaguchi T., Nishikawa T., Nishi E., Yamanishi R., Hayashi I., Okoshi K., Kosuge T., Suzuki T., Henmi Y., Furota T. and Mukai H. 2004. Human-mediated Introduction and dispersal of marine organisms in Japan: results of a questionnaire survey by the Committee for the Preservation of the Natural Environment, the Japanese Association of Benthology. *Japanese Journal of Benthology.* V. 59. P. 22–44. [in Japanese with English abstract].

(TF, SN)

Hydroides elegans (Haswell, 1883)

Common name: Calcareous tube-worm; piled tube-worm;

Japanese name: Kasane-kanzashi.

Taxonomy: Annelida, Polychaeta, Canalipalpata, Serpulidae.

Fig. 34. *Hydroides elegans.*

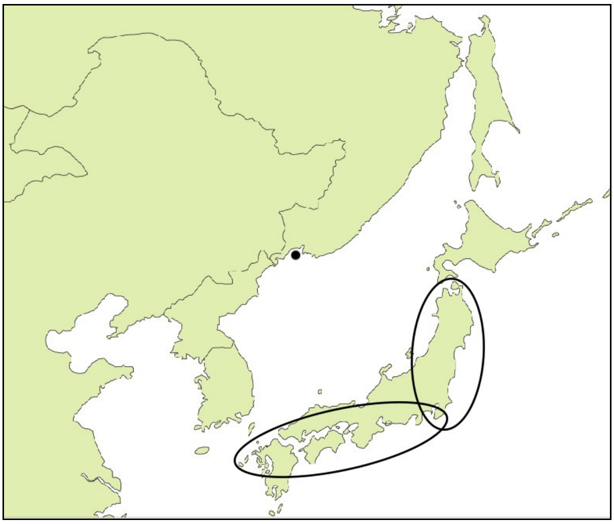

Fig. 35. Distribution of *Hydroides elegans* in Japan and Russia.

Regional distribution: **Japan:** Pacific coast of Honshu and Shikoku, northern Kyushu;

Russia: Peter the Great Bay.

Possible origin: Southwest Pacific?

Possible way of introduction: Ballast water.

Habitat: This tube-worm occurs on artificial hard substrata and oyster shell in enclosed subtidal waters. In Russia, it is a dominant biofouling species of vessels, especially in Vladivostok Port (Zolotoy Rog Bay).

Impact: Mortality of aquaculture shells and fishes, biofouling.

Bibliography:

Bagaveeva E.V. and Zvyagintsev A.Yu. 2000. The introduction of polychaetes *Hydroides elegans* (Haswell), *Polydora limicola* Annenkova, and *Pseudopotamilla occelata* Moore to the northwestern part of the East Sea. *Ocean Research*. V. 22, N 1. P. 25–36.

Iwasaki K., Kimura T., Kinoshita K., Yamaguchi T., Nishikawa T., Nishi E., Yamanishi R., Hayashi I., Okoshi K., Kosuge T., Suzuki T., Henmi Y., Furota T. and Mukai H. 2004. Human-mediated Introduction and dispersal of marine organisms in Japan: results of a questionnaire survey by the Committee for the Preservation of the Natural Environment, the Japanese Association of Benthology. *Japanese Journal of Benthology.* V. 59. P. 22–44. [in Japanese with English abstract].

Zvyagintsev A.Yu. 2003. Introduction of species into the northwestern Sea of Japan and the problem of marine fouling. *Russian Journal of Marine Biology.* V. 29, Suppl. 1. P. S10–S21.

(TF, SN, KL)

Hydroides dianthus (Verrill, 1873)

Japanese name: Nadeshiko-kanzashi; Pink (a plant of genus Dianthus) tube-worm.

Taxonomy: Annelida, Polychaeta, Canalipalpata, Serpulidae.

Fig. 36. Pink tube-worm, *Hydroides dianthus.*

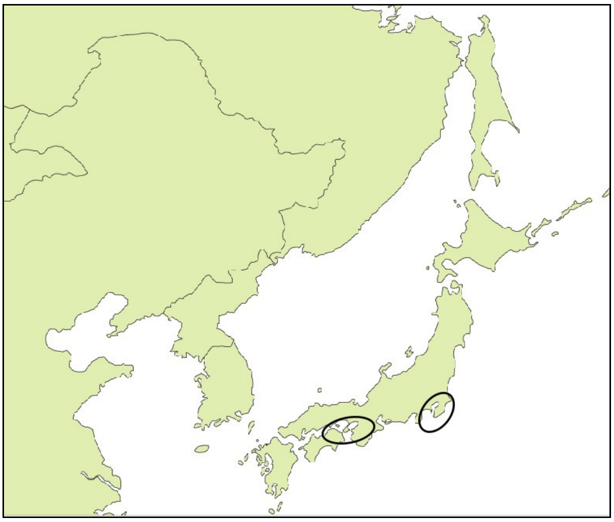

Fig. 37. Distributional region of *Hydroides dianthus* in Japan.

Regional distribution: Japan: Osaka Bay, Tokyo Bay.

Possible origin: East coast of North America.

Possible way of introduction: Ship hull-fouling.

Habitat: Hard substrata in embayment shallow waters. Assemblage of the worm is usually found in shallow subtidal hard substrata as well as other exotic tube-worms. It is distributed in wide range of salinity conditions.

Impact: Mortality of aquaculture shells and fishes.

Bibliography:

Otani M. and Yamanishi R. 2007. Two newly recorded alien species *Rhithropanopeus harrisii* (Crustacea; Panopeidae) and *Hydroides dianthus* (Polychaeta; Serpulidae). *Proceedings of the Annual Meeting of the Japanese Society of Sessile Organisms,* 2007. P. 9. [in Japanese].

Yamakita T. 2009. *Hydroides dianthus* (Polychaeta: Serpulidae), an alien species introduced into Tokyo Bay, Japan. *Marine Biodiversity Records.* V. 2. P. e87.

(TF, SN)

Pseudopotamilla occelata Moore, 1905

Common name: Fun worm.

Taxonomy: Annelida, Polychaeta, Canalipalpata, Sabellidae.

Fig. 38. *Pseudopotamilla occelata.*

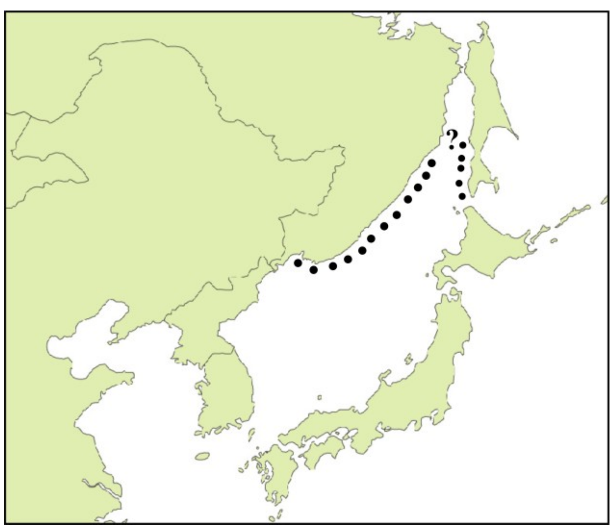

Fig. 39. Distribution of *Pseudopotamilla occelata* in Russia.

Regional distribution: Russia: Peter the Great Bay, Primorye, western Sakhalin.

Possible origin: Eastern Pacific.

Possible way of introduction: Ballast water.

Habitat: Hard substrata in shallow waters.

Impact: Biofouling. Impact on bottom subtidal communities due to high dominance.

Bibliography:

Bagaveeva E.V. and Zvyagintsev A.Yu. 2000. The introduction of polychaetes *Hydroides elegans* (Haswell), *Polydora limicola* Annenkova, and *Pseudopotamilla occelata* Moore to the northwestern part of the East Sea. *Ocean Research.* V. 22, N 1. P. 25–36.

Zvyagintsev A.Yu., Ivin V.V., Kashin I.A. 2009. *The Methodical Advisories to Research of Ship Ballast Waters during Realization of Marine Bioinvasions Monitoring.* Vladivostok: Dalnauka. 123 p. [In Russian].

(KL)

Haliotis discus Reeve, 1846

Common name: Disk abalone.

Taxonomy: Mollusca, Archaeogastropoda, Haliotidae.

Fig. 40. *Haliotis discus.*

Fig. 41. Distribution of *Haliotis discus* in China.

Regional distribution: China: coastal areas of Dalian.

Possible origin: Japan.

Possible way of introduction: Aquaculture and self dispersion.

Habitat: Intertidal zone.

Impact: *H. discus* competes with native abalones and makes a competitive advantage, leading to decrease of the native abalone populations. It causes genetic diversity damage and contamination.

Bibliography:

Cai M., Ke C., Zhou S. 2004. Advances in genetics and breeding in abalone: a review. *Journal of Fisheries of China.* V. 28, N 2. P. 201–208. [in Chinese with English abstract].

Liang Y., Wang B. 2001. Alien marine species and their impacts in China. *Biodiversity Science.* V. 9, N 4. P. 458–465. [in Chinese with English abstract].

Yan J., Sun H., Fang J. et al. 1999. Study on the technology of crossbreeding abalones *Haliotis discus discus* and *Haliotis discus hannai. Marine Fisheries Reseach.* V. 20, N 1. P.35–39. [in Chinese with English abstract].

(XJ)

Haliotis gigantea Gmelin, 1791

Common name: Giant abalone.

Taxonomy: Mollusca, Archaeogastropoda, Haliotidae.

Fig. 42. *Haliotis gigantea.*

Fig. 43. Distribution of *Haliotis gigantea* in China.

Regional distribution: China: coastal areas of Liaoning and Shandong.

Possible origin: Japan, Korea.

Possible way of introduction: Aquaculture and self dispersion.

Habitat: Subtidally down to 10 m, hard bottom.

Impact: This species can hybridize and compete with native species, causing genetic diversity damage and contamination.

Bibliography:

Cai M., Ke C., Zhou S. 2004. Advances in genetics and breeding in abalone: a review. *Journal of Fisheries of China.* V. 28, N 2. P. 201–208. [in Chinese with English abstract].

Yan J., Sun H., Fang J. et al. 1999. Study on the technology of crossbreeding abalones *Haliotis discus discus* and *Haliotis discus hannai. Marine Fisheries Reseach.* V. 20, N 1. P. 35–39. [in Chinese with English abstract].

(XJ)

Haliotis rufescens Swainson, 1822

Common name: Red abalone.

Taxonomy: Mollusca, Archaeogastropoda, Haliotidae.

Fig. 44. *Haliotis rufescens.*

Fig. 45. Distribution of *Haliotis rufescens* in China.

Regional distribution: China: coastal areas of Liaoning and Shandong.

Possible origin: West coast of North America and Mexico.

Possible way of introduction: Aquaculture.

Habitat: Embayments (rocky shore), exposed rocky shore, kelp forest, protected rocky shore.

Impact: *H. rufescens* does not adapt to the environment of the NOWPAP area, but hybrids of this species with other abalones can compete with native species causing genetic diversity damage and contamination.

Bibliography:

Cai M., Ke C., Zhou S. 2004. Advances in genetics and breeding in abalone: a review. *Journal of Fisheries of China.* V. 28, N 2. P. 201–208. [in Chinese with English abstract].

Hou X. 1998. On biological characteristics of significant economical abalones in the world. *Shandong Fisheries.* V. 15, N 4. P. 20–22. [in Chinese].

Liang Y., Wang B. 2001. Alien marine species and their impacts in China. *Biodiversity Science.* V. 9, N 4. P. 458–465. [in Chinese with English abstract].

Wang R., Fan J. 1999. Artificial breeding of red abalone (*Haliotis refescens*) and cross breeding with Pacific abalone (*Haliotis discus hannai* Ino). J*ournal of Dalian Fisheries University.* V.14, N 3. P. 64–66. [in Chinese with English abstract].

(XJ)

Haliotis fulgens Philippi, 1845

Common name: Green abalone.

Taxonomy: Mollusca, Archaeogastropoda, Haliotidae.

Fig. 46. *Haliotis fulgens.*

Fig. 47. Distribution of *Haliotis fulgens* in China.

Regional distribution: China: Coastal areas of Liaoning and Shandong.

Possible origin: Tropical waters.

Possible way of introduction: Aquaculture.

Habitat: In shallow water, in open/exposed coast from low intertidal to at least 9 m and perhaps as deep as 18 m deep. Individuals are found in rock crevices, under rocks and other cryptic cavities.

Impact: *H. fulgens* does not adapt to the environment of NOWPAP area, but hybrids of this species with other abalones can compete with native species causing genetic diversity damage and contamination.

Bibliography:

C**ai M., Ke C., Zhou S.** 2004. Advances in genetics and breeding in abalone: a review. *Journal of Fisheries of China.* V. 28, N 2. P. 201–208. [in Chinese with English abstract].

Hou X. 1998. On biological characteristics of significant economical abalones in the world. *Shandong Fisheries.* V. 15, N 4. P. 20–22. [in Chinese].

Liang Y., Wang B. 2001. Alien marine species and their impacts in China. *Biodiversity Science.* V. 9, N 4. P. 458–465. [in Chinese with English abstract].

(XJ)

Crepidula onyx G.B. Sowerby I, 1824

Common name: Onyx boat-snail;

Japanese name: Shima-menou fune-gai.

Taxonomy: Mollusca, Gastropoda, Neotaenioglossa, Calyptraeidae.

Fig. 48. *Crepidula onyx* in Japan.

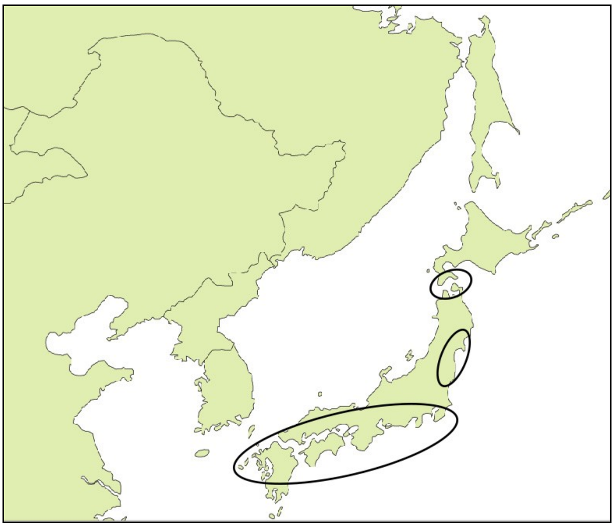

Fig. 49. Distribution of *Crepidula onyx* in Japan.

Regional distribution: Japan: Hokkaido, Miyagi and Fukushima Prefs, Pacific coast from Chiba Pref. to Shikoku, Seto Inland Sea, Northern Kyusyu, Ariake Inland Sea.

Possible origin: Eastern Pacific.

Possible way of introduction: Ship hull-fouling.

Habitat: Subtidal living shells, rocks This sessile snail is commonly found in eutrophicated bay waters, usually on large snails such as Rapana venosa, but it also occurs on the hard substratum.

Impact: Unknown.

Bibliography:

Egawa K. 1985. Distribution and dispersion of *Crepidula onyx* in Japan. *Chiribotan* (Newsletter of the Malacological Society of Japan). V. 16. P. 37–44. [in Japanese].

(TF, SN)

Nassarius sinarus (Philippi, 1851)

Common name: Chinese scavenger snail;

Japanese name: Kara-mushiro.

Taxonomy: Mollusca, Gastropoda, Neogastropoda, Nassariidae.

Fig. 50. Chinese scavenger snail, *Nassarius sinarus* in Japan.

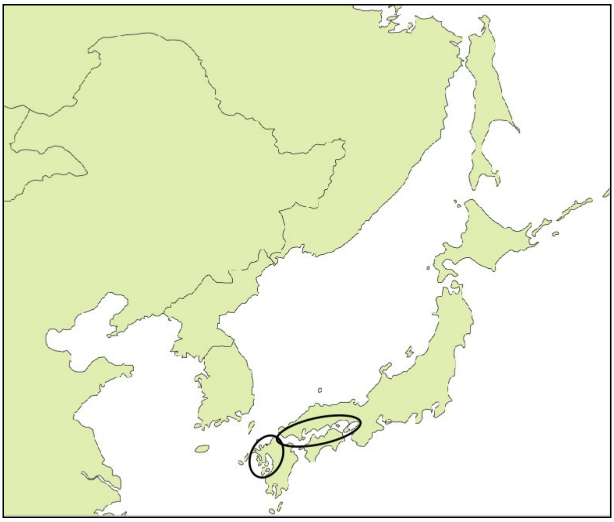

Fig. 51. Distribution of *Nassarius sinarus* in Japan.

Regional distribution: Japan: Ariake Inland Sea, Seto Inland Sea.

Possible origin: China, Korea.

Possible way of introduction: With imported aquaculture clams.

Habitat: Intertidal and shallow subtidal sediment bottoms. This snail lives on intertidal mud flats and subtidal mud bottoms. It crowds on fishes in fishermen's bait traps, causing damage to the fishery.

Impact: Predation on trapped fishes, possibly compete with native scavenger snails.

Bibliography:

Tamaki A., Mahori N., Isihbashi T. and Fukuda H. 2002. Invasion of two marine alien gastropods *Stenothyra* sp. and *Nassarius (Zeuxis) sinarus* (Caenogastropoda) into the Ariake Inland Sea, Kyushu, Japan. *Yuriyagai.* V. 8. P. 63–81.

(TF, SN)

Euspira fortunei (Reeve, 1855)

Common name: Black top-point moon snail;

Japanese name: Sakiguro tama-tsumeta.

Taxonomy: Mollusca, Gastropoda, Sorbeoconcha, Naticidae.

Fig. 52. *Euspira fortunei* in Japan.

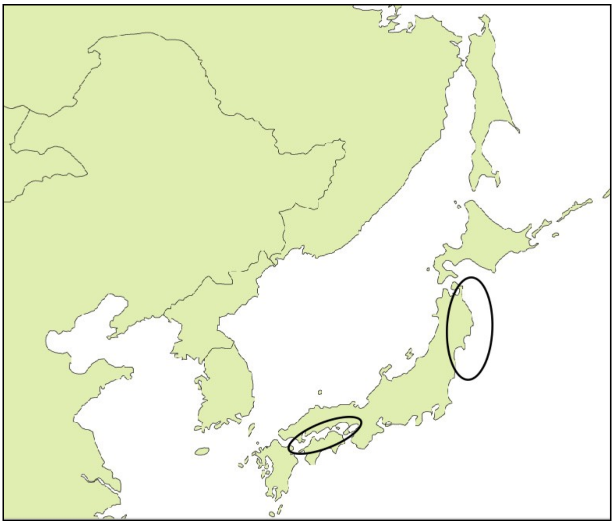

Fig. 53. Distribution of *Euspira fortunei* in Japan.

Regional distribution: Japan: Pacific coast from Aomori Pref. to Shizuoka Pref., Seto Inland Sea, Ariake Sea.

Possible origin: China, Korea.

Possible way of introduction: With aquaculture imports.

Habitat: Tidal flats. The moon-snail was unintentionally released in tidal flats with juvenile Asari clams (*Ruditapes philippinarum*) that were imported from China or Korea. In some tidal flats in Tohoku region, Asari clam fishing and recreational clam digging collapsed, due to high predation effect on the clam populations by the moon-snail.

Impact: Predation on fishery clams.

Comments:

This species is a possible synonym of ***Laguncula pulchella* (Benson, 1842)** (see: Torigoe K. and Inaba A. 2011. Revision on the classification of Recent Naticidae. *Bulletin of the Nishinomiya Shell Museum*. V. 7. P. 133 + 15 pp., 4 pls.) (comments by KL).

Bibliography:

Okoshi K. 2004. Alien species introduced with imported clams: the clam eating moon snail *Euspira fortunei* and other unintentionally introduced species. *Japanese Journal* of *Benthology*. *N* 59. P. 74–82. [in Japanese with English abstract].

(TF, SN)

Mytilus galloprovincialis Lamarck, 1819

Common name: Mediterranean blue mussel;

Japanese name: Murasaki igai;

Korean name: Ji-jung-hae-dam-chi;

Russian name: Sredizemnomorskaya midiya.

Taxonomy: Mollusca, Bivalvia, Mytilidae.

Fig. 54. Mediterranean blue mussel, *Mytilus galloprovincialis* in Japan, left; in Pusan Port, Korea, right.

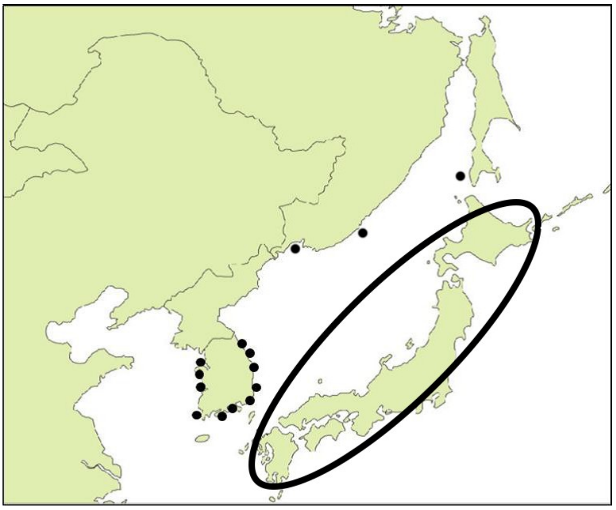

Fig. 55. Distribution of *Mytilus galloprovincialis* in Japan, Korea and Russia.

Regional distribution: **Japan:** All Japanese main islands, Okinawa and Ogasawara islands;
Korea;
Russia: Peter the Great Bay, Vladimira Bay, Moneron Island.

Possible origin: Mediterranean Sea.

Possible way of introduction: Unintentional, via balast water and hull fouling of ships.

Habitat: Intertidal and shallow subtidal concrete walls, rocks and aquaculture crafts. Pier walls and other port structures. Fishery rope, net, and other aquaculture facilities; Depth range is intertidal to 5 m deep (mainly less than 3 m).

Impact: Biofouling, competition with native sessile organisms, genetic contamination with native mussels. Organic pollution by deposited mussels. One of the most abundant sessile bivalves on hard substrata in enclosed waters. *M. galloprovincialis* can reduce the productivity of mussles, oysters, or sea squirt aquaculture by fouling aquaculture gear massively. Deposited dead mussels that were peeled off from concrete walls cause organic pollution in ports and bays.

Comments:

This species is additionally known in China (see: Xu F., Zhang S. 2008. An Illustrated Bivalvia Mollusca Fauna of China Seas. Beijing: Science Press. 336 p.) (comment by KL).

Bibliography:

Ivanova M.B. and Lutaenko K.A. 1998. On the distribution of *Mytilus galloprovincialis* Lamarck, 1819 (Bivalvia, Mytilidae) in Russian Far Eastern seas. *Bulletin of the Institute of Malacology, Tokyo*. V. 3, N 5. P. 67–71.

Lee S.Y. and Morton B.S. 1985. The introduction of the Mediterranean mussel *Mytilus galloprovincialis* into Hong Kong. *Malacological Review*. V. 18. P. 107–109.

Lutaenko K.A. and Noseworthy R.G. 2012. Catalogue of the Living Bivalvia of the Continental Coast of the Sea of Japan (East Sea). Vladivostok: Dalnauka. 247 p.

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S., and Kim S.H. 2010. *Oceanic introduced species of Korea*. Ministry of Land, Transport and Maritime Affairs. 27 p.

(TF, SN, KL, KS)

Perna viridis L., 1758

Common name: Green mussel;

Japanese name: Midori igai.

Taxonomy: Mollusca, Bivalvia, Mytilidae.

Fig. 56. Green mussel, *Perna viridis* in Japan.

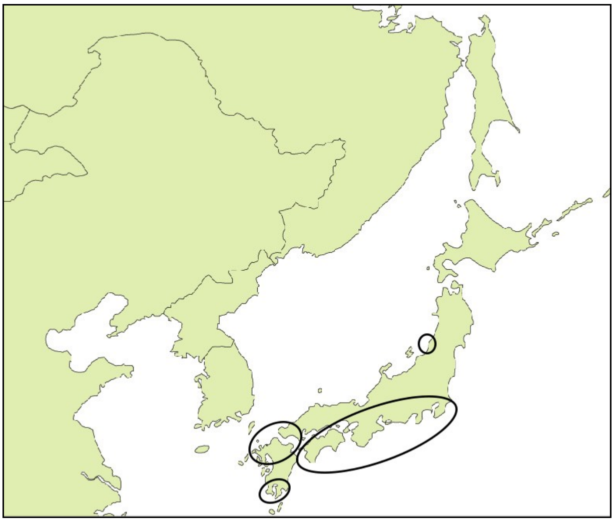

Fig. 57. Distribution of *Perna viridis* in Japan.

Regional distribution: Japan: Yamagata Pref., Pacific coast from Chiba to Kagoshima prefs., north Kyushu, western Ryukyu Archipelago.

Possible origin: Indian Ocean, Southeast Asia.

Possible way of introduction: Ship hull-fouling.

Habitat: Intertidal and shallow subtidal concrete, rocks and aquaculture crafts. Abundantly occurs on the concrete walls in enclosed eutrophicated waters during late summer to early winter. Since native habitats of the mussel are in tropical and subtropical warm waters, they usually die in late winter under low temperature. However, overwintering mussels were found in and near warm-water outlet channels of electric power plants.

Impact: Biofouling, organic pollution by deposited mussels, competition with native sessile organisms.

Bibliography:

Ueda I. 2001. Sedentariness of the green mussel in Japan. In: Kajiwara T. and Okutani T. (Eds). *Kuroshozoku no Shinnyusha* (*Invaders Dressed with Black Cloths*). Tokyo: Kouseisha Kouseikaku. P. 27–45. [in Japanese].

(TF, SN)

Xenostrobus securis (Lamarck, 1819)

Common name: Canal-wall mussel;

Japanese name: Koroen kawa hibari-gai.

Taxonomy: Mollusca, Bivalvia, Mytilidae.

Fig. 58. Small channel mussel, *Xenostrobus securis* in Japan.

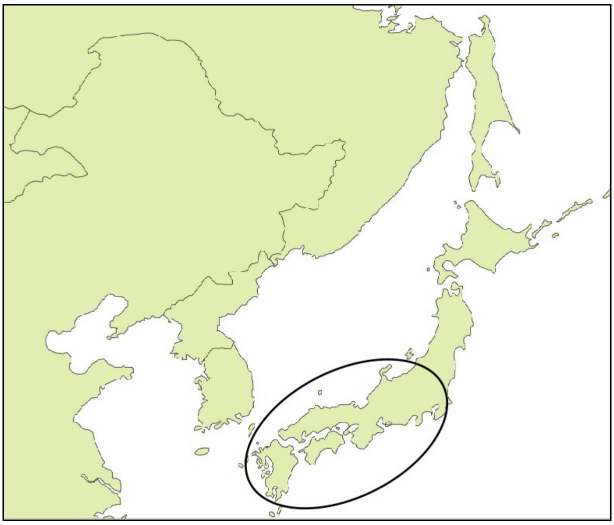

Fig. 59. Distribution of *Xenostrobus securis* in Japan.

Regional distribution: **Japan:** Eastern half of Honshu, Shikoku and Kyushu;
Korea.

Possible origin: Oceania.

Possible way of introduction: Ship hull-fouling.

Habitat: Intertidal and subtidal concrete and rocks in estuarine and enclosed waters. It occurs in similar habitats of the Mediterranean blue mussel, *Mytilus galloprovincialis*. However, it tends to be more abundant in estuarine intertidal hard substrata.

Impact: Biofouling, competition with native sessile organisms.

Bibliography:

Kimura T., Tabe M. and Shikano Y. 1999. *Limnoperna fortunei kikuchii* Habe, 1981 (Bivalvia: Mytilidae) is a synonym of *Xenostrobus securis* (Lamarck, 1819): introduction into Japan from Australia and/or New Zealand. *Venus*. V. 58. P. 101–117.

(TF, SN)

Mytilopsis sallei (Récluz, 1849)

Common names: Estuarine mussel; pseudo-blue-mussel;

Japanese name: Igai-damashi.

Taxonomy: Mollusca, Bivalvia, Dressenidae.

Fig. 60. Estuarine mussel, *Mytilopsis sallei* in Japan.

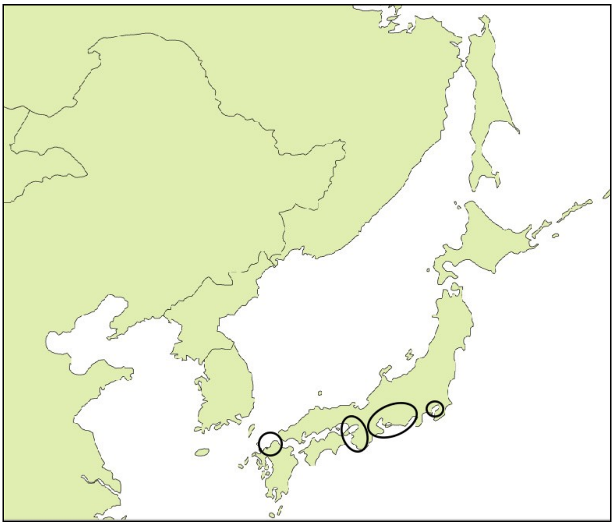

Fig. 61. Distribution of *Mytilopsis sallei* in Japan.

Regional distribution: Japan: Kanto to Northern Kyushu.

Possible origin: Southeast Asia.

Possible way of introduction: Ship hull-fouling, cargo fouling.

Habitat: Estuarine in enclosed waters. Intertidal hard substratum in estuarine and enclosed waters. Occurrence of this mussel is restricted in lower saline waters in estuaries comparing with other exotic mussels. It is usually found in the intertidal zone.

Impact: Unknown

Bibliography:

Nabeshima Y. 2002. *Mytilopsis sallei*, Dreissenidae bivalve of Caribbean Sea origin. In: Ecological Society of Japan (ed.). *Handbook of Alien Species.* Tokyo: Chijin-shokan. P. 189. [in Japanese].

(TF, SN)

Argopecten irradians (Lamarck, 1819)

Common name: Atlantic bay scallop.

Taxonomy: Mollusca, Bivalvia, Pectinidae.

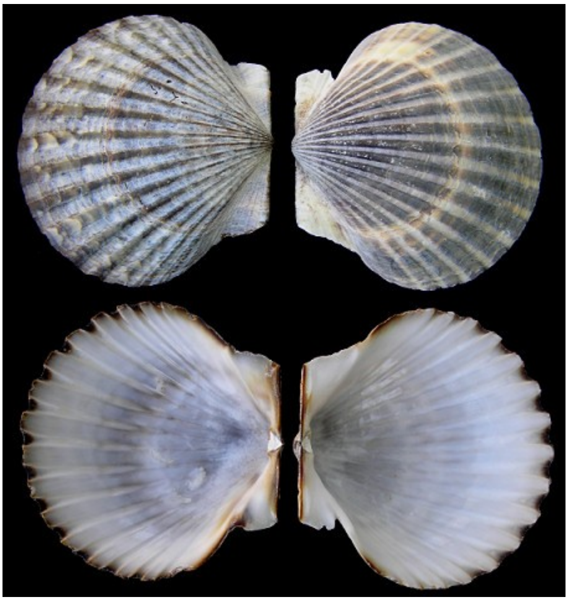

Fig. 62. *Argopecten irradians*.

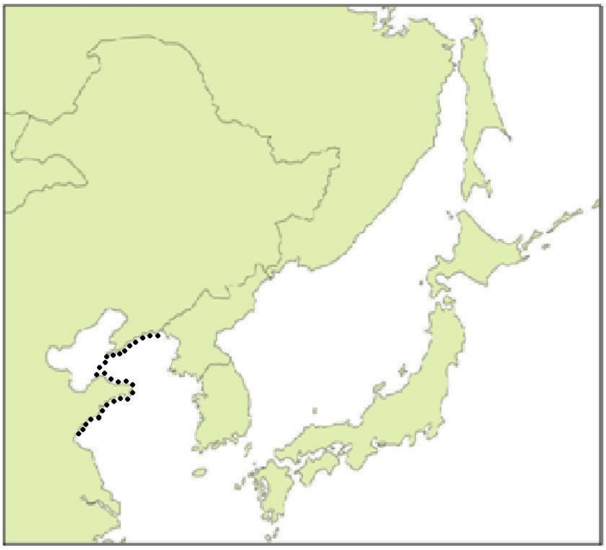

Fig. 63. Distribution of *Argopecten irradians* in China.

Regional distribution: China: coastal areas of Liaoning and Shandong; **Korea.**

Possible origin: Atlantic coast of both Americas (eastern Canada to Colombia).

Possible way of introduction: Aquaculture and self dispersion.

Habitat: Shallow waters with rocky bottom.

Impact: *A. irradians* can hybridize with native species, causing genetic diversity damage and contamination of the native marine ecosystem.

Bibliography:

Chen L. and Wang Z. 1994. Effects of temperature on the fertilization and embryonic development of *Argopecten irradians* Lamarck, *Patinopecten yessoensis* Jay and their hybrids. *Journal of Dalian Fisheries University*. V. 9, N 4. P. 1–9. [in Chinese with English abstract].

Lutaenko K.A. and Noseworthy R.G. 2012. Catalogue of the Living Bivalvia of the Continental Coast of the Sea of Japan (East Sea). Vladivostok: Dalnauka. 247 p.

Zhang F., He Y., Liu X. et al. 1986. A report on the introduction, spat-rearing and experimental culture of bay scallop, *Argopecten irradians* Lamarck. *Oceanologia et Limnologia Sinica*. V. 17, N 5. P. 367–374. [in Chinese with English abstract].

Zhang F., He Y., Qi L. et al. 1997. Studies on the restoration of cultured bay scallop *Argopecten irradians* through reintroduction of broodstock. *Oceanologia et Limnologia Sinica.* V. 28, N 2. P.146–152. [in Chinese with English abstract].

(XJ)

Mizuhopecten yessoensis (Jay, 1857)

Common name: Japanese scallop.

Taxonomy: Mollusca, Bivalvia, Pectinidae.

Fig. 64. *Mizuhopecten yessoensis.*

Fig. 65. Distribution of *Mizuhopecten yessoensis* in China.

Regional distribution: China: coastal areas of north China，especially Liaoning and Shandong provinces.

Possible origin: northern Japan, Russian part of the NOWPAP area and southern Sea of Okhotsk.

Possible way of introduction: Aquaculture and self dispersion.

Habitat: In China, shallow waters (6–60 m deep) with high salinity.

Impact: This species can hybridize with native species causing genetic diversity damage and contamination of the native marine ecosystem.

Bibliography:

Chen L. and Wang Z.. 1994. Effects of temperature on the fertilization and embryonic development of *Argopecten irradians* Lamarck, *Patinopecten yessoensis* Jay and their hybrids. *Journal of Dalian Fisheries University*. V. 9, N 4. P. 1–9. [in Chinese with English abstract].

Yang A., Wang Q., Liu Z. et al. 2004. The hybrid between the scallops *Chlamys farreri* and *Patinopecten yessoensis* and the inheritance characteristics of its first filial generation. *Progress in Fishery Sciences*. 25, N 5. P. 1–5.

Zhang F., He Y., Ma J. et al. 1984. The introduction of the Japanese scallop, *Patinopecten yessoensis* (Jay), into China, its spat-rearing and experimental cultivation. *Marine Sciences*. V. 36, N 5. P.38–45.

(XJ)

Crassostrea gigas (Thunberg, 1793)

Common names: Pacific oyster, Japanese oyster, giant oyster.

Taxonomy: Mollusca, Bivalvia, Ostreidae.

Fig. 66. *Crassostrea gigas.*

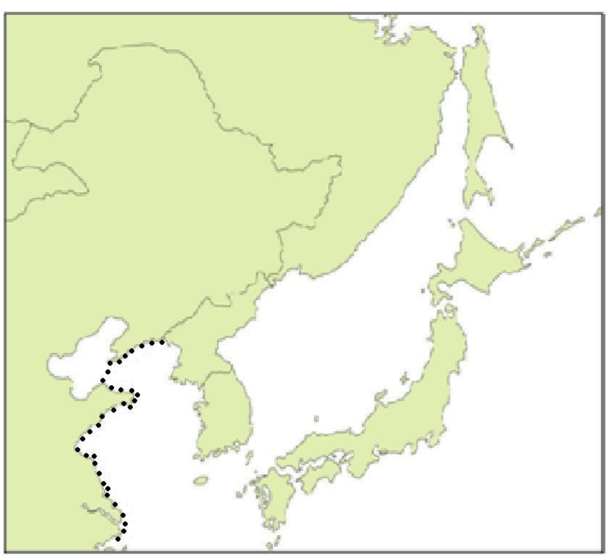

Fig. 67. Distribution of *Crassostrea gigas* in China.

Regional distribution: China: All the coastal areas.

Possible origin: Japan?

Possible way of introduction: Aquaculture and self dispersion.

Habitat: C. *gigas* prefers to live on hard surfaces in sheltered waters within the intertidal zone. This species can survive in salinities between 10 and 32‰, and temperatures of –1 to 35º C.

Impact: Pacific oysters may have diseases that would negatively affect other species, with no apparent negative effects on themselves. They can also hybridize with native species, causing genetic diversity damage and contamination of the native marine ecosystem.

Comments:

According to paleontological data (Wang H., Fan C.-F., Li J.-F., Li F.-L., Yan Y.-Z., Wang Y.-S., Zhang J.-Q., Zhang Y.-F. 2006. Holocene oyster reefs on the northwest coast of the Bohai Sea, China. *Geological Bulletin of China.* V. 25, N 3. P. 315 – 331), this species lived throughout the Chinese coast in the Holocene, and it is known in the Bohai Sea since 7750 years B.P. and, therefore, *C. gigas* may be a native species in China (comments by KL).

Bibliography:

Cai Z., Zhuang D., Lin R. et al. 1999. Biological effeects of environmental factors on *Crassostrea gigas* in mesocosms. *Journal of Oceanography in Taiwan Strait*. V. 18, N 4. P. 389–392.

Lou Y. 2003. A study and comparison in morphology of oysters. *Strait Pharmaceutical Journal*. V. 15, N 6. P.51–53.

Wang Z., Jiang B., Kong L. et al. 2004. Large-scale production of all-triploid Pacific oyster (*Crassostrea gigas*) seeds by crossing tetraploids and diploids. *Journal of the Ocean University of Qingdao*. V. 34, N 5. P. 742–746.

Yang A., Niu X., Shen J. et al. 1995. Study on cultchless spat and culture techniques of Pacific oyster *Crassostrea gigas. Journal of Fishery Sciences of China*. V. 2, N 3. P. 29–35.

(XJ)

Mercenaria mercenaria (L., 1757)

Common names: Hard-shell clam; quahog;

Japanese name: Hon-binosu gai.

Taxonomy: Mollusca, Bivalvia, Veneridae.

Fig. 68. *Mercenaria mercenaria.*

Fig. 69. Distribution of *Mercenaria mercenaria* in China and Japan.

Regional distribution: China: coastal areas of Shandong;

Japan: Tokyo Bay, Osaka Bay.

Possible origin: Western Atlantic.

Possible way of introduction: Aquaculture and self-dispersion.

Habitat: Intertidal and shallow fine-mud bottoms in estuarine and enclosed waters.

Impact: This species can hybridize and compete with native species causing genetic diversity damage and contamination of the native marine ecosystem.

Bibliography:

Lin Z., Cai X., Fang J. et al. 2002. An aptitude test on the environmental habits of *Mercenaria mercenaria*. *Journal of Ningbo University* (*Natural Science & Engineering Edition*). V. 15, N 1. P.19–22.

Lin Z., Shan L., Cai X. et al. 2005. The reproductive biology of hard clam *Mercenaria mercenaria* (Linnaeus, 1758). *Oceanologia et Limnologia Sinica*. V. 36, N 5. P. 430–436.

Nishimura K. 2003. The introduced clam *Mercenaria mercenaria* in inner Tokyo Bay. *Hitachiobi* (*The Reports of the Tokyo Malacological Society*). V. 94. P. 13–17. [in Japanese].

Wen H., Zhang T., Yang H. et al. 2004. Effect of temperature on respiration and excretion of hard clam *Mercenaria mercenaria* (Linnaeus, 1758). *Oceanologia et Limnologia Sinica*. V. 35, N 6. P. 549–554.

(TF, SN, XJ)

Panopea japonica A. Adams, 1850

Common name: Pacific geoduck clam.

Taxonomy: Mollusca, Bivalvia, Hiatellidae.

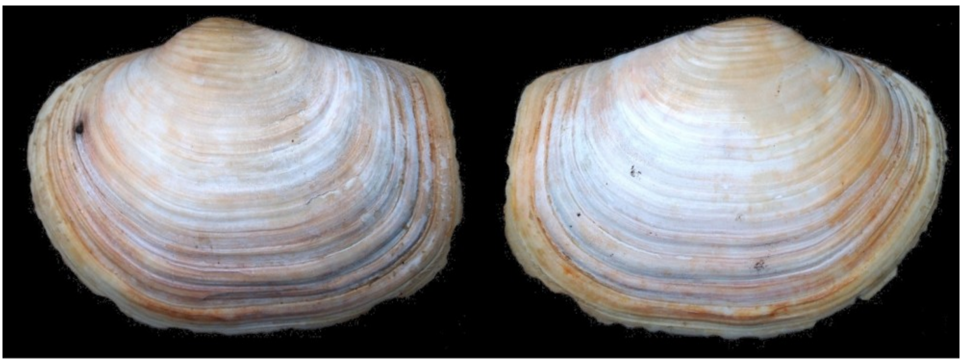

Fig. 70. *Panopea japonica.*

Fig. 71. Distribution of *Panopea japonica* in China.

Regional distribution: China: coastal areas of Shandong.

Possible origin: Northwest Pacific Ocean.

Possible way of introduction: Aquaculture and self dispersion.

Habitat: Mud, from intertidal zone to 110 m deep.

Impact: Unknown.

Bibliography:

Dong Y., Yang A., Li Y. 2004. Current research and perspectives of geoduck clam *Panopea abrupta. Progress in Fishery Science*. V. 25, N 4. P. 90–95.

Xu H., Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 455–456.

(XJ)

Balanus glandula Darwin, 1854

Common name: North American barnacle;

Japanese name: Kita-amerika fujitubo.

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

Fig. 72. North American barnacle, *Balanus glandula* in Japan.

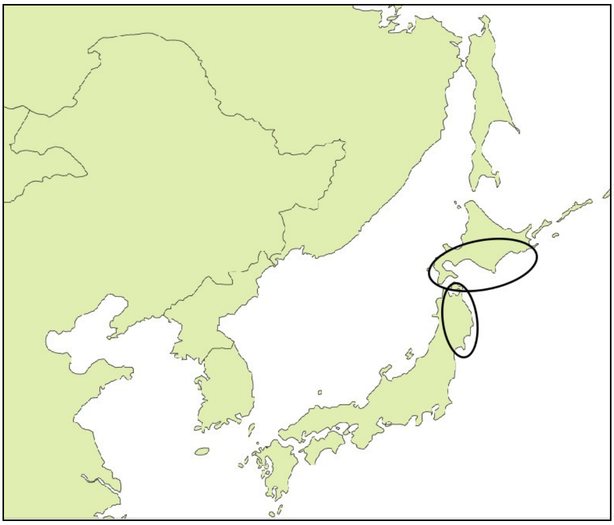

Fig. 73. Distribution of *Balanus glandula* in Japan.

Regional distribution: Japan: Northern Pacific coasts from Hokkaido to Sanriku, and Mutsu Bay.

Possible origin: Pacific coast of North America

Possible way of introduction: Ship hull-fouling

Habitat: Hard substrata in ports. Along the Pacific coast of North America, the barnacle *B. glandula* is one of the most common barnacle species on rocky intertidal shores. Exotic populations of this barnacle in Japanese waters have been reported after the year 2000.

Impact: Unknown.

Bibliography:

Kado R. 2003. Invasion of Japanese shores by the NE Pacific barnacle *Balanus glandula* and its ecological and biogeographical impact. *Marine Ecology Progress Series*. V. 249. P. 199–206.

(TF, SN)

Amphibalanus amphitrite (Darwin, 1854)

Common name: Vertical stripe barnacle;

Japanese name: Tatejima fujitsubo;

Korean name: Ju-geog-dda-gae-bi (means spatula-shaped).

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

Fig. 74. Vertical stripe barnacle *Amphibalanus amphitrite* in Japan, left; in Pusan Harbor, right.

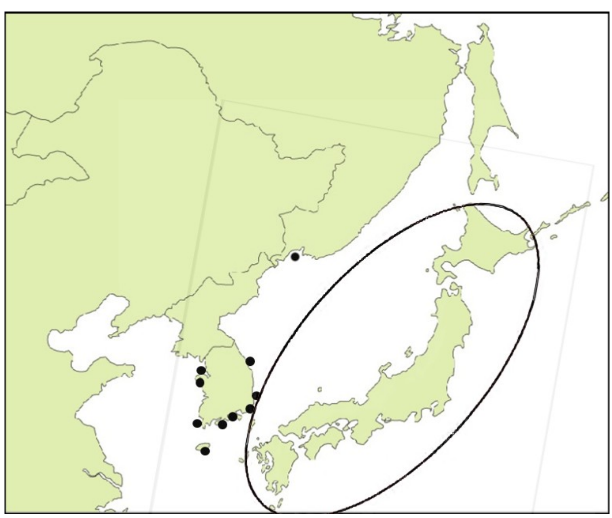

Fig. 75. Distribution of *Amphibalanus amphitrite* in Japan, Korea and Russia.

Regional distribution: **Japan:** Almost entire Japanese coasts, and Okinawa;
Korea;
Russia: Peter the Great Bay.

Possible origin: southwest Pacific and Indian Ocean.

Possible way of introduction: Ship hull-fouling, ballast-water.

Habitat: Intertidal concrete walls and rocks in embayment waters. One of the most dominant sessile animals on the intertidal hard substrata in enclosed waters in central to western Japan. It is shoreline species distributed from upper to mid intertidal zone; it inhabits intertidal hard substrates such as rocks, oyster bed, shell surface, ship bottom, pilings, seawalls and other hard substrates.

Impact: Compete with native barnacles, biofouling. *B. amphitrite* is a serious problem for ship hulls, buoy, and pilings. Probably some competition for space with native barnacles or other bio-fouling organisms. However, recent report suggested that *B. amphitrite* and the congener *B. eburneus* are capable of persisting side-by-side.

Bibliography:

Kim I.H. 1998. *Illustrated Encyclopedia of Fauna and Flora of Korea.* Vol. 38: *Cirripedia, Symbiotic Copepoda, Pycnogonida.* Seoul: Ministry of Education. 1038 p.

Otani M. 2004. Introduced marine organisms in Japanese coastal waters, and the process involved in their entry. *Japanese Journal of Benthology*. V. 59. P. 45–57. [in Japanese with English abstract].

Poltarukha O.P., Korn O.M. and Ponomarenko E.A. 2006. Crustacea (Thoracica and Facetotecta). *Biota of the Russian Waters of the Sea of Japan.* V. 6. Vladivostok: Dalnauka. P. 1–152. [in Russian and English].

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea.* Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

Zevina G.B. and Gorin A.N. 1975. Fluctuation of cirripede barnacles in the fouling of buoys in Peter the Great Bay. **In**: G.B. Zevina (Ed.). *Fouling in the Sea of Japan and Sea of Okhotsk.* Vladivostok: Far East Sci. Center, USSR Academy of Sciences. P. 71–78. [in Russian].

Zvyagintsev A.Yu. 2003. Introduction of species into the northwestern Sea of Japan and the problem of marine fouling. *Russian Journal of Marine Biology.* V. 29, Suppl. 1. P. S10–S21.

(TF, SN, KL, KS)

Amphibalanus improvisus (Darwin, 1854)

Common name: European barnacle;

Japanese name: Yoroppa fujitsubo;

Korean name: Heuin-Dda-Gae-Bi.

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

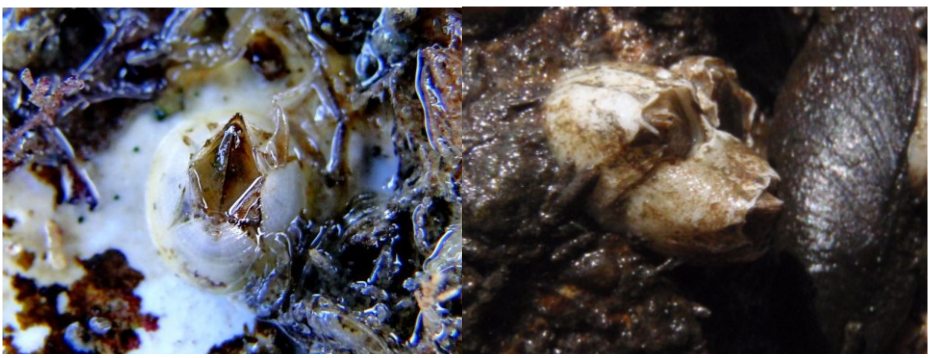

Fig. 76. European barnacle, *Amphibalanus improvisus* in Japan; left; in Dasan harbor, Korea, right.

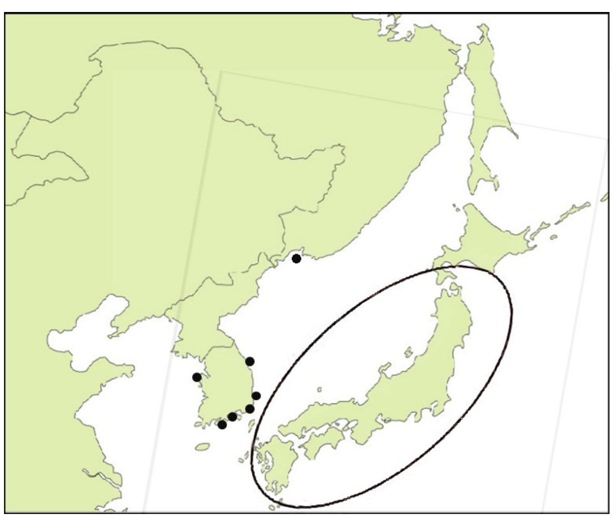

Fig. 77. Distribution of *Amphibalanus improvisus* in Japan, Korea and Russia.

Regional distribution: **Japan:** Honshu, Shikoku, and Kyushu;
Korea;
Russia: Peter the Great Bay.

Possible origin: North Atlantic.

Possible way of introduction: Ship hull-fouling and ballast water.

Habitat: Hard substrata in estuary and embayment waters. The European barnacle tends to be abundant in eutrophicated brackish waters. Habitats are partially overlapped with the American barnacle that tends to prefer more saline waters than the European barnacle. Attached to rocks and other hard substrata such as submerged wood, ship hulls, and oyster or mussel shells. Frequently found in lagoons in Gangwon Province (Korea).

Impact: Fouling organism. It is common fouler caused to large aggregations on a variety of harbor structures, aquaculture gears, and ship hulls. Space competition is likely to occur with other hard fouling species. It can causes fouling of water intake pipes and heat exchangers.

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Kim I.H. 1998. *Illustrated Encyclopedia of Fauna and Flora of Korea.* Vol. 38: *Cirripedia, Symbiotic Copepoda, Pycnogonida*. Seoul: Ministry of Education. 1038 p.

Kosaka A. 1985. Barnacles, competition for wharf surface. **In**: M. Okiyama and K. Suzuki (Eds.) *Marine Organisms in Japan*, *Ecology of Invasion and Disturbance.* Tokyo: Tokai University Press. P. 61–68. [in Japanese].

Ovsyannikova I.I. 2008. Barnacles in benthic communities of the inner part of Amursky Bay (Sea of Japan). **In**: K.A. Lutaenko and M.A. Vaschenko (Eds.). *Ecological Studies and the State of the Ecosystem of Amursky Bay and the Estuarine Zone of the Razdolnaya River* (*Sea of Japan*). Vladivostok: Dalnauka. P. 207–222.

Poltarukha O.P., Korn O.M. and Ponomarenko E.A. 2006. Crustacea (Thoracica and Facetotecta). *Biota of the Russian Waters of the Sea of Japan.* V. 6. Vladivostok: Dalnauka. P. 1–152. [in Russian and English].

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

Zevina G.B. and Gorin A.N. 1971. Introduction of *Balanus improvisus and B. eburneus* into the Sea of Japan. *Zoologichesky Zhurnal*. V. 50, N 5. P. 771–773.

Zvyagintsev A.Yu. 2005. *Marine Fouling in the North-West Part of Pacific Ocean*. Vladivostok: Dalnauka. 431 p. [in Russian].

(TF, SN, KL, KS)

Amphibalanus eburneus Gould, 1841

Common name: American barnacle;

Japanese name: Amerika fujitsubo;

Korean name: Datch-dda-gae-bi (ivory banacle).

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

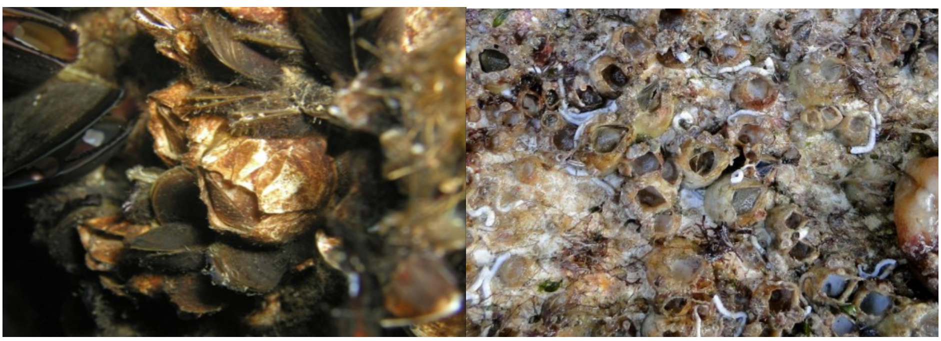

Fig. 78. American barnacle, *Amphibalanus eburneus* in Japan, left; in Tongyeong Harbor, Korea, right.

Fig. 79. Distribution of *Amphibalanus eburneus* in Japan and Korea.

Regional distribution: Japan: Honshu, Shikoku, and Kyushu;
Korea;
Russia: only ship fouling.

Possible origin: West Atlantic.

Possible way of introduction: Ship hull-fouling and ballast water.

Habitat: Concrete walls and rocks in estuaries and embayment waters. The American barnacle occurs in brackish and enclosed waters in Japan. This species sometimes competes with the European barnacle, but tends to be abundant in more saline waters compared with the European barnacle. Attached massively to the hard substrates such as rocks, oyster beds, shell surfaces, ship bottom, buoys.

Impact: *B. ebruneus* is a serious problem as fouling organism on ship hulls, buoys, and dock pilings. Space competition is likely to occur with native barnacle *B. trigonus* or other hard fouling species; however, recent report suggested that *B. eburneus* and the congener *B. amphitrite* are capable of persisting side-by-side.

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Henry D.P. and McLaughlin P.A. 1975. The barnacles of the *Balanus amphitrite* complex (Cirripedia, Thoracica). *Zoologische Verhandelingen.* V. 141. P. 1–254.

Kim I.H. 1998. *Illustrated Encyclopedia of Fauna and Flora of Korea*. Vol. 38: *Cirripedia, Symbiotic Copepoda, Pycnogonida*. Seoul: Ministry of Education. 1038 p.

Poltarukha O.P., Korn O.M. and Ponomarenko E.A. 2006. Crustacea (Thoracica and Facetotecta). *Biota of the Russian Waters of the Sea of Japan*. V. 6. Vladivostok: Dalnauka. P. 1–152. [in Russian and English].

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

Zevina G.B. and Gorin A.N. 1971. Introduction of *Balanus improvisus* and *B. eburneus* into the Sea of Japan. *Zoologichesky Zhurnal*. V. 50, N 5. P. 771–773.

(TF, SN, KL, KS)

Amphibalanus zhujiangensis Ren, 1989

Common name: Zhujiang barnacle;

Japanese name: Zujan fujitsubo; Zujan barnacle.

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

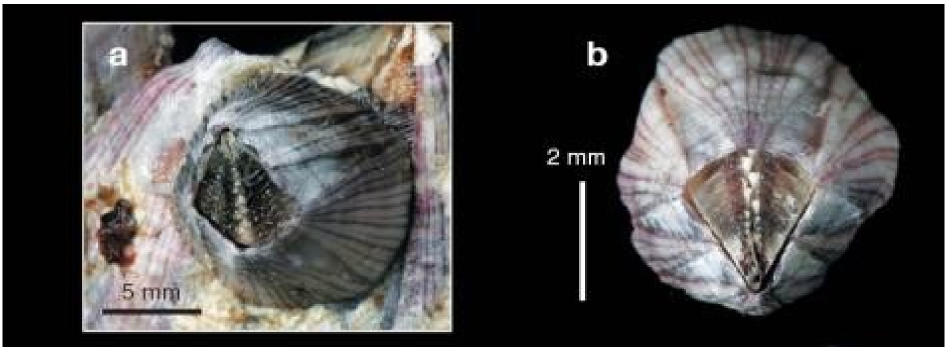

Fig. 80. *Amphibalanus zhujiangensis* in Taiwan, a, b: top views.

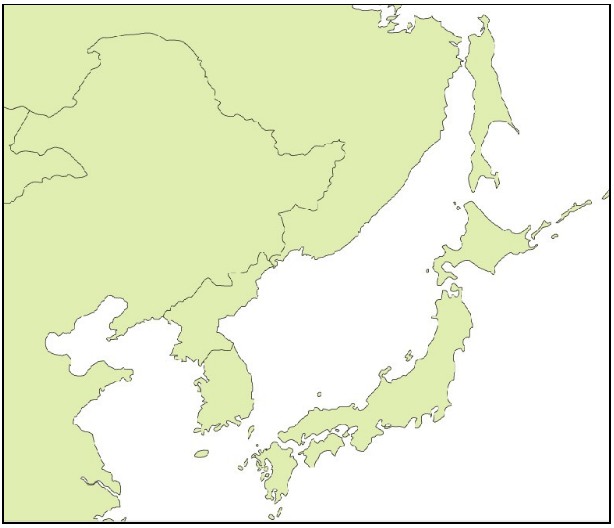

Fig. 81. Distribution of *Amphibalanus zhujiangensis* in Japan (only Okinawa, not shown).

Distribution: Japan: Okinawa.

Possible origin: China or Indonesia.

Possible way of introduction: Ship hull-fouling.

Habitat: Intertidal and shallow rocks.

Impact: Unknown.

Bibliography:

Yamaguchi T. 2010. New exotic barnacles: the newest information. **In:** The Plankton Society of Japan and the Japanese Association of Benthology (Eds.). *Marine Aliens Introduced by Human Activities and Their Impacts on Ecosystems and Industries*. Hatano: Tokai University Press. P. 49–71. [in Japanese].

(TF, SN)

Megabalanus coccopoma (Darwin, 1854)

Common name: Titan acorn barnacle;

Japanese name: Kokopoma aka-fujitsubo; Coccopoma red barnacle.

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

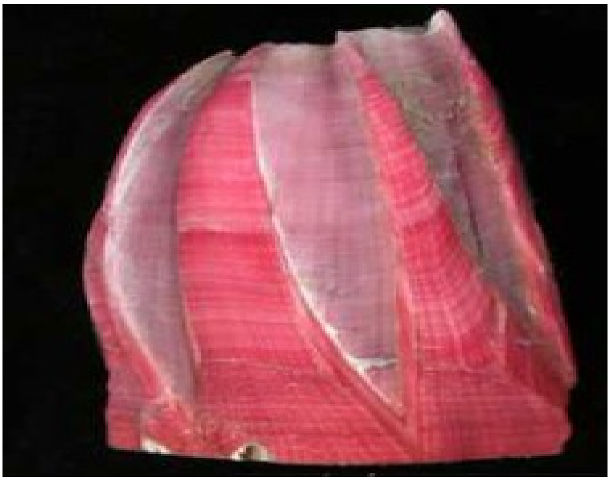

Fig. 82. *Megabalanus coccopoma.*

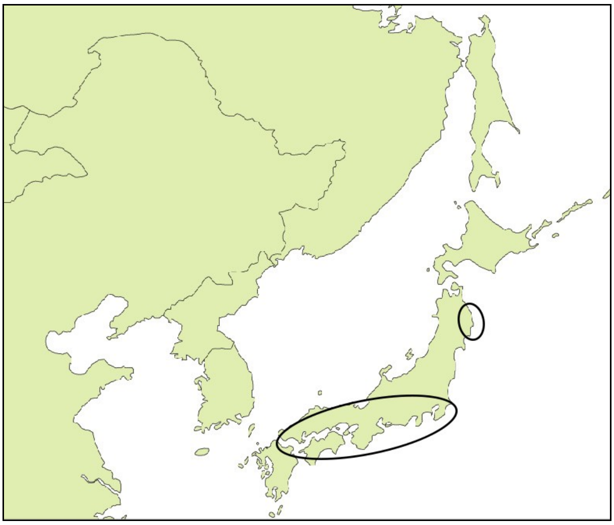

Fig. 83. Distribution of *Megabalanus coccopoma* in Japan.

Regional distribution: **Japan:** Iwate Prefecture to Tokyo Bay, Sagami Bay, Izu Peninsula, Kii Peninsula, Seto Inland Sea, Kochi Prefecture.

Possible origin: Tropical East Pacific.

Possible way of introduction: Ship hull-fouling.

Habitat: Shallow concrete and rocks, buoys. This barnacle occurs on subtidal rocks and aquaculture ropes in open and enclosed waters.

Impact: Unknown.

Bibliography:

Yamaguchi T., Prabowo R.E., Ohshiro Y., Shimono T., Jones D., Kawai H., Otani M., Oshino A., Inagawa S., Akaya T., and Tamura I. 2009. The introduction to Japan of the Titan barnacle, *Megabalanus coccopoma* (Darwin, 1854) (Cirripedia: Balanomorpha) and the role of shipping in its translocation. *Biofouling*, V. 25. P. 325–333.

(TF, SN)

Perforatus perforatus (Bruguière, 1789)

Common name: Perforate barnacle; Korean name: Hwa-san-dda-dae-bi (means volcano in habitus).

Taxonomy: Arthropoda, Maxillopoda, Thoracica, Sessilia, Balanidae.

Fig. 84. *Perforatus perforatus* in Guryongpo Harbor, Korea.

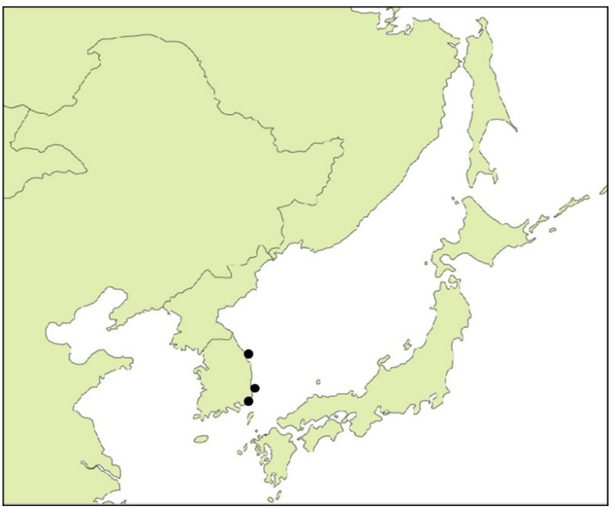

Fig. 85. Distribution of *Perforatus perforatus* in Korea.

Regional distribution: Korea;
Russia: only ship fouling.

Possible origin: This species is an eastern Atlantic warm-water species, occuring commonly in the Mediterranean. Its range extends southward to the north-western coast of Africa.

Possible way of introduction: unintentional, via balastwater and hull fouling of ships.

Habitat: Lower tidal species distributed from Gangneung to Pusan in only harbor condition; mainly attached to the hard substrates such as dock pilings (or wall), buoys, and other hard substrates in harbor.

Impact: Fouling organism. It is common fouler caused to large aggregations on a variety of harbor structures such as dock pilings, buoys, and other hard substrates. May not spread to natural rocky shore and small harbor. Space competition is likely to occur among *B. perforatus* and other barnacles or other hard fouling species.

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Kim I.H. 1998. *Illustrated Encyclopedia of Fauna and Flora of Korea*. Vol. 38: *Cirripedia, Symbiotic Copepoda, Pycnogonida.* Seoul: Ministry of Education. 1038 p.

Poltarukha O.P., Korn O.M. and Ponomarenko E.A. 2006. Crustacea (Thoracica and Facetotecta). *Biota of the Russian Waters of the Sea of Japan.* V. 6. Vladivostok: Dalnauka. P. 1–152. [in Russian and English].

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

(KL, KS)

Paracerceis sculpta (Holmes, 1904)

Common name: Horn tail sea-cicada;

Japanese name: Tsuno umisemi; horn sea-cicada.

Taxonomy: Arthropoda, Crustacea, Isopoda, Sphaeromatidae.

Fig. 86. *Paracerceis sculpta* in Australia.

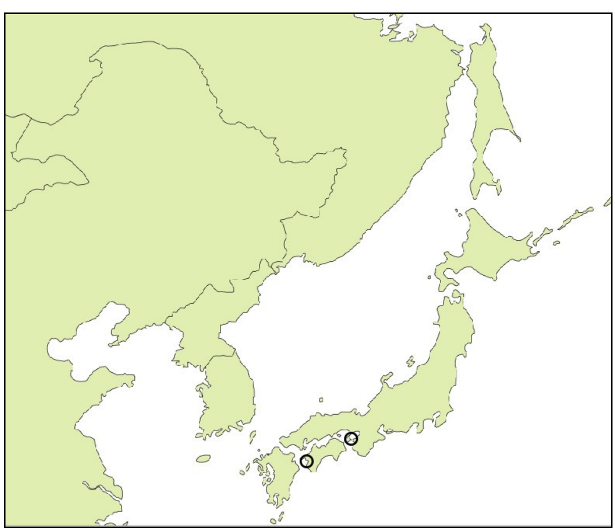

Fig. 87. Distribution of *Paracerceis sculpta* in Japan.

Regional distribution: Japan: Ehime Prefecture, Osaka Bay.

Possible origin: East Pacific.

Possible way of introduction: Ship hull-fouling.

Habitat: Intertidal and shallow subtidal artificial substrata and artificial sandy beaches.

Impact: Unknown.

Bibliography:

Ariyama H. and Otani M. 2004. *Paracerceis sculpta* (Crustacea: Isopoda: Sphaeromatidae), a newly introduced species into Osaka Bay, Central Japan. *Benthos Research*. V. 59. P. 53–59.

(TF, SN)

Portunus sanguinolentus (Herbst, 1783)

Common name: Blood-spotted swimming crab.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Portunidae.

Fig. 88. *Portunus sanguinolentus* in Taiwan.

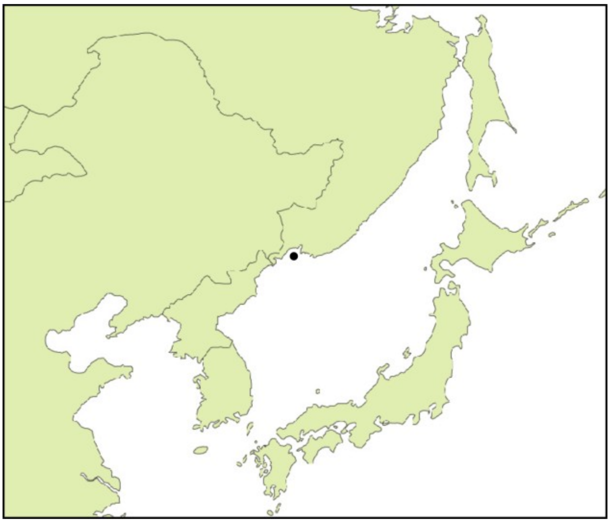

Fig. 89. Distribution of *Portunus sanguinolentus* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin: Tropical Indo-Pacific.

Possible way of introduction: drifting buoys.

Habitat: This tropical species occurs only in warm seasons with transported marine litter that serves as substrate for crabs and other organisms.

Impact: Unknown.

Bibliography:

Kepel A.A. and Tsareva L.A. 2005. First record of tropical crabs *Portunus sanguinolentus* (Herbst, 1783) and *Plagusia depressa tuberculata* Lamarck, 1818 in Peter the Great Bay, Sea of Japan. *Russian Journal of Marine Biology*. V. 31, N 2. P. 124–125.

(KL)

Plagusia depressa tuberculata Lamarck, 1818

Note: A possible synonym of *Plagusia squamosa* (Herbst, 1790).

Common name: Scaly rock crab.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Plagusiidae.

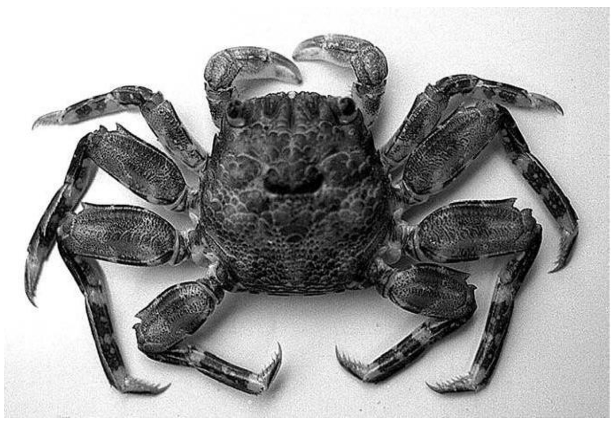

Fig. 90. Crab *Plagusia depressa tuberculata* in Peter the Great Bay.

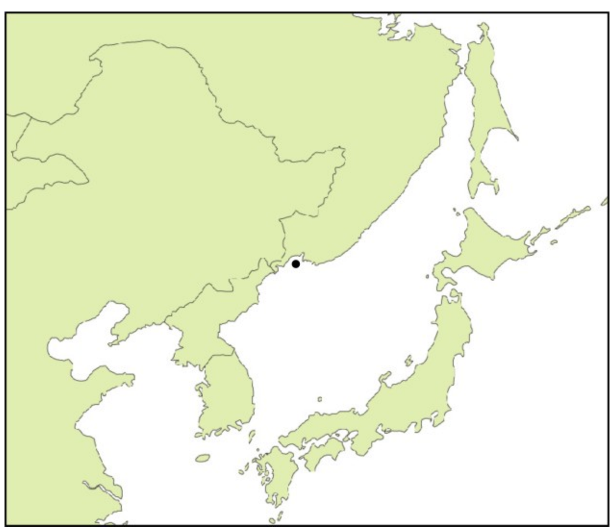

Fig. 91. Distribution of *Plagusia depressa tuberculata* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin: Tropical Indo-Pacific.

Possible way of introduction: Drifting buoys.

Habitat: This tropical species occurs only in warm seasons with transported marine litter that serves as substrate for crabs and other organisms.

Impact: Unknown.

Bibliography:

Kepel A.A. and Tsareva L.A. 2005. First record of tropical crabs *Portunus sanguinolentus* (Herbst, 1783) and *Plagusia depressa tuberculata* Lamarck, 1818 in Peter the Great Bay, Sea of Japan. *Russian Journal of Marine Biology.* V. 31, N 2. P. 124–125.

(KL)

Pyromaia tuberculata (Lockington, 1877)

Common name: Single-horn spider crab, American spider crab;

Japanese name: Ikkaku kumo-gani, Uni-horn spider crab.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Majidae.

Fig. 92. Single-horn spider crab *Pyromaia tuberculata* in Japan.

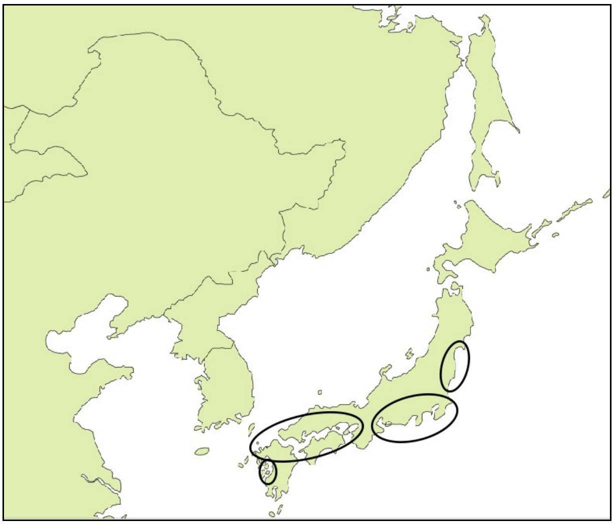

Fig. 93. Distribution of *Pyromaia tuberculata* in Japan.

Regional distribution: Japan: Pacific coast from Sendai to Yamaguchi including Seto Inland Sea, northern Kyushu, Ariake Bay;
Korea.

Possible origin: East Pacific.

Possible way of introduction: Ballast water and ship hull-fouling.

Habitat: Sand and mud shallow bottoms in enclosed waters. This crab abundantly occurs on subtidal bottom in eutrophicated enclosed waters where summer hypoxia tends to be severe. Rapid growth (reach maturity within 3 months after hatched) and omniseasonal breeding (breeds throughout the year) supports quick recovery of local populations which had disappeared by summer hypoxia.

Impact: Unknown.

Bibliography:

Furota T. and Kinoshita K. 2004. Life histories of introduced crabs, the majid, *Pyromaia tuberculata* and the portunid, *Cercinus aestuarii*, in Tokyo Bay, and their adaptability to seasonal hypoxic environment caused by organic pollution. *Japanese Journal of Benthology*. V. 59. P. 96–104. [in Japanese with English abstract].

Oh S.M. and Ko H.S. 2010. Complete larval development of *Pyromaia tuberculata* (Crustacea: Decapoda: Majoidea: Inachoididae). *Animal Cells and Systems.* Volume 14, Issue 2, 2010. P. 129–136.

(TF, SN, KS)

Rhithropanopeus harrisii (Gould, 1841)

Common name: Estuarine mud crab, Harris mud crab;

Japanese name: Minato Ogi-gani, port panopeid crab.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Panopeidae.

Fig. 94. *Rhithropanopeus harrisii* in Japan.

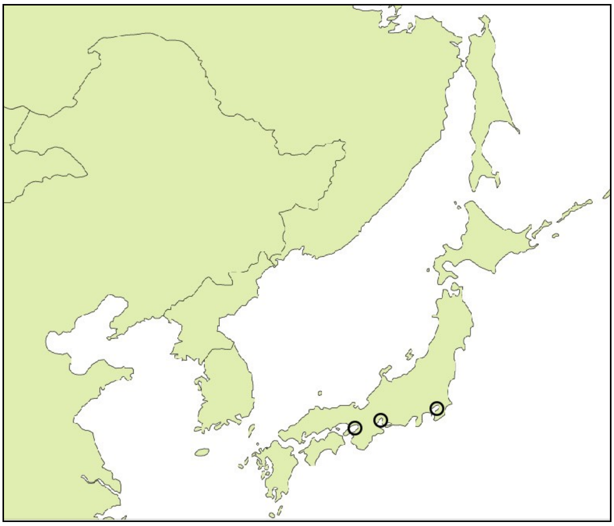

Fig. 95. Distribution of *Rhithropanopeus harrisii* in Japan.

Regional distribution: Japan: Ise Bay, Osaka Bay, Tokyo Bay.

Possible origin: West Atlantic

Possible way of introduction: Ship hull-fouling.

Habitat: Enclosed low saline waters. This crab was abundantly found in brackish-water ports in enclosed areas. A small number of the crab was also found in upper small estuaries.

Impact: Unknown.

Bibliography:

Iseda M., Otani M. and Kimura T. 2007. First record of an introduced crabs *Rhithropanopeus harrisii* (Crustacea: Brachyura: Panopeidae) in Japan. *Japanese Journal of Benthology*. V. 62. P. 39–44. [in Japanese with English abstract].

(TF, SN)

Carcinus aestuarii Nardo, 1847

Common name: Mediterranean green crab;

Japanese name: Chichuukai Midori-gani; Mediterranean green crab.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Portunidae.

Fig. 96. Mediterranean green crab *Carcinus aestuarii* in Japan.

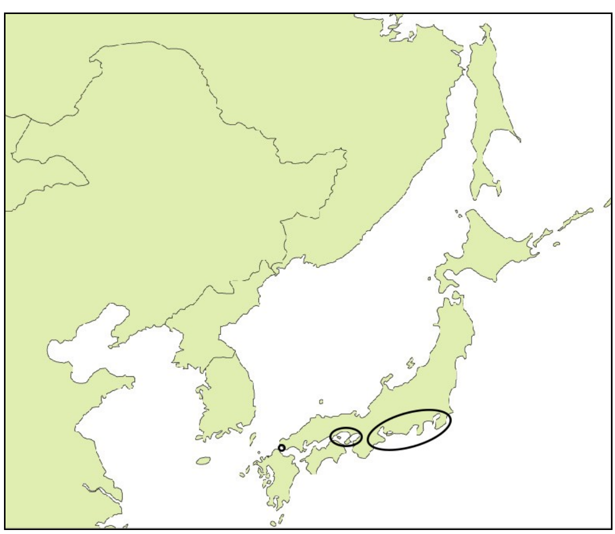

Fig. 97. Distribution of *Carcinus aestuarii* in Japan.

Regional distribution: Japan: Pacific coast from Tokyo Bay to Osaka Bay, northern Kyushu.

Possible origin: Mediterranean Sea.

Possible way of introduction: Ballast water, ship hull-fouling.

Habitat: Artificial canals, ports and cobble shores. The green crab occurs on shores in brackish and eutrophicated enclosed waters, such as ports and artificial channels in urbanized bays. The crab migrates offshore to the bay bottom during winter when it breeds, but comes back to the shore in spring and stays there during warmer seasons. This migratory pattern is very well adapted to survive in eutrophicated waters, as the crab can avoid being captured in summer-hypoxic bottom water.

Impact: Unknown.

Bibliography:

Furota T. and Kinoshita K. 2004. Life histories of introduced crabs, the majid, *Pyromaia tuberculata* and the portunid, *Cercinus aestuarii*, in Tokyo Bay, and their adaptability to seasonal hypoxic environment caused by organic pollution. *Japanese Journal of Benthology*. V. 59. P. 96–104. [in Japanese with English abstract].

(TF, SN)

Diogenes nitidimanus Terao, 1913

Common name: Sand-dwelling hermit crab.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Diogenidae.

Fig. 98. *Diogenes nitidimanus* from Peter the Great Bay.

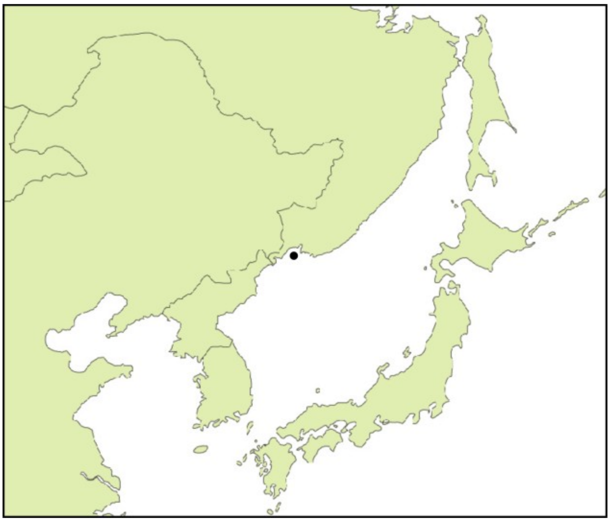

Fig. 99. Distribution of *Diogenes nitidimanus* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin: Japan.

Possible way of introduction: Ballast water.

Habitat: This hermit crab's settlement was found in the estuarine part of Vostok Bay (eastern Peter the Great Bay) on a silty bottom at a depth of 2–3 m; the hermit crabs inhabits shells of the gastropod mollusks *Batillaria cumingii, Linatia pallida*, *Littorina squalida,* and *Umbonium costatum* (Korn et al., 2007). The larva of the hermit crab was found in the ballast waters of the tanker *Minotaur* that arrived from the Chinese port of Laizhou (Yellow Sea) (Zvyagintsev, Kornienko, 2008).

Impact: Unknown.

Bibliography:

Korn O.M., Kornienko E.S. and Komai T. 2008. A reexamination of adults and larval stages of *Diogenes nitidimanus* (Crustacea: Decapoda: Anomura: Diogenidae). *Zootaxa.* N 1693. P. 1–26.

Korn O.M., Kornienko A.S. and Zvyagintsev A.Yu. 2007. Naturalization of the hermit crab *Diogenes nitidimanus* Terao, 1913 (Decapoda: Anomura: Diogenidae) in Vostok Bay, Sea of Japan: hypothesis or reality? *Izvestiya TINRO*. V. 150. P. 291-297. [in Russian with English abstract].

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(KL)

Litopenaeus stylirostris Stimpson, 1894

Common name: Blue shrimp.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Penaeidae.

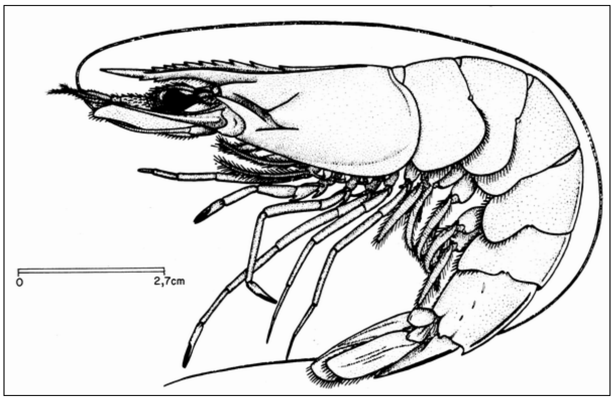

Fig. 100. Blue shrimp *Litopenaeus stylirostris.*

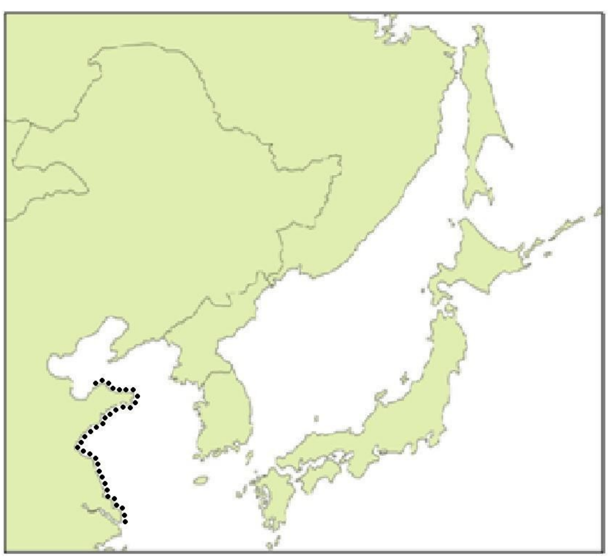

Fig. 101. Distribution of *Litopenaeus stylirostris* in China.

Regional distribution: China: coastal areas of Shandong and Jiangsu.

Possible origin: Eastern Pacific.

Possible way of introduction: Aquaculture and self-dispersion.

Habitat: Sandy, muddy bottom in subtidal zone.

Impact: The species can hybridize and compete with native species, causing genetic diversity damage and contamination of the native marine ecosystem.

Bibliography:

Huang J. 2001. Farming technology of blue shrimp. *Journal of Aquaculture.* V. 5. P. 26–28.

Song Q. 2005. Study on biology of blue shrimp, *Litopenaeus stylirostris,* muscle nutrient composition and post-larvae acclimation technique for fresh water farming practice: Master's Degree Thesis, Nanjing Agricultural University. P. 11–17. [in Chinese with English abstract].

(XJ)

Litopenaeus vannamei Boone, 1931

Common name: White shrimp.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Penaeidae.

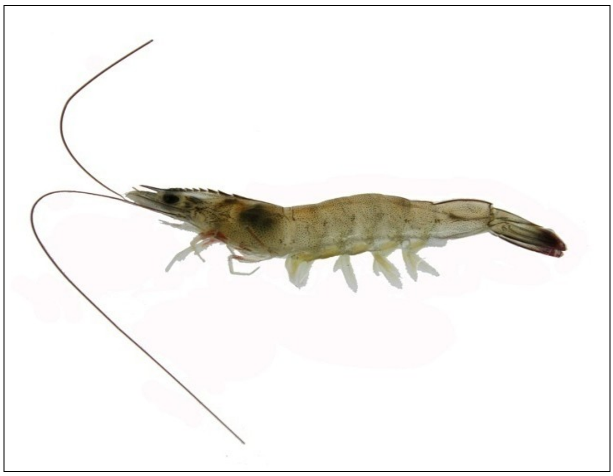

Fig. 102. White shrimp *Litopenaeus vannamei.*

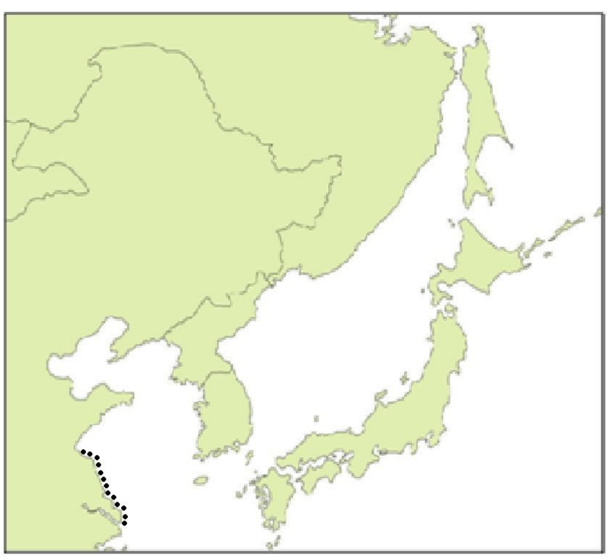

Fig. 103. Distribution of *Litopenaeus vannamei* in China.

Regional distribution: China: Jiangsu Province.

Possible origin: East coast of the Pacific Ocean.

Possible way of introduction: Aquaculture and self-dispersion.

Habitat: Muddy bottom, 0-72 m deep.

Impact: Imported white shrimps often carry pathogens leading to a shrimp disease. Farming white shrimps in pools also cause salinization of land.

Bibliography:

Chen C., Huang B., Ye Z. et al. 2001. Effect of temperature on growth, food intake and survival rate in *Penaeus vannamei* under different temperature conditions. *Journal of Jimei University, Natural Science*. V. 6, N 4. P. 296–300.

Wang X., Ma S., Dong S. 2004. Studies on the biology and cultural ecology of *Litopenaeus vannamei*: a review. *Transactions of Oceanology and Limnology.* V. 4. P. 94–100.

Yano I., Kanna R.A., Oyama R.N. and Wyban J.A. 1988. Mating behaviour in the penaeid shrimp *Penaeus vannamei. Marine Biology*. V. 97, N 2. P. 172–175.

(XJ)

Marsupenaeus japonicus Bate, 1888

Common name: Kuruma prawn.

Taxonomy: Arthropoda, Malacostraca, Decapoda, Penaeidae.

Fig. 104. *Marsupenaeus japonicus*.

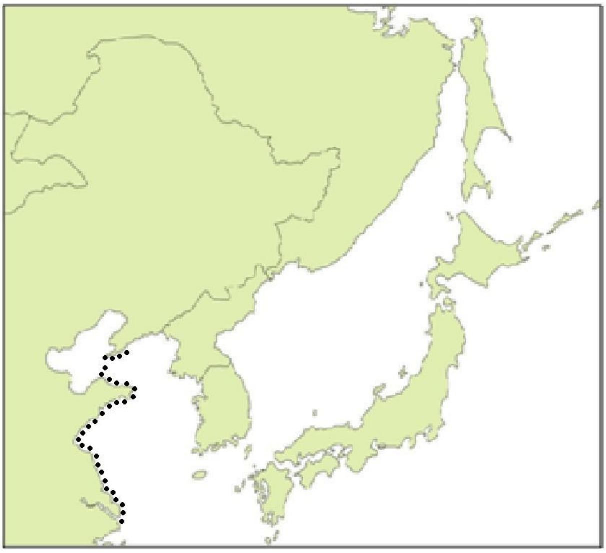

Fig. 105. Distribution of *Marsupenaeus japonicus* in China.

Regional distribution: China: coastal areas of the north China.

Possible origin: Japan.

Possible way of introduction: Aquaculture and self dispersion.

Habitat: Sandy and muddy bottom in coastal waters usually less than 30 m deep.

Impact: This species can hybridize and compete with native species causing genetic diversity damage and contamination of the native marine ecosystem.

Bibliography:

Song H., Yu C., Yao G. et al. 2005. Biomass variation and distribution of *Penaeus japonicus* in the East China Sea. *Donghai Marine Science*. V. 23, N 1. P. 48–53.

Song L., Xiang J., Li C. et al. 1999. Study of population genetic structure in *Penaeus japonicus* with RAPD markers. *Oceanologia et Limnologia Sinica*. V. 30, N 5. P. 261–266.

Wang R., Jiang L., Li J. 2007. The effects of ammonia-N and sulfureted hydrogen on the growth and ecdysis of *Penaeus japonicus* larvae. *Marine Sciences*. V. 20, N 11. P. 51–54.

(XJ)

Monocorophium acherusicum (Costa, 1851)

Common name: Mediterranean corophiid, tube-building amphipod.

Taxonomy: Arthropoda, Malacostraca, Amphipoda, Corophiidae.

Fig. 106. Mediterranean corophiid *Monocorophium acherusicum*.

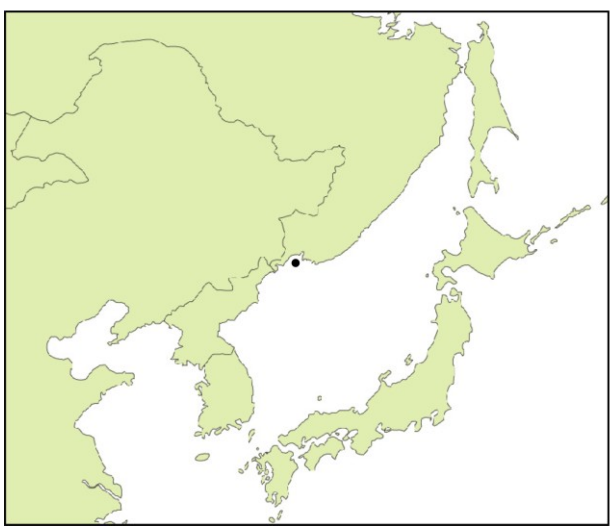

Fig. 107. Distribution of *Monocorophium acherusicum* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin: Atlantic.

Possible way of introduction: Ballast water, ship fouling.

Habitat: This species was first found in Peter the Great Bay only as a component of fouling communities (Zevina, Gorin, 1975) and then was recorded in benthic communities in southwestern Peter the Great Bay and around the mouth of the Tumen River (Budnikova, 2001).

Impact: *M. acherusicum* was found in the fouling of the water cooling system on Heat and Power Station No. 2 of Vladivostok (Zvyagintsev, Budnikova, 2003).

Bibliography:

Budnikova L.L. 2001. Benthic amphipods (Crustacea: Amphipoda) in the southwestern part of Peter the Great Bay. **In:** V.L. Kasyanov, M.A. Vaschenko and D.L. Pitruk (Eds.). *The State of Environment and Biota of the Southwestern Part of Peter the Great Bay and the Tumen River Mouth.* Vladivostok: Dalnauka. V. 2. P. 98–109.

Zevina G.B. and Gorin A.N. 1975. Fluctuation of cirripede barnacles in the fouling of buoys in Peter the Great Bay. **In:** G.B. Zevina (Ed.). *Fouling in the Sea of Japan and Sea of Okhotsk.* Vladivostok: Far East Sci. Center, USSR Academy of Sciences. P. 71–78. [in Russian].

Zvyagintsev A.Yu. and Budnikova L.L. 2003. Amphipods (Amphipoda, Crustacea) in the fouling of water cooling system of Heat and Power Station No. 2 in Vladivostok. *Izvestiya TINRO-Center*. V. 132. P. 280–298. [in Russian with English abstract].

(KL)

Bugula neritina (L., 1758)

Common name: Brown bryozoan;

Korean name: Keun-da-bal-i-ggi-beol-re (means large bundle).

Taxonomy: Bryozoa, Gymnolaemata, Cheilostomata, Bugulidae.

Fig. 108. *Bugula neritina* in Tongyeong Harbor, Korea.

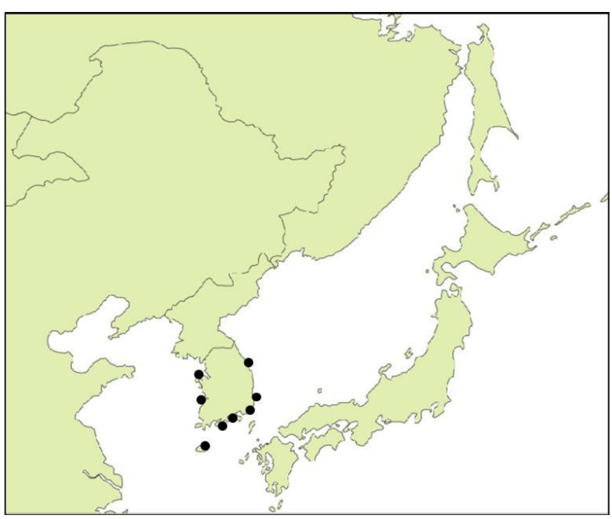

Fig. 109. Distribution of *Bugula neritina* in Korea.

Regional distribution: Korea.

Possible origin: Western Atlantic.

Possible way of introduction: unintentional, via balastwater and hull fouling of ships.

Habitat: Submerged rope, fishery net, other aquaculture gears; harbor or marine structures and ship bottoms; natural rocks from lower intertidal to more than 20 m deep.

Impact: Fouling organism. *B. neritina* populations may tolerate high levels of pollution (including copper) which increases its potential to be a fouling pest. It is a common fouling organism growing in large aggregations on a variety of harbor structures, aquaculture gears, and ship hulls. Space competition is unclear but likely to occur with other fouling species .

Bibliography:

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

(KS)

Bugula stolonifera Ryland, 1960

Taxonomy: Bryozoa, Gymnolaemata, Cheilostomata, Bugulidae.

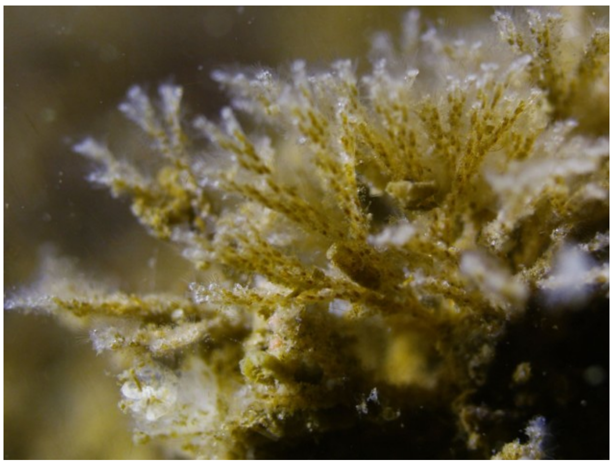

Fig. 110. *Bugula stolonifera* in Japan.

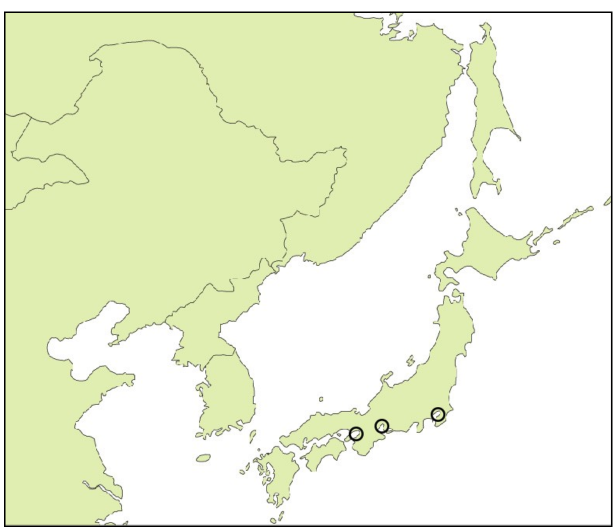

Fig. 111. Distribution of *Bugula stolonifera* in Japan.

Regional distribution: Japan: Tokyo Bay, Ise Bay, Osaka Bay.

Possible origin: Unknown.

Possible way of introduction: Ship hull-fouling.

Habitat: Artificial hard substrata in enclosed waters, in ports and canals.

Impact: Unknown.

Bibliography:

Scholz J., Nakajima K., Nishikawa T., Kaselowsky J. and Mawatari S.F. 2003. First discovery of *Bugula stolonifera* Ryland, 1960 (phylum Bryozoa) in Japanese waters, as an alien species to the Port of Nagoya. *Bulletin of the Nagoya University Museum.* V. 19. P. 9–19.

(TF, SN)

Bugula californica Robertson, 1905

Common name: Spiral bryozoan;

Korean name: Kael-ri-po-ni-a-i-ggi-beol-re (means Califormia).

Taxonomy: Bryozoa, Gymnolaemata, Cheilostomata, Bugulidae.

Fig. 112. *Bugula californica* in Tongyeong Harbor, Korea.

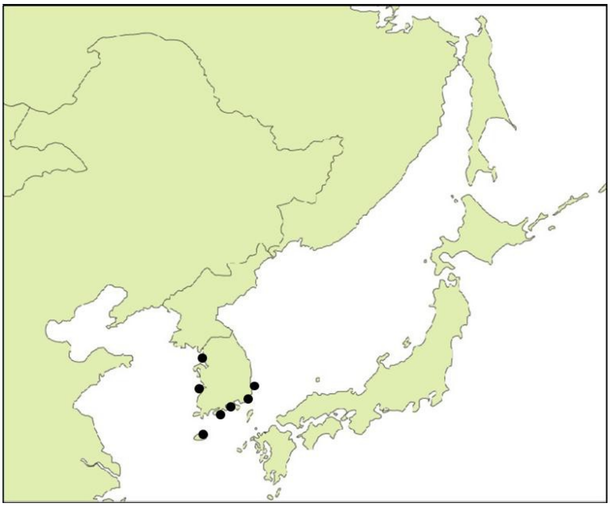

Fig. 113. Distribution of *Bugula californica* in Korea.

Regional distribution: Korea.

Possible origin: British Columbia to the Galapagos Islands, Hawaii.

Possible way of introduction: unintentional, via balastwater and hull fouling of ships.

Habitat: Harbor or marina structures and ship hulls; aquaculture facilities such as submerged rope, fishery net, other culture gears; attached to rocks, sponges, macroalgal species, and invertebrate surfaces from lower intertidal to mainly below 10 m deep.

Impact: Fouling organism. It lives in large aggregations on a variety of harbor structures, aquaculture gears, and ship hulls. Space competition is unclear but likely to occur with other hard fouling species in the minor level.

Bibliography

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

Seo J.E. 2005. *Illustrated Encyclopedia of Flora and Fauna of Korea*. Vol. 40. *Bryozoa*. Seoul: Ministry of Education and Human Resources Development. 596 p.

(KS)

Tricellaria occidentalis (Trask, 1857)

Korea name: Se-bang-ga-si i-ggi-beol-re (means tri-cell spine as genus name).

Taxonomy: Bryozoa, Gymnolaemata, Cheilostomata, Scrupocellariidae.

Fig. 114. *Tricellaria occidentalis* in Tongyeong Harbor.

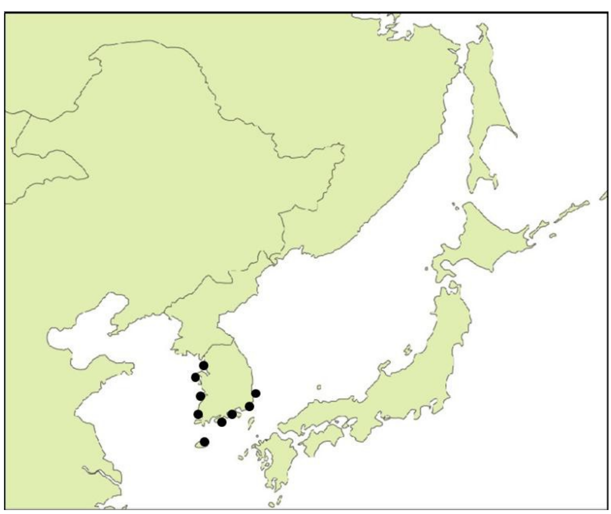

Fig. 115. Distribution of *Tricellaria occidentalis* in Korea.

Regional distribution: Japan; Korea.

Possible origin: California, and possibly British Columbia and Baja California.

Possible way of introduction: unintentional, hull fouling of ships and balast water.

Habitat: Intertidal to 40 m deep in fouling communities, on hard substrates and algae.

Impact: Fouling organism. It lives in large aggregations on a variety of harbor structures, aquaculture gears, and ship hulls. Space competition is unclear but likely to occur with other hard fouling species in the minor level.

Bibliography:

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

Mawatari S. 1951. On *Tricellaria occidentalis* (Trask), one of the fouling bryozoans in Japan. *Miscellaneous Reports of the Research Institute of Natural Resources.* V. 22. P. 9–16.

(KS)

Conopeum seurati (Canu, 1928)

Taxonomy: Bryozoa, Gymnolaemata, Cheilosromatida, Electridae.

Fig. 116. *Conopeum seurati.*

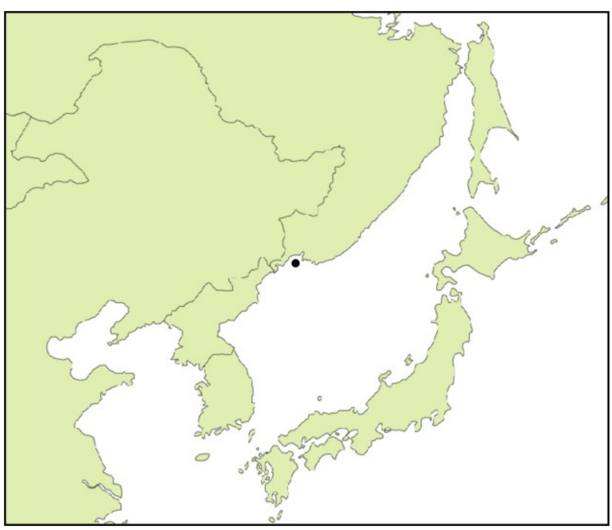

Fig. 117. Distribution of *Conopeum seurati* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin: Eastern Atlantic.

Possible way of introduction: Ship hull fouling.

Habitat: Fouling organism. It lives on hard substrata in the upper subtidal zone.

Impact: Unknown.

Bibliography:

Zvyagintsev A.Yu. 2003. Introduction of species into the northwestern Sea of Japan and the problem of marine fouling. *Russian Journal of Marine Biology*. V. 29, Suppl. 1. P. S10–S21.

(KL)

Schizoporella unicornis (Johnston 1874)

Common name: Orange encrusting bryozoan.

Taxonomy: Bryozoa, Gymnolaemata, Cheilosromatida, Schizoporellidae.

Fig. 118. *Schizoporella unicornis*.

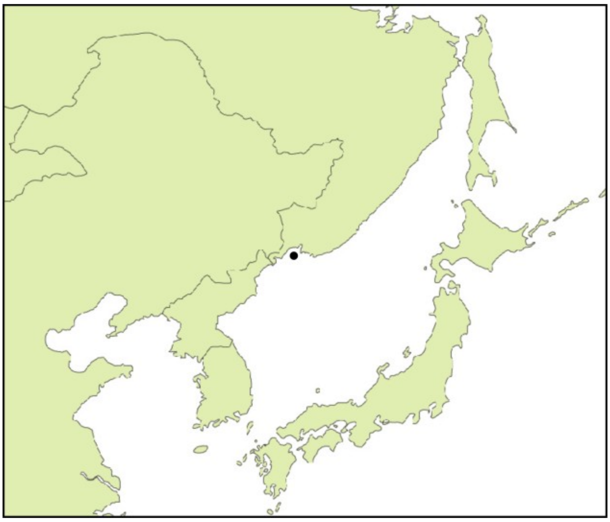

Fig. 119. Distribution of *Schizoporella unicornis* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin:

Possible way of introduction: Ship hull fouling.

Habitat: Fouling organism. It lives on hard substrata in the upper subtidal zone.

Impact: Unknown.

Bibliography:

Zvyagintsev A.Yu. 2003. Introduction of species into the northwestern Sea of Japan and the problem of marine fouling. *Russian Journal of Marine Biology.* V. 29, Suppl. 1. P. S10–S21.

(KL)

Strongylocentrotus intermidus A. Agassiz, 1863

Common name: Grey sea urchin.

Taxonomy: Echinodermata, Echinoidea, Camarodonta, Strongylocentrotidae.

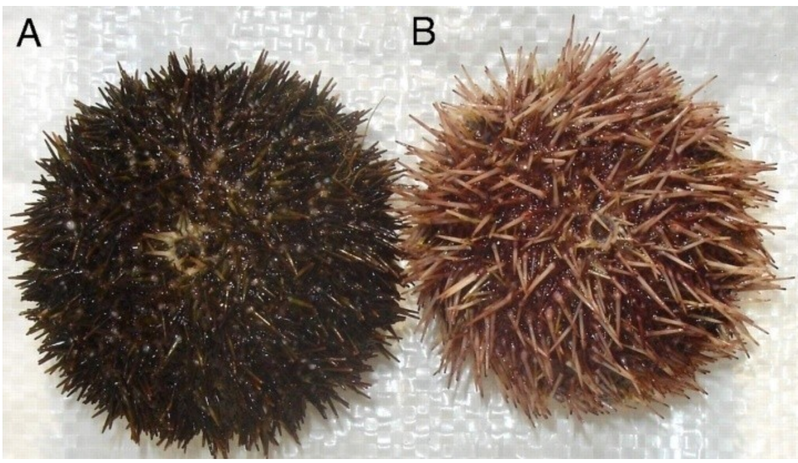

Fig. 120. *Strongylocentrotus intermidus*.

Fig. 121. Distribution of *Strongylocentrotus intermidus* of China.

Regional distribution: China: Coastal areas of Dalian and Rongcheng, Shandong.

Possible origin: Japan, Russian Far East?

Possible way of introduction: Aquaculture and self dispersion.

Habitat: rocky intertidal zone and ypper subtidal zones, 0–50 m.

Impact: This species competes with native species for food and living space.

Bibliography:

Balakirev E. S., Pavlyuchkov V. A. and Ayala F. J. 2008. DNA variation and symbiotic associations in phenotypically diverse sea urchin *Strongylocentrotus intermedius. Proceedings of the National Academy of Sciences of the United States of America.* V. 105, N 42. P. 16218–16223.

Ding J., Li R., Chang Y. et al. 2008. Isolation of microsatellite markers and genetic diversity analysis in three cultured populations of sea urchin (*Strongylocentrotus intermedius*). *Journal of Molecular Science.* V. 24, N 3. P.173–179.

Liang Y., Wang B. 2001. Alien marine species and their impacts in China. *Biodiversity Science*. V. 9, N 4. P. 458–465. [in Chinese with English abstract].

(XJ)

Styella plicata Lesuer, 1823

Common name: Pleated sea squirt, rough sea squirt;

Korean name: Ju-reum-mi-deo-deog (means winkles or projection).

Taxonomy: Chordata, Ascidacea, Pleurogona, Styelidae.

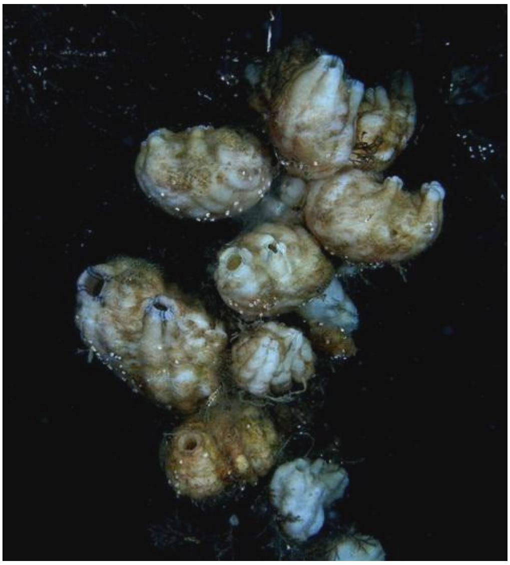

Fig. 122. *Styella plicata* in Tongyeong sea farm, Korea.

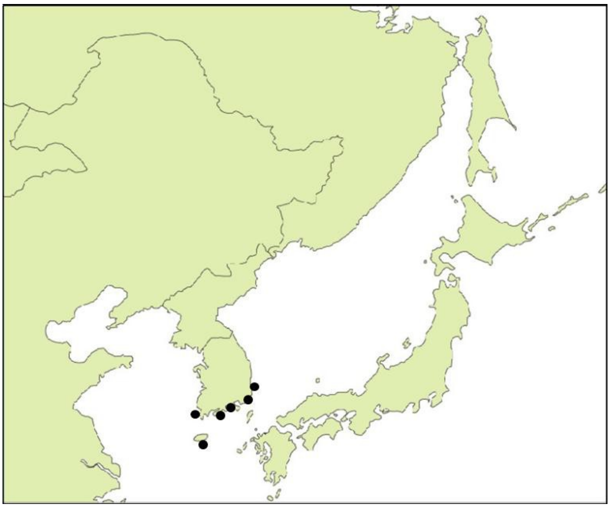

Fig. 123. Distribution of *Styella plicata* in Korea.

Regional distribution: Korea.

Possible origin: Indo-Pacific?

Possible way of introduction: Ballast water, hull fouling of ships, live bivalve for aquaculture.

Habitat: Aquaculture cages, rope, net and other man-made facilities; also found on pier walls and other harbor constructions. It may not spread to natural rocky shore. Commonly attached from surface to 5 m deep.

Impact: *S. plicata* is an aquaculture species in Korea. It is widespread in the southern coast of Korea and common fouler of aquaculture rope, net, and other floating or submerged man-made structures. It is also a common fouling organism of harbor constructions.

Bibliography:

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

(KS)

Ciona intestinalis (Linnaeus, 1767)

Common name: Sea vase;

Korean name: Yu-ryeong-meong-ge (means ghost in habitus).

Taxonomy: Chordata, Ascidacea, Euterogona, Cionidae.

Fig. 124. *Ciona intestinalis* in Tongyeong Harbor (photo by INTHESEA Korea, Inc.).

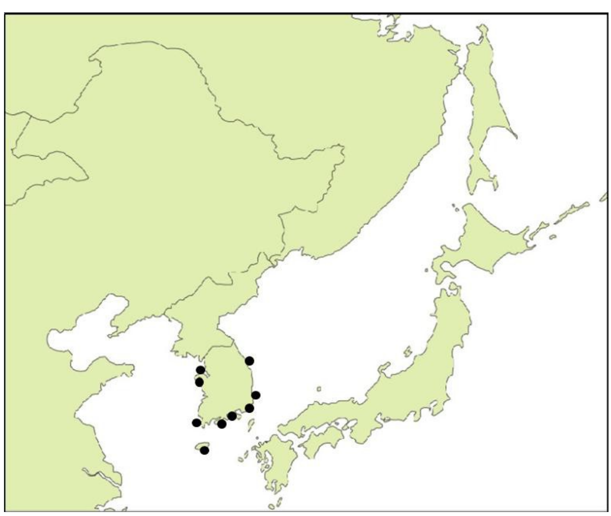

Fig. 125. Distribution of *Ciona intestinalis* in Korea.

Regional distribution: Korea.

Possible origin: northern Atlantic.

Comments: This species is considered as non-indigenous in northern Atlantic Canada. Molecular studies have identified two cryptic species: type A is now widely distributed in the Mediterranean and the Pacific, type B is widely distributed in the northern Atlantic, with both coexisting in the UK.

Possible way of introduction: Hull fouling of ships, ballast water, live aquaculture organisms.

Habitat: Aquaculture gear, farming organism surfaces; pier walls and other harbor or marina structures; it may not spread to natural rocky shore, however, sometimes observed in the natural rocky shore near sea farm, marina, and harbor. It is found from the lower intertidal down to at least 10 m deep.

Impact: Fouling organism. Ecological impact unstudied, but space competition is likely to occur with native or non-native invertebrates on the artificial constructions. *C. intestinalis* can reduce the productivity of mussel, oyster, or sea squirt farming by fouling aquaculture gear.

Bibliography:

Shin S., Sim J.J, Park J.H., Lee J.S., Kim I.H., Seo J.E., Kim H.S. and Kim S.H., 2010. *Oceanic Introduced Species of Korea*. Republic of Korea: Ministry of Land, Transport and Maritime Affairs. 27 p.

Suzuki M., Nishikawa T., and Bird A. 2005. Genomic approaches reveal unexpected genetic divergence within *Ciona intestinalis*. *Journal of Molecular Evolution*. V. 61. P. 627–635.

(KS)

Ciona savignyi Herdman, 1882

Common name: Pacific transparent sea squirt, solitary sea squirt.

Taxonomy: Chordata, Ascidacea, Euterogona, Cionidae.

Fig. 126. *Ciona savignyi.*

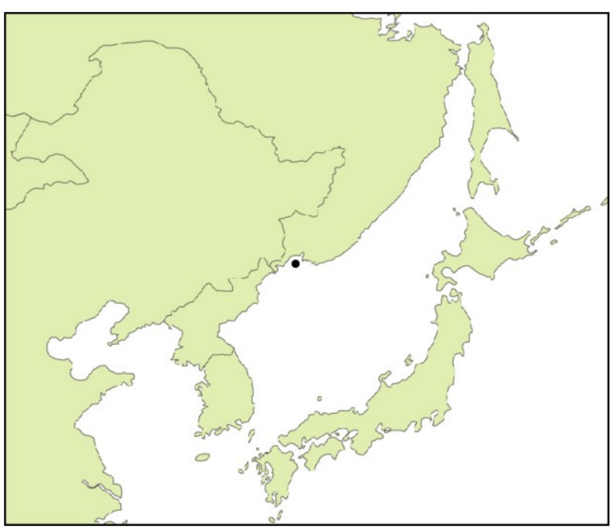

Fig. 127. Distribution of *Ciona savignyi* in Russia.

Regional distribution: Russia: Peter the Great Bay.

Possible origin: Japan?

Possible way of introduction: Hull fouling of ships.

Habitat: Hard substrata in the upper subtidal zone, including mussel shell surface.

Impact: Fouling organism.

Bibliography:

Zvyagintsev A.Yu., Sanamyan K.E. and Kashenko S.D. 2007. On the introduction of the ascidian *Ciona savignyi* Herdman, 1882 into Peter the Great Bay, Sea of Japan. *Russian Journal of Marine Biology*. V. 33, N 2. P. 133–136.

(KL)

Molgula manhattensis (De Kay, 1843)

Common name: Sea grape; Manhattan tunicate;

Japanese name: Manhattan boya.

Taxonomy: Chordata, Ascidiacea, Pleurogona, Molgulidae.

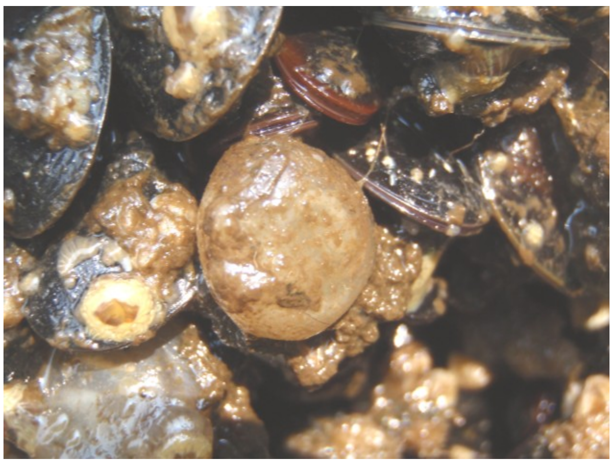

Fig. 128. *Molgula manhattensis* in Japan.

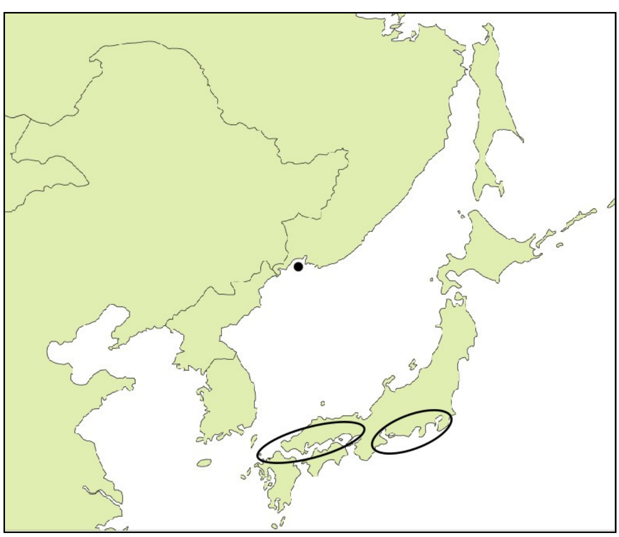

Fig. 129. Distribution of *Molgula manhattensis* in Japan and Russia.

Regional distribution: **Japan:** Pacific coast from Tokyo Bay and southward, northern Kyushu;

Russia: Peter the Great Bay.

Possible origin: Northeast and northwest Atlantic.

Possible way of introduction: Ship hull fouling.

Habitat: Subtidal hard substrata in estuarine and enclosed waters. This tunicate is occasionally found on artificial substrata and introduced mussels in enclosed waters. It tends to be abundant during colder seasons.

Impact: Fouling organism. It competes with aquaculture bivalves.

Bibliography:

Iwasaki K., Kimura T., Kinoshita K., Yamaguchi T., Nishikawa T., Nishi E., Yamanishi R., Hayashi I., Okoshi K., Kosuge T., Suzuki T., Henmi Y., Furota T. and Mukai H. 2004. Human-mediated Introduction and dispersal of marine organisms in Japan: results of a questionnaire survey by the Committee for the Preservation of the Natural Environment, the Japanese Association of Benthology. *Japanese Journal of Benthology*. V. 59. P. 22–44. [in Japanese with English abstract].

Zvyagintsev A.Yu. 2003. Introduction of species into the northwestern Sea of Japan and the problem of marine fouling. *Russian Journal of Marine Biology*. V. 29, Suppl. 1. P. S10–S21.

(TF, SN, KL)

Polyandrocarpa zorritensis (Van Name, 1931)

Common name: Black Polyandrocarpa tunicate;

Japanese name: Kuromameita-boya.

Taxonomy: Chordata, Ascidiacea, Enterogona, Ascidiidae.

Fig. 130. Black Polyandrocarpa tunicate, *Polyandrocarpa zorritensis* in Japan.

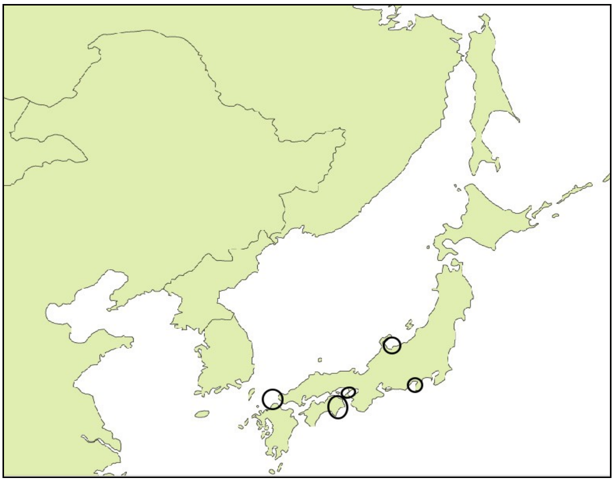

Fig. 131. Distribution of *Polyandrocarpa zorritensis* in Japan.

Regional distribution: Japan: Toyama Bay, Izu Peninsula, Osaka Bay, southeastern Shikoku, Dokai Bay.

Possible origin: Unknown.

Possible way of introduction: Ship hull-fouling or ballast water.

Habitat: Subtidal hard substrata in port waters. This tunicate forms dense colony on artificial hard substrata in enclosed subtidal waters.

Impact: Compete with native sessile species.

Bibliography:

Nishikawa T., Kajiwara K. and Kawamura K. 1993. Probable introduction of *Polyandrocarpa zorritensis* (Van Name) to Kitakyusyu and Kochi, Japan. *Zoological Science*. V. 10. P. 176.

(TF, SN)

Ascidiella aspersa (Müller, 1776)

Common name: European rough-surface tunicate;

Japanese name: Yoroppa zara-boya.

Taxonomy: Chordata, Ascidiacea, Enterogona, Ascidiidae.

Fig. 132. European tunicate, *Ascidiella aspersa* in Japan.

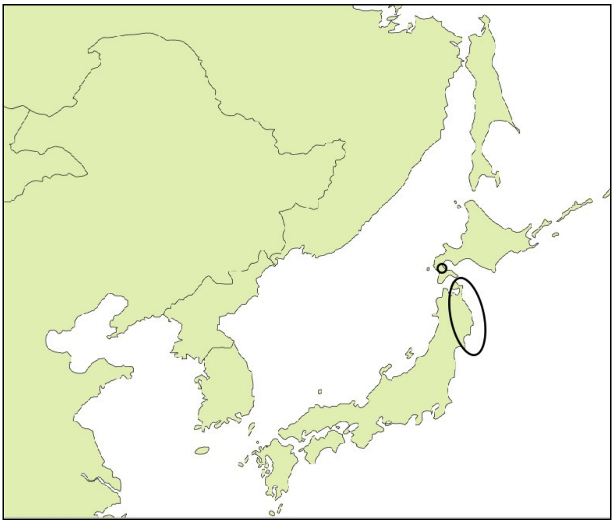

Fig. 133. Distribution of *Ascidiella aspersa* in Japan.

Regional distribution: Japan: Funka Bay, Hokkaido and Northeastern Pacific coasts.

Possible origin: Europe.

Possible way of introduction: Unknown.

Habitat: Aquaculture gear. This tunicate aggregatively grows on scallop shells, causing damage of scallop aquaculture.

Impact: Damage on scallop aquaculture.

Bibliography:

Kanamori M., Baba K., Hasegawa N. and Nishikawa T. 2012. Biological characteristics, distinction and identification of *Ascidiella aspersa* （Müller, 1776), as an alien ascidian in northern Japan (technical report). *Science Reports of the Hokkaido Fishery Research Institute*. V. 81. P. 151−156. [in Japanese].

Sugawara E. and Nishikawa T. 2010. Sessile Tunicata *Ascidiella aspersa* (Müller, 1776) damaged scallop aquaculture. **In:** Abstracts from the 62th Annual Meeting of the Kanto Branch of the Zoological Society of Japan Held in March, 2010, at the University of Tsukuba. [in Japanese with English abstract].

(TF, SN)

Halocynthia roretzi (Drasche, 1884)

Common name: sea squirt.

Taxonomy: Chordata, Ascidiacea, Stolidobranchia, Pyuridae.

Fig. 134. *Halocynthia roretzi.*

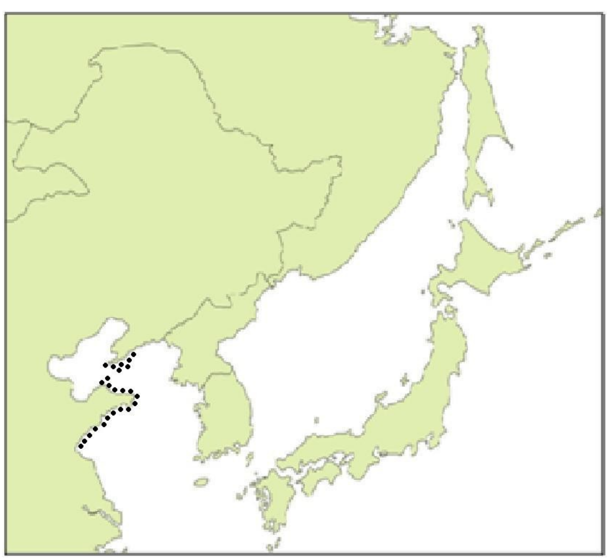

Fig. 135. Distribution of *Halocynthia roretzi* in China.

Regional distribution: China: Coastal areas of Liaoning and Shandong.

Possible origin:

Possible way of introduction: Aquaculture and self dispersion.

Habitat: Upper subtidal rocky coast, 10−20 m deep.

Impact: Affecting aquaculture.

Bibliography:

Li W. 2006. Culture of sea squirt (*Halocynthia roretzi* Drasche) in Korea. *Fisheries Science*. V. 33, N 3. P. 138.

Zheng C. 1995. Species diversity of ascidians in the coastal China seas. *Chinese Biodiversity*. V. 3, N 4. P. 201−205.

(XJ)

Lateolabrax sp.

Common name: Continental sea bass, *Lateolabrax* sp.;

Japanese name: Tairiku Suzuki.

Taxonomy: Chordata, Pisces, Actinopterygii, Perciformes, Lateolabracidae.

Fig. 136. Continental sea bass, *Lateolabrax* sp.

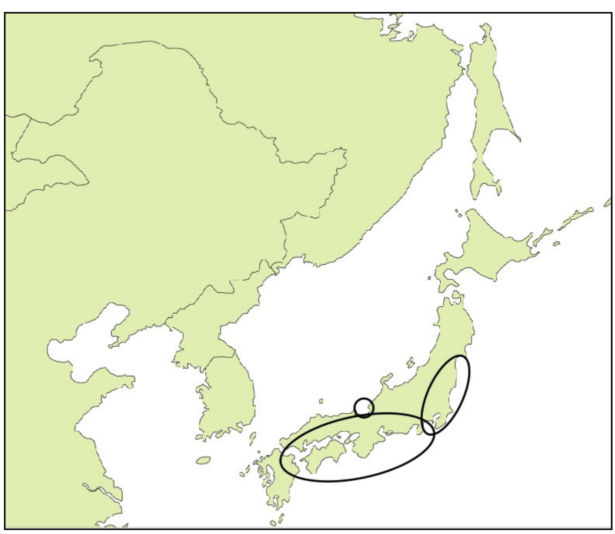

Fig. 137. Distribution of *Lateolabrax* sp. in Japan.

Regional distribution: **Japan:** Central to western Japan.

Possible origin: China.

Possible way of introduction: Import for aquaculture.

Habitat: Coastal waters. This imported Chinese bass have been cultured in the western part of the Japanese main islands. Amateur fishermen often catch basses in natural waters. These basses may have escaped from culturing nets. A scientific species name of the bass has not been given.

Impact: Predation on small fishes, compete with native sea bass.

Bibliography:

Konishi H. 1993. The third bass, spotted bass. *Fishing Sunday* (January 24th). V. 18. P. 63−70. [in Japanese].

(TF, SN)

Oncorhynchus kisutch (Walbaum, 1792)

Common name: Coho salmon, silver salmon.

Taxonomy: Chordata, Pisces, Actinopterygii, Salmoniformes, Salmonidae.

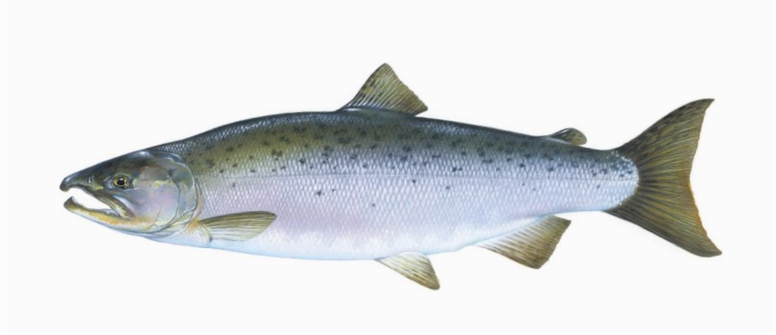

Fig. 138. *Oncorhynchus kisutch.*

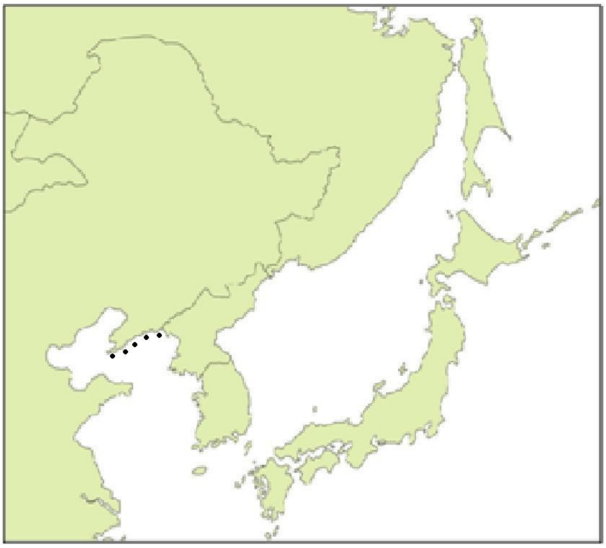

Fig. 139. Distribution of *Oncorhynchus kisutch* in China.

Regional distribution: China: Liaoning Province.

Possible origin: Northern Pacific.

Possible way of introduction: Aquaculture and self-dispersion

Habitat: River and ocean with cold water. Anadromous species; born in freshwater, spends most of life in sea.

Impact: The species with biological advantage may compete with native species, causing genetic diversity damage and contamination.

Bibliography:

Cui C., Ma X., Liu M. et al. 2003. Artificial propagation experiments of silver salmon. *Reservoir Fisheries*. V. 23, N 2. P. 22−23.

Kuang Y., Yin J., Bai Q. et al. 2004. Measurement of morphometric characters in Coho salmon (*Oncorhynchus kisutch*). *Chinese Journal of Fisheries.* V. 17, N 1. P. 21−25.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 633−634.

(XJ)

Oncorhynchus mykiss (Walbaum, 1792)

Common names: Rainbow trout, steelhead trout.

Taxonomy: Chordata, Pisces, Actinopterygii, Salmoniformes, Salmonidae.

Fig. 140. *Oncorhynchus mykiss.*

Fig. 141. Distribution of *Oncorhynchus mykiss* in China.

Regional distribution: China: Liaoning and Shandong provinces.

Possible origin: North Pacific.

Possible way of introduction: Aquaculture.

Habitat: River and ocean with cold and clean water.

Impact: The species with biological advantage may compete with native species, causing genetic diversity damage and contamination.

Bibliography:

Liang Y. and Wang B. 2001. Alien marine species and their impacts in China. *Biodiversity Science*. V. 9, N 4. P. 458−465. [in Chinese with English abstract].

Ma Z., Zhang Y. and Zhao X. 2008. Biological characteristics and farming techniques of rainbow trout. *Fishery Guide to be Rich.* V. 5. P. 48−51. [in Chinese].

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 634−635.

Zhao S., Zhang X., Li C. et al. 2006. Alien fishes of mariculture in China. *Marine Sciences*. V. 30, N 10. P. 75−80.

(XJ)

Salmo salar L., 1758

Common names: Atlantic salmon, black salmon, parr.

Taxonomy: Chordata, Pisces, Actinopterygii, Salmoniformes, Salmonidae.

Fig. 142. *Salmo salar*.

Fig. 143. Distribution of *Salmo salar* in China.

Regional distribution: China: Liaoning Province.

Possible origin: Atlantic.

Possible way of introduction: Aquaculture.

Habitat: River and ocean with cold water.

Impact: Atlantic salmon has biological advantages in competing with native species. Reared Atlantic salmons also transmit diseases to wild salmons when they escape.

Bibliography:

Xia Z., Chen J. and Mou Z. 1998. Ecological information of Atlantic salmon. *Chinese Journal of Fisheries*. V. 11, N 2. P. 61−65.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 635−636.

Zhao W. 1994. Gonadal differentiation and effects of heat shock in Atlantic salmon (*Salmo salar*). *Chinese Journal of Fisheries*. V. 7, N 2. P.1−5.

(XJ)

Paralichthys dentatus (L., 1766)

Common names: Summer flounder, large-tooth flounder, arrow-tooth flounder.

Taxonomy: Chordata, Pisces, Actinopterygii, Pleuronectiformes, Paralichthyidae.

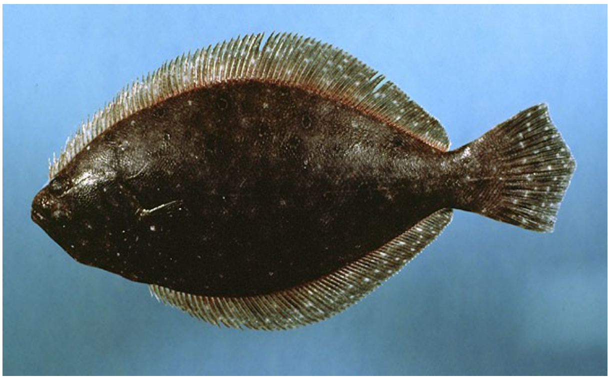

Fig. 144. *Paralichthys dentatus.*

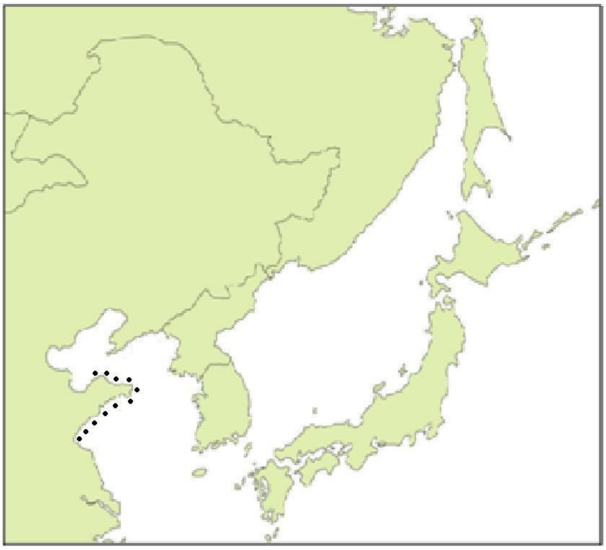

Fig. 145. Distribution of *Paralichthys dentatus* in China.

Regional distribution: China: Coastal areas of Shandong.

Possible origin: Northwest Atlantic.

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Central and shallow areas of bays, seaweed beds, muddy, sandy bottoms.

Impact: This species with biological advantage may compete with native species, causing genetic diversity damage and contamination.

Bibliography:

Wang B., Zhang C., Zhang J. et al. 2004. Advance of study on reproduction biology and breeding technology of the summer flounder, *Paralichthys dentatus* Linnaeus. *Progress in Fishery Sciences*. V. 25, N 1. P. 90−96.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 647−649.

Zhou J. 2003. A survey of the introduction and biological characteristics of the summer flounder, *Paralichthys dentatus* Linnaeus. *Fishery Guide to be Rich.* V. 5. P. 43−44.

(XJ)

Paralichthys lethostigma Jordan et Gilbert, 1884

Common name: Southern flounder.

Taxonomy: Chordata, Pisces, Actinopterygii, Pleuronectiformes, Paralichthyidae.

Fig. 146. *Paralichthys lethostigma.*

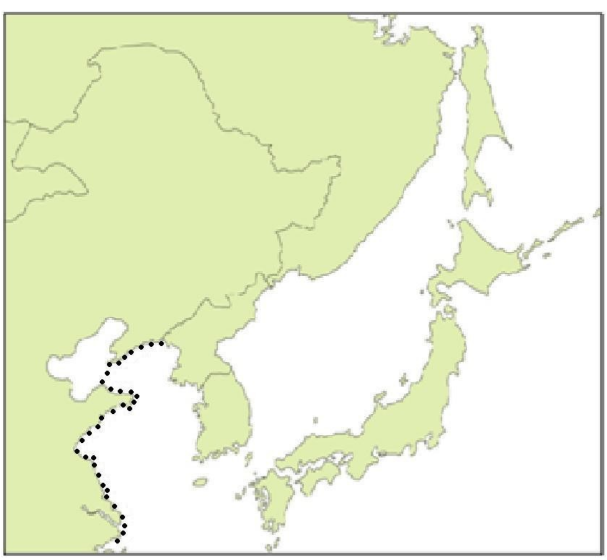

Fig. 147. Distribution of *Paralichthys lethostigma* in China.

Regional distribution: China: all coastal regions.

Possible origin: Northwest Atlantic.

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Estuaries and bays in spring and summer, open ocean in autumn and winter.

Impact: This species with biological advantage may compete with native species, causing genetic diversity damage and contamination.

Bibliography:

Wang X., Yan B., Cao M. et al. 2006. Studies on the biology and culture of *Paralichthys lethostigma:* a review. *Transactions of Oceanology and Limnology.* V. 3. P. 128−134.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 649−650.

Zhang Y., Jia Z., Li C. et al. 2006. Biology and culture of *Paralichthys lethostigma. Chinese Journal of Fisheries*. V. 19, N 1. P. 77−83.

(XJ)

Verasper moseri Jordan et Gilbert, 1898

Common name: Barfin flounder.

Taxonomy: Chordata, Pisces, Actinopterygii, Pleuronectiformes, Pleuronectidae.

Fig. 148. *Verasper moseri.*

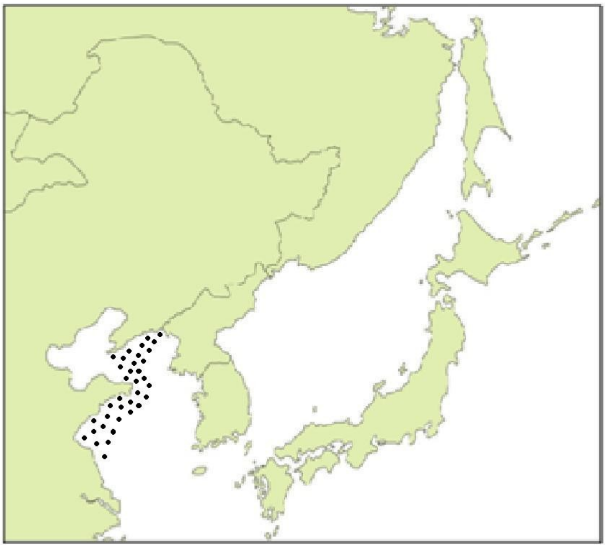

Fig. 149. Distribution of *Verasper moseri* in China.

Regional distribution: China: Waters to east of northern China.

Possible origin:

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Shallow water areas with sandy substrate.

Impact: This species can compete with native species.

Bibliography:

Li W. and Li H. 2006. Biology and culture of Barfin flounder *Verasper moseri* in Japan. *Fisheries Science.* V. 25, N 10. P. 533−536.

Wang X., Li J., Xiao Zhizhong et al. 2008. Primary research on morphologic characteristics and inner structure of Barfin flounder *Verasper moseri. Marine Sciences.* V. 32, N 5. P. 90−96.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 651−652.

Zhao S., Zhang X., Li C. et al. 2006. Alien fishes of mariculture in China. *Marine Sciences.* V .30, N 10. P. 75−80.

(XJ)

Solea senegalensis Kaup, 1858

Common name: Senegalese sole.

Taxonomy: Chordata, Pisces, Actinopterygii, Pleuronectiformes, Soleidae.

Fig. 150. *Solea senegalensis.*

Fig. 151. Distribution of *Solea senegalensis* in China.

Regional distribution: China: Shandong Province.

Possible origin: Eastern Atlantic.

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Lagoons and other shallow waters with muddy substrate.

Impact: This species with biological advantage may compete with native species.

Bibliography:

Liu X. and Lei J. 2005. Biological characteristics of *Solea senegalensis* and its industrialized culture technology. *Scientific Fish Farming.* V. 10. P. 22−23.

Liu X., Liu X., Lian J. et al. 2008. Large-scale artificial reproduction and rearing of Senegal sole, *Solea senegalensis* Kaup. *Progress in Fishery Science*. V. 29, N 2. P. 10−16.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 652−653.

Zhao S., Zhang X., Li C. et al. 2006. Alien fishes of mariculture in China. *Marine Sciences*. V. 30, N 10. P. 75−80.

(XJ)

Solea solea (L., 1758)

Common names: Common sole, Dover sole, slip.

Taxonomy: Chordata, Pisces, Actinopterygii, Pleuronectiformes, Soleidae.

Fig. 152. *Solea solea.*

Fig. 153. Distribution of *Solea solea* in China.

Regional distribution: China: Shandong Province.

Possible origin: Eastern Atlantic.

Possible way of introduction: Aquaculture, self dispersion

Habitat: Shallow waters (0–150 m), sandy or mudddy bottom.

Impact: This species with biological advantage may compete with native species.

Bibliography:

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 653−654.

(XJ)

Anguilla anguilla (L., 1758)

Common name: European eel.

Taxonomy: Chordata, Pisces, Actinopterygii, Anguilliformes, Anguillidae.

Fig. 154. *Anguilla anguilla.*

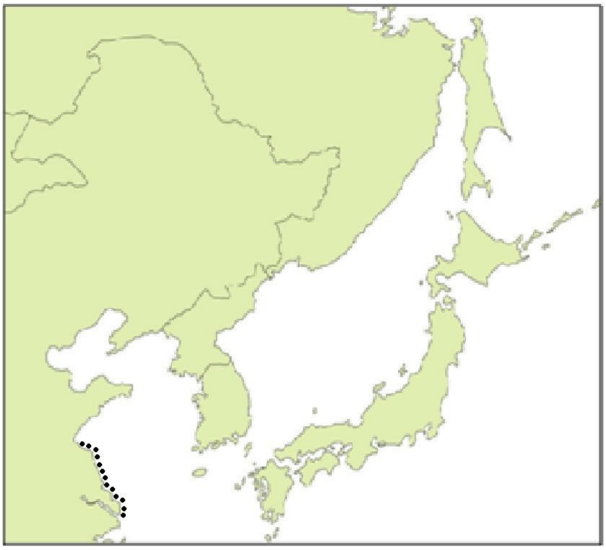

Fig. 155. Distribution of *Anguilla anguilla* in China.

Regional distribution: China: Jiangsu Province.

Possible origin:

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Marine environment for juveniles, rivers and streams for adult fishes. Muddy bottom.

Impact: The MIS with biological advantage may compete with native species.

Bibliography:

Du M. and Liao G. 2006. Comparison of the biological characteristics and farming techniques of European eel and American eel. *China Fisheries*. V. 1. P. 24−26.

Liu S. 1995. Biological characteristics and farming techniques of European eel. *Reservoir Fisheries.* V. 2. P. 6−8.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 654−655.

(XJ)

Anguilla rostrata (Lesueur, 1817)

Common name: American eel.

Taxonomy: Chordata, Pisces, Actinopterygii, Anguilliformes, Anguillidae.

Fig. 156. *Anguilla rostrata.*

Fig. 157. Distribution of *Anguilla rostrata in* China.

Regional distribution: China: Jiangsu Province.

Possible origin:

Possible way of introduction: Aquaculture, self-dispersion

Habitat: Marine environment for juveniles, rivers and steams for adult fishes. Muddy and sandy bottom, depth range 0−464 m.

Impact: This species with biological advantage may compete with native species.

Bibliography:

Du M. and Liao G. 2006. Comparison of the biological characteristics and farming techniques of European eel and American eel. *China Fisheries.* V. 1. P. 24−26.

Fan H. and Zeng Z. 1998. The experiment on tolerance of *Anguilla rostrata* to water temperature, salinity and pH. *Acta Agriculturae Zhejiangensis*. V. 10, N 2. P. 94−96.

Hong W. 1998. Biological characteristics and farming techniques of American eel. *Marine Sciences*. V. 2. P. 34−35.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 655−656.

(XJ)

Morone saxatilis (Walbaum, 1792)

Common name: Striped bass;

Russian name: Okun' polosatyi.

Taxonomy: Chordata, Pisces, Actinopterygii, Perciformes, Moronidae.

Fig. 158. *Morone saxatilis.*

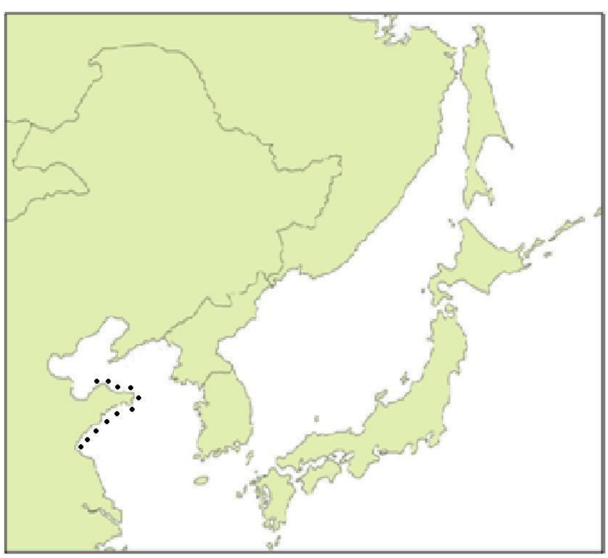

Fig. 159. Distribution of *Morone saxatilis* in China.

Regional distribution: Shandong Province.

Possible origin: Atlantic?

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Benthic anadromous species. Estuarine environment for juveniles, shallow coastal waters for adult fishes.

Impact: Competing with native species.

Bibliography:

Lei Q., Ma M., Liu X. et al. 1996. A study on feasibility of striped bass, *Morone saxatilis* (Walbaum) and its hybrid species introduced into China for aquaculture. *Modern Fisheries Information*. V. 11 N 8. P. 8−11.

Liao G. 1998. Culture and perspective of induced hybrid of *Morone saxatilis* (Walbaum) x *Morone chrysops* (Rafinesque). *Modern Fisheries Information*. V. 13, N 5. P. 10−19.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species*. Beijing: Science Press. P. 662−663.

(XJ)

Sciaenops ocellatus (L., 1766)

Common names: Red drum, channel bass.

Taxonomy: Chordata, Pisces, Actinopterygii, Perciformes, Sciaenidae.

Fig. 160. *Sciaenops ocellatus.*

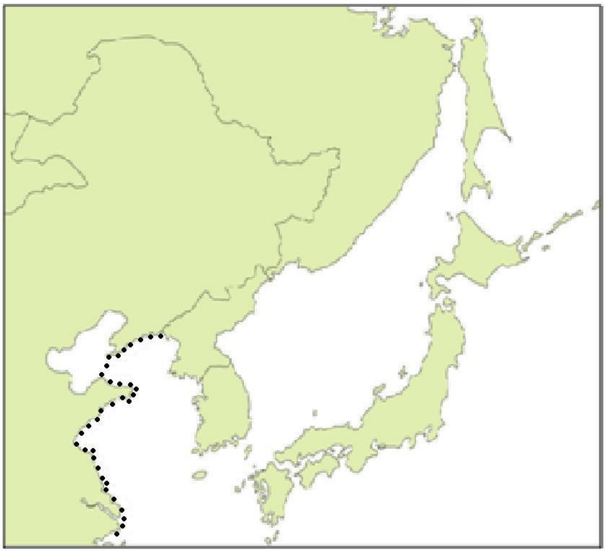

Fig. 161. Distribution of *Sciaenops ocellatus* in China.

Regional distribution: Shandong Province.

Possible origin: Northwest Atlantic.

Possible way of introduction: Aquaculture, self-dispersion.

Habitat: Shallow waters down to 30–40 m deep with muddy, sandy or rocky bottom.

Impact: Competing with native species.

Bibliography:

Jin H., Xu H., Xu W. et al. 2008. Study on feeding habits of the escaped red drum *Sciaenops ocellatus* in Zhejiang sea area. *Marine Fisherries Reseach*. V. 29, N 1. P. 103−108.

Wang B., Liu S., Zhang X. et al. 2002. Study on morphological and growth parameters of red drum (*Sciaenops ocellatus*). *Marine Fisherries Reseach*. V. 23, N 1. P. 47−53.

Xu H. and Qiang S. 2011. *China's Invasive Alien Species.* Beijing: Science Press. P. 665−666.

(XJ)

List of sources for species illustrations in the atlas

Fig. 6, *Saccharina japonica* (http://www.fao.org/fishery/culturedspecies/Laminaria_japonica/en);
Fig. 8, *Macrocystis pyrifera* (http://eol.org/data_objects/16890877);
Fig. 10, *Undaria pinnatifida* (http://www.dbw.ca.gov/);
Fig. 12, *Desmarestia ligulata* (photo by Bárbara Ignacio; http://www.marinespecies.org);
Fig. 14, *Cutleria multifida* (photo by T. Horiguchi);
Fig. 16, *Ulva* sp. (photo by T. Furota);
Fig. 18, *Spartina alterniflora* (photo by Caiyun Zhao);
Fig. 19, *Spartina alterniflora* (photo by E. Fujioka);
Fig. 21, *Spartina anglica* (photo by Qiang Sheng);
Fig. 23, *Pseudo-nitzschia calliantha* (photos by Park J.-G);
Fig. 25, *Chattonella marina* (photos by Jung Seung Won);
Fig. 26, *Heterosigma akashiwo* (photo by by Keun-Yong Kim);
Fig. 27, *Alexandrium catenella* (photo by Keun-Yong Kim);
Fig. 28, *Cochlodinium polykrikoides* (photo by Jung Seung Won);
Fig. 29, *Karlodinium veneficum* (photo by Jung Seung Won);
Fig. 30, *Heterocapsa circularisquama* in Japan (photo by T. Horiguchi);
Fig. 32, *Ficopomatus enigmaticus* (photos by M. Taru);
Fig. 34, *Hydroides elegans* (photo by J. Lewis, http://adl.brs.gov.au/marinepests/index.cfm?fa=main.spDetailsDB&sp=6000008439);
Fig. 36, *Hydroides dianthus* (photos by M. Taru);
Fig. 38, *Pseudopotamilla occelata* (after: Zvyagintsev et al., 2009);
Fig. 40, *Haliotis discus* (http://upload.wikimedia.org/wikipedia/commons/0/09/Haliotis_discus.jpg);
Fig. 46, *Haliotis fulgens* (photo by Ron Wolf);
Fig. 42, *Haliotis gigantea* (photo by Kim Jinsuk);
Fig. 44, *Haliotis rufescens* (http://www.jaxshells.org/);
Fig. 48. *Crepidula onyx* (photo by T. Furota);
Fig. 50, *Nassarius sinarus* (photo by H. Fukuda);
Fig. 54, *Mytilus galloprovincialis* in Japan (photo by T. Furota); in Korea (photo by INTHESEA Korea, Inc.);
Fig. 56, *Perna viridis* (photo by T. Furota);
Fig. 58, *Xenostrobus* securis (photo by T. Furota);
Fig. 60, *Mytilopsis sallei* (photo by T. Furota);
Fig. 62, *Argopecten irradians* (http://www.jaxshells.org/);
Fig. 64, *Mizuhopecten yessoensis* (after: Lutaenko, Noseworthy, 2012);

Fig. 66, *Crassostrea gigas* (after: Lutaenko, Noseworthy, 2012);

Fig. 68, *Mercenaria mercenaria* (http://en.wikipedia.org);

Fig. 70, *Panopea japonica* (after: Lutaenko, Noseworthy, 2012);

Fig. 72, *Balanus glandula* (photo by R. Kado);

Fig. 74, *Amphibalanus amphitrite* in Japan (photo by T. Furota), left; in Pusan Harbor (photo by INTHESEA KOREA, Inc.), right;

Fig. 76, *Amphibalanus improvisus* in Japan; left (photo by T. Furota); in Dasan harbor, Korea, right (photo by INTHESEA KOREA Inc.);

Fig. 78, *Amphibalanus eburneus in* Japan, left (photo by M. Taru); in Tongyeong Harbor, Korea, right (photo by INTHESEA KOREA Inc.);

Fig. 80, *Amphibalanus zhujiangensis* (http://barnacle.biota.biodiv.tw/node/679);

Fig. 82, *Megabalanus coccopoma* (http://www.sms.si.edu/irlspec/Megabalanus_coccopoma.htm);

Fig. 84. *Perforatus perforatus* in Guryongpo Harbor, Korea (photo by INTHESEA KOREA, Inc.);

Fig. 86, *Paracerceis sculpta* (photo by A. Hosie, http://museum.wa.gov.au/explore/blogs/museummarine/creature-feature-paracerceis-sculpta-holmes-1904);

Fig. 88, *Portunus sanguinolentus* (http://seafood.nmmba.gov.tw/seafood_en/SeafoodChoices_detail.aspx?foodNo=3);

Fig. 90, *Plagusia depressa tuberculata* (after: Tsareva, Kepel, 2005);

Fig. 92, *Pyromaia tuberculata* (photo by T. Furota);

Fig. 94, *Rhithropanopeus harrisii* in Japan (photo by M. Taru);

Fig. 96, *Carcinus aestuarii* (photo by T. Furota);

Fig. 98, *Diogenes nitidimanus* (http://pacificinfo.ru/data/cdrom/11/html/7_4_1_3.html);

Fig. 100, *Litopenaeus stylirostris* (after: http://www.fao.org/fishery/species/2585/en);

Fig. 102, *Litopenaeus vannamei* (http://scsagr.scsfri.ac.cn/resource-info.asp?id=f08414183254);

Fig. 104, *Marsupenaeus japonicus* (http://scsagr.scsfri.ac.cn/resource-info.asp?id=f084141335430);

Fig. 106, *Monocorophium acherusicum* (http://adl.brs.gov.au/marinepests/index.cfm?fa=main.spDetailsDB&sp=6000009471);

Fig. 108, *Bugula neritina* (photo by INTHESEA KOREA, Inc.);

Fig. 110, *Bugula stolonifera* (photo by M. Taru);

Fig. 112, *Bugula californica* (photo by INTHESEA KOREA, Inc.).

Fig. 114, *Tricellaria occidentalis* (photo by INTHESEA KOREA, Inc.);

Fig. 116, *Conopeum seurati* (http://www.marbef.org/modules.php?name=Photogallery&album=288&pic=23740);

Fig. 118, *Schizoporella unicornis* (http://www.european-marine-life.org/17/photo-schizoporella-unicornis-wb01.php);

Fig. 120, *Strongylocentrotus intermidus* (after: Balakirev et al., 2008);

Fig. 122, *Styella plicata* (photo by INTHESEA Korea, Inc.);

Fig. 126, *Ciona savignyi* (http://pacificinfo.ru/data/cdrom/11/html/7_4_1_3.html);

Fig. 128, *Molgula manhattensis* (photo by T. Furota);

Fig. 130, *Polyandrocarpa zorritensis* (photo by T. Nishikawa);
Fig. 132, *Ascidiella aspersa* (photo by M. Kanamori);
Fig. 134, *Halocynthia roretzi* (http://www.lib.NOAA.gov/);
Fig. 136, *Lateolabrax* sp. (photo by M. Kano);
Fig. 138, *Oncorhynchus kisutch* (http://commons.wikimedia.org/wiki/File:Salmon_coho_fish_oncorhynchus_kisutch.jpg);
Fig. 140, *Oncorhynchus mykiss* (http://commons.wikimedia.org/wiki/File:Oncorhynchus_mykiss_mid_res_150dpi.jpg);
Fig. 142, *Salmo salar* (http://www.marinespecies.org/photogallery.php?album=758&pic=15624);
Fig. 144, *Paralichthys dentatus* (photo by Flescher Don);
Fig. 146, *Paralichthys lethostigma* (http://upload.wikimedia.org/wikipedia/commons/7/70/Paralichthys_lethostigma.jpg);
Fig. 148, *Verasper moseri* (http://cysjk.flatfishfarming.ac.cn/qiantai/yangzhipinzhongx.aspx?id=43);
Fig. 150, *Solea senegalensis* (http://eol.org/data_objects/25770969);
Fig. 152, *Solea solea* (http://commons.wikimedia.org/wiki/File:Solea_solea_1.jpg);
Fig. 154, *Anguilla anguilla* (http://content60.eol.org/content/2012/05/23/05/66890_orig.jpg);
Fig. 156, *Anguilla rostrata* (http://commons.wikimedia.org/wiki/File:American_Eel.jpg);
Fig. 158, *Morone saxatilis* (http://ian.umces.edu/imagelibrary);
Fig. 160, *Sciaenops ocellatus* (http://eol.org/data_objects/2763834).

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