



Asia-Pacific Network for Global Change Research

Marine Biodiversity of the Coastal Zones in the NW Pacific: Status, Regional Threats, Expected Changes and Conservation

Final report for APN project: ARCP2008-05CMY-Adrianov

The following collaborators worked on this project:

Project Leader - Dr. **Andrey V. Adrianov**, Institute of Marine Biology FEB RAS, Russia, Email: inmarbio@mail.primorye.ru

Dr. **Konstantin A. Lutaenko**, Institute of Marine Biology FEB RAS, Russia, Email: lutaenko@mail.primorye.ru

Prof. **Kwang-Sik Choi**, Cheju National University, Republic of Korea, Email: skchoi@cheju.ac.kr

Prof. **Liu Ruiyu**, Institute of Oceanology CAS, P.R. China, Email: jyliu@ms.qdio.ac.cn

Marine Biodiversity of the Coastal Zones in the NW Pacific: Status, Regional Threats, Expected Changes and Conservation

Project Reference Number: ARCP2008-05CMY-Adrianov

Final Report submitted to APN

Overview of project work and outcomes

Summary

The APN project aimed to investigate biodiversity status and changes in coastal zones of the NW Pacific with emphasis on intertidal and island's ecosystems, alien invasive species and documenting of overall BD. New data on intertidal biota of Russky (Sea of Japan), Kunashir (Kurile Isl.) and Jeju Islands (Korea) were obtained, and recent changes in the species composition and abundance are described. In total,

2211 species of marine biota are known for China. Data on the ship fouling in the Russian sector of the Sea of Japan collected since 1975 are reviewed and summarized, and altogether 16 species-invasives of bottom invertebrates (cirripede barnacles, amphipods, hydroids, polychaetes and bryozoans) have been registered. Distributional patterns of the coral diversity in the Indo-West Pacific are described and global trends in the coral reef ecosystems' changing are summarized; main drivers leading to the global biodiversity changing in the coral reef ecosystems were identified as follows: 1, the possible invasion of the alien species; 2, the overexploitation of the bioresources of the coral reefs together with the man-made pollution of the coastal seas, and 3, the global climate changing and environmental stress. Based on the data on species composition and chronology of mollusks lived in the coastal areas of the Sea of Japan during the Holocene, a model of expected changes in the fauna was developed. Two workshops held in China and Korea, development of a website and involvement of young scientists contributed to the capacity building in global change research in the region. Three books and 12 papers published as a result of project activity are important in terms of new BD information for scientific community and can be useful for decision-makers.

Objectives

The main objectives of the project were: **1)** to collect information about overall species diversity and to compile species lists of biota; **2)** to undertake coastal expeditions to survey intertidal and subtidal zone; **3)** to inspect and study the species composition and ecological characteristics of the biofouling communities and ballast waters of ships; **4)** to summarize data on biodiversity loss and modifications on tidal flats in three involved countries; **5)** documenting of species diversity in island's ecosystems as a baseline study for conserving coastal and marine biological diversity.

Amount received and number years supported

The Grant awarded to this project was:

US\$ 40,000 for Year1, 2007/2008

US\$ 40,000 for Year 2, 2008/2009

Activity undertaken

According to project objectives and timeline, during 2007-2009 research teams performed five main kinds of activities: **1,** field-works in the Russian part of the Sea of Japan/East Sea (Russky Island) and in Jeju (Cheju) Island in Korea; **2,** gathered information about state of the biodiversity and invasive species to prepare a review; **3,** held workshops in the Institute of Oceanology CAS, Qingdao, China (October 2007) and in Cheju National University, Korea (October 2008) followed publication of two proceedings with full-length papers and abstracts, **4,** prepared and published papers in peer-reviewed journals; **5,** development and maintenance of the project website: <http://www.imb.dvo.ru/misc/apn/bio/index.htm>.

Results

Marine biodiversity in China

The marine biodiversity studies in China have been carried out for more than half century since the establishment of the Institute of Oceanology, Chinese Academy of Sciences in 1950. Through the survey of marine fauna, flora and living resources along the China coasts and a series of nation-wide multi-disciplinary oceanographic investigations mainly in the continental shelf, hundreds thousands number of marine fish, invertebrate and seaweed specimens were collected and deposited mainly in the two institutes, IOCAS (CAS Marine Biological Museum) and SCSIOCAS. As the result of taxonomic and ecological studies, some 70 monographs and about 800 papers on marine fauna and flora of the China seas have been published. Results of intensive studies on marine fauna and flora have shown the richness of marine species and high biodiversity of the China seas. A total of 20070 species belonging to 20 phyla of marine biota of China seas have been enumerated in 2006, about 2211 spp., or an 15.6 % increase over those recorded in 1994.

The fast development of industrial production in coastal cities and increase of fishing catch intensity in inner shelf area, environmental pollution and decline of living resources, the high biodiversity and richness of marine biota and living resources seriously decreased. Sustainable development of fishery production seems to be difficult.

Biodiversity surveys of island's ecosystems

The **intertidal zone of Russky Island** (north-western Sea of Japan/East Sea) is described, and quantitative characteristics of 23 benthic communities, represented by 50 macrophytic and 181 animal species, are given based on field-works carried out in 2007. It is noted that pseudomeiobenthic portion in meiobenthos is greater than that of eumeiobenthos not only with reference to biomass, but also to population density. When comparing species richness of macrobenthos of the intertidal zone of Russky Island with that of the estuarine area in the top of neighbouring Amursky Bay, on the one hand, and with that of the islands of the Far-Eastern Marine Reserve, situated in the open part of Peter the Great Bay, on the other hand, a biodiversity gradient was revealed, that is a regular increase of macrobenthic species number beginning from the desalinated areas of the bay and up to the open sea shores. Russky Island, with nearly untouched nature, has been developed since 2008 as a new part of Vladivostok City, with construction of a bridge from continent, campus of a new federal university, hotels, aquarium, etc. and investments of several billion dollars, and thus this study is important in terms of future biodiversity and ecosystem monitoring.

Peculiarities of vertical distribution, species composition and zonal-biogeographical structure of macrobenthos of the **intertidal communities of Kunashir Island** (South Kurile Islands) are described on the basis of the results of the expedition of 1991; published data of 1951–1988 are revised taking into account current taxonomic literature. Pacific low-boreal and Pacific wide-boreal species prevail. Intertidal biota in Izmeny Bay and in the Sea of Okhotsk coasts is more thermophilous as compared to the Pacific coast. It is connected with circulation of warm waters of Soya Current. On the rocky and stony intertidal zone poorly populated communities of *Chthamalus dalli* and *Littorina sitkana*, are typical for the upper horizon. A furoid complex is developed in the middle horizon. Dense thickets of laminarian algae develop in the lower horizon, in this communities total macrobenthos biomass can reach 100 kgWW m⁻². On sandy beaches affected by surf and formed by clean sand, population is very poor, macrophytes and other attached forms are absent. Communities *Zostera japonica*, *Z. marina* and *Batillaria cumingii* not found in the other sites of Kunashir are located on the silty-sandy intertidal zone of the southern island coast in Izmeny Bay. Decrease in species diversity and increase of biomass of macrobenthos happened during the recent 30 years in Izmena Bay exposed to anthropogenic impact is recorded. Intertidal zone of Kunashir Island has many common features with that of the neighboring Shikotan Island by composition and patterns of distribution of communities. Composition and distribution of intertidal biota of Kunashir Island is typical for the low-boreal intertidal zone with well-expressed tides.

A total of 1072 species and subspecies of **mollusks** (Mollusca) have been recorded

from Jeju Island, 1015 marine species and 57 land and freshwater species. There are 812 gastropods, of which 755 are either entirely marine or, as in the case of the Truncatellidae, Ellobiidae, and other similar families, have marine affinities. Of those the Pyramidellidae are best represented, followed by the Trochidae and Oculidae. The bivalves are represented by 225 species, with the Veneridae, Mytilidae, and Arcidae having the largest number of species. Among the smaller classes there are sixteen Cephalopoda, eleven Polyplacophora, and eight Scaphopoda. Of particular note is the absence of some of the more common, edible mainland species, e.g. *Rapana venosa* (Valenciennes, 1846) and *Meretrix* spp., because of the relative lack of muddy substrates.

Ostracods, fine indicators of water ecosystem condition and climatic changes, were studied in the intertidal surveys of 2007-2008 **of the coastal zone of Jeju Island**, Korea. 73 ostracod species were found. In general, ostracod fauna of Jeju Island coast remains poorly studied. Judging by species diversity of ostracod fauna of similar regions, one could suppose that not less than 600 ostracod species inhabit the shelf of Jeju Island.

Bioinvasions and alien species in the NW Sea of Japan/East Sea

Data on the ship fouling studied by the Institute of Marine Biology FEB RAS since 1975 are reviewed and summarized. The large material on fouling of more than 600 ships of a various operation mode in different regions of World Ocean is assembled which has allowed revealing a number of exotic species, introduced in the northwest part of the Sea of Japan with the help of ship fouling and their ballast waters. In the fouling of anthropogenic substrates and in benthos communities of Peter the Great Bay, altogether 16 species-invaders have been registered; among them cirripede barnacles, amphipods, hydroids, polychaetes and bryozoans. The alien species damage native communities and step by step are playing a significant role in the coastal ecosystems leading to modifications, increase of biomass, etc.

Coral diversity in the Indo-West Pacific

Distributional patterns of the coral diversity in the Indo-West Pacific are described and global trends in the coral reef ecosystems' changing are summarized. The main drivers leading to the global biodiversity changing in the coral reef ecosystems were identified as follows: **1**, the possible invasion of the alien species (or group of the species) using the various pathways of the overseas connectivity; **2**, the overexploitation of the bioresources of the coral reefs together with the man-made pollution of the coastal seas, and **3**, the global climate changing and environmental stress.

The Holocene migrations of mollusks and future changes

Based on the data on species composition and chronology of mollusks lived in the coastal areas of the Sea of Japan during the Holocene, one can predict expected changes in the fauna, i.e., appearance/disappearance of abundant species became regionally extinct during the second half of the Holocene due to a series of coolings. It is expected that, at least, about three species of bivalve mollusks (*Anadara broughtonii*, *A. inaequivalvis*, *Trapezium liratum*) would migrate to the coast of southern Sakhalin, three (*A. inaequivalvis*, *A. kagoshimensis* and *Meretrix lusoria*) – to Peter the Great Bay, one (*A. broughtonii*) to middle Primorye, two (*Anadara granosa* and *Anomalocardia squamosa*) – to Wakasa Bay, and three (*A. inaequivalvis*, *A. kagoshimensis*, *A. squamosa*) would appear in Ishikari Bay (Hokkaido).

Relevance to APN's Science Agenda and objectives

The proposed project is directly related to one of the themes of the APN agenda – *Ecosystems, Biodiversity and Land Use*. The project addressed issues of the biodiversity assessment, modification and future changes, and results contribute to raising awareness of global environmental changes with particular reference to coastal zones where the most human population is concentrated. The research findings and recommendations are expected to be used by regional/national/international policy- and decision makers.

Self evaluation

We have accomplished many objectives to a satisfactory level. The project results contain new data on the intertidal biotic communities and fauna of three large

island ecosystems lying in different climatic zones and experiencing various levels of human pressure (Russky Isl. in the Sea of Japan, Kunashir Isl, Kurile Islands group, and Jeju Isl. in Korea), and good summaries on invasive species, coral ecosystems and expected biotic changes during global warming useful for the scientific community and policy makers. The project definitely helped to achieve wider understanding about biodiversity problems and collaboration among scientific partners from Russia, China and Korea. The Project has made a significant contribution to APN goals through integration between scientists of different countries, involvements of young scientists, through co-learning and understanding about biodiversity changes. However, still links between scientific communities of three countries should be strengthened.

Potential for further work

We plan to continue collaboration between research teams which would result in a joint publications and a collective book. Moreover, research activity on bioinvasions problem in the Sea of Japan will be continued through a project supported by UNEP NOWPAP (United Nations Environmental Programme, Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region) in May 2009, and one of the participants of the APN Project, K.A. Lutaenko, was nominated as a national expert by NOWPAP. Another project on local assessment of impact of alien species in Far East Biosphere Reserve (north-western Sea of Japan) supported by UNDP will start in 2009 with involvement of participants of the APN Project.

Publications

Books

K.A. Lutaenko (Ed.). Biodiversity of the Marginal Seas of the Northwestern Pacific Ocean: Proceedings of the Workshop, Institute of Oceanology CAS, Qingdao, China, November 21-23, 2007. Qingdao: IOCAS, 2007. 105 pp.

K.A. Lutaenko (Ed.). Marine Biodiversity and Bioresources of the North-Eastern Asia: Book of Abstracts, Workshop, Marine and Environmental Research Inst., Cheju Nat. Univ., 21-22th October, 2008. Jeju: Cheju Nat. Univ., 2008. 227 pp.

Zvyagintsev A.Yu., Ivin V.V., Kashin I.A. The Methodical Advisories to Research Ship Ballast Waters During Realization of Marine Bioinvasions Monitoring. Vladivostok: Dalnauka, 2009. 123 pp. [in Russian with English abstract].



Papers in peer-reviewed journals and chapters in books

Belogurova L.S., Zvyagintsev A.Yu., Moshchenko A.V. Meiofauna of fouling communities on the cooling system hydrotechnical installations of Vladivostok Thermo-electric Power Station No. 2. - *Izvestiya TINRO*, 2007, vol. 150, pp. 250-270. [in Russian].

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

Lutaenko K.A., Xu F. A catalogue of types of bivalve mollusks in the Marine Biological Museum, Chinese Academy of Sciences (Qingdao). - *The Bulletin of the Russian Far East Malacological Society*, 2008, vol. 12, pp. 42-70.

Lutaenko K.A., Zhushchikhovskaya I.S., Mikishin Yu.A., Popov A.N. Mid-Holocene climatic changes and cultural dynamics in the basin of the Sea of Japan and adjacent areas. **In:** D.G. Anderson, K.A. Maasch and D.H. Sandweiss (Eds.). **Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions.** Amsterdam, etc.: Elsevier Inc., 2007, pp. 331-406.

Pavlyuk O.N., Tarasova T.S., Trebukhova Yu.A. Foraminifera and Nematoda communities within the area of *Ahnfeltsia tobuchiensis* field in Stark Strait (Peter the Great Bay of the Sea of Japan). - *Russian Journal of Marine Biology*, 2008, vol. 34, no. 3, pp. 151-158.

Pavlyuk O., Trebukhova Y. Community structure of free-living marine nematodes in the area of agar-producing alga *Ahnfeltsia tobuchiensis* (Starka Strait, Peter the Great Bay, East Sea). - *Ocean Science Journal*, 2007, v. 42, no. 3, pp. 165-170.

Pavlyuk O.N., Trebukhova Yu.A., Belogurova L.S. Effect of the Razdolnaya River on structure of the free-living nematode community of the Amursky Bay, Sea of Japan. - *Russian Journal of Marine Biology*, 2007, vol. 33, no. 4, pp. 213-221.

Pavlyuk O.N., Trebukhova Yu.A., Nguyen Vu Thanh, Nguyen Dinh Tu. Meiobenthos in estuary part of Ha Long Bay (Gulf of Tonkin, South China Sea, Vietnam). - *Ocean Science Journal*, 2008, v. 43, no. 3, pp. 153-160.

Zvyagintsev A.Yu. Study of marine fouling in the Institute of Marine Biology FEB RAS. - *Bulletin of the Far Eastern Branch, Russian Academy of Sciences*, 2007, no. 4, pp. 3-16. [in Russian].

Zvyagintsev A.Yu., Ivin V.V., Kashin I.A., Orlova T.Yu., Selina M.S., Kasyan V.V., Korn O.M., Kornienko E.S., Kulikova V.A., Bezverbnyaya I.P., Zvereva L.V., Radashevsky V.I., Belogurova L.S., Begun A.A., Gorodkov A.N. Acclimation and introduction of hydrobionts ships' ballast water organisms in the Port of Vladivostok. - *Russian Journal of Marine Biology*, 2009, vol. 35, no. 1, pp. 41-52.

Zvyagintsev A.Yu., Sanamyan K.E., Kashenko S.D. On the introduction of the ascidian *Ciona savignyi* Herdman, 1882 into Peter the Great Bay, Sea of Japan. - *Russian Journal of Marine Biology*, 2007, vol. 33, no. 2, pp. 133-136.

Zvyagintsev A.Yu., Selifonova J.P. Study of the ballast waters of commercial ships in the sea ports of Russia. - *Russian Journal of Biological Invasions*, 2008, no. 2, pp. 20-29. [in Russian with English abstract].

Acknowledgments

We are grateful to administrations of the Institute of Marine Biology FEB RAS (IMB, Vladivostok, Russia), Institute of Oceanology CAS (IOCAS, Qingdao, China), Cheju National University (CNU, Jeju, Korea) for logistic and financial support for workshops and field-works in Russia and Korea. O.N. Pavlyuk, T.S. Tarasova, Yu. Trebukhova, E.E. Kostina, A.V. Chernyshev, T.N. Dautova, A.Yu. Zvyagintsev, M.B. Ivanova, A. Tsurpalov, L.S. Belogurova, T.V. Lavrova (IMB), R. Noseworthy (CNU), Sun Xiaoxia and Ma Junying (IOCAS) much contributed to the success of the project and prepared drafts of relevant parts of the Final Activity Report. We are thankful to K.A. Borzenko for layout of the Proceedings of the Qingdao meeting and this two reports. Soo-Jin Heo (CNU) did much for preparation of the Proceedings and workshop in Jeju. Finally, we are grateful to Linda Stevenson, Kristine Garcia, Yukihiko Imanari and other staff of the APN Secretariat for assistance, advices and general guidance during implementation of the project.

Technical Report

Preface

The project intended to study marine biological diversity in coastal zones of the Northwest Pacific with emphasis to Japan (East) and Yellow Seas, its modern status, threats, recent and future modifications due to human impact and ways of its conservation which is directly related to one of the themes of the APN agenda – *Ecosystems, Biodiversity and Land Use*. Below are presented scientific results and project activities are described including field-works in the Russian part of the Sea of Japan/East Sea (Russky Island) and in Jeju (Cheju) Island in Korea and two workshops held in the Institute of Oceanology CAS, Qingdao, China (October 2007) and in Cheju National University, Korea (October 2008).

Table of Contents

1.0 Introduction.....	11
2.0 Methodology.....	11
3.0 Results & Discussion.....	14
3.1 Present status of marine biodiversity studies in China.....	15
3.2 Intertidal biota of Russky Island (Sea of Japan/East Sea): an island ecosystem.....	18
3.3 Composition and distribution of macrobenthos in the intertidal zone of Kunashir Island (South Kurile Islands).....	26
3.4 Diversity of mollusks of Jeju Island (Korea) as an example of island biodiversity baseline study.....	35
3.5 Ostracods of the coastal zone of Jeju Island, Korea.....	37
3.6 Introduction of invasive species into the northwestern Sea of Japan/East Sea... ..	40
3.7 Free-living marine nematodes in Starka Strait, Russky Island ecosystem (Sea of Japan/East Sea), a meiobenthic study.....	53
3.8 Distributional patterns of the coral diversity ecosystems' changing in the Indo-West Pacific: understanding of the global trends in the coral reef ecosyst.....	58
3.9 Nemertean fauna of northeast Asia	74
3.10 Mid-Holocene palaeoceanography of the Sea of Japan and migrations of mollusks: towards a model of future (expected) faunal changes	78
4.0 Conclusions	84
5.0 Future Directions.....	86
Appendix.....	87

1.0 Introduction

NW Pacific, an area of APN interests, is one of the richest region with respect to biodiversity in Asia, but, at the same time, it is undergoing modifications due to increasing human impact. At the same time, coastal zones are the most sensitive areas experiencing long-term modifications in ecosystems and biodiversity. Biodiversity issue is at stake now, and it is still lesser known aspect of global change. Enourmas human population in Asian countries produces ever increasing effect on the biota causing the extinction of endangered species, processes of bioinvasions, biodiversity loss, ecosystem unbalancing. Coastal zones are the most sensitive areas experiencing long-term modifications in ecosystems and biodiversity. There is still not enough synthesis studies to understand the status and changes in biodiversity, although some initiatives are ongoing. Capacity building at the regional level and improving decision-making process at national and international levels are the urgent needs.

The main objectives of the project were: **1)** to collect information about overall species diversity and to compile species lists of biota; **2)** to undertake coastal expeditions to survey intertidal and subtidal zone; **3)** to inspect and study the species composition and ecological characteristics of the biofouling communities and ballast waters of ships; **4)** to summarize data on biodiversity loss and modifications on tidal flats in three involved countries; **5)** documenting of species diversity in island's ecosystems as a baseline study for conserving coastal and marine biological diversity.

The proposed project was directly related to one of the themes of the APN agenda – *Ecosystems, Biodiversity and Land Use*. The project addressed issues of the biodiversity assessment, modification and future changes, and results contribute to raising awareness of global environmental changes with particular reference to coastal zones where the most human population is concentrated. The project was concerted efforts of participants from three countries – China, Korea and Russia, and included documenting biodiversity (taxonomic and faunal/biota studies), analysis and synthesis of literature data on biodiversity, studying historical changes (Quaternary) for prediction of future modifications of coastal ecosystems, studying fouling communities and ballast waters of ships to reveal potential new immigrants. Field-works, literature studies and workshops planned in course of the project resulted in peer-reviewed publications, development of a website and recommendations to policy-makers and should significantly improve our knowledge about biodiversity status and modifications as a part of global change.

2.0 Methodology

Intertidal biota study

The data from the intertidal zone of the Kunashir Isl. (Southern Kurile Isl.) are based on the materials of 1991 samplings taken on the southern coast of Kunashir Island in Izmeny Bay (near Golovnino Village), on the eastern coast (a reef near Cape Rogacheva and in the southern part of Yuzhno-Kuril'skaya Bay), and on the western coast (a reef near Cape Krugly, and a reef in the northern part of Pervukhina Bay). The materials were collected according to the method of chorological investigation in the intertidal zone (Kussakin & Kostina, 1996; Ivanova et al., 2001). A hydrobiological transect was performed in the surveyed area of the intertidal zone perpendicularly to the coastline. The distribution of intertidal communities was provisionally estimated visually. The communities were distinguished in this case by dominating (usually belt-forming) species of the macrobenthos. The survey areas were bounded by metal frames 250 and 500 cm² in area on loose substrates and 100, 250, and 500 cm² on the rocky reef. When collecting samples in communities of small evenly distributed objects, we used smaller frames, as opposed (to collection in the communities of relatively large species or species that were randomly distributed and not so common. We took two or three samples in each com-

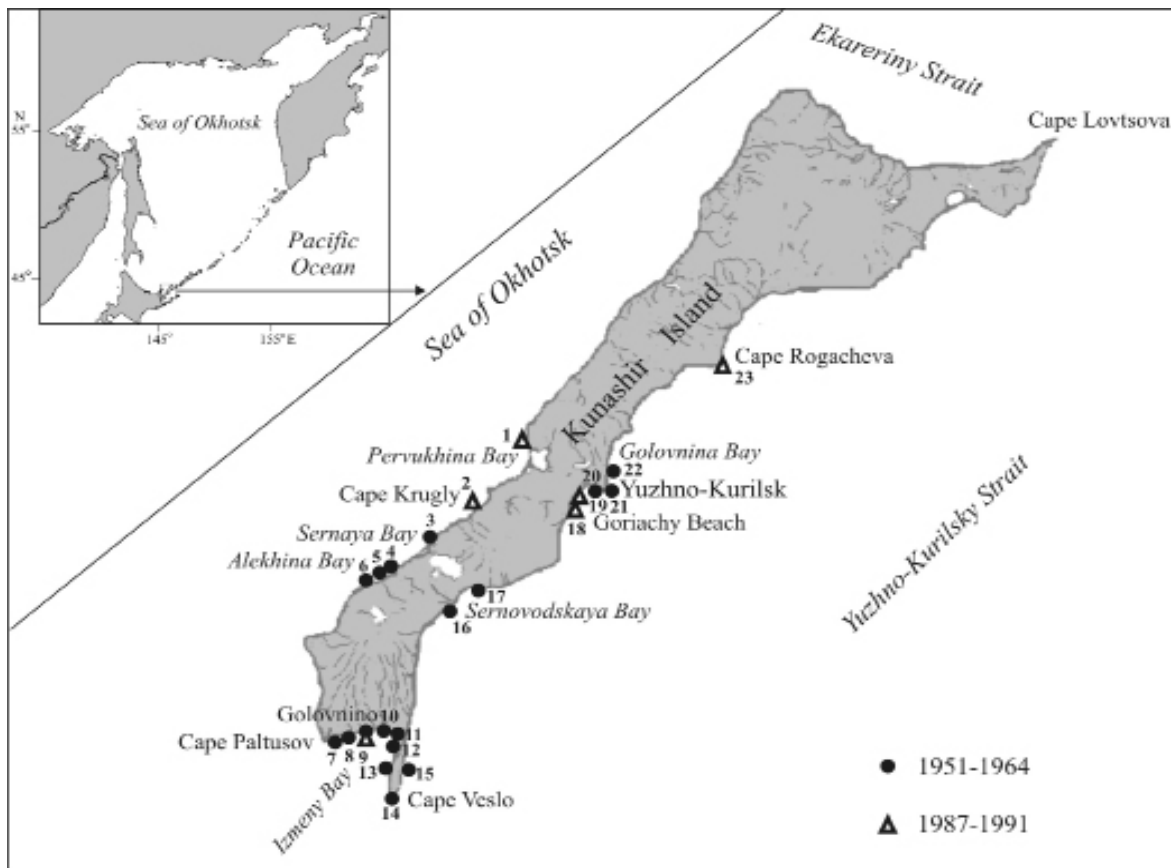


Fig. 1. A scheme of the studied area in Kunashir Island, south Kurile Islands. 1–23 – numbers of transects.

munity. To remove bottom deposits from the macrobenthos samples, we used a set of soil meshes. The collected samples were analyzed, all the organisms were registered and, after drying on a filter paper, weighed using pharmaceutical scales accurate to 10 mg; large plants were weighed on a technical balance accurate to 1 g. The obtained data were extrapolated for 1 m². The biomasses presented in the paper including shells, and other skeletal structures are provided as wet weights. The collections were fixed in 75% alcohol or 4% formalin.

For the identification of intertidal horizons, we used Vaillant's principle of vertical stratification (Vaillant, 1891). Because ice appears in the coast of Kunashir Island in November, which seems to cause the death of a portion of intertidal biota, the estimations of tidal levels and corresponding horizons in the intertidal area were performed by the data for tidal range from May to October. The boundaries of the upper, middle, and lower horizons were determined as the highest tide mark from May to October; the mean high and mean low water stages for the same period, and the lowest possible tide mark respectively.

In total, five hydrobiological transects were made in the intertidal zone (Fig. 1), 68 quantitative and 6 qualitative samples of macrobenthos were collected, and 147 herbarium pages of algae and seagrasses were prepared. The material of 1951–1991 on qualitative composition of macrobenthos was statistically analyzed on a personal computer using StatSoft STATISTICA 6.0. Classification of zonal-biogeographical terminology is given in details by O.G. Kussakin (1990) and K.A. Lutaenko (1993).

In Russky Island, the materials have been collected also according to the standard technique of chorological investigations in intertidal zone (Kussakin et al., 1974). Preliminarily on the studied area distribution of intertidal communities was estimated visually, distinguishing them by dominating macrobenthic species. Hydrobiological section was carried out obliquely to the coastline (Fig. 2). Sample grounds were bounded by 100 and 500 cm² metal frames. When taking samples in communities of small regularly distributed objects, smaller frames were used than in communities of relatively big species or species, distributed rarely and irregularly. In some cases meiobenthic samples were

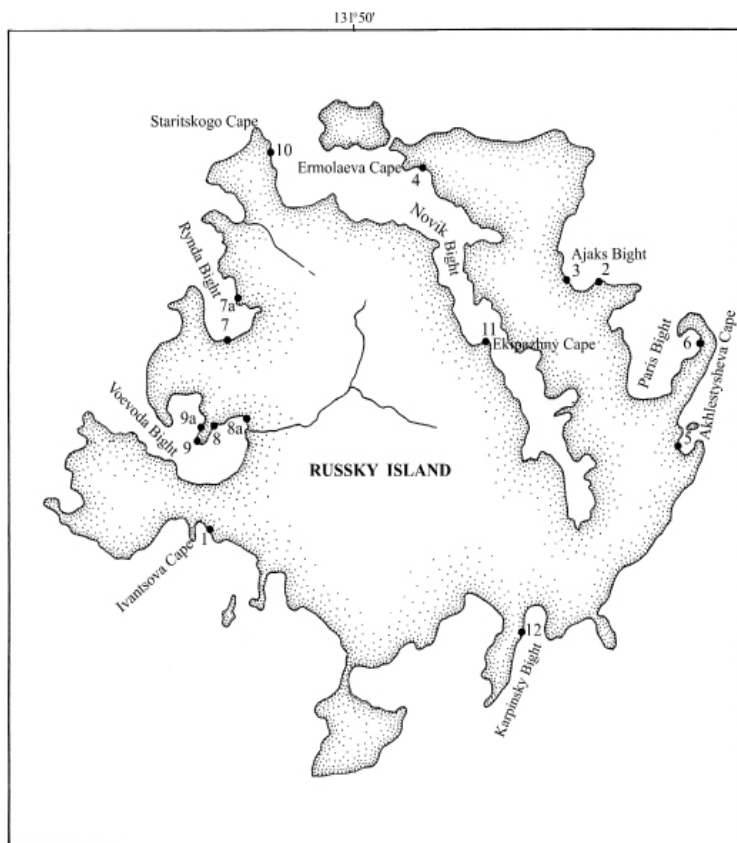


Fig. 2. The scheme of the studied area in Russky Island, Sea of Japan. 1-12 – hydrobiological transects, and 7a, 8a, 9a – recognisance transects.

taken separately from macrobenthic ones, using a 19.6 cm² sectional area and 5 cm height soil nozzle. One or two samples were taken in every community. In order to wash benthic samples from soil, a 59 µm mill gauze sieve was used. The collected samples were sorted out, macrobenthic organisms were counted, and weighted after drying by filter paper (big organisms were weighted using pharmaceutical scales with 10 mg accuracy, and small ones – using torsion scales with 1 mg accuracy). The washed meiobenthos was colored by bengal rose vital dye, sorted out and counted in Bogorov chamber using a binocular. The obtained quantitative data were extrapolated for 1 m². The collections were fixed with 75% alcohol and 4% formalin. The collected animals and plants were identified mainly by specialists of IMB: macrophytes –

by I.R. Levenets, actinians – by E.E. Kostina, nematodes – by L.S. Belogurova, polychaetes – I.L. Davydkova, cirripedes – I.I. Ovsiannikova, amphipods – L.L. Budnikova (TINRO-Center), isopods – O.A. Golovan', decapods and nemertines – A.P. Tsurpalo, gastropods – A.V. Chernyshev, bivalves – M.B. Ivanova, echinoderms – A.P. Tsurpalo and M.B. Ivanova.

Meiobenthic study

Meiobenthos samples collected in August 2006 in the Starka Strait (Peter the Great Bay, Sea of Japan) under the layer of *A. tobuchiensis* (stations 1 and 2) and on a site located outside of the field (station 3) were used for this research (Fig. 3). Water depth at the stations was 10 m. The samples were collected by scuba divers using a tubular bottom sampler with the mouth diameter of 5 cm with the height of the ground sample columns measuring 5 cm. Four replicate sediment samples at each station were taken. The samples were washed through 1mm and 42 µm nylon sieves, fixed by 4% formaldehyde solution and then stained with "Rose Bengal".

Samples for granulometric analysis were also taken at each station; sediments were classified depending on the domination of particles of different size classes (Parsons et al., 1982). Three types of sediments were detected. Samples for the analysis of organic content were immediately frozen. Chemical properties of the bottom layer determined with a CTD "Valeport 660+" elemental analyzer.

The Wieser classification (Wieser, 1953), based on the structure of the mouth cavity of animals, was used for the estimation of the trophic structure of the nematode community. According to this classification four groups of feeders were defined: selective deposit feeders (1A), non-selective deposit-feeders (1B), epistratum feeders (2A) and omnivores (2B).

The similarities in the species composition of nematodes in different types of substrates were estimated using the Chekanovsky-Sorensen index of similarity (*Ics*) (Pesenko, 1982).

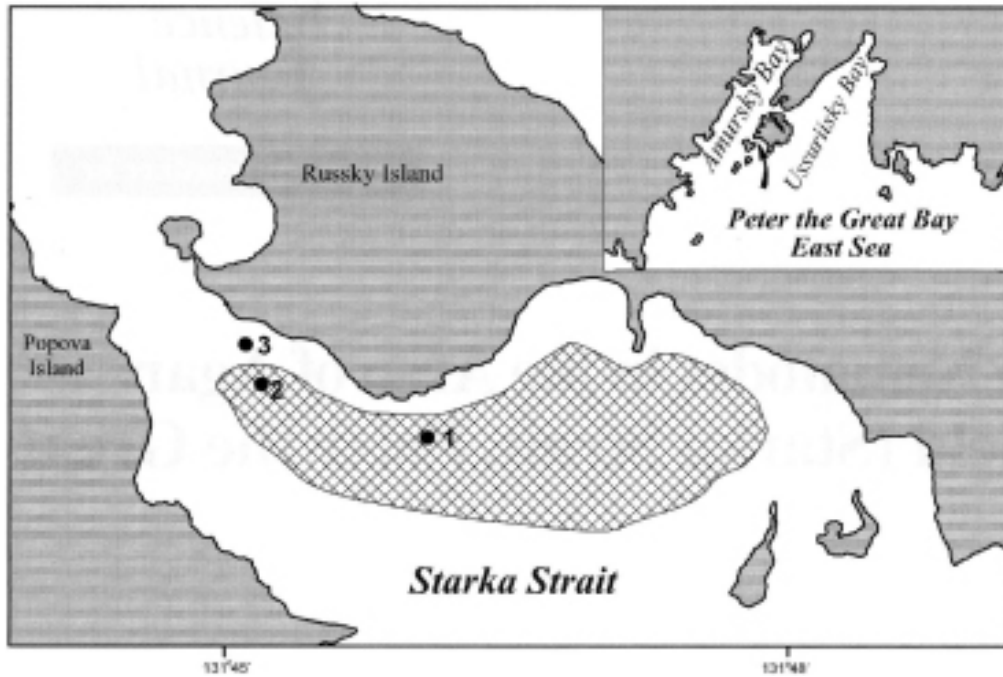


Fig. 3. A schematic map of sampling stations in Starka Strait (Peter the Great Bay, Sea of Japan).

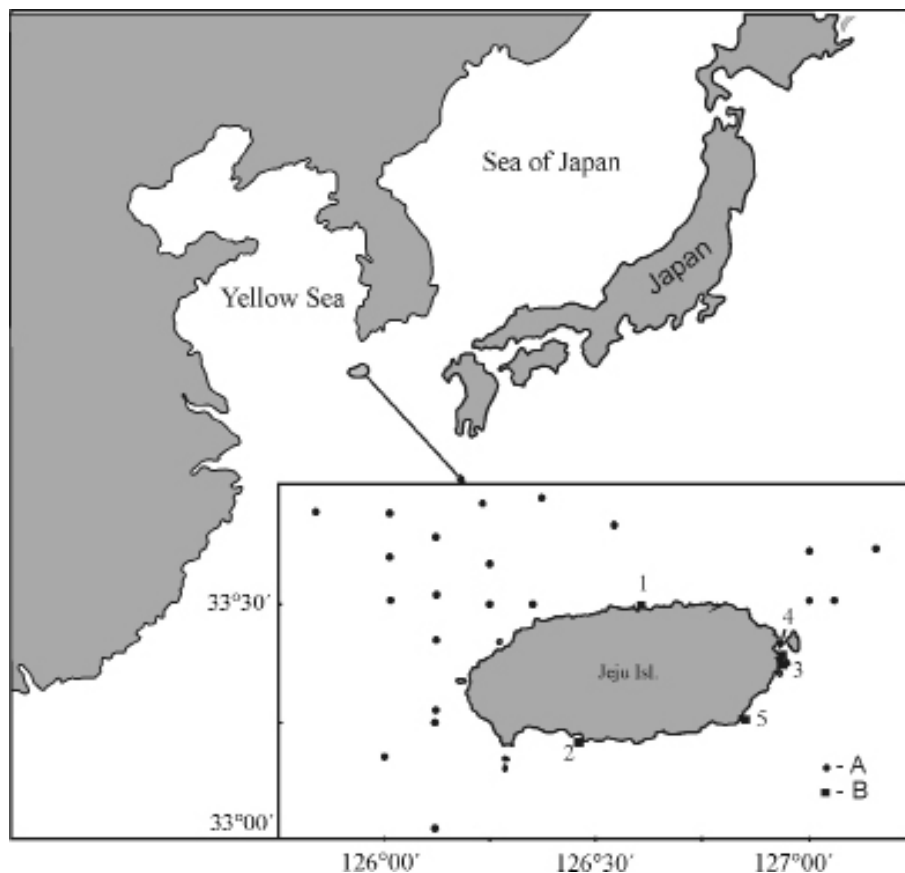


Fig. 4. Schematic map of sampling locations in the coastal zone of Jeju Island: A – stations presented in the Ph.D. Thesis of Choe (1985); B – samples collected from the intertidal zone of Jeju Island in 2007 by K.A. Lutaenko; 1, 2...- numbers of sampling points.

$$Ics = 2a/(a+b) + (a+c),$$

where a - is the number of common species on two lists, b and c - is the number of species in both lists under comparison.

The Shannon-Wiener diversity index (H), the Simpson domination index (C) and Pielou evenness index (e) were used in the characterization of the nematodes community structure:

$$H = -\sum n_i / N \cdot \log n_i / N,$$

$$C = \sum (n_i / N)^2,$$

$$e = H / \log S,$$

where n_i - is community density of each species,

N - total density of communities,

H - index of Shannon-Wiener,

S - number of species

Statistica 6.0 software was used for statistical analysis of material.

Ostracods as meobenthic organisms were collected qualitatively around Jeju Island intertidally and subtidally (Fig. 4). Part of data were taken from Ph.D. Thesis of Choe (1985).

Other data and information were reviewed based on published literature and presented in relevant parts of the Technical Report.

3.0 Results & Discussion

3.1 PRESENT STATUS OF MARINE BIODIVERSITY STUDIES IN CHINA

The seas surrounding China mainland and the southern islands and reefs cover great range of tropical, subtropical and warm-temperate climate zones, and with widest continental shelf in the east, the marine flora and fauna of China seas are rich in species and basically of warm-water nature, with high dominance of some economically important endemic species, and accept tropical Indo-Malaysian biotic elements from the south, but with cold-water elements dominated the Yellow Sea where a heterogeneous cold water body - the Yellow Sea Coldwater Mass - occupied. High marine biodiversity has thus been found in the China seas, particularly in the east and the south.

The marine biodiversity studies in China have been carried out for more than half century since the establishment of the Institute of Oceanology, Chinese Academy of Sciences in 1950. Through the survey of marine fauna, flora and living resources along the China coasts and a series of nation-wide multi-disciplinary oceanographic investigations mainly in the continental shelf, hundreds thousands number of marine fish, invertebrate and seaweed specimens were collected and deposited mainly in the two institutes, IO-CAS (CAS Marine Biological Museum) and SCSIOCASA. As the result of taxonomic and ecological studies, some 70 monographs and about 800 papers on marine fauna and flora of the China seas have been published. A total of 19234 species of marine biota were recorded with geographic information in 1994.

Results of intensive studies on marine fauna and flora have shown the richness of marine species and high biodiversity of the China seas. A total of 20070 species belonging to 20 phyla of marine biota of China seas have been enumerated in 2006, about 2211 spp., or an 15.6 % increase over those recorded in 1994.

The fast development of industrial production in coastal cities and increase of fishing catch intensity in inner shelf area, environmental pollution and decline of living resources, the high biodiversity and richness of marine biota and living resources seriously decreased. Sustainable development of fishery production seems to be difficult.

To maintain and conserve the highly diversified marine biota and the rich living resources, the China Government has adopted laws and regulations for the conservation of them, at the same time, many natural conservation areas (reserve) and fishing forbidden area or forbidden period have been established. Various research projects have

been approved and financially supported. Change of biodiversity in various habitats such as intertidal mud flats, coral reefs, mangrove swamps, have been monitored and studied. Endangered species were assessed and the results published in "The Red List of Endangered Species" of major vertebrate groups (the mammals, amphibians and reptiles, birds and fishes) in the 1990's. Recently in the new century, a new Red List of plant and animal species, terrestrial, freshwater and marine, based on historical and new data with the threaten category of species assessed using new IUCN criteria, the "China Species Red List" have been published (2004, 2005), in which we can find that endangered species are distinctly increased due to stress of human activities (mainly overexploitation and environmental pollution) and global climate change.

In the present report a brief introduction is given to the present status of the marine biodiversity studies carried out for half a century in China. We hope it will be helpful for developing China's CoML project and for promoting the study and conservation of marine biodiversity of the north-western Pacific waters.

I. Collection and accumulation of research materials (specimens and data) for biodiversity study.

A great number of marine life specimens (fishes, invertebrates and seaweeds) have been collected by the Marine Biological Laboratory (Institute of Oceanology), CAS, marine biota and resource survey along the China coasts since 1950, and a series of multidisciplinary oceanographic survey.

Specimens of various groups of phyto- and zooplankton and zoobenthos, as well as pelagic and demersal fishes, have been identified to species category by taxonomic experts for biodiversity, faunal and floral community analysis.

II. Main publications of CAS on marine fauna and flora of China seas are listed below:

A. *Studia Marina Sinica*, edited and published by the Institute of Oceanology, Chinese Academy of Sciences, one or two numbers a year since 1962.

B. Publications of South China Sea Institute of Oceanology (SCSIOCAS) "CAS Nansha Islands Comprehensive Expedition, Science Reports" (1984, 1987).

C. "Marine Species and Their Distributions in China's Seas", ed. by HUANG Zongguo, 1994.

III. Information concerning studies on marine biodiversity and species, and change in the past years observed in various sea areas and habitats.

1. Study and monitoring on changes of benthic fauna biodiversity of a muddy-sand tidal flat: Cangkou tidal flat, Jiaozhou Bay, Yellow Sea.

Great changes in species composition, biodiversity, and abundance have been found in coastal industrial areas stressed by coastal exploitation, eutrophication, pollution and loss of habitats. Species composition and abundance of intertidal benthic fauna and flora of a sandy mud tidal flat in Cangkou flat at east coast of Jiaozhou Bay, Yellow Sea, had been studied and monitored. A total of 67 species of benthic invertebrates dominated by Mollusca and Crustacea were found in 1957 (Gurjanova, Liu et al., 1958); while 141 species (52 species were Crustacea, 41 Polychaeta, 40 Mollusca, 3 Echinoderms (Li & Fan, 2003) were recorded in the period 1963-64; 164 species were recorded depends upon the 16 month data obtained in 1967-68 by Zhuang and Cui (1983). Unfortunately, only 7 species were found in 1980s, but no any living benthic animals were found at the same place after 1989. The biodiversity also greatly changed after the 1970s (Li and Fan, 2004) because of heavy industrial pollution and the great change of intertidal environment due to coastal exploitation.

2. Studies on biodiversity changes of coral reef communities in Sanya Luhuitou, Hainan Island.

High biodiversity in tropical reef community in Sanya Luhuitou coastal fringing coral reef, southernmost Hainan Island, had been observed and monitored. Zonal structure of vertical distribution of living corals in intertidal zone had been lost in 1990-92, but no big change had been found in subtidal zone reef-structure as recorded by Zou in 1966.

3. Biological productivity and living resources.

1) Decline and collapse of resources of major high-abundance fishery resources species due to over exploitation and deterioration of habitats.

1. The large croaker *Latimouchthys crocea*.

The total annual catch amounted to 180,000 tons in the 1970-1980's, overfishing collapsed the resource in 1990's; only 163 individuals were caught during the environment and resource survey in 1997-2000 in the East China Sea Continental Shelf area.

2. The total catch of the Chinese shrimp *Fenneropenaeus chinensis* in the Bohai Gulf decreased from some 40,000 tons (in 1979) to less than 200 ton (1997-2000), while the Pearl River Estuary and west Guangdong population had recently entirely collapsed, no one individual specimen had been caught in the 1997 Exploratory Trawling Cruise (Chen et al., 1998).

The two species were assessed to be endangered in the "China Species Red List", vols. I, III (2004, 2005).

2) Juvenile releasing of the Chinese shrimp for stock enhancement in Jiaozhou Bay, Yellow Sea.

To maintain sustainable development of natural stock of the shrimp, after a 3-year monthly survey of oceanographic environment and living resources in 1980-82, juvenile Chinese shrimp *Fenneropenaeus chinensis* and olive flounder *Paralichthys olivaceus* were released into the bay by my research group in 1983. The same experiment had been carried out again in 1984 and subsequent years up to 1993. The increase of more than 10 folds of the stock size in August and the resulted high shrimp catch in and out of the bay indicated the success of the practice, and that the estimation was reliable. Low catch in 1987 was due to no juvenile shrimps available for releasing practice.

3) Global climate change and biodiversity of cold-water fauna of the Yellow Sea.

The marine fauna of China seas is basically of warm water nature. The Yellow Sea is a semi-enclosed shallow marginal sea situated at mid-latitude (32°00'-40°50'N)m between north (mainland) China and Korea Peninsula. Main part of the sea is less than 100 meters deep. The components of its marine fauna consists of three main kinds of faunal elements; 1, *cold-water species of North Pacific temperate fauna*, most of which inhabit central deeper part of the Yellow Sea no less than 40-50 meters deep; but with some species abundantly distributed in shallow or coastal waters; 2, *eurythermal warm-water species* dominating the shallow and coastal waters, some of them are warm water originated and / or endemic to the China seas.

It is very interesting that almost all of the cold-water species are common to the Yellow Sea and waters surrounding Japanese Islands, and no (or very few in certain invertebrate groups, e.g., the polychaetes) endemic cold-water species has been found from the Yellow Sea.

Available data and information indicated that the Yellow sea cold-water faunal elements under the stress of global climate change (warming), is now declined. Some species such as, the tellinid bivalve *Peronidia zyonoensis* Hatai et Nisiyama, 1939, which had been found to live in East China Sea, 6000 BC (Zheng & Xu, 1982), is now extinct, while living individuals could still be found in the northern Sea of Japan (Russian Far East) and east (Pacific) coast of Honshu.

IV. "IUCN Red List of Endangered Species" [1990's] and "China Species Red List" [2004,2005].

In order to strengthen the conservation of biodiversity and natural resources, the 4-volumed monograph series "China Red List of Endangered Species" were published in the 1990s. A new Red List entitled "China Species Red List" of animal and plant species (including terrestrial, freshwater and marine mammals, amphibians and reptiles, birds-fishes, invertebrates, and higher plants) of China has just been published by the IUCN Biodiversity Group, with the threaten category of species assessed on the base of the newly adopted "IUCN Red List Endangered Categories and Criteria" (2000). In this list, many, not few, marine species have been assessed to be "endangered", for example:

1. The Chinese shrimp *Fenneropenaeus chinensis*, an endemic species of large size and high economic value, and with high production of more than 40,000 tons in 1979 in China, is now very few in its natural habitat in North China waters because of over-fishing and deterioration of spawning and nursing ground in the Bohai and Yellow Sea, and is now becoming endangered species in the List.

2. The horse shoe crab, *Tachypleus tridentatus*, had been very abundant in the South China Sea, particularly in the Gulf of Tonkin, but is now assessed as endangered species because of over exploitation.

3. Among 256 species of scleractinian corals, 26 species have been assessed to be endangered, and all the others are vulnerable endangered;

of the Mollusca, 23 species were endangered, and 22 were critically endangered, 12 were extinct;

of the Crustacea Decapoda, 56 species were endangered;

of the 3 species of living fossil Xiphosura, 2 were endangered and 1 vulnerable endangered;

of the fish fauna, 270 species were endangered, 19 species critically endangered and 4 extinct.

Worse information is that among the 150 species of holothurid echinoderms, 53 were endangered due to over exploitation.

V. Establishing National Committee of *Census of Marine Life* Project in China.

The National Committee is chaired by Prof. Song Sun, Director of the Institute of Oceanology CAS. Studies on biodiversity of marine life is being strengthened.

3.2 INTERTIDAL BIOTA OF RUSSKY ISLAND (SEA OF JAPAN/EAST SEA): AN ISLAND ECOSYSTEM

No special works were devoted to biota of the intertidal zone of Russky Island, but scientific publications on Peter the Great Bay, where the Island is situated, contain a considerable amount of data on this subject (Zaks, 1927; Derjugin, 1939; Shchapova, 1957; Mokievsky, 1960; Perestenko, 1980; Volova, 1985; Gulbin et al., 1987; Kafanov, Zhukov, 1993; Kostina et al., 1996; Kashenko, 1999; Ivanova et al., 2006; Kepel', 1999, 2004, 2007).

The height of the intertidal zone ranges from 0.4 to 1.0 m in various areas of Peter the Great Bay, and in the water area of Vladivostok City, where Russian Island is situated, it makes about 0.8 m over 0 depth (Tables ..., 2004). The lowest and the highest calculated sea levels, theoretically possible by astronomical reasons, taking into account seasonal fluctuations, are considered as limits of the intertidal zone. Seasonal variations of sea level have a yearly period in Primorye (Galerkin, 1961, 1968). They significantly affect vertical distribution of benthos, as their size reaches 0.3 m. That is why hydro-biological works on Peter the Great Bay take into account summer and winter levels of

maximal tides, conventionally named by some authors as summer and winter "zeros" of depth (Shchapova, 1957; Mokievsky, 1960; Kudriashov, 1980; Perestenko, 1980).

I.G. Zaks (1927) and K.M. Derjugin (1939) distinguished two horizons in the intertidal zone of Peter the Great Bay based on the key floro-faunistic groups (communities). K.M. Derjugin, describing chiefly summer condition of biocenoses, probably did not take into account seasonal fluctuations of the sea level, and overstated zero depth mark. If we take into account that the sea level lowers in winter, then *Corallina-Laurencia*, *Chordaria* biocenosis, on his scheme (Derjugin, 1939) located in transitional levels of the intertidal and subtidal zones, joins the limits of the intertidal zone. The other authors also divided the Sea of Japan intertidal zone into two levels (Mokievsky, 1956, 1960; Shchapova, 1956, 1957; Perestenko, 1980; Kafanov, Zhukov, 1993; Kostina et al., 1996; Kashenko, 1999; Kozhenkova, Galysheva, 2006). In T.F. Shchapova's works, though she took into account the annual sea level fluctuations and correctly determined the intertidal zone height for Putiatin Island (Shchapova et al., 1957), the height of the intertidal zone of Bolshoy Pelis Island and that of the other areas of Peter the Great Bay were understated (Shchapova, 1957). Difficulties of distinguishing levels and stories in the intertidal zone of Peter the Great Bay are stipulated by the fact that sizes of tides only slightly exceed sizes of seasonal fluctuations, contrary to the areas of highly boreal zone of the Far-Eastern seas, where the nature of seasonal variations is also different (Galerkin, 1968).

Following the tradition, elaborated in the process of intertidal studies of the Institute of Marine Biology in the Far-Eastern seas (Kafanov et al., 2004), we divided the intertidal zone of Russky Island into three levels. The scheme of division of intertidal zone into three levels was developed by O.G. Kussakin (1961) for the intertidal zone with irregular semidiurnal tides, which can be found in Peter the Great Bay. During our investigations the lower level remained almost completely submerged, as low tides did not exceed 0.3-0.5 m. The middle and upper levels were exposed during our works.

Investigation of intertidal zone of Russian Island was carried out by the littoral group of A.V. Zhirmunsky Institute of Marine Biology FEB RAS chiefly in August-September of 2007. The following areas were investigated: Ajaks Bight, Paris (Zhitkova) Bight, a shallow backwater near Akhlestyshveva Cape, Karpinsky Bight, an area to the east from Ivantsov Cape, Voevoda Bight (Melkovodnaya and Kruglaya Bights), Rynda and Novik Bights in the area of Staritsky, Ekipazhny and Ermolaev Capes (Figs. 2, 5). Fifteen hydrobiological sections have been made (12 routine and 3 reconnaissance ones), 63 quantitative and more than 40 qualitative macrobenthos samples, and 58 meiobenthos samples (meiobenthos have not been taken at the 1 and 4 sections) have been collected (Figs. 6-8).

In the intertidal zone of the studied area 50 plant species (32 – Rhodophyta, 5 – Chlorophyta, 11 – Phaeophyceae, 2 – Magnoliophyta) and 179 animal species (32 – Gastropoda, 24 – Bivalvia, 1 – Polyplacophora, 24 – Polychaeta, 4 – Cirripedia, 34 – Amphipoda, 12 – Isopoda, 10 – Decapoda, 31 – Nematoda, 5 – Echinodermata, 1 – Actiniaria, 1 – Nemertea) have been found, including 128 species of macrobenthic animals and 51 – meiobenthic ones. Meiobenthos included Nematoda, Foraminifera, Ostracoda, Copepoda (Harpacticoida, Calanoida), Acarina, Turbellaria, young and adult forms of Polychaeta and Oligochaeta, as well as juvenile individuals of Bivalvia (11 species of them were met only in meiobenthos), Gastropoda (3), Isopoda (4), Amphipoda, Ophiuroidea and Insecta larvae.

In the intertidal zone of Russian Island (80 plant and animal species) the greatest species diversity of macrobenthos was observed in Stark Strait to the east of Ivantsov Cape on the stony-rubble bottom, a little bit less (68 species) – in the middle part of Ajaks Bight on the pebble bottom, and the third place is occupied by the rocky-rubble littoral in Karpinsky Bight (63 species). The smallest species diversity was observed in the shallow creek near Akhlestyshveva Cape on the silty-sandy drying place with single stones (22 species), in Novik Bight near Ekipazhny Cape on the crushed stone bottom (20 species), and near Ermolaev Cape on the sandy-pebble bottom (19 species). In the other investigated areas the number of found plants and animals varied from 25 to 52 species.



Fig. 5. Research team of the Institute of Marine Biology during intertidal survey in Russky Island.

When comparing species richness of macrobenthos of the intertidal zone of Russian Island with that of the estuarine area of the top of Amursky Bay, on the one hand, and with the islands of the Far-Eastern Marine Reserve, situated in the open part of Peter the Great Bay, on the other hand, it is necessary to notice a natural increase of the number of macrobenthic species from desalinated areas of the Bay to the open sea coasts. In Peter the Great Bay in the indicated three areas the materials were collected in accordance with the same technique during the summer period, that is why the obtained values are quite comparable (Table 1), except for the number of algal and sea grass species in the Marine Reserve. This figure is slightly overstated, as it is adduced taking into account seasonal dynamics, and for the entire Reserve.

Earlier, when studying macrobenthos of the intertidal zone of Shikotan Island (the Lesser Kuril Ridge), we recorded a similar regularity in macrobenthos distribution, having considered 226 species from 16 habitats, and named it conventionally "biodiversity gradient" (Ivanova, Tsurpalo, 2007). "Biodiversity gradient" is not a universal feature of biota, and is typical for macrobenthos, as it reflects regularities of its distribution, connected with salinity gradient and surf degree. For those meiobenthos groups, for which substrate properties and especially presence of fine fractions of bottom sediments are more important for distribution, an inverse regularity was observed. For example, the number of nematode species is greater in the intertidal zone of the estuarine area of Amursky Bay (45 species) than in the intertidal zone of Russian Island (31 species).



Fig. 6. Intertidal zone in Russky Island. Photo by M.B. Ivanova.



Fig. 7. Sponge encrustation of rocks from intertidal zone of Russky Island. Photo by M.B. Ivanova.



Fig. 8. Intertidal zone in Russky Island. Photo by M.B. Ivanova.

Table 1

Variations of species richness of macrobenthos in the intertidal zone of Peter the Great Bay

Systematic groups of macrobenthos	Estuarine zone of Amursky Bay top	Rusky Island	Marine Reserve islands
Crustacea (Cirripedia, Decapoda, Amphipoda, Isopoda)	33	56	85
Mollusca (Gastropoda, Bivalvia, Polyplacophora, Cephalopoda)	21	43	63
Polychaeta	6	22	37
Echinodermata	1	5	9
Actiniaria	1	1	3
Plants (Rhodophyta, Phaeophyceae, Chlorophyta, Magnoliophyta)	32	50	173

On the whole, in the intertidal zone of Russian Island, characterized by various soils, fairly great amount of macrobenthic communities develop, among which 23 plant and animal species dominate by biomass. But in every specific habitat communities are not numerous. Maximal number of communities (8 and 7) was registered respectively in Stark Strait eastwards from Ivantsov Cape and in Karpinsky Bight respectively.

Chthamalus dalli community can be met the most frequently within the entire vertical range of the intertidal zone. Biomass of dominating species varies in it from 140 to 1140 g/m² in the upper horizon, from 100.7 to 750 g/m² in the middle horizon, and from 985 to 1270 g/m² in the lower horizon. Dominating species biomass can reach 100% of the total one, and can be reduced to 56.2% in some cases. In *Ch. dalli* + *Littorina mandshurica* community modification *Ch. dalli* biomass is reduced to 48 % of the total one, at that 45.8 % falls to the share of the subdominant species. *Ch. dalli* community can be met on rocky, boulder, stony substrates and on single stones, situated on sites among silty sand (Melkovodnaya Bight). In the upper intertidal horizon this community includes small number of species. Gastropods *Littorina brevicula*, *L. mandshurica*, *Lottia kogamogai*, *Lottia versicolor*, isopods *Dynoides dentisinus*, and Cyanobacteria can be met among them. In the middle horizon dominating species is accompanied by a greater species number: red algae *Gloiopeltis furcata*, *Masudaphycus irregularis*, *Ceramium kondoi*, *Polysiphonia japonica* and different animals. *L. brevicula* and other gastropods (*Littorina squalida*, *L. mandshurica*, *Falsicingula athera*, *Lottia tenuisculpta*, *Epheria turrita* and others), crustaceans *Caprella bispinosa*, *D. dentisinus*, *Pagurus brachiomastus*, *Amphibalanus improvisus*, *Hyale sp.* and others are the most frequently met among them. In the lower horizon accompanying species include red calcareous alga *Corallina pilulifera*, gastropods *Littorina sitkana*, *L. mandshurica*, *L. squalida*, *F. athera*, *Hima acutidentata*, *L. kogamogai*, *L. tenuisculpta*, barnacle *Balanus rostratus*.

Littorina brevicula community is very frequent in the intertidal zone of Russian Island. As well as the previous one, it can be met within the entire vertical range of the zone. In the upper intertidal horizon *L. brevicula* biomass in some accumulations in rock and stone hollows can reach from 150.2 to 7189 g/m², smaller biomass is registered in the middle horizon – from 333 to 1984 g/m², whereas in the lower horizon it is even small – to 278 g/m². *L. brevicula* biomass, being a biomass of the dominating species, can make from 59.9 to 100% of the total biomass of the community. *L. brevicula* community can be met on rocks, boulders, blocks, on big pebbles among stones. In the upper intertidal horizon this community includes algae *Gloiopeltis furcata* and animals *Ch. dalli* and *Falsicingula athera*. In the middle horizon dominating species is accompanied by the listed above species and crustaceans *Amphibalanus improvisus*, *Hyale bassargini*, *Hemigrapsus sanguineus*, *Hemigrapsus penicillatus*, *Gnorimosphaeroma rayi*, limpets *Lottia tenuisculpta* and polychaetes *Nereis vexillosa*, *Nereis multignatha*, *Capitella capitata* and *Typosyllis pulchra occidentalis*. In the lower horizon sponges and *Ch. dalli* were registered as accompanying species.

A community of the red calcareous alga *Corallina pilulifera* is also very typical for the intertidal zone of Russky Island. It is frequent in the lower intertidal horizon. Dominating species biomass ranges from 270 to 894 g/m², and makes from 48.4 to 78.1% of the total community biomass. *C. pilulifera* community can be met on rocks, boulders and stony bottom. It also includes various animals and some algae as accompanying species: *Scytosiphon lomentaria*, *Dictyota dichotoma*, *Analipus japonicus*; and animals: the most numerous small gastropods *Falsicingula athera*, *Pusilina plicosa*, *Ansola angulosa* and *Ansola angustata*, *Epheria turrita*, juvenile *L. brevicula*, *L. squalida*, *Homalopoma sangarense*, *Lucidestea ornata*. Bivalves *Turtonia minuta*, juvenile *Crenomytilus grayanus*, *Mytilus trossulus kussakini*, *Venerupis philippinarum* can be met not so often. Besides, polychaetes *Nereis multignatha*, *N. zonata tigrina*, *Platynereis bicaniculata*, crustaceans *Ampithoe zachsi*, *Ampithoe sp.*, *Hyale sp.*, *Jassa marmorata*, *Guernea quadrispinosa*, as well as *Dynoides dentisinus*, *Holotelson tuberculatus*, and *Ch. dalli* can be met in the community. In addition to the mentioned above, communities with dominating gastropods *Littorina mandshurica*, *L. squalida*, *Lottia kogamogai* and *Batillaria cumingii* can be recorded as typical for the intertidal zone of Russian Island.

L. mandshurica community was observed in the upper intertidal horizon on boulders having dominating species biomass up to 1467 g/m², and in the lower horizon on pebble-sandy bottom with dominating species biomass of 463 g/m². It makes on boulders up to 100%, and on pebble-sandy bottom up to 68% of the total community biomass. In the upper horizon *Littorina* is accompanied by *Ch. dalli*, whereas in the lower horizon *C. pilulifera*, *L. squalida*, *N. vexillosa* and *Ch. dalli* can be distinguished among numerous accompanying species having a substantial biomass.

L. squalida community is frequent in the middle intertidal horizon on pebble-sandy silted bottom and in the upper part of the lower one on stones. *L. squalida* biomass reaches 1495 g/m² and makes up to 58.7 % of the total community biomass. In the middle horizon red algae *Gracilaria gracilis*, crustaceans *Eogammarus possjeticus* and *Pagurus hirsutiusculus*, as well as polychaetes *Heteromastus filiformis* are accompanying species. In the lower horizon algae *Ralfsia fungiformis*, *Bossiella compressa*, *Clathromorphum compactum* can be attributed to accompanying species. Following animal species can be observed here: crustaceans *Hemigrapsus sanguineus*, *Caprella sp.*, *Melita sp.*, mollusks *Venerupis philippinarum*, *Homalopoma sangarense*, *Tegula rustica*, *Lottia tenuisculpta*, polychaetes *N. vexillosa*, *Harmothoe imbricata*.

In the upper intertidal horizon on boulders and blocks a community of limpets *Lottia kogamogai* was observed with dominating species biomass of 180 g/m², which makes 63 % of the total community biomass. *Ch. dalli*, *L. sitkana*, *Falsicingula athera* and *Dynoides dentisinus* were accompanying species.

Batillaria cumingii colonies were typical for pebble-sandy silted bottoms of the middle and lower intertidal horizons. Dominating species biomass in this community reaches 109 g/m², and makes up to 100 % of the total biomass. The only accompanying species was observed – *Nereis sp. juv.*

Mollusks in *Macoma contabulata* + *Hima fratercula* community form less abundant accumulations. Their biomass reaches 53 and 47 g/m², which makes respectively 41.6 and 36.9 % of the total one respectively. This community can be met on silted sand with pebble admixture in the lower intertidal horizon in a shallow creek to the southwest of Ahlestyshev Cape. Red algae *Polysiphonia japonica* and *Gracilaria gracilis*, as well as amphipods *Pontogeneia intermedia* can be attributed to accompanying species.

In addition to that *Hemigrapsus penicillatus* + *Gnorimosphaeroma rayi* community is typical for pebble bottoms of the middle horizon. Its biomass reaches 38.7 and 26.3 g/m², which makes respectively 33.5 and 22.8 % of the total biomass. Gastropods *Epheria turrita*, *Littorina brevicula*, *L. squalida*, *Cecina manchurica*, *Pusilina plicosa* and *Lucidestea ornata*, as well as amphipods *Pontogeneia sp.* and polychaetes *Neanthes sp.* can be permanently found among accompanying animals.

Among red algae, inhabiting the Russian Island intertidal zone, in addition to the above-mentioned *Corallina pilulifera*, the following species form communities: *Grateloupiaturuturu*, *Neorhodomela larix aculeata*, *N. munita*, *Gracilaria gracilis*, *Lomentaria hakodatensis* and two species of *Ceramium* genus in a joint *C. japonicum* + *C. kondoii* community. Communities of red algae *Gloiopeltis furcata* and *Campylaephora crassa* develop in the middle horizon.

Among red algae the maximal biomass was registered for *G. turuturu* – 4200 g/m², which makes 99 % of the total community biomass. This species is accompanied by epiphyte *Polysiphonia japonica* and polychaetes Spirorbidae.

N. larix aculeata have less biomass – to 3300 g/m², which makes 87.9 % of the total community biomass. This species is accompanied by mollusks *Mytilus trossulus kussakini*, *Ansola angustata*, *Falsicingula athera*, *Epheria turrita*, *Alaba picta*, *Littorina squalida*, *Pusilina plicosa*. *F. athera* is the most abundant among them, and its population density reaches 132800 spec./m² with 344 g/m² biomass. Algae *C. pilulifera*, *Ceramium japonicum* and *Gracilaria gracilis* accompany dominating species. As to animals, there are a lot of amphipods (*Caprella scaura diceros*, *C. bispinosa*, *Ampithoe djakonovi*, *A. lacertosa*, *Jassa marmorata* and others), and pagurians *Pagurus middendorffii*, isopods *Holotelson tuberculatus*, polychaetes *Nereis multig-natha* can be also met.

The other species of *Neorhodomela* genus - *N. munita* – forms a community situated in a shape of spots in *C. pilulifera* zone. Dominating species biomass in this community reaches 1650 g/m², which makes 73.3 % of the total biomass. This species is also accompanied by numerous and various amphipods *Caprella mutica*, *Pontogeneia intermedia*, *J. marmorata*, *Guernea quadrispinosa*, *Ampithoe sp.*, *A. lacertosa*, *Ischi-rocerus sp.* and others, pagurians *P. middendorffii*, isopods *H. tuberculatus*, bivalves *Turtonia minuta* and *M. trossulus kussakini*, and numerous gastropods *F. athera*, *Homalopoma sangarense*, *Lucidestea ornata*, *Ansola angulosa*, *Mitrella burchardi*, *Pusilina plicosa*, *L. squalida*.

The following red algae species – *Gracilaria gracilis* – forms a community in the lower intertidal horizon, attaching to small stones on sitly-sandy bottoms in Melkovodnaya Bight (Voevoda Bight). Dominating species biomass is not great – 330 g/m², which makes 47.2 % of the total community biomass. The main accompanying species in this case are mollusks *Batillaria cumingii* with 213 g/m² biomass (30.5 %), and *Littorina mandshurica* (151 g/m²). Amphipods *Eogammarus possjeticus* and *Monocorophium acherusicum* can be also met in this community. Besides, it is necessary to mention epiphytes *Polysiphonia japonica* and diatoms.

Lomentaria hakodatensis forms a community on the upper surface of boulders with a small dominating species biomass -260 g/m², which makes 75.3 % of the total one. Gastropods *F. athera*, amphipods *J. marmorata*, *Ampithoe sp.*, *Ischi-rocerus sp.*, *Hyale sp.* and brown alga *Dictyota dichotoma* are registered here as accompanying species.

Ceramium japonicum + *C. kondoi* community is the last red algae community in the lower intertidal horizon. These species do not form great biomass. It reaches only 94 и 64 g/m², which makes respectively 30.1 and 20.5 % of the total community biomass. These species are accompanied by the other algae: *Laurencia nipponica*, *N. larix aculeata*, *C. pilulifera*, *P. japonica*, *D. dichotoma*; and animals: amphipods *J. marmorata*, *P. intermedia*, *Ampithoe sp.*, mollusks *F. athera* and *Lottia tenuisculpta*, and barnacles *Ch. dalli*.

Gloiopeltis furcata community is typical for the middle intertidal horizon, especially for its upper part. It does not form a great biomass. Maximal biomass of dominating species in this community, found on blocks, is 195 g/m², which makes 72.2 % of the total biomass, and minimal one – 84.5 g/m² (65.8 %) - is observed on boulders. The main accompanying species is *Ch. dalli*. In addition to it, isopods *Holotelson tuberculatus*, mollusks *Tritonalia japonica* and *L. squalida* were found.

In addition to *G. furcata* community, red alga *Campylaeophora crassa* community is developed on the blocks surface in the middle horizon. Dominating species biomass in it reaches 620 g/m², which makes 79.9 % of the total one. *Ch. dalli* is also the main accompanying species in this community (up to 110 g/m²), besides, amphipods *J. marmorata*, *Caprella cristibrachium*, *Ischi-rocerus sp.*, *Ampithoe sp.*, *Pontogeneia sp.*, isopods *Dynoides dentisinus*, and gastropods *F. athera*, *Ansola angustata* and *Mitrella burchardi* are also found.

Brown algae can also form communities in the lower and middle horizons of the Russky Island intertidal zone.

Maximal biomass among brown algae in the lower horizon is formed by *Sargassum pallidum* – 3800 g/m², which makes 90.6 % of the total community biomass. This dominating species is accompanied by algae *Neorhodomela munita* with epiphytes *Lithophyllum tumidulum*, *Polysiphonia morrowii*, *Gelidium vagum*, *Sphacelaria furcigera*, *Cladophora stimpsonii*. Besides, algae *Ulva fenestrata*, *Scytosiphon lomentaria*, *Grateloupia divaricata*, *Ahnfeltia tobuchiensis*; and animals: amphipods *Ampithoe* sp., *A. annenkovae*, *Caprella penantis*, *C. algaceus*, *J. marmorata*, *Platorchestia pachipus*, *Orchomenella* sp., mollusks *Turtonia minuta*, *L. squalida*, *M. burchardi*, *F. athera*, *Lucidestea ornata*, *Alaba picta*, polychaetes *Nereis multignatha* and pagurians *Pagurus middendorffii* are also found here.

In the lower intertidal horizon on pebble bottoms *Coccophora langsдорфii* community develops with dominating species biomass of 240 g/m², which makes 50.6 % of the total biomass. Mollusks *F. athera*, *L. brevicula*, *Hima fratercula*, *Lottia tenuisculpta*, *L. squalida*, *Epheria turrita*, *M. trossulus kussakini*, amphipods *Caprella laevis*, *Erichthonius tolli*, *Ampithoe* sp., and epiphyte *Polysiphonia japonica* are accompanying species in this community.

Brown algae *Chordaria flagelliformis* and *Dictyota dichotoma* communities are the most typical for the middle intertidal horizon.

Ch. flagelliformis biomass reaches 2030 g/m², which makes 99.3 % of the total community biomass. Mollusks *F. athera*, *L. squalida*, *Pusilina plicosa*, *Lucidestea ornata*, *Lirularia iridescens*, *M. burchardi*, *Ansola angustata* and *Turtonia minuta*, isopods *Dynoides dentisinus*, and amphipods *Caprella penantis*, *C. laevis*, *J. marmorata*, *Calliopius laeviusculus*, *Paracalliopiella litoralis*, *Parallorchestes zibellina* and *Ampithoe* sp. are accompanying species in *Ch. flagelliformis* community.

Dictyota dichotoma forms a community on rocks, having biomass up to 465 g/m², which makes 39.8 % of the total one. Numerous algae *N. larix aculeata*, *Ch. flagelliformis* with epiphyte *Saundersella simplex*, *C. pilulifera*, *Laurencia pinnata*, mollusks *F. athera*, *E. turrita*, amphipods *Ampithoe djakonovi* and *Hyale* sp. accompany the dominating species in this community.

Phyllospadix iwatensis and *Zostera marina* are higher plants forming communities in the intertidal zone of Russian Island. These two species inhabit the lower intertidal horizon and the upper sublittoral zone.

Ph. iwatensis community is formed on rocks and boulders. Dominating species biomass in this community reaches 8280 g/m², which makes 62.5 % of the total one. Numerous gastropods *Homalopoma sangarense*, *Ansola angulosa*, *Alaba picta*, *M. burchardi*, *Pusilina plicosa*, *L. ornata*, *Littorina squalida*, *Lirularia iridescens*, *F. athera*, bivalves *T. minuta*, and amphipods *Ampithoe* sp., *Caprella bispinosa*, *C. penantis*, *J. marmorata*, *Paradexamine fraudatrix* and Lysianassidae are recorded as accompanying species.

Z. marina community develops on soft silted bottoms. Dominating species biomass is not so great and reaches 1290 g/m², which makes 71.7 % of the total community biomass. Как сопутствующие виды отмечены crustaceans *Hemigrapsus sanguineus* and gastropods *B. cumingii* and *L. squalida* are registered as accompanying species.

Thus, rather diverse and abundant biota develops in the intertidal zone of Russian Island, although it has a small height. Nevertheless, in comparison with the other areas of the Far-Eastern seas, especially such as Kuril and Comandor Islands, the intertidal zone of Russian Island is poorly populated.

In Ajaks and Paris Bights, connected with Bosfor Vostochny Strait, a considerable anthropogenic pollution, coming from Vladivostok City, can be observed. It affects the nature of vegetation in Ajaks Bight, where green algae *Ulva* and *Codium* prevail in the upper sublittoral (down to 2-3 m depth) and sublittoral border instead of usual for similar habitats brown and red algae sensitive to pollution. In Zhitkova Bight (Paris Bight) the coast is covered by plastic garbage (plastic bottles, bags and other wastes) above the belt of sea grass casting ashore in the upper supralittoral. But during the studied period no oil film was observed within the limits of the intertidal zone of the Island.

3.3 COMPOSITION AND DISTRIBUTION OF MACROBENTHOS IN THE INTERTIDAL ZONE OF KUNASHIR ISLAND (SOUTH KURILE ISLANDS)

Kunashir Island is the southernmost island of the Greater Kurile Ridge. Its coastline is weakly indented, especially from the Sea of Okhotsk side, though the surf regime at the Pacific side of the Island is stronger than that of the western coast. Sandy bottoms dominate on the south and southeastern coasts, whereas the northern coast is rocky and has occasionally stony-pebbly beaches.

Investigation of population of intertidal zone which is typically amphibiotic is one of the aims of the Far-Eastern seas ecological/environmental studies. Daily and seasonal fluctuations of temperature, salinity and humidity are the most sharply expressed in this zone which results in eurytopic fauna and flora possessing adaptation to unfavorable environment.

Intertidal zone of the South Kurile Islands was investigated in most details by O.G. Kussakin. In 1951, he examined flora and fauna of the intertidal zone of Kunashir Island (Sernovodskaya, Alekhina, Yuzhno-Kurilskaya and Izmeny Bays) (Kussakin, 1956), but quantitative data were not obtained at that time. Additional sampling of materials (Fig. 1) was carried out in 1963–1964 in the same areas and in Sernaya and Golovnina Bays, and on the basis of these results some data on quantitative distribution of the intertidal macrobenthos were obtained (Kussakin & Tarakanova, 1977). In 1987–1988, we investigated composition and distribution patterns of macrobenthic communities in the intertidal zone of Goriachy Beach where gasohydrothermal venting activity were located (Kostina, 1991).

The last coastal expedition to Kunashir Island was carried out in 1991 by the Laboratory of Chorology of the Institute of Marine Biology FEB RAS. Littoral areas in Pervukhina Bay, near Cape Rogacheva and Cape Krugly, not examined earlier by O.G. Kussakin, were described. In Izmeny Bay, quantitative survey was conducted at one of the sites studied in 1963, and in Yuzhno-Kurilskaya Bay the material was collected at the opposite inlet cape. The purpose of this paper is to describe distribution features of macrobenthos in the Kunashir Island intertidal zone based on the results of the last expedition, to compare the obtained data with that of 1951–1988, and to summarize the results of investigation of the island's intertidal zone on the zonal-biogeographical composition of biota, vertical distribution of intertidal communities on various bottom types. The comparison of long-term changes of the intertidal macrobenthos in Izmena Bay taken place from 1963 to 1991 was also carried out and distribution pattern of the intertidal communities of Kunashir Island and neighboring Shikotan Island are compared. Data on the number of species found in Kunashir Island were obtained and based on them, evaluation of the qualitative composition of macrobenthos in transects 1-23 was made.

Rocky intertidal zone

A reef southward of Cape Krugly (transect 2) is a flat rocky indented platform with a weak slope. The coast is poorly protected and exposed to almost permanent surf. Vertical stratification of communities is sufficiently well expressed.

Population of the upper intertidal horizon is uniform. Two communities can be distinguished: *Littorina sitkana* and *Chthamalus dalli*. Plants are not typical for these communities. The upper horizon part and partially supralittoral zone are occupied by *L. sitkana* belt. *Littorina* biomass makes up 99% of the total macrobenthos biomass, and it is more abundant here (more than 90 thousand indiv. m⁻²). The following animals were also found in the community: *Falsicingula kurilensis*, *Ch. dalli*, *Lottia pelta*, and *Gnorimosphaeroma noblei*. The lower part of the upper horizon was occupied by *Ch. dalli* community with a small biomass of macrobenthos.

Gloiopeltis furcata community inhabits the boundary between the upper and middle horizons of the intertidal zone (total biomass of macrobenthos is up 2200 gWW m⁻²). Gastropods *F. kurilensis* (44700 indiv. m⁻²) and *L. sitkana* (8220 indiv. m⁻²) are remarkable for their population density.

In the middle intertidal horizon, fucoids dominate. As our investigations showed,

Fucus evanescens community does not form its own belt, in contrast to *Silvetia babingtonii* community. Dominant species makes up 95% of the total biomass. *L. sitkana* dominates among animals. In *F. evanescens*+*S. babingtonii* community, other algae almost were not found. Biomass of dominant and subdominant species makes up 90% of the total macrobenthos biomass. As well as in *G. furcata* community, *L. sitkana* and *F. kurilensis* prevail among animals. Gastropod *Hima fratercula* and amphipods *Hyale bassargini*, *Anisogammarus spasski*, *Ampithoe kussakini* frequently occur.

Besides, rather poor in its species composition mono-dominant community of *Analiplus japonicus* can be found in the upper part of the middle intertidal horizon. Dominant species constitute 95% of the total macrobenthos biomass (up to 1500 gWW m⁻²).

Other algae were not found in a mono-dominant community of *Corallina pilulifera*. Gastropods *F. kurilensis*, *H. fratercula*, *L. sitkana* and amphipods *A. kussakini*, *Paralorchestes ochotensis* are abundant among animals. Dominant species makes up 80% of the total biomass.

A community of the green alga *Chaetomorpha moniligera* can be frequently found in the middle horizon. Though the total biomass of the community is not significant (up to 550 gWW m⁻²), the animal population is rather rich. Gastropods *F. kurilensis*, *Nucella heyseana*, *H. fratercula*, *L. sitkana*, amphipod *A. kussakini* are the most abundant species.

Neorhodomela larix community is one of the most diverse communities of the middle horizon with twenty-two animal species. Gastropods *H. fratercula*, *L. pelta* and *F. kurilensis*, amphipod *P. ochotensis*, decapods *Pagurus middendorffii* and *Telmessus cheiragonus*, tunicate *Schizoplax brandti*, isopods *Holotelson tuberculatus* and *Idotea ochotensis*, Pantopoda, Caprellidae are the most frequent. *Sargassum miyabei* and *C. pilulifera* are equally represented among algae. A mixed community of *Neorhodomela larix*+*N. munita*+*S. miyabei*, being poor both in biomass and in species diversity, can be also found here, at that more than 95% of the total biomass (up to 800 gWW m⁻²) fall to the share of algal species.

In areas where rocky bottom has splits filled with sand, *Phyllospadix iwatensis* community develops with insignificant total biomass of macrobenthos (Table 6). Abundant groups of macrobenthos (in all, 26 species were found) are represented by gastropods *H. fratercula*, *Lottia borealis*, *Mitrella burchardii*, *Cryptonatica hirasei*, *Homalopoma sangarense*, isopods *I. ochotensis*, *I. gurjanovae*, *H. tuberculatus*, and amphipods *A. kussakini*, *P. ochotensis*. *Phyllospadix* rhizomes contain many polychaetes: *Chone teres*, *Nereis vexillosa*, *Naineris jacutica*, Cirratulidae, Maldanidae and others.

Communities of brown algae *Sargassum miyabei* and *S. thunbergii* with rather rich composition of animals and plants are typical for the lower horizon. *S. miyabei* biomass makes up not more than 60% of the total biomass, whereas biomass of accompanying algal species – *N. larix* and *Mastocarpus pacificus* – 30%. Gastropods *F. kurilensis*, *Pusillina plicosa*, *H. fratercula*, *L. sitkana*, *H. sangarense*, amphipods *A. kussakini*, *H. bassargini*, *Caprella bispinosa* and isopods *I. ochotensis*, *H. tuberculatus* are frequently found in the community. In a mono-dominant community of *S. thunbergii* 95% of the total biomass falls to the share of the dominant species. The community composition is slightly different in comparison with the community of *S. miyabei*. Gastropods *F. kurilensis*, *N. heyseana* and amphipods *H. bassargini*, *Ischyrocerus* sp., *Caprella cristibrachium* are the most abundant here.

An intertidal pool about 20 m diameter and about 30 cm depth, separated from the open sea by a rocky terrace, which protects it from the heavy surf, was examined on a flat reef in the middle horizon at **Cape Rogacheva** (transect 23). Vertical stratification of communities was observed only on the walls of the upper pool part, whereas on the bottom communities had a mosaic arrangement.

At the level of boundary of transition of the pool walls into the top reef part belt-forming communities of *Chthamalus dalli*+*Littorina sitkana* and *L. sitkana* are developed. Community population is poor, represented mainly by dominant species, and algae were not found here. A community of *Gloiopeltis furcata* is situated along the edge of the pool. *L. sitkana* dominates among animals.

A belt of fucoids with more diverse population is located lower. In *Silvetia babingtonii* community with rare spots of *Fucus evanescens* vegetable biomass is dozens of times

greater than that of animal biomass, at that more than 95% of the total biomass fall on the dominant species. The gastropod *L. sitkana* dominates among animals.

Horizontal flat unevenly indented bulges on the pool walls are occupied by a monodominant community of *F. evanescens*. Population of the community is abundant (*L. sitkana*, *Nucella freycinetii*, *N. heyseana*, *Hyale bassargini*, *Ch. dalli* and others), but with small biomass. A community of the brown alga *Analipus japonicus* with a poor biomass and species diversity of macrobenthos is situated lower than a fucoids belt.

Rather a mixed content of population is typical for the pool bottom. Sea grasses, red and green algae prevail. A community of calcareous red alga *Corallina pilulifera* forms almost an entire carpet on the pool bottom. About 95% of the total macrobenthos biomass falls at the share of the dominant species. Animal biomass is dozens of times smaller than that of plants. Among them, *Falsicingula kurilensis* and *L. sitkana* predominate.

Phyllospadix iwatensis community is typical for the pool bottom in places of sand accumulation, with the dominant species biomass of about 95% of the total biomass (Table 6). Animal population of this community is very diverse (40 species were registered), but it has small biomass. Infaunal (polychaetes *Naineris jacutica*, *Nereis pelagica*, *N. vexillosa*, sipunculoid *Phascolosoma japonicum*, nemertine *Tubulanus punctatus*, bivalve *Protothaca euglypta*) and onfaunal forms (decapods *Telmessus cheiragonus*, *Pagurus middendorffii*, *P. hirsutiusculus*, *P. brachiomastus*, *Dermaturus mandtii*, *Paralithodes brevipes*, butterflyfish *Alectrias alectrolophus alectrolophus* and Pantopoda) can be found in this community.

Among red algae *Neodilsea yendoana*, *Pterosiphonia bipinnata*, *Neorhodomela larix*+*N. oregona*, *Iridaea cornucopiae*+*C. pilulifera* communities are found in a form of spots. Flora in the communities is represented by several species, whereas fauna is very rich. In *N. yendoana* community, isopods *Idotea ochotensis*, *Cliamenella fraudatrix* and amphipods *H. bassargini*, *Allorchestes malleolus* are the most frequent among animals. In *P. bipinnata* community isopod *C. fraudatrix*, polychaete *N. pelagica*, barnacle *Ch. dalli*, amphipods *H. bassargini* and *Pontogeneia* sp. are the most abundant. Abundant development of *L. sitkana* and *Pontogeneia* sp. is typical for *Neorhodomela larix*+*N. oregona* community, whereas for *I. cornucopiae*+*C. pilulifera* community – occurrence of mollusks *Hiatella arctica*, *L. sitkana*, *F. kurilensis*.

Chaetomorpha linum and *Ch. melagonium* represent communities of green algae in the pool. Though their total biomasses are different, species composition of macrobenthos is almost identical. Abundant animal species are *L. sitkana*, *F. kurilensis* and *H. bassargini*.

From the seaside of the pool, at the edge of the terrace, there is *Alaria ochotensis* bush. Population of this community is rather rich and diverse in species composition. Mass plant species is *P. bipinnata*, whereas that of the animals – barnacles *Ch. dalli* and *Semibalanus cariosus*, gastropods *N. freycinetii*, *Lottia pelta* and *L. sitkana*, bivalves *Mytilus trossulus kussakini* and *Hiatella arctica*, amphipod *P. ochotensis* and polychaete *N. pelagica*.

Rubble-rocky intertidal zone

A reef in Pervukhina Bay (transect 1) is a flat rocky platform with a scattering of rubbles under the high break. A cape, situated nearby, protects the reef from a heavy surf. Vertical stratification of the communities is sufficiently well pronounced.

In the upper horizon *Chthamalus* and *Littorina* colonies are rarefied, and do not form a continuous belt. *Littorina sitkana* community occupies lateral surfaces of rubbles. *Littorina* biomass is not great. *Chthamalus dalli* community is situated lower and also has a small total biomass.

The top of the middle horizon of the intertidal zone is occupied by *Silvetia babingtonii* and *Fucus evanescens* communities with rare spots of green algae *Cladophora opaca* and *Chaetomorpha moniligera* and poor animal population. In comparison with the other investigated areas of the rocky intertidal zone, the total biomass of these communities is not great, though about 95% of biomass fall at the dominant species, and other algae, as a rule, are not included into these communities.

Communities of green algae *Ulva fenestrata* and *C. opaca*+*Chaetomorpha* sp. are situated lower (total biomass of macrobenthos is up to 1000 gWW m⁻²). In *Ulva* community among algae *Mazzaella japonica*, *Sargassum miyabei* and germs of *Laminaria* sp. dominate, whereas in *Cladophora* community – *U. fenestrata*. Abundant animal species in the communities are gastropod *Falsicingula kurilensis*, bivalve *Turtonia minuta* and amphipod *Ampithoe kussakini*.

Communities of the red algae *Laurencia nipponica*, *Chondrus pinnulatus* and *Mastocarpus pacificus*, not found in the other studied areas, are observed in Pervukhina Bay. Dominant species make up 95% of biomass (up to 3000 gWW m⁻²). In the latter community, the calcareous alga *Corallina pilulifera* constitutes 1/3 of *M. pacificus* biomass.

Comparatively widespread in Kunashir Island, community of *Neorhodomela larix* is also found in the middle horizon. Species composition in the community is rather diverse, but amphipods basically prevail: *Ampithoe japonica*, *A. kussakini*, *Parallorchestes ochotensis*, *Caprella irregularis*, *C. cristibrachium*, *C. bispinosa* and others.

In splits on the reef surface filled with sand, *Phyllospadix iwatensis* spreads out. More than 40 animal species occur in this mono-dominant community, however their biomass does not exceed 5% of the total biomass. A great number of polychaetes *Naineris jacutica*, *Nereis vexillosa*, *N. zonata*, *Glycinde armigera* and others dwells in *Phyllospadix* roots, and *Chone teres* is the most abundant. Gastropods *Nucella heyseana*, *F. kurilensis*, *Lacuna minor*, *Epheria turrita*, bivalves *Protothaca euglypta*, *Mysella kurilensis* *litoralis*, *T. minuta*, isopods *Idotea ochotensis*, *Holotelson tuberculatus*, *Cleantiella isopus*, *Synidotea lata*, *Gnorimosphaeroma noblei*, amphipods *A. kussakini*, *Thethygenia kondakovi*, echinoderms *Strongylocentrotus intermedius*, *Evasterias retifera* *tabulata*, decapods *Pagurus middendorffii*, *P. brachiomastus*, *Telmessus cheiragonus*, *Pugettia quadridens*, sea anemones *Cnidopus japonicus*, *Aulactinia* sp., ascidians, sponges, hydroids and other groups are also met.

In the upper part of the lower horizon, communities of *Sargassum miyabei* and *Scytosiphon lomentaria* with almost similar total macrobenthos biomass occur. A diverse fauna is developed on *Sargassum* thalli: gastropods *F. kurilensis*, *Pusillina plicosa*, amphipods *Hyale bassargini*, *A. kussakini*, *A. japonica*, *P. ochotensis*, bivalves *T. minuta*, *P. euglypta*, *Volutarpa ampullacea*. Among algae, only *N. larix* grows. In the community of *S. lomentaria* 15 algal species are recorded (*S. miyabei*, *U. fenestrata*, *Costaria costata*, *Tichocarpus crinitus*, *Chordaria flagelliformis*, *L. nipponica* and others), though on the whole, it is more poor in species diversity as compared with *S. miyabei*. Amphipods *C. bispinosa* and *Ampithoe* sp. are the most frequently found animal species.

A mono-dominant community of *Laminaria* sp. forms a belt in the lower part of the lower horizon of the rubble-rocky intertidal zone, at that 99% of macrobenthos biomass falls on *Lamanaria*. Animal population is represented only by several species. The most frequently found are *F. kurilensis*, *Ampithoe volki* and *Typosyllis* sp.

Rubble-sandy littoral

Inlet cape of the Yuzhno-Kurilskaya Bay (transect 19) is a scatter of rubbles and blocks among sand. The coast is weakly protected from the surf. Vertical stratification of the communities is insignificantly pronounced, punctuation is typical in macrobenthos distribution. The intertidal population, on the one hand, is represented by a rich infauna of soft bottoms, and on the other hand – by some depletion of population of firm bottoms.

In the upper horizon of the intertidal zone, community of the barnacles *Chthamalus dalli*+*Semibalanus cariosusi* with rather big biomasses are found on stones. Species composition of the communities is rather numerous: gastropods *Littorina sitkana*, *Nucella heyseana*, *Lottia borealis*, polychaete *Typosyllis adamanteus kurilensis*, insect larvae and others. Plants are absent. Fairly poor community of *Gloiopeltis furcata*+*Ch. dalli* with numerous amphipods *Corophium* sp. and gastropod *L. sitkana* is located on the boundary between the upper and the middle horizons.

In the middle horizon, poor in diversity mono-dominant communities of brown algae *Silvetia babingtonii*, *Fucus evanescens* and *Analipus japonicus* are developed on the lateral surfaces of rubbles. Not less than 90% of the total biomass falls on dominant spe-

cies. Population of the communities is poor, but their species composition is different. In *Silvetia* community, *Ch. dalli* and amphipod *Hyale bassargini* prevail, in *Fucus* community – *L. sitkana* and isopod *Gnorimosphaeroma noblei*, in *Analipus* community – *N. heyseana*, and small species of polychaetes and amphipods are abundant.

Communities of green algae are prevalent on stones. Lower, *Analipus* communities are located, and in the pools of the upper part of the middle intertidal horizon, a community of the green alga *Blidingia minima* is developed. Animal population is scanty, only *Ch. dalli* can be frequently found, and of algae – *A. japonicus*. In *Chaetomorpha melagonium* community, animal population is poor, and among algae, there is a great number of *Ulva fenestrata*. Total biomass of macrobentos communities is up to 1400 gWW m⁻². *Ulva fenestrata* community can be frequently occur on rubbles sides (total biomass is up to 800 gWW m⁻²). *Devaleraea* sp., *Mazzaella japonica* and *Cladophora speciosa* are also observed in this area. Among animal species, only *Ch. dalli*, *Corophium* sp. and *Turtonia minuta* are found.

Corallina pilulifera monodominant community can be found on horizontal rubble surfaces. Though biomass of the dominant species is about 95% of the total macrobenthos biomass, animal species composition is rather diverse. *Falsicingula kurilensis*, *Nereis pelagica*, *Telmessus cheiragonus*, Pantopoda frequently occur. Communities of red algae *Tichocarpus crinitus*, *Odonthalia annae* and *Palmaria marginicrassa*, not found in the other studied areas, are also found in the Yuzhno-Kurilskaya Bay (total biomass is up to 10 kgWW m⁻²). *Halichondria panicea* sponge makes 35% of the total biomass in the *O. annae* community. *Laminaria* sp. young germs are quite a few in *T. crinitus* and *O. annae* communities. Animals are diverse in these two communities. Amphipods *Caprella cristibrachium*, *Jassa marmorata*, *Pontogeneia* sp. and *H. bassargini*, hydroids *Abietinaria filicula*, *A. thujarioides* and *Eudendrium annulatum*, decapods *Telmessus cheiragonus*, sea spiders are plenty in algal bushes. Only three animal species are found in *P. marginicrassa* community. Species composition of *Iridaea cornucopiae* community is rather diverse (total biomass of macrobenthos is up to 5 kgWW m⁻²), but gastropods *F. kurilensis*, *L. sitkana*, *Lottia borealis*, bivalves *Panomya arctica*, *Hiatella arctica*, *T. minuta*, *Musculus laevigatus*, *Modiolus kurilensis*, hydroids *Obelia longissima*, *Sertularia robusta*, amphipod *H. bassargini*, polychaete *N. pelagica* mainly prevail. Among algae, only *C. pilulifera* is observed.

Formation of a separate settlements of the hydroid *Abietinaria filicula* with diverse population is a peculiarity of rubble-sandy intertidal zone. Only young germs of *Laminaria* sp. occur. Among animals, *Lottia pelta*, *N. pelagica*, *Cnidopus japonicus*, hydroids *Eudendrium annulatum*, *Abietinaria* sp., *Halecium lucium*, *Campanularia everta*, *S. robusta*, ascidians and bryozoans can be found in this community. Numerous Sabellidae populations are found in littoral pools on sand at rubbles bases, and plants are absent. Among animals, only sea anemone *Oulactis orientalis* was found among numerous and diverse polychaetes.

In the middle horizon, *Phyllospadix iwatensis* thickets are observed on sand among rubbles. The most animals in this monodominant community inhabit *Phyllospadix* rhizomes. Polychaetes *Naineris jacutica*, *Chone teres*, *Nereis vexillosa*, *Eudistylia polymorpha*, *Eteone longa*, *Typosyllis orientalis*, *Pseudopotamilla ocellata*, sea anemone *O. orientalis*, gastropods *N. heyseana* and *L. sitkana* prevail quantitatively.

Laminaria sp. belt stretches in the lower horizon. The total biomass of *Laminaria* sp. community makes more than 100 kgWW m⁻², at that 99% falls at the dominant species. Animal population is diverse, but the number of species and abundance are not as great as in *P. iwatensis* community. A great number of polychaetes (*N. pelagica*, *Naineris jacutica*, *Capitella capitata*, *Typosyllis* sp., *Chone* sp.) are found in *Laminaria* rhizoids, whereas amphipods (*Parallorchestes ochotensis*, *Parallorchestes* sp., *H. bassargini*, *Corophium* sp.) are found in thalli.

Sandy intertidal zone

A sandy intertidal zone of Izmeny Bay (transect 9) is protected from the heavy surf. Species diversity of its population is poorer as compared to the other studied areas. In the area of Golovino Village, the intertidal zone is exposed to domestic effluents and

effluents from sea food processing.

In the upper intertidal horizon, animals and plants are not found. The middle horizon is occupied by *Zostera japonica* belt. Population is rather rich with 22 species found. Infaunal forms are typical: bivalves *Ruditapes philippinarum*, *Macoma incongrua*, polychaetes *Abarenicola pacifica*, *Nereis vexillosa*, *Orchomene* af. *magdalenensis*. Gastropod *Batillaria cumingii* and isopod *Gnorimosphaeroma noblei* are abundant.

The lower part of the middle and the upper part of the lower intertidal horizons are occupied by *Batillaria cumingii* belt. *B. cumingii* community is represented by several animal species, and about 90% of the biomass falls at the dominating species. The lower part of the lower horizon are occupied by *Zostera marina* belt. *Z. marina* community is monodominant, and richer in composition as compared with the previous communities. As well as in *Z. japonica* community, infaunal organisms of the same species composition prevail along with *Nereis brandti*, *N. pelagica*, *Naineris jacutica*, *Glycinde armigera* and *Chone* sp. Gastropods *Minolia iridescens*, *Pusillina plicosa*, *Cerythiopsis stejneri* dwelling on the leaves of *Zostera*, and *B. cumingii* and *Hima multigranosa* – on the bottom.

In Kunashir Island intertidal zone, 127 plant and 275 animal species are found. Zonal-biogeographical composition of biota is typical for low-boreal sub-region of the Pacific Boreal Region. Pacific low-boreal and Pacific wide-boreal species prevail (for the western coast – 32, or 27%, respectively, for the eastern one – 25, or 32%, and for the southern coast – 32, or 22%), as well as representatives of tropical-boreal and subtropical-boreal flora and fauna (in the western coast – 21%, in the eastern one – 18%, and

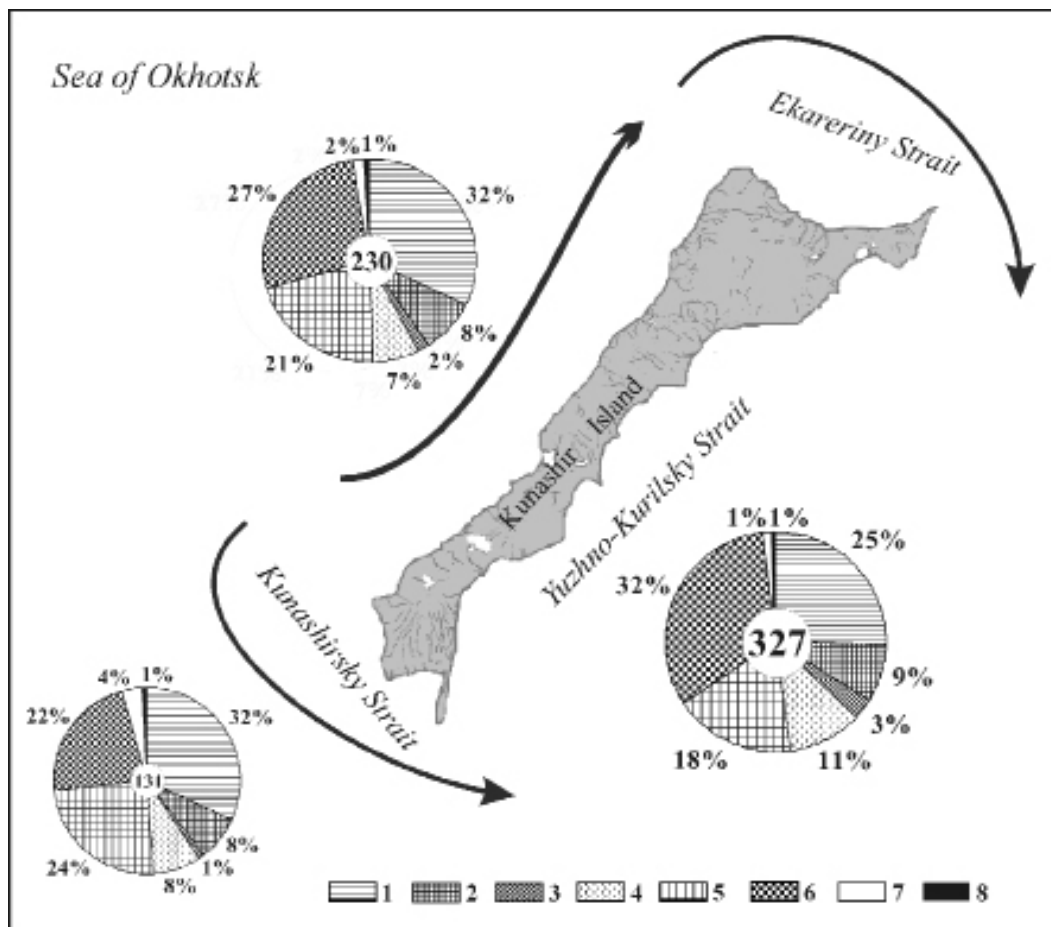


Fig. 9. Zonal-biogeographical structure of macrobenthos in the intertidal zone of Kunashir Island. 1 – Pacific low-boreal, 2 – amphiboreal, 3 – Pacific high-boreal, 4 – boreal-arctic, 5 – tropical-boreal, 6 – Pacific wide-boreal, 7 – cosmopolite, 8 – boreal-notal species. The branches of Soya Current are shown by arrows; the number species are shown in the circles centre.

in the southern one – 24%) (Fig. 9). Zonal-biogeographical structure of macrobenthos in various Kunashir coasts is somewhat different.

Intertidal biota in Izmeny Bay and in the Sea of Okhotsk coasts is more thermophilous as compared to the Pacific coast (low-boreal and tropical-boreal species make totally 56, 53 and 43%, respectively, whereas representatives of high-boreal and boreal-arctic complexes are 9, 9 and 14%). Estimation of similarity of qualitative composition of macrobenthos showed that the studied areas of Kunashir Island intertidal zone can be divided into several groups (Fig. 10). One group contains transects from Izmeny Bay. The most transects of the western and eastern coasts also form separate groups, though there is no clear difference in species composition of macrobenthos in these coasts. It is connected with circulation of warm waters of Soya Current which brings its waters to the Sea of Okhotsk in summer-spring season which allows to consider biota of the Sea of Okhotsk coast of the island as having some warm-water features. One of the current branches flows out to the ocean through the Kunashirsky Strait, but not coming to the Yuzhno-Kurilsky Strait. The other branch passing through Ekateriny Strait fills only the northern part of the Yuzhno-Kurilsky Strait, and also flows out to the ocean. That is why Soya Current does not significantly affect the Pacific coast of the island. Besides, summer water temperature is a leading factor affecting distribution of marine organisms in Kurile shelf, since in winter time thermal conditions along the entire Kurile Ridge are approximately the same. In July-October, Soya Current waters come the closest to the South Kurile Islands, whereas during the other seasons the Yuzhno-Kurilsky Strait is filled with cold waters from the Sea of Okhotsk and Oyashio Current (Bobkov, 2004). Thus, changes in proportion of cold- and warm-water species in the Kurile Islands intertidal zone take place in accordance with variations of the mean long-term temperature of the coastal waters during warm season (Kussakin, 1976). The maximal relative number of thermophilic species is found in Izmeny Bay. It completely conforms to peculiarities of hydrological conditions of this area. In summer, water surface temperature reaches +27°C (Kussakin, 1956). Besides, well pronounced permanent currents, together with strong tide currents facilitate intensive mixing of water mass in the area of the Yuzhno-Kurilsky Strait (Bobkov, 2004), and the surf at the eastern coast is stronger than at the western one (Kussakin, 1956), which creates favorable conditions for development of a more diverse population in the intertidal zone of the Pacific coast of the island: 327 macrobenthic species are found here, whereas at the Sea of Okhotsk coast - 230, and at the south one – 131 species.

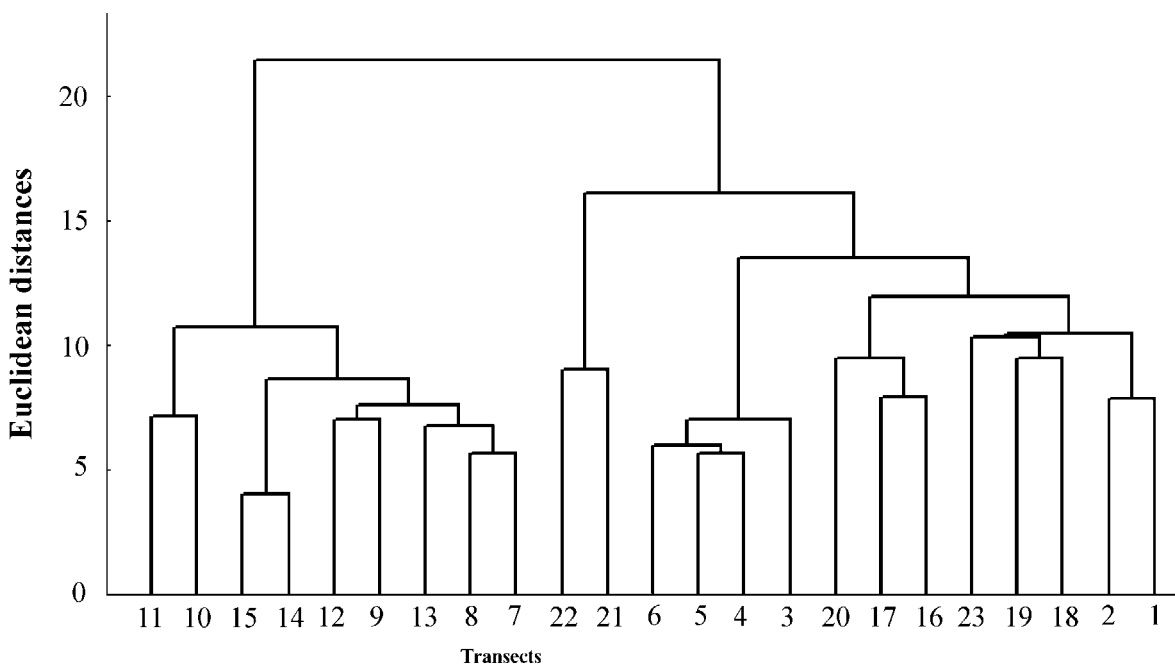


Fig. 10. A dendrogram of similarity of species composition of the studied intertidal areas. The dendrogram is made using the Ward's method.

A great number of warm-water starfishes – *Lethasterias fusca*, *Aphelasterias japonica*, *Asterias amurensis*, *Evasterias retifera* f. *tabulata*, *Lysastrosoma anthosticta* – is a peculiar feature of the intertidal zone of the western Kunashir coast. Such warm water species as crab *Pugettia quadridens quadridens*, isopod *Dynoides dentisinus* and others are also found here (Kussakin, 1956). The maximal number of species of the subtropical low boreal complex is found in the southern part of the island, mainly in Izmeny Bay intertidal zone.

In Kunashir Island, vertical distribution of intertidal communities is typical for low-boreal intertidal zone with well-pronounced tides (Kussakin, 1977). Poorly populated, almost vegetationless communities of *Chthamalus dalli* and *Littorina sitkana*, sometimes having a belt-like distribution pattern, are typical for the upper horizon of the **rocky and stony intertidal zone**. *Semibalanus cariosus* communities, more typical for the Middle and North Kurile Islands (Kussakin et al., 1974) and not found earlier in Kunashir intertidal zone, can be found on the Pacific coast. The border of the upper and medium horizons is inhabited by a monodominant community of *Gloiopeltis furcata*, typical for the low-boreal intertidal zone which was registered by us but not distinguished as a community by O.G.Kussakin (1956, 1977).

A fucoid complex is developed in the middle horizon. The upper part of the horizon is occupied by *Silvetia babingtonii* community, often forming a belt, whereas lower, in separate settlements, *Fucus evanescens* community is developed. Macrobenthos biomass in the communities can reach more than 25 kgWW m⁻². Other algal communities are arranged in spots in the lower part of the middle intertidal horizon. *Corallina pilulifera* monodominant community often develops in intertidal puddles and on the bottom of intertidal pools in places where some water remains in rock pockets after the tide. Communities of red (*Neorhodomela larix*, *Iridaea cornucopiae*, *Pterosiphonia bipinnata*, *Laurencia nipponica*, *Chondrus pinnulatus*, *Mastocarpus pacificus*, *Tichocarpus crinitus*, *Odonthalia annae* and others) and green (*Chaetomorpha moniligera*, *Ch. linum*, *Ch. melagonium*, *Ulva fenestrata*, *Cladophora opaca*, *Blidingia minima* and others) algae, diverse in population composition, are spread in a form of spots among almost entire bush of fucoids and *Corallina*. *Analipus japonicus* community, poor in species composition, is also typical for the middle intertidal horizon. *Phyllospadix iwatensis* community with a diverse animal population due to a great number of infauna representatives develops in rock splits filled with sand or on sand between rubbles. *C. pilulifera* and *Ph. iwatensis* thicket is also extended to the lower intertidal horizon. Belt-like communities of *Poly-siphonia* sp. and *Chordaria chordaeformis* were also distinguished earlier in the middle horizon of the rocky intertidal zone of the eastern island coast (Kussakin, 1956).

Dense thickets of laminarian algae, mainly of *Alaria ochotensis* and *Laminaria* sp., develop in the lower horizon and intertidal border. The total macrobenthos biomass can reach 100 kgWW m⁻². Communities of warm-water brown algae *Sargassum miyabei*, *S. thunbergii*, *Scytosiphon lomentaria* and others with rather rich animal and plant composition are frequently found in the rocky inshore intertidal zone of the western island coast. In some cases, in the intertidal areas with strong surf exposed to ice abrasive action in winter, laminarians are suppressed and instead populations of annual small algae develop. Among them, *Spongomorpha duriuscula* (= *Acrosiphonia sonderi*) prevails and develops in summer on rocks exposed to surf where perennial species cannot survive because in winter a majority of algae settlements (including laminarians germinated in spring) are destroyed (Kussakin et al., 1974, Kussakin & Tarakanova, 1977). On the Sea of Okhotsk side, in 1963–1964 communities of *Neorhodomela larix aculeata*+*Ph. iwatensis* were observed on the rocky inshore littoral with sand in rock cavities, in littoral pools in the lower horizon whereas in the stony intertidal zone of the Pacific coast *Arthrothamnus bifidus* was found (Kussakin & Tarakanova, 1977). In the lower horizon of the stony littoral communities of brown and red algae are often distributed in a form of spots, and on the whole vertical stratification of the communities is pronounced weaker in the stony intertidal than in the rocky one though dominant species in the communities are similar.

In rocky intertidal pools, zonality in distribution of communities is observed only on pools walls whereas spotty distribution of communities is typical for the bottom. Besides, population of big pools differs by macrobenthos richness due to development of a

complex of organisms, typical for the lower littoral and sublittoral: as to algae, these are purple-fish and laminarians, as to animals – numerous and diverse sponges, hydroids, polychaetes, crustaceans, bryozoans, echinoderms, ascidians (Kussakin, 1956). In areas of volcanic activity in Kunashir Island, impoverishment of the intertidal communities can be observed only in the immediate vicinity to gas hydrothermal springs but they do not affect intertidal biota significantly (Kostina, 1991).

Sandy intertidal zone of the western and eastern coasts of Kunashir Island differs from rocky and stony intertidal areas by macrobenthic composition and distribution. On sandy beaches affected by surf and formed by clean and well-washed sand, population is very poor, macrophytes and other attached forms are absent. The upper part of such beaches and supra-littoral are inhabited by amphipods, mainly by Talitridae, mysid *Archaeomysis grebnitzkii* and various insects. In the upper part the fauna is not rich in species number (infaunal forms mainly found here: bivalves *Spisula sachalinensis*, *Protothaca euglypta*, *Megangulus luteus* and others, polychaete *Abarenicola pacifica*, nemertines), but its biomass reaches 1 kg m⁻², mainly due to development of the big mollusk *S. sachalinensis*. Fauna of silty-sandy beaches of the western and eastern coasts of Kunashir Island is close to the fauna of purely sandy intertidal zone (Kussakin, 1956, Kussakin & Tarakanova, 1977).

Communities not found in the other sites of Kunashir are located on the silty-sandy intertidal zone of the southern island coast in Izmeny Bay. Quantitative survey of the site in Izmeny Bay to the east of Golovnino Village in 1991 was accomplished at the same transect as in 1963 which gave the opportunity to compare long-term changes of intertidal macrobenthos in Izmeny Bay during the recent 30 years. The middle intertidal horizon is occupied by a belt-forming community of *Zostera japonica*. In 1963, 26 macrobenthic species were found in this community whereas in 1991 – 20 species. Biomass of macrobenthos increased in *Z. japonica* community (1280.5 gWW m⁻² and 1947.4 gWW m⁻² in 1963 and 1991, respectively). Earlier, community of *Ulva* (= *Enteromorpha*) *linza* developed on shell debris and pebbles was observed at the border between the middle and the lower horizons (Kussakin & Tarakanova, 1977), but in our samples this alga was not found.

The lower intertidal horizon are occupied by a belt-forming community of *Batillaria cumingii*. A reduction of species richness took place here (in 1963 – 15 species, in 1991 – 5). Biomass of macrobenthos increased in this community (329.0 gWW m⁻² and 503.6 gWW m⁻² in 1963 and 1991, respectively).

A belt-forming community of *Zostera marina* occupies the lower intertidal horizon and upper sublittoral zone. In 1963 and 1991, 15 plant and 15 animal species were found in this community. However, common species were only six: *Z. marina*, *Nereis vexillosa*, *Abarenicola pacifica*, *Macoma incongrua*, *B. cumingii* and *Hima multigranosa*. Along with the fact that species composition of the community changed, a change of the subdominant species took place in the community (*M. incongrua* – in 1963 and *Ruditapes philippinarum* – in 1991).

Intertidal zone of Golovnino Village is exposed to the effect of domestic effluents and effluents from seafood processing. During 30 years a quantitative and qualitative change of intertidal biota took place here: species diversity of macrobenthos reduced, whereas biomass increased. It fully conforms to the observed earlier tendency when under the effect of weak and moderate organic impurity eutrophication of biotopes takes place and growth of total benthic biomass is observed, and at the same time species richness steadily declines (Kussakin & Tsurpalo, 1999).

Intertidal zone of Kunashir Island has many common features with that of the neighboring Shikotan Island by composition and patterns of distribution of communities. The maximal similarity can be observed between the eastern coast of Kunashir Island and the northwestern coast of Shikotan Island, but distinctions also can be found. Thus, *Chordaria chordaeformis* community is not developed at Shirkotan Island (Kussakin, 1956). Thickets of *Fucus evanescens* often forming a separate belt here, whereas in similar sites of the Kunashir intertidal zone they do not form separate belts, are well-represented at weak-surf sites of the Shikotan intertidal zone. *Silvetia babingtonii* community is represented on Kunashir Island in a greater abundance than on Shikotan Island. The red alga *Porphyra* sp., typical for the inshore Shikotan intertidal zone is very rare on Kunashir Island. The crab *Hapalogaster grebnitzkii*, frequent for the rocky inter-

tidal areas of Shikotan Island is not found in the Kunashir intertidal zone but the crab *Cancer gibbosulus* not found in Shikotan Island dwells here (Kussakin, 1956).

3.4 DIVERSITY OF MOLLUSKS OF JEJU ISLAND (KOREA) AS AN EXAMPLE OF ISLAND BIODIVERSITY BASELINE STUDY

Jeju Island, Korea's largest island, is situated about 80 km south of the Korean peninsula. The coastline of this volcanic island is composed of rocky shore and sand beaches with a few sand tidal flats (Jeju: General Facts and Figures, 2005). Mud flats are virtually nonexistent. Because of the influence of the warm northeastward-flowing Kuroshio Current, the climate is subtropical. The Tsushima Current branches from the Kuroshio Current and washes the southern coastal area of the island, giving this area somewhat warmer sea temperatures. The prevailing winds from the Pacific Ocean are southeasterly in summer, and also help to raise the temperature of the water. Cool water masses from the north and northwest also influence the ocean temperatures. This blending of warm and cool currents has resulted in an abundance of marine life.

Korea is part of the warm temperate Japonic faunal province which extends from southern Hokkaido through Japan to Korea and northeastern China (Corpus Christi Museum, 2005). However, because the southern coast of the Korean Peninsula, and especially Jeju Island, are influenced by the warm currents flowing from the southwest, the marine mollusk fauna of this area also exhibits strong subtropical and tropical characteristics, showing a connection with the Indo-West Pacific faunal province. This mainly tropical province extends through the western Pacific, from southern Japan to northern Australia, and through the Indian Ocean to East Africa and the Red Sea (Corpus Christi Museum, 2005).

For the past seven years the mollusks of Jeju Island have been the subject of an extensive survey because, as far as can be determined, there had previously been no comprehensive report on the mollusk fauna of Jeju Island. An attempt has been made to visit as many localities with a wide variety of habitats as possible. To date a total of 55 localities around the island have been visited, comprising coastal regions and inland areas where the land and freshwater fauna was sampled. Mara and U Islands have also been visited. Throughout this period several localities have been visited on two or more occasions thus producing a representative sample of the species occurring there (the main survey stations are shown in Fig. 11). Collecting of marine species has been done mainly from the intertidal and upper subtidal zones, as well as beach driftlines (Figs. 12, 13). However, a limited amount of dredging and SCUBA diving has also been done

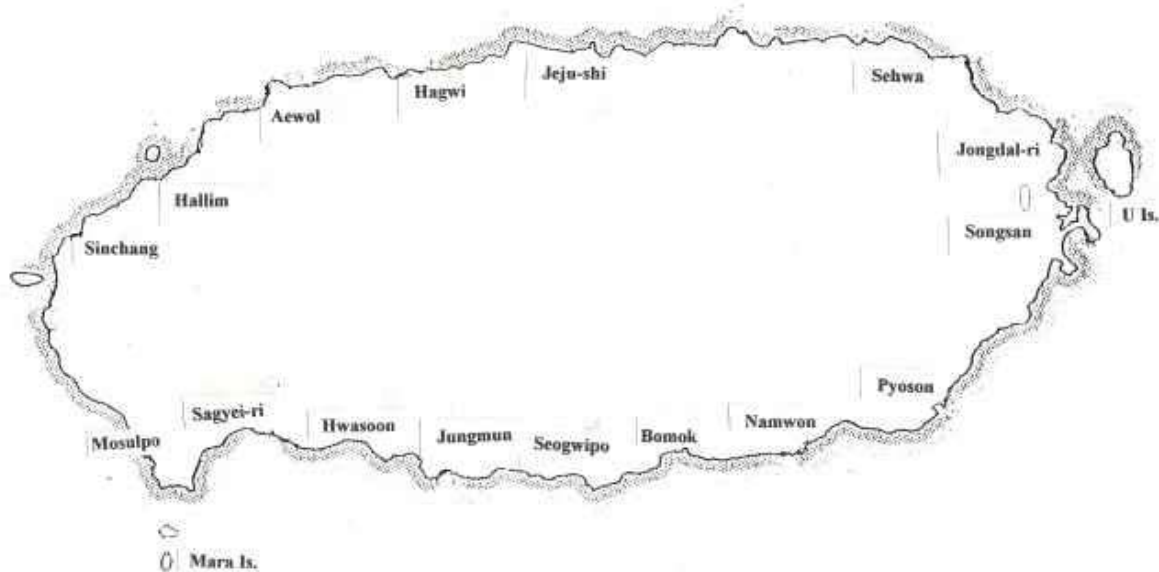


Fig. 11. Main survey stations of mollusks in Jeju Island, Korea.

by students of JNU. During our surveys several species previously unreported from Jeju Island were added to its fauna. Additional locality records and species lists have been obtained from the regional literature, the most helpful being the Illustrated Encyclopedia of Flora and Fauna of Korea (Choe, 1992), A Catalogue of Molluscan Fauna in Korea (Lee & Min, 2002), and Mollusks in Korea. In many cases the locality records from our field research correspond with those found in the literature, and most of those localities have also been covered in this survey. Localities for each species, both from field col-



Fig. 12. Intertidal zone of Jeju Island (Jeju-do), near Jeju City, Sam Yang, rocky coast. Photo by K.A. Lutaenko.

lections and literature, have been listed in a database. World distribution ranges have also been assembled and listed. This has given some insight on the connection between the faunal provinces represented by those mollusks, and also on the number of species representative of each regional fauna.

A total of 1072 species and subspecies have been recorded from Jeju Island, 1015 marine species and 57 land and freshwater species. There are 812 gastropods, of which 755 are either entirely marine or, as in the case of the Truncatellidae, Ellobiidae, and other similar families, have marine affinities. Of those the Pyramidellidae are best represented, followed by the Trochidae and Ovulidae. The bivalves are represented by 225 species, with the Veneridae, Mytilidae, and Arcidae having the largest number of species. Among the smaller classes there are sixteen Cephalopoda, eleven Polyplacophora, and eight Scaphopoda. Of particular note is the absence of some of the more common, edible mainland species, eg. *Rapana venosa* (Valenciennes, 1846) and *Meretrix* spp., because of the relative lack of muddy substrates.

An examination of the world distributions of the marine species recorded from Jeju Island reveals the influence of two distinct faunal regions: the Japonic and Indo-West Pacific provinces. The northern Pacific part of the latter province also includes some subtropical areas, such as southern Japan, with its accompanying islands, and northern Taiwan (Lee & Chao, 2003).

Although Korea overall is part of the warm temperate Japonic province, the mollusk fauna of Jeju Island also exhibits strong subtropical and tropical characteristics. Approximately half of the marine mollusks recorded here have a southern distribution. Of the three smaller classes, the Polyplacophora and Cephalopoda are mainly warm temperate species, while about half of the Scaphopoda are tropical or subtropical species. The same holds true for the Gastropoda and Bivalvia, of which about half are species that extend either to the subtropical western Pacific or throughout



Fig. 13. Intertidal zone of Jeju Island (Jeju-do), eastern coast, 1.5 km west of Seongsan, sandy beach and rocky coast. Photo by K.A. Lutaenko.

the tropical Indo-West-Pacific province. Only a very few species have a northern, or boreal, distribution.

Of the major gastropod families, the Pyramellidae show an almost exclusively Japonic affinity. The Trochidae are split almost evenly between warm temperate, and tropical and subtropical species, while the Ovulidae are mainly a tropical and subtropical family. As for the bivalves, the Veneridae exhibit a tropical and subtropical affinity, as does the Arcidae. However, the faunal affinities of the Mytilidae are split almost equally between the Japonic and Indo-West Pacific provinces. This blending of faunas suggests that Jeju Island is part of a transition zone between the Japonic and Indo-West Pacific faunal provinces that also includes parts of southern Japan.

Many more areas will have to be surveyed before any specific distribution patterns for the island are revealed. Most families appear to have an island-wide distribution. However, it appears that the mainly tropical and subtropical families, such as Cypraeidae, Ovulidae, Conidae, and Terebridae, are found primarily in the southern half of the island, which experiences somewhat warmer sea temperatures.

We believe that the results from our surveys, and the species lists and locality records from the selected publications and websites we have included, give a good overview of the mollusk fauna of this island. There are, no doubt, other faunal lists from specific localities for Jeju Island in the literature, and these will be examined as they are located. More surveys are planned for the future and there are many more mollusks to be identified. Therefore, this is very much "a work in progress", and we look forward to other malacologists and fieldworkers to add their efforts to the contribution we have made.

3.5 OSTRACODS OF THE COASTAL ZONE OF JEJU ISLAND, KOREA

Ostracods are fine indicators of water ecosystem condition and climatic changes. However, they cannot be used from this point of view as they have not been sufficiently studied. Highly detailed data on fauna of the modern ostracods from the South Korea coast are presented in the doctoral thesis of Choe (1984). She examined 200 samples and found 222 species belonging to 96 genera. Among them 125 species were new for science. She studied 21 samples from Jeju Island area (Fig. 4) collected at the depths from 63 to 135 m. Among them she found 111 ostracod species, including 44 species new for science. Only 5 new species she found were described formally (Choe, 1988),

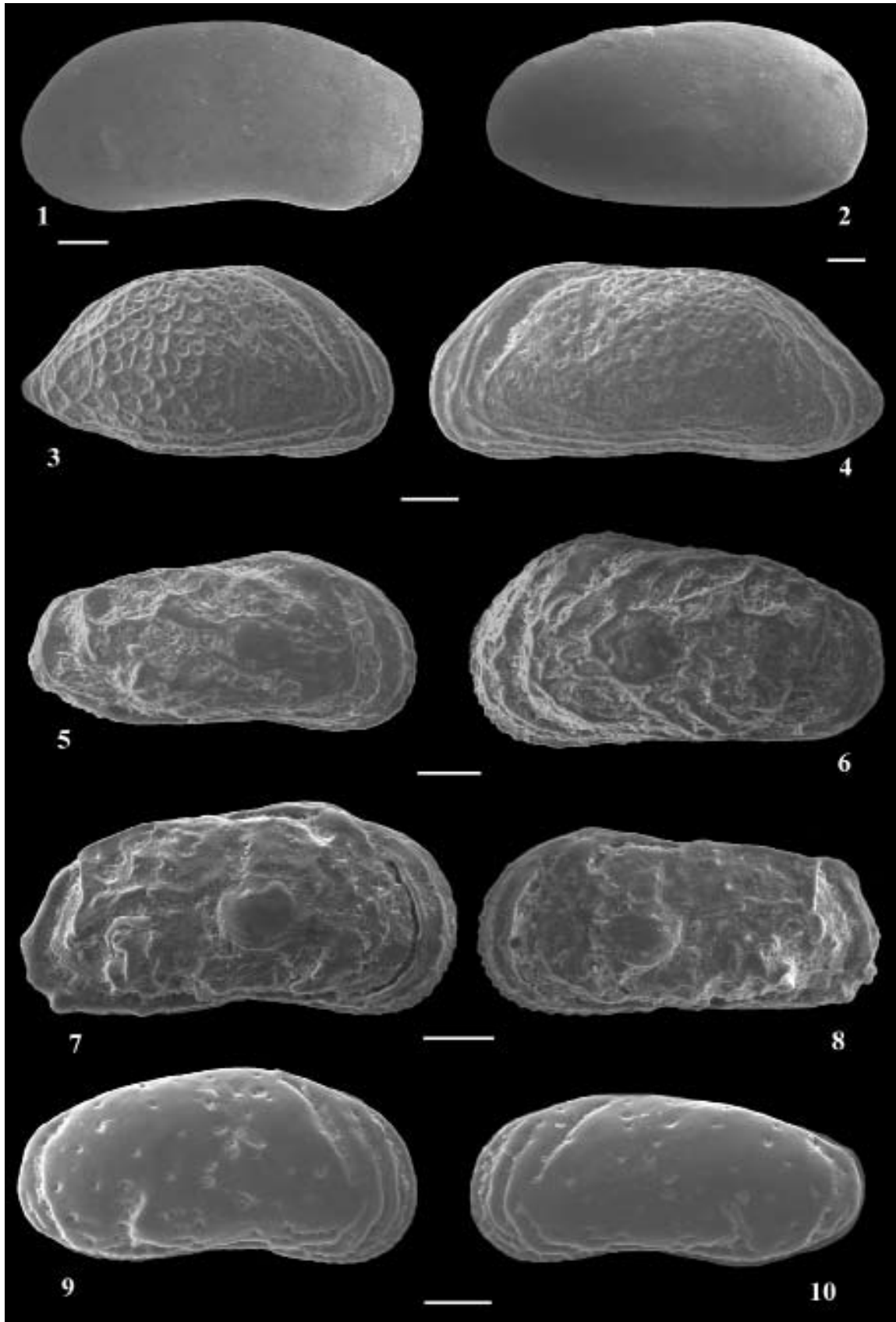


Fig. 14. Photographs of the ostracod species found around Jeju Island, Korea. 1. *Anchistrocheles* sp. 2 Schornikov in Lee et al., 2000, right valve of female; 2. *Saipanetta* sp., right valve of female; 3, 4. *Perissocytheridea* cf. *japonica* Ishizaki, 1968; right valve of female and left valve of male; 5, 6. *Coquimba* aff. *ishizakii* Yajima, 1978; right valve of male and left valve of female; 7, 8. *Coquimba* cf. *ishizakii* Yajima, 1978; right valve of female and left valve of male; 9, 10. *Leptocythere* sp.; right valve of female and left valve of male. Scale: 100 µm for images 1, 3-8; 40 µm for images 2, 9, 10.

whereas the rest of names she gave remain invalid because they have been proposed in unpublished theses (ICZN, 1999, art. 9.9).

Five qualitative meiobenthic samples collected 24-28.07.2007 from the intertidal zone of Jeju Island by Dr. K.A. Lutaenko served as material for the present report (Fig. 4). In these samples 73 ostracod species were found. They are listed in the Table 2 below. Only one species belongs to subclass Myodocopa, whereas the remaining ones belong to 8 families and 35 genera of subclass Podocopa. Among them only 27 species have been described. Many undescribed species are known from the South Korea coast (Lee et al., 2000) and Peter the Great Bay (Schornikov, Chavtur, 2001) in the East Sea and from the Pleistocene deposits of the Jeju Island (Lee, 1990). Among the other species, listed in the open nomenclature, 15 new species were found, and 12 ones were identified only to a genus level, since they were presented in the sample as unidentified early age stages. Forty species were encountered as living, and 7 ones were found only as shells and valves. Images of the most interesting found species are presented in Fig. 14.

In general ostracod fauna of Jeju Island coast remains poorly studied. Judging by species diversity of ostracod fauna of similar regions, one could suppose that not less than 600 ostracod species inhabit the shelf of Jeju Island.

Table 2

Species composition and distribution of ostracods in the intertidal zone
of Jeju Island

Species composition	Station
<i>Polycope</i> sp.	3b*
<i>Saipanetta</i> sp. (Pl. 1, fig. 2)	4
<i>Neonesidea oligodentata</i> (Kajiyama, 1913)	3°, 3b,
<i>Neonesidea</i> sp. 11 Schornikov in Lee et al., 2000	4
<i>Neonesidea</i> sp. 12 Schornikov in Lee et al., 2000	3b, 4
<i>Triebelina trapezoidalis</i> Lee(MS), 1990	2, 3b, 4*
<i>Anchistrocheles</i> sp. 2 Schornikov in Lee et al., 2000 (Pl. 1, fig. 1)	3b, 4
<i>Pontocypris</i> sp. 1 Schornikov in Lee et al., 2000	3a; 4
<i>Sclerochilus</i> cf. sp. 22 Schornikov in Lee et al., 2000	3b*
<i>Sclerochilus</i> sp.	3b*
<i>Sclerochilus</i> sp. 1	3b*
<i>Cythere?</i> sp.	3a,
<i>Schizocythere kishinouyei</i> (Kajiyama, 1913)	3a, 4
<i>Spinileberis quadriaculeata</i> (Brady, 1880)	4
<i>Perissocytheridea</i> cf. <i>japonica</i> Ishizaki, 1968 (Pl. 1, fig. 3, 4)	4*
<i>Leptocythere</i> sp. (Pl. 1, fig. 9, 10)	4*
<i>Callistocythere hayamensis</i> Hanai, 1957	3a*, 3b, 4
<i>Callistocythere</i> sp.	4
<i>Pontocythere</i> cf. <i>spatiosa</i> Hou, 1982	4
<i>Pontocythere subjaponica</i> (Hanai, 1959)	4
<i>Pontocythere minuta</i> Ikeya et Hanai, 1982	4*
<i>Pontocythere miurensis</i> (Hanai, 1959)	3a, 4*
<i>Parakrithella pseudadonta</i> (Hanai, 1959)	3°
<i>Aurila inabai</i> Okubo, 1976	2; 3°*, 3b*, 4
<i>Aurila</i> cf. <i>munechikai</i> Ishizaki, 1968	2*, 3°*, 3b
<i>Aurila</i> sp.	2, 3°
<i>Robustaurila ishizakii</i> (Okubo, 1980)	2
<i>Cornucoquimba</i> sp. Schornikov et Chavtur, 2001	4
<i>Coquimba</i> aff. <i>ishizakii</i> Yajima, 1978 (Pl. 1, fig. 5, 6)	4
<i>Coquimba</i> cf. <i>ishizakii</i> Yajima, 1978 (Pl. 1, fig. 7, 8)	4*
<i>Cletocythereis bradyi</i> Holden, 1967	4
<i>Loxoconcha uranouchiensis</i> Ishizaki, 1968	4*
<i>Loxoconcha</i> aff. <i>uranouchiensis</i> Ishizaki, 1968	4
<i>Loxoconcha</i> spp. juv. sp. 1, sp. 2, sp. 3	3°
<i>Loxoconcha</i> spp. juv. 2 sp.	3b
<i>Loxocorniculium</i> cf. <i>mutsuense</i> Ishizaki, 1971	3a, 3b
<i>Cytheromorpha acupunctata</i> (Brady, 1880)	4
<i>Hemicytherura</i> cf. <i>kunchiatiena</i> (Hu, 1984)	3a*, 3b*
<i>Hemicytherura tricarinata</i> Hani, 1957	4*

Table 2 (continued)

<i>Semicytherura kazahana</i> Yamada, Tsukagoshi et Ikeya, 2005	4
<i>Semicytherura mukaishimensis</i> Okubo, 1980	3 ^{o*} , 4
<i>Semicytherura polygonoreticulata</i> Ishizaki et Kato, 1976	4*
<i>Cytheropteron miurense</i> Hanai, 1957	4
<i>Xestoleberis hanaii</i> Ishizaki, 1968	1, 3a*, 4
<i>Xestoleberis</i> cf. <i>hanaii</i> Ishizaki, 1968	1*, 2, 3b*
<i>Xestoleberis sagamiensis</i> Kajiyama, 1913	1*, 2
<i>Xestoleberis setouchiensis</i> Okubo, 1979	3b*
<i>Xestoleberis</i> cf. <i>setouchiensis</i> Okubo, 1979	3b*
<i>Xestoleberis setouchiensis?</i> Okubo, 1979	1, 3a, 3b*
<i>Xestoleberis</i> sp. 5. Schornikov in Lee et al., 2000	
<i>Cytherois</i> sp. 3 Schornikov in Lee et al., 2000	4
<i>Flabellicytherois</i> sp. 3	2, 3b*
<i>Boreostoma bingoense</i> (Okubo, 1977)	1*, 2, 3b*
<i>Boreostoma</i> aff. <i>bingoense</i> (Okubo, 1977)	3a*, 4
<i>Boreostoma coniforme</i> (Kajiyama, 1913)	3a*
<i>Boreostoma</i> cf. <i>yatsui</i> (Kajiyama, 1913)	3 ^o , 3b*
<i>Brunneostoma brunneatum</i> (Schornikov, 1975)	3 ^o ,
<i>Brunneostoma brunneum</i> (Schornikov, 1974)	3b
<i>Obesostoma</i> sp.	1*, 2*, 3b*
<i>Paradoxostoma flaccidum</i> Schornikov, 1975	3a*, 3b
<i>Paradoxostoma setoense</i> Schornikov, 1975	3a*
<i>Paradoxostoma</i> spp. juv. 7 sp.	3a(4sp.), 3b(3sp.)
<i>Pontostoma honssuense</i> (Schornikov, 1975)	3a*, 3b*
<i>Paracytherois</i> sp. 5. Schornikov in Lee et al., 2000	3b

Note: asterisked (*) are stations where ostracod species were found alive.

3.6 INTRODUCTION OF INVASIVE SPECIES INTO THE NORTHWESTERN SEA OF JAPAN/EAST SEA

Introduction

The problem of introduction of non-indigenous species is one of major ecological problems of the late 20-th century. For the recent 50-60 years, due to rapid development of maritime traffic, the cases of distribution of non-indigenous species into different regions of the World Ocean became more frequent. Sometimes not even certain single species are introduced, but global changes could be observed that happen at the level of faunas.

More often the ships transport sessile organisms, like the members of the suborder Balanomorpha; 9% of the overall number of species in this group have been encountered in the fouling of ships. For example, *Elminius modestus* was introduced from the coasts of Australia to the European coasts on ships during the Second World War. There is a belief that the barnacle *Balanus improvisus* has been introduced in 19-th century to European coasts from the eastern coast of America, however, this is not supported by most recent paleontological evidences. After the opening of Volga-Don Canal in 1955, *B. improvisus* penetrated into the Caspian Sea and then distributed in the Pacific. A similar way has been passed by the barnacle *B. eburneus* that was known in the past from tropical areas of the Western Atlantic.

Radical changes in the fauna of the Caspian Sea happened soon after the opening of the Volga-Don Canal, when about 20 species penetrated into the Caspian Sea for just a single decade. The process of colonization of the Caspian Sea by new species is described in much detail in the available literature. For example, G.B. Zevina published a series of papers, which not only retraced the changes that took place in the fauna of fouling, but also provided forecasts for possible new invaders to come. The process of introduction of invaders into the Caspian Sea has been analyzed by G.B. Zevina in two monographs. An example of drastic changes in indigenous fauna after an introduction of just a single species is introduction and naturalization of *Mytilaster lineatus* in the Cas-

pian Sea. The fact of the naturalization of several species-invaders in the Caspian Sea in later years has been confirmed by Latypov.

From the coast of India a sessile polychaete *Mercierella enigmatica* has penetrated into different regions of the World Ocean. For less than 50 years this species occupied the coasts of both the Atlantic and Pacific Oceans and inland European seas and now is distributed throughout in-between 60° N and 45°S latitudes (Ruller, 1966).

Some cases are known also of such a distribution among free-living mobile species. A crab *Rhithropanopeus harrisi* was introduced to Europe from the American coast by ships and, despite the fact that it is a relatively recent invader, it already plays an important role in the ecology of benthos and fouling in European seas. A similar pathway of distribution in the waters of the Western Europe is shown by an Eastern

Much attention is being given to the problem of the distribution of species by Japanese scientists. The process of introduction of fouling organisms into Tokyo Bay (Honshu Island) has been described for the first time in early 20-th century and still continues in our days. Thus, the introduction of the mussel *Mytilus galloprovincialis* into Tokyo Bay took part in 1929; the barnacle *Balanus amphitrite* appeared there in 1950. The barnacle *B. improvisus* penetrated into Tokyo Bay in the late 1960-es. Starting from the late 1970s, Japanese scientists registered the introduction into Tokyo Bay of *Molgula manhattensis* and three more species of bivalve mollusks that occur in the fouling, namely *Limnoperna fortunei*, *Chloromytilus viridis*, and *Mytilopsis sallei*.

The mussel *Limnoperna fortunei* was for the first time registered in Tokyo Bay in 1983; and in 1989 it already occupied, in occurrence frequency, the second position after *M. galloprovincialis*. In some cases, this species has become the dominating in fouling communities of the harbors of Kawasaki and Yokohama. *L. fortunei* penetrated into Hamana Lake and during only 5 years it replaced local species of bivalve mollusks there (Okamoto, 1955). At present, this species already has naturalized.

Chloromytilus viridis appeared in the Japanese Inland Sea and along the coast of Takatsu Prefecture in the late 1960s, but then disappeared. In Tokyo Bay this species has been found for the first time in 1986, three years later it has been registered on a pier of the harbor of Yokohama. In winter time, when water temperature dropped down, all specimens of *C. viridis* perished. In the summer of 1994 the water temperature in Tokyo Bay was abnormally high, which caused mass mortality of *M. galloprovincialis*, however the populations of *C. viridis* survived in some areas close to the surface of the pier. During next winter all specimens of *C. viridis* in the fouling of the pier perished due to low water temperature, but some large specimens of this species survived at the point of warm water discharge from the water cooling system of the local power plant (Ito, unpublished data). Wintering specimens of *C. viridis* have also been registered at the coast of Honshu Islands (Enoshima Harbor), at the area, where the water from the cooling systems of a local power plant, heated up to 15° C were discharged into the sea. *Mytilopsis sallei* was for the first time found in benthos at the coast of Japan in Shimizu Bay in 1975 and in Tokyo Bay, in the fouling of bridge pillars, in 1983. According to unpublished data of Japanese scientists (Ito and Kajichara), the settling of *M. sallei* takes place from August through November.

Balanus amphitrite is considered a recent invader into Tokyo Bay. In 1963 it turned the dominating species in intertidal communities and penetrated also into upper subtidal zone, where it almost entirely replaced *B. reticulatus*. On experimental plates installed in Yokosuka Harbor, two species of cirripede barnacles have been found, *B. amphitrite* and *B. eburneus*, while *B. reticulatus* was not registered. According to Henry and McLaughlin, the introduction of *B. amphitrite* into Tokyo Bay happened in the period from 1930 to 1950. In the harbors of Yokohama and Tokyo, *B. amphitrite* is much more common now than the indigenous species *B. reticulatus*, i.e., one may conclude about the naturalization of *B. amphitrite* in Tokyo Bay.

A summary of the introduction of 18 species of sessile marine organisms into the waters of Japan with ships is presented in a recent paper of Otani. The latter discusses in detail the introduction and naturalization of some species of cirripede barnacles, polychaetes, bryozoans, and gastropod and bivalve mollusks, from the moment of their first

occurrence at the coast of Japan in the early 20-th century and until now. Many of the species listed by M. Otani have also penetrated into Peter the Great Bay.

The examples of the transfer of different organisms with ships are much more numerous; we presented here only the most well-known cases characterized by a great scale of introduction.

Introduced species in the Sea of Japan

The study of ship fouling by Institute of Marine Biology is begun in 1975. The large material on fouling of 600 ships of a various operation mode in different regions of World Ocean is assembled, which has allowed revealing a number of exotic species, introduced in the northwest part of the Sea of Japan with the help of ship fouling and their ballast waters.

To estimate more accurately the role of species-invaders that they play in the Sea of Japan, we present here a brief biogeographic characteristic of the latter. We also show peculiarities of Peter the Great Bay as a main acclimation area for exotics coming from southern seas.

Like all Far-Eastern seas of Russia, Sea of Japan is a part of Boreal Pacific Biogeographic Province. The Bering Sea and the bulk of the Sea of Okhotsk belong to High Boreal Subprovince, whereas northern Sea of Japan and southern areas of the Sea of Okhotsk are referred to as Low Boreal Subprovince. In the Sea of Japan the border with Subtropical Subprovince of Tropical Indo-West-Pacific Province passes from the middle of the Korean Peninsula to Noto Peninsula on Honshu Island. The position of the Sea of Japan at the border between two biogeographic provinces with different temperature regimes benefits processes of natural distribution of species. The northwestern part of the sea might be inhabited by widely-boreal, subtropical and subtropical-low-boreal species living together.

In Peter the Great Bay these specific features are the most pronounced. The bay is located at the border between temperate and subtropical zones and is washed simultaneously by the cold Primorye Current and a branch of the warm Tsushima Current. Peter the Great Bay is characterized by great diversity in hydrological regimes and environmental conditions, which also benefits great species diversity in its flora and fauna.

The rate of species distribution by means of ships with different regimes of exploitation depends primarily on the intensity of maritime traffic and availability of harbors appropriate for colonization. In later time, as the available harbors are colonized, the rate of species distribution increases due to cabotage ships. Among Far-Eastern seas of Russia only the Sea of Japan (mostly Peter the Great Bay) has been studied in relation to species-invaders. Since the time, when these papers have been published certain changes took place in fouling and benthos communities; the status of some introduced species changed and new species appeared at different stages of acclimation. However, until now there are no reviews analyzing the introduction of species into the northwestern Sea of Japan. In the fouling of anthropogenic substrates and in benthos communities of Peter the Great Bay, altogether 16 species-invaders have been registered, whose characteristics are presented below.

Cirripede barnacles

Balanus improvisus. Zevina [1972], who gave a detailed analysis of the process of naturalization of this species to the Caspian Sea, suggested that the Sea of Japan was also suitable for its introduction. For the first time *B. improvisus* was registered in the fouling of the hydrotechnical constructions (HTC) of Peter the Great Bay in 1969 [Zevina, Gorin, 1971]. I recorded this species in the fouling of all coasters and operating port ships examined in the Bay not later than the last days of July, i.e. the beginning of settling of the juvenile *B. improvisus*. On the ships examined at the end of the navigation period (October, November) this species often was among the typical fouling species and in some cases was even dominant. Thus, on the transport refrigerator ship "Askaniya" operating on the route Vladivostok-Svetlaya *B. improvisus* was registered in 100% of all samples, reaching 710 g/m² in some samples with a population density of 1200 ind/m².

In the fouling of the towboat BK-146, operating in Amurskii Bay - Golden Horn Bay, *B. improvisus* was a dominant species. The biomass of *B. improvisus* on this ship after only six months of exploitation reached 9600 g/m² with a population density of 80000 ind/m². Several specimens of *B. improvisus* were found even on the propeller blades of the ship PSK-30, operating on the line Golden Horn Bay - Posyeta Bay.

From the above it may be assumed that *B. improvisus* by now has become a typical species in the fouling of the coasters and port ships in Peter the Great Bay. In the fouling of HTC in this bay *B. improvisus* was found on almost all examined objects being a typical species in the fouling communities of HTC in Amurskii Bay (after the mussel *Mytilus trossulus* and the oyster *Crassostrea gigas*) and Golden Horn Bay (after the tube polychaete *Hydroides elegans*).

We registered *B. improvisus* in 1992 in a number of the benthic communities of Amursky Bay. Previously this species was known only from the fouling of Peter the Great Bay and was recorded in it not every year [Zevina, Gorin, 1975]. This species was registered in the composition of the bottom communities of the studied area, more often settles epibiontically. For example, the observations of the upper sublittoral of Amurskii Bay, conducted in August for four years, showed the presence of *B. improvisus* in the community of *Zostera marina* at a depth of 0.5-3 m. The barnacles settled on the surface of *Zostera* leaves. To calculate the population density of the barnacles per 1 m² by use of the common methods turned to be difficult. Per 10 cm of the leaf length there were 3-5 individual barnacles with a shell diameter of 5-7 mm, usually not exceeding the width of the leaf. Later on, until 1995 during the settlement of this species the barnacles settled on the leaves of *Zostera* in Amursky Bay regularly, with a population density reaching 6-9 ind. per 10 cm of leaf.

In Sportivnaya Harbor of Vladivostok *B. improvisus* was found in the fouling of the shells of the scallop *Mizuhopecten yessoensis* in benthic communities, on the carapace of the crab *Cancer amphiocteus*, on the ascidians *Styela clava*, sometimes forming dense settlements. In Alekseyeva Inlet (Popov Island), *B. improvisus* was a typical species in the fouling of the valves of the cultivated scallops *Mizuhopecten yessoensis*, comprising 25-30% of the total biomass of the fouling of the valves. In all these parts of the Amursky Bay *B. improvisus* was not found in the bottom. It was found only in epibiontic form. Quite an opposite picture could be observed in the inner part of the bay influenced by the fresh water of the Razdolnaya River. In the upper sublittoral and on the rocks near Rechnoy Cape a mass settlements of *B. improvisus* (on the average 3500-4000 g/m², 60000 ind./m²) was found at a depth of 0-1.5 m. A high ecological plasticity and ability to endure almost complete desalination allowed this species to occupy a vacant ecological niche [Zevina, Strelkov, 1983]. A close aboriginal species *B. crenatus*, typical for Amursky Bay, not tolerating salinity below 10‰ was not found in the vicinity of Rechnoy Cape. However, in August 1984, sexually mature specimens of *B. improvisus* were found for the first time on the rocks of the upper sublittoral in the area with a normal sea water salinity (Firsova Cape) where it was constantly observed until 1995.

The discovery of *B. improvisus* in the benthos of Peter the Great Bay allowed us to make a conclusion about the naturalization of this species. The fact that it is an introduced species and is not an aboriginal one, not found by the researches previously, is confirmed by the full conformation of these species characteristics to the ones of aboriginal species as distinguished by G.B. Zevina and her co-authors [1975].

To prove whether Peter the Great Bay is a part of *B. improvisus* habitat area, an analysis of a number of specimens collected in August-September of 1990-1995 was conducted. The barnacles with a shell diameter of 5-6 mm, found on *Zostera*, contained developing embryos in the mantle cavity. The specimens from the benthos of the upper sublittoral contained the larvae of the last stage before release; some of them had already been released. As it follows, in Peter the Great Bay a local population has formed that inhabits both artificial substrata and benthos, has formed and reproduced.

Balanus amphitrite is an eurybiontic subtidal species widely distributed in Tropical and Subtropical Provinces. According to Zevina and Gorin [1975] this species occurred in the fouling of buoys in Nakhodka, Strelok and Amurskii Bays only in warm years. Under favorable temperature conditions the population of *B. amphitrite* is recruited at the expense of transfer of larvae by currents from the coasts of Japan and introduction of adult spawning specimens with foreign-going ships.

In Peter the Great Bay we found *B. amphitrite* in the fouling of 46% of the examined active ships except ships that spent no less than 20% of time in Zolotoi Rog Inlet (Vladivostok harbor), where this species has been registered on all examined objects. On most ships from Peter the Great Bay *B. amphitrite* was among secondary species of the first or second order. On ships that stood in Zolotoi Rog Inlet for a long time, *B. amphitrite* often was a characteristic species.

We did not find *B. amphitrite* in benthos communities of Peter the Great Bay. On the other hand, in the fouling of ships of cabotage and harbor navigation in this bay *B. amphitrite* occurs every year and not only in warm years, as Zevina and Gorin believed [1975]. Certain specimens could survive wintering; however on most examined ships this species was not registered after winter exploitation. *B. amphitrite* has been registered by Rudyakova [32] as a secondary form in fouling communities of ships in Peter the Great Bay. According to the latter author, even a short-term (about two weeks) stay in cold northerly waters perishes this species. We did not find *B. amphitrite* on examined ships of harbor navigation arranged in the harbors of the Sea of Japan located to the north off Povorotny Cape; however, it is common on cabotage ships running at the route Vladivostok-Svetlaya. Evidently, an entry of a ship in Peter the Great Bay in summer time is a necessary requirement for presence of this species in the fouling.

In 2001 we for the first time performed integrated studies of reproduction pattern, larval development and settling dynamics of the cirripede barnacle *B. amphitrite* on artificial substrates in Zolotoi Rog Inlet [Zvyagintsev, Korn, 2003]. It is shown that reproduction in this species and settling of the larvae happen from August to October, under wide temperature range, from 13 to 22.5°C. In Peter the Great Bay, in the warm period of the year there is a dependent population of *B. amphitrite* inhabiting only anthropogenic substrates. Adult specimens introduced into the bay with foreign-going ships in the season favorable for the life of the species, produce larvae that have enough time to settle and grow up, but then dying during winter decrease of water temperature.

Balanus eburneus is a tropical-subtropical subtidal species, very vulnerable to low temperatures. It was found for the first time in the fouling of small bights, well heating by the sun [17]. According to the latter authors, *B. eburneus* could appear again later on, especially in warm years, however it could never inhabit Peter the Great Bay. Our studies proved that assumption, the only specimen of *B. eburneus* has been found in the fouling of a marine towboat "Shportov" operating in the area of Amursky Bay. This species has never been registered in benthos communities.

Balanus trigonus is a species widely distributed in Tropical and Subtropical Provinces, which is common in warm waters of Japan. In 1970 it has been found on buoys in Amerika Bay [Zevina, Gorin, 1975]. G.B. Zevina with co-authors [1975] believe that the barnacle *B. trigonus* was brought to the bay on foreign-going ships and released larvae, which settled on the buoys installed in the bay. We have found only several dead specimens of this species on a tanker "Molodechno" arrived from India and operating for one navigation at the outer harbor of Vladivostok. As it has been supposed by Zevina with co-authors, *B. trigonus* could not acclimate in Peter the Great Bay.

Amphipods

Corophium acherusicum. This species has been registered in Peter the Great Bay only as a component of a fouling community [Zevina, Gorin, 1975]. It has been supposed that this species is transferred at autotransplantation of *B. improvisus* and *B. eburneus* settling in the shells of dead barnacles. The geographical ranges of these species distributed throughout most part of Subtropical and Tropical Provinces are very similar. Earlier on we have found several adult specimens of *C. acherusicum* in the fouling of a sealer schooner anchored for some time in Posyeta Bay. In benthos communities of Peter the Great Bay this species in that time has not been registered. According to G.B. Zevina with co-authors [Zevina, Gorin, 1975], like *B. eburneus* that was at the first stage of acclimation, *C. acherusicum* could hardly naturalize in Peter the Great Bay. However, in our days this species occurs in benthos communities in southwestern Peter the Great Bay and around the mouth of the Tumen River [4]. Moreover, *C. acherusicum* has been found on the shelf of eastern Sakhalin in 2002 by an expedition of TINRO-

Center and also registered by us in the fouling of water cooling system on Heat and Power Station no. 2 of Vladivostok. This data provide an evidence about naturalization of *C. acherusicum* in Peter the Great Bay.

Hydroids

Gonothyrea loveni. This hydroid species known from the Northern Atlantic has been found by us for the first time in fouling of ships from Tatarskii Strait and identified by A.E. Antsulevich (unpublished data) as *Obelia loveni*. In the literature, the first information about findings of this species, also identified as *O. loveni*, in fouling of ships and HTC of this area has been published by Chaplygina [1980]. We have found this species in the fouling of ships from Tatarskii Strait, harbor fleets of

Kholmsk and Nevelsk, and Aniva Bay, however primarily in qualitative samples. It seems that *G. loveni* is there at the first stage of acclimation as it does not show great qualitative characteristics and is not registered in composition of benthic communities.

Campanularia johnstoni. This is a species widely distributed in both hemispheres that, however, does not penetrate into polar regions. According to Chaplygina [1980], in the northwestern Sea of Japan *C. johnstoni* has been found on almost all kinds of anthropogenic substrates except ships. In the fouling of ships that we examined in that area, *C. johnstoni* was common, however all findings were either registered in qualitative samples or its biomass did not exceed 0.1 g/m². According to Bagaveeva with co-authors [1984], this species has naturalized in bottom communities of the northwestern Sea of Japan.

Laomedea flexuosa. Until now this species, described from the coast of Great Britain (Alder, 1857; cited after Chaplygina [33]) is widely distributed in waters of the Northern Atlantic as well as in the White and Barents Seas. In Peter the Great Bay it has been found for the first time on the hull of a foreign-going ship arrived from the Atlantic. Later on it has been found also on Cabot age ships and in northern Primorye. In the 1990-es it was registered everywhere in the fouling of piers and mooring facilities in Peter the Great Bay, at Plastun village and on southwestern Sakhalin.

Laomedea calceolifera. In the past the geographical range of this species comprised temperate waters of the Northern Atlantic. Since 1875 it is known from American coasts, South Africa and the Yellow Sea [Chaplygina, 1992]. During the last two decades *L. calceolifera* was found in Peter the Great Bay on the same substrates as closely related *L. flexuosa*, however in smaller numbers. We consider both *L. flexuosa* and *L. calceolifera* to be new invaders into the Sea of Japan; the former species is also new for the fauna of the Pacific in general. However, it is still too early to speak about naturalization of these two species as they are registered primarily on anthropogenic substrates and their populations exist at the expense of the flux of autointroducents arrived with ships.

Polychaetes

Polydora limicola. The history of findings of this species in the benthos of the Barents Sea, Avachinskaya Guba Bay, Shikotan Island and the coast of California is known from the literature [Hartman, 1969]. This species is characterized by great ecological plasticity, it withstands desalination down to 6‰ and significant pollution by oil products. In the 1960s it has been introduced with ships into the Black Sea and then naturalized there [Bagaveeva, 1981]. In the Barents Sea *P. limicola* has been registered only in the fouling of ships and is absent in benthos [Zevina, 1962]. We have found this species in the fouling of HTC in Vladivostok, Nakhodka, Kholmsk and Uglegorsk, but did not register this polychaete in benthos [Bagaveeva, 1981].

We encountered *P. limicola* in the composition of fouling communities of examined ships as a secondary species, mostly in Peter the Great Bay. On Sakhalin the *Polydora* has been found in harbors of Kholmsk and Korsakov. Bagaveeva [1981] supposes that introduction and acclimation of *P. limicola* in the Sea of Japan take place at present. It is evident that in the northwestern Sea of Japan this species is at the first stage of acclimation, as it has been encountered only on anthropogenic substrates, in harbor areas.

Hydroides elegans. This is an eurybiontic species that withstands significant fluctuations in salinity and rather strong pollution. Rudyakova [1981] distinguishes two types of ships with fouling of *H. norvegica*, those laid up and those navigating in Peter the Great Bay with the speed of up to 16 knots. On the opinion of E.V. Bagaveeva the case in point here is *H. elegans* however reidentification of the species appeared impossible. Unfortunately, this did not allow us to compare our data with the results reported by N.A. Rudyakova.

The species *H. elegans* has been found in the fouling of experimental plates installed in Zolotoi Rog Inlet [Gorin, 1975]. First report about a finding of this species in the fouling community of a laid up ship has been published by Bagaveeva [1981].

We have found *H. elegans* on the majority of the ships examined in Peter the Great Bay. The analysis of the routes of the ships has showed that a necessary condition for the presence of this species in the fouling is visiting Golden Horn Inlet and at least short time docking there in August-September [Bagaveeva, Zvyagintsev, 2000, 2001]. Maximum quantitative characteristics have been registered on a tanker "Volgograd" that spent 4 months in Golden Horn Inlet. The biomass of this species reached 21 kg/m², the tubes were to 10 cm in length growing perpendicularly to the surface of the ship hull and covering 100 percent of the surface.

On the ships that often come to this bay or work only there, a community of tubular polychaete *H. elegans* has been registered. These ships can be divided into three groups in accordance with the regime of exploitation: 1 - laid up ships; 2 - ships that spend 70% time in Zolotoi Rog Inlet; 3 - ships that spend 20% time in this bay. For group 1 the total biomass of the fouling has been 5468 g/m² with a maximal value of 27326 g/m². Four algae species have been registered, their sum biomass accounts 4.6% of the total biomass, and 34 animal species. *H. elegans*, that has been recorded in 88% samples, accounts for 53% of the total biomass (the highest value is 21000 g/m²). A typical species of 1 group is *M. trossulus* (30% of total biomass, to 24000 g/m²). Besides *H. elegans*, 7 polychaete species have been observed in the community, of which the most common is *Nerieis pelagica* - to 200g/m². Of four barnacle species, *B. improvisus* и *B. amphitrite*, that have been registered in almost all samples, have the highest quantitative values. The role of other groups represented by a number of amphipods, isopods, bryozoans and hydroids is insignificant. The remaining groups are represented by individual specimens.

For group 2 of the ships the fouling biomass was twice as small (2496 g/m² with the highest value 7100 g/m²). Only two species of green algae have been registered, which together account for 2.4% of the total biomass. Thirty animal species has been registered, out of which the biomass of *H. elegans* makes up about one half of the total biomass with a frequency of occurrence of 95%. The structure of this variant of community does not differ significantly from the previous one. However, the typical species there include *B. crenatus* (to 7700 g/m², 30500 ind./m²). Moreover, on the ships of this group oysters are often observed, which are lacking in the previous variant.

For the fouling communities of the ships of group 3, which rarely come to Golden Horn Inlet, a decrease in the biomass of *H. elegans* to 907 g/m² (39.5% of the total biomass) is typical. The structure community remains the same in this case.

On the basis of data on Zolotoi Rog Inlet it may be assumed that the quantitative parameters of the dominant species of the fouling community on the ships in this bay are dependent on the time that the ships spend in the bay. As it follows from data mentioned above, the ships that have worked in Zolotoi Rog Inlet or often come there are characterized by a very special composition of the fouling. The dominant species there is *H. elegans*. The community of *H. elegans* reaches its maximal development on the ships that spend long time anchoring in this bay. Often, the biomass of the polychaetes reaches tens of kg/m², their tubes lime tubes grow perpendicularly to the surface of the ship hull, reaching 10-12 cm in length and forming a 100 per cent covering. We have not met anything similar in other parts of Peter the Great Bay. When looking for the explanation of this phenomenon, we, first of all, have taken into consideration the temperature regime as the main limiting factor of the process of acclimatization. It has been found that during the last decades this bay has suffered the "thermal pollution" caused

by the discharge of the warm waters of the water cooling system of TEPS-2 of Vladivostok. In 1970, an experimental power-generating unit was put into operation and at the beginning of 1971 four water pumps with a capacity of 6000 m³ per hour each were established and started to work for the cooling system of TEPS-2. In 1976 four water pumps with a doubled capacity of 12000 m³ per hour were established. The seawater that was used for cooling passed from Ussuriysky Bay (area of Tikhaya Inlet) through the system of the electrical power station and was discharged into the Obyasneniya River that falls into Zolotoi Rog Inlet. It is known that water is significantly heated during its passing through the pipes of the electrical power stations and industrial enterprises: when it is discharged into the environment its temperature is 5-10° C, and sometimes 24° C higher than the natural one. According to data received from the administration of TEPS-2, the temperature of the water that is discharged from the cooling system of the electrical power station varies within 18.4 - 30.8° C, the volume of the discharged water varies within 18793000 - 22546000 m³, correspondingly, per month. In Golden Horn Inlet, no such big temperature difference is observed as compared with the neighboring aquatoria, which is due to the significant remoteness of TEPS-2 from the discharging point of the heated waters. However, since this electrical power station started to operate, the bay stopped to get frozen in winter. According to our data, in the inner part of the bay (the discharging place of heated waters) the water does not get colder than 0° C during the whole winter.

"Thermal pollution" caused by a discharge of heated waters may result in different ecological consequences for populations of benthos and fouling. In particular, it can facilitate the process of acclimatization of exotic species. In this case, as a result of this phenomenon, Zolotoi Rog Inlet serves as an interface or an intermediate that enhances the spread of warm-water species, first of all *H. elegans*. In this bay, there is an all-year round flourishing population of this species, which is able to reproduce. However, it is found only in the fouling communities of the ships because in Golden Horn Inlet there are almost no natural hard substrates. Judging from the presented information, it is possible to conclude that *H. elegans* in Zolotoi Rog Inlet is now at the stage of "ecological explosion".

Pseudopotamilla ocellata. The naturalization of this species is a beautiful example of autotransplantation of an exotic, with all expected consequences including global changes at the level of faunas [Zvyagintsev, Bagaveeva, 1998]. According to available literature, *P. ocellata* inhabits intertidal and subtidal area on Alaska, Oregon, California, and Japan [Imajima, Hartman, 1964]. For this reason it is worthwhile to have a more detailed look at the introduction of *P. ocellata* to Peter the Great Bay.

On the basis of the many-year observations of the community of *P. ocellata* on natural and anthropogenous substrates, a conclusion can be made that this species is an immigrant one. During an examination of the fouling settlement in Nevelsk in 1970, the dominance of an immigrant species *Polydora limicola* in the community of the fouling of hydrotechnical structures was observed. Ten years later no *Polydora* specimens were found on the wharf constructions of Nevelsk. The fouling consisted of a monodominant community of *P. ocellata*. Because this species had not been recorded in the Russian waters previously, and it was first found in the ports and small ports, it is obvious that *P. ocellata* was brought to the northwestern part of the Sea of Japan by means of ships (individual findings of this species are known to us from the fouling of the coasters in the coastal zone of Primorye).

On the basis of data on hydrotechnical structures for 1980-1983, a conclusion can be made that the immigrant species *P. ocellata* in this region was at the stage of an "ecological explosion" at the time of study, which corresponds to Stage 3 of introduction. The mass occurrence of this species in the benthos of Peter the Great Bay testifies of the last 5th stage, i.e. naturalization of the species. The lack or rare occurrence of *P. ocellata* in the fouling of the hydrotechnical structures in this bay can be explained by the peculiarities of its ecology. For these polychaetes the optimal conditions of their existence occur on open surf-washed capes. The port constructions, as a rule, are located in the Inlet that is protected from the rough wave motion. However, we have observed a typical community of *P. ocellata* with a biomass to 800g/m² on a submerged dredge in the

tidal part of Lazurnaya Inlet (Ussuriysky Bay). It is possible that the mass development of this species in Ussuriysky Bay is facilitated by the antropogenically-caused eutrophication that has been increasing in the recent years. If this fact is proved experimentally, *P. ocellata* will perhaps serve as an indicator of this phenomenon.

The emergence of the immigrant species *P. ocellata* followed by its naturalization in Peter the Great Bay has caused significant changes in the benthic composition of the upper sublittoral. Taking into consideration the degree of the naturalization and the changes in the benthos at the level of entire communities, this phenomenon approaches global significance, with corresponding ecological aftermaths. Thus, at most depths, the community of *P. ocellata* has a very high biomass that reaches sometimes 39 kg/m² or more. Moreover, these values do not greatly exceed the average ones, since the colonies attain areas of tens of m² in size with a 100 percent covering of the substrate. Even data known to be underestimated give the total stock of these polychaetes only on Engelma Cape in Ussuriysky Bay (northern part of Emar Inlet) as no less than 40 tons. At present, published data on benthic communities in the upper sublittoral of surf-washed capes of the bay do not reflect the true picture, because these communities are buried under a thick layer of the polychaete *P. ocellata*.

Succession of benthic communities is well expressed after large defaunations caused by storms, antropogenous influence, etc. Certain species facilitate succession by being the first to colonize a surface and preparing the substrate for the species to come. For example, the tubes of polychaetes serve as a substrate for those species for which loose ground is unsuitable [8]. In this case, a similar phenomenon is observed at the horizons of 0,5-1 m in a community of *Phyllospadix iwatensis* on silty-sand bottom. When this community is colonized by an immigrant species *P. ocellata*, a substrate is created for the existence of a wide range of new species (Table) that have previously been absent. The total biomass of the community *P. ocellata* at different depth ranges varied within 178-332 g/m². Polychaetes are a known major foodstuff for most benthophagous fish. According to data obtained from trawling surveys, the biomass of the far-eastern redfins *Tribolodon brandti* in Peter the Great Bay increased 2.8 times from 1990 to 1994.

Bryozoans

Bugula californica. This bryozoan species from the Pacific coast of North America has penetrated by means of autotransplantation into the areas of Brazilian coast and the Atlantic coast of North America (Marcus, 1937; cited after Kubanin [1980]). We found this species in the fouling of cabotage ships in the northwestern Sea of Japan. The bryozoan *B. californica* was encountered on 41% of examined ships in Peter the Great Bay and on 83% of examined ships in Zolotoi Rog Inlet, in the community of *H. elegans*. In the communities of mussels and oysters *B. californica* has been encountered on 69% and 50% of examined ships respectively. This species has not been registered on ships operating to the north off Povorotnyi Cape. In this case we cannot agree with the opinion of Bagaveeva with co-authors [1984], who believe that *B. californica* in the northwestern Sea of Japan is now passing the phase of striking increase in population density. In all likelihood, this species is still only at the first stage of acclimation.

Conopeum seurati. The species is common on the Atlantic coast of Europe, from the British Islands to Mediterranean and Black Sea. It is known from the coast of New Zealand, where it has been introduced with foreign-going ships. In the Caspian Sea it distributed with cabotage ships. This species was also found in bottom communities of Posyeta and Vostok Bays, Sea of Japan and on experimental plates installed in Zolotoi Rog Inlet and on a buoy on Uliss Cape [Zevina, Gorin, 1975].

C. seurati, for the first time identified by Kubanin [1975] is very common in the fouling of examined ships from Peter the Great Bay. It has been found on 65% of ships that did not run beyond Povorotnyi Cape. The greatest biomass of this species (12 g/m²) has been registered on ships that were staying or operating in Zolotoi Rog Inlet, on other ships the biomass of this species was insignificant. Beyond Povorotnyi Cape this bryozoan was found as single specimens on harbor fleet ships in the harbors of Rudnaya Pristan' and Preobrazhenie. The introduction of this species into Peter the Great Bay

may be considered as a classical example of an introduction with the following acclimation and naturalization. First *C. seurati* has been registered in the harbor of Vladivostok, where it was introduced with foreign-going ships. Then it was found in the fouling of cabotage ships. At present this species has naturalized in the well-heating bight of Peter the Great Bay, where it had been introduced with these ships. The penetration of *C. seurati* to the north off Povorotnyi Cape is less probable, as it could hardly withstand the cooling effects of the Primorskoe Current.

Schizoporella unicornis. This species is a member of fouling communities of Posyeta Bay and is widely distributed in the benthos of the upper subtidal zone of Posyeta and Vostok Bays [Zevina et al., 1975]. It is found on 25% of examined ships in Peter the Great Bay showing insignificant biomass and occurrence frequency in samples of only 6%. Most findings fall onto the ships from Posyeta Bay, where it has been found in the community of *Crassostrea gigas*. In the community of mussels and barnacles this species has been registered on 22% of ships, while in Zolotoi Rog Inlet, in the community of *H. elegans* - only on one ship. *S. unicornis* is absent on ships from Sakhalin, on the coast of Primorye beyond the Povorotnyi Cape it has been found only in the harbor of Preobrazhenie. In the fouling of ships operating on passenger routes it has been registered only in qualitative samples.

It is pertinent to note that *S. unicornis* has been repeatedly transferred in long distances during neotransplantation of oysters, as this bryozoan most often settles on the surface of these mollusks. Prior to the early 20-th century this species was absent along the Pacific coast of America. It has been found for the first time at California, where it had been introduced with oysters, by the 1940-es it became the most common species of bryozoans in California. In the opinion of Zevina with co-authors [1975], it is not improbable that into Peter the Great Bay this species has also been transferred with introduced oysters as a result of cotransplantation and then has naturalized.

Bowerbankia gracilis. Bagaveeva with co-authors [1984] believe that this species was introduced through autotransplantation and then naturalized in Peter the Great Bay. However, we have registered *B. gracilis* only on one from 245 cabotage ships operating along the western coast of Sakhalin. If to use the scheme of the characteristics of species-invaders proposed by Zevina with co-authors [1975], so we do not observe here the second and third characteristic features of an invader, repeated findings of these species in areas of large harbors and on the bottoms of ships. Thus, this species could hardly be considered as an invader, in all likelihood it is an indigenous species of the northwestern Sea of Japan, which, however, could hardly survive environmental conditions in harbor waters.

Ascidians

In 1999 the fact of the introduction of a solitary ascidian *Molgula manhattensis* has been registered for the first time in the fouling community of experimental plates in Zolotoi Rog Inlet (the harbor of Vladivostok) and Rynda Bay (Russky Island) of Peter the Great Bay, Sea of Japan [Zvyagintsev et al., 2003]. For only 4-5 months of the exposure of plates this species turns the dominating species of the community, which is characteristic of multiannual communities of fouling and benthos in Peter the Great Bay. The natural geographical range of *M. manhattensis* is probably located on the Atlantic coast of North America and extends from Maine to Louisiana. However, this species is rapidly distributing throughout the world. In the 1950s it has been found in great amount on the Pacific coast of North America, in San Francisco Bay. In Japan the ascidian *M. manhattensis* has been introduced on bottoms of ships. In 1975 it has been registered for the first time in Australia. At the Far-Eastern coasts of Russia *M. manhattensis* has been registered for the first time. This is one of a few species of ascidians that could easily adapt to reduced salinity and may occur in great amounts in closed water bodies with strongly desalinated seawater and in water with great amount of suspended matter. The ascidians of this species live for about one year; they rapidly attain sexual maturity and reproduce several times throughout the life. However, *M. manhattensis* was not found on experimental plates that were installed in Zolotoi Rog Inlet for one winter.

Thus, proceeding from the presence of 16 introduced species in the fouling of the examined ships, one may conclude about the important role of ships in autotransplan-

tation. Using a scheme of Zenkevich [1940] with some modifications, we distinguished 4 groups of introduced species, which are now at different stages of acclimation. The acclimatization process of these species in the bay is very specific, and it does not fit the classical scheme suggested by Zenkevich [1940]: 1 phase of insignificant development; 2 phase of heavy reproduction; 3 phase of slowing of development; 4 phase of existence when high density indices, 5 phase of insignificant decrease of population; 6 phase of sharp decrease of population; 7 phase of slowing of decrease of population; 8 stage of stabilization.

(1) Introduced species that cannot adapt for new conditions even in harbor waters, where free ecological niches are usually available. To this group we referred two species of barnacles, *B. eburneus* and *B. trigonus*, which primarily have been registered on foreign-going ships. They extremely rarely occur on cabotage ships, do not reproduce and are absent in bottom communities.

(2) Potential invaders, species that are in the first stage of introduction and small-scaled development. To this group we referred *G. loveni*, *L. flexuosa*, *L. calceolifera*, *P. limicola*, and *B. californica*. They show greater ecological plasticity than the species of the first group and relatively frequently occur in the fouling of harbor fleet ships and HTC in the northwestern Sea of Japan, however they usually do not develop mass aggregations and are absent in benthos. 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. It is still not known, what species of this group could naturalize in the Sea of Japan. Judging from qualitative indices of species density in the fouling of ships and from the number of findings of the species in different harbors, the species that could naturalize most probably are *B. californica* (in Peter the Great Bay) and *P. limicola* (throughout the northwestern Sea of Japan).

(3) Species that are at the stage of sharp reproduction (ecological "explosion"). This group comprises three species, *B. amphitrite*, *H. elegans*, and *M. anhattensis*. They demonstrate great qualitative characteristics in the fouling of examined ships and experimental plates. Their characteristic feature is their particular localization on ships from Zolotoi Rog Inlet. The naturalization of these species is probably prohibited by the absence of natural hard substrates in the bay; they show mass development only on anthropogenic substrates.

(4) Naturalized species. We referred to this group some species that have been found not only in fouling communities, but also in the benthos of upper subtidal zone. These are *B. improvisus*, *P. ocellata*, *C. ascherusicum*, *C. johnstoni*, *C. seurati*, and *S. unicornis*. The problem about naturalization of the bryozoan *B. gracilis* still remains open as it is almost absent in the fouling.

As it follows from the data discussed above, a peculiar composition of fouling is characteristic of ships working or entering frequently Zolotoi Rog Inlet. Among dominating and characteristic species there are three introduced species, *H. elegans*, *B. amphitrite*, and *M. manhattensis*. Thermal pollution caused by the discharge of warmed waters from the Thermal Power Station N 2 into Zolotoi Rog Inlet analyzed in detail in our recent papers [Zvyagintsev, Budnikova, 2003; et al.] benefits the process of acclimation of exotics. This species exist only in fouling communities of ships and hydrotechnical structures due to the absence of natural hard substrates in the bay. The process of acclimation of these species is somewhat peculiar; therefore we cannot proceed here from the classical scheme of Zenkevich [1940], which does not allow us to consider them as naturalized.

Fouling and the problem of species distribution as a reason of changes in benthos communities

Geographical distribution of organisms that constitute the fouling is one of the most important theoretical and practical aspects of this phenomenon. Fouling communities provide significant contribution into biodiversity of certain regions; for example in tropical zone some species of algae have been registered only on anthropogenic substrates and are absent in benthos.

The dissipation of larvae is the only distribution pattern known in most species of

sessile organisms. However, in some of them not less or even more important is distribution on driftwood (rafting) or distribution on nekton animals. Rafting differs from distribution by means of larvae in the fact that adult organisms live much longer than the larvae and could produce dissipating stages themselves. Such a dissipation in many species of cirripede barnacles is performed in all turnovers of marine currents. The drifting of driftwood in areas significantly different in hydrological characteristics results in the death of the animals, however if the differences are small the animals could survive and provide a viable offspring. All opportunities provided by such a distribution pattern are entirely exhausted for the moment, as the latter functioned from the moment of the origin of life in the World Ocean. Some examples of this distribution pattern might be cirripede barnacles of the genera *Balanus*, *Megabalanus*, and *Lepas*.

Nekton organisms support distribution of strictly specialized species of cirripede barnacles of the genera *Chelonibia*, *Platylepas*, *Coronula*, *Xenobalanus*, *Cryptolepas*, and also the species *Conchoderma auritum* that can survive both in the fouling of ships and as an epibiont. The distribution of epibionts by nekton organisms have restrictions corresponding to geographical ranges of their hosts. And, finally, in the recent 2-3 centuries there was an "explosion" in the number of introducents due to increasing number of ships. The results of the studies on distribution of foulers provide evidences about a great role of marine transport as a factor of changes in zonal-geographical characteristics of certain species.

The fouling of sea ships might be a beautiful object of island biogeography. According to the equilibrium theory of MacArthur and Wilson [1967], a ship might correspond to a small and remote island, in the course of its colonization the number of species should finally stabilize. This stabilization is prevented upon completion of the cruise of docking of the ship; therefore the number of species does not reach the point of dynamic equilibrium, i.e., the potential species diversity of such an island.

The problem of conservation of endangered species might be resolved through creation of artificial isolated "reserve" populations on islands. All activities for introduction of biogeographically alien species of biota into natural ecosystems should be preceded by ecological expertise and search for alternative pathways. In some cases the non-transplantation of exotics for the purpose of their conservation does not provide the desired effect with the following ecological explosion in the population density of the introducent.

During the primary colonization of a ship or hydrotechnical installation by foulers, there are free ecological niches available and, first of all, there is substrate appropriate for settling of larvae (spores). The developed fouling community is a very young biota that did not pass its own way of ecological and evolutionary "equilibration," the coadaptational development. Just in case of young non-equilibrium biotas of these "anthropogenic islands" (ships) the success of the introduction of biogeographically alien species should be higher than in equilibrium benthos communities. Most often the biota of such as "island" is identical, from positions of historical biogeography, to the biota of natural geographical ranges of species inhabiting this "island" and is entirely constituted from common, easily dispersing species of animals and plants. However, in certain cases, on foreign-going ships, there is a "zoo in nature" and the consequences of naturalization of its exhibits in benthos might result in global changes of indigenous communities.

The analysis of theoretical aspects of acclimation would remain incomplete, if not to discuss relations between this process and evolution. In his monograph, Railkin [29] distinguishes four stages in the evolution of fouling (the sessile benthos of hard substrates this scientist also refers to as fouling). He believes that on the first stage the life on sea bottom represented a fouling; on the second stage benthos appeared displacing the fouling from the bottom; on the third stage, with development of large multicellular animals, epibioses arose in the sea; and on the fourth stage the primary factor of fouling evolution are anthropogenic substrates.

In our opinion, the theory of acclimation is of a certain importance for theoretical biology as it allows us to understand better the processes of evolution; both these processes are connected with adaptive speciation. However, until now we do not have any reliable information concerning development of a new species (or even a subspecies) as

a result of naturalization, so all following discussion is, to a certain degree, speculative. Many authors use facts of rapid speciation in introducents as examples of microevolution. During both acclimation and speciation, there are common species-building factors: isolation, mutagenesis, sharp fluctuations in population density (population waves), and natural selection. Both these processes begin with isolation of a group of specimens from their parental population and development of a geographical isolate.

Microevolution (in the case of allopatric speciation) begins from a natural distribution of a group of specimens beyond the borders of their geographical range, as a result of this process a marginal isolate appears. This might require the exchange of numerous generations, as the probability of survival of specimens beyond the borders of geographical range of the species is very small. The acclimation process begins as a result of either noo- or autotransplantation onto a certain area beyond the borders of the geographical range of the species. If the conditions are favorable for this species, the naturalization takes the smallest period of time. The difference between processes of microevolution and acclimation is that the former is initiated by natural reasons, whereas the latter is driven by the man. This difference is not of fundamental importance, as in both cases speciation begins after the development of isolates. The acclimation processes show high rates and might be monitored throughout a life time of a single scientist.

A similar large-scale experiment is performed every time, when a new ship or other artificial object is brought into exploitation; as the larvae of foulers begin mass settling on the free surface of this object. Such an interpretation of the acclimation process (the development of a fouling community) is of a high theoretical importance, as acclimation and survival of organisms in the fouling might be used to understand the process of microevolution. The theory and practices of acclimation, favoring the studying of microevolution, approach the resolution of a fundamental problem in biology, the creation of a man-driven evolution, which would allow us to "construct" desired communities with great quantitative indices, organisms with desired features and characteristics and mariculture with desired high productivity. Thus, despite its anthropogenic starting point, the acclimation process is an ecological process showing all characteristic features of the latter.

Therefore, if an exotic fouler is found only on foreign-going ships, it might be considered as either an autotransplantant or, more rarely, as an introducent (if there are introduced specimens that have been registered on hydrotechnical construction and cabotage fleet ships). If it has been proved that the invader inhabits a harbor area with disturbed natural communities and the local population survives at the expense of permanently coming transplantants, so we also could consider the species as an introducent. If the exotic is reproducing and discovered in different bottom communities and its density is increasing, it could confidently be considered as an acclimant. In particular, one would see obvious correlations of its density, biomass and other indices of abundance with inter-annual fluctuations of climate. Finally, regular findings of a species in bottom communities in the course of multi-annual observations and findings of all its developmental stages throughout many years, is evidence that the species has naturalized.

It is known that autotransplantation results in development of new interrupted (bipolar) and amphiboreal ranges, together with such global processes as exchange of faunas following changes in temperature regime and transgressions of the World Ocean. Anthropogenic transplantation makes this process to pass many times faster. When developing biogeographic hypotheses, one should not forget about the role of auto- and nootransplantation in the formation of recent disjunctive ranges. Our data completely agree with the opinion of Zevina [1994] that the increasing maritime traffic, increasing number of sea ships with different regimes of exploitation and arising connection between different seas via canals should necessarily result in the formation of common fouling faunas for more and larger regions of the World Ocean, within the limits of different biogeographic regions.

3.7 FREE-LIVING MARINE NEMATODES IN STARKA STRAIT, RUSSKY ISLAND ECOSYSTEM (SEA OF JAPAN/EAST SEA), A MEIOBENTHIC STUDY

Introduction

An agar-producing red alga *Ahnfeltia tobuchiensis* forms friable layer on a bottom of Starka Strait. During the stormy weather this layer rises above the bottom, overturns and mixes up (Titlyanov et al., 1993). Numerous studies are done on communities living on *A. tobuchiensis* with an attention accent on structure and distribution of bottom macrophytes and macrofaunae in the layer of *A. tobuchiensis* (Titlyanova, 1980; Titlyanov et al., 1993; Ivanova et al., 1994; Zhiltsova et al., 2002). There are almost no studies done on meiobenthos both in the layer of *A. tobuchiensis* and in the ground deposits under the layer.

The purpose of the present work is the comparative study on meiobenthic community structure and free-living marine nematodes in particular under the layer of *A. tobuchiensis* and in the bottom sediments on a site located outside of the layer using the main characteristics of the communities – species composition, abundance and ecological indices. Data on bottom deposits and environmental data are presented in Tables 3 and 4.

The thickness of *A. tobuchiensis* layer reached up to 50 cm at the station 1. Bottom sediments were represented by silted heterogeneous sand. Nematodes were dominating group and an average density was determined to be at 208.9 ± 72.3 thous. ind/m² (Fig. 15). Thirteen species of nematodes were found in this biotope, dominated by

Table 3

Granulometric composition of bottom sediments (%) in Starka Strait

Sta- tions	Sediment particle size, mm										Type of bottom sedi- ments
	>10	7-10	5-7	3-5	2-3	1-2	0.5-1	0.25- 0.5	0.15 -0.25	<0.15	
1	0.84	0.09	0.24	0.59	6.36	25.44	19.97	23.99	9.64	12.84	I
2	-	-	0.08	0.30	0.30	2.84	26.57	59.58	4.94	5.39	II
3	-	-	-	-	0.07	0.84	18.35	68.91	8.74	3.09	III

Note: I – silted heterogeneous sand; II - silted medium and fine sand; III – silted fine sand

Table 4

Environmental data of sampling stations in Starka Strait

Station	Temper- ature, °C	Salinity, PSU	O ₂ mg/l	O ₂ %	C _{org} %
1	12.5	33	4.9	78.1	2.4
2	15	33	5.7	96.2	2.22
3	15	33	5.7	96.2	2.7

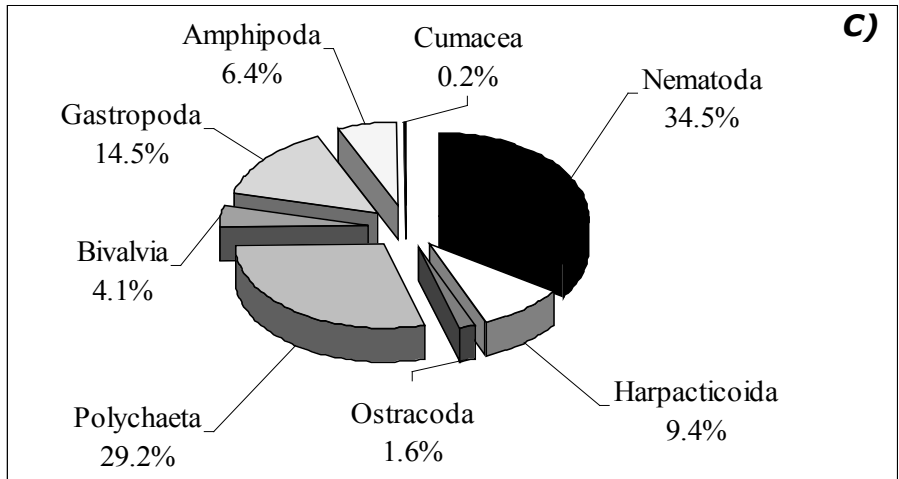
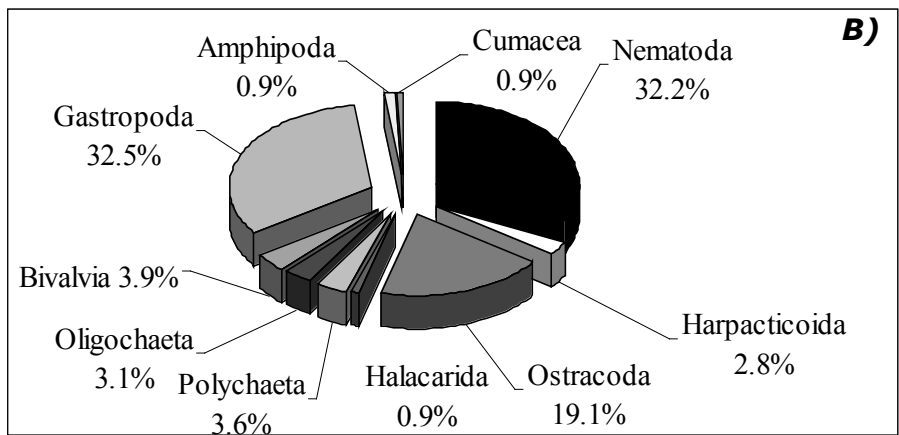
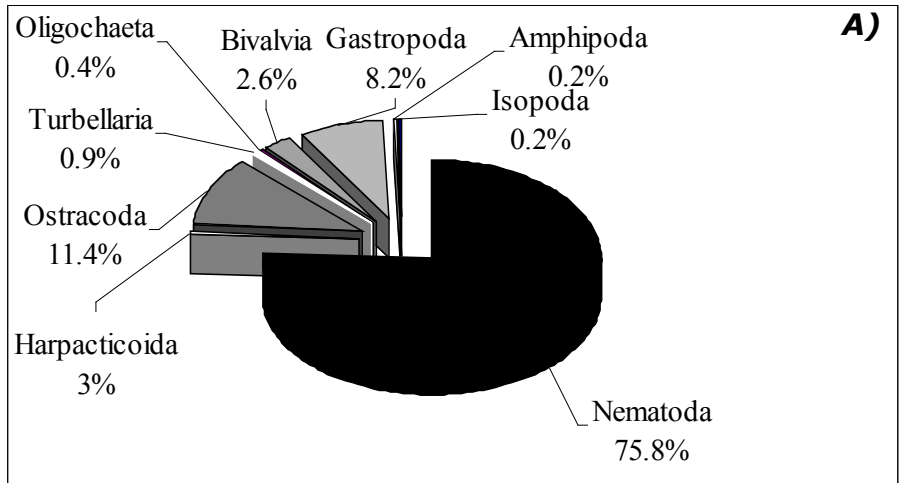


Fig. 15. The percentage of major meiobenthic groups at stations in. Starka Strait: A – station 1, B – station 2, C – station 3

the species of the Comesomatidae family. *Sabatieria pulchra* dominated (88.2 ± 37.1 thous. ind/m², 42.7%), *S. palmaris* (45.2 ± 25.7 thous. ind/m², 21.7%) and *S. finitima* (40.5 ± 27.1 thous. ind/m², 19.6%) subdominated (Table 5). Non-selective deposit-feeders (1B) dominated among nematodes with different feeding types - 88.5% (Fig. 16). The Shannon-Wiener diversity index (2.32), and Pielou evenness index (1.19) were lowest for this station, while the Simpson domination index (0.27) was the highest.

Table 5

Species composition, portion (%) of each species, and trophic groups in Starka Strait

Species	TG	1 station	2 station	3 station
Family Enoplidae Dujardin, 1845				
<i>Enoplus anisospiculus</i> Nelson, Hopper et Webster, 1972	2B	-	-	0.3
<i>Enoplus michaelsoni</i> (Linstow, 1896)	2B	-	-	0.7
Family Thoracostomatidae Filipjev, 1927				
<i>Enoploides rimiformis</i> Pavlyuk, 1984	2B	-	-	1.6
<i>Enoplolaimus medius</i> Pavlyuk, 1984	2B	0.3	9.9	4.5
Family Phanodermatidae Filipjev, 1927				
<i>Phanoderma</i> (Phanoderma) <i>platonovae</i> Belogurov, 1980	2B	-	-	3.6
Family Anticomidae Filipjev, 1918				
<i>Anticoma possjetica</i> Platonova, Belogurov et Sheyenko, 1979	1A	-	-	4.2
Family Oncholaimidae Filipjev, 1916				
<i>Pseudoncholaimus furugelmus</i> Belogurov, 1977	2B	1.9	5.4	-
<i>Viscosia stenostoma</i> Platonova, 1971	2B	4.3	5.4	-
Family Enchelidiidae Filipjev, 1918				
<i>Calyptronema stomodentata</i> Belogurov, 1980	2B	-	-	0.7
Family Oxystominidae Chitwood, 1935				
<i>Halalaimus leptoderma</i> Platonova, 1971	1A	-	-	0.7
<i>Oxystomina elegans</i> Platonova, 1971	1A	0.6	-	1
Family Rhabdodemaniidae Filipjev, 1934				
<i>Rhabdodemia orientalis</i> Platonova, 1974	2A	-	-	1
Family Chromadoridae Filipjev, 1917				
<i>Chromadora heterostomata</i> Kito, 1978	2A	0.6	15.2	-
<i>Panduripharynx unidentatum</i> Dashchenko, Belogurov et Fadeeva, 1985	2A	-	0.8	-
<i>Rhips</i> sp.	2A	-	-	0.3
Family Cyatholaimidae Filipjev, 1918				
<i>Paracanthonchus macrodon</i> (Ditlevsen, 1919)	2A	-	0.8	20.5
<i>Pomponema</i> sp.	2B	-	-	0.3
Family Selachinematidae Cobb, 1915				
<i>Cheironchus</i> sp.	2B	0.3	-	-
<i>Halichoanolaimus possjetiensis</i> Belogurov et Fadeeva, 1980	2B	-	-	8.2
<i>H. sonorous</i> Belogurov et Fadeeva, 1980	2B	-	-	0.3
<i>Richtersia</i> sp.	2B	-	-	1.9

Table 5(continued)

<i>Synonchium</i> sp.	2B	-	-	0.3
Family Desmodoridae Filipjev, 1922				
<i>Chromaspirina</i> sp.	2A	-	-	2.3
<i>Metachromadora itoi</i> Kito, 1978	2A	-	-	9.1
<i>Spirinia</i> sp.	2A	-	0.8	0.3
Family Monoposthiidae de Man, 1889				
<i>Monoposthia latiannulata</i> Platonova, 1971	2A	0.3	20.5	15.6
Family Xyalidae Chitwood, 1951				
<i>Daptonema variasetosus</i> (Pavlyuk, 1984)	1B	0.6	22	0.7
<i>Pseudosteineria inaequispiculata</i> (Platonova, 1971)	1B	-	5.4	-
<i>Theristus</i> (<i>Penzancia</i>) <i>longispiculata</i> (Platonova, 1971)	1B	-	9.8	-
Family Linhomoeidae Filipjev, 1922				
<i>Metalinhomoeus</i> sp.	1B	-	-	2.2
<i>Megadesmolaimus rhodinus</i> Chesunov et Yushin, 1991	1B	2.5	2.3	1.3
<i>Terschellingia</i> sp.	1B	-	0.8	-
Family Axonolaimidae Filipjev, 1918				
<i>Axonolaimus seticaudatus</i> Platonova, 1971	2A	-	0.8	16.2
Family Comesomatidae Filipjev, 1918				
<i>Comesomoides</i> sp.	1B	-	-	1.6
<i>Dorylaimopsis peculiaris</i> Platonova, 1971	2A	-	-	0.3
<i>Sabatieria intacta</i> Fadeeva et Belogurov, 1984	1B	4.7	-	-
<i>S. finitima</i> Fadeeva et Belogurov, 1984	1B	21.7	-	-
<i>S. palmaris</i> Fadeeva et Belogurov, 1984	1B	19.6	-	-
<i>S. pulchra</i> (Schneider, 1906)	1B	42.5	-	-

Note: " - " species not found at this station; TG – trophic groups.

The thickness of *A. tobuchiensis* layer at the station 2 reached up to 30 cm. Bottom sediments were represented by silted medium and fine sand (sediment type II). The density of nematodes was lowest (21.1 ± 12.2 thous. ind/m²) and comprised 32% of the total meiobenthos density (Fig. 15). Fourteen species were found. *Daptonema variasetosum* (4.6 ± 2.2 thous. ind/m², 22%) and *Monoposthia latiannulata* (4.3 ± 2.7 thous. ind/m², 20.5%) dominated. Non-selective deposit-feeders (1B, 40.3%) and epistratum feeders (2A, 38.9%) dominated among nematodes with different feeding types. Meaning of the index of species diversity was 3.09, Simpson domination – 0.21 and Pielou – 1.58, respectively.

Station 3 is situated at some distance away from *A. tobuchiensis* layer. Bottom sediments were presented by silted fine sand [sediment type III]. The average density of nematodes was determined to be at 216.5 ± 52.9 thous. ind/m², comprised 34.5% of the total meiobenthos density (Fig. 10). 28 nematode species were found, *Paracanthochus macrodon* (43.2 ± 22.9 thous. ind/m², 20.2%), *Axonolaimus seticaudatus* (33.8 ± 17.1 thous. ind/m², 16.2%) and *M. latiannulata* (33.5 ± 15.2 thous. ind/m², 15.6%) dominated. Epistratum feeders (2A, 64.3%) formed the most important trophic group (Fig. 11). The highest indices of species diversity (3.7) and Pielou evenness (1.69) were recorded in this biotope, while the Simpson domination index (0.14) was the lowest.

Overall thirty nine species of nematodes were found in the researched area. The highest index of similarity between the stations 1 and 2 – amounts to 34.15%, and the lowest index between stations 1 and 3 to 19.6%.

Water exchange between Amursky Bay and the south part of Ussuryisky Bay is carried out through the Starka Strait. In the summer the basic features of a field of currents in a passage are anticyclonic circulations in the pass of the strait and the cyclonic

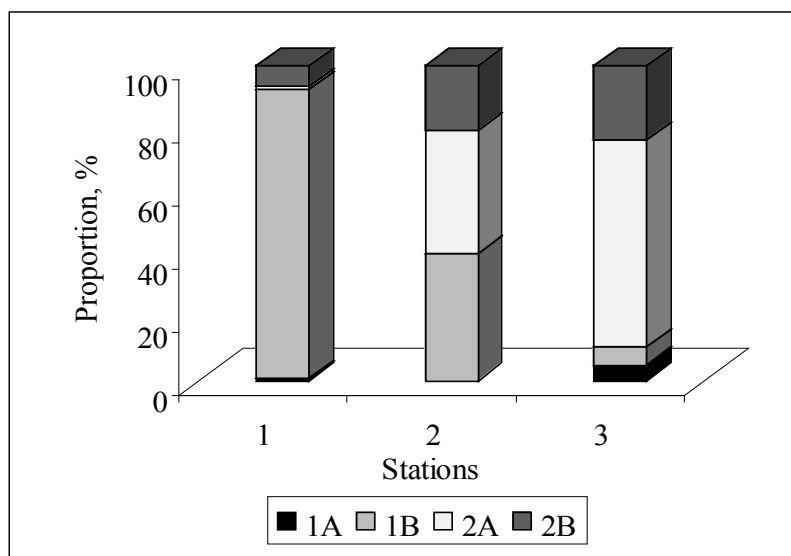


Fig. 16. Percentage of nematodes belonging to different trophic groups at stations. Trophic groups: (1A) selective deposit-feeders; (1B) non-selective deposit-feeders; (2A) epistrate feeders; (2B) omnivores.

turbulences adjoining from southeast. Movement of water defines a configuration, integrity and thickness of the *A. tobuchiensis* layer (Novojilov 1980, Ivanova *et al.* 1994). Under the influence of waves layer of *A. tobuchiensis* is capable to accumulate ground deposits. On the depth of 10 m the wide areas of the bottom ground are covered by the silted fine sands which can move under influence of weak wave and currents movement colliding with *A. tobuchiensis* layer and filling it in. Vertical pulsations of a layer serve as the mechanism for removal of fine silt sediment fractions from *A. tobuchiensis* itself and underlying areas of the ground. Silted fine sands prevail in the zones of the maximal congestion of seaweed (thickness of a layer of 30-50 cm) however, on depth of 8-10 m sand is prevailing sediment and by the coast line prevails gravel (Titlyanov *et al.*, 1993). The sediment particle size is one of the most important factors for meiobenthic animals and in particular nematodes. Increase in concentration of the silt sediment fractions over 2% significantly influences conditions of a life in a deposit changing specific structure in the layer of sediment (Gerlach 1958). Specific structure significantly varied from station to station with similar environmental conditions (water depth, dissolved oxygen saturation in the bottom layer, organic carbon content, salinity, temperature) in Starka strait. Under the layer of *A. tobuchiensis* (the layer of alga 50 cm thick) where the percentage of silt particles was over 12% members of Comesomatidae family were dominant in nematodes community which is usual for the silted sediments (Tietjen 1980). In sediment under the layer of *A. tobuchiensis* (the layer of alga 30 cm thick) the concentration of the silt particles was 5.39%, community density of nematodes was low, species from families Xyalidae and Monoposthiidae dominated. Out of the *A. tobuchiensis* field the concentration of silt particles from the bottom sediments was minimal (3.1%), species of Cyatholaimidae and Axonolaimidae families were dominant.

Thus nematodes communities under the layer of *A. tobuchiensis* with higher concentration of silt is characterized by low level of species diversity but high degree of dominance, while the species composition of the sands with the low concentration of silt particles is characterized by high index of species diversity and low Simpson domination index.

3.8 DISTRIBUTIONAL PATTERNS OF THE CORAL DIVERSITY IN THE INDO-WEST PACIFIC: UNDERSTANDING OF THE GLOBAL TRENDS IN THE CORAL REEF ECOSYSTEMS' CHANGING

Introduction

There is a growing recognition that reduced diversity makes the world and its inhabitants increasingly vulnerable to natural and human-induced changes. The past decades have seen a rise of interest in biological and cultural dimensions of diversity, the interactions between them and their connection to social and economic development (<http://unesdoc.unesco.org/images/0015/001592/159255e.pdf>).

This has resulted in increasing awareness of the 'inextricable link between biological and cultural diversity'¹, and the recognition of the crucial role that it plays in sustainable development and human well-being Worldwide (UNESCO-UNEP High Level Round Table on 'Cultural Diversity for Sustainable Development', 2002, <http://unesdoc.unesco.org/images/0013/001322/132262e.pdf>).

The Convention on Biological Diversity (CBD) defines biological diversity as: "The variability among living organisms from all sources, including inter alia terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." The "biological resources include genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity" (<http://www.cbd.int>).

The high level of biodiversity is considered as the essential requirement for the resilience of the ecosystems. The resilience is defined as the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and restore itself when necessary. Resilience, as applied to ecosystems, or to integrated systems of people and the natural environment, has three defining characteristics:

- 1.** the amount of change the system can undergo and still retain the same controls on function and structure;
- 2.** the degree to which the system is capable of self-organization;
- 3.** the ability to build and increase the capacity for learning and adaptation (<http://www.resalliance.org>).

The numerous links between cultural and biological diversity are increasingly viewed as key elements in achieving sustainable development and the Millennium Development Goals. UNESCO has developed a number of joint activities in the framework of the Main Line of Action on "*Enhancing linkages between cultural and biological diversity as a key basis for sustainable development*" - including initiatives focused on local, traditional and indigenous knowledge, languages, sustainable management of natural resources, as well as the publication on "Conserving Cultural and Biological Diversity: The Role of Sacred Natural Sites and Cultural Landscapes" - to better understand and enhance the linkages between biological and cultural diversity and relate them to sustainable development policies at national, regional and international levels (<http://unesdoc.unesco.org/images/0015/001592/159255e.pdf>).

Perception of biological diversity is always rooted in a specific culture and environment. The main goals for the conservation and sustainable use of biological diversity and other natural resources are inseparably linked with distribution of benefits resulting from integrated and participatory approaches to sustainable management of the coupled social-ecological systems. Changes in biological diversity are forced by common drivers which can be discussed as inevitable consequences of the globalization, meaning the ensemble of global trends in social, political and economic processes. The ecosystem' biodiversity is threatened by changes in traditional agroecosystems, pastureland and forest cover (e.g. abandonment of traditional cultivation, development of homogenous ecosystems). Homogenization ultimately leads to loss of important components of the world's diversity (e.g. loss of genetic diversity, species, ecosystems and landscape mosaics, languages, traditional knowledge and teaching methods, art, music and rituals,

world views, cultural and social practices and structures, healing and agricultural practices and techniques).

The marine bottom ecosystems are among the traditional bioresources for the long-term cultures and social demography trends in the countries having the long maritime boundaries such as in the South East Asia. The region of the East Asia Seas has been observed to have a high population growth. Around 1.9 billion people have been estimated for this region if one considers that around 77% live within 100 km of the coast (Burke et al., 2001). Various pathways of connectivity occur between the socials inhabiting this area. Some of these pathways are seen for example through hydrographic - meteorological - oceanographic - linkages that mediate dynamics of nature of the ecosystems' productivity and movement of its biophysical resources. Indeed, the seas and oceans offer more of a linkage than a barrier to its people and its ecosystems.

The high productive marine ecosystems (such as coral reefs) values provide an important life support system to the coastal states especially through food from fisheries. Estimates for the South China Sea would be at least 10 million tons per year and occupies at least 4% (except China) share in the world imports of fishery products worth at least \$45 billion (ca. 1995, Talaue-McManus 2000). But perhaps nowhere else in the marine regions of the world, considering the rich biodiversity and dependence on the fisheries, that its fisheries are in a severe state of overexploitation (GIWA 2001). Both the Sulu-Celebes Sea and the South China Sea have rated overfishing and destructive fishing as its priority concerns. Considering the rate of population growth and the rate of fisheries exploitation in these two regions it has been projected that conditions will not improve in the next 20 years and may even decline (GIWA 2001) (Fig. 17).

Grigg (1976) estimated the effect of commercial collection by comparing undisturbed and harvested populations using a mathematical model of population dynamics. For slow growing species of precious corals population changes and reduced abundance were described by him as being inevitable (Grigg 1977). The most thorough attempt to quantify the effect of collection in the field was carried out by Ross (1984) who compared coral community parameters at two sites, one heavily harvested, off Cebu in the Philippines. Driven by a market demand for large, mature colonies for the ornamental trade collection had resulted in a reduction in coral density (31%) and percent coral cover (64%) on the lower reef crest (Ross, 1984). *Seriatopora* spp., common in the area, were completely absent from the harvested site, and the population structure of one species, *Pocillopora verrucosa*, had been altered by the extraction of large, sexually mature colonies to consist predominantly of small, juvenile colonies (Ross, 1984). So, not surprisingly, the intense extraction of corals at a particular location can profoundly alter the community structure.

Bentley (1998) compared the live and dead (ornamental) coral trade in Indonesia with other extractive and destructive practices, namely the mining of reefs for construction material and the production of lime from burning coral. Historically the amount of coral mined for construction in the Jakarta area has been estimated at between 10,000-25,000m³ per year (Polunin, 1983) which equates to 15,000-37,500t at an intermediate skeletal density of 1.25g per cm³ (for measurements of density see Bosscher, 1993). Bentley (1998) estimated the quantity of coral being mined nowadays to be no more than 5000 t annually. Data on the production of lime from coral are patchy, but the best documented case study is from West Lombok where 60 families produce six hundred 25kg bags of lime per year (Cesar, 1996), an annual total of 900t which necessitates the collection of approximately 1600t of coral.

Considering that Indonesia has never exported more than 2000t of coral it is clear that there are processes extracting considerably more coral there than either the live or ornamental trade. Elsewhere, the amount of coral mined in a single year for construction in the Maldives, where other building materials are particularly scarce, is 20,000m³ (Brown and Dunne, 1988) or 25,000t at an intermediate skeletal density of 1.25g per cm³ - more than all the coral traded since 1985. In a similar vein dynamite fishing is having a major impact on coral reefs in Indonesia and has increased dramatically over recent years. Cesar (1996) conservatively assumed a bombing rate of one bomb per day per km² which, over a reef area of 41,960km² (Spalding and Grenfell, 1998), equates to a total of 15 million bombs per year. If each bomb destroyed only 1kg of coral then the



Fig. 17. The fishers in Vietnam: the motor boats are ready to the work. Nha Trang, Vietnam, 2006.

amount of coral killed annually in this manner would be approximately ten times that exported from Indonesia each year during the 1990s.

The marine farming is another fastly growing sector of the national economy for the region. However, this productive industry needs the professional management including the ecology working out the prediction models of the eutrophication consequences for the coral reefs in the local and large-scaled areas with intensive farming in the sea.

The coral reefs being the cradle of fish reproduction and fattening represent a complicated ecosystem. These ecosystems provide the full life cycle for the numerous invertebrates and algae which are widely used as food sources, in particular, as a source for the chip protein diet. The overpressure and overconsumption of the mollusks, holothurians, worms, lobsters and others coral reef animals can lead to the homogeneity of the structure of these ecosystems instead of their high biodiversity (Fig. 18).

Unfortunately over exploitative and destructive fishing practices are not the only pressure on coral reefs. More than 75% of the world's reefs are threatened by human activity ranging from coastal development, marine pollution, sedimentation and eutrophication from inland deforestation and farming (Bryant et al.1998). The main amount of the coral reefs in the coastal waters in South East Asia is placed shallow; these reefs are affected by the complex environmental influence (including the anthropogenic impact). The overheating of the corals at shallows can lead to the bleaching and subsequent death of the corals (Wilkinson, 2004). The bleaching, which process lie in the loss of the micro-algae (zooxanthellae) by corals, leads to the starvation in the corals. The mass bleaching of the corals have leaded 60 % of the coral reef ecosystems to the death or hardly reversed destructions along with the sustainable decreasing of the corals diversity at the damaged reef complexes. The survey of the relations between the environmental factors and biodiversity in the reef ecosystems show the very diverse conditions for the bottom animals (the different grounds, seasonal wave activity, the different level of the water exchange) and different levels of the sedimentation influx from the rivers' dis-

charge. The high biodiversity in coral reefs is closely related to this environmental multiformity and possess the ability of the coral ecosystems to the recovery and their resilience.

So, the main drivers leading to the global biodiversity changing in the coral reef ecosystems can be discussed as:

the possible invasion of the alien species (or group of the species) using the various pathways of the overseas connectivity;

the overexploitation of the bioresources of the coral reefs together with the man-made pollution of the coastal seas.

the global climate changing and environmental stress.

The joint efforts of the ecologists to trace the global and local trends and perspectives in the biodiversity changing in the coral ecosystems have to be focused on the main components of these ecosystems. These components which

may be called critical functional groups (both corals and reef fishes) are fundamental to understanding resilience and avoiding phase shifts from coral dominance to less desirable, degraded ecosystems. Among the reef-building corals two main groups should be placed in a focus of the careful study and monitoring – stony corals and soft corals (Cnidaria: Octocorallia). The diversity of the Scleractinia (stony) corals was surveyed in the tropical zone (Veron 2000); this data allow the conducting the subsequent investigations in the field of the estimation of these corals bioresources and status. However, the information on the biodiversity and dispersal of the mass genera of the soft corals (*Sinularia*, *Dendronephthya*, *Sarcophyton*) is few and restricted by several local faunas – Palau (Indonesia), Red Sea, New Guinea.



Fig. 18. Large flourishing coral reef – the 3-dimensional construction is seen through the water layer (to the left). The bleached reef – the reefbuilding corals loss their symbiotic algae (to the right).

The invasion: a case with soft coral

The soft coral *Carijoa riisei* (Duchassaing and Michelotti, 1860), or Snowflake coral, has native range in the Western Atlantic, from Florida to Brazil. The species forms erect, branching colonies with flexible stems. Each tall axial polyp has many short lateral polyps. Polyps, when extended, have eight white frilly tentacles, like the rays of a snowflake. The long stems or branches of the coral are a dirty white color, but they are almost always covered with a very thinly encrusting orange-red sponge, yet to be identified. The species is most commonly found in the fouling community of harbors, usually on pier pilings or wrecks which are not exposed to direct sunlight. Polyps may reproduce asexually by simply splitting in two, or sexually by release and fertilization of gametes into the water column. The resulting planula larvae settle to the bottom and develop directly into young polyps. *C. riisei* exhibits high fecundity compared to other corals

(clonal benthic marine invertebrates like corals in general exhibit much lower fecundity than a clonal benthic marine invertebrates like mussels).

Carijoa coral was firstly found in 1966 at Hawaii Archipelago. Later on, the subsequent findings were made through 2005. In present, the coral is noted outside of harbors, especially along the leeward coast of Oahu, on shipwrecks or in sheltered and shaded crevices or shallow caves on the deeper reefs. The invasive characteristics of the *Carijoa* include: low mortality, the absence of the superior competitors and significant predators, fast population growth and the fast growth of the coral individuals (1cm per week), continuous reproduction (Concepcion, 2006). The single possible predator can be a recently discovered introduced nudibranch, *Phyllodesmium poindimiei*.

In favorable conditions *C. riisei* saturates substrata excluding native benthic fauna. The target for this fouler can be not only the artificial or natural substrata, but the several coral species of the Hawaiian reefs may under the *Carijoa* pressure. The black coral *Antipathes dichotoma* has the native Hawaiian population being both the traditional source for the precious jewelry making and among the major and famous components of the coral reef ecosystems of Hawaii. However, the black corals have a very low growth rate in comparison with *Carijoa*. As a result, the displacement of the *Antipathes* by *Carijoa* is increasing. The deep-water surveys conducted near Maui in Hawai'i discovered *C. riisei* overgrowing >70% of the black coral colonies (*Antipathes dichotoma* and *A. grandis*) in certain areas at depths of 65-115 m (Grigg 2003). *C. riisei* has been described as the most invasive of the 287 non-indigenous marine invertebrates in Hawai'i (Toonen, 2004). Toonen (2004) points out that as *C. riisei* unique characteristics aid its dispersal via maritime vectors, research into its reproductive system and larval development are a primary requirement in the development of an effective management strategy aimed at preventing spread and containing existing populations. A research programme supported by Sea Grant and the Hawai'i Undersea Research laboratory (HURL) is underway to study the ecological impacts of *C. riisei* on Hawai'i's deep water and shallow coral reef communities. An update on the results of the study can be obtained at the web-site of [Hawai'i Coral Reef Initiative Research Programme](#).

This orange soft coral or "snowflake coral" native to the western Atlantic Ocean from Florida to Brazil, was first found in 1972 in the fouling community in Pearl Harbor (Thomas, 1979, as *Telesto riisei*). Muzik (pers. comm.) noted that a species of *Carijoa* is now also known from Chuuk, Palau, the Philippines, "Indonesia", Australia, and Thailand: whether some of these also represent the species *riisei* is not known, although it could certainly have achieved such a wide distribution in more than 20 years of ship-mediated dispersal if it were first introduced to the Hawaiian Islands in the late 1960s or early 1970s. Colin and Arneson (1995) published photographs of *Carijoa sp.* from Chuuk, in Micronesia, and from a cement ship in Enewetak, Marshall Islands, noting that "it is a very common fouling organism found on buoys, wharves and ship bottoms, plus turbid water reefs." *C. riisei* is reported to grow well in turbid waters rich in organic matter and zooplankton on which it feeds. It requires a firm surface to which it attaches using stolons (root like structures). It also grows well on artificial hard surfaces such as metal, plastic, concrete etc. It is commonly reported on artificial reefs visited by recreational SCUBA divers. It is a passive filter feeder and needs moderate amounts of water flow, which is provided wave surges and tidal or long-shore currents. It does not proliferate in direct sunlight and is usually most abundant on rocky surfaces or other hard substrates at depths below significant light penetration. Grigg (2003) states that not only can this species be found on pier pilings in shallow water, but that it is also abundant in much deeper water (down to 120 m), particularly in shaded environments.

The newest data on the southern Vietnam coral reefs are show that *Carijoa riisei* inhabits the shallows in the Nha Trang Bay, South China Sea (T. N. Dautova, pers. comm.). The settlements are found at the 6 collecting stations in the range of depth 8-16 m. At the moment, this coral could be discussed as common in Nha Trang Bay, but not abundant. The further monitoring is needed to trace the possible emission of the species.

While shallow-water soft corals are well described in the Caribbean, their taxonomy in the Indo-Pacific is less well defined. Many genera of soft corals in the Indo-Pacific are not defined to the species level. In Hawai'i, the *Carijoa* species was identified as *C. riisei* by the leading Octocorallia taxonomist. However, recent molecular sequencing work in

progress is now casting doubt on the Caribbean/Atlantic origin for the Hawaiian population (Samuel Kahng., pers. comm., 2005).

The taxonomy of the species needs a revision because of the phylogeography data showed that the *Carijoa riisei* didn't come to Hawaii from the Caribbean. From the other hand, the haplotypes of the Hawaiian *Carijoa* are found in the Pacific, so the multiple introductions from Pacific are more likely (Concepcion, 2006).

The biodiversity centre and pathways for the soft coral

distribution and dispersal

In the South East Asia is found the highest marine biodiversity of the world. Consider for example that in this area of highest marine diversity, around 2,500 fish species are found (e.g. the Philippines) while in Australia around 1,500 is estimated and only a third in the Caribbean (Thresher, 1992; PEMSEA, 2001). This is consistently seen in other taxa such as for the scleractinian corals with over 400 species while in the GBR would be around 400 species and only half as much in the Caribbean (only 100-200 species; Veron, 1995). Though the significance of the high biodiversity remains to be fully appreciated, the diverse ecosystems of Southeast Asia such as its coral reefs have been estimated at around \$112.5 billion a year (Ruitenbeek, 1999).

Since Ekman in 1953 considered the Malay Archipelago as the faunistic centre of Indo-West Pacific (IWP) from where species dispersed to peripheral areas, the position of this area was discussed by many authors during last decades. The high-usage opinion is that this Indo-Malayan Centre of Maximum Marine Biodiversity (or Coral Triangle) can be found where most Indo-West Pacific species show overlaps of their distributional ranges. The finding of exact position and the boundaries of this triangle area is very important for wide range of reasons from the basic evolutionary and ecology problems up to human-practice purposes such as management of coastal ecosystems, marine tourism and conservation efforts. The latest opinions presume the occurrence the single major centre of generic and species diversity in Indo-Pacific and the newest summaries include into the Coral Triangle eastern Indonesia and most part of the Philippines as was summarized by Hoeksema (2007).

The coral reefs at the northern edge of the Southeast Asian centre of biodiversity and as such share many of the species and characteristics of reefs to the south. Coral bleaching and mortality seriously damaged the reefs of southern Japan and Taiwan, and possibly of China, from July to September, 1998, when seasonal winds and currents slowed during the El Niño climate change. Bleaching stopped in late September when the first typhoon of the season came. There were many reports of coral losses of 30-60% and some as high as 80-90%, with some localized extinctions of prominent corals reported. The Japanese government has established an international coral reef centre on Ishigaki Island (the southern islands of Okinawa) to facilitate coral reef conservation in the region and assist the GCRMN with monitoring. All countries have improved policies concerning coral reefs, but more attention is needed for designating and managing MPAs and building capacity as reefs in this region come under extreme pressures from overfishing, as well as high levels of sediment and nutrient pollution arising from activities on land.

The Anthozoans are important component of marine ecosystems. Among them the stony corals Scleractinia are very remarkable and frame-building animals on the coral reefs of tropical zone. The role of Octocorallia, i.e. soft corals, sea fans and sea pens, in the reef-building process is less obvious. However, soft corals can occupy the large areas on the reef making the biomass up to 35 kg/m². The skeletal elements of the soft corals, i.e. sclerites (which are limebodies in the soft tissue of these corals), are depositing on the reefs after the coral' dead. The deposits of these calcareous bodies which are the so-called "spiculites" input the significant contribution to the reef building process. Soft corals and sea fans (Gorgonians) can also deserve the high interest due to their abundance in marine bottom ecosystems as well as they are source of the pharmacologically important compounds. The studying of the Octocorallia species richness is substantially in the frame of the worldwide and local biodiversity problems. However, the solving of the complex problems of the taxonomy, genetic diversity and species-specific ecology is needed to trace the possible ways for the soft corals dispersal.

For example, the *Sinularia* genus containing more than 128 nominal species is the largest among the zooxanthellate soft corals. *Sinularia* species are widely distributed throughout the Indo Pacific and inhabit the various reef biotopes. The latest revision of the genus (Verseveldt 1980) allows identifying specimens of *Sinularia* with reasonable certainty (Ofwegen 2002). Due to it the *Sinularia* local faunas could be the useful instrument to trace the dispersal patterns of soft corals in the tropical Pacific zone. However, the range of problems in *Sinularia* identification continuously complicates their listing. For the competent tracing of the trends in the status of the stony corals and soft corals populations the joint efforts of the specialists in the coral taxonomy and ecology together with the analysis of the dispersal ways are needed. The possible dispersal ways by oceanic currents should be analyzed along with the genetic similarity of populations in order to learn how distribution ranges are generated and how they are maintained.

The useful taxonomy tools are coral colony shape and skeletal elements, i.e. sclerites, arrangement (Verseveldt 1980). *Sinularia* species represent highly variable growth forms from encrusting with small surface knobs or ridges to tall tree-like and abundantly branched. The wide range can be found even in the same species probably due to dependence of the colony shape on ecological factors such as amount of light and wave exposure. The colony shape changes drastically due to the sampling and fixation. To add the real knowledge on the *Sinularia* morphology, the underwater images of the living colonies using SCUBA and the professional sources of the light are hardly needed. The investigation of a substantial sampling is needed to understand the intra-species limits of the variation. The result of such work may be that the discontinuous range of the shape variations can be placed between two primary types having the same sclerite composition and architecture; the synonymy of two or three nominal species under the one oldest name can be proposed in such cases (Vennam & Ofwegen 1996; Benayahu et al., 1998).

The using of the sclerites composition and architecture for samples identification may be difficult due to incompleteness of the data in old literature. The overwhelming majority of the publications which are were made before last decades of the 20 century are unsuitable because of sclerites hand-made inaccurate drawings. Apart from the fact that these drawings very often were made using low microscopy magnifications, the opinion that the full sclerite set per specimen/species may provide for the sample identity was established only towards the end of the 20th century. In the latest revision of *Sinularia* the data about the colony body sclerites are incomplete; moreover, information about polyp sclerites is absent (Verseveldt 1980). It can shadow the identity of samples. For example, *Sinularia manaarensis* was described for a piece of colony from the Gulf of Manaar, Ceylon. Dr. J. Verseveldt pointed out: "According to the enclosed label the specimen was collected by Herdmann in 1902; it was recorded as "type" by Pratt and identified with *S. gardineri* (see Pratt, 1905: 233)". Verseveldt firstly recognized the specimen as distinct from *S. gardineri* (Pratt, 1903), presented sclerites drawings (1980, fig. 43) and placed the species into his *Sinularia* group 4 as having the clubs without the central wart on the heads. However, his drawings were not a comprehensive representation of all sclerite types in *S. manaarensis*; the information of polyp sclerites was not presented. The new material of *S. manaarensis* collected in 2006 in Nha Trang Bay, South China Sea (SCS), shows much more about the sclerites set – the sclerites occurrence in the polyp, more large sclerites in the colony surface layer and the clubs with well distinct central wart on a head. Such features required attributing the samples to another *Sinularia* species.

Verseveldt (1980) noted out the occurrence of clubs "with a tuberculate head, sometimes with an inconspicuous central wart" in the lobes surface of *S. manaarensis* (Verseveldt, 1980, p. 88, fig. 43 a-d). From his drawings it is obvious the central wart exists in all clubs showed by Verseveldt, but sometimes indistinct because of the all head warts are good developed and crowded. The same is observed in Vietnamese samples of *S. manaarensis*.

Colony shape, described for *S. manaarensis*, is the same as in our material; the sizes of the holotype and Vietnamese colonies are close. The investigation of microscopic slides of holotype showed the matching of the sclerite set for the polyps and other colony parts with the specimens from Nha Trang Bay. The only difference in comparing

with Verseveldt's description for surface sclerites is the maximal size of the clubs with thickened blunt-ended shafts – 0.4 mm vs 0.7 mm long (with more thick handles) in Nha Trang's material. The incompleteness of the single colony described as holotype, what circumstance was noted by Verseveldt, may be a reason, but the geographical or ecological variability should not be excluded as a reason for this difference.

The molecular phylogenetic analyses can also help to discover cryptic or sibling species and the timing of speciation processes (Lessios et al., 1999; McCartney et al., 2000; Bowen et al., 2001; Dawson and Jacobs, 2001; Dawson and Martin, 2001; McCafferty et al., 2002; Landry et al., 2003). If sibling species are discovered, their biogeographic ranges need to be re-evaluated and their biodiversity patterns need to be corrected. Knowing the time of particular speciation events will help to get insight in the development of species ranges, for instance whether the ranges might have been affected by sea-level fluctuations. This has direct impact on species richness as sibling species are able to co-exist in the same area (Hoeksema, 2007).

Many of the *Sinularia* species are described as widely distributed, both from Ceylon to Vietnam and from Vietnam to Great Barrier reef, but some "old" and the latest described new species are noted to be endemics up to present day (Ofwegen 2000 with the full list of the *Sinularia* species occurrences). At the same time the detailed examination of sclerites using SEM allows to revise and to synonymy some species (Vennam & Ofwegen, 1996); the molecular-genetic approaches may support the uniting of some species or discrimination of one species into several. As a result their geographical distribution may be revised too. The *S. manaarensis* distribution both in Indian Ocean and South China Sea supports the point of view (after Ofwegen 2000) that the Indo-Malayan region including New Guinea is the centre of the greatest *Sinularia* diversity.

However, the highest number of recorded *Sinularia* species is not found in the central Indo-Pacific until the present day. If the Indonesian Archipelago and New Guinea score rather well, the Philippines *Sinularia*, on the other hand, with only 7 species are poorly known from the scarce publications (Ofwegen 2000). Nevertheless, the summarizing knowledge about the possible dispersal ways and barriers in Indo-West Pacific, i.e. currents and the areas of river discharge/low salinity in the western part of the Indo-Malayan region, show that the dispersion of the marine species may be directed from Coral Triangle into the Indian Ocean; the Java Sea and the SCS are likely the westernmost part of the border area between the Pacific and the Indian Oceans with very little input from the Indian Ocean (Hoeksema, 2007 with a range of references discussed). At least, the finding in the SCS of the *Sinularia* species, previously noted only in Indonesia (*S. ceramensis*, *S. shlieringsi*) and New Guinea (*S. sobolifera*, *S. verseveldti*) as well as the occurrence in SCS of the species, which were found before close to Eastern Africa (*S. abhishiktae*) or westerly than Strait of Malacca (*S. manaarensis*) are in according with it. Therefore, the new data about the true richness of Octocorallia fauna in Indo-Malayan region just need more intensive field investigations.

Another substantial question is – what ways may be usable for species dispersal from Coral Triangle to periphery. It is essentially to know how the local and regional marine ecosystems depend on each other for the interchange of organisms. The study of distribution patterns requires the good understanding both detailed records of the coral fauna throughout the distribution range and high quality oceanographic data to be correlated with these distributions (Veron and Minchin, 1992; Hoeksema, 2007). The warm water of the Kuroshio Current passes east of the Philippines to southern pacific side of the Japan and intrudes into the South China Sea moving along of southern Taiwan. It can influence on the corals richness on the reefs of the central part of Vietnam as well as southern Taiwanese reefs. Really, the stony corals fauna of the reefs of Central Vietnam is quite rich and includes more than 65 genera and, moreover, the several species of the *Porites* genus which were firstly described from Philippines. The same situation can be considered concerning with Octocorallia fauna of the region. The preliminary Alcyonacea list of the soft corals (with *Briareum* genus) of Central Vietnam includes 27 genera; the *Sinularia* species list has 36 "old" species and a range of the new species (Dautova, pers. comm.). The reefs of the southern Taiwan contain 22 genera including *Sinularia* with species (Fig. 19).

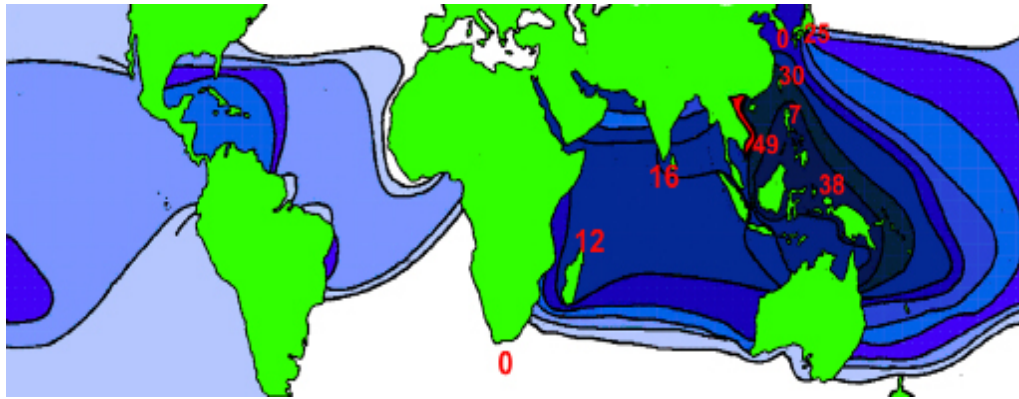


Fig. 19. Number of *Sinularia* species registered up today in the world (is shown by red font). The newest data on the stony corals diversity are shown by the different levels of the blue color saturation.

The lacking of the genera *Anthelia*, *Asterospicularia*, *Cespitularia* and *Heteroxenia* in the list of Vietnamese soft corals is probably because of the collected material is at the moment in processing. However the presence in Central Vietnam of the most of Nephtheidae genera as well as longer list of *Sinularia* species may be considered as a result of the direct connection of the region with Coral Triangle in addition to the Kurioshio influence. The single finding in SCS of the *Sinularia yamazatoi* which species was before recorded only at Southern Ryukyu shows that this species: a) probably has the dispersal from the Indo-Malayan centre; b) may be rare and due to it is not recorded on Taiwanese reefs; c) can pass into the Vietnamese waters both directly from Coral Triangle and by Kurioshio influx. The recent Indonesian finding of the *S. mammifera* which species was described from Vietnam (Manuputti, Ofwegen, 2007) anticipate the same.

The coral reefs of Taiwan and Japan are closely linked by the northward flowing Kurioshio Current (Fijiwara et al., 2000). The soft coral fauna of both areas shows a close resemblance between their faunas in terms of generic composition and number of species (Table 6). The finding of *S. higai* and *Sarcophyton nanwanensis* both from Japan and Taiwan anticipate that similar patterns also exist for other important soft coral genera (Benayahu et al., 2004).

The Chinese reefs (mainly on Hainan Island) at the northern part of the SCS, have links with reefs of Vietnam and the Spratly Arch. The geographic location of these reefs close to northern margin of Indo-Pacific coral reef centre of high biodiversity can allow the quite rich coral fauna existing, but there is lack of taxonomic capacity to confirm this. Studies are required to assess the possible important role of these reefs in global reef system. Only reefs around Hong Kong are significantly studied. Lam and Morton (2008) showed the full list of Hong Kong's Octocorallia studied since the middle of the 19th century. Besides of the needed studying of some taxa, it is interesting to note the total absence of widely spreaded tropical zooxanthellate genera *Sinularia* and *Sarcophyton* along with presence/predominating of azooxanthellate genera, such as *Eleuthero-bia*, *Paraminabea*, *Scleronephthya*, *Nephtyigorgia* and *Dendronephthya*.

Trends for the Octocorallia dispersal in the temperate waters: the biogeographic boundaries and the retrieval of the cold water biodiversity centre

The geographic location of the coral communities which exist in South Korea waters has produced coral fauna of special biogeographical interest. The tropical and the subtropical marine invertebrates are being distributed together with the temperate ones in the southern part of Cheju Island at south of Korea peninsula, as this place is directly being affected by the Kurioshio Current. As a result, 65% of total Korean Anthozoa species are encountered here including 40 species of gorgonians, 12 Alcyonacea and 4 Penatulacea species. Approximately 20 soft coral species are being distributed downwards 45m deep in subtidal zones surrounding the island such as Munsom and Boemsom forming soft coral beds (Song, 2001). The several species of *Dendronephthya* are presented here as well as "tropical" gorgonians *Menella*, *Ellisella* and *Acabaria*, but the temperature

restricts here zooxanthellate soft corals, such as *Sinularia* or *Lobophytum*.

From the other hand, the Tsushima Current are directed across Korean/Tsushima Strait into the Sea of Japan during summer and winter seasons (Chen et al., 1994). It can limit the dispersal of many temperate Octocorallia to Yellow and East China Seas. By this reason seems to be the temperate gorgonian genus *Primnoa* is not found to the south of Jeodong, Dodong and Sadong Islands in the southern part of the Sea of Japan (Song, 1981). Another temperate gorgonian genus -*Calcigorgia* - has the range restricted to the south by the Sea of Japan too.

This genus can indicate the possible dispersal way for temperate Octocorallia in Northern Pacific. Two *Calcigorgia* species including *C. spiculifera* are occurred in Aleutian Islands area. However, the list of gorgonians of Kurile Islands is richer because of includes five new *Calcigorgia* species in addition to *C. spiculifera* (T. N. Dautova, pers comm). The waters of the Oyashio Current form probably the richest fishery in the world owing to the extremely high nutrient content of the cold water (Fig. 20). This current circulating counterclockwise in the western North Pacific by Kurile Islands had the intrusion into the Japan Sea across the Tsugaru Strait during the Holocene history (Takei et al., 2002). Does the centre of temperate coral diversity take place in North Pacific as the source of dispersal? It can be the subject of the future investigations using model taxa which are well revised equally with molecular and paleoceanography data.

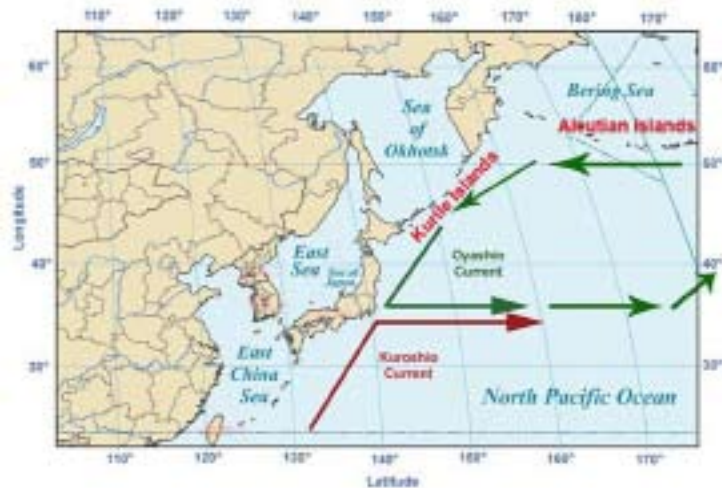


Fig. 20. The Oyashio current circulation along the Kurile Islands.

The main reef-builders: the critical functional groups of the corals

Opportunistic corals of the genus *Porites* are the principal reef builders in the tropical zone of the World Ocean. Other opportunists, such as *Acropora*, *Pocillopora*, and some faviids exceed *Porites* in interspecific aggression, growth rate, self-cleaning capacity, and resistance to temperature jumps. *Porites* spp. belong to the corals predominating in shallow water, where coral communities are exposed to strong unfavorable environmental effects such as desalination, desiccation, overheating, high insolation, lack of a hard substratum etc. The predominance of *Porites* in scleractinian communities may result from the suppression of other corals by the combined action of unfavorable environmental conditions. *Porites* display high survival capacity after various extreme or catastrophic events such as hurricanes, oil spill, or dinoflagellate blooms. They are capable of actively colonizing both artificial substrates and, in certain cases, destructed reefs. The intense economic activity occurring presently in the tropical coastal zone, as well as mass bleaching, may lead to suppression and other changes in coral communities, which, in turn, may result in an increase of the portion of *Porites*.

- The species composition and diversity, size-age structure, and other parameters of a coral community are strongly affected by the environment (Glynn, 1976; Loya, 1976a; Sheppard, 1980; Done, 1982). The main environmental factors affecting coral communities are temperature and salinity fluctuations, sedimentation rate, low tides, water currents, and catastrophic reef destruction (Loya, 1972; Ditlev, 1978; Bradbery and Yonge, 1981; Dollar, 1982; Rogers, 1990). Other substantial factors are related to biotic relationships such as competition for substrate among corals

Table 6

List of the Octocorallia taxa of the orders Helioporacea Bock, 1938, Alcyonacea Lamouroux, 1816 (soft corals and Briareidae Gray, 1859) for Central Vietnam (Dautova, pers. data), Taiwan (Benayahu et al., 2004 with comments and list of previous records) and Japan (by Imahara 1996), Hong Kong (by Lam and Morton, 2008 with list of previous records), South Korea (Song 1976, 1981, 1994, 1995; Song, Lee 1998). "+" – the presence of the genus on reefs investigated, "-" – the genus is not recorded.

Genera	Central Vietnam	Southern Taiwan	Japan	Hong Kong
<i>Heliopora</i> Blainville, 1830	+	+	-	-
<i>Cervera</i> López-González, Ocaña, García-Gómez & Núñez, 1995	+	-	-	-
<i>Clavularia</i> Blainville, 1830	+	+	+	-
<i>Pachyclavularia</i> Roule, 1908	-	-	+	-
<i>Sarcodyction</i> Forbes, 1847	-	-	+	-
<i>Cornularia</i> Lamarck, 1816	-	-	+	+
<i>Carijoa</i> Müller, 1867	+	-	+	+
<i>Telesto</i> Lamouroux, 1812	-	-	+	-
<i>Paratelesto</i> Utinomi, 1958	-	-	+	-
<i>Pseudocaladochonus</i> Versluys, 1907	-	-	+	-
<i>Tubipora</i> Linnaeus, 1758	+	+	+	-
<i>Alcyonium</i> Linnaeus, 1758	-	-	+	-
<i>Anthomastus</i> Verrill, 1878	-	-	+	-
<i>Bellonella</i> Gray, 1862	-	-	+	-
<i>Dampia</i> Alderslade, 1983	+	-	-	-
<i>Cladiella</i> Gray, 1869	+	+	+	+
<i>Dampia</i> Alderslade, 1983	+	-	-	-
<i>Eleutherobia</i> Pütter, 1900	+	+	+	+
<i>Klyxum</i> Alderslade, 2000	+	+	+	-
<i>Lobophytum</i> Marenzeller, 1886	+	+	+	+
<i>Paraminabea</i> Williams & Alderslade, 1999	+	+	+	+
<i>Rhytisma</i> Alderslade, 2000	-	+	+	-
<i>Sarcophyton</i> Lesson, 1834	+	+	+	-
<i>Sinularia</i> May, 1898	+	+	+	-
<i>Capnella</i> Gray, 1869	+	+	+	-
<i>Coronephthya</i> Utinomi, 1966	-	-	+	-
<i>Daniela</i> Koch, 1891	-	-	+	-
<i>Dendronephthya</i> Kükenthal, 1905	+	-	+	+
<i>Duva</i> Koren & Danielssen, 1883	-	-	+	-
<i>Gersemia</i> Marenzeller, 1878	-	-	+	-
<i>Lemnalia</i> Gray, 1868	+	+	+	-
<i>Litophyton</i> Forckal, 1775	-	-	+	-
<i>Nephtea</i> Audouin, 1826	+	-	+	+
<i>Paralemnalia</i> Kükenthal, 1913	+	+	+	-
<i>Scleronephthya</i> Studer, 1887	+	+	+	+
<i>Stereacantha</i> Thomson & Henderson, 1906	-	-	+	-
<i>Stereonephthya</i> Kükenthal, 1905	-	-	+	-
<i>Umbellulifera</i> Thomson & Dean, 1831	-	-	+	-
<i>Chironephthya</i> Studer, 1887	+	-	-	-
<i>Nephtyigorgia</i> Kükenthal, 1910	+	-	-	+
<i>Nidalia</i> Gray, 1835	-	-	+	-
<i>Siphonogorgia</i> Kölliker, 1874	+	-	+	-
<i>Anthelia</i> Lamarck, 1816	-	+	+	+
<i>Asterospicularia</i> Utinomi, 1951	-	+	+	-
<i>Cespitularia</i> Milne Edwards & Haime, 1857	-	+	+	-
<i>Fungulus</i> Tixier-Durivault, 1987	-	-	+	-
<i>Heteroxenia</i> Kölliker, 1874	-	+	+	-
<i>Efflatounaria</i> Gohar, 1939	+	-	-	-

Table 6(continued)

<i>Sansibia</i> Alderslade, 2000	+	+	-	+
<i>Sympodium</i> Ehrenberg, 1834	-	-	+	-
<i>Xenia</i> Lamarck, 1816	+	+	+	-
<i>Studeriototes</i> Thomson & Simpson, 1909	-	-	+	-
<i>Carotalcyon</i> Utinomi, 1952	-	-	+	-
<i>Briareum</i> Blainville, 1830	+	+	+	-
Total:	27	22	46	12

or predator pressure (Sheppard, 1979, 1980, 1982; Sammarco, 1980; Wellington, 1980; Cope, 1981; Bak et al., 1982; Highsmith, 1982; Logan, 1984). As a result, opportunistic scleractinians such as branched *Acropora* and *Pocillopora* dominate the coral community all over the reef or in some of its portions. These fast-growing corals are resistant to wave action, low tide, and silting (Geister, 1977; Ditlev, 1978). Opportunistic corals with massive growth forms such as Faviidae and *Porites* have stronger skeletons but grow slower. Massive *Porites* may thus be overtopped and shaded by faster growing corals (Stimson, 1985; Done and Potts, 1992).

- Despite of the above, *Porites* are found in abundance in some coral communities such as those in reefs off Barbados or Caño islands or in the Eastern Pacific (Glynn et al., 1972; Glynn, 1973, 1988; Tomascik and Sander, 1987; Guzmán and Cortés, 1989b). High abundance of *Porites* was also reported for the reef communities of Sri Lanka, Southern India, Philippines, the Great Barrier Reef, and many reefs of the South China Sea (Faustino, 1927; Ditlev, 1978; Potts et al., 1985; Sakai, 1985; Chou and Teo, 1985; Sakai et al., 1986; Latypov, 1986, 2003; Chou, 1988; Sudara et al., 1988; Done and Potts, 1992).

Hence, to understand the peculiarities of *Porites* allowing them to compete successfully with other corals, one needs, first, to compare the data available on the physiology of *Porites* to those on other principal reef builders and, second, to elucidate environmental conditions favoring the abundance and predominance of *Porites* and their in coral communities.

High linear extension rate of coral colonies results in an increase in the colony surface, occupation of new substrates, and overshadowing neighboring colonies. Branched corals have a higher linear extension rate compared to massive corals. For example, the average annual extension rate in *Acropora palmata* is 60–100 mm, while in *Pocillopora* spp., only 29.8–34.8 mm (Bak, 1976; Guzmán and Cortés, 1989a). Massive *Porites* colonies show rather low competitiveness. Average skeletal extension rate registered in *Porites lobata* at Clipperton Atoll varies between 13.2–15.1 mm yr⁻¹ (Glynn et al., 1996). Linear extension rate and other growth parameters of coral colonies vary with geographical location (Grigg, 1981, 1997; Isdale, 1983). In five massive *Porites* species (GBR), the average extension rate varied between 8.3 and 16.7 mm yr⁻¹ in strong correlation with average annual sea surface temperature (Lough and Barnes, 2000).

The factors limiting coral growth rate are terrigenous sediment influx, water turbidity, depth, winter water temperature, and light level (Logan and Tomascik, 1991; Scoffin et al., 1992; Heiss, 1996). Thus, the growth rate of massive *Porites* colonies varied from 10.5 to 17.4 mm yr⁻¹ depending on water transparency, suspended matter and plankton content, and wave action (Priess et al., 1995).

The comparison of the linear extension rates of different corals under similar conditions shows that both branched and massive *Porites* colonies grow much slower than branched opportunistic *Pocillopora*. The linear extension rate of *Porites* is close to that of opportunistic corals with massive colonies.

Porites hold an intermediate position in the hierarchy of interspecific coral interactions via direct contact (Lang, 1973; Cope, 1981). In the reefs of the Southern Taiwan, Dai (1990) distinguished five groups of coral species based on their competitive ability. Massive *P. australiensis*, *P. lutea* and *P. lichen* proved to be intermediate or subordinate, while some *Acropora*, *Montipora*, and Faviidae (*Hydnophora*, *Platygyra*, *Gonyastrea*, *Favia* and *Echinopora*), aggressive to moderately aggressive. The result of an interaction may be affected by colony shape, growth rate, and environmental conditions (Sheppard,

1979; Bak et al., 1982; Dai, 1990). At the same time, Bradbury and Young (1983) examined the significance of coral interactions by paired statistic analysis of both small-scale (neighborhood) and large-scale (reef zonation) coral distribution patterns on the Heron Island reef (GBR) and revealed no strong relations between the distribution patterns and interspecific coral interactions. The authors concluded that interspecific interactions play minor role in coral distribution.

The competition between corals and benthic algae play an important role in the evolution of reef community, especially at reef deterioration due to excessive exploitation or eutrophication. Studies of direct contacts between filamentous algal turfs and *Porites lobata* showed that the presence of *Porites* suppresses algae growth, while algae do not noticeably effect *Porites* growth. The *Porites* advantage over algae in competition for substrate was greater in areas of the highest terrigenous sediment and organic influx (McCook, 2001). On the contrary, algal turfs were reported to overgrow *Colpophyllia natans* (Faviidae) (Nugues and Roberts 2003). The radial growth of this coral is additionally suppressed by increase in terrigenous sediment influx, which furthers competitive success of algae in coastal reefs (Nugues and Roberts 2003).

Coral communities dominated by *Porites* may be exposed to combined action of several extreme environmental factors. Thus, in Hawaii, where heavy oceanic surf and predator activity influence the structure of the coral communities, massive *Porites* occupy some 30% of coral settlement area (Grigg 1983). Off the Costa-Rican Pacific coast, the extreme factors are the predation pressure and warming catastrophes caused by ENSO. Guzmán and Cortés emphasized (1989b) that the structure of the reef community on Caño Island (Costa Rica), dominated by *P. lobata*, is largely determined by the factors influencing this species. The predominance of *P. lobata* in that coral community is probably accounted for not only by its abundant spawning and high capacity to asexual reproduction via fragmentation, but also by its high resistance to predation and drastic environmental changes such as ENSO (Guzmán and Cortés 1989b).

Siltation has a profound adverse effect on coral communities. In particular, intense sedimentation hinders larvae settlement, while high water turbidity restricts the light available, slows down the linear growth of the colonies, and decreases the population density. The species resistant to intense sedimentation gain in many respects (Aller and Dodge 1974; Loya 1976a; Rogers 1990; Hodgson 1990). Reef-flats off Sri Lanka and Southern India, exposed to hard anthropogenic sedimentation, are dominated by *Porites* (Mergner and Scheer 1974). Coral reefs of Thailand are exposed to considerable siltation, both anthropogenic and natural (Sakai et al. 1986; Sudara et al. 1988). *Porites* spp. are also reported to dominate the fringing reef in Opunohu Bay (Moorea, French Polynesia), exposed to desalination and high water turbidity after heavy rains during the wet season (Adjeroud and Salvat 1996).

Anthropogenic eutrophication may affect the structure of coral communities as is the case of the fringing reefs off the western coasts of Barbados (Tomascik and Sander 1985, 1987). The combined action of a number of factors such as biogen content increase, sedimentation rate, water turbidity and toxicity resulted in a decrease in the

species diversity and favored predominance of *Porites* on these reefs. *Porites*, together with *Siderastrea radians* and *Agaricia agaricites*, were most abundant in three most contaminated reefs. The average projective coverage of *Porites* species (*P. astreoides* and *P. porites*) varied there from 25.2 to 66.6%. Tomascik and Sander (1985, 1987) attributed the predominance of *Porites* in the contaminated reefs to their high resistance to anthropogenic sedimentation due to the production of bacteria-resistant mucus.

The projective coverage of massive *Porites* in scleractinian communities in the north-eastern part of the Gulf of Tonkin (South China Sea) reaches 22% (reefs of the Bai Tu Long Archipelago) (Khomenko 1993). These communities suffer abundant terrigenous sediment influx via numerous rivers resulting the exposure of local coral populations to coastal waters with high content of organic and mineral suspended matter. The sediment (originally, finest grain clay) flow in the reef slopes may run up to 10.0–11.9 mg cm⁻¹ per day (Moschenko 1990; Latypov 1995; Dautova et al 1999). Based on the survey performed off the Cahuita Island (Costa Rica), Cortés and Risk (1985) proposed that sediment flow capable of invoke siltation stress must be not less than 30 mg cm⁻¹

per day. This is more than twice as much as the flow rate in the Bai Tu Long reefs. However, coral reefs in the north of the Gulf of Tonkin (South China Sea) grow under extreme climatic conditions. They are situated in the monsoon climate zone characterized by considerable variation in water salinity and wind intensity and direction. In winter, the temperature of superficial waters in this zone drops down to 16–20°C (Yet 1989), and salinity, to 21–22‰ (Thanh 1999). It is the combined action of these factors that probably determines the peculiarity of the reefs of the Bai Tu Long Archipelago, where Poritidae and Faviidae are the main reef-builders (Latypov 2003).

A similar situation was revealed off Inhaka Island (Southern Mozambique), situated at the boundary of temperate to warm and subtropical zones. The monsoon climate conditions, together with considerable tidal range (up to 3.7 m) and abundant fluvial influx, limit the zone of reef growth to a depth of 6 m. The reef formation there is mainly hindered by specific environmental factors, first of all, water temperature and salinity fluctuations, high water turbidity, and the presence of highly movable substrates. The basis of these reefs, used as a substrate by other corals, is formed by massive *Porites* sp. colonies (Perry 2003).

Local trends in the coral spatial distribution: a case

study of the estuarine environments

The Gulf of Tonkin is located in northeastern Vietnam, close to the northern border of the Tropical Zone. Water temperature in this area in winter can fall to 16–18°C; salinity in rainy seasons decreases to 26–31‰. Fluvial waters cause desalination in the western and northwestern parts of the bay and form a steady drainage current with a salinity of 21–22‰, directed southward along the western coast. A significant role is played by the considerable water runoff from the mainland brought by numerous rivers that enter the Gulf of Tonkin. For example, the Red River alone brings every year 137 billion m³ of fresh water and 116 million tons of suspended matter. Every day more than 180 g of argillaceous materials yields onto 1 m² of the bottom. During typhoons these indices increase significantly. During periods of wide-range tidal fluctuations of sea level (up to 3.5–3.7 m

between the low and high tides), entire coral communities can be extinguished in large areas of drained reefs due to heavy rainfall. The shallowness of the Gulf of Tonkin and its peculiar bottom relief are of particular significance. In the northern part of the gulf, extensive areas are occupied by shallows limited from the south by a 50-m isobath. A wide band with depths shallower than 50 m runs along the western coast of the gulf. The bottom of the gulf is mostly smooth and covered with

soft grounds dominated by silts, silted sands with an admixture of broken mollusk shells, and organogenic materials. Silts and silted substrates fill up the central trench of the gulf, which is limited to 50- to 60-m isobaths. The lack of hard substrates provides additional limitations for the development of reef structures.

Water temperature and salinity, the intensity of sedimentation, and wave and tidal currents are major factors that determine the structure and composition of coral communities in shallow waters. In different years, on certain reefs, the correlations were studied between the distribution of reef-building corals and certain abiotic environmental factors. This paper provides the results of studies on the structure and composition of reef-building coral communities in different reefs in the Gulf of Tonkin and describes peculiarities of the sedimentation regime in the areas of coral populations. Physico-chemical indices were measured on reefs located in a water area of more than 300 km² (Table 2).

On surveyed reefs, the number of species ranged from 62 (Cong Tau Island) to 105 (Cong Do Island). In general, during the field surveys, 125 species of scleractinian (stony) corals belonging to 41 genera were found on the reefs. The smallest species diversity was characteristic of reefs on capes and in straits, whereas the greatest one was registered on the reefs in bays (Table 2). It was supposed that there are the correlations between the level of differences of the reefs in species composition and differences in environmental conditions. A comparison of the obtained values of the Chekanovsky-Sø-

resen Index with the differences in measured environmental factors showed a correlation ($r = -0.622$) which was somewhat smaller than the threshold level, but still close to the latter ($0.01 > p > 0.05$; for $p < 0.05$ $r_{st} = 0.0632$). The life cycle of corals includes a pelagic larva; therefore, one may suppose that the distance between the reefs provides a significant contribution to the similarities in species composition observed on different reefs. However, the coefficient of correlation of the index of species similarity and geographical distance between the surveyed reefs was equal to $r = -0.38$, which demonstrates a tendency (insignificant at a level of 95%) toward the increase of differences in species composition with increasing distance between the reefs; however, this correlation is also insignificant at a level of 95%. It is possible that the differences in species composition observed between different reefs are due to two factors: the sedimentation regime and their distance from each other.

The most similar in composition (88% of common species) and structure were coral communities of large bays (Bo Hung and Cong Do Islands). A moderate sedimentation flux both in the water column and close to the bottom was characteristic of the latter. The intensity and strength of resuspension in the precipitating suspended matter immediately above the coral populations

in these areas also showed moderate values. Bo Hung Bay is larger and open. A community of *Acropora aspera* + *Goniopora columna* has developed there, which is dominated by *A. aspera* in both degree of substrate coverage (40% and more) and the size of colonies (3–7 m in diameter). The corals of the second species formed colonies up to 1.5 x 1.5 m in size and provide substrate coverage of up to 15%. Inside almost solid thickets of acropores, the aggregations of fungiids (*Fungia fungites*, *F. scutaria*, *F. repanda*, and *Sandalolitha robusta*) are occurred with densities of up to 17 specimens/m². The diversity of other corals rarely exceeded 10–15 species. In the lower part of the slope, a polyspecific coral community characterized by greater diversity in the number of species and shape of colonies has developed. No domination of any certain species has been registered. The conspicuous large (1.5–3 m in diameter and 1–1.5 m high) colonies of *Lobophyllia hemprichii*, *Pavona decussata*, *Merulina ampliata*, *Micedium elephantotus*, *Podobacia crustacean*, *E. echinata*, *P. lobata*, *G. columna*, and *G. fascicularis* live at the reef' slope zone. In some reefs, the base of the reef slope was composed of two species *Lobophyllia* sp. or *Goniopora* sp.

In Cong Do Bay, a community of *Goniopora stokesi* + *Galaxea fascicularis* has developed. The colonies of *G. stokesi* form 5- to 30-m wide dense settlements characterizing by a high degree of substrate coverage (45–60%). Inside these thickets, there were scattered spots of the populations of *G. fascicularis* colonies that provided up to 15–47% of substrate coverage. The polyspecific settlements (consisting of 20–35 colonies) of different scleractinians *Acropora cytherea*, *A. aspera*, *Montipora digitata*, *M. hispida*, or, less often, soft corals *Sarcophyton trocheliophorum* and *Lobophytum pauciflorum* are developed inside the thickets of *Goniopora* and *Galaxea*. On the other hand, faviids stood out for the density of colonies and species diversity. Fungiids, *Fungia fungites*, *F. repanda*, and *Sandalolitha robusta* occurred more often, sometimes making up aggregations with densities of 4–7 specimens/m². Developing under almost the same abiotic conditions, the communities of both the bays were similar in many respects. However, having the greatest number of common species, these communities were significantly different in the composition of dominating and subdominating coral species. The obvious domination of *Goniopora stokesi* and *G. fascicularis* in Cong Do Bay is probably due to the somewhat greater sedimentation flux coming onto the bottom compared with Bo Hung Bay. *Goniopora* and *Galaxea* having large polyps and long tentacles are capable of escaping rapidly from precipitating sediments.

Reefs located around capes and in straits are characterized by a greater amount of suspension in both the water column and the near-bottom horizon. On the other hand, probably due to relatively intensive integral water exchange, on these reefs a relatively great degree of sediment resuspension is observed immediately above the coral settlements. The removal of the bulk of precipitating sediment might benefit the development of monospecific scleractinian settlements in large areas, a phenomenon was observed at the Cong Tau and Van Boi Islands. The community of *Acropora aspera* registered in the area of the reef slope on Cong Tau Island stood out because *A. aspera* there pro-

vided almost 100% substrate coverage in 2- to 10-m-wide bands. Inside the thickets of *Acropora*, the monosettlements of *G. fascicularis* and *G. columna* occupy 30–70 m². At deeper depths (toward the middle part of the reef slope), a zone of *Acropora aspera* + *Goniopora columna* developed, where the *Acropora* occupy no more than 40% of the substrate and *Goniopora* cover

up to 15% of the substrate. In this zone, different species of other corals have been registered (*Acropora*, *Montipora*, *Pavona*, *Favia*, *Favites*, *Cyphastrea*, *Leptastrea*, *Pectinia*, and *Micedium*), as 20 specimens/m² and isolated alcyonarians of the genus *Cladiella*. In the lower part of the slope, massive and encrusting colonies of the genera *Lobophyllia*, *Symphyllia*, *Echinophyllia*, *Porites*, *Podobacia*, *Turbinaria*, *Merulina*, and *Pectinia* and various faviids were common. The soft corals *Cladiella*, *Sinularia* and *Sarcophyton* were common at the base of the slope, while the *Acropora*, dominating the upper part of the slope, was represented only by isolated colonies showing densities of 3 to 7 specimens/m².

In a strait close to Van Boi Island, on a bank which was 1 to 6 m high and 130–150 m wide, a community of *Goniopora columna* has developed. As in the community of *Acropora aspera*, the dominating species made up extensive monosettlements. Inside these settlements there were distributed large spread-out branched colonies of *Acropora*; massive and crustose colonies (0.5–1.5 m in diameter and up to 0.6 m high) of *Montipora*, *Porites*, *Podobacia*, *Lobophyllia*, *Echinophyllia*,

Pectinia, and different faviids. On the slopes of the bank and at its base, there were mostly scleractinians with massive funnellform and encrusting colonies, such as *Favia*, *Favites*, *Pseudosiderastrea*, *Lobophyllia*, *Symphyllia*, *Echinophyllia*, *Turbinaria*, *Merulina*, *Pectinia*, and *Micedium*. Dominating species belonged to the former two genera; they made up small colonies from 3–5 to 20 cm in size.

The much closed bay of Han Chai Island is characterized by a small narrow entrance and shallowness (less than 5 m deep). Probably due to these reasons, the intensity of water exchange and resuspension there was the smallest among all surveyed bays. Sedimentation flux in this bay was one half to one fifth as great as on other reefs, which could be due either to the small resuspension rate or to the small input of suspended matter into the bay. However, almost all suspended matter precipitates and is accumulated on the bottom; this is proved by the similar characteristics of sedimentation flux at the bottom and considering resuspension. Existing under abiotic conditions that are so unusual for the surveyed area, the reefs of Han Chai Bay stood out for their composition and structure of communities (Table 3). In the community of *Pavona decussata* + *Pavona cactus* developed in this bay, both these species, due to their submassive colonies with bilateral foliaceous branches, expanded from the lower intertidal horizon to a depth of 4.5 m. They formed the carcass of the living reef, while dead parts of the colonies were used by numerous inhabitants of the reef and new colonies of the same species as a substrate. As living specimens of *Pavona* covered substrate with an almost solid thick layer, other scleractinian species, such as *Montipora*, *Galaxea*, *Pectinia*, *Porites*, *Lobophyllia*, *Acropora*, *Favia*, and *Favites*, although being diverse enough, occurred as 2–4 isolated colonies. From a depth of 1–0.75 m toward the shoreline, the colonies of *Pavona* were gradually replaced by settlements of branched scleractinians *Montipora digitata*, *Acropora nobilis*, and *A. aspera*, massive *Porites lutea*, *P. lobata* (mostly in the shape of "microatolls"), *Favites abdita*, *Goniastrea pectinata*, *G. aspera*, *Lobophyllia hattai*, and others.

Silting significantly hampers the settlement and attachment of coral larvae to substrate, as well as the formation of coral colonies. The mean annual amount of suspended matter equals 5–10 mg/l and is not considered critical for coral settlements located on fringing reefs. However, when sediment is resuspended by tidal currents, this index can exceed 20 mg/l, while under the effects of a storm it may grow further, reaching values an order of magnitude greater. Sedimentation flux in the near-bottom water layer exceeds 30 mg/(cm² per day), decreases the species diversity and population density of corals on the reefs, and results in an increasing proportion of scleractinians tolerant against intensive sedimentation. In calm weather, the mean values of sedimentation flux on the reefs of the Bai Thu Long Archipelago do not exceed 6–7 mg/(cm² per day) (Table 3). However, the data obtained during a typhoon provided evidence that during

storm season the sedimentation flux in open bays can be several times greater, thereby affecting both species composition and the structure of coral communities. The structure of most coral communities of the surveyed reefs was determined by species of the genera *Acropora*, *Goniopora* and *Galaxea* characterized by high tolerance against silt-ing and capable of existence in turbid water. Under the peculiar conditions of Han Chai Bay, a community dominated by *Pavona decussata* + *P. cactus* developed that is not characteristic of the reef communities in this area. The domination of *P. decussata* has been registered once on a reef located in the eastern part of the Gulf of Tonkin. Thus, the reefs in the Gulf of Tonkin are significantly different in the intensity of sedimentation flux, integral water exchange, and sediment resuspension above coral settlements in both open and closed bays and other areas of reef formation. Similarities and differences in the composition and structure of coral communities could easily be revealed that are due to similarities or differences in the respective abiotic conditions.

Conclusions

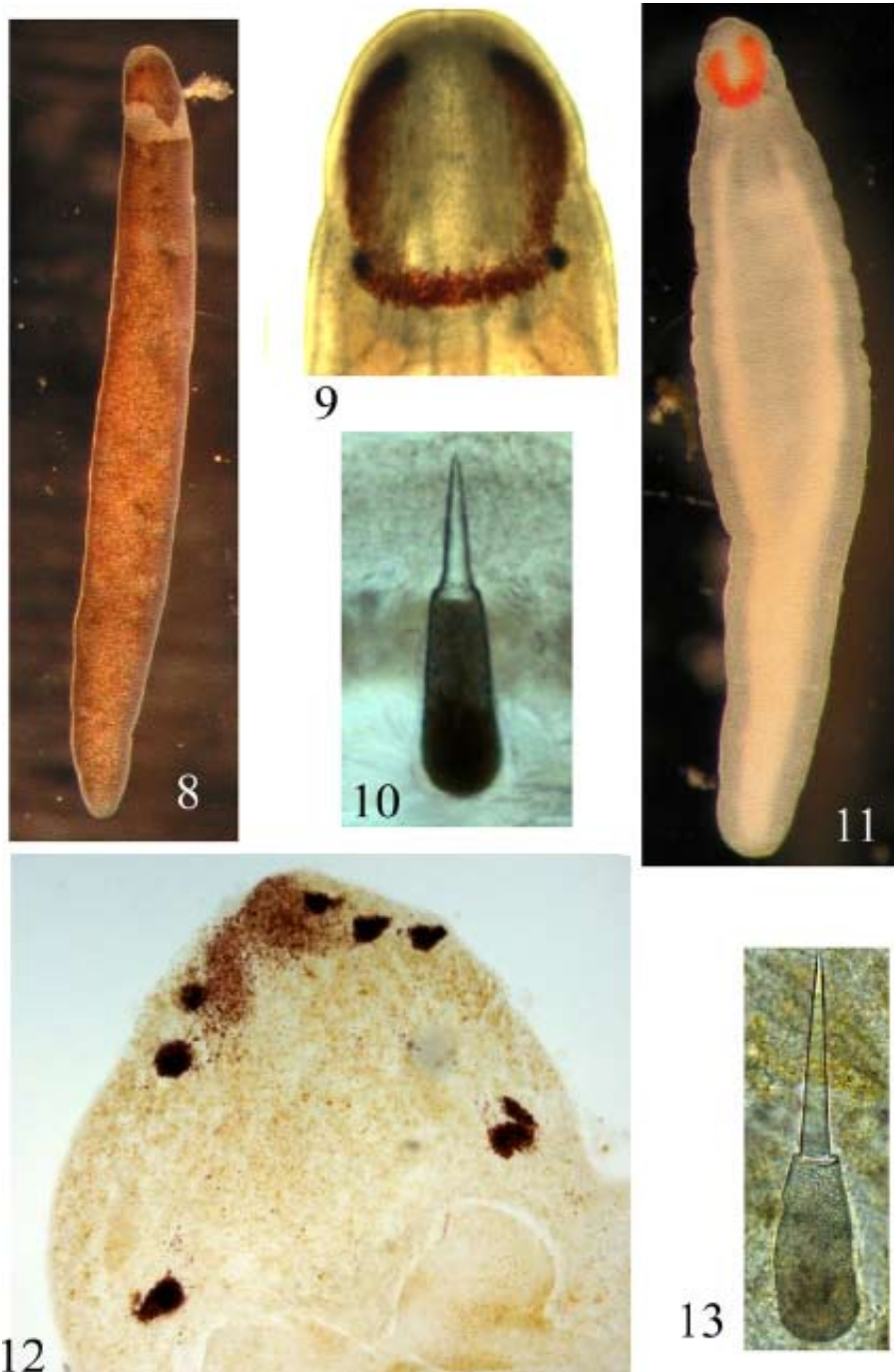
For a good understanding of processes regulating species diversity we need to understand how species disperse and which factors restrict their settlement and survival. We may need to know more about oceanic currents but also about the genetic similarity of populations in order to learn how distribution ranges are generated and how they are maintained. In addition, we need to know about the ecological factors that regulate species diversity. Although various hypothetical models have been proposed for explaining how the centre of maximum diversity originated, a combination of various models offers the most satisfying solution as clarification for the position and shape of the most likely centre of maximum marine diversity (Hoeksema, 2007). The reduction of the value of the marine ecosystems redounds to lowered food security in the region which may lead to reduced supply of cheap protein (Bernaseck, 1996). Consequently these could lead to a greater incidence of malnutrition. Deficits in fisheries productivity have been suggested to result in transmigration and eventually leading to social conflicts. Much of these consequences have been considered to be driven by the overcapitalization of the fishery and an undervalued ecosystem goods and services. The well developed institutional arrangements need to be addressed for an effective monitoring, control and systems. In future, the uneven playing field for sustenance fishers can be of great concern with further globalization thrust in the region. Though much of the ecosystem threats have relatively been less pronounced in this area (e.g. habitat deterioration, destructive fishing and overexploitation) the transboundary concerns both in the living and non-living resources make it a paramount global hotspot in the future. These human induced threats have been suggested to interact with natural threats (e.g. ENSO and storms).

This can be observed by the differential recovery of reefs after the bleaching event and the effects of ENSO in the upwelling regions in the South China Sea (e.g. off the coast of Vietnam and NW Philippines) (Alino, 2002). Initiating adaptive management efforts at each of the national fisheries management councils, by improving monitoring, control and surveillance systems based on an ecosystem framework for management could be a good start for the coral reefs keeping as they are the world' heritage. It is with hope and perseverance that the actions at the local levels translate to the broader understanding and shared stewardship of the larger marine tropical ecosystem.

3.9 NEMERTEAN FAUNA OF NORTHEAST ASIA

Nemertea is a phylum of the invertebrates known as nemerteans, or ribbon worms, which includes 1275 valid species [Kajihara et al., 2009]. These worms are found from the supralittoral to the abyssal zone on different bottoms, including silt, sand, algae, sea-grasses, and dead corals. About 40 species are symbionts of decapods, bivalve mollusks, ascidians, star-fishes, barnacles, sea anemones, and echiurids. At present, 22 species of fresh-water nemerteans and 13 species of nemerteans living on land are described. The distribution of land nemerteans is of particular interest in that they occur primarily on Australia and oceanic islands (including Ogasawara Islands in Japan). Widely distributed species *Geonemertes pelaensis* may be found on Jeju Island.

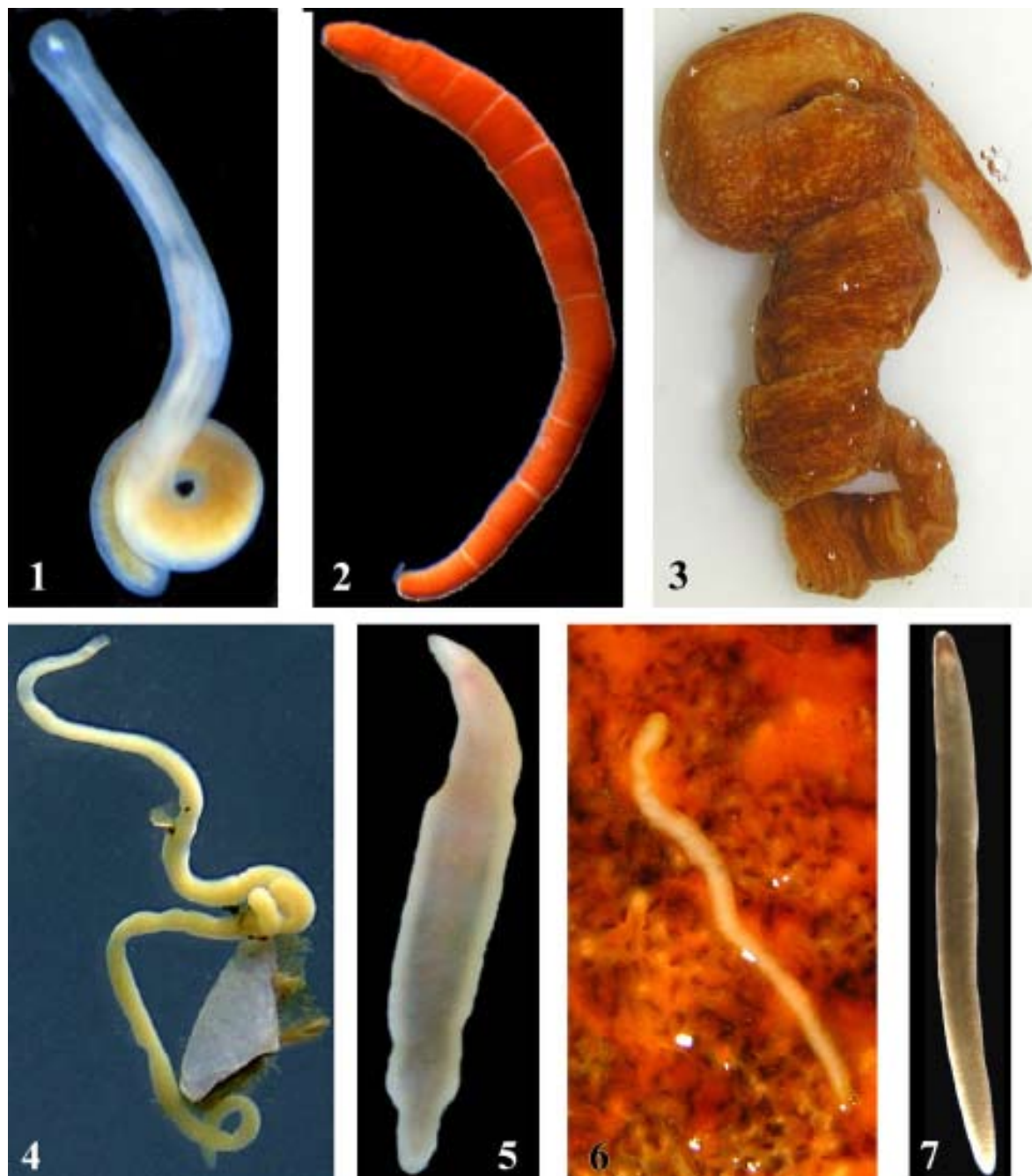
William Stimpson [1857] was the first researcher of the nemerteans of Northeast Asia. During American scientific expedition from 1853 to 1856 he collected and briefly described 22 new species from the coastal waters of China and Japan. Now all these species (for exception of *Iwatanemertes piperata*) belong to dubious taxa. Almost 300 species of ribbon worms are known currently for the seas of Northeast Asia, including the seas surrounding Japan [Crandall et al., 2002; present study]. The actual number of species, however, should be at least 600. The fact is that the nemertean fauna of this region is investigated rather irregularly. The northwestern Sea of Japan (62 species) and the Pacific coast of Japan (about 100 species) have received the most study, but even here not more than half of the species inhabiting these regions have been described. Data on the ribbon worms of the Sea of Okhotsk and the Kurils are very fragmentary:



Figs. 22. Nemerteans of the coastal waters of Jeju Island. 8 – *Oerstedia phoresiae* (Kulikova, 1987); 9-11 – *Tetrastemma roseocephalum* (Yamaoka, 1947); 12, 13 – *Emplectonema mitsuii* Yamaoka, 1947.

only 35 benthic and 11 pelagic species are known. The number of nemerteans recorded for the Pacific coast of Kamchatka and the western Bering Sea is still lower: 16 benthic and 10 pelagic species.

Data on the ribbon worms of China are also very fragmentary: 12 species registered from the Yellow Sea and 44 species from the coastal waters of south China. Gibson and Sundberg [2003] mention that at least 80-100 species inhabit the coastal waters of Hong Kong. There is almost no information on the nemerteans of the coastal waters of Korea. Korean guides show only two species (*Notospermus geniculatus* and *Lineus fuscoviridis*), and one more species, *QuasitetraSTEMMA nigrifrons*, was collected by Dr. Konstantin Lutaenko in Yongil Bay; yet the study of Korean region is very important for the understanding of biogeography of Northeast Asia nemerteans. There are 58 ribbon



Figs. 21. Nemerteans of the coastal waters of Russia. 1 – *Hubrechtella juliae* Chernyshev, 2003; 2 – *Micrura kulikovae* Chernyshev, 1992; 3 – *Baseodiscus* cf. *princeps* (Coe, 1901); 4 – *Ototyphlonemertes valentinae* Chernyshev, 2003; 5 – *Poseidonemertes maslakovae* Chernyshev, 2002; 6 – *Asteronemertes* cf. *gibsoni* Chernyshev, 1991 (on starfish *Pteraster* sp.); 7 – *Sacconemertopsis belogurovi* Chernyshev, 1991.

worms species recorded from Peter the Great Bay, and 20 species (35%) of them have not been registered from the other regions of the world.

That they are endemics of the Russian waters is rather doubtful. Unquestionably many of these species occur around the Japanese Islands and the Korean Peninsula, but it is unknown to us how far southward they are distributed.

As of now, we can assert that:

(1) The currently stated endemism of the nemerteans of Peter the Great Bay, Sagami Bay, the coastal waters of Hokkaido and Hong Kong stems from the fact that many adjacent water areas are not adequately studied. Some species previously recorded only from Peter the Great Bay have been found later off the Pacific coasts of Japan (*Ototyphlonemertes nikolaii*, *O. martynovi*, *Oerstedia zebra*) and the Kurils (*Oerstedia oculata*, *Nipponnemertes arenaria*). There is a probability that these species would be registered near the eastern coast of Korea. One such species, *Oerstedia phoresiae* (Fig. 22), described from Peter the Great Bay, was collected on Jeju Island during our expedition in October of 2008th year. Some ribbon worms described from southern China and South Japanese Islands are the potential inhabitants of the waters around Jeju Island. So, in October of 2008th we collected on Jeju Island two nemertean species previously recorded only from Japan – *Tetrastemma roseocephalum* (Fig. 22) and *Emplectonema mitsuui* (Fig. 22).

(2) Members of the superorder Pilidiophora having long-swimming larvae (*pilidia*) are usually wider distributed than members of the superorder Hoplonemertea. Only two of 15 species of pilidiophoran nemerteans from Peter the Great Bay (*Hubrechtella juliae* and *Micrura kulikovae* – Fig. 21) have not been recorded outside this bay while there are as much as 17 species of 39 hoplonemertean ribbon worms recorded from nowhere else except Peter the Great Bay. Pilidial larvae of pilidiophoran nemerteans swim in plankton about one month and can drift for long distance. The larvae of hoplonemerteans have short swimming (about one week). The range of many Pilidiophora in the Sea of Japan assumingly extends well south of Peter the Great Bay, and they may appear not boreal, but boreal-subtropical nemerteans. On the other hand, there have been no one subtropical species and only three genera (*Baseodiscus*, *Ototyphlonemertes*, and *Poseidonemertes* – Fig. 21), members of which inhabit mostly tropical and subtropical waters, described from the Russian waters. The northern limit of the distribution of subtropical nemerteans in Northeast Asia must be established. These worms are presumably distributed no farther than South Korea on the continent.

(3) The nemertean fauna of the intertidal and upper subtidal zones exhibits the greatest species diversity. Most new species of ribbon worms from the boreal waters of Asia were found among algae and sea grasses, but many yet undescribed species in tropical and subtropical waters live among corals and hydrocorals. Symbiotic nemerteans living in the mantle cavity of barnacles (3 species of the genus *Nemertopsis*) and in ambulacral grooves of the star-fishes (2 species of the genus *Asteronemertes* – Fig. 21) have been recorded only from the Asian waters of the Pacific. The highest number of endemic brackish-water nemerteans is known from Northeast Asia, namely 6 species of 5 endemic genera (Fig. 21). New investigations would unquestionably allow us to find and describe many new genera and species of ribbon worms.

The main difficulty for the studies of the nemerteans of Northeast Asia is that there are only four specialists in this group working in the region: Dr. Fumio Iwata (Professor Emeritus), Dr. Hiroshi Kajihara (Hokkaido University), Dr. Sun Shichun (Ocean University of China), and Dr. Alexey Chernyshev. One specialist can describe on average one or two species a year, because it's a very laborious and time-consuming process concerned with making serial histological sections. Consequently, not less than 50 years of active research will be needed to study the nemertean fauna of Northeast Asia as thoroughly as the fauna of bivalvian mollusks currently studied.

3.10 MID-HOLOCENE PALAEOCEANOGRAPHY OF THE SEA OF JAPAN AND MIGRATIONS OF MOLLUSKS: TOWARDS A MODEL OF FUTURE (EXPECTED) FAUNAL CHANGES

The Sea of Japan (East Sea in Korean terminology) - a marginal, deep basin enclosed by an island arc which separates it from the Pacific Ocean. The Sea of Japan is directly connected with the Sea of Okhotsk by the Tatarsky (Mamiya) Strait (sometimes called "the Gulf of Tartary"), with the East China Sea by the Tsushima and Korea Straits (between Korea and Kyushu Island). Tsugaru (between Honshu and Hokkaido) and La Perouse (or Soya; between Sakhalin and Hokkaido) Straits connect the sea with the Pacific Ocean. The sea is rather isolated as the straits mentioned are shallow; the maximum depth of Korea Strait is 150 m, and Tsugaru Strait, 200 m; Nevelskogoko Strait (northernmost Tatarsky Strait) has a sill depth of 5 m, La Perouse Strait, 53 m. This suggests that the deep basin of the Sea of Japan has no exchange with deep Pacific waters (the maximum depth of the sea is 3695 m in its eastern part - Nishimura 1983, or 3670 m - Yurasov and Yarichin 1991). The Sea of Japan is unique among the enclosed seas of the northwestern Pacific in having strong ocean currents in the form of powerful streams, and we will briefly describe the present-day system of currents based on S. Nishimura (1983) and G.I. Yurasov and V.G. Yarichin (1991).

The Sea of Japan is divided by frontal zone (or "polar front") into two distinct areas: the southeastern warm-water area washed by the Tsushima Current with three branches (T-1, coastal branch flowing along western Japan; T-2 and T-3, offshore branches; T-3 is called the East Korean Current in Russian oceanographical literature), and the northwestern area dominated by the cold Liman(ian), Primorskoye and North Korean Currents. This division is clearly reflected in the biota and biological production of the sea (Nishimura, 1965a, 1965b, 1966, 1968, 1969). The Tsushima Current enters the sea particularly through the Korea Strait and flows northeastward in three meanders including the East Korean Current. According to Russian authors (Yurasov and Yarichin 1991), only two stable branches can be recognized in the warm area of the sea. The Tsushima Current flows out into the Pacific Ocean, mostly through the Tsugaru Strait and partly through the La Perouse (Soya) Strait into the Sea of Okhotsk but its northernmost part reaches middle Sakhalin Island in Tatarsky Strait. The northern cold area of the Sea of Japan is washed by three cold currents collectively known in Japanese literature as the Liman Current, but the latter by itself is a current washing continental coast of the northern Sea of Japan - between Tatarsky Strait and mid-Primorye. Because the Liman Current bears no similarity in its hydrophysical characteristics to waters of the Amur River estuary as well as the cold Primorskoye Current flowing south of the Liman Current, it was proposed to re-name the latter to the Schrenck Current (Yurasov and Yarichin 1991). It is believed that the cold currents whose volume transport and speed are much smaller than those of the Tsushima Current, are counter- or compensation currents of the latter (Nishimura 1983).

The system of currents influenced significantly the climatic conditions (air temperatures, humidity, etc.), distribution of coastal and open-sea organisms and, probably, cultural dynamics of along-shore settlements of the ancient people. Estimations of time of the appearance of warm currents in different areas of the Sea of Japan are controversial and are based chiefly on diatom analysis, oxygen isotope analysis of benthic and planktonic foraminifers, distributions of the foraminifers alone, and molluscan assemblages considerations. According to K. Chinzei and T. Oba (1986), the inflow of the Tsushima Current started after 9500 y BP, and, at the level of 6300 y BP, low δ 18 O value as well as planktonic foraminifers and other microfossils rich in warm water species indicate a predominant influence of the Tsushima Current in the southeastern Sea of Japan. The influx of the Tsushima Current might occur on a full scale since 8000 y BP and it caused a remarkable wetting in Japan, but the strongest influx was after 6000 y BP (Koizumi 1987, 1989). After that time, four peaks of "diatome temperature" were detected in the mid- and late Holocene. H.-I. Yi et al. (1997) estimated the time of full circulation of water mass between the East Sea (Sea of Japan) and the East China Sea ("the South Sea [of Korea] and Okinawa Sea"), i.e., the full influence of Tsushima Current on the southern part of the Sea of Japan (Ulleung Basin) at the level of 8000 y

BP. Y. Igarashi (1993) also supported the viewpoint on the full-scale onset of the Tsushima Current approximately 8000 y BP. S.A. Gorbarenko et al. (1995) assumed that the oceanographic parameters, similar to those of the present, set in the Sea of Japan some 7000 y BP. The rising sea surface temperatures is recorded from 6000 y BP by study of the ratio of planktonic foraminifers (Gorbarenko 1991). The isotopic values of mollusk shells collected from archaeological sites and natural shell beds in central Japan (the Pacific side) indicate that the water temperature was highest 7000 y BP, and then became lower at around 4500-4000 y BP (Chinzei et al. 1987b). S.A. Gorbarenko and J.R. Southon (2000) concluded that the warmest conditions in the Sea of Japan occurred at 6500 – 6000 y BP. A brief cooling event that occurred about 4000 y BP is registered also for the Okinawa area (Ujiie 1997) and the northeastern South China Sea (Wei et al. 1997, 1998; see also Jian et al. 1998). Y. Sakaguchi (1987) also recorded a cold episode at 4500 y BP in the Ozegahara peat bog. The same trend seems to be shown for the subtropical Kuroshio front along the Pacific coast of Japan based on the oxygen and ecological analyses of microfossil assemblages; an increase of warm-water species continued until about 6500 y BP when temperature record shows a value much higher than present (Chinzei et al. 1987a). K. Taira (1975) established that 7000 y BP, the Kuroshio temperatures were up to 8° C or averaging 6° C above the present values. This estimate seems to be too high. Likewise, figures given by Y. Matsushima and K. Ohshima (1974) who analysed molluscan assemblages - minimum surface temperature of the southern Sea of Okhotsk was to be 5° C higher than at present. Taira's (1975) estimates were based on the oxygen isotope analysis of molluscan shells and corals. K. Chinzei et al. (1987b) demonstrated that direct conversion of isotope values to the water temperatures yields higher temperature values than expected, i.e., the minimum summer temperature for 7000 y BP would be 35° C which is unnatural for this area (Boso Peninsula).

Y. Sakaguchi et al. (1985) found a tropical-subtropical (in zonal-geographical terminology used hereafter; for explanation see Lutaenko 1993) species of bivalve mollusk, *Trapezium liratum*, in a core obtained in Tokoro Plain (northern Hokkaido) at the level of 8520 ± 120 y BP. Y. Sakaguchi (1992) suggested that this finding indicates the birth of the warm La Perouse (Soya) Current, a branch of the Tsushima Current. Thus, the Tsushima Current reached the Sea of Japan side of Hokkaido before 8500 y BP, which accords with data of M. Akamatsu and his co-workers (Akamatsu and Kitagawa 1983; Akamatsu et al. 1995) on the appearance of warm-water mollusks in the western Hokkaido at about 7500 - 8000 y BP. However, the warm-water mollusks invaded the Hokkaido coast of the Sea of Okhotsk at about 6800 y BP (Takagi et al. 1990). This controversy may be explained by insufficient geochronological evidence and it will be settled with increasing of AMS datings of molluscan shells.

K. Taira (1979) suggested an abrupt Holocene oceanic warming which started between 9000 and 8000 y BP. At 9000 - 7800 y BP (T-1 transgressive stage, according to his scheme), warm waters were introduced into the Sea of Japan, Yellow Sea and north-western Pacific, but it seems that the Tsushima Current did not move northward at that time, at least, the current did not reach Hokkaido yet (Taira 1992, 1995). The warmest interval in relative surface temperatures occurred 5900 - 4700 y BP, the Tsushima Current reached north Hokkaido, and warm waters were first imported into the Sea of Okhotsk through the Soya Strait, and at 4300 - 3900 y BP the Kuroshio Current retreated southward (Taira 1992); this nearly corresponds to the lowering of temperature on the Pacific side of Japan during 4500 - 4000 y BP (Chinzei et al. 1987b) and cooling event around 4000 – 2000 y BP based on planktonic foraminifera from Okinawa Trough and South China Sea (Jian et al. 1996). The warming of surface waters in the Sea of Japan seems to occur later than that of the Pacific side of Japan because of cold deep circulation, meltwater discharge from the Siberia, and winter sea ice in the northern part of the sea (Taira 1992). A pronounced, but relatively short period regional cooling (called Kuromatsunai cold episode 2) was detected at 9000 y BP; it was caused by cold meltwater spreading over the Seas of Okhotsk and Japan because the maximum solar radiation brought about an enormous volume of permafrost meltwater from the Amur River basin, Primorye, Sakhalin and Hokkaido (Sakaguchi 1992). In this case, the scenario of Taira (1992) explaining the discrepancy between Holocene current patterns around Japan is possible. For instance, T. Oba (1997) demonstrated that the Kuroshio front migrated

nortward passing off Boso Peninsula (Tokyo) at 10000 y BP but the Tsushima was not active at that time.

Another important feature of the mid-Holocene palaeoceanography is a difference in the rate of penetration of warm currents not only along the Pacific and Sea of Japan sides of Japan, but also along the island and continental coasts of the sea, as was demonstrated by using molluscan assemblages (Taira and Lutaenko 1993). In the Early Holocene, coasts of North Korea and Primorye were washed by intensified cold currents of Liman (Schrenck), Primorskoye and North Korean Currents, and thereby their cold waters acted as a barrier to any nortward flow of warm waters. This seems to be supported by the lack of subtropical bivalve mollusks in the Early Holocene deposits along the Primorye (Evseev 1981). We suggested that about 7000 - 6000 y BP, the East Korean Current, a branch of the Tsushima, moved northward at about 40° N, and subtropical bivalve mollusks reached Peter the Great Bay (northwestern Sea of Japan) (Taira and Lutaenko 1993). The meandering stream of the Tsushima Current, T-3 offshore stream (= East Korean Current), is known to be strongest (Nishimura 1983). The possibility of the East Korean Current axis shifting northeastward in the mid-Holocene is confirmed by the fact that even at present, during some "warm" years, the T-3 can be observed near Peter the Great Bay, as evidenced by the findings of some pelagic subtropical and tropical animals like some fishes, etc. (Ivankov 1996). The intensification of the East Korean Current in the mid-Holocene led to the appearance not only of subtropical, but also of tropical-subtropical bivalve mollusks (whose geographical ranges are extended southward to the Philippines, Vietnam, and Indonesia) in the northwestern Sea of Japan formed stable populations with annual reproduction - *Anadara inaequalis*, *T. liratum*, *Dosinia penicillata* (Lutaenko 1991a, 1993). They settled in bays with an intense summer warming-up which is necessary for successful reproduction (winter cooling in itself does not prevent warm-water fauna from living in temperate latitudes - Scarlato 1981). Thus, a combination of such factors as the considerable indentation of the coast (ria type of bays with shallow-water semi-enclosed areas in their tops) and penetration of the warm Tsushima waters to the northwestern Sea of Japan which intensified the effect of local warming had resulted in the formation of subtropical-type molluscan fauna in this area during the Middle Holocene (Lutaenko 1991b, 1993). The correlation between relative role of warm currents and geomorphological processes in the appearance/disappearance of thermally-anomalous molluscan faunas (TAMAs) has been discussed in the literature (DeVries and Wells 1990; Sandweiss et al. 1996, 1997; DeVries et al. 1997; Wells and Noller 1997) illustrating the importance of correct interpretation of paleomalacological data when reconstructing the Holocene oceanographical conditions. The example of Peter the Great Bay mid-Holocene TAMA shows that three species of warm-water bivalves became extinct in the course of the Late Holocene coolings (distributional ranges of two of them are shown in Fig. 23), while embaymental environments are still existing. This means that the climatic changes, not only coastal, are responsible for local extinctions of warm-water species.

The Kuroshio Current extended to the Hokkaido coast, probably, earlier than 5900 - 4700 y BP as first warm-water mollusks appeared here about 7500 - 8000 y BP. However, there is still no direct evidence on the chronological ranges of existence of thermophilous species on Hokkaido due to a lack of AMS datings. Fifteen AMS dates of three "extinct" (locally disappeared) bivalves from the coast of Peter the Great Bay demonstrate that their Holocene ranges lie between 7140 - 1260 y BP (taking into account a reservoir effect) (Jones and Kuzmin 1995; Kuzmin 1995). As mollusks reflect the effect of the East Korean Current, we can assume that the current penetrated to the northwestern Sea of Japan since about 7000 y BP, which is 500 - 1000 years later compared to Hokkaido. A comparison of the mid-Holocene TAMAs from the shell-middens of Hokkaido and Primorye (Rakov et al. 1996; Rakov and Lutaenko 1997) revealed a difference in species composition: at least five species found in Hokkaido have never lived in Peter the Great Bay. The oyster, *Crassostrea gigas*, invaded the coast of Terpenye Bay (~ 50° N) in Sakhalin Island (Sea of Okhotsk side) (Akamatsu and Ushiro 1992) and also penetrated to the coast of middle Primorye (Vladimir Bay - V.A. Rakov, pers. comm.). Another example is provided by the subtropical mollusk, *Anadara broughtoni*, discovered in the Neolithic shell-midden in Chertovy Vorota Cave (Khudik 1991). A refuge of

the oyster exists in the northern Tatarsky Strait - De Kastri Bay (Scarlato 1981), clearly illustrating the mid-Holocene strong influence of the Tsushima Current flowing along the eastern side of Sakhalin as continental coastal area was occupied by the cold Schrenck Current. These new data make it possible to reject an early interpretation postulating the absence of subtropical species of bivalve mollusks on the mid-Primorye coast (Lutaenko 1993).

S.P. Pletnev et al. (1987) suggested that an increase of convective mixing of water masses occurred during the Atlantic in the eastern part of Tatarsky Strait despite the influence of the Tsushima Current. This resulted in a lack of stable stratification and warming of surface water layer manifested in a high (for the period of climatic optimum) population density of diatoms (due to upwelling of nutrients to photic zone) and an increase of the level of carbonate compensation (strong dissolution of planctonic foraminifers). However, the boundary of winter drift-ice shifted northward during the mid-Holocene compare to the present in the area of Tatarsky Strait (Korotky et al. 1997).

H.-I. Yi et al. (1996b) suggested that a series of "old" spits (mid- and late Holocene in age) consisting of gravel mixed with reworked oyster shells (beach driftage) discovered on the western coast of Korea should be interpreted as traces of storm or, at least, storm-influenced deposits. Their origin is believed to be related to a global warming which caused high storm frequency (Yi et al. 1996b; Lutaenko 2001). We explained in a similar way the origin of a high gravel terrace with abundant TAMA's elements, *Anadara inaequalvis*, found near the Russian/North Korean border, northern coast of Talmi Lagoon (Lutaenko 1997; Fig. 24). The height of this terrace (old beach ridge) is about 4 m above the present sea level. Molluscan fossils from the "old" terrace were dated by both conventional and AMS methods (Alekseev and Golubeva 1980; Jones and Kuzmin 1995), and their ages are 5320 ± 45 (OS-3026), 5360 ± 35 (OS-3028), 6000 ± 130 (GIN-759b), and 5630 ± 110 (GIN-759a) y BP. This provides an example of geomorphic imprint of the mid-Holocene storm activity in the Sea of Japan between 5000 - 6000 y BP. At present there is no evidence of storm accumulation of coarse-grained deposits in the two above areas of Korea and Primorye.

The suggestion about increased storm activity during the mid-Holocene in the Asian marginal seas seems to be confirmed by the analysis of data on the prevalence of different types of coastal accumulation throughout the Holocene in Japan, Primorye and Sakhalin (Afanasyev 1992). This author used more than 400 radiocarbon datings of coastal terraces characterized by different sedimentological composition. According to the scheme compiled, there were three synchronous phases of storm and storm-influenced accumulation in the above areas, i.e., 5300-6000, 3000-4300 and 1400-1700 y BP. It is likely that increased storm frequency was one of the paleoceanographic features in the Sea of Japan along with intensification of the warm currents.

Table 7

Possible new inhabitants – bivalve mollusks in different parts of the Sea of Japan in course of global warming (after Lutaenko, 1999, with corrections)

Species	Southern Sakhalin	Peter the Great Bay	Middle Primorye	Wakasa Bay	Ishikari Bay
<i>Anadara granosa</i>	-	-	-	+	-
<i>A. broughtonii</i>	+	*	+	*	*
<i>A. inaequalvis</i>	+	+	-	?	+
<i>A. kagoshimensis</i>	?	+	-	*	+
<i>Anomalocardia squamosa</i>	-	-	-	+	+
<i>Trapezium liratum</i>	+	*	-	*	?
<i>Meretrix lusoria</i>	-	+	-	*	?

Note: "+" – immigration is expected; "-" – immigration is not expected; "*" – the species inhabits this area at present.

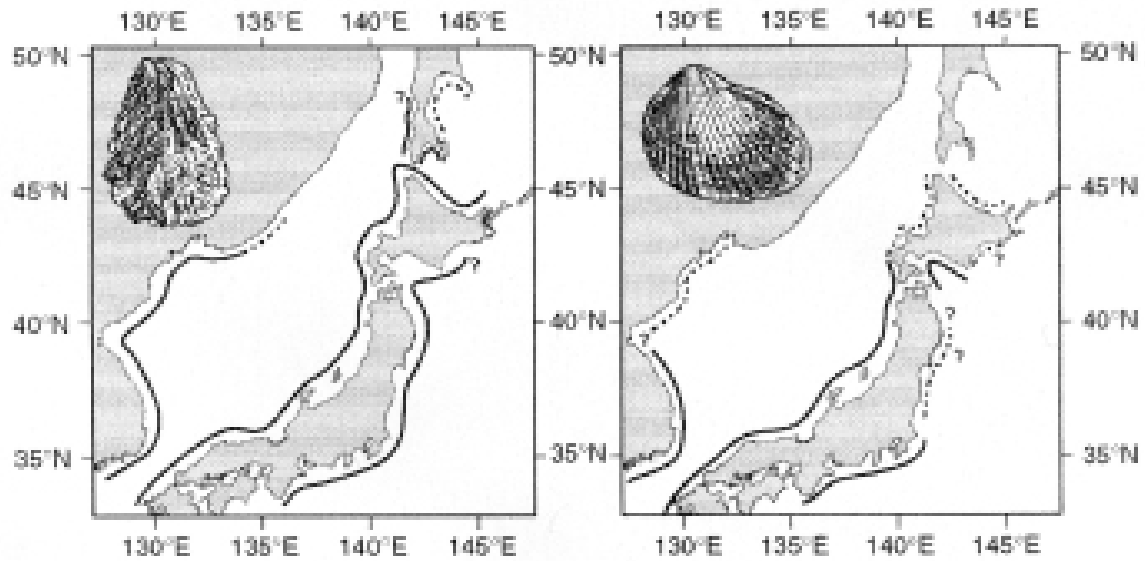


Fig. 23. The distribution of the TAMA's elements - warm-water bivalve mollusks *Anadara kagoshimensis* (right) and *Crassostrea gigas* (left) during the mid-Holocene in the Sea of Japan and adjacent areas (after Lutaenko et al., 2007).



Fig. 24. Storm deposits (5000-6000 years BP) with extinct bivalve *Anadara inaequalvis* in Peter the Great Bay, Sea of Japan).

Based on the data on species composition and chronology of mollusks obtained, one can predict expected changes in the fauna, i.e., appearance/disappearance of abundant species became regionally extinct during the second half of the Holocene due to a series of coolings (Table 7). This reconstruction may be very important in terms of future dramatic impacts of new invaders on ecosystems. There are many examples, especially for benthic communities of Mediterranean and Black Seas, of unpredictable and ecologically complicated consequences of appearance of alien species. From the other side, coastal warming and introduction of new species may favour aquaculture and fisheries.

In course of the project, two workshops were held in China and Korea. The workshop *Biodiversity of the Marginal Seas of the Northwestern Pacific Ocean* was held on November 21-23, 2007, in the Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China, with participation of more than 20 scientists (Fig. 25), and proceedings



Fig. 25. Collective photo of the participants of the workshop *Biodiversity of the Marginal Seas of the Northwestern Pacific Ocean*, November 21-23, 2007, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China.



Fig. 26. Collective photo of the participants of the workshop *Marine Biodiversity and Bioresources of the North-Eastern Asia*, October 21-22, 2008, Cheju National University, Jeju, Korea.

containing full-length papers was published. Participants discussed state of biodiversity researches in the area and presented research findings on different groups of marine organisms. The workshop *Marine Biodiversity and Bioresources of the North-Eastern Asia* was held in Cheju National University, Jeju, October 21-22, 2008 and full-length papers were published: there were more than 30 participants from Korea, Russia, China, France, India, and Thailand (Fig. 26). The workshop included 19 oral presentations and 29 posters with main themes related to the Holocene migrations of organisms, long-term changes in the biodiversity of benthic animals in the Sea of Japan, distributional patterns of the octocorals, biodiversity study on mollusks from Jeju, long-term changes of macrobenthos in Yellow Sea, nemertean fauna of North-east Asia, Ocean Biogeographic Information System (OBIS) in China, influence of pollution on ostracods.

4.0 Conclusions

The main objectives of the project were to collect information about overall species diversity and to compile species lists of biota; to undertake coastal expeditions to survey intertidal and subtidal zone; to inspect and study the species composition and ecological characteristics of the biofouling communities and ballast waters of ships; to summarize data on biodiversity loss and modifications on tidal flats in three involved countries; documenting of species diversity in island's ecosystems as a baseline study for conserving coastal and marine biological diversity. During 2007-2009 research teams performed five main kinds of activities: field-works in the Russian part of the Sea of Japan/East Sea (Russky Island) and in Jeju (Cheju) Island in Korea; gathered information about state of the biodiversity and invasive species to prepare a review; held workshops in the Institute of Oceanology CAS, Qingdao, China (October 2007) and in Cheju National University, Korea (October 2008) followed publication of two proceedings with full-length papers and abstracts; prepared and published papers in peer-reviewed journals; developed and maintained of the project website: <http://www.imb.dvo.ru/misc/apn/bio/index.htm>.

Main research findings of the project participants can be summarized as follows:

The marine biodiversity studies in China have been carried out for more than half century since the establishment of the Institute of Oceanology, Chinese Academy of Sciences in 1950. Through the survey of marine fauna, flora and living resources along the China coasts and a series of nation-wide multi-disciplinary oceanographic investigations mainly in the continental shelf, hundreds thousands number of marine fish, invertebrate and seaweed specimens were collected and deposited mainly in the two institutes, IO-CAS (CAS Marine Biological Museum) and SCSIOCAS. As the result of taxonomic and ecological studies, some 70 monographs and about 800 papers on marine fauna and flora of the China seas have been published. Results of intensive studies on marine fauna and flora have shown the richness of marine species and high biodiversity of the China seas. A total of 20070 species belonging to 20 phyla of marine biota of China seas have been enumerated in 2006, about 2211 spp., or an 15.6 % increase over those recorded in 1994.

The fast development of industrial production in coastal cities and increase of fishing catch intensity in inner shelf area, environmental pollution and decline of living resources, the high biodiversity and richness of marine biota and living resources seriously decreased. Sustainable development of fishery production seems to be difficult.

The *intertidal zone of Russky Island* (north-western Sea of Japan/East Sea) is described, and quantitative characteristics of 23 benthic communities, represented by 50 macrophytic and 181 animal species, are given based on field-works carried out in 2007. It is noted that pseudomeiobenthic portion in meiobenthos is greater than that of eumeiobenthos not only with reference to biomass, but also to population density. When comparing species richness of macrobenthos of the intertidal zone of Russky Island with that of the estuarine area in the top of neighbouring Amursky Bay, on the one hand, and with that of the islands of the Far-Eastern Marine Reserve, situated in the open part of Peter the Great Bay, on the other hand, a biodiversity gradient was revealed, that is a regular increase of macrobenthic species number beginning from the desalinated areas of the bay and up to the open sea shores. Russky Island, with nearly untouched nature, has been developed since 2008 as a new part of Vladivostok City, with construction of

a bridge from continent, campus of a new federal university, hotels, aquarium, etc. and investments of several billion dollars, and thus this study is important in terms of future biodiversity and ecosystem monitoring.

Peculiarities of vertical distribution, species composition and zonal-biogeographical structure of macrobenthos of the *intertidal communities of Kunashir Island* (South Kurile Islands) are described on the basis of the results of the expedition of 1991; published data of 1951–1988 are revised taking into account current taxonomic literature. Pacific low-boreal and Pacific wide-boreal species prevail. Intertidal biota in Izmeny Bay and in the Sea of Okhotsk coasts is more thermophilous as compared to the Pacific coast. It is connected with circulation of warm waters of Soya Current. On the rocky and stony intertidal zone poorly populated communities of *Chthamalus dalli* and *Littorina sitkana*, are typical for the upper horizon. A fucoid complex is developed in the middle horizon. Dense thickets of laminarian algae develop in the lower horizon, in this communities total macrobenthos biomass can reach 100 kgWW m⁻². On sandy beaches affected by surf and formed by clean sand, population is very poor, macrophytes and other attached forms are absent. Communities *Zostera japonica*, *Z. marina* and *Batillaria cumingii* not found in the other sites of Kunashir are located on the silty-sandy intertidal zone of the southern island coast in Izmeny Bay. Decrease in species diversity and increase of biomass of macrobenthos happened during the recent 30 years in Izmena Bay exposed to anthropogenic impact is recorded. Intertidal zone of Kunashir Island has many common features with that of the neighboring Shikotan Island by composition and patterns of distribution of communities. Composition and distribution of intertidal biota of Kunashir Island is typical for the low-boreal intertidal zone with well-expressed tides.

A total of 1072 species and subspecies of *mollusks* (Mollusca) have been recorded from *Jeju Island*, 1015 marine species and 57 land and freshwater species. There are 812 gastropods, of which 755 are either entirely marine or, as in the case of the Truncatellidae, Ellobiidae, and other similar families, have marine affinities. Of those the Pyramidellidae are best represented, followed by the Trochidae and Ovulidae. The bivalves are represented by 225 species, with the Veneridae, Mytilidae, and Arcidae having the largest number of species. Among the smaller classes there are sixteen Cephalopoda, eleven Polyplacophora, and eight Scaphopoda. Of particular note is the absence of some of the more common, edible mainland species, e.g. *Rapana venosa* (Valenciennes, 1846) and *Meretrix* spp., because of the relative lack of muddy substrates.

Ostracods, fine indicators of water ecosystem condition and climatic changes, were studied in the intertidal surveys of 2007–2008 of *the coastal zone of Jeju Island, Korea*. 73 ostracod species were found. In general, ostracod fauna of Jeju Island coast remains poorly studied. Judging by species diversity of ostracod fauna of similar regions, one could suppose that not less than 600 ostracod species inhabit the shelf of Jeju Island.

Data on the ship fouling studied by the Institute of Marine Biology FEB RAS since 1975 are reviewed and summarized. The large material on fouling of more than 600 ships of a various operation mode in different regions of World Ocean is assembled which has allowed revealing a number of exotic species, introduced in the northwest part of the Sea of Japan with the help of ship fouling and their ballast waters. In the fouling of anthropogenic substrates and in benthos communities of Peter the Great Bay, altogether 16 species-invaders have been registered; among them cirripede barnacles, amphipods, hydroids, polychaetes and bryozoans. The alien species damage native communities and step by step are playing a significant role in the coastal ecosystems leading to modifications, increase of biomass, etc.

Distributional patterns of the coral diversity in the Indo-West Pacific are described and global trends in the coral reef ecosystems' changing are summarized. The main drivers leading to the global biodiversity changing in the coral reef ecosystems were identified as follows: **1**, the possible invasion of the alien species (or group of the species) using the various pathways of the overseas connectivity; **2**, the overexploitation of the bioresources of the coral reefs together with the man-made pollution of the coastal seas, and **3**, the global climate changing and environmental stress.

Based on the data on species composition and chronology of mollusks lived in the coastal areas of the Sea of Japan during the Holocene, one can predict expected changes in the fauna, i.e., appearance/disappearance of abundant species became regionally

extinct during the second half of the Holocene due to a series of coolings. It is expected that, at least, about three species of bivalve mollusks (*Anadara broughtonii*, *A. inaequivalvis*, *Trapezium liratum*) would migrate to the coast of southern Sakhalin, three (*A. inaequivalvis*, *A. kagoshimensis* and *Meretrix lusoria*) – to Peter the Great Bay, one (*A. broughtonii*) to middle Primorye, two (*Anadara granosa* and *Anomalocardia squamosa*) – to Wakasa Bay, and three (*A. inaequivalvis*, *A. kagoshimensis*, *A. squamosa*) would appear in Ishikari Bay (Hokkaido).

5.0 Future Directions

We plan to continue collaboration between research teams which would result in a joint publications and a collective book. Moreover, research activity on bioinvasions problem in the Sea of Japan will be continued through a project supported by UNEP NOWPAP (United Nations Environmental Programme, Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region) in May 2009, and one of the participants of the APN Project, K.A. Lutaenko, was nominated as a national expert by NOWPAP. Another project on local assessment of impact of alien species in Far East Biosphere Reserve (north-western Sea of Japan) supported by UNDP will start in 2009 with involvement of participants of the APN Project.

Appendix

WORKSHOPS

BIODIVERSITY OF THE MARGINAL SEAS OF THE NORTHWESTERN PACIFIC OCEAN

21-22 November 2007, Qingdao, China

Venue: Institute of Oceanology, Chinese Academy of Sciences

PROGRAMME

Day 1 (Nov. 21)

9:00-9:15 Welcoming remarks from the IOCAS

9:15-9:30 Remarks from delegates of the Russian side

9:30-9:50 Group photo & coffee break

9:50-10:30 **Song Sun.** Present status of marine biodiversity studies in China

10:30-11:10 **Anatoly N. Kachur.** Main environmental issues in the Northwest Pacific region and biodiversity conservation

11:10-11:50 **J. Y. Liu.** Global climate change on biodiversity of Yellow Sea coldwater fauna

11:50-13:30 Lunch

13:30-14:10 **Tatyana V. Lavrova.** Biodiversity studies in the Institute of Marine Biology FEB RAS

14:10-14:50 **Shouyi Zheng.** Foraminifera

14:50-15:30 **Konstantin A. Lutaenko.** Biogeography of the embaymental molluscan faunas in the Japan/East Sea

15:30-15:50 Coffee break

15:50-16:30 **Xinzheng Li.** The biodiversity of macrobenthos from the Jiaozhou Bay, Shandong Peninsula

16:30-17:10 **Ron Noseworthy.** Mollusks of the Jeju Island in Korea

17:30 Reception

Day 2 (Nov. 22)

9:00-9:40 **Kuidong Xu.** Biodiversity of Trichodinid (Protozoa, Ciliophora, Peritrichia)

Ectoparasites from Marine Molluscs and Fishes in the Yellow Sea

9:40-10:20 **Yanli Lei.** Ciliate diversity and distribution in solar salterns of the Yellow Sea

10:20-10:40 Coffee Break

10:40-11:20 **HuiLian Liu.** A preliminary study on Conescharellinidae bryozoans off China coast

11:20-12:00 **Haiyan Wang.** Classification of common oysters from north China

12:00-13:30 Lunch

13:30 Excursion

List of participants

**Workshop *BIODIVERSITY OF THE MARGINAL SEAS OF THE
NORTHWESTERN PACIFIC OCEAN*, Institute of Oceanology CAS,
Qingdao, China, November 21-22, 2007**

R U S S I A

Dr. Konstantin A. Lutaenko

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-317-111
Fax: +7-4232-310-900
E-mail: lutaenko@mail.primorye.ru

Dr. Tatyana V. Lavrova

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-317-111
Fax: +7-4232-310-900
E-mail: tlavrova@mail.ru; tatylavr@yandex.ru

Dr. Anatoly N. Kachur

Pacific Institute of Geography
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Fax: +7-4232-312-159
E-mail: kachur@tig.dvo.ru

C H I N A

Prof. Song Sun, Director

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
Tel: 0532-82898598, 0532-82898602
Fax: 0532-82898612, 0532-82868008
E-mail: sunsong@ms.qdio.ac.cn

Dr. Xiaoxia Sun

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
Fax: 0532-82898612, 0532-82868008
E-mail: xsun@ms.qdio.ac.cn

Prof., Academician J. Y. Liu

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
Tel: +86-532-82898672, 82866316
Fax: +86-532-82898672, 82866316
E-mail: jyliu@ms.qdio.ac.cn

Prof., Academician Shouyi Zheng

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
Tel./Fax (532) 828-986-75
Tel. (532) 828-98-676
E-mail: zsy@ms.qdio.ac.cn

Prof. Xinzheng Li

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
Tel: 86-532-82898771
Fax: 86-532-82898798
E-mail: lixzh@ms.qdio.ac.cn

Dr. Kuidong Xu

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
Tel/Fax: +86-532-82898776
e-mail: kxu@ms.qdio.ac.cn; xukd@hotmail.com

Dr. Yanli Lei

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China
e-mail: leiyanli@ms.qdio.ac.cn

Dr. Hui-Lian Liu

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China

Dr. Haiyan Wang

Institute of Oceanology
Chinese Academy of Sciences
Qingdao 266071, P.R. China

REPUBLIC OF KOREA

Dr. Ronald G. Noseworthy

Cheju National University
School of Applied Marine Science,

College of Ocean Science
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130
e-mail: rgnshells@yahoo.ca

JAPAN

Mr. Norio Baba
UNEP/NOWPAP RCU Toyama Office
5-5 Ushijimashin-machi, Toyama 930-0856, Japan
Tel: +81-76-444-1611
Fax: +81-76-444-2780
e-mail: Norio.Baba@nowpap.org

**MARINE BIODIVERSITY AND BIORESOURCES OF THE
NORTH-EASTERN ASIA**

**October 21-22, 2008, Jeju, Republic of Korea
Cheju National University, Jeju City**

PROGRAMME

Welcome reception

Welcome address. Prof. Dr. Choong-Suk Koh, President of Cheju National University

Session. Chair: Dr. Li Xinzheng

Group Photo

Opening address. Prof. Dr. You-Jin Jeon, Director of Marine and Environmental Research Institute, Cheju National University

Dr. Konstantin A. Lutaenko, A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences

Session. Chair: Dr. You-Jin Jeon

THE HOLOCENE MIGRATIONS OF BIVALVE MOLLUSKS IN THE SEA OF JAPAN (EAST SEA) AS A MODEL OF EXPECTED FAUNAL CHANGES DUE TO GLOBAL WARMING

Konstantin A. Lutaenko (Russian Academy of Sciences, Russia)

BIODIVERSITY STUDIES IN THE A.V. ZHIRMUNSKY INSTITUTE OF MARINE BIOLOGY FEB RAS

Tatyana V. Lavrova and Konstantin A. Lutaenko (Russian Academy of Sciences, Russia)

LONG-TERM CHANGES IN BIODIVERSITY OF JUVENILE BENTHIC BIVALVE ASSEMBLAGE RELATED TO DECREASE OF ANTHROPOGENIC INFLUENCE

Alla V. Silina and George A. Evseev (Russian Academy of Sciences, Russia)

DISTRIBUTIONAL PATTERNS OF THE OCTOCORALS IN THE INDO-WEST-PACIFIC AND THE SPECIES IDENTIFICATION PROBLEM: WHAT TAXA COULD BE THE INDICATORS?

Tatyana N. Dautova (Russian Academy of Sciences, Russia)

FUNCTIONAL PROPERTIES OF *ECKLONIA CAVA*, A BROWN SEAWEED, IN JEJU ISLAND

You-Jin Jeon and Soo-Jin Heo (Cheju National University, Korea)

FATTY ACIDS OF MARINE MICROALGAE: TAXONOMIC AND PHYSIOLOGICAL INDICATORS

Natalya V. Zhukova (Russian Academy of Sciences, Russia)

MOLLUSKS IN PREHISTORIC HUMAN MATERIAL CULTURE: RUSSIAN FAR EAST AS A CASE OF STUDY

Irina S. Zhushchikhovskaya (Russian Academy of Sciences, Russia)

MOLLUSKS FROM NORTHEASTERN CHINA (A BIODIVERSITY STUDY)

Ronald G. Noseworthy (Cheju National University, Korea)

Session. Chair: Dr. Konstantin A. Lutaenko

LONG-TERM CHANGES OF MACROBENTHOS DURING 1980 TO 2005 FROM JIAOZHOU BAY, SOUTHERN COAST OF SHANDONG PENINSULA

Li Xinzheng, Li Baoquan, Wang Hongfa, Wang Jinbao, Zhou Jin, Han Qingxi, Wang Xiaochen, Ma Lin, Dong Chao, and Zhang Baolin (Chinese Academy of Sciences, China)

COMMUNITY STRUCTURE OF MACROBENTHOS IN COASTAL WATER OFF RUSHAN, WOUTHERN SHANDONG PENINSULA, AND THE RELATIONSHIPS WITH ENVIRONMENTAL FACTORS

Li Baoquan, Li Xinzheng, Wang Hongfa, Wang Jinbao, Zhou Jin, Han Qingxi, Wang Xiaochen, Ma Lin, Dong Chao, and Zhang Baolin (Chinese Academy of Sciences, China)

ECOLOGICAL CHARACTERISTICS OF MACROBENTHOS FROM THE SOUTHERN YELLOW SEA

Wang Jinbao and Li Xinzheng (Chinese Academy of Sciences, China)

THE IMPACT OF IMPLANTED WHALE CARCASS ON MEIOFAUNA IN PETER THE GREAT BAY (SEA OF JAPAN/EAST SEA)

Olga N. Pavlyuk, Yulia A. Trebukhova, Vitaly G. Tarasov, Tatyana S. Tarasova, Luisa N. Propp and Gennady M. Kamenev (Russian Academy of Sciences, Russia)

MARINE BIODIVERSITY AND BIORESOURCES OF THE NORTH-EASTERN ASIA (October 21-22, 2008) TRIBOLODON HAKONENSIS (PISCES: CYPRINIDAE): POPULATION GENETIC STRUCTURE AS A REFLECTION OF PALEOENVIRONMENTAL CHANGES IN THE NORTH-WEST PACIFIC

Neonila E. Polyakova, Alisa V. Semina and Vladimir A. Brykov (Russian Academy of Sciences, Russia)

Session. Chair: Dr. Kwang-Sik Choi

COMPARATIVE STUDY ON ANNUAL GAMETOGENESIS OF MANILA CLAMS (RUDITAPES PHILIPPINARUM) COLLECTED FROM EIGHT LOCATIONS ON THE WEST COAST OF KOREA IN 2007

Yanin Limpanont, Hyun-Sung Yang, Hyun-Ki Hong, Bong-Kyu Kim, Hee-Do Jeong, Kyu-Sung Choi, Hee-Jung Lee, Jasim Uddin, Kwang-Jae Park, Young-Je Park, and Kwang-Sik Choi (Cheju National University, Korea)

DEVELOPMENT OF COMMON SIPUNCULID SPECIES OF THE NORTH-WEST PACIFIC

Anastassya S. Maiorova (Russian Academy of Sciences, Russia)

Session. Chair: Dr. Tatyana Dautova

NEMERTEAN FAUNA OF NORTHEAST ASIA

Alexei V. Chernyshev (Russian Academy of Sciences, Russia)

OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM (OBIS): A USEFUL TOOL FOR MARINE BIODIVERSITY RESEARCH

Xiaoxia Sun (Chinese Academy of Sciences, China)

OSTRACODS OF THE COASTAL ZONE OF JEJU ISLAND, KOREA

Evgeny I. Schornikov and Mariya A. Zenina (Russian Academy of Sciences, Russia)

INFLUENCE OF POLLUTION ON THE OSTRACOD FAUNA NEAR THE EASTERN COAST OF AMURSKY BAY (SEA OF JAPAN/EAST SEA)

Maria A. Zenina (Russian Academy of Sciences, Russia)

Farewell Reception

List of participants

**Workshop *MARINE BIODIVERSITY AND BIORESOURCES OF THE NORTH-EASTERN ASIA*, Marine and Environmental Research Institute, Cheju National University,
Jeju, Korea, China, October 21-22, 2008**

R U S S I A

Dr. Konstantin A. LUTAENKO

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-317-111
Fax: +7-4232-310-900
e-mail: lutaenko@mail.primorye.ru; lutaenko@mail.ru

Dr. Tatiana V. Lavrova

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-317-111
Fax: +7-4232-310-900
e-mail: tlavrova@mail.ru; tatlavr@yandex.ru

Dr. Alla V. Silina

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-311-182
Fax: +7-4232-310-900
e-mail: allasilina@mail.ru

Dr. Tatyana N. Dautova

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-311-182
Fax: +7-4232-310-900
e-mail: tndaut@mail.ru

Dr. Anastassya S. Maiorova

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-310-905
Fax: +7-4232-310-900
e-mail: amajorova@mail.ru

Dr. Natalya V. Zhukova

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-310-905

Fax: +7-4232-310-900
e-mail: nzhukova35@list.ru

Dr. Neonila E. Polyakova

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-310-905
Fax: +7-4232-310-900
e-mail: nila.polyakova@gmail.ru

Dr. Alexei V. Chernyshev

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-310-905
Fax: +7-4232-310-900
e-mail: chernyshev@marbio.dvgu.ru

Dr. Maria A. Zenina

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-310-905
Fax: +7-4232-310-900
e-mail: maria_zenina@mail.ru

Dr. Evgeny I. Schornikov

Institute of Marine Biology
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
Tel: +7-4232-310-905
Fax: +7-4232-310-900
e-mail: inmarbio@mail.primorye.ru

Dr. Yulia A. Trebukhova

Far Eastern State Biosphere Marine Reserve
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690041, Russia
E-mail: julit@inbox.ru

Prof. Irina S. Zhushchikhovskaya

Institute of History, Archaeology and Ethnography of the Peoples of the Far East
Far East Branch of the Russian Academy of Sciences
Vladivostok, 690950, Russia
Fax: +7 -4232- 26-80-85
e-mail: irinazh@mail.primorye.ru

REPUBLIC OF KOREA

Prof. Kwang-Sik Choi

Cheju National University

School of Applied Marine Science
College of Ocean Science
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130
e-mail: choi3422@hanmail.net

Dr. Choong-Suk Koh

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Soo-Jin Heo

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130
e-mail: skysjheaven@paran.com

Dr. You-Jin Jeon, Director

Cheju National University
Marine and Environmental Research Institute
Jeju-do, Korea, 690-756
Tel: +82-64-754-3475
Fax: +82-64-756-3493
e-mail: youjinj@cheju.ac.kr

Dr. Ronald G. Noseworthy

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130
e-mail: rgnshells@yahoo.ca

Dr. Yanin Limpanont

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Hyun-Sung Yang

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Hyun-Ki Hong

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Bong-Kyu Kim

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Hee-Do Jeong

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Kyu-Sung Choi

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Hee-Jung Lee

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Jasim Uddin

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Kwang-Jae Park

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

Dr. Young-Je Park

Cheju National University
Jeju-do, Korea, 690-756
Tel: +82-64-754-2114, 754-3114
Fax: +82-64-755-6130

CHINA

Dr. Xiaoxia Sun

Institute of Oceanology,
Chinese Academy of Sciences
Qingdao, 266071, P.R. China
Tel.: +86-532-82898599
Fax: +86-532-82868008
e-mail: xsun@ms.qdio.ac.cn

Dr. Ma Junying

Institute of Oceanology,
Chinese Academy of Sciences
Qingdao, 266071, P.R. China
Tel: (0532) 82898623
Fax: (0532) 82898620
e-mail: majy@ms.qdio.ac.cn

Prof. Li Xinzheng

Institute of Oceanology,
Chinese Academy of Sciences
Qingdao, 266071, P.R. China
Tel: 86-532-82898771
Fax: 86-532-82898798
e-mail: lixzh@ms.qdio.ac.cn

***The list of plants and animals
of the Russky Island intertidal zone***

Taxon	Population density, ind./m ²	Biomass, g/m ²	Size	
			Macrobenthos	Meiobenthos
<p>Imperium Cellulata</p> <p>Dominium Procaridia (Bacteria)</p> <p>Regnum Oxyphotobacteriobiontes</p> <p>Phylum Cyanobacteria (=Cyanophyta)</p> <p>Dominium Eukaryota</p> <p>Subdominium Metakaryota</p> <p>Regnum Rhodobiontes</p> <p>Phylum Rhodophyta</p> <p>Classis Florideophyceae</p> <p>Ordo Hildenbrandiales</p> <p>Fam. Hildenbrandiaceae</p> <p>Hildenbrandia rubra (Sommerf., 1826) Meneghini, 1841</p> <p>Ordo Corallinales</p> <p>Fam. Corallinaceae</p> <p>Bosziella compressa Klixsova, 1978</p> <p>B. cretacea (Postels et Ruprecht, 1840) Johansen, 1969</p> <p>Clathromorphum compactum (Kjellman, 1883) Foslie, 1898</p> <p>Corallina pilulifera Postels et Ruprecht, 1840</p> <p>Lithophyllum tumidulum Foslie, 1901</p> <p>Lithothamnion phymatodeum (Foslie, 1902) Foslie, 1929</p> <p>Prosephyllum kejolsii (Rosanoff, 1866) Chamberlain, 1983</p> <p>Ordo Acrochaetales</p> <p>Fam. Acrochaetaceae</p> <p>Colaconema daviesii (Dilwyn, 1882-1889) Steyenga, 1985</p> <p>Rhodophysemia elegans (Crouan et Crouan, 1867) Dixon, 1964</p> <p>Ordo Palmariales</p> <p>Fam. Palmariaaceae</p> <p>Palmaria stenogona (Perestenko, 1973) Perestenko, 1980</p>		<p>ZD.0</p> <p>4.2</p> <p>1D-894.0</p> <p>1D.0</p> <p>6.9-37.0</p>	<p>5</p> <p>2</p> <p>2,3</p> <p>2</p> <p>2,3</p> <p>1,3,6-12</p> <p>1-3,12</p> <p>1,3,8,9</p> <p>4,6,7,9,10</p> <p>8</p> <p>9</p> <p>1</p> <p>1</p>	<p>5</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p>

<p><i>Symphodiadia labiiscula</i> (Harvey ex Gray, 1857) Yamada, 1941</p> <p><i>Polysiphonia japonica</i> Harvey ex Perry, 1856</p> <p><i>P. morrowii</i> Harvey ex Gray, 1856</p> <p><i>Nesoriodomela larix</i> (Turner, 1819) Masuda, 1982 subsp. <i>aculeata</i> Perestenko, 1984</p> <p><i>N. munita</i> (Perestenko, 1988) Perestenko, 1994</p> <p><i>Laurencia nipponica</i> Yamada, 1931</p> <p><i>L. pinnata</i> Yamada, 1931</p> <p>Regnum Chromobiontes</p> <p>Phylum Ochrophyta</p> <p>Classis Phaeophyceae</p> <p>Ordo Ectocarpales</p> <p>Fam. Chordariaceae</p> <p><i>Chordaria flagelliformis</i> (Mueller ex Flora Danica, 1775) C. Agardh, 1817</p> <p><i>Saundersella simplex</i> (Saunders, 1911) Kytin, 1948</p> <p>Fam. Scytosiphonaceae</p> <p><i>Colpomenia peregrina</i> (Sauvageau, 1900-1904) Harmel, 1924-1930</p> <p><i>Scytosiphon lomentaria</i> (Lyngbye, 1819) J. Agardh, 1848</p> <p>Ordo Ralfsiales</p> <p>Fam. Heterochordariaceae</p> <p><i>Anallipus filiformis</i> (Ruprecht, 1850) Wynne, 1971</p> <p>Fam. Ralfsiaceae</p> <p><i>Ralfsia fungiformis</i> (Gunnerus, 1772) Setchell et Gardner, 1924</p> <p>Ordo Dictyotales</p> <p>Fam. Dictyotaceae</p> <p><i>Dictyota dichotoma</i> (Hudson, 1762) Lamouroux, 1809</p> <p>Ordo Sphaecelariales</p> <p>Fam. Sphaecelariaceae</p> <p><i>Sphaecelaria furigera</i> Kuetzing, 1855</p> <p>Ordo Fucales</p> <p>Fam. Sargassaceae</p> <p><i>Coccolophora langsdorfi</i> (Turner, 1819) Greville, 1838</p> <p><i>Sargassum miyabei</i> Yendo, 1907</p> <p><i>S. pallidum</i> (Turner, 1819) C. Agardh, 1820</p>	<p>120.0-3450.0</p> <p>0.9-44.0</p> <p>1.0</p> <p>90.0-2030.0</p> <p>360.0</p> <p>2.3-445.0</p> <p>4.0</p> <p>5.0-35.5</p> <p>3.0-465.0</p> <p>10.0</p> <p>240.0</p> <p>1449.0-3800.0</p> <p>0.005-2.2313*</p>	<p>2,3,10,12</p> <p>1,7,9</p> <p>9-12</p> <p>12</p> <p>1,7,7a,12</p> <p>12</p> <p>1</p> <p>1</p> <p>9,10,12</p> <p>2</p> <p>2,9,10,12</p> <p>1,10</p> <p>6,7,10</p> <p>12</p> <p>1,3,6,9</p> <p>-</p>	<p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>3,5-12</p>
---	--	---	---

Classis Anthozoa					
Fam. Actiniidae					
<i>Cnidopus japonicus</i> (Verrill, 1868)				12	-
Phylum Plathelminthes					
Classis Turbellaria					
Phylum Nemertea					
Fam. Lineidae					
<i>Lineus torquatus</i> Coe, 1901	100	1.0		1	1.1
Phylum Annelida	510	0.0459		1.1	
Classis Polychaeta					
Fam. Phyllodoceidae	100	1.0		2,6	
<i>Eulalia viridis</i> (Linnaeus, 1767)	200	7.0		3,6,9,10	
<i>Eulalia</i> sp. juv.	300-400	0.027-0.036		12	
Fam. Polynoidae					
<i>Gattyana ciliata</i> Moore, 1902	1008; 80-2040*	8.3; D.0072-D.1836*			2,7
<i>Hamnothoe imbricata</i> (Linnaeus, 1767)	200*	0.018*		3	6
Fam. Pholodoceidae	200	1.0			
<i>Pholoe longa</i> (Muelker, 1776)	100-1300	0.8-5.2		3	
Fam. Nereidae	300-1300	21.0-52.0		1,7,10,12	
<i>Lycastopsis pontica</i> (Bobretzky, 1872)	100-1020*	0.009-0.0918*		2,3,6,12	10-12
<i>Chaetozone setosa</i>	100	0.3			
<i>Nesarithes</i> sp.	100; 510*	1.0; D.0459*		8,11,12	8
<i>Nereis multignatha</i> Imajima et Hartman, 1964	100-200; 180-2040*	0.5-1.1; D.009-0.1836*		4	7,8,10,12
<i>N. vexillosa</i> Grube, 1849				3,4,6,9,10,12	2,7,11
<i>N. zonata</i> Malmgren, 1867					2,8,12
<i>N. zonata tigrina</i> Zsch, 1933	20-1020*	0.0018-0.0918*			10
<i>Nereis</i> sp. juv.	1020*	0.0918*			8,12
<i>Platynereis bicancaliculata</i> (Baird, 1863)	1530*	0.1377		3	6
Fam. Syllidae	400-2040*	0.036-0.1836*		3	8,12
<i>Exogone gemmifera</i> Pagenstecher, 1862	400	0.4		3	
<i>Odontosyllis maculata</i> Uschakow, 1950				3	
<i>Pionosyllis compacta</i> Malmgren, 1867				6	
<i>Sphaerosyllis hirsuta</i> Ehlers, 1897	200*	0.018*			12
<i>Typesyllis fasciata</i> Malmgren, 1867	40*	0.0036*			2
<i>T. orientalis</i> Imajima et Hartman, 1964					
<i>T. pulchra occidentalis</i> Buzhinskaja, 1980	2550*	0.2295*		3	
Fam. Lumbrineridae					
<i>Lumbrineris</i> sp.				3	

<i>Epheria turnita</i> (A. Adams, 1861)	1D0-40D0	0.4-1495.0	1-11	-
<i>Epheria</i> sp.	1D0	0.5	1,3,6,7a,8,12	-
<i>Litorina brevicula</i> (Philippi, 1844)	1D0-132B8D	0.1-344.0	1,12	-
<i>L. manschurica</i> Schrenck, 1867	510B*	0.357*	1-12	-
<i>L. sikkana</i> (Philippi, 1846)	1D0-3K0D	0.2-1.0	3	5
<i>L. squafida</i> Broderip et Sowerby, 1829	1D0-20D00; 10B-255B*	0.1-27.2; 0.007-0.1785*	1,3,5-12	2,5,7,11,12
Fam. Pomatiopsidae				
<i>Cecina manchurica</i> A. Adams, 1861	2D0-81D0	0.2-16.0	1D	5,7,8,10
Fam. Rissoidae	1D2B-816B*	0.0714-0.5712*	1,3	-
<i>Falsicingula athera</i> Bartsch in Golikow et Scarlato, 1967	2D0-40B0*	0.014-0.2856*	1,3,5-7,9,10,12	5,7
<i>F. mundana</i> (Yokoyama, 1926)	1B0-36312D*	0.0126-25.4184*	1,7a,12	3,5-7,9,11,12
<i>Setia candida</i> A. Adams, 1861	510-22695D*	0.357-15.8865*	1,7a,9,10,12	3,6,7,12
<i>Lucidestea ornata</i> Golikow et Kussakin in Golikow et Scarlato, 1967	2D0-39D0	0.3-18.4	-	-
<i>Puzosina plicosa</i> (Smith, 1875)	2D0-14D0	3B.3-300.0	1	-
Fam. Barleeidae				
<i>Ansoala angulosa</i> Golikow et Kussakin, 1978	3D0-40D	2B.D-47.0	1,4,6,7a,10	-
<i>A. angustata</i> (Pilsbry, 1901)	2D0	1.0	4,5,7,7a,8	-
Fam. Assimineidae	1D0-17D0	2.2-112.0	3,5,6,7,7a,9	-
<i>Assiminea</i> sp.	1D0	55.0	4,6	-
Fam. Caecidae				
<i>Fartulum bucerius</i> Golikow in Golikow et Scarlato, 1967	1D0*	0.07*	1,2,6,10-12	7
<i>Brochira derjugini</i> Golikow in Golikow et Scarlato, 1967	2D0	0.014	1,9,10	7
Fam. Litiopsidae				
<i>Alaba picta</i> A. Adams, 1861				
Fam. Batillariidae				
<i>Batillaria cumingii</i> (Crosse, 1862)				
Fam. Nassariidae				
<i>Hima fratercula</i> (Dunker, 1868)				
<i>H. multigranosa</i> (Dunker, 1847)				
Fam. Columbellidae				
<i>Mitrella burchari</i> (Dunker, 1877)				
Fam. Muricidae				
<i>Tribonalia japonica</i> (Dunker, 1850)				
Fam. Thaididae				
<i>Nucella heysesana</i> (Dunker, 1882)				
Fam. Turbellidae				
<i>Ordostrmia culta</i> Dall et Bartsch, 1906				

<p><i>Odostomia</i> sp. Classis Bivalvia Subclassis Neotoxodonta Ordo Arcoïda Superfam. Arcoïdea Fam. Arcoïdæ <i>Arca boucardi</i> Jousseaume, 1894 Subclassis Pteriomorpha Ordo Mytiloïda Superfam. Mytiloïdea Fam. Mytilidæ Subfam. Mytilinæ <i>Mytilus (Mytilus) galloprovincialis</i> Lamarck, 1819 <i>Mytilus (Mytilus) trossulus kussakini</i> Scarlato et Starobogatov, 1979 <i>Mytilus (Crassimylus) conus</i> Gould, 1861 <i>Mytilus</i> sp. <i>Crenomytilus grayanus</i> (Dunker, 1853) Subfam. Crenellinæ <i>Arvella japonica</i> (Dall, 1897) <i>Musculista senhousia</i> (Benson in Cantor, 1842) <i>Villosina pilula</i> Bartsch in Scarlato, 1960 Subfam. Modiolinæ <i>Modiolus modiolus</i> (Linnaeus, 1758) Subfam. Septiferinæ <i>Septifer (Mytilisepta) keense</i> Nomura, 1936 Ordo Ostreoida Superfam. Ostreoidæ Fam. Ostreidæ <i>Crassostrea gigas</i> (Thunberg, 1793) Superfam. Pectinoïdea Fam. Pectinidæ <i>Chlamys (Azumapekten) farreni</i> (Jones et Preston, 1904) <i>Mizuhopecten yessoensis</i> (Jay, 1857) Subclassis Heterodonta Ordo Veneroïda Superfam. Lucinoïdea Fam. Lucinidæ</p>	<p>100-400* 100* 100-700; 100-2600* 100-1500* 510* 100; 100-510* 600* 100* 100* 100-700* 100; 510*</p>	<p>0.0035-0.014* 0.0035 1.0-8.0; 0.0035-0.091* 0.0035-0.0525* 0.01785* 10.0; 0.0035-0.01785* 0.021* 0.0035* 0.0035* 0.0035* 0.0035-0.0245* 5.0; 0.1785*</p>	<p>1.1 1.1 1.2 2,6,7,9-12 10,12 1.1 6,12 1.2 1.1 - 1,3,8,9,12 - - 1 3 2,3,6-9 10,11 9 0.0035* 0.0035*</p>	<p>1.1,12 1.1 1.2 2,6,7,9-12 10,12 1.1 6,12 1.2 1.1 - 9,12 6,9,11,12 7 - - 12 12</p>
---	--	--	--	--

<p><i>Pillucina pisidium</i> (Dunker, 1860) Superfam. Glossoides Fam. Kellielidae <i>Alveinus ojanus</i> (Yokoyama, 1927) Superfam. Veneroides Fam. Veneridae <i>Mercenaria simpsoni</i> (Gould, 1861) <i>Venerupis</i> (Rudolphi) philippinarum (A. Adams et Reeve, 1850) Fam. Turtoniidae <i>Turtonia minuta</i> (Fabricius, 1780) Superfam. Tellinoides Fam. Tellinidae <i>Macoma</i> (<i>Macoma</i>) <i>centabulata</i> (Deshayes, 1854) <i>Macoma</i> sp. Ordo Myxida Subordo Myina Superfam. Myiodes Fam. Myidae <i>Mya</i> (<i>Arenomya</i>) <i>arenaria</i> Linnaeus, 1758 <i>Mya</i> sp. juv. Subordo Pholadina Superfam. Pholadoides Fam. Pholadidae <i>Barnes</i> sp. Fam. Teredinidae <i>Teredo japonica</i> Clessin in Kuster et Kabelt, 1893 <i>Bankia setacea</i> (Tryon, 1863) Subclassis Anomalodesmata Ordo Pholadomyoidea Superfam. Thracioidea Fam. Laternulidae <i>Laternula</i> (<i>Exolaternula</i>) <i>maritima</i> (Reeve, 1863) Phylum Arthropoda Subphylum Crustacea Superclassis Crustacea Classis Maxillopoda Subclassis Thecostraca</p>	<p>ZDO-51D* 1D0-30D; 18D-408D*</p> <p>1D0-36D0; 4D-320D*</p> <p>1D0 1D0*</p> <p>1D0; 51D* 1D0*</p> <p>1D0*</p> <p>51D-102D* 1D0-51D*</p> <p>5D0-75D0*</p> <p>ZD0-41D0*</p>	<p>0.007-0.01785* 3.0-35.8; 0.0035- 0.1428*</p> <p>2,4,6,8,12</p> <p>1,12</p> <p>5</p> <p>53.D 0.0035*</p> <p>1.0-5.0; 0.01785* 0.0035*</p> <p>0.0035*</p> <p>0.01785-0.0357* 0.0035-0.01785*</p> <p>0.00015-0.00225*</p>	<p>-</p> <p>-</p> <p>2,4,6,8,12</p> <p>1,12</p> <p>5</p> <p>-</p> <p>3,4,6,8</p> <p>-</p> <p>-</p> <p>5,8</p>	<p>7,9,11,12 6,7,9-12</p> <p>12</p> <p>9,1D</p> <p>9</p> <p>6 1D</p> <p>9</p> <p>6 7</p> <p>2,3,7(larvae)</p> <p>2,5,6,9-12 (juv.)</p>
---	--	--	---	---

<p>Fam. Paguridae</p> <p><i>Pagurus brachiomastus</i> (Thalwitzer, 1891)</p> <p><i>P. hirsutusculus</i> (Dana, 1851)</p> <p><i>P. middendorffii</i> Brandt, 1851</p> <p>Fam. Callinassidae</p> <p><i>Upogebia issaeffi</i> (Balss, 1913)</p> <p>Fam. Cancridae</p> <p><i>Cancer amphioebus</i> Rathbun, 1898</p> <p>Fam. Grapsidae</p> <p><i>Hemigrapsus penicillatus</i> (de Haan, 1835)</p> <p><i>H. sanguineus</i> (de Haan, 1835)</p> <p><i>Eriocheir japonicus</i> de Haan, 1835</p> <p>Subphylum Chelicerata</p> <p>Classis Arachnoidea</p> <p>Ordo Acarina</p> <p>Phylum Nematelminthes</p> <p>Classis Nematoda</p> <p>Subclassis Enoplia</p> <p>Ordo Enopliida</p> <p>Fam. Eriopidae</p> <p><i>Eriophus anisopikus</i> Nelson, Hopper et Webster, 1972</p> <p>Fam. Theracostronopsidae</p> <p><i>Eriopholaimus medius</i> Pavljuk, 1984</p> <p>Fam. Auticomidae</p> <p><i>Auticoma possjetica</i> Platonova, Belogurov et Scheenko, 1971</p> <p>Fam. Oncholaimidae</p> <p><i>Admirandus multicaeus</i> Belogurov et Belogurova, 1979</p> <p><i>Oncholaimium domesticum</i> Chitwood et Chitwood, 1938</p> <p><i>O. japonicum</i> Belogurov et Belogurova, 1981</p> <p><i>O. parasilium</i> Belogurov et Fadiseva, 1980</p> <p><i>O. ramosum</i> Simolanko et Belogurov, 1987</p> <p><i>O. unicum</i> Belogurov et Belogurova, 1978</p> <p><i>Oncholaimus brachycercus</i> de Man, 1889</p> <p><i>Pseudoncholaimus furugelmus</i> Belogurov, 1977</p> <p><i>P. mediocaudatus</i> Pavljuk, 1991</p> <p><i>P. vesicarius</i> (Wiesser, 1959) Belogurov, Belogurova et Pavljuk, 1975</p>	<p>100-500</p> <p>100</p> <p>200-2040*</p> <p>200-7140*</p> <p>Z00*</p> <p>500-85170*</p> <p>510-2550*</p> <p>500-10710*</p> <p>Z040*</p> <p>100-71400*</p> <p>120-63240*</p> <p>300-62730*</p> <p>40-5610*</p> <p>Z00-1020*</p> <p>Z00-78030*</p> <p>500-1600*</p> <p>40-78540*</p> <p>800*</p>	<p>8.7</p> <p>5.5-40.2</p> <p>0.8-58.0</p> <p>1.5-105.1</p> <p>0.0001-0.00102*</p> <p>0.0002-0.00714*</p> <p>0.0002*</p> <p>0.0005-0.008517*</p> <p>0.00051-0.00255*</p> <p>0.0005-0.01071*</p> <p>0.00204*</p> <p>0.0001-0.0714*</p> <p>0.00012-0.06324*</p> <p>0.0003-0.06273*</p> <p>0.0004-0.00561*</p> <p>0.0002-0.00102*</p> <p>0.0002-0.07803*</p> <p>0.0005-0.0016*</p> <p>0.00004-0.07854*</p>	<p>2,3,6,7,7a,10</p> <p>3-6</p> <p>1-3,6,7,10</p> <p>4</p> <p>3,6</p> <p>2-7,8,9,11</p> <p>1-</p> <p>3,6,7,9,10,12</p> <p>8</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>-</p>	<p>-</p> <p>-</p> <p>-</p> <p>-</p> <p>3,5,9-12</p> <p>6,7,9-12</p> <p>9</p> <p>6,7,12</p> <p>5,8</p> <p>3,6,7</p> <p>8</p> <p>6-9,9a,11</p> <p>2,5-7</p> <p>6,7,12</p> <p>3,9,9a,10,11</p> <p>6,11</p> <p>2,5-7,10</p> <p>2,5,12</p> <p>6,9,9a,10</p> <p>12</p>
--	--	---	--	--

**Species composition, population density and biomass of macrobenthos in
the intertidal communities of Kunashir Island, Kurile Islands**

(Tables 1-10)

Table 1

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the upper intertidal horizon in *Littorina sitkana* belt-forming community.

Taxa	Taxonomic-group*	Cape Rogacheva		Pervukhina Bay		Cape Krugly	
		N	B	N	B	N	B
Animals							
<i>Littorina sitkana</i>	Ga	5800	290.0	6700	45.0	91700	5260.0
<i>Falsicingula kurilensis</i>	Ga	-	-	+	+	2100	15.0
<i>Chthamalus dalli</i>	Ci	-	-	-	-	900	10.0
<i>Lottia pelta</i>	Ga	-	-	-	-	100	7.0
<i>Gnorimosphaeroma noblei</i>	Is	-	-	-	-	800	7.0
Total biomass			290.0		45.0		5299.0

* See Tables 1-10: Rh - Rhodophycota, Ph - Fucophycota, Ch - Chlorophycota, Mag - Magnoliophyta, Hy - Hydroidea, Ac - Actiniaria, Ne - Nemertini, Si - Sipuncula, Lo - Loricata, Ga - Gastropoda, Bj - Bivalvia, Po - Polychaeta, Ci - Cirripedia, Le - Leptostraca, Cu - Cumacea, Am - Amphipoda, Is - Isopoda, De - Decapoda, Pa - Pantopoda, Bry - Bryozoa, As - Ascidia, In - Insecta. The sign «+» designates species found within the limits of a considered community, but their abundance is not registered; the sign «-» means that species is not found.

Table 2

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the upper intertidal horizon in the *Chthamalus dalli* belt-forming community.

Taxa	Taxonomic group	Yuzhno-Kurilskaya Bay		Cape Rogacheva		Pervukhina Bay		Cape Krugly	
		N	B	N	B	N	B	N	B
Animals									
<i>Chthamalus dalli</i>	Ci	16300	2242.5	5000	70.0	2880	68.0	5400	125.0
<i>Semibalanus cariosus</i>	Ci	300	895.0	-	-	-	-	-	-
<i>Littorina sitkana</i>	Ga	5750	76.5	6100	50.0	2080	12.3	5800	27.0
<i>Nucella heyseana</i>	Ga	50	0.4	-	-	-	-	100	70.0
<i>Lottia borealis</i>	Ga	-	-	-	-	-	-	300	15.0
Spirorbidae	Po	-	-	-	-	-	-	-	5.2
Insecta (larvae)	In	600	5.0	-	-	-	-	-	-
Polychaeta	Po	150	4.0	-	-	-	-	-	-
<i>Typosyllis adamanteus kurlensis</i>	Po	50	1.5	-	-	-	-	-	-
<i>Cliamenella fraudatrix</i>	Is	-	-	-	-	-	-	200	0.2
Amphipoda	Am	50	0.1	-	-	-	-	-	-
Total biomass			3425.0		120.0		80.3		242.4

Table 3.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the middle intertidal horizon in the *Silvetia babingtonii* belt-forming community.

Taxa	Taxonomic group	Yuzhno-Kurilskaya Bay		Cape Rogacheva		Pervukhina Bay		Cape Krugly	
		N	B	N	B	N	B	N	B
Plants									
<i>Silvetia babingtonii</i>	Ph		25080.0		18440.0		1508.0		5512.8
<i>Fucus evanescens</i>	Ph		-		10.0		71.6		-
<i>Cladophora opaca</i>	Ch		-		-		21.6		-
<i>Ulva fenestrata</i>	Ch		-		-		4.0		-
Total plants			25080.0		18450.0		1605.2		5512.8
Animals									
<i>Chthamalus dalli</i>	Ci	4640	224.0	240	13.6	-	-	120	2.8
<i>Littorina sitkana</i>	Ga	280	18.0	18400	360.0	440	3.2	1840	280.0
<i>Hyale bassargini</i>	Am	440	18.0	920	12.0	+	+	-	-
Spirorbidae	Po	-	-	-	-	-	-	-	28.0
<i>Lottia borealis</i>	Ga	-	-	160	20.4	+	+	-	-
<i>L. patina</i>	Ga	-	-	-	-	40	0.4	-	-
<i>L. pelta</i>	Ga	-	-	-	-	-	-	80	6.0
<i>Hima fratercula</i>	Ga	-	-	-	-	-	-	120	12.0
<i>Falsicingula kurilensis</i>	Ga	-	-	-	-	1680	5.2	160	0.4
<i>Nucella heyseana</i>	Ga	+	+	+	+	+	+	40	8.8
<i>Turtonia minuta</i>	Bi	-	-	-	-	360	1.2	-	-
<i>Ansola angustata</i>	Ga	40	0.2	-	-	-	-	-	-
<i>Gnorimosphaeroma noblei</i>	Is	-	-	40	0.04	-	-	-	-
<i>Abietinaria filicula costata</i>	Hy		+		0.2		-		-
Polychaeta	Po	80	3.2	-	-	-	-	-	-
Total animals			263.4		406.24		10.0		338.0
Total biomass			25343.4		18856.2		1615.2		5850.8

Table 4.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the middle intertidal horizon in the *Fucus evanescens* community.

Taxa	Taxonomic group	Yuzhno-Kurilskaya Bay		Cape Rogacheva		Pervukhina Bay		Cape Krugly	
		N	B	N	B	N	B	N	B
Plants									
<i>Fucus evanescens</i>	Ph		16264.0		8208.0		3232.0		10440.0
<i>Silvetia babingtonii</i>	Ph		-		-		-		5680.0
<i>Cladophora opaca</i>	Ch		-		-		76.8		-
<i>Chaetomorpha moniligera</i>	Ch		-		-		36.8		-
<i>Corallina pilulifera</i>	Rh		-		-		+		8.8
<i>Ulva fenestrata</i>	Ch		-		-		5.2		-
Total plants			16264.0		8208.0		3350.8		16128.8
Animals									
<i>Littorina sitkana</i>	Ga	160	2.4	4720	128.0	520	6.0	41120	1388.8
<i>Falsicingula kurilensis</i>	Ga	-	-	-	-	6920	22.0	119240	428.8
<i>Hima fratercula</i>	Ga	-	-	-	-	-	-	1320	66.0
<i>Nucella freycinetii</i>	Ga	+	+	80	36.0	-	-	-	-
<i>N. heyseana</i>	Ga	+	+	+	+	+	+	40	32.0
<i>Hyale bassargini</i>	Am	-	-	1400	6.0	40	0.2	680	2.8
<i>Chthamalus dalli</i>	Ci	-	-	160	6.0	-	-	-	-
<i>Ambithoe kussakini</i>	Am	-	-	-	-	360	1.4	200	1.6
<i>Lottia borealis</i>	Ga	-	-	+	+	40	4.8	-	-
<i>Anisogammarus spasski</i>	Am	-	-	-	-	-	-	240	0.7
<i>Turtonia minuta</i>	Bi	-	-	-	-	320	0.8	-	-
<i>Gnorimosphaeroma noblei</i>	Is	160	0.4	+	+	-	-	-	-
<i>Parallorchestes ochotensis</i>	Am	-	-	-	-	+	+	40	0.3
<i>Allorchestes malleolus</i>	Am	-	-	-	-	-	-	40	0.2
<i>Lacuna minor</i>	Ga	80	0.2	-	-	-	-	-	-
Amphipoda	Am	120	4.8	-	-	-	-	-	-
Total animals			7.8		176.0		35.2		1921.2
Total biomass			16271.8		8384.0		3386.0		18050.0

Table 5.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the middle intertidal horizon in the *Corallina pilulifera* community.

Taxa	Taxonomic group	Yuzhno-Kurilskaya Bay		Cape Krugly	
		N	B	N	B
Plants					
<i>Corallina pilulifera</i>	Rh		1560.0		1530.0
Total plants			1560.0		1530.0
Animals					
<i>Falsicingula kurilensis</i>	Ga	3600	11.0	39700	150.0
<i>Hima fratercula</i>	Ga	-	-	2400	97.0
<i>Littorina sitkana</i>	Ga	-	-	5400	95.0
<i>Nereis pelagica</i>	Po	1000	30.0	-	-
<i>Nereis</i> sp.	Po	100	0.6	-	-
<i>Ampithoe kussakini</i>	Am	-	-	2200	13.3
<i>Nucella heyseana</i>	Ga	100	12.0	-	-
<i>Synidotea lata</i>	Is	100	8.3	-	-
<i>Polychaeta</i>	Po	-	-	300	8.0
<i>Telemessus cheiragonus</i>	De	300	7.0	-	-
<i>Paraliorchestes ochotensis</i>	Am	-	-	1500	5.3
<i>Typosyllis adamanteus kurilensis</i>	Po	100	2.5	-	-
<i>Lyonsia</i> sp.	Bi	200	2.1	-	-
<i>Orchomena</i> sp.	Am	-	-	200	1.3
<i>Ciamenella fraudatrix</i>	Is	-	-	100	0.5
<i>Schizoplax brandtii</i>	Lo	-	-	100	1.0
<i>Orchomenella</i> sp.	Am	100	0.8	-	-
<i>Corophium</i> sp.	Am	-	-	100	0.8
<i>Turtonia minuta</i>	Bi	100	0.5	-	-
<i>Mytilus trossulus kussakini</i>	Bi	100	0.1	-	-
Sabellidae	Po	-	1.0	-	-
Pantopoda	Pa	200	0.5	-	-
Total animals			76.4		372.2
Total biomass			1636.4		1902.2

Table 6. Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the intertidal pools in the *Phyllospadix iwatensis* community.

Taxa	Taxonomic group	Yuzhno-Kurilskaya Bay		Cape Rogacheva		Pervukhina Bay		Cape Krugly	
		N	B	N	B	N	B	N	B
Plants									
<i>Phyllospadix iwatensis</i>	Mag		5528.0		8320.0		10928.0		620.0
<i>Corallina pilulifera</i>	Rh		-		292.0		+		6.0
Total plants			5528.0		8612.0		10928.0		626.0
Animals									
<i>Oulactis orientalis</i>	Ac	80	604.0	-	-	-	-	+	+
<i>Naineris jacutica</i>	Po	5080	404.0	1160	33.3	80	24.0	480	21.4
<i>Chone teres</i>	Po	6240	364.0	-	-	11840	390.0	2560	90.0
<i>Nucella heyseana</i>	Ga	80	130.0	+	+	40	0.8	+	+
<i>N. freycinetii</i>	Ga	+	+	+	+	-	-	-	-
<i>Telmessus cheiragonus</i>	De	40	80.0	+	+	+	+	-	-
<i>Eudistylia polymorpha</i>	Po	40	48.0	-	-	-	-	-	-
<i>Protothaca euglypta</i>	Bi	-	-	760	48.0	40	8.0	-	-
<i>Nereis vexillosa</i>	Po	120	35.0	+	+	40	31.4	80	25.5
<i>N. zonata</i>	Po	-	-	-	-	80	5.0	80	1.4
<i>N. pelagica</i>	Po	-	-	560	18.9	-	-	-	-
<i>Pseudopotamilla ocellata</i>	Po	40	34.8	-	-	-	-	-	-
<i>Littorina sitkana</i>	Ga	120	16.0	1640	20.0	-	-	-	-
<i>Phascolosoma japonicum</i>	Si	-	-	40	16.0	-	-	-	-
Cirratulidae	Po	-	-	-	-	+	+	240	11.2
<i>Idotea ochotensis</i>	Is	80	10.0	+	+	40	0.4	+	+
<i>I. gurjanovae</i>	Is	-	-	-	-	-	-	+	+
<i>Hima fratercula</i>	Ga	-	-	+	+	-	-	40	8.0
<i>Glycinde armigera</i>	Po	-	-	-	-	40	6.4	80	5.6
<i>Hiatella arctica</i>	Bi	-	-	80	4.8	-	-	-	-
<i>Eudendrium annulatum</i>	Hy		4.4		0.4		-		-
<i>Eteone longa</i>	Po	120	4.0	-	-	-	-	-	-
Polynoidae	Po	40	3.6	-	-	+	+	-	-
Maldanidae	Po	-	-	-	-	-	-	200	2.4
<i>Capitella capitata</i>	Po	-	-	-	-	40	0.4	120	2.0

<i>Ampithoe kussakini</i>	Am	40	2.0	-	-	+	+	+	+	+
<i>Falsicingula kurilensis</i>	Ga	40	0.4	1000	2.0	80	0.4	-	-	-
<i>Lumbrineris</i> sp.	Po	-	-	80	1.5	-	-	40	1.0	1.0
<i>Typosyllis adamanteus kurilensis</i>	Po	-	-	-	-	-	-	40	1.2	1.2
<i>Typosyllis</i> sp.	Po	80	1.0	-	-	-	-	-	-	-
<i>Typosyllis orientalis</i>	Po	40	0.2	40	0.2	-	-	-	-	-
<i>Mysella kurilensis litoralis</i>	Bi	-	-	40	0.4	120	1.0	-	-	-
<i>Epheria turrita</i>	Ga	-	-	-	-	40	0.8	-	-	-
<i>Pontogeneia</i> sp.	Am	-	-	-	-	160	0.8	-	-	-
Pantopoda	Pa	-	-	80	0.8	-	-	-	-	-
Bryozoa	Bry	-	-	-	0.8	-	-	-	-	-
<i>Sertularia similis</i>	Hy	-	-	-	0.4	-	-	-	-	-
<i>Lacuna minor</i>	Ga	-	-	-	-	40	0.4	-	-	-
<i>Turtonia minuta</i>	Bi	-	-	-	-	80	0.4	-	-	-
<i>Thethygeneia kondakovi</i>	Am	-	-	-	-	80	0.3	-	-	-
<i>Anonyx</i> sp.	Am	-	-	-	-	40	0.3	-	-	-
<i>Gnrimosphaeroma noblei</i>	Is	40	0.3	-	-	80	0.1	-	-	-
<i>Abietinaria filicula costata</i>	Hy	-	+	-	0.2	-	-	-	-	-
<i>Parallorchestes ochotensis</i>	Am	-	-	-	-	40	0.2	+	+	+
<i>Holotelson tuberculatus</i>	Is	-	-	-	-	40	0.2	+	+	+
<i>Cleantella isopus</i>	Is	-	-	-	-	40	0.04	-	-	-
Total animals			1741.7		147.7		471.34		169.7	169.7
Total biomass			7269.7		8759.7		11399.3		795.7	795.7

Table 7.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the lower horizon of the intertidal zone in the brown algae communities.

Taxa	Taxonomic group	Cape Krugly			Pervukhina Bay		
		Sargassum thunbergii		N	Sargassum miyabei		N
		B	N		B	N	
Plants							
<i>Sargassum thunbergii</i>	Ph	6008.0					
<i>S. miyabei</i>	Ph	-		1992.0		36.0	
<i>Scytosiphon lomentaria</i>	Ph	-		-		4280.0	
<i>Neorhodomela larix</i>	Rh	-		644.0		200.0	
<i>Mastocarpus pacificus</i>	Rh	-		273.2		-	
<i>Corallina pilulifera</i>	Rh	73.6		28.0		-	
<i>Ulva fenestrata</i>	Ch	-		-		-	1.6
<i>Costaria costata</i>	Ph	-		-		-	24.8
<i>Tichocarpus crinitus</i>	Rh	-		-		-	8.8
<i>Chordaria flagelliformis</i>	Ph	-		-		-	6.0
<i>Laurencia nipponica</i>	Rh	-		-		-	4.0
<i>Porphyra</i> sp.	Rh	-		-		-	4.0
Total plants				2937.2		4516.0	2.0
Animals							4579.2
<i>Falsiclingula kurilensis</i>	Ga	16200	22600	57.9	6760	22.0	40
<i>Hima fratercula</i>	Ga	40	640	58.0	-	-	-
<i>Littorina sitkana</i>	Ga	40	600	30.0	-	-	-
<i>Homalopoma sangarense</i>	Ga	-	80	30.0	+	+	+
<i>Nucella heyseana</i>	Ga	120	-	-	-	-	-
<i>Hyale bassargini</i>	Am	24160	200	0.8	200	0.6	-
<i>Idotea ochotensis</i>	Is	-	40	14.0	-	-	-
<i>Lottia borealis</i>	Ga	80	-	9.2	-	-	-
<i>Pusillina plicosa</i>	Ga	-	1440	9.1	80	0.3	-
<i>Ambithoe</i> sp.	Am	-	-	-	120	0.8	-
<i>Amphithoe kussakini</i>	Am	480	440	7.4	120	1.0	360
<i>A. japonica</i>	Am	-	-	-	40	1.2	-
<i>Telemessus cheiragonus</i>	De	-	40	2.0	40	3.2	-
Polynoidae	Po	-	-	-	40	3.0	-
<i>Ischyrocerus</i> sp.	Am	2960	-	-	-	-	-
<i>I. cristatus</i>	Am	40	40	0.08	-	-	-
<i>I. anquipes</i>	Am	-	40	0.08	-	-	-
<i>Nereis</i> sp.	Po	-	-	-	40	2.0	-
<i>Harmothoe imbricata</i>	Po	-	40	2.0	-	-	-

Actiniidae juv.	Ac	-	-	-	-	40	2.0	-	-	-
<i>Caprella bispinosa</i>	Am	-	-	120	0.5	-	-	520	-	1.3
<i>C. cristibrachium</i>	Am	840	0.7	-	-	-	-	-	-	-
<i>Caprella</i> sp.	Am	-	-	80	0.2	80	0.1	-	-	-
<i>Metopa</i> sp.	Am	440	0.8	-	-	-	-	-	-	-
<i>Turtonia minuta</i>	Bi	40	0.2	-	-	160	0.8	-	-	-
<i>Holotelson tuberculatus</i>	Is	-	-	360	0.5	-	-	-	-	-
<i>Protothaca euglypta</i>	Bi	-	-	-	-	40	0.5	-	-	-
<i>Typosyllis</i> sp.	Po	-	-	40	0.4	-	-	-	-	-
<i>Pagurus</i> sp. juv.	De	-	-	100	0.4	-	-	-	-	-
<i>Pontogenela</i> sp.	Am	120	0.3	-	-	-	-	-	-	-
<i>Ciamenella fraudatrix</i>	Is	120	0.2	-	-	-	-	-	-	-
<i>Parallorchestes ochotensis</i>	Am	-	-	-	-	40	0.2	-	-	-
<i>Pleusymtes</i> sp.	Am	-	-	80	0.2	-	-	-	-	-
Pantopoda	Pa	-	-	-	-	40	0.02	-	-	-
Total animals			131.2		213.56		37.72			5.3
Total biomass			6212.8		3150.8		4553.7			4584.5

Table 8.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the communities in the intertidal pool at Cape Rogacheva.

Taxa	Taxonomic group	Corallina pilulifera		Neodilsea yendoana		Pterosiphonia bipinnata		Chaetomorpha melagonium		Chaetomorpha linum		Neorhodomela larix+N. oregona	
		N	B	N	B	N	B	N	B	N	B	N	B
Plants													
<i>Corallina pilulifera</i>	Rh		1282.0		200.0		-		-		10.0		81.3
<i>Neodilsea yendoana</i>	Rh		+		3950.0		-		-		-		-
<i>Pterosiphonia bipinnata</i>	Rh		-		-		6950.0		-		-		-
<i>Neorhodomela larix</i>	Rh		-		-		-		177.0		-		1832.5
<i>N. oregona</i>	Rh		-		-		-		-		-		975.0
<i>N. munita</i>	Rh		1.0		-		-		-		-		-
<i>Cladophora opaca</i>	Ch		10.0		-		-		-		-		-
<i>Chaetomorpha melagonium</i>	Ch		-		-		-		320.0		+		-
<i>Ch. linum</i>	Ch		-		-		-		-		2620.0		12.5
<i>Ch. moniligera</i>	Ch		0.5		-		-		-		-		-
<i>Ch. tortuosa</i>	Ch		-		-		-		-		+		-
<i>Phyllospadix iwatensis</i>	Mag		-		-		-		-		-		6.3
Total plants			1293.5		4150.0		6950.0		497.0		2630.0		2907.6
Animals													
<i>Littorina sitkana</i>	Ga	6400	20.0	200	2.0	200	5.0	1500	4.1	7300	30.0	6575	113.5
<i>Chthamalus dalli</i>	Ci	-	-	-	-	500	100.0	-	-	-	-	-	-
<i>Nereis pelagica</i>	Po	-	-	-	-	1700	50.0	-	-	-	-	-	-
<i>Falsicingula kurilensis</i>	Ga	9700	39.0	-	-	300	0.6	900	1.0	700	5.0	375	1.8
<i>Idotea ochotensis</i>	Is	-	-	80	25.0	-	-	-	-	-	-	25	0.2
<i>Pontogeneia</i> sp.	Am	-	-	-	-	1400	3.0	-	-	-	-	6175	20.2
<i>Hyale bassargini</i>	Am	-	-	100	9.0	4000	16.6	100	17.4	500	2.0	225	0.6
<i>Cliamenella fraudatrix</i>	Is	400	1.0	100	0.5	9400	17.0	-	-	100	0.7	650	1.3

<i>Nucella heyseana</i>	Ga	100	1.0	-	-	-	-	-	-	-	-	-	-	-	-	50	15.0
<i>N. freycinetii</i>	Ga	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ascidia	As		-		5.0												
Polychaeta	Po	200	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hima fratercula</i>	Ga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	2.5
<i>Panomya</i> sp.	Bi	-	-	-	-	200	2.0	-	-	-	-	-	-	-	-	-	-
<i>Lottia borealis</i>	Ga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	1.0
<i>Abietinaria filicula costata</i>	Hy		-		1.0												
<i>Allorchestes malleolus</i>	Am	-	-	100	1.0	-	-	-	-	-	-	-	-	-	-	-	-
<i>Gnorimosphaeroma noblei</i>	Is	-	-	-	-	-	-	-	-	100	0.6	-	-	-	-	-	-
<i>Hiatella arctica</i>	Bi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	0.5
<i>Ischyrocerus</i> sp.	Am	-	-	100	0.4	-	-	-	-	-	-	-	-	-	-	25	0.03
Total animals			66.0		43.9		194.2				22.5				39.3		156.63
Total biomass			1359.5		4193.9		7144.2				519.5				2668.3		3064.2

Table 9.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the lower horizon of the intertidal zone in the Laminariales communities.

Taxa	Taxonomic group	Yuzhno-Kurilskaya Bay						Pervukhina Bay			Cape Rogacheva		
		Laminaria sp.		Laminaria sp.		Alaria ochotensis		Laminaria sp.		Alaria ochotensis		Alaria ochotensis	
		N	B	N	B	N	B	N	B	N	B	N	B
Plants													
<i>Laminaria</i> sp.	Ph		106880.0		10280.0								+
<i>Alaria ochotensis</i>	Ph		-		-								8850.0
<i>Pterosiphonia bipinnata</i>	Rh		-		-								596.0
<i>Iridaea cornucopiae</i>	Rh		-		-								164.0
<i>Corallina pilulifera</i>	Rh		-		-								46.0
<i>Analipus japonicus</i>	Ph		-		-								13.0
Total plants			106880.0		10280.0								9669.0
Animals													
<i>Semibalanus cariosus</i>	Ci	-	-		-						500		827.0
<i>Chthamalus dalli</i>	Ci	-	-		-						1740		420.0
<i>Nucella freycinetii</i>	Ga	-	-		-						80		67.8
<i>Eudendrium annulatum</i>	HY		56.0		-								0.4
<i>Lottia pelta</i>	Ga	-	-		-						200		50.0
<i>Mytilus trossulus kussakini</i>	Bi	-	-		-						60		49.0
<i>Littorina sitkana</i>	Ga	-	-		-						2380		43.0
<i>Falsicingula kurilensis</i>	Ga	-	-		600						-		-
<i>Parallorchestes ochotensis</i>	Am	60	0.8		-						560		28.0
<i>Parallorchestes</i> sp.	Am	80	1.0		-						-		-
<i>Nereis pelagica</i>	Po	280	6.5		-						720		15.0
<i>N. vexillosa</i>	Po	-	-		-						+		+
<i>N. zonata</i>	Po	-	-		-						+		+

<i>Hiatella arctica</i>	Bi	-	-	-	-	-	-	-	380	10.0
Nemertini	Ne	-	-	-	-	-	-	-	60	4.0
<i>Cliamenella fraudatrix</i>	Is	-	-	-	-	-	-	-	640	1.6
<i>Typosyllis</i> sp.	Po	80	0.06	120	1.2	-	-	-	-	-
<i>Ampithoe volki</i>	Am	-	-	360	1.0	-	-	-	-	-
<i>A. kussakini</i>	Am	-	-	40	0.2	-	-	-	-	-
<i>Naineris jacutica</i>	Po	20	0.8	-	-	-	-	-	-	-
<i>Chone</i> sp.	Po	80	0.7	-	-	-	-	-	-	-
<i>Hyale bassargini</i>	Am	120	0.6	40	0.2	-	-	80	0.2	0.2
<i>Jassa marmorata</i>	Am	-	-	-	-	-	-	60	0.4	0.4
<i>Musculista senhousia</i>	Bi	-	-	-	-	-	-	620	0.2	0.2
<i>Campanularia volubilis</i>	Hy	-	0.2	-	-	-	-	-	-	-
<i>Pontogeneia</i> sp.	Am	-	-	40	0.2	-	-	-	-	-
<i>Capitella capitata</i>	Po	40	0.2	-	-	-	-	-	-	-
Pantopoda	Pa	20	0.1	-	-	-	-	-	-	-
<i>Corophium</i> sp.	Am	20	0.02	-	-	-	-	-	-	-
Total animals			66.98		34.8					1516.0
Total biomass			106947.0		10314.8					11185.0

Table 10.

Population density (N, indiv. m⁻²) and biomass (B, gWW m⁻²) of macrobenthos in the intertidal zone in the belt-forming communities at Izmeny Bay.

Taxa	Taxonomic group	<i>Batillaria cumingii</i>		<i>Zostera japonica</i>		<i>Zostera marina</i>	
		N	B	N	B	N	B
Plants							
<i>Zostera japonica</i>	Mag		-		1427.7		-
<i>Z. marina</i>	Mag		-		-		1265.6
<i>Chordaria</i> sp.	Ph		-		60.0		-
Total plants			-		1487.7		1265.6
Animals							
<i>Batillaria cumingii</i>	Ga	1600	445.6	140	67.6	200	77.6
<i>Ruditapes philippinarum</i>	Bi	80	15.6	30	342.3	80	1027.6
<i>Hima fratercula</i>	Ga	120	22.8	80	11.3	-	-
<i>H. multigranosa</i>	Ga	-	-	-	-	120	9.6
<i>Abarenicola pacifica</i>	Po	80	15.6	100	12.8	40	0.2
<i>Nereis vexillosa</i>	Po	-	-	140	14.1	120	12.8
<i>N. brandti</i>	Po	-	-	-	-	40	6.0
<i>N. pelagica</i>	Po	-	-	-	-	120	2.8
<i>Nereis</i> sp.	Po	-	-	150	0.1	-	-
<i>Macoma incongrua</i>	Bi	-	-	30	2.5	40	7.6
<i>Naineris jacutica</i>	Po	-	-	-	-	80	4.6
<i>Glycinde armigera</i>	Po	-	-	-	-	40	4.2
<i>Neanthes japonica</i>	Po	40	4.0	-	-	-	-
<i>Chone</i> sp.	Po	-	-	-	-	840	3.6
<i>Gnorimosphaeroma noblei</i>	Is	-	-	240	1.3	-	-
<i>Polychaeta</i>	Po	-	-	30	0.9	-	-
<i>Orchomene</i> af. <i>magdalenensis</i>	Po	-	-	150	0.7	-	-

<i>Turtonia minuta</i>	Bi	-	-	160	0.4	-	-	-
<i>Cerythiopsis stejneri</i>	Ga	-	-	-	-	80	0.4	-
<i>Pusilina plicosa</i>	Ga	-	-	-	-	200	0.2	-
<i>Ampithoe</i> sp.	Am	-	-	10	0.1	-	-	-
<i>Gastropoda</i> juv.	Ga	-	-	30	0.1	-	-	-
<i>Dogielinotus moskvitini</i>	Am	-	-	10	0.07	-	-	-
<i>Falsicingula kurilensis</i>	Ga	-	-	30	0.05	-	-	-
<i>Minolia iridescens</i>	Ga	-	-	-	-	840	0.04	-
<i>Allorchestes malleolus</i>	Am	-	-	10	0.01	-	-	-
<i>Leptostraca</i>	Le	-	-	10	0.01	-	-	-
Cumacea	Cu	-	-	10	0.01	-	-	-
Total animals			503.6		454.35		1157.32	
Total biomass			503.6		1942.1		2422.9	

Funding sources outside the APN

The following institutions and agencies provided in-kind support:

Institute of Marine Biology FEB RAS (IMB FEB RAS), Vladivostok, Russia

Institute of Oceanology CAS, Qingdao, China (IOCAS), Qingdao, China

Cheju National University (CNU), Jeju, Korea

Glossary of Terms (acronyms and abbreviations)

APN – Asia-Pacific Network For Global Change Research

CAS – Chinese Academy of Sciences

CNU – Cheju National University

FEB RAS – Far East Branch, Russian Academy of Sciences

IGBP – International Geosphere-Biosphere Programme

IHDP – International Human Dimension Programme

IMB FEB RAS – Institute of Marine Biology FEB RAS

IOCAS – Institute of Oceanology, Chinese Academy of Sciences

LOICZ – Land-Ocean Interactions in the Coastal Zone (IGBP)

RAS – Russian Academy of Sciences

SCSIOCASA – South China Sea Institute of Oceanology, Chinese Academy of Sciences

START – Global Change System for Analysis, Research and Training