Asia-Pacific Network for Global Change Research

Climate Variability and Human Activities in Relation to Northeast Asian Land-Ocean Interactions and Their Implications for Coastal Management

Final report for APN project 2005-05-CMY-Adrianov

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Final Report submitted to APN

Overview of project work and outcomes

Summary

In course of the 2-year APN-funded project, new data on estuarine and coastal changes in areas adjoining the Amur, Tumen and Razdolnaya Rivers were obtained, and recommendations for management of sustainable coastal development of the region are presented including China and Korea coastal zones. Two expeditions to Amur and Razdolnaya Rivers mouth areas were organized, and hydrological regime, oceanography, environmental contamination, state of benthic and plankton comminities were investigated in connection with climatic changes. Three workshops were held: in Nanjing, China, Dec. 2004; Training Course for Young Scientists, Vladivostok, Russia, Oct. 2005; back-to-back with a science session for local policy-makers; in Vladivostok, May 2006. A website of the project was created (http://www.imb.dvo.ru/misc/apn/index.htm), and two books, *Ecological Studies and State of the Ecosystem of Amursky Bay and Razdolnaya River Mouth* and a collective monograph are in preparation. Two books and 19 papers in peer-reviewed journals were published and/or prepared. Future directions may include comparison of different coastal management strategies and understanding of how we can use these national strategies to develop complex management approach.

Objectives

The main objectives of the project were:

1. to identify estuarine and coastal changes in terms of hydrology, hydrochemistry, geochemistry, geomorphology, ecosystem and material cycling patterns of the Northeastern Asia region, with special reference to the Amur, Tumen and Razdolnaya Rivers;

2. to evaluate the sensitivity of regional changes in relation to anthropogenic processes and climate change;

3. to provide recommendations to management of sustainable coastal development of the region and to provide assistance to policy/decision makers.

Amount received for each year supported and number of years supported

2004–2005 – 60,000 USD
2005–2006 – 58,000 USD

Participating Countries

Participants from the following countries were funded: P.R. China, Republic of Korea and Russia.

Work undertaken

One the main activities in course of the project was collection, compilation and collation of the existing data sets and literature reviews on the changes in coastal and near-estuarine areas which included the following topics: climatic tendencies in the North East Asia and Northwest Pacific; climatic changes and river discharges; seasonal and annual variability of the concentration and output of nutrients by the Razdolnaya (Suyfun) River (Russia); concentration of metals in the rivers of the southern part of the Russian Far East; state of coastal ecosystems in near-estuarine areas of Razdolnaya (Suyfun), Tumen and Amur Rivers (Russia); long-term changes in the hydrological regime of the Amur River; changes in material fluxes from the Changjiang (Yangtze) River in China; coastal zone management in China; environment management for Han River estuary in Korea; and nature management within the Russian Far East coastal zones.

Expeditions and field-works. In 2005, two expeditions were undertaken: 1) expedition to the Razdolnaya (Suifun) River mouth and neigboring areas of Amursky Bay, Sea of Japan, June–

September, 2005; and 2) expedition with the R/V *Professor Gagarinsky* to the Amur River estuary, July, 2005 (see details about both expeditions: http://www.imb.dvo.ru/misc/apn/e_017.htm). Chinese team carried our field-works in 2005–2006 in Changjiang (Yangtze) and Tumen Rivers.

Workshops. First project workshop, *Climate variability and human activities in relation to Northeast Asian land-ocean interactions and their implications for coastal zone management,* was held in Nanjing University, Nanjing, China, from 4 to 9th December **2004** (Co-organizers, Prof. Shu Gao and Dr. Konstantin A. Lutaenko). Main themes discussed during the workshop were as follows: Good aquaculture practice for sustainable coastal management; Nature management within the Russian Far East coastal zones; Study of the state of coastal ecosystems in the near-estuarine area of Razdolnaya River: comparative analysis of the data of 1980s, 1990s and 2000s; Environment management strategy for Han River estuary in Korea; Long-term changes in the hydrological regime of the Amur River; The impact of climate variability and human activities on flood and drought disaster in the Yangtze Valley; Change in Changjiang suspended load after completion of the Three-Gorges Dam and its impacts on the delta evolution; The changes of sediment concentration and discharge in recent five years from the Pearl River to the Pearl River Delta. The workshop was accompanied by the business meeting to discuss the science plan and implementation strategy structure of the project, and field excursion to the apex areas of the Changjiang (Yangtze) River delta.

In **2005**, *Training Course for Young Scientists in Global Change*, October 24–26, 2005 and *Scientific Session for Russian Policy-makers* focussing on the project activities, October 27, **2005** were held.. During both workshops, the following topics were covered: Comparative analysis of environmental changes in the area of Tumen and Razdolnaya Rivers; Climate variability in Northeast Asia; Complex management problems within coastal zones of the Far East; Sea-level rise in the Sea of Japan and its practical aspects; Ecological State of Amursky Bay; Biomarkers of marine environment contamination; Long-term changes in the coastal zone and marine environment in Hong Kong; Chemical and microbiological monitoring of the marine environment. In addition to collecting new information about environmental and coastal changes for the Russian rivers, Korean and Chinese collaborators continued to collect data on the climate variability, human activities, river runoff, changes in physical environment of the coast, material cycling pattern, ecosystem characteristics, and implications on CZM in their area as to be parts of planned joint monograph.

In **2006**, *Final Workshop* for authors of the planned collective monograph was held in Vladivostok (May, 24–26). It was decided that future monograph will include the following chapters: Introduction, Climate variability, Human activities, River runoff, Changes in physical environment of the coast, Material cycling patterns, Ecosystem characteristics, Intercomparison, Implications on CZM, Summary and knowledge gaps.

Results

Climate. It was shown that ENSO signal and climatic trends in the Northwest Pacific marginal area have similar seasonality and major patterns. Anomaly of ENSO cycle with El Nino prevailing during last several decades seems to be related to semi-centennial tendencies in the Northwest Pacific and Northeast Asia. The significant ENSO signal in the NW Asian-Pacific thermal conditions in the ocean and over land including Okhotsk Sea area shows inversed anomalies in winter and summer in the subarctic area. The surface air temperature anomalies in Okhotsk Sea area and SSTs in the subarctic North Pacific are very sensitive to the extratropic ENSO signal.

Riverine changes. Changes in the water regime of the Amur River in the last 100 years have led to the disturbance of the ecological equilibrium in the valley of the lower Amur. These changes are fairly dynamic and occur not only in the floodplain of the Amur River, but also in the neighboring flat and mountain territories and in the adjacent areas of the Okhotsk and Japan seas. Razdplnaya River is characterized by the elevated level of easy oxidisable organic substances and ammonium. Relatively increased concentration of these components is observed upstream of river that is caused, probably, by anthropogenic influence in the Chinese part of Razdolnaya River. The phosphates and nitrates concentration in the upstream of Razdolnaya River is close to the basic level. Despite obvious and significant anthropogenic influence on metal concentration in solution and suspended solids of Razdolnaya River, self-cleaning ability of the river is sufficient and in the downstream concentration of the dissolved metals is reduced close to basic level. The basic mechanism of self-cleaning is, probably, sorption on suspended matter. Concentration of metals in downstream of Tumen River does not show heavy anthropogenic press, but dissolved Cu, Zn and Cu in suspended matter are higher as compared to downstream of Razdolnaya River and unpolluted rivers of the southern Russian Far East.

Within the catchment basin of the Changjiang River, the construction of more than 48000 dams within the river valley has led to sediment discharge reduction by 40% over the last 20 years. In the near future, the mean freshwater discharge will also change, with a more significant seasonal variability, in response to the water diverting scheme for water supply to northern China. In contrast, the discharge of nutrients (N and P) of the river has been increasing, due to the extensive use of chemical fertilizers and the large output of industrial and domestic sewage. These changes modify the coastal and shelf oceanographic conditions. The flushing time becomes longer in summer but shorter in winter. Increase in the nutrient input, in association with the shelf environmental setting, generates additional primary and secondary production for the East China Sea region; this, in turn, enhances fishery potential and fishery catch. At the same time, the enhancement of nitrogen input and the biological productivity give rise to red tides, with a possibility that in the future red tides will occur more frequently when the freshwater discharge and the suspended sediment concentration in the estuarine waters are reduced.

Environmental changes in coastal zone. Based on the analysis of long-term data on the density of microalgae in the water, the level of the sediment contamination with oil hydrocarbons, heavy metals and organochlorine pesticides, and the state of benthic communities, no positive conclusion about improvement of the state of coastal ecosystems in Amursky Bay and estuarine zone of Razdolnaya River in 2000s as compared to 1980s and 1990s can be made. Decreasing trends have been revealed for concentrations of oil hydrocarbons and cadmium in the sediments, while concentrations of other metals and total DDTs remained rather high. Moreover, input of "fresh" DDT in the ecosystem of Amursky Bay was registered in 2001–2002. The Razdolnaya River runoff has contributed to the enrichment of adjacent waters of the bay in organic matter and oil hydrocarbons but not technogenic heavy metals and DDT. Biodiversity of the species forming bottom communities of soft sediments has significantly decreased in 2001 compared to 1986–1989. We believe that chronic pollution of the bay is the major cause of negative changes in the state of its biota.

In the near-estuarine zone of Tumen River, negative effects of pollution are recorded at different trophic levels from primary producers to mammals and humans. In connection with pollution following phenomena are found to be the most dangerous to the marine biota:oxygen deficiency in the near-bottom water layer, as a result of dissolved oxygen consumption for the oxidation of organic compounds; disturbance of the nutrient balance due to the input of large amounts of organic and mineral nitrogen and phosphorus compounds into the coastal waters, i.e., eutrophication of the water; bioaccumulation of toxic substances by marine organisms.

Coastal zone management recommendations. Social-economic and environmental issues recently emerged in China's coastal zone were identified and examined. Evaluation of management scheme and progresses in perspectives of coordinated legislation, institutional arrangement, public participation, capacity building, and scientific research in China's coastal zone were made. Comprehensive coastal management in China is a big challenge facing with great difficulties such as shortage of baseline information, deficiency in scientifically sound planning and zonation scheme, lack of coordination amongst resource users and governance, lack of public involvement, insufficient local intelligence, lack of monitoring and evaluation, and poor financial support. For Han River estuary in Korea, major recommendations can be summarized as follows: development and implementation of basic estuary surveys and researches, development and implementation of estuary monitoring systems, and designations of the 'Estuary Ecosystem Conservation Area' and the 'Natural Reserved Area'; implementation of the 'Total Pollution Load Management System' in the estuary, conducting post-environmental impact assessment for the Singok Submerged Weir, and identification of exposure pathways of toxic chemicals; designation of the 'Natural Landscape Conservation Area' and development of the 'Natural Landscape Management Plan' for downstream of the Singok Submerged Weir; improvement of the fishery management system, estimation of quantitative fishery stocks, and life cycle study of estuarine commercial fishes. For the Russian coast, a system approach is necessary which includes developing and introducing the system of Integrate Coastal Area Management of the for the Russia's Far East. It includes a continuous process of decision- making directed to a harmonization of the social-economic development of the coastal regions in an effort of sustainability of their development.

Relevance to APN scientific research framework and objectives

The project is direcly related to main objectives of the APN – identification, explaination and prediction of changes in the context of both natural and anthropogenic processes, and also its participants tried to contribute to the development of policy of sustainable development. Research findings are related to climate, ecosystems, biodiversity, changes in coastal zone which are priority topics of the APN. Capacity building was part of our project through involvement of young scientists, sharing of knowledge and scientific information within Northeastern Asia – a part of the AP region.

Self evaluation

Meetings held in frames of the project were successful in terms of capacity building, the training of young scientists and providing information and recommendations for national policy-makers and, more broadly, improving communications between scientists and society. The collaboration between Russian, Korean, and Chinese scientists was strengthened through the project activities. Sufficiently new data were obtained during field-works. So, we have accomplished many objectives to a satisfactory level. However, coordination between national teams was not good enough, and more integration and intercomparison of research findings/analyses are in need. We hope to achieve this through preparation of planned collective monograph under preliminary title *Global Change in Northeast Asia: Climate Variability, Land-Ocean Interactions, Coastal Zone Management.*

Potential for further work

We believe that results of this project are important in terms of future closer cooperation between China, Korea and Russia in both institutional and personal aspects. Problems of environmental changes in the river systems and river-ocean interactions in these countries are different in scale, human impact, because of different climate zones, etc., but it is critical that we compared for the first time processess taken place in these areas and, at least, tried to understand similarities/dissimilarities as well as methodical approaches to solve these problems.

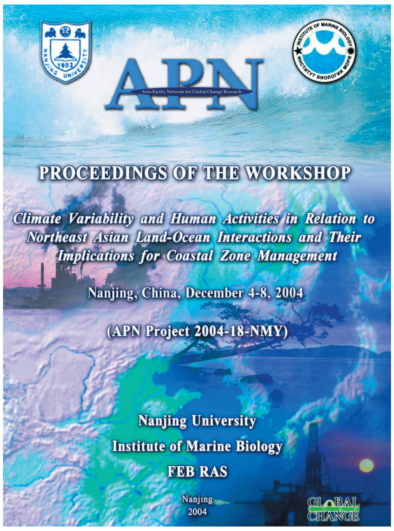
Potential for future work is to compare different coastal management strategies based on data obtained, to understand how we can use these national strategies to develop complex management approach; to involve as many as possible decision-makers in the process of development of coastal management strategies; and to stimulate young scientists to undertake research in global change in these countries, to enhance sharing of knowledge of global change. We did not pay much enough attention to biodiversity issue of the coastal zones and its modifications under global warming, bioinvasions, etc.; it can be a topic of a new, more biodiversity-focussed project.

Publications

Books and proceedings:

1. **Proceedings of the Workshop *Climate variability and human activities in relation to Northeast Asian land-ocean interactions and their implications for coastal zone management,* Nanjing, China, December 4–8, 2004.** Nanjing: Nanjing Univ., 2004. 157 pp.

2. ***Condition of Marine Ecosystems Influenced by River Flow.*** Ed. L.M. Gramm-Osipov. Vladivostok: Dalnauka Publ. House, 2005. 260 pp. [the book comprises 10 chapters].



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2. *Belan T.A., Belan L.S.* Composition and quantitative distribution of macrozoobenthos in Amursky Bay // Oceanology [Moscow], 2006, v. 46, N 5, pp. 678–688.
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4. *Gao S., Wang Y. P.* Changes in Material Fluxes from the Changjiang River: Implications on the Adjoining Continental Shelf Ecosystem // Continental Shelf Research (submitted).
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9. *Kasyan V.V.* Composition, peculiarities of distribution and interannual variability of zooplankton at the inner part of Amursky Bay (East/Japan Sea) // PICES Fifteenth Annual Meeting (PICES XV),Yokohama, Japan (in press).
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11. *Orlova T.Yu.* Red tides and toxic macroalgae in the Far Eastern seas of Russia // Bulletin of the Far Eastern Branch, Russian Academy of Sciences, 2005, N 1, pp. 27–31.
12. *Pavlyuk O.N., Trebukhova Yu.A.* Composition and distribution of meiobenthos in Amursky Bay (Peter the Great Bay, the East Sea) // Ocean Science Journal, 2005, v. 40, N 3, pp. 119–125.
13. *Pavlyuk O.N., Trebukhova Yu.A., Belogurova L.S.* Influence of the Razdolnaya River on the structure of marine free-living nematodes (Amursky Bay, Sea of Japan) // Russian Journal of Marine Biology (in press).
14. *Ponomarev V.I., Kaplunenko D.D., Krokhin V.V.* Climatic trends of the second half of the 20^{th} century in northeastern Asia, Alaska and northwestern Pacific // Meteorology and Hydrology [Moscow], 2005, N 3, pp. 15–26.
15. *Ponomarev V.I., Savelieva N.I., Rudykh N.I., Dmitrieva E.V., Makhinov A.N.* Changing linkages between Amur River discharge and ice extent in the seas of Okhotsk and Japan // Pacific Oceanography, 2005, v. 3, N 2, pp. 144–158.
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Technical Report

Preface

The APN-supported project was intended to investigate estuarine and coastal changes in the Northeastern Asia region, especially in the estuaries of Amur, Tumen, and Razdolnaya Rivers in Russia, Han River in Korea and Yangtze and Pearl Rivers in China, and to provide recommendations for management of sustainable development of the region. This has been done through extensive literature reviews, scoping workshops and knowledge exchanges, and gaining new data in course of field-works. Below are presented some results of the project, and an effort made to analyse and compare data obtained by different national teams. Further synthesis would be undertaken when a joint monograph based on project results will be published.

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1.0 Introduction

Recognizing the need and importance for the regional global change community to study river-ocean interactions and environmental changes in river basins and near-estuarine coastal zones of major rivers of the Northeast Asia, and as a result of APN activity in the Russian Far East and, particularly, two APN and START-funded workshops held in Vladivostok (2002, 2003), a proposal, *Climate Variability and Human Activities in Relation to Northeast Asian Land-Ocean Interactions and their Implications for Coastal Zone Management,* was developed by a group of Russian, Chinese and Korean scientists to investigate and assess the effects of the natural climatic variability and socio-economic development on environmental changes. The key questions of the project to be addressed were: (1) How are humans altering the mass balance of water, sediment, nutrient and contaminant fluxes, and what are the consequences? (2) How do changes in land use, climate and sea level alter fluxes and retention of water and particulate matter in coastal zones, and affect the morphodynamics? (3) How can we apply knowledge of processes and impacts of biogeochemical and socio-economic changes to improve integrated coastal zone management? The 2-year APN-funded collaborative and multidisciplinary project intended to answer these questions, alone with aims to improve regional capacity building and to expand APN network.

2.0 Methodology

In order to identify estuarine and coastal environmental changes in the Northeastern Asia region, we undertook a series of studies related to climate and meteorology, ecosystems of estuaries, geochemistry and coastal sedimentology. Below is given a description of methods used.

For **climatic/meteorological studies,** monthly mean time series of air temperature and precipitation at the meteorological stations were selected for the area studied from data bases of NOAA Global History Climatic Network (USA), RIHMI-WDC (Russia) and JMA (Japan) for the period of instrumental observations since late 19th century to 2000–2003. To outline the details of climate change associated with extreme cooling or warming in winter and summer, we also used the daily time series of surface air temperature at some meteorological stations. Monthly dataset of the Northwest Pacific SST on different grids were selected from JMA data base of time series (1946–2000) with horizontal resolution 2x2° for the ocean area 15–65° N, 110–180° E. We also analyze monthly/seasonal/annual time series of Razdolnaya (Suyfun) river (total length is 245 km) discharge near its estuary in Tavrichanka (1930–1986), as well as Amur river discharge near its estuary in Bogorodskoye (1900–1985) and in mid area of the Amur Basin in Blagoveschensk (1900–1985) situated in the offshore continental region (50.25° N, 127.57° E). Initial time series of air temperature, precipitation and SST have missing data. To use complete datasets, missing data of the time series in each month were recovered by the statistical method of incomplete multivariate data analysis using EM and AM algorithms. Linear trend of monthly mean precipitation and air/water temperature is estimated by two statistical methods. The first one is the least squares method with the Fisher's test for a significance level. The second method is a nonparametric robust method based on the Theil's rank regression and the Kendall's test for a significance level applicable to the dataset with the abnormal distribution function typical for the precipitation time series (Krokhin 2001; Ponomarev et al., 2002, 2003). We also used wavelet techniques from MATHAB to reveal amplitude-phase characteristics of dominating climate oscillation in the area studied (Ponomarev et al., 2003).

For **ecological/environmental studies** in the coastal zone, we used sediment samples taken in the coastal zone of Amursky Bay and near-estuarine areas of Amur River. Four replicate sediment samples at each site were taken with van-Veen grab (0.11 m^2). Only surface sediments (1–2 cm) were collected for chemical analysis (trace metals, chlorinated hydrocarbons and total non-polar petroleum hydrocarbons). For biological analysis, sediments were washed by seawater through 1.0 mm sieve, and residues including macrobenthos were preserved by 4% buffered formaldehyde. In the laboratory, benthic organisms were sorted to major taxa. All individuals were identified to species level, but some organisms could only be identified to higher taxa. Wet weight of macrofauna was determined: organisms were blotted and air-dried for approximately one minute prior to weighting. Benthos parameters were calculated using four replicate samples and included the following: total biomass (B), abundance (A), Shannon–Wiener diversity index (H), Pielou evenness index (e), Margalef richness index (R), and Simpson domination index (Si). For determination of species structure of benthic communities SIMPER-analysis (PRIMER Program) was used (UNEP, 1995). For chemical and granulometric analysis about 200 g of sediment were taken from the sample upper layer. Granulometric composition was determined through a combination of suspension settling and subsequent sieving. Data were used to compute average grain size ($\overline{M}$), standard deviation (*SD*), and entropy (H_r). Contents of metals, petroleum hydrocarbons (*PHC*), organochlorine pesticides (sum of α- and γ-hexachlorcyclohexane, Σ*HCH*, and that of *DDT* and its metabolites, Σ*DDT*), phenols (*PHE*) and C_{org} were determined by standard methods. For comparison, data on 1979–1989 were used.

To evaluate the total level of contamination an average grade of the rank value of contaminant contents was applied: $TPF = (PHC + PHE + Pb + Cu + \Sigma DDT)/5$, where *PHC*, *PHE*, *Pb*, *Cu* and Σ*DDT* are the rank estimations (5 ranks in logarithmic scale) of the contents of corresponding substances. Data processing includes the application of different statistical tests and procedures: Kruskal–Wallis ANOVA median test, Mann–Whitney *U* test, multiple linear and non-linear regression, cluster and factor analysis.

We also used meiobenthic samples collected in August 2001 in Amursky Bay (10 stations). The depth at the stations changed from 8.5 m up to 35 m. The samples (4 samples per station) were taken with a tubular 20 cm^2 bottom sampler, the height of the core sample was 5 cm. A millnet sieve 63 μm was used for the sample washing and samples were processed according to standart methods (Gal'tsova, 1976).

Meiobenthos samples, collected in June 2005 in the inner part of Amursky Bay (19 stations) were used as sample material for this work. Depth at stations varied from 0.5 to 18 m. Samples of the ground sediments (4 from each station) were collected by a 14.1 cm^2 tubular sediment core sampler, the sample ground columns measuring 5 cm. Samples of meiobenthos were washed out through mill gas with 63 μm gauge mesh, fixed in 4% formalin, and stained with "Rose Bengal" before analysis. All groups of meiobenthos were considered except for foraminifers. Nematodes were identified at a species level, except for damaged and immature specimens.

The index of Shennon–Wiener was used in the characterization of the nematode species diversity:

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

n_i being the density of each species, N the total density.

The hierarchical cluster analysis (Ward's method) was used for allocation of bottom communities. The material was statistically analyzed on a personal computer using Statistica 6.0 software.

Collection of plankton was made with a Juday net (mouth diameter 37 cm, gauze no. 49). Simultaneously, water temperature and salinity were measured at the surface and near bottom.

To characterize effect of contamination of coastal waters, we used fishes caught between May and October 1995–2001. All the individuals were thoroughly inspected for the presence of visible pathological changes. Samples of the tumors, which were found visually, and pieces of liver and gills were taken for histological analysis. Because it was impossible to find the same fish species at all stations due to their limited geographical distribution, several species were used, but the same species were captured at neighboring stations. On the whole, histopathology of gills and liver of 6 flatfish were studied (*Pleuronectes pinnifasciatus*, *P. obscurus*, *P. punctatissimus*, *P. herzensteini*, *Platichthys stellatus*, and *Kareius bicoloratus*). Tissue samples were fixed in Bouin's solution and embedded in paraffin. Sections of 5 μm thickness were stained with hematoxylin and eosin and examined. Classification of lesions in the plaice liver was based on generally accepted diagnostic criteria used in other flatfish species including a description of degenerative, pre-neoplastic and neoplastic changes (Hinton et al., 1992). The greatest importance was paid to revealing the following alterations in the plaice liver: neoplasms, foci of cellular alterations, spongiosis hepatis, hydropic vacuolization, coagulative necrosis, foci of regeneration, biliary hyperplasia, and cholangiofibrosis, which are well-established as histopathological biomarkers of contaminant effects in fish and show strong evidence of a contaminant-associated etiology based on previous field and laboratory studies (Hinton et al., 1992; Au, 2004).

All maps with stations/sampling points in Amursky Bay (estuarine zone of Razdolnaya River) and Amur River estuarine area referred to expeditions in 2005 directly supported by APN are provided **in Results and Discussion** section.

Hydrochemical studies included the following procedures. Two sampling along Razdolnaya River were carried out at low water in June and in September 2003 from headwaters to the downstream (Fig. 1), and additional sampling at the high water in July, 2002 and July 2004. Sampling point R1 settled down in headwaters of the river in 2 km from border China/Russia, R5 – is lower than the ma in output of municipal sewage of Ussurisk – the largest city on watershed and the main source of anthropogenic influence on Razdolnaya River. The down stream of Tumen River had been sampled several times from 1998 till 2004, including high water in July 2002. Besides the data on metal concentration in unpolluted rivers of southwestern part of Primorski Krai has been used. Sampling were carried out in preliminary washed polyethylene bottles with use of pump MasterFlex ™ and capsule filter AquaPrep ™ with the effective pore size 0.45 microns to obtain filtrate with dissolved forms of metals directly on a place of sampling. The received filtrates preserved nitric acid up to pH 2.5. At the sampling pH and conductivity, as a parameter of the general mineralization were determined. Simultaneously 5–8 litres of water were sampled for subsequent segregation and analysis of suspended solids. The filtration of these samples was carried out in laboratory through filters Nucleopore with a same pore size 0.45 microns.

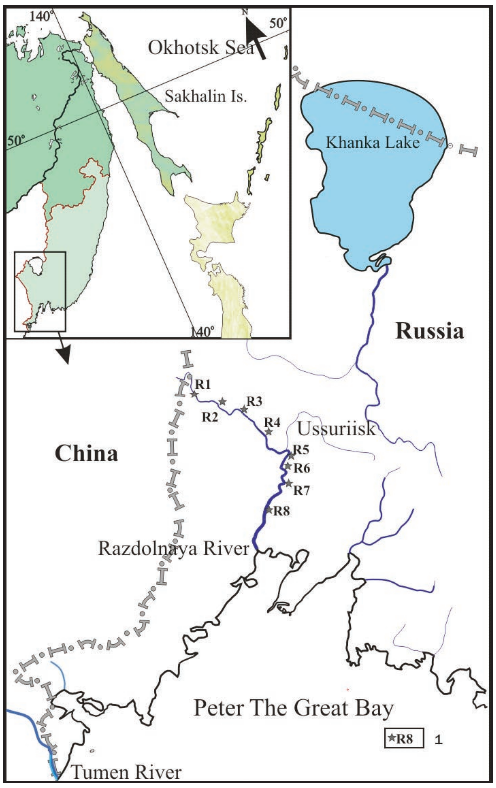


Fig. 1. Hydrochemical sampling points along Razdolnaya River.

The concentration of the dissolved forms of metals determined by atomic-absorption spectrophotometry (AAS) on device Shimadzu-6800F/G in flame and in graphite furnace after concentration of metals by extraction with dietilditiocarbaminat-Na in $CHCl_3$ (Chelation/Solvent…, 1975). The accuracy of the analysis was controlled by a method of standard additions. The reproducibility of spikes was 80–85% at a level of concentration of the dissolved metals less than 0,5 µg/l.

Filters with a suspended solids were dried, weighed for definition of quantity of the weighed material, decomposed by mixture of HF-$HClO_4$ and were analyzed for metals by AAS method. The control of accuracy carried out by the analysis of blind tests, reproducibility of standard additives, and the analysis of standard reference material BCSS-1 and PACS-2. The divergence with passport data did not exceed 10–12%.

Seasonal variability of Razdolnaya River hydrochemical parameters was considered for 2002 as an typical example. Chemical analyses were carried out in the Center for Environmental Monitoring of Primorski Krai HydrometService by recommended standard techniques: the dissolved nutrients by photocolourimetry, biological consumption of oxygen (BOD5) – on reduction of concentration of oxygen at the standard conditions, chemical consumption of oxygen (COD) – after oxidation by $K_2Cr_2O_7$, and suspended solids (SS) – by weighing after filtration. Quality assurance of chemical analyses was carried out in conformity with the normative documents regulating quality assurance of results of the analysis. For calculation of an output of chemical substances the concentration data were multiplied on water discharge data from Hydrological Year-Books.

For physico-chemical modeling of behaviour of trace elements in the mixing zone of Razdolnaya River and Amursky Bay, physico-chemical simulation of migration forms and their change on geochemical barrier was made by means of the SELECTOR software package, which uses methods of equilibrium thermodynamics and helps to solve various geochemical, chemical and physical problems. Using this software package, we have made and solved models of river water of the Razdolnaya River and seawater of Amursky Bay, and have simulated the mixing process of these waters. Each model contained 443 potentially possible dissolved particles (simple and complex ions, complex compounds, associates), as well as 11 gases. The multisystems constructed by us represented 1 kg of aqueous phase, which was in equilibprium with 100 kg of the atmosphere. Chemical composition of the atmosphere was calculated. The chemical composition of seawater was calculated from a salinity of 27.41‰, using the known ratios. Activity coefficients were calculated by the Debai–Huckel equation in the modification of Helgeson. Simulation was made for the following conditions: temperature 25°C and general pressure 1 bar.

The contents of dissolved forms of elements in river water were taken to be $2.88 \cdot 10^{-8}$ mole/kg for chrome, $5.77 \cdot 10^{-8}$ mole/kg for arsenium, $1.96 \cdot 10^{-8}$ mole/kg for vanadium, $5.0 \cdot 10^{-8}$ mole/kg for cobalt, $3.4 \cdot 10^{-10}$ mole/kg for mercury; and in seawater – $3.85 \cdot 10^{-9}$, $2.3 \cdot 10^{-8}$, $2.94 \cdot 10^{-8}$, $5.0 \cdot 10^{-9}$, and $1.5 \cdot 10^{-10}$ mole/kg, respectively.

Since the overwhelming majority of organic matter (more than 90%) in natural waters are organic polymers, among which are humic and fulvic acids, then only these substances were taken into account in the simulation of interaction of trace elements with organic matter. The concentrations of humic and fulvic acids in river water are $3.5 \cdot 10^{-7}$ and $7.8 \cdot 10^{-7}$ mole/kg, respectively; in seawater, only fulvic acids were found (concentration $2.8 \cdot 10^{-7}$ mole/kg).

Gibbs energy of organometallic compounds of vanadium, cobalt, and mercury was calculated from stability constants. For chrome, constants of stability were those with serine, which contains functional groups similar to humic and fulvic acids.

Literature data were analyzed when preparing analysis and recommendations for coastal zone management.

3.0 Results & Discussion

Climatic tendencies in the North East Asia and Northwest Pacific

High seasonality of the climatic tendencies and relationship between temperature anomalies in the Northeast Asia and Northwest Pacific is revealed in Ponomarev et al. (2002, 2003). It is shown that the semi-centennial summer cooling in a central continental area of Asia accompanies the semi-centennial negative SST anomaly in the offshore region of the western Subarctic Pacific gyre. At the same time, warming at Kamchatka Peninsula and marginal subtropic area of the Northeast Asia accompanies the positive SST trend in the Kuroshio and Aleutian current systems. Statistically significant (with 95–99% confidence probability) trends of precipitation for the second half of the 20th century (1945–2000), as well as for the 20th century (1900–2000; 1916–2000) are revealed in large-scale areas of the Northeast Asia for each month of a year (Ponomarev et al., 2002, 2003). A sign and confidence probability of semi-centennial trend (1945–2000) of monthly precipitation estimated by the nonparametric robust (NR) method are shown in Fig. 2.

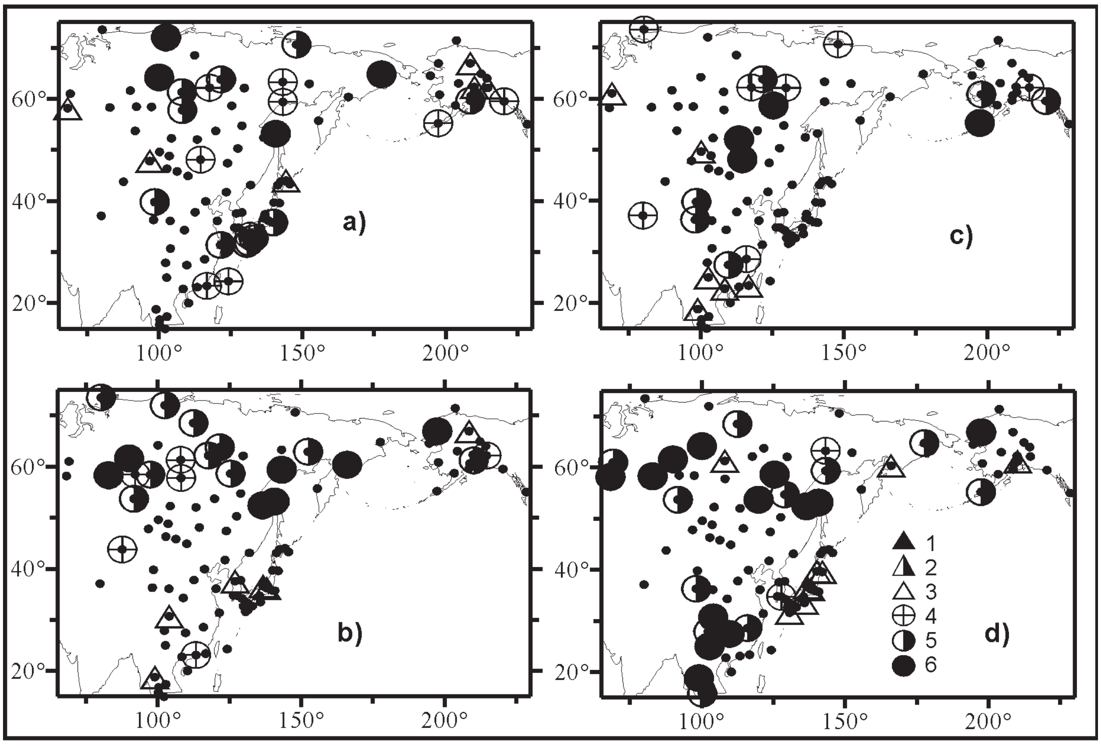


Fig. 2. Negative (*1*, *2*, *3*) and positive (*4*, *5*, *6*) linear trends of precipitation sum (1945–2000) with confidence probability 90% (*3*, *4*), 95% (*2*, *5*) and 99% (*1*, *6*) in Mar. (*a*), Oct. (*b*), Jun. (*c*), and Jan. (*d*) estimated by nonparametric robust method in Ponomarev et al. (2002, 2003).

Increase of precipitation in the second half of the 20th century is found in large-scale continental areas of the Northeast Asia prevailing in Oct.–May in the moderate and arctic latitude zones. Typical monthly precipitation rise of high confidence probability (99%) is 0.2–0.4 mm/year, and maximum values are in the range of 1.4–1.7 mm/year at some Russian meteorological stations in the continental area of the moderate latitudes. In Oct.–Feb.

the positive semi-centennial trend of monthly precipitation sum occurs east of 55° E in the whole latitude band of 45–70° N, but in March, May and June it occurs in the area east of 100° E in the same latitude band. In February the positive precipitation trend of high confidence probability (99%) also occurs in the tropical and subtropical marginal area east of 95–100° E adjacent to the East China Sea, where the air temperature trend in winter is also positive.

Negative precipitation trend (0.1–0.2 mm/year) in this subtropical area is found in May and October, and only at some meteorological stations it takes place from July to September. Bands of positive precipitation trend in summer months are stretched out from southwest to northeast, parallel to the Northwest Pacific marginal zone (Fig. 2c). Positive patterns of precipitation and air temperature trends are very similar in the continental area of the Northeast Asia. Dominant winter warming accompanies winter precipitation rise in the Asian continental area of moderate latitudes.

Relatively weak (with confidence probability of 90–94.9%) negative precipitation trends of both centennial and semi-centennial (Fig. 2c, d) scales are found in Russian Primorye region adjacent to the Northwest Japan Sea, including Razdolnaya (Suyfun) River basin for the most months (Krokhin, 2001; Ponomarev et al., 2002, 2003), Similar trends with low confidence probability (<90%) are found over Kyushu and Honshu Islands in Sep., Oct., Dec., and Jan. In this area of the NW Pacific marginal zone centennial and semi-centennial warming accompanies weak precipitation decrease.

Typical climate oscillations of borderline ENSO scale (3–8 years), decadal (8–15 years), interdecadal (15–30 years), and quasi-semicentennial (50–60 years) time scales in the surface air temperature, precipitation, and SST, were briefly reviewed and described in Ponomarev et al. (2003). It was shown that ENSO signal and climatic trends in the Northwest Pacific marginal area have similar seasonality and major patterns. Anomaly of ENSO cycle with El Nino prevailing during last several decades seems to be related to semi-centennial tendencies in the Northwest Pacific and Northeast Asia.

Climatic changes and river discharges

The climatic oscillations with semi-centennial (50–60 years, Minobe, 1997), inter-decadal (15–25 years, Mantua et al., 1997), quasi-decadal (8–15 years), ENSO (4–7 years), and biennial oscillations time scales play a significant role in the Asian-Pacific climate variability. Major effects of both climate change and most of climatic oscillations in the North-East Asia are associated with monsoon system variability similar to the climate variability in China (Li et al., 2001) and India (Webster and Yang, 1992; Pai, 2004). This effect is accompanying seasonal anomalies which are usually inversed in winter and summer in the subarctic area like in the ENSO signal in the Northeast Asia (Ponomarev et al., 1999, 2003). Negative statistical relationship between decadal-scale oscillation in the Okhotsk Sea ice extend and Amur River discharge/annual precipitation in the Amur River basin/summer SST in the NW Okhotsk Sea was found by Ogi et al. (2001) for the time series since 1966 till 1994. Our study is focused on the regional features of climate variability of different time scale in the Amur River Basin, and Sea of Okhotsk Ice Extend affected by the large-scale climate oscillation/change in the Asian Pacific. The study is based on the statistical data analyses of the long-term time series for the observational records of precipitation using different methods including EOF decomposition and wavelet analyses.

Okhotsk Sea Ice extend and Amur River discharge. The opposite relationship between anomalies of the Amur River Discharge at Bogorodskoye/Komsomolsk and Okhotsk Sea Ice Extend (OSI) was found by Ogi et al. (2001) for the period from 1971 to 1993 with high negative correlation coefficients (-0.8) for the time series filtered with a three moving average procedure. We have analyzed long term annual mean time series (Figs. 3–5) of the Okhotsk Sea Ice Extend (1957–2001) with Amur River Discharge in Khabarovsk (ADK) correlated well with river discharge in Bogorodskoye which is situated near the Amur River estuary. The averaging of the initial decadal mean time series was made from the beginning of the cold season (first decade of the ice formation in the Amur River) in previous year to the end of the warm season in current year. The time-period related to the data analyses presented by Ogi et al. (2001) is shown in Figs. 3–5 by frame.

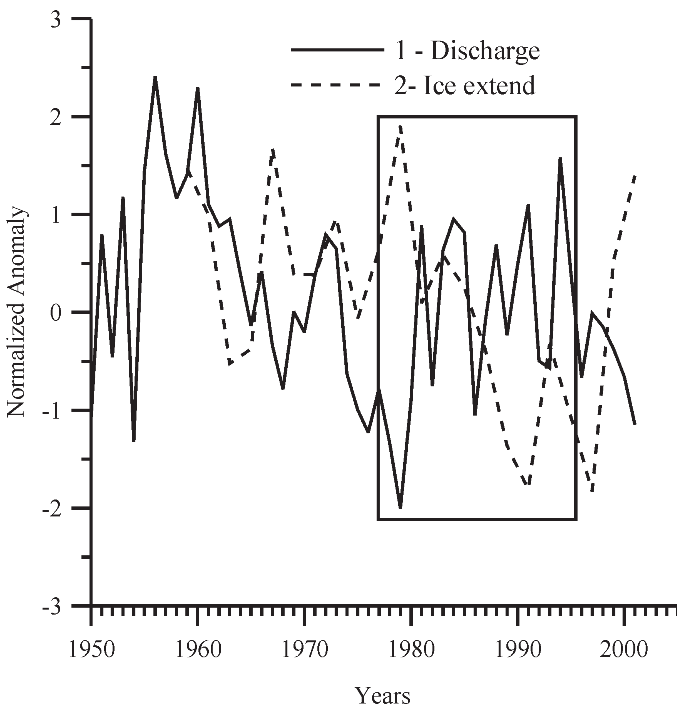


Fig. 3. Normalized anomalies of the Amur River discharge in Khabarobsk (*1*) and Ice Extend in the Okhotsk Sea (*2*). The time series with opposite relationship analyzed in Ogi et al. (2001) is presented in frame.

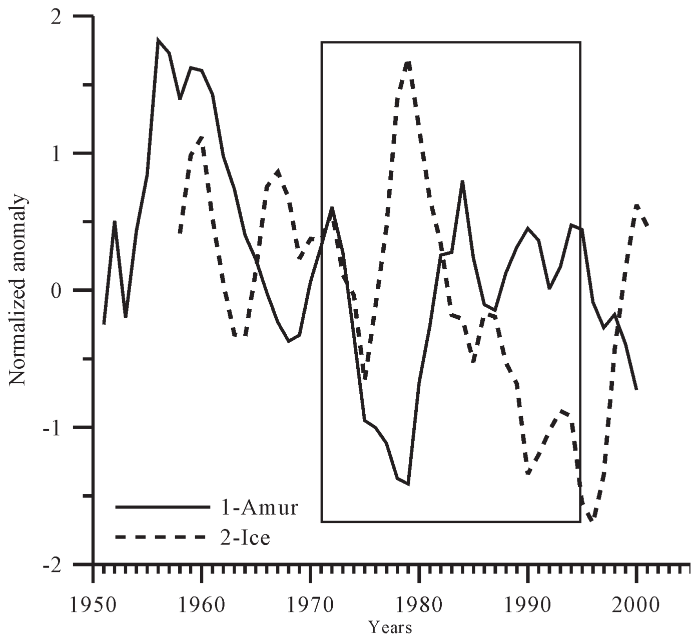


Fig. 4. Three year moving average normalized anomalies of the Amur River discharge in Khabarobsk (*1*) and Ice Extend in the Okhotsk Sea (*2*). The time series with opposite relationship analyzed in Ogi et al. (2001) is presented in frame.

In the whole, the opposite relationship between anomalies of OSI and ADK is typical for the both decadal and interdecadal dominated time scales of variability in the historical data of the annual anomalies from 1965 till 2001. The interdecadal oscillation and opposite OSI-ADK relationship for this time scale is presented in terms of cumulative anomalies in Fig. 4. Nevertheless, the correlation coefficient of this statistical relationship even for the interdecadal time scale of variability is not high (0.4) for the period from 1957 through 2001 due to another features of the relationship before 1965 and lagged OSI and ADK anomalies after 1994. Indeed the best negative unlagged OSI-ADK correlation is found for the 3 and 5 years moving average time series in the historical period 1965–1994 analyzed by Ogi et al. (2001) and presented in our time series by frame in Figs. 2–4. The unlagged correlation coefficient between OSI and ADK annual time series from 1957 to 2001 is 0.2, and between three moving average OSI and ADK time series it is -0.14, but with one year lag it is -0.26.

The frequency of the substantial anomalies occurrence in both OSI and ADK time series is irregularly varied due to nonlinear processes in the atmosphere-ocean system, many physical feedbacks in the multiscale variability. For example, high positive normalized anomalies (> STD) of the ice extend in the Okhotsk Sea related to low frequency variability are observed in 1959 (1.5), ***1967 (1.7)***, 1973 (1.0), **1979 (1.9)**, and **2001 (1.4)**. These anomalies occur in **8, 6, 6, and 22** years correspondently during this long-term period from 1956 to 2001 (Fig. 3). The correspondent negative normalized anomalies (> 0.7STD) of the Amur River Discharge in Khabarovsk were observed in 1954 (-1.3), ***1968 (-0.8)***, 1976 (1.2), **1979 (1.9)**, 1986 (-1.0), **2001 (-1.2)**. These anomalies occur in **14, 8, 3, 7, and 5** years correspondently. Only in **1979** and **2001** high positive anomalies of OSI and negative anomalies of ADK were at the same years.

High negative normalized anomalies (< -STD) of the Ice Extend in the Okhotsk Sea associated with low frequency variability are observed in 1974 (-1.0), **1984 (-1.5)**, **1991 (-1.8)**, **1994 (-1.4)**, and 1996 (-2.2). These anomalies occur in **10, 7, 3 and 2** years correspondently (Fig. 3). The correspondent positive normalized anomalies (> 0.7STD) of the Amur River Discharge in Khabarovsk were observed in 1960 (2.3), 1963 (1.0), 1972 (0.8), **1984 (1.0)**, 1988 (0.7), **1991 (1.1)**, and **1994 (1.6)**. These anomalies occur in **3, 9, 12, 4, and 3** years correspondently. During three years high negative anomalies of OSI and

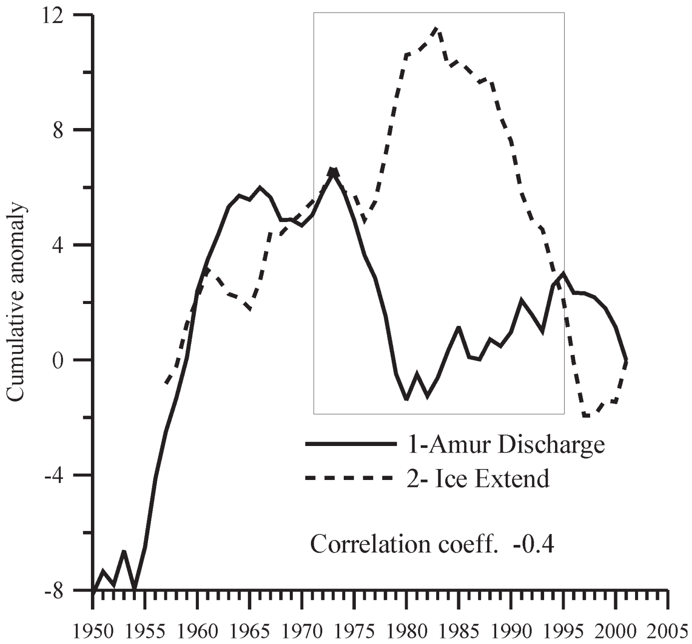


Fig. 5. Cumulative anomalies of the Amur River discharge (*1*) in Khabarobsk and Ice Extend in the Okhotsk Sea (*2*). The time series with opposite relationship analyzed in Ogi et al. (2001) is presented in frame.

positive anomalies of ADK occurred at the same time.

Totally, high inversed anomalies of OSI and ADK were observed at the same years in **1979, 1984, 1991, 1994**, and **2001**, that is typical for this historical period from 1976 through 2001. Due to this fact the negative correlation of the three year moving average time series of the anomalies is significant for the period 1971–1994 presented in Ogi et al. (2001). For the previous period from 1957 till 1966 this correlation is positive. Therefore, during certain historical period one can find significant negative unlagged OSI-ADK correlation, for the next historical period one can find lagged correlation, and for other period it is positive one. This feature of the statistical linkages is typical for the relationship between time series of meteorological/hydrological characteristics over land and oceanographic characteristics in the North Pacific/its marginal seas. Similar situation with change in relationship between OSI and Siberian High Intensity or pressure difference between the Siberian High and Aleutian Low was described by Vasilevskaya et al. (2003) for the time series from 1926 through 2000. It is also one of the relationship which may be high during certain multidecadal historical period and weak during other one.

The most realistic physical device of this link during cold period of a year is inversed anomalies of the occurrences of warm southern cyclones over the northwest Okhotsk Sea and cold northwest continental wind outbreaks over this sea area. Some features of this typical physical device was described by different authors in the second half of the previous century, including Il'inskii (1965), Yakunin (personal communication, 1989), and others. Another physical device of the Okhotsk Sea Ice coverage variability related to the feedback through the anomalies of precipitation, Amur River discharge and SST in the warm period of a year was discussed in Ogi et al. (2001). Both devices are associated with the Northeast Asian Monsoon system variability, and second one deals with inversed summer and winter anomalies, in particularly, with monsoon anomalies in the subarctic NW Pacific marginal and continental areas.

Principal linkages of the biennial/ENSO scale anomalies of meteorological/oceanographic characteristics and Monsoon system in the Asian Pacific equatorial, tropical and subtropical regions were described in details in many papers, including (Webster and Yang, 1992) on the Indian/South Asian Monsoon-ENSO relationship, its strengthening/weakening (Pai, 2004), as well as on the China Monsoon-TBO/ENSO relationship (Li et al., 2001).

The significant ENSO signal in the NW Asian-Pacific thermal conditions in the ocean (Hanawa et al., 1988; Ponomarev et al., 2002) and over land including Okhotsk Sea area (Ponomarev et al., 1999a, 1999b, 2002) shows inversed anomalies in winter and summer in the subarctic area. The surface air temperature anomalies in Okhotsk Sea area and SST in the subarctic North Pacific are very sensitive to the extratropic ENSO signal. Both unlagged and 6 month lagged (SOI leading) air temperature relationships with SOI/Nino3 are significant, at least, for the second half of the 20^{th} centuty (Ponomarev et al., 1999a, 1999b, 2002). Unfiltered seasonal/annual anomalies of precipitation, Amur River Discharge, and Okhotsk Sea Ice Extend have no statistically significant unlagged correlation with SOI/Nino3 for the similar long-term time series. Nevertheless, during significant El Nina in winter the positive anomaly of the Ice Extend occur, and during significant winter La Nino usually negative Ice Extend anomaly takes place in the Okhotsk Sea with rare exception. It is in line with ENSO-scale anomalies in surface air temperature over Northwest Okhotsk Sea area (Ponomarev et al., 1999a, 1999b).

At the same time, for the variability of ENSO-decadal-interdecadal time scales one can found interaction between decadal and ENSO oscillations (Sekine and Yamada, 1996), or ENSO like interdecadal variability (Zhang et al., 1997). Frequency drift in some period is also take place in the multiscale variability (Ponomarev, 2003). There are many large-scale and regional processes which influence on the Okhotsk Sea Ice Extend (Akagawa, 1977; Ogi et al., 2001; Vasilevskaya et al., 2003; Ustinova et al., 2004, and others), as well as on the Amur River Discharge and precipitations (Mahinov, 2004; Ponomarev and Rudykh 2004, and others). Most of the impacts occur through the synoptic scale processes and stormtrack anomalies (Branstator, 1995) in the Northeast Asia and Northwest Pacific related to the ENSO, decadal, and interdecadal Monsoon System variability.

Long-term changes in the hydrological regime of the Amur River

Among the rivers flowing into the Pacific Ocean, the Amur is the largest in area of its basin. The area of the Amur River basin is 1.855 million square kilometers and it is situated on the territory of four countries – Russia, China, Mongolia, and North Korea (Table 1).

Table 1. The area of basin and the volume of flow of the Amur River in four neighboring countries

Country	Area, thousands km^2	Annual volume of flow, km^2
Russia	1003.0	261.7
China	820.0	105.4
Mongolia	32.0	2.0
North Korea	~0.005	~0.002
Total	**1855.0**	**369.1**

Average long-term flow of the Amur River is 369.1 km^3 (Mordovin, 2003). Maximum annual flow over the whole observation period (459.2 km^3 in 1985) exceeds minimum flow (250.8 km^3 in 1979) by a factor of 1.8. Fluctuations of values of maximum annual discharge are even more drastic, from 15000 to 40000 m^3/s. Absolute maximum water discharge exceeds absolute minimum value by a factor of more than 65.

Rainfall is the major source of water feed of the Amur River, contributing 70–80% of its flow. Groundwater input is 17–25% of the Amur water. Snowmelt water and rainfall during the spring flood make up 3–5%.

There are four major phases in the distribution of flow within the year: winter low water, spring flood, summer low water, and summer-fall floods. The winter low-water period is the longest, from November through March. At that period, water discharge gradually decreases, reaching minimum values in late March. The proportion of groundwater feed reaches 100% and mineralization of water is 100–150 mg/dm^3.

Spring flood is formed by snowmelt and atmospheric precipitation such as rain and sleet. The duration of this phase is about 2 months, from early April to late May. Mineralization of water is much reduced, 35–60 mg/dm^3.

A short summer period of low water (never longer than 30 days) is observed in June–early July. At that period, the role of groundwater sources as well as runoff from lakes and swamped lands increases. Water mineralization increases to 60–80 mg/dm^3.

The phase of rainfall floods in the hydrological regime of the Amur River is clearly seen from July to October. At that period, there are 2 to 5 sharp increases of water level in the middle part of the river, while in the lower reaches of the river of the rise of water is continuous. Mineralization decreases to 40–60 mg/dm^3.

The long-term regime of the flow of the Amur River is characterized by the alternation of periods of low and high water abundance, each lasting 8-15 years. Periods of high water abundance were observed in the 1910s, 1930s, 1950s, and 1980s. Water abundance increased from period to period and reached maximum in the 1950s when there was a series severe floods causing great economic damage. The last period of high water abundance (in the 1980s) was less significant, compared to the preceding, because the major tributaries of the Amur (Zeya and Sungari Rivers) are subject to strong anthropogenic impact. In spite of the regulating role of the Zeya hydroelectric power station, water levels at maximum floods (1984, 1991) nearly reached historical maximum. Local floods on unregulated confluents of the Amur (Bikin, Khor, Anyui rivers) increased markedly.

Periods of decreased abundance of water were observed in the 1920s, 1940s, 1970s, and 1990s. During the last period of low water abundance, there was some reduction in discharge also caused by anthropogenic factors. Against the background of generally decreased water abundance in the late 1990s–early 2000s, extraordinarily low water levels occurred in summer 2000, 2001 and 2002, which had record-breaking characteristics over the whole observation period.

Thus, growing contrast between the extremes of the major hydrological characteristics, namely water level and discharge, water turbidity and sediment transport, increased intensity processes in the riverbed and so on, leads to increasing nonuniformity of organic, dissolved and solid matter runoff from the Amur River into the sea.

Within-year variation of the Amur River flow is accompanied by a sharply pronounced reduction in the amplitude of annual flow anomalies over the last 20 years, although during the preceding period of more than 80 years we note the prevalence of positive anomalies, which increases with each period of high water abundance.

Increase in water abundance of the Amur River over the 100-year period is estimated at 10–12%. It is related to increased atmospheric precipitation in the basin of the Amur River, specifically in its lower reaches. Between 1891 and 2003, precipitation for the cold season of the year (November–March) increased by a factor of 2.0 and for the warm season (April–October), by a factor of 1.22 (Butova et al., 2004). Over that period, humidity of the Amur River basin increased by 31%. However, the increase in water abundance in the Amur was not as great because of increased evaporation due to the rise in average annual air temperature, as well as the use of water for economic purposes, specifically in agriculture in the Sungari River basin.

Among anthropogenic factors, hydrotechnical development projects involving the construction of large reservoirs with a long-term control regime on the large tributaries of the Amur greatly affect the water regime of this river. The largest volume of water (about 60 km^3) is contained in the Zeya reservoir. After the reservoir began to fill up in 1975, within-year runoff of the Zeya River changed radically. Under natural conditions, water discharge of the Zeya River during the winter low water period was 5–10 m^3/s; however, after the Hydroelectric Power Station on the Zeya had been put into operation, it increased to 600–800 m^3/s. Summer discharge is merely 300–500 m^3/s, which is tens times lower than water discharges during floods before river flow regulation.

The Amur River runoff exerts great influence on coastal waters of the Okhotsk Sea and the Sea of Japan. It brings into the World's oceans about 24.0 million tons of particulate matter, 20.2 million tons of dissolved substances, and 5.3 million tons of organic matter (Table 2).

Long-term sediment runoff and water runoff show similar tendencies. In the 1960s, sediment runoff was increased; it was decreased in the 1970s and again increased in the 1980s. Because of the short time series of observation, it is impossible to evaluate the trend of change in suspended matter runoff. With nearly the same water abundance of the Sungari River (Tszyamusy) in the 1980s and 1960s, comparison of sediment discharges reveals an 8–10% increase in water turbidity and sediment runoff over 20 years.

Table 2. The main hydrological characteristics of the Amur River (Pogadaev, 1990; Chudaeva, 2002; Ecological problems…, 2003)

Characteristics	Values
Average long-term flow, km^3	369.1
Maximum annual flow, km^3	459.2
Minimum annual flow, km^3	135.0
Maximum discharge, m^2/s	40 000.0
Minimum discharge, m^2/s	153.0
Average annual sediment runoff, million tons	24.0
Average annual water turbidity, mg/dm^3	90.0
Maximum water turbidity, mg/dm^3	517.0
Average dissolved matter runoff, million tons	20.2
Average organic matter runoff, million tons	5.3

Throughout the lower part of the Amur River, the balance of solid runoff is positive. In the area between Khabarovsk and Komsomolsk-on-Amur, on average about 5000000 tons are accumulated every year. For the entire lower part of the river, this index is up to 20000000 tons. Such dynamics of sediment runoff result in sediment accumulation and elevation of the bottom of the Amur River valley at a rate of about 1.0 mm a year.

Sediment deposition occurs in the riverbed, on flood-lands, and in lakes near the mouths of Amur tributaries. The largest-size particles are the first to settle to the bottom; therefore, down the Amur River valley increasingly small particles prevail among suspended matter (Table 3).

Table 3. Change in particle size of suspended matter along the Amur River valley (Long-term…, 1986)

Locality	Particle size, mm					
	1–0.5	0.5–0.2	0.2–0.1	0.1–0.005	0.005–0.001	<0.001
Khabarovsk	24.2	38.4	11.7	6.9	18.8	–
Komsomolsk-on-Amur	4.6	21.8	8.9	5.3	20.6	38.8
Bogorodskoe	0.2	5.3	9.6	18.6	44.6	21.7

The input of small-size particles into the estuary of the Amur River adversely influences the formation of its delta. Runoff, wind, and tidal currents in the estuary and the Tatar Strait exhibit a complex pattern of change in directions and high velocities, which exceed the flow velocity in the lower part of the Amur River. In shallow waters of the estuary and the adjacent area of the sea, high wind waves during storms re-suspend bottom sediments, which are then transferred offshore.

Ice plays an important role in the bottom sediment transfer in the estuary and Tatar Strait. The mechanism of inclusion of terrigenous material into the ice mass is clearly displayed in shallow water, banks, and fringing areas of Vospri and Oremif islands, which are the only elements of the above-water delta of the Amur. Ice-incorporated terrigenous material is up to 10 kg/m^3 (Makhinov and Ivanov, 2001). Bottom sediment transport via ice ensures a stable balance of the input of terrigenous material and its transport into the Amur estuary.

Directional sediment accumulation in the valley of the lower Amur markedly reduces transport of terrigenous material into the sea. Up to 20000000 tons of sediment per year are deposited. Deposition in the Amur River valley accounts for specificity of certain factors determining the state of aquatic ecosystems of the lower part of the Amur, its estuary, and the adjacent areas of the Sea of Okhotsk and the Sea of Japan.

Sediment deposition accounts for specific and highly dynamic processes in the riverbed. The river has many arms of different size with relatively shallow depths (5–7 m) and lower velocities of the flow than in the mountain areas of the valley. As a result, in summer water temperature sometimes reaches 26°C. Therefore, the Amur River is a powerful source of warm water for the southwestern part of the Sea of Okhotsk.

One of the consequences of increased water abundance of the Amur is the activation of riverbed deformations. This is suggested by the wide zones of recent and low massifs of floodplain along large arms in flat areas of the valley. Mean levels of floodplain are practically lacking. Bank erosion at a rate of 10–20 m/year causes the formation of extensive unstable spits of 2x10 km. This leads to further furcation of river arms, reduction in their transporting capacity, and large sediment accumulation. Where the flow is redistributed among the river arms (e.g., channels straightening the stroll of river), washing-out of the banks occurs even in winter.

Elevation of the erosion basis in the Amur valley because of sediment deposition results in the enlargement of lakes, of which many are more than 50 km^2 in area, and their transgression along the valleys of inflowing rivers. Gently sloping banks in the lower Amur basin become increasingly swampy. This changes chemical runoff and increases the transport of dissolved substances and organic matter into the river.

Since the flow of the Amur River is nonuniform, particularly in summer, there are large fluctuations in organic matter runoff. With unusually low water levels in summer (years 2000, 20001), the overgrowing of the bottom was observed in dried-up lakes and channels. In fall when water levels in the Amur rose, the water brought into the sea a huge quantity of biomass.

Thus, the changes in the water regime of the Amur River in the last 100 years have led to the disturbance of the ecological equilibrium in the valley of the lower Amur. These changes are fairly dynamic and occur not only in the floodplain of the Amur River, but also in the neighboring flat and mountain territories and in the adjacent areas of the Okhotsk and Japan seas.

Changes in material fluxes from the Changjiang River

1. Introduction

Changes of the catchment-coast system of the world represent an important part of the global change. Even under the condition of constant external forcing, because of the energy and material exchange between the catchment and the coastal zone, the geomorphological, oceanographic and ecosystem characteristics have been modified (e.g. river deltas grow in response to sediment input from the river). The evolution of the catchment-coast system becomes more complicated when shift in the external forcing takes place; such shift results from combined anthropogenic and natural processes. Today, human activities in the catchment have a large scale that was not seen in any period of time in history, with a background of global climate and sea level changes. Thus, catchment-coast interaction becomes a focus for investigations in the second phase of LOICZ, a sub-program of IGBP (LOICZ IPO, 2005); emphasis will be placed upon human induced changes in the driving force and the resultant societal/economic consequences. In Europe, a project known as EUROCAT (European Catchments) has been implemented for several years (Salomons, 2004); this project attempts to identify the impact of catchment changes on the coast and to develop integrated models to predict future catchment and coastal changes, with a hope that stakeholders and policy makers will apply the research findings. Likewise, the NSF (Natural Science Foundation) of the United States has updated recently the science plan for the catchment-ocean system ("source to sink") research (MARGINS Office, 2003), for investigations into the processes of material transfer from rivers to deep oceans in response to climate changes and anthropogenic activities, on large temporal scales.

Comparatively, the problems associated with the Asian region are more complex. This region is the most densely populated in the world, with large catchment systems with rivers originating from the highest plateau of the world (i.e. the Qinghai-Tibet Plateau). Among these rivers, many are of global importance (e.g. Indus, Brahmaputra-Ganges, Irrawaddy, Mekong, Pearl, Changjiang and Yellow Rivers). High elevation of the catchment basin, monsoon climate, intense weathering lead to high water and sediment discharges, for both large and small rivers of the region. More than two thirds of the world river sediment discharges are from this region. Human activities further intensify this pattern. In a background of global changes in climate, land-ocean morphology and ecosystems, natural processes and anthropogenic activities in the catchments of these rivers are important in controlling the environmental characteristics on the adjacent coastlines. The modification to the coastal environments, in turn, affects the catchment areas.

Thus, the objectives of the present contribution are: (1) to describe the changes in Changjiang material (freshwater, sediment and nutrient) discharges under the anthropogenic influences (e.g. agriculture, dam construction, water diverting project, and other catchment development schemes), in terms of the mean quantity and variability; (2) to analyse the resultant modifications to the coastal and shelf oceanographic conditions caused by the material flux changes; and (3) to discuss about the impact on the estuarine and shelf ecosystem.

2. Environmental setting

2.1 Cathcment characteristics

The Changjaing River, with a catchment area of around 1.8×10^6 km^2, is the largest river system in China. It is originated from snow-capped mountainous areas (maxi-

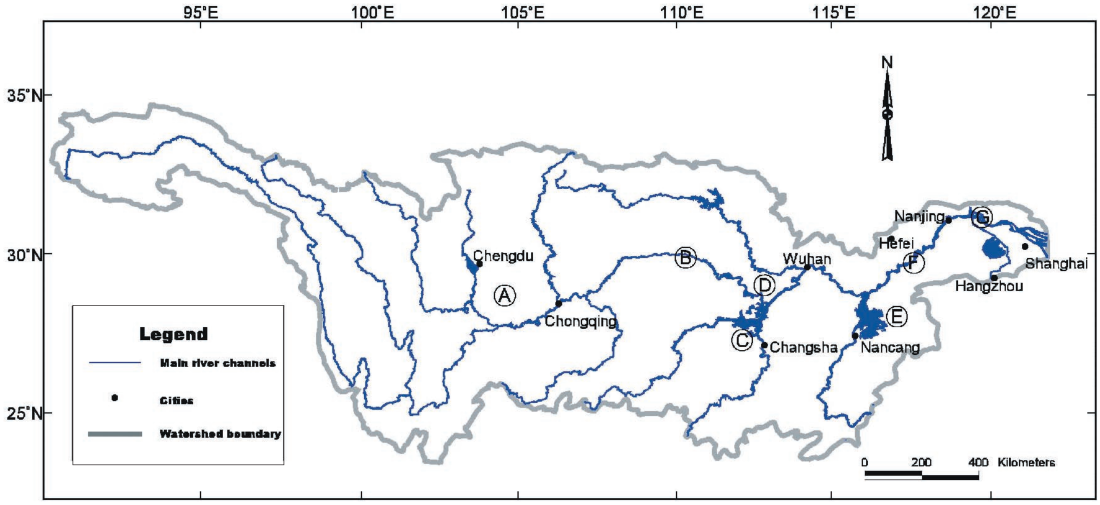


Fig. 6. Environmental settings of the Changjiang River catchment (*A* – Chengdu plain (Sichuan basin); *B* – the Three Gorges; *C* – Dongting Lake; *D* – the Jianghan Plain; *E* – Boyang Lake; *F* – the Datong Station; *G* – Jiangdu Water Diverting Station).

mum elevation greater than 6000 m above sea level) on the Qinghai-Tibet Plateau, flowing through the Sichuan Basin, Three Gorges, the Jianghan Plain and the Middle-Lower Reach Plain and meeting the sea at Shanghai (Fig. 6**).** Generally, the cathcment basin is characterised by mountainous and hilly regions. It should be noted that the river is often called "Yangtze River", but actually the term refers only to the lower reaches of the river. For the whole river, the name is "Changjiang", meaning "Long River".

In the catchment basin, there are strata from pre-Cambrian to Quaternary. In the upper reac hes above the Sichuan Basin, there are Paleozoic to Cenozoic strata (Yang, 2004); on the Qinghai-Tibet Plateau Paleozoic and Mesozoic sedimentary rocks dominate (Zhao et al., 2001). The Sichuan Basin (or Chengdu Plain) is characterised by Quaternary sequences (Liu, 1983). Pre-Cambrian and Paleozoic rock formations are exposed in the Three Gorges region (Yang, 2004). Over the Jianghan and the Middle-Lower Reach Plains, thick Quaternary sedimentary layers have been formed, with Paleozoic to Tertiary strata being exposed in many places; away from the river valley plains, Paleozoic to Cenozoic strata are present in the middle-lower reach regions (Chen and Wu, 1989; Yang, 2004), with the lower Changjiang River metallogenic belt which forms unique tracing fingerprints in the Changjiang water and sediment (Pan and Dong, 1999).

Located in a mid-latitude region with a monsoon climate, the freshwater discharge is large (Beardsley et al., 1985). According to statistical analysis of the gauge record at Datong, which is located 624 km to the west of the Changjiang River mouth, the long-term average water discharge of the River (before the 1980s) is of the order of magnitude of 3×10^4 $m^3\cdot s^{-1}$ (or 9×10^{11} $m^3\cdot yr^{-1}$). Maximum discharge occurs in July and minimum in February. Soil erosion is mild because of the good vegetation cover in the watershed, but the sediment discharge still reaches around 15 $t\cdot s^{-1}$ (or 5×10^8 $t\cdot yr^{-1}$) before the 1980s. Hence, the Changjiang River carries with it a large quantity of dissolved materials including nutrients.

2.2 The shelf and coastal waters

The continental shelf waters are characterized by a typical epi-continental sea system. The East China Sea, bounded by the Korean Peninsula, Tsushima Strait and Japanese islands in the north, consists of a continental shelf area and the Okinawa Trough, with a shelf width of around 500 km. The continental shelf (water depth 0–200 m) has an area of 530×10^3 km^2 (Qin et al., 1996). The shelf currents during the summer include the Kuroshio, Tsushima Warm Current, Tsushima Current, the Yellow Sea Warm Current, Taiwan Warm Current, and North Jiangsu Coastal Current (this current goes further to the south along the Zhejiang coastline in winter). Many rivers, large and small, discharge into the region, forming a plume extending towards the east, with the 0.005 $kg\cdot m^3$ suspended sediment concentration line reaching some 300 km from the river mouth. The East China Sea water is slightly diluted, with an average salinity value of 33.8 for the bottom layers, and 32.9 for the surface layers (Zheng et al., 2003). Near the Changjiang River mouth, there are three well-known fishing grounds, i.e., Zhoushan, Luisi and River Mouth fishing grounds, with many brackish water species.

The transport of the materials derived from the Changjiang over the East China Sea is controlled by tidal currents, shallow sea circulations, Changjiang estuarine processes and storm events. The resultant deposition rate is of the order of 10^1–10^2 $mm\cdot yr^{-1}$ on the inner shelf and 1 $mm\cdot yr^{-1}$ on the outer shelf. The region is characterized by strong tidal action (Larsen et al., 1985; Fang, 1986; Yanagi et al., 1997); in shallow waters, the tides are mostly regularly semi-diurnal or irregularly semi-diurnal in character, with maximum tidal ranges (6–9 m) occurring in Hangzhou Bay and along the central Jiangsu coast. Consequently, tidal currents are strong; maximum tidal currents of 3–5 $m\cdot s^{-1}$ are present.

2.3 Human activities

With a population of around 400 million, human activities represent the most important factor for environmental changes in the Changjiang River catchment, natural factors such as climate change playing only a secondary role. For instance, since 1950 more than 48000 dams have been built in the cathcment, with the Three Gorges Dam being the largest (it has a height of more than 200 m). Since the early-middle 20th century, a large number of dams have been built, for the purposes of irrigation, water storage for industrial and domestic uses, power generating and canalization/navigation (World Commission on Dams 2000). In the catchment of the Changjiang River alone, by 2004 more than 48000 dams have been constructed, according to the Ministry of Hydraulic Engineering of China). The purpose of the dam construction is for power generation, water supply, irrigation and flood defense.

The electricity that can be generated is of course very attractive; in 2005 the Three Gorges Power Station provided around 50×10^9 kwh of electricity (the power plant will be in full operation in 2009). On the other hand, the problem of river flooding has long been a problem to be solved. The flooding disasters are indeed serious; interestingly, there appears to have a periodicity (each cycle lasted for 50–60 years. In the 20th century many hydraulic engineering projects were carried out in the catchment, but there were still large flooding disasters, e.g., the flooding events in 1954 (Administration of Changjiang Hydraulic Engineering, 2004) and 1998 (Administration of Changjiang Hydraulic Engineering, 2000).

At the same time, in order to solve the problem of water shortage in northern China, it has been planned to transport up to 10% of the annual discharge from the river to the north. It is hoped that this will supply sufficient water for urban, industrial and agricultural uses in this region. There are three optional routes for the transport (located in the upper, middle and lower reaches of the river basin, respectively); the lower reach route (between Shanghai and Nanjing, see Fig. 6) has been under construction.

The human activities are modifying the catchment at an increasing rate. In response to industrial and agricultural development, the nutrient load (N and P) is increasing, reaching an order of magnitude of 10^6 t·yr^{-1} (Zhang 1996; Yan et al., 2001). With regard to large coastal engineering schemes near the river mouth, the construction of Yangshan Harbour on the Qiqu Archipelago (Chen, 2000) off the Shanghai coast, with a huge bridge (32 km in length) linking the harbour with the land, is indicative of their scale and social/economic influences on the catchment regions.

3. Changes in material fluxes

3.1 Freshwater and suspended sediment discharges

Changes of the discharges may be considered on inter-annual and seasonal time scales. The records, which cover a period between 1950 and 2004, do not show a decreasing trend for freshwater discharge, but have a trend of decrease in suspended sediment discharge, especially for the second half of the period. Over the last ten years, i.e. for the period of 1995–2004, the average value was 2.9×10^8 t/yr; this is much lower than the values adopted in many publications, 4.86×10^8 t/yr, which was based upon the record before the 1980s. Such changes have taken place on a time scale much smaller than the scale for global climate and sea level changes. They are associated with the cathcment human activities. Because the water in relatively abundant in the Changjiang River, the extract of river water for urban and domestic uses does not play a significant role. This differs from the situation in the Yellow River catchment, where water has been taken for domestic uses, causing significant reduction in the water flow. The main reason lies in the construction of numerous dams. As described above, since 1950 more than 48000 dams have been built in the cathcment, with the largest ones being built after 1980. Before the Three Gorges Dam came into effect in 2003, it was estimated that more than 15% of the sediment discharge was trapped in the reservoirs. Today, according to the records, perhaps more than 40% of the sediment discharge is left behind the dams.

In terms of the timing for the discharges, there have been some changes, according to a comparison between the average discharge for each month for the periods of 1950–1987 and 1998–2004. The first period represents a more or less natural condition, when only a few dams were built, although at later stages of the period large scale construction of dams took place. The second period is characterized by the completion of many large dams including the Gezhouba and Three Gorges Dams. During the 1950–1987 period, the highest and the lowest discharges account for 14.64% and 3.0%, respectively, of the annual total (similar patterns were also identified by Shi et al. (1985) when they analysed the data sets covering the period of 1943–1979); in the 1998–2004 period, the highest discharge was reduced to 14.08% and the lowest discharge increased to 3.94% of the annual total. Thus, there is indeed some effect of the construction of the dam building. However, it should be noted that so far the changes are not as significant as observed in other rivers over the Asian region. For instance, In Indus River, following the construction of the Korri barrage (located around 270 km from the river mouth) in 1931, seasonal patterns of water discharge started to decrease (Jorgensen et al., 1993); since the catchment area of this river is much smaller than the Changjiang River, the effect of damming is more significant. In the case of the Changjiang River, the present dams can only hold around 15% of the total annual discharge. However, in the future, with the construction of more dams and the water diverting scheme to transport water to northern China (see above), more remarked changes can be anticipated.

3.2 Nutrient discharge

The nutrient load that is associated with catchment development is increasing in the Changjiang River. Studies have revealed that nitrogen and phosphorus discharges have been enhanced significantly since the 1960s; these changes are mainly due to the use of chemical fertilizers and industrial/domestic sewage discharges, according to many studies (Shen et al., 2001, 2003; Yan et al., 2001) Over a period of 30 years, between 1968 and 1998, the DIN discharge increased from 0.2×10^6 $t{\cdot}yr^{-1}$ to 1.4×10^6 $t{\cdot}yr^{-1}$. The trend of increase has been maintained recently (Liu et al., 2002).

Phosphorous, represented by PO_4^{3-}–P, also shows an increasing trend, but at a lower rate. In the late 1960s, its flux was of the order of 3×10^3 $t{\cdot}yr^{-1}$ but it increased to around 7×10^3 $t{\cdot}yr^{-1}$ in the early 1980s (Liu et al., 2002). During the summer of 1998, when a large flood occurred, around 84×10^3 t of phosphorous passed by the Datong Station (Duan et al., 2001).

4. Modifications to coastal oceanographic conditions by flux changes

4.1 Suspended sediment concentrations

The suspended sediment concentration (SSC) in the freshwater is decreasing, but what is happening to the estuarine waters? In order to examine this, appropriate data sets are required. First, it has been known for a long time that the SSCs of the river water and the estuarine water are different. During the period of 1916–1920, measurements of SSCs were undertaken at an estuarine station and a river channel station and the monthly average SSCs were highly different (Chen, 1957). This phenomenon was thought to be caused by tides and waves in the estuarine waters. Subsequently, many studies have revealed that it is related to the formation of turbidity maxima in the estuary (e.g. Li et al., 1998; Chen et al., 1999) and seabed resuspension outside the river mouth (e.g. Sternberg et al., 1985). Thus, reduction in the river SSCs does not necessarily mean decrease of the estuarine SSCs. Second, the SSCs vary with flood-ebb tidal cycles: they differ from time to time. Therefore, in order to examine any long-term changes, tidal cycle measurements are required to derive average values; instantaneous values are of little uses. Third, on a larger time scale, the SSCs vary with spring-neap tidal cycles and seasons. The patterns of turbidity maxima and seabed resuspension processes are highly different for different combinations of runoff, tide range and weather conditions (Milliman et al., 1984). Finally, there is a significant spatial difference in the SSC within the estuary; high concentrations are found at the core of the turbidity maxima and, away from the maxima, they decrease. Hence, the SSC depends upon the location where the measurements are carried.

With these considerations, it is difficult to establish a time series to delineate the long-term changes. Nevertheless, if flood-ebb tidal cycle averaged SSCs from different stations and times are plotted, then a general trend may be identified. In order to evaluate the long-term SSC changes, tidal cycle measurements have been carried out since 2002 by our research team, over the Changjiang River estuaries region, at a number of stations. To undertake the measurements, water samples were collected, current velocities were recorded, using a fishing boat. The water samples were filtered to obtain the SSC data, and the current, salinity and temperature data were processed real time. Based upon the tidal cycle measurements and water sample analyses, average SSCs have been calculated. In addition, historical data sets have been collated from literature (Yang and Milliman, 1983; Su and Wang 1986; Anonymous, 1998; Li and Zhang, 1998; Li, 2000; Wu et a., 2003; Yun, 2004; Wang et al., 2006) to obtain average SSCs. It does not appear to have a well-defined change. Outside the river mouth, no trend of decrease in the SSC has been observed, too. During large flooding events, like the 1998 flooding event, the turbid plume can reach 123.5°E (Gao et al., 2000).

Numerical studies have shown that the SSC associated with turbidity maxima may be reduced if the river flow decreases (Zhu et al., 2004). Thus, although there is so far no well defined changes in the estuarine SSC, in the future reduction may occur after the water diverting project is completed.

4.2 Accretion/erosion patterns

Field observations (Yang et al., 2002, 2003) and numerical modeling studies (Gao, 2006) have revealed several consequences of the Changjiang River sediment input changes, including modifications to the seabed accretion/erosion and river delta growth patterns. The present Changjiang River delta is a result of sediment accumulation over the last several thousand years. The increase of land is very important for the region and, therefore, reclamation of land from the sea has been an intensive human activity here for many years. However, the sediment from a cathcment basin does not deposit entirely on the deltaic areas: some materials are transported to offshore by oceanic forces (Milliman et al., 1985; Su and Wang, 1989; Nittrouer and Wright, 1994; Chen et al., 1999). This implies that if the sediment discharge is reduced to a certain level, then accretion will not continue. In fact, in recent years on the Changjiang deltaic coast, erosion has been intensified and shoreline retreating has occurred (Yang et al., 2002, 2003). Modeling studies on the basis of a lumped delta growth model show that if the sediment input of 500×10^6 $t\cdot yr^{-1}$ can be maintained then the delta will continue to grow for another 5–10 km (with influences of regional subsidence and sea level rise), but at a lower rate than before; on the other hand, if the sediment discharge is decreased to a level of 300×10^6 $t\cdot yr^{-1}$, then the growth will stop. Records show that the sediment input is now 290×10^6 $t\cdot yr^{-1}$ (averaged over the period of 1995–2004). This means that the delta will not grow further and the seabed over the estuarine waters will be subjected to erosion.

The end of net sediment accumulation will change the carbon burial patterns. Originally, before the 1980s, every year around 200×10^6 $t\cdot yr^{-1}$ of sediment was accumulated, causing a deposition rate of 1–6 $cm\cdot yr^{-1}$ over the sub-aqueous delta (McKee et al., 1984; De Master et al., 1985). The sediment contained on average 0.53% organic carbon (Zhang et al., 1987), which was partly from the catchment and partly from the marine environment. Thus, around 10^6 t $C\cdot yr^{-1}$ would be buried with the sediment in the deltaic areas. Because now seabed accumulation have ceased, the carbon burial will approach to zero. This means that the estuarine region will no longer work as a sink for carbon. On the other hand, because the seabed is frequently reworked, the conditions of dissolved oxygen will be improved.

4.3 Water flushing and exchange patterns

The flushing time for the freshwater that discharges into a shelf area can be calculated by (Fischer et al., 1979):

$$T_f = \frac{V}{Q_R} \qquad (1)$$

where T_f is the flushing time, V is the volume of the water mass within a region in consideration, and Q_f is the freshwater discharge into the region. In order to evaluate the flushing characteristics of the adjacent waters to the Changjiang River mouth, three regions were used to calculate the flushing times. Region I adopted for the calculation is located immediate to the rover mouth, Region II covers the three major fishing grounds near the river mouth, and Region III represents an further enlarged area, covering the areas of regions I and II and deeper continental shelf waters.

For each of the regions, flushing times on annual time scale and for summer/winter seasons was calculated for the following four cases:

• Case 1a, associated with the conditions that the long-term annual discharge is adopted (i.e. $Q_S = 9\times10^{11}\ m^3\cdot yr^{-1}$) and the effect of dam construction is small (i.e. using the discharge percentage data of the period 1950–1987)

• Case 1b, under the condition of long-term annual discharge but with the dam influences (i.e. using the discharge percentage data of the period 1998–2004)

• Case 2a, for the condition that the long-term annual discharge is reduced by 10% (in response to the water diverting scheme), using the discharge percentage data of the period 1950–1987

• Case 2b, the same to Case 2a, but using the discharge percentage data of the period 1998–2004

As such, the results of the calculation represent an "average condition" of flushing time. The results indicate that flushing time is generally large, except for the immediate estuarine waters. In the estuary itself (Region I), the water mass is renewed within a month, with faster water exchange occurring in summer than in winter. For region II, the flushing time reaches more than a year; for Region III it is of the order of 10 years. In all cases water exchange is more rapid under the summer condition than under the winter condition. Likewise, because of the changes in the seasonal distribution pattern of the discharge, the flushing time under the summer condition will increase, but it will decrease under the winter condition.

Furthermore, if 10% of the Changjiang River water will be transported to northern China after the completion of the water diverting project, then the average flushing time will increase by around 10 % for all the Regions. This means that the river water will stay in the shelf areas longer, following the reduction in the discharge.

4.4 Salinity distributions

A number of physical factors should be examined, in order to understand the fate of the discharging materials from the river. First, where is the freshwater going? And, if there are changes in the water discharge, what will happen? For answers to these questions, we may have a look a regional water and salt balance patterns. This can be approached by looking at water exchange for a given area. It should be noted that this water mass definition has a scale problem, i.e., if you consider a different volume of water body, then the physical parameters related will vary.

For the area, an equation of water balance can be derived, with the meaning of the variables being denoted by the slide:

$$Q_R + Q_O + Q_P - Q_V - Q_C = 0 \qquad (2)$$

where Q_R is the mean freshwater discharge from the river, P is precipitation, V is evaporation. Assuming $Q_P - Q_V = 0$, we have

$$Q_R + Q_O - Q_C = 0 \qquad (3)$$

For salt balance, we can write

$$Q_R S_R + Q_O S_O - Q_C S_C = 0 \qquad (4)$$

where S_R, S_O and S_C are the salinity values for the river water, saline sea water and the shelf water mass in consideration, respectively. Since $S_R = 0$, we have

$$Q_C = \frac{Q_O S_O}{S_C} \qquad (5)$$

Combining (2) and (5) leads to

$$S_C = \frac{Q_O S_O}{Q_O + Q_R} \qquad (6)$$

If we take $S_O = 34$ (Zhang et al., 1987), under the present condition of Q_R, $S_C = 15$, 20, 25, 30 (these are approximately equivalent to the salinity values for the estuarine water, Regions I, II and III, respectively, according to a synthesis of historical salinity observations from literature (e.g. Tian et al., 1993), then $Q_O = 7.1$, 12.9, 25, 57.5×10^{11} $m^3 \cdot yr^{-1}$. Using these Q_O values, under the condition that 10% of the river flow will be diverted to northern China in the future, the salinity values will be 15.9, 20.9, 25.7, 30.4, respectively. This means that an increase of salinity by 1 can be expected for the shelf waters adjacent to the river mouth (i.e., Regions I and II), but the influence becomes small for the wider shelf region (i.e. Region III). Therefore, for a 10% decrease in water discharge, there will be a salinity decrease by 0.4 to 0.9, depending upon the size of the water mass in consideration.

4.5 Nutrient balance

Before biological consumption, the nutrient balance and the related nutrient associated could be calculated. For a shelf water body,

$$V_R = V - V_O \qquad (7)$$

where V_R is the volume of freshwater from the river, retained in the water body; V is the volume of the total water body, as defined in Equation (1); and V_O is the volume of oceanic saline water. Since the salt balance within the water body is

$$VS_C = V_O S_O \qquad (8)$$

we have

$$V_R = V(1 - \frac{S_C}{S_O}) \qquad (9)$$

The total amount of nutrient contained within the water body, which is derived from the river, will be

$$M = C_R V_R = C_R V(1 - \frac{S_C}{S_O}) \qquad (10)$$

where M is the total nutrient quantity, and C_R is the nutrient concentration of river water. The concentration of nutrient within the water body will be

$$C = \frac{M}{V} = C_R(1 - \frac{S_C}{S_O}) \qquad (11)$$

Hence, the concentration will be proportional to the nutrient concentration in the river.

Here we calculate the quantity of runoff-derived dissolved inorganic nutrients retained in shelf waters and their concentrations, using Equations 10 and 11, to demonstrate the effect of freshwater discharge changes. In the calculations, the following conditions are adopted:

- Condition A: DIN discharge 0.2×10^6 t·yr^{-1}, DIP discharge 3×10^3 t·yr^{-1}
- Condition B: DIN discharge 1.6×10^6 t·yr^{-1}, DIP discharge 10×10^3 t·yr^{-1}
- Condition C: DIN discharge 2.0×10^6 t·yr^{-1}, DIP discharge 14×10^3 t·yr^{-1}

Condition A represents the base line discharges, with an order of magnitude associated with the observations at the Datong Station before the 1970s. Condition B approximately represents the situation of 2005, by extrapolation of the DIN and DIP time series data using the historical records in literature (Yan et al., 2001). Condition C represents a scenario for the future, assuming that the catchment nutrient output will continue to rise, but some management measures for pollution control will become effective.

The construction of the dams in normal years will reduce the peak flow in summer (i.e. rainy season), hence reduce the effect of N input increase; however, in big flood years (e.g. 1998), large, extreme N input may occur. This may be reflected by a large primary production event in marine waters.

It should be understood that these values cannot be compared with field observations, because the processes of biological uptake, nutrient sources of the ocean and seabed, and the transformation between the different forms of nutrients (e.g. particulate – dissolved and organic – inorganic transforms) are not taken into account. Nutrients are also transported into the shelf areas from the deep ocean (Chen et al., 1995; Gong et al., 1995, 1996; Chen, 1996). Nevertheless, the results show that both the DIN and DIP quantities retained and their concentrations in Regions I, II and III have an increasing trend. Further, the quantity of DIN is much higher than the DIP quantity (with the former being 60 to 140 times of the latter), indicating a significant deviation from the Redfield ratio (Redfield et al., 1963); this observation has several biological implications (see below).

5. Ecosystem responses to flux changes

5.1 Primary and secondary productions

As stated previously, between 1968 and 1998 the DIN discharge in the Changjiang River increased from 0.2×10^6 t·yr^{-1} to 1.4×10^6 t·yr^{-1} (Yan et al., 2001). Assuming that in the DIN ($NH_4^+ + NO_3^- + NO_2^-$) discharge the mass of nitrogen accounts for around a third, the increased discharge becomes 0.4×10^6 t N·yr^{-1}. According to the Redfield ratio, if the nutrient is used at least once in the shelf waters, then the carbon fixed by this nutrient input is of the order of 2.27×10^6 t C·yr^{-1}. This is equivalent to a total primary production of around 60×10^6 t·yr^{-1} (assuming that the organisms consist of 90% of water and 10% dry material in which carbon accounts for 40% in terms of mass). This value denotes extra primary production for the region, in the form of phytoplankton, in addition to the baseline value.

Using a transform ratio of 132:703 (Mckenzie et al., 1998), this implies a total secondary production (represented by zooplankton) of 11.3×10^6 $t\cdot yr^{-1}$, which in tern supports a biological production of around 0.95×10^6 $t\cdot yr^{-1}$, consisting of fish and other high trophic level animals.

It has been observed that the average N and P concentrations for the entire East China Sea water are 4.31 $\mu mol\cdot dm^{-3}$ and 4.31 $\mu mol\cdot dm^{-3}$, respectively (Zheng et al., 2003). This represents a situation of N limitation or deficit. Thus, the pattern of larger increase in the N input than that for P input is beneficial to the enhancement of primary production. In situ investigations have revealed that the daily nutrient discharge increases with the freshwater discharge, and similar relationships exist between the primary/secondary production and the freshwater discharge (e.g. Chen et al., 2004; Ning et al., 2004; Wu et al., 2004); statistical analysis under taken by Wang et al. (2004) has demonstrated that the total zooplankton biomass over the Changjiang estuary and adjacent waters has more than doubled over the last 40 years, on the basis of a comparison of the data of 1959 and 1999. These observations provide evidence of the enhancement of the biological productivity of the East China Sea. The relationship between nutrients, irradiance, mixing and primary production has been identified elsewhere (e.g. Lohrenz et al., 1999).

A side effect of the enhancement of N input and the biological production is the occurrence of red tides. Before the 1960s red tides were rarely observed, but they are occurring now with an increasing frequency (e.g. Qiao et al., 2000; Wu et al., 2004). The red tides tend to be present at the plume front close to the river mouth, which is also a nutrient front (Tian et al., 1993; Ning et al., 2004). This is due to the fact that in the turbid estuarine water photosynthesis is weak, but light limitation is no longer a controlling factor at the frontal areas. This observation implies that red tides occur where the nutrient concentration is relatively high; in the future, if the freshwater discharge and the suspended sediment concentration in the estuarine waters are reduced further, then the red tides will occur more frequently.

It should be noted that the above mentioned situations are related to normal river discharge years. When big floods (like the flood event of 1998) occur, the dams will only have a limited effect in controlling the flood, since at the present stage the overall reservoir capacity of the cathcment is not sufficiently large. In this case, the behavior of the freshwater discharge will be more or less similar to a “natural discharge”; furthermore, in this case the plume front will be located in deeper waters and, therefore, most of the nutrient carried by the flow will not be consumed by red tide organisms.

5.2 Impact on fishery

The fishery catch for marine wild fish and other fishery products from the East China Sea region almost accounts for half of the total of the country. From time to time the potential of fishery catch has been estimated on the basis of trophic relationships (Zheng et al., 2003). It was proposed that overfishing took place in 1975–1983 and this would influence significantly the fishery industry. However, interestingly, fishery catch of the region of the East China Sea had increased rapidly between 1992 and 1998 (Fig. 7), when it was supposed that fishery resources would be exhausted. Since 1998 the fishery catch has been maintained at a level of 5 to 6×10^6 $t\cdot yr^{-1}$. Since 2000, some measures have been adopted by the Chinese Government to protect the fishery resources (e.g. reducing the number of fishing vessels and extending the non-fishing season), so the catch has been reduced slightly.

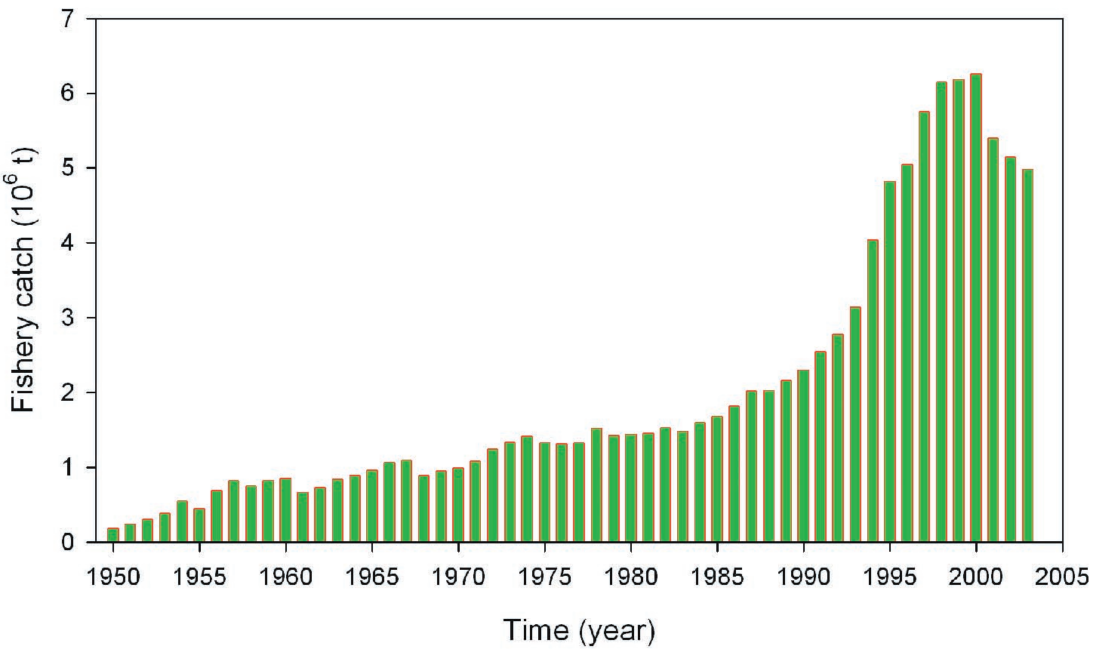


Fig. 7. Fishery catch from the East China Sea region 1950–2003 (original data from Zheng et al. (2003) and the Ministry of Agriculture of China).

From the interrelationships between the runoff, nutrient input, primary and secondary productions, and the trend of fishery catch, it is clear that the high catch is maintained by the increasing nutrient input. To understand fully the mechanisms further studies are required, but we may notice that the biomass and the nutrient input within the ecosystem are interrelated. Under the condition of overfishing, the composition and trophic level of the fishery products are changed (Zheng et al., 2003), but the overall output can be maintained. In addition, future changes in salinity distribution patterns may influence the brackish species, which is abundant under the present day conditions (Liu et al., 1987).

6. Conclusion

The study on the synthesis of the changing patterns of Changjiang material fluxes under the catchment anthropogenic influences and the analysis the resultant modifications to the coastal and shelf oceanographic and ecological conditions can be summarised as follows.

(1) <u>Changes in Changjiang River material fluxes</u>

Within the catchment basin of the Changjiang River, intense development activities are causing changes in the material fluxes. In particular, because of the construction of more than 48000 dams within the river valley (including the Three Gorges Dam), the sediment discharge has been reduced by 40% over the last 20 years. Meanwhile, the timing of seasonal freshwater discharge has been modified by the dams. In the near future, it is anticipated that the mean freshwater discharge and its seasonal variability will change significantly, in response to the water diverting scheme for water supply to northern China. In contrast, the discharge of nutrients (nitrogen and phosphorous) of the river has been increasing, due to the use of chemical fertilizers and the discharge of industrial and domestic sewage.

(2) Modifications to the coastal and shelf oceanographic conditions

The changes in the timing of freshwater discharges are causing longer flushing time in summer but shorter flushing time in winter. In the future, if 10% of the Changjiang River water will be transported to northern China by the water diverting system, then the average flushing time will increase by around 10 % for the shelf waters, with salinity decrease by 0.4 to 0.9. Increase in the nutrient load in the river water and/or reduction of freshwater discharge result in an enhanced nutrient concentration in the shelf waters.

Although the suspended sediment concentration in the freshwater is decreasing, three a re no well-defined patterns of change in the estuarine water according to *in situ* measurements. The mechanisms for this phenomenon include resuspension of seabed sediment, estuarine circulations and tidal pumping that form turbidity maxima in the estuarine waters. However, in the future the concentration may be reduced after the completion of the water diverting project in the catchment. Further, due to the reduced sediment discharge, net sediment accumulation and carbon burial will no longer take place on the deltaic areas.

(3) Impact on the shelf ecosystems

The increase in the nutrient input, in association with the shelf environmental setting, enhances the primary and secondary production of the East China Sea region. This results in an increasing fishery potential and the fishery catch, which is beneficial to fishery industry, although due to the overfishing the composition and trophic level of the fishery products are changed. At the same time, the enhancement of N input and the biological production causes red tides, which occur with an increasing frequency. In the future, red tides will occur more frequently in response to further reduction of the freshwater discharge and the suspended sediment concentration in the estuarine waters.

Seasonal and annual variability of the concentration and output of nutrients by the Razdolnaya (Suyfun) River (Russia)

The southern part of Primorski Krai of the Russian Federation is the most developed territory of the Russian Far East. There is a certain deficiency of fresh waters here. Therefore the water quality of Razdolnaya River – the main river of this territory is a subject for the monitoring by the State Agency on Hydrometeorology and research institutes. The purpose of these works is to provide information for prevention of water pollution and rational water use. Besides headwaters of Razdolnaya River is located within the Chinese People's Republic and it is necessary to allocate and characterize possible influence of intensively developing northern provinces of China on a chemical composition of river waters in the Russian territory.

Among problems of the water quality caused by economic activities, it is possible to allocate three aspects: 1) superfluous amount of nutrients (N, P, Si, C) which leads to enhanced bioproduction, consumption of oxygen, hypoxia and degradation of water ecosystem; 2) receipt of potentially toxic chemical compounds of heavy metals, pesticides, phenols, surfactants which can render negative influence on biota and reduce quality of water as resource; and 3) changes of a chemical composition of water, caused by change of physical characteristics of water systems (construction of water basins and dams). Besides the increase in concentration of chemical compounds in river water causes increase in their delivery to the coastal waters.

For Razdolnaya River the first problem is most actual, and the purposes of given paper are: 1) the analysis of seasonal and spatial variability of concentration and output of nutrients, especially different forms of nitrogen; 2) definition of a trend of change of a chemical composition of river waters for the period of 1980–2002; 3) the characteristic of a modern level of anthropogenic influence on a chemical composition of Razdolnaya River.

Study of seasonal variability of nutrient concentrations at the Russian part of the Razdolnaya River has shown that the concentration of the dissolved silicon is controlled by bioproduction processes and irrespective of anthropogenic loading. Contrariwise seasonal variability of phosphates and the ammonium strongly depends on anthropogenous influence. In the upstream of the rivers where it is minimal, seasonal variability is reduced to slight increase of concentration during the winter period due to increase in a role of delivery from ground water. Near Ussuriisk city - the main source of pollution, the extent of winter maxima grows and summer maximum of phosphates and ammonium, connected with high-water, has been added (Fig. 8).

Significant annual variability of ammonium, BOD5, and dissolved oxygen concentrations is found in Razdolnaya River for last 20 years. The ammonium concentration is reduced, since 1993 г, but BOD5 and the dissolved oxygen ones are increased, especially down stream of Ussuriisk city.

In comparison with other rivers of region Razdplnaya River is characterized by the elevated level of easy oxidisable organic substances (by BOD5) and ammonium. Relatively increased concentration of these components is observed upstream of river that is caused, probably, anthropogenic influence at the Chinese part of Razdolnaya River. The phosphates and nitrates concentration in the upstream of Razdolnaya River is close to the background, and rises in 1.5–4 times near Ussuriisk city.

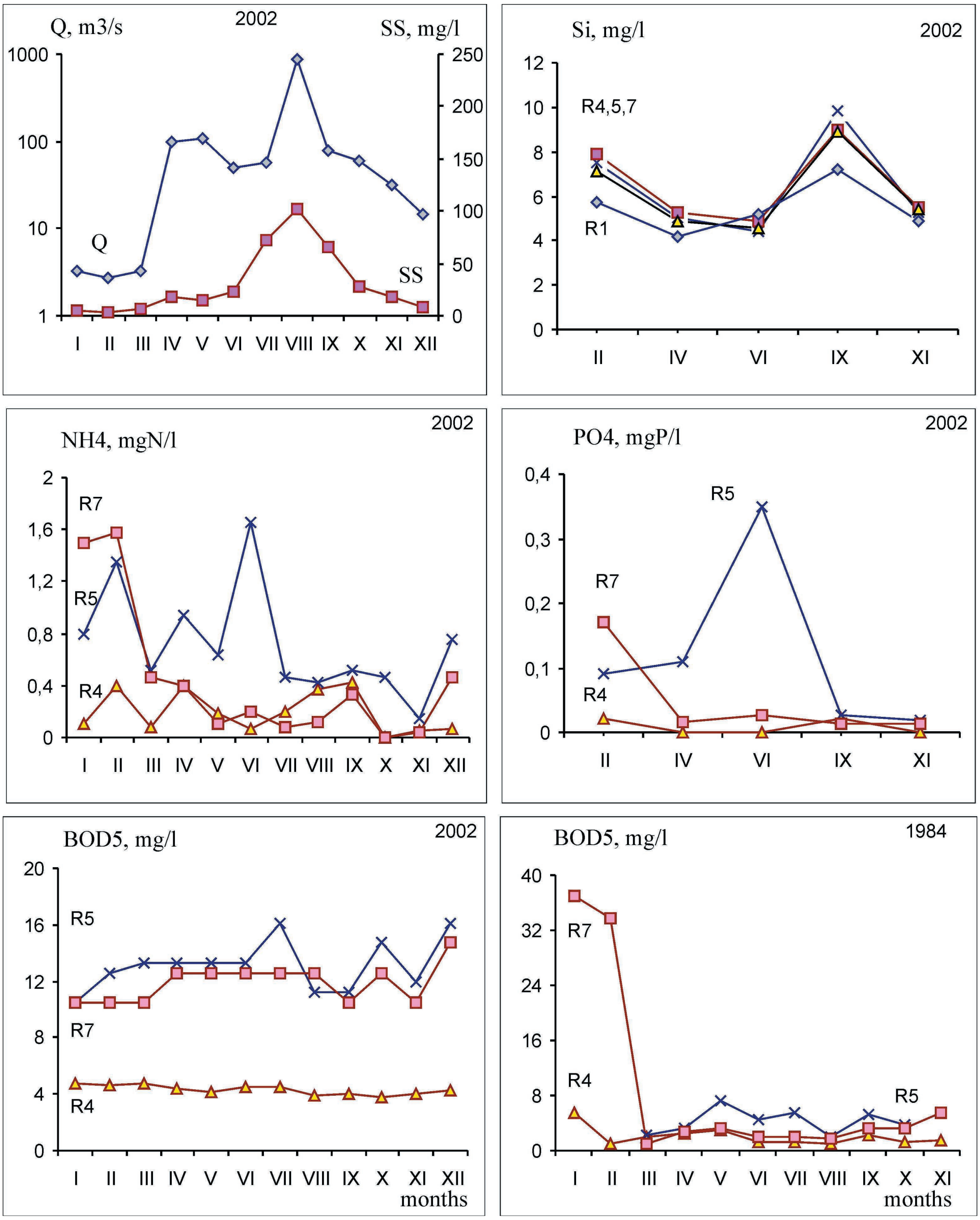


Fig. 8. Seasonal changes of water discharge, some nutrient concentrations, dissolved oxygen and BOD5 at the different places along Razdolnaya River on the example of 2002.

Output of nutrients by the Razdolnaya River during the year changes on the order and more, and is defined, first of all, by seasonal variations of water discharge. Annual variability of output also reaches the order, but is caused both fluctuations of a mid-annual water discharge and trends in change of a chemical composition.

Concentration of metals in the rivers of the southern part of the Russian Far East

Determination of the authentic level of metals concentration in river waters continues to be actual for many regions of Russia, including Primorski Krai It is connected with difficulties of sampling and chemical analysis of metals in quantity 0.00n–0.n µg/l. As a result of improvement of sampling and analysis technique there is a revision of many data published earlier, aside reduction (Shiller, 1997). Especially it concerns rather poorly contaminated and pristine rivers (Taylor and Shiller, 1995).

However other consequence of these researches is the increase in contrast of distribution of metals at the significant anthropogenic influence and enhance of opportunities to use metals as indicator of biogeochemical processes and/or anthropogenic loading (Shulkin, 2004).

Researches of microelement composition of the rivers of Primorski Krai were carried out repeatedly (Ignatova and Chudaeva, 1983; Chudaeva, 2002), however the data on the concentration of some metals in river waters continue to remain debatable. The behavior of metals in the rivers under specific influence of the mining industry is most obvious (Elpatyevski, 2000). But outside these areas, the degree of anthropogenic influence on the metal concentration in river waters of Primorski Krai is characterized not enough.

The purpose of the given chapter of the report is a presentation of the new data on the content of dissolved Fe, Mn, Zn, Cu, Pb, Cd and their concentration in suspended solids in Razdolnaya River – one of the main rivers of the south of Primorski Krai. It is necessary to note, that headwaters of Razdolnaya River is located in China and it is necessary to allocate and characterize possible influence of intensively developing economy of northern provinces of China on a metal concentrations in Razdolnaya River. The characteristic of metal concentration in the downstream of Tumen River – the biggest river of Japan/East Sea basin, is a next aim of this paper.

Concentrations of dissolved Mn, Zn, and Cu in headwaters of Razdolnaya River are 20–30; 0.3–0.7; 1.2–1.3 µg /l, accordingly, that is close to the level observable in unpolluted rivers (Fig. 9). However, the concentration of dissolved Pb and Cd is 3–10 time higher than background, due to additional input from Chinese People's Republic, or due to unknown sources at the Russian territory. Concentration Fe, Zn, Cu in suspended solids of headwaters is equal to background, but on Pb and Cd in suspended solids is observed 2–10 time increase upon background level as well as for the dissolved forms of these metals.

Change of concentration of metals in solution and in suspended matter along Razdolnaya River allows to characterize confidently a degree and character of anthropogenic influence, and to assess existing self-cleaning ability of the river. Anthropogenic influence on the concentration of metals in Razdolnaya River could be registered on distance of 10–20 km downwards from Ussuriisk. At the greater water discharge anthropogenic increase of concentration of the dissolved metals is traced further downstream. However on distance of 40 km downstream off Ussuriisk concentration of the majority of the dissolved metals in June and September are compared and reduced up to a background level (0.09–0.9 µg/l Zn, 0.005–0.008 µg/l Pb, 0.004 µg /l Cd, 2–12 µg /l Mn).

Despite of obvious and significant anthropogenic influence on metal concentration in solution and suspended solids of Razdolnaya River, self-cleaning ability of the river is sufficient and in the downstream concentration of the dissolved metals is reduced close to background. The basic mechanism of self-cleaning is, probably, sorption on suspended matter.

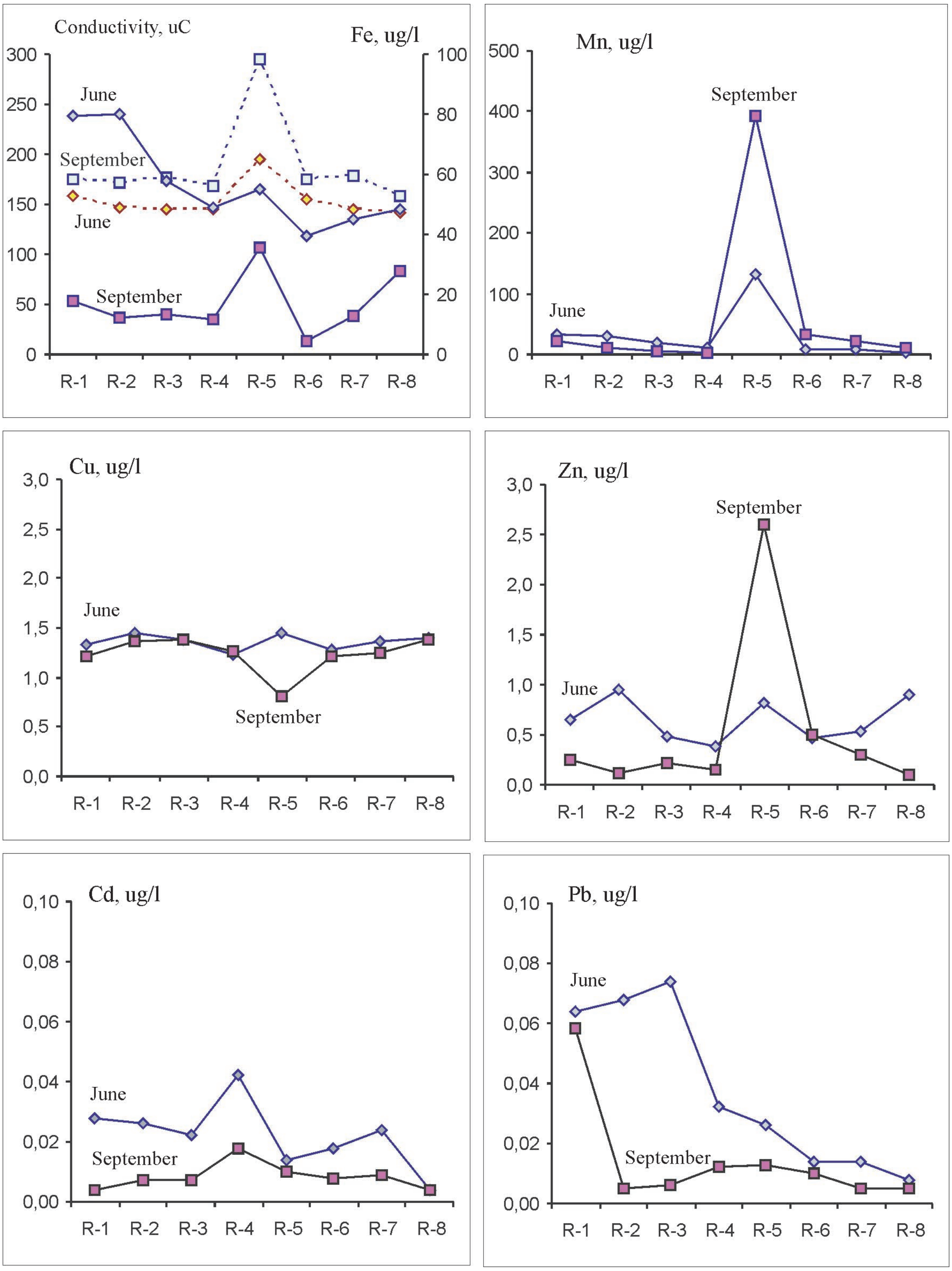


Fig. 9. Change of dissolved metal concentrations (μg/l) and conductivity (μS) in Razdolnaya River water from headwaters (R1) to downstream (R8) in June and September 2003.

Concentration of metals in downstream of Tumen River do not show heavy anthropogenic press, but dissolved Cu and Zn and Cu in suspended matter are elevated compare with down stream of Razdolnaya River and unpolluted rivers.

Behavior of microelements in a mixture zone of Razdolnaya River – Amur Bay according to physical and chemical modeling

On their way to ocean, chemical elements migrating in rivers meet a powerful geochemical barrier in the form of a near-mouth zone of the river and sea waters mixture, such zone got the name of "a marginal filter". Various on their chemical composition, river waters of low ionic strength face salty sea waters of high ionic strength. As a result of mixture of the river water with the sea water containing a significant volume of electrolytes, the suspended particles lose stability, stick together with each other and drop out on a bottom as units, that most intensively occurs at salinity of 2–8‰. As a rule, in the estuary, river waters richer in trace elements (and more muddy) are diluted with the sea waters of low turbidity, impoverished by trace elements, as a result, the content of the last ones in a solution and in suspension of the mixture zone waters decreases. In conditions of the marginal filter the processes of sorption and desorption get especially great value. The main sorbing agents are hydroxides of iron and manganese, suspended organic substance, clay minerals, siliceous and carbonaceous rests of organisms. All these processes result in changes in the ratio of trace elements migration forms in the rivers on a river-sea barrier: part of the dissolved trace elements is removed from a solution, another one, on the contrary, is mobilized as a result of transformation into more mobile forms.

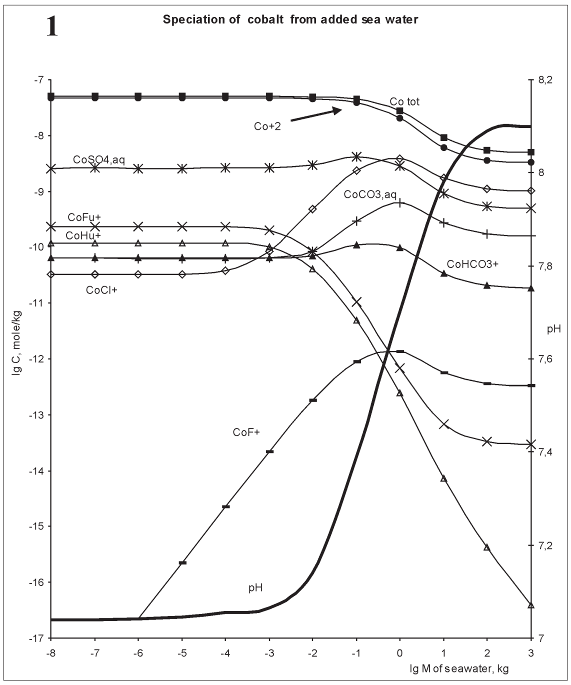
At geochemical researches of natural waters first of all it is necessary to distinguish the suspended and dissolved forms of migration of chemical elements, for that the water is filtered through the filter of 0.45 microns. The ionic form, inorganic complexes, complexes with the dissolved organic substance, associates and ionic pairs, and also some colloids, passed through the filter, all they are referred to the dissolved forms of an element. Except colloids, the above forms of elements are understood as the physical and chemical form of the element presence in a solution.

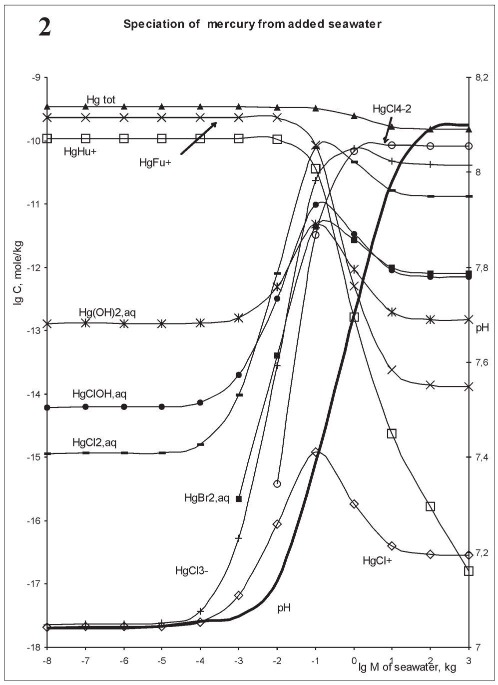
In the given work results of determining physical and chemical forms of occurrence and behavior of chrome, vanadium, arsenic, mercury and cobalt in a mixture zone of Razdol'naya River – Amur Bay by a method of physical and chemical modeling are given.

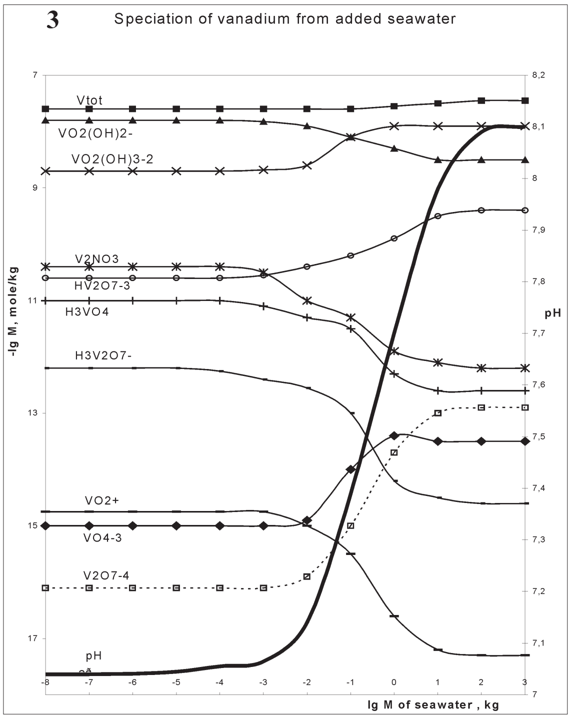
Physical and chemical modeling with the SELECTOR software package has shown that prevailing forms of vanadium in sea water are HVO_4^{2-} (75.2%) and $H_2VO_4^-$ (22.75%), chrome occurs as CrO_4^{2-} (69.67%) and $NaCrO_4^-$ (29.0%), arsenic – as $HAsO_4^{2-}$ (98.3%) and $H_2AsO_4^-$ (1.53%); cobalt – Co^{2+} (48.2%), $CoCl^+$ (29.06%), $CoSO_4^0$ (16.73%), $CoCO_3^0$ (4.82%); mercury – $HgCl_4^{2-}$ (54.70%), $HgCl_3^-$ (37.3%), $HgCl_2^0$ (7.33%). In the river water vanadium is as HVO_4^{2-} (9.45%) and $H_2VO_4^-$ (90.5%), chrome – as CrO_4^{2-} (77.96%) and $HCrO_4^-$ (21.99%), arsenic – $HAsO_4^{2-}$ (74.15%) and $H_2AsO_4^-$ (25.84%), cobalt – Co^{2+} (93.68%), $CoSO_4^0$ (5.10%).

The quantity of organic compounds, arsenic, vanadium and chrome in both types of waters is negligible. In the river water mercury is presented, basically, by organic complexes – $HgFu^+$ (67.88%) and $HgHu^+$ (32.06%). In the river water organic complexes of cobalt are contained in much smaller quantities, than of mercury: $CoFu^+$ (0.47%) and $CoHu^+$ (0.24%). At transition from the river water to the sea water the value of complex formation with organic substance for cobalt and mercury considerably decreases.

For studying the behavior of trace elements in a zone of mixture of the river and sea waters it was carried out physical and chemical modeling of the mixture of waters of vari-





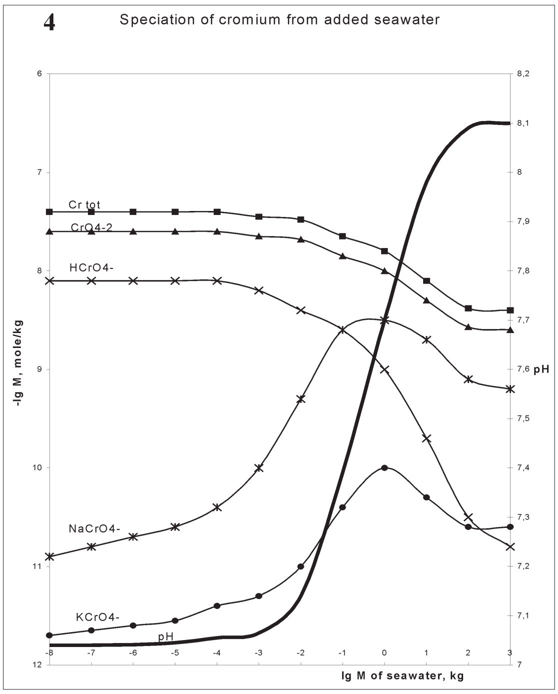


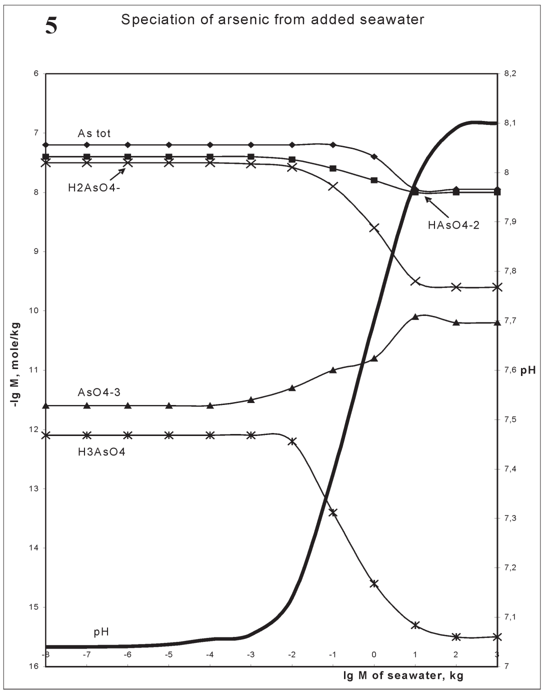
ous natures by gradual addition of sea water to 1kg of the river water. It was accepted, that the process of mixture is finished, when final pH of the mixture solution equals 8, 10. It was achieved as a result of addition of 32.49 kg of sea water. Chemical composition fully complying to the sea water, is achieved at addition of 1028.53 kg of sea water.

Addition of less than 0.0001 kg of sea water poorly influences the change of the mixture solution pH. More appreciable change of pH starts to occur at addition of sea water from 0.0001 kg up to 0.01 kg. Sharp jump of pH up to the value of 8.10 is observed at addition of sea water from 0.01 kg up to 32 kg that results in the formation of a barrier by pH.

Results of modeling are given in Figures (1–5). Figures show the change of concentrations of the physical and chemical forms of investigated elements depending on the quantity of the added sea water. Both values are presented on a logarithmic scale, and lgV = −1, 0, 1 corresponds to the salinity values of 2.28; 13.70 and 25.14‰ accordingly. The behavior of the main components at the mixture of river and sea waters is considered in detail in paper.

As figures show, at the passage through a geochemical barrier the dominating arsenic forms do not change, there is only their redistribution at sharp increase of the role of





$HAsO_4^{2-}$ ion. Concentration of $As_3O_4^0$ form considerably decreases due to pH increase. For the same reason the dominating forms of vanadium and partly chrome (reduction of $HCrO_4$ – share) change. Share of $NaCrO_4^-$ during mixture increases and becomes one of dominating ones for the account of very high content of sodium cations in a final mixture solution. pH change does not render essential influence on the distribution of cobalt and mercury forms. Change of forms of migration of these elements is related to high content of ligands of chloride – ions and sulfate – ions in a final solution of mixture. Mercury is the only of five investigated elements which are rather strongly influenced by organic substance (practically all mercury in the river water is bound into fulvic and humic complexes). Humic and fulvic acids influence on the other elements is extremely insignificant.

Modeling of sorption balance was carried out with the help of the program complex MINTEQA2/PRODEFA2. Results of modeling are given in Table 4. For the river water we received the following total (tot) contents of elements (a solution+in a suspension): $Co_{tot} = 5.76*10^{-8}$ mole/kg, $Hg_{tot} = 7.55*10^{-6}$ mole/kg, $As_{tot} = 2.90*10^{-5}$ mole/kg, $Cr_{tot} = 3.03*10^{-8}$ mole/kg, and $V_{tot} = 1.11*10^{-4}$ mole/kg. For the sea water the values of total concentration are $5.0*10^{-9}$, $1.89*10^{-8}$, $1.44*10^{-7}$, $3.85*10^{-9}$ and $4.63*10^{-7}$ mole/kg, accordingly.

At modeling the sorption processes in the estuary the following conditions and admissions are accepted: the content of suspension for the sea water is accepted to be 0.2 mg/l, for the river water – 50 mg/l; all suspended substance both introduced by the river, and formed due to colloids coagulation in the estuary is precipitating not on all extent of a barrier, but in a point with salinity of 5.33‰ (pH = 7.72) where the process of colloids coagulation is most active; concentration of the newly formed substances equals the difference between turbidity in the estuary and the river turbidity (200 − 50 = 150 mg/l); due to the absence of constants of investigated elements sorption on clay minerals, organic substance and manganese dioxide a sorbent is only iron hydroxide (III), and its concentration is equal to the total concentration of the suspended substance (turbidity). For imitation

Table 4. Ratio dissolved and sorbed forms of microelements and influence sorbtion processes on their migration

Elements	River water, mol/kg		Sea water, mol/kg		$Э_{tot}^{New1}$ и $Э_{tot}^{New2}$, mol/kg	Sedimentation for the account sorbtion processes, %
Cobalt	$Co_{to}t = 5.76*10^{-8}$ mol/kg	$Co_{sol} = 86.7\%$ $(5.0*10^{-8})$ $Co_{sorb} = 13.3\%$ $(7.7*10^{-9})$	$Co_{tot} = 5.00*10^{-9}$	$Co_{sol} = 99.96\%$ $(5.0*10^{-9})$ $Co_{sorb} = 0.04\%$ $(2.05*10^{-12})$	$Co_{tot}^{NEW1} = 4.998*10^{-8}$ $Co_{tot}^{NEW2} = 3.53*10^{-8}$	14.16
Mercury	$Hg_{tot} = 7.55*10^{-6}$ mol/kg	$Hg_{sol} = 0.004\%$ $(3.4*10^{-10})$ $Hg_{sorb} = 99.99\%$ $(7.55*10^{-6})$	$Hg_{tot} = 1.887*10^{-8}$	$Hg_{sol} = 0.79\%$ $(1.5*10^{-10})$ $Hg_{sorb} = 99.22\%$ $(1.87*10^{-8})$	$Hg_{tot}^{NEW1} = 3.77*10^{-7}$ $Hg_{tot}^{NEW2} = 1.89*10^{-8}$	99.84
Arsenic	$As_{tot} = 2.90*10^{-5}$ mol/kg	$As_{sol} = 0.2\%$ $(5.77*10^{-8})$ $As_{sorb} = 99.8\%$ $(2.89*10^{-5})$	$As_{tot} = 1.44*10^{-7}$	$As_{sol} = 16.0\%$ $(2.3*10^{-8})$ $As_{sorb} = 84.0\%$ $(1.21*10^{-7})$	$As_{tot}^{NEW1} = 1.51*10^{-6}$ $As_{tot}^{NEW2} = 7.53*10^{-8}$	100
Chromium	$Cr_{tot} = 3.03*10^{-8}$ mol/kg	$Cr_{sol} = 95.4\%$ $(2.88*10^{-8})$ $Cr_{sorb} = 4.6\%$ $(1.399*10^{-9})$	$Cr_{tot} = 3.85*10^{-9}$	$Cr_{sol} = 99.996\%$ $(3.85*10^{-9})$ $Cr_{sorb} = 0.004\%$ $(1.367*10^{-13})$	$Cr_{tot}^{NEW1} = 2.87*10^{-8}$ $Cr_{tot}^{NEW2} = 2.30*10^{-8}$	16.7
Vanadium	$V_{tot} = 1.11*10^{-4}$ mol/kg	$V_{sol} = 0.05\%$ $(1.96*10^{-8})$ $V_{sorb} = 99.95\%$ $(1.11*10^{-4})$	$V_{tot} = 4.63*10^{-7}$	$V_{sol} = 6.5\%$ $(2.94*10^{-8})$ $V_{sorb} = 93.5\%$ $(4.44*10^{-7})$	$V_{tot}^{NEW1} = 5.617*10^{-6}$ $V_{tot}^{NEW2} = 2.80*10^{-7}$	Increase V_{sol} to 1.5 time

of the sedimentation process, 95% of the trace elements related to the suspended substance of the river (Эsorb) are withdrawn from the system, and the rest 5% are summed up with the total content of an element in solution (Эsol). As a result we receive new values of the total content of these elements – $Этот^{New1}$ which are used at calculating the sorption balance with sorbent concentration of 150 mg/l (turbidity in the estuary); then again 95% of the content of each element related to the newly formed suspension are withdrawn from the system. By analogy with calculation of $Этот^{New1}$ we receive the values of total concentration $Этот^{New2}$ which should be in the sea water at the elements passage through a geochemical barrier provided that the change of contents of the given elements is 100% related to the physical sorption. Further, we find a degree of the influence (in %) of sorption processes on the trace elements migration at mixture of sea and river waters under the formula:

$$\Delta Э_{tot}\,\% = \left(1 - \frac{Э_{tot}^{New2} - Э_{tot}^{sea}}{Э_{Tot}^{New2}}\right) *100\%$$

In case $Э_{tot}^{sea} > Э_{tot}^{New2}$ removal of an element from solution is 100% related to the processes of sorption.Results of modeling are presented in Table 4. Table shows that the reduction of the total concentration of mercury and arsenic in a zone of mixture is practically completely related to the sorption processes. Influence of sorption on reduction of total concentration of chrome and cobalt is less significant, 16.7 and 14.16% accordingly. Other part is withdrawn from the system due to other processes, probably biological and the processes of co-precipitation with hydroxides of aluminium and manganese. Vanadium at its passage through a geochemical barrier is stripped from the river suspensions therefore its concentration in a solution is getting larger by half.

Physical and chemical modeling has shown, that physical and chemical forms of the elements occurrence in the river and sea water (except for arsenic) are various. Evolution of a mixture solution presents a complex chemical process as a result of which it takes place the formation of a geochemical barrier on which there is a change of forms of the chemical elements occurrence in a solution. It is established the influence of sorption processes on behavior of investigated elements in the river and sea water, and also in a zone of mixture. The received data will be useful at estimating the influence of a geochemical barrier on the flows and migratory ability of chemical elements in the river – sea system.

The state of coastal ecosystems in near-estuarine areas of Razdolnaya (Suyfun) River (Russia)

Peter the Great Bay is the largest bay in the northwestern part of the Sea of Japan. It is considered to be one of the richest and most productive regions in the Far East seas. For instance, ichthyofauna of the bay is extremely rich and comprises over 300 of salt- and fresh-water fish species (Sokolovskaya et al., 1998). Amursky Bay, one of the secondary bays of Peter the Great Bay (Fig. 10), is an important area for spawning, nursery and migration of commercially valuable fish species. Many invertebrates species also inhabit the bay; some of them have high commercial value. On the other hand, the basin of Amursky Bay is the most developed area in Primorye Region. In this area, there are large cities such as Vladivostok (the largest seaport in Russian Far East with a population over 630,000 people) and Ussuriysk (over 160,000 people), and one of the largest recreational zones in the Far East. Numerous mining enterprises exploit different kinds of minerals in the basins of the rivers entering the bay. Intensive farming is developed in the basin of the Razdolnaya River, which feeds into the bay in the north. This river is the largest (after the Tumen River) of the rivers of southern Primorye, and it greatly influences hydrological and hydrochemical regimes of the bay.

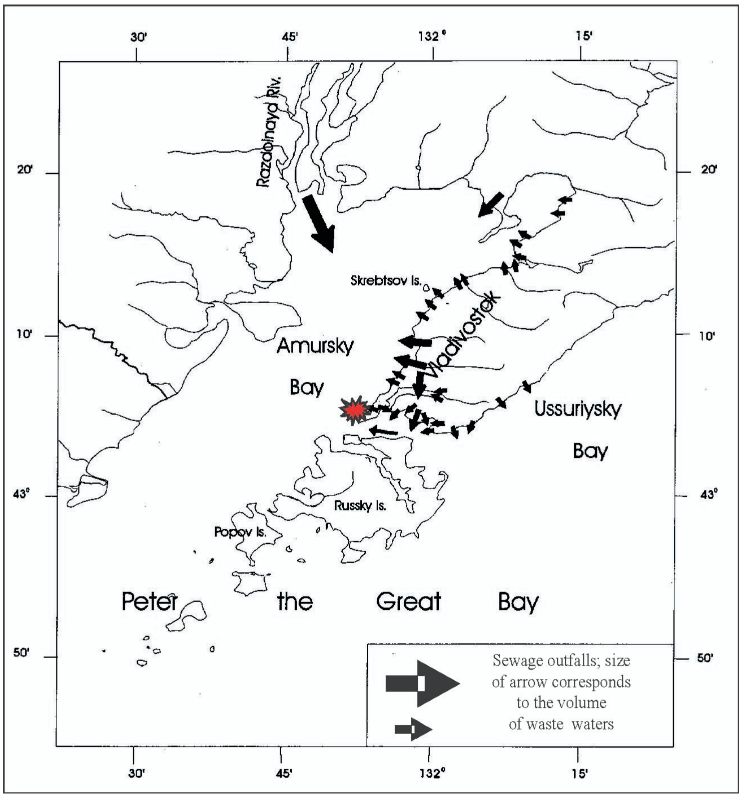


Fig. 10. Scheme of location of sewage outfalls in Amursky Bay.

Economic development of the region from the 1960s through the 1990s was not accompanied by construction of sufficiently powerful and effective treatment facilities, and the coastal waters of Amursky Bay were used as a receptacle of almost untreated sewage. The major contamination sources in Amursky Bay are (Fig. 10):

– industrial and domestic wastewaters of Vladivostok and its suburbs;
– marine transportation;
– agricultural effluents and untreated wastes of Ussuriysk feeding into the bay together with the waters of the Razdolnaya River;
– input of pollutants through air and rain-storms;
– dredged material damping.

According to the expert estimations, the annual volume of wastewater discharged into Amursky Bay is about 120 million m^3 that is 0.6% of total water masses of the bay (Ogorodnikova et al., 1997). About 90% of wastewater is not purified at all before discharge. With these waste waters, approximately 104,600 t organic substances, 110,050 t suspended solids, 1540 t fat, 880 t oil hydrocarbons, 980 t detergents, 4.5 t phenols, and 1.2 t pesticides were introduced to coastal waters of Amursky Bay annually 1980s (Long-term program..., 1992). Dredged material dumping was terminated in 1985, but even in 1990s the sediments in this area were heavily contaminated with petroleum hydrocarbons, heavy metals and organochlorine pesticides (Tkalin et al., 1993; Belan et al., 2003).

The state of the marine environment and biota in Amursky Bay has always attracted particular interest. In the middle of 1970s, both individual researchers and state programs of environmental monitoring have begun to investigate the levels of anthropogenic contaminants in water, sediments and biota of the bay as well as to study ecological consequences of pollution. The major scientific organizations conducting monitoring surveys of Amursky Bay are Far Eastern Regional Hydrometeorological Research Institute, several institutes of Far Eastern Branch of Russian Academy of Sciences, and Far Eastern State University. According to these data of the investigations conducted since the 1970s through 1980s, concentrations of different contaminants such as phenols, oil hydrocarbons, organochlorine pesticides, and heavy metals in water column and sediments of the bay were rather high and exceeded both background levels in Peter the Great Bay and maximum permissible concentrations accepted in Russia. Amursky Bay (especially its innermost part and the northeastern zone adjacent to Vladivostok) was considered to be one of the most polluted areas of Peter the Great Bay.

During the last decade, in the Primorye Region both industrial and agricultural activity has sharply decreased. This gave rise to hope for improvement of the ecological situation in Amursky Bay. In this connection, it is of great interest to compare the data of 1980s, 1990s and 2000s on the state of marine environment and biota in Amursky Bay. The main attention will be concentrated at the next items:

– eutrophication of the bay;
– contamination of bottom sediments;
– the state of benthos communities.

Eutrophication of Amursky Bay. The enrichment of coastal waters of the bay with biogenic elements such as phosphorus, nitrogen and silicon that are necessary for photosynthesis in unicellular algae results in increase in phytoplancton production. The results of hydrochemical studies show that contents of biogenic elements in the nothern part of the bay exceed those in the southern open part of the bay by a factor of 1.2–15 (Podorvanova et al., 1989). The main sources of the bay eutrophication are the runoff of Razdolnaya River and numerous sewage outfalls of Vladivostok city. The study of phytoplankton conducted in the beginning of 1990s by the researches of the Institute of Marine Biology allowed to distinguish three parts in the bay: hypereutrophic, eutrophic and mesotrophic (Stonik and Selina, 1995). The hypereutrophic covered the innermost part of the bay exposed to the river runoff and northeastern part of the bay located close to the sewage outfalls (Fig. 11). The greatest values of microalgae density here were 17.9–31.1 million cells/l. The eutrophic area uncluded several stations in the northeastern part of the bay as well as one station in the southern part of the bay. The intermediate values of microalgae density here were registered (5.3–9.4 million cells/l). The mesotrophic area was the farthest from the sources of eutrophication and included one station in the island zone of the

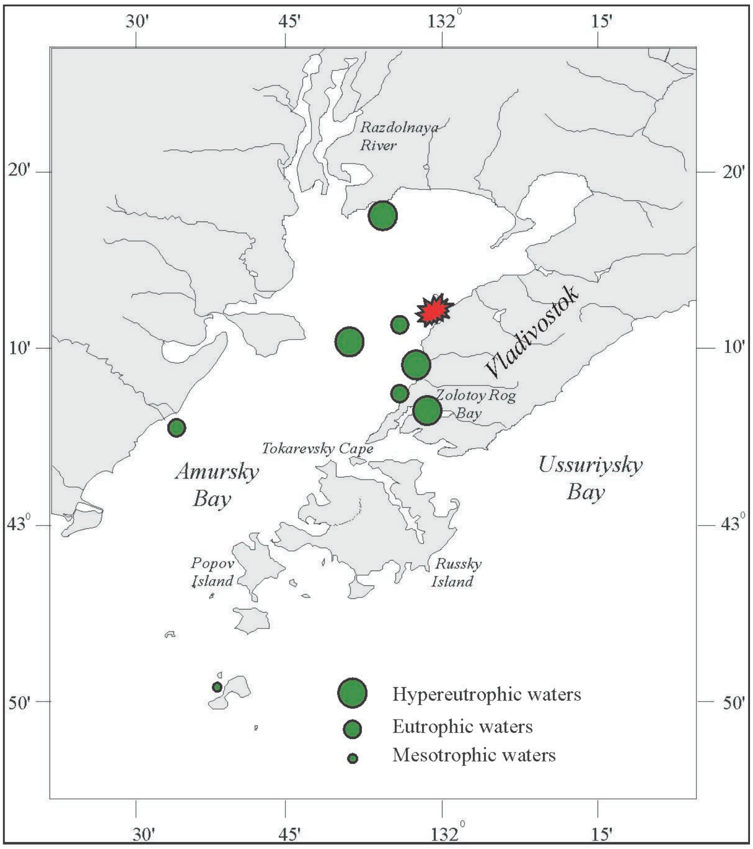


Fig. 11. Eutrophication of Amursky Bay in 1990s (according to: Stonik and Orlova, 2004). Red star indicates the monitoring station.

bay. The smallest value of phytoplankton density was found here (up to 1.9 million cells/l).

The structure of phytoplankton in strongly eutrophic waters differs from that in relatively clean areas due to decreased species diversity because of mass development of the diatom alga *Skeletonema costatum*. In 1991–1995, this species, which is known from the literature as an indicator of organic pollution, accounted for about 90% of the overall plankton density in Amursky Bay (Stonik and Orlova, 2004). An analysis of the summer–autumn phytoplankton showed that in summer of 1991 the density of *S. costatum* increased with decreasing distance from the source of eutrophication (the mouth of Razdolnaya River). For instance, the greatest density of *S. costatum* (7.7 and 12.1 million cells/1) was observed in the hypereutrophic area, whereas the smallest value (1.6 million cells/1) was recorded in the mesotrophic area. The smallest (0.7 bit/cell) and the greatest (2.7 bit/cell) values of the species diversity index were recorded in the hypereutrophic and eutrophic areas, respectively (Stonik and Orlova, 2004).

Long-term study (1991–2000) of the phytoplankton in Amursky Bay at the monitoring station (red star in Fig. 11) showed that the density and biomass of phytoplankton ranged between 0.01–13 million cells/l and 0.005–45.624 g/m^3, respectively. The maximum of phytoplankton density and biomass were recorded in July 1996 and in February, 1998, respectively. The greatest peaks of phytoplankton density (12.4–13 million cells/l) were observed in August 1991 and July 1996. These summer peaks of phytoplankton density were recorded after heavy rains under conditions of substantial freshening of the surface waters, while the salinity were 7–16 and 24–27‰, respectively. The diatom *S. costatum* accounted 40–87% of the total phytoplankton density (7.6–12.7 million cells/l) during the summer bloom period in 1991 and 1996. Sewage pollution is known to stimulate the growth of the diatom *S. costatum,* which prefers a heterotrophic mode of nutrition. In the end of 1990s, a tendency has arisen for a decrease in density of *S. costatum,* compared with the level of 1991 and 1996. Nevertheless, the authors (Stonik and Orlova, 2004) concluded that there was no significant decrease in the level of organic pollution in Amursky Bay over recent years because the density of *Sceletonema costatum* remains rather high (up to 3 million cells/l). This value exeeds the reportedly eutrophic level (Yamada et al., 1980).

In summary, the following trends in the phytoplankton composition with decreasing distance from the sources of eutrophication (the Razdolnaya River water flow and sewage outfalls) were revealed: 1) total density and biomass increased; 2) the density of the diatom *S. costatum,* which reflects a decrease in the Shannon–Weaver species diversity index during the summer microalgal bloom, increased significantly; and 3) the density of the non-diatom component of the phytoplankton increased (Stonik and Orlova, 2004).

Contamination of bottom sediments in Amursky Bay. Recent bottom sediments of the coastal zone represent the final stage in the migration pollutants from the neighboring land and atmosphere. The concentrations of pollutants in bottom sediments, pore waters, and the near-bottom water layer are significantly higher than in water column; therefore, the chemical composition of the upper (2–5 cm) layer of bottom sediments allows us to judge the degree and pattern of anthropogenic disturbance in the coastal water areas.

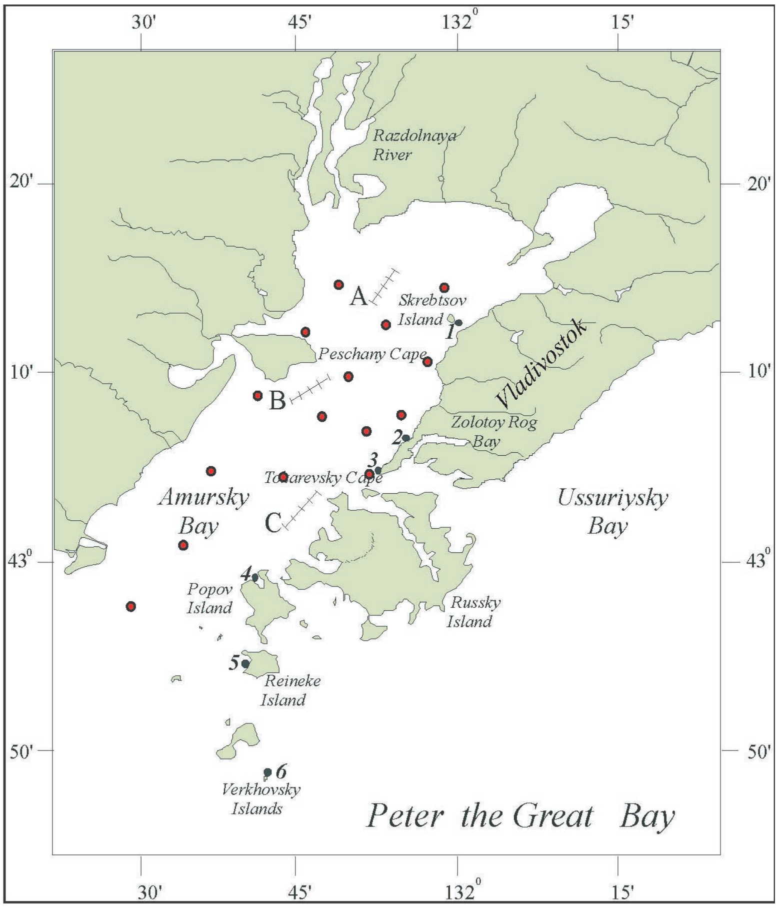


Fig. 12. Sampling stations in Amursky Bay. Red circles – stations in the monitoring surveys of Far Eastern Regional Hydrometeorological Research Institute (1986–1989, 1994 and 2001); *A*, *B*, *C* – transects near Skrebtsov Island, Peschany Cape and Russky Island, respectively (2001); black circles *1–6* – coastal stations (1999–2002): *1* – Skrebtsov Island, *2* – Sport Harbor, *3* – Tokarevsky Cape, *4* – Popov Island, *5* – Reineke Island, *6* – Verkhovsky Islands.

In the present paper, analysis of the level of bottom sediment contamination in Amursky Bay is based on the data of the monitoring surveys conducted in the period from 1980s to 2000s. Schematized map of the area studied is presented in Fig. 12. Surface bottom sediments were sampled at a number of stations. Red circles correspond to the monitoring stations of Far Eastern Regional Hydrometeorological Research Institute. Black circles numerated from 1 to 6 denote coastal stations studied in the surveys of the Institute of Marine Biology and Pacific Oceanological Institute conducted in 1999–2002. These stations were located both in "near city" zone and in open island zone of the bay. Besides, in 2001 bottom sediment samples were collected from three deep-water sites located in the inner (A), middle (B) and open (C) parts of Amursky Bay.

In the sediment samples, concentrations of heavy metals (Fe, Mn, Zn, Cu, Ni, Co, Pb, Cr), total oil hydrocarbons (OH), and organochlorine pesticides (DDT and its metabolites, DDD and DDE; α- and γ-isomers of hexachlorocyclohexane – HCH) were determined using standard methods.

Oil hydrocarbons. The majority of bottom sediments samples from Amursky Bay were represented by silt, sometimes with an admixture of fine-grain sand (Belan et al., 2003; Vaschenko et al., 2003). In 2002, portions of the sediment particles with size less than 100 μm in the sediment samples from coastal stations were about 80%. At the majority of stations, the concentrations of OH were very close to or slightly higher than maximal normal environmental background level, 100 μg/g dry weight; maximal OH concentration (240 μg/g d.w.) was registered at st. 2. In previous surveys conducted in 1986–1989 and in 1994, a wider range of hydrocarbons concentrations in the sediments of Amursky Bay has been found: 30–2720 μg/g d.w. (Belan, 2001). Analysis of the data obtained suggest a decrease in the level of sediment contamination with OH in the beginning of 2000s compared with the level of 1980s–1990s (Belan et al., 2003). Mean values of OH concentrations in 1980s–1990s (0.62±0.72) were significantly ($p < 0.05$) higher than in 2001 (0.10±0.07). The influence of Razdolnaya River discharge and sewage outfalls on the distribution of OH concentrations in bottom sediments of Amursky Bay was evident both in 1980s–1990s and in 2001(Tkalin et al., 1993; Belan et al., 2003).

Organochlorine pesticides. Only two of a great variety of organochlorine compounds has been monitored in Amursky Bay, namely HCH and DDT. HCH was detected in the sediments from almost all stations; its concentrations were very low (0–0.35 ng/g d.w.) except st. 2 (7.4 ng/g d.w.). These values are close to those obtained in 1990s: the highest HCH concentrations (1.45–5.61 ng/g) were found near the southeastern coast of the bay (Tkalin, 1996; Tkalin et al., 1997).

In 2001–2002, total concentration of DDT and its metabolites (DDTs) in bottom sediments collected at the sites A, B and C, at "near city" stations 1–3 and at "island" stations 4–6 varied from 1.7 to 47 ng/g d.w. (Vaschenko et al., 2003; Zhadan et al., 2005). Maximal DDT content was registered at st. 2. It is interesting that at all locations (excepted st. 2) DDT comprised a significant proportion of total DDTs (62–90%); at st. 2 its proportion was 17.6%.

The ratio of concentrations of DDT to its metabolite DDE is usually used for determination of the DDT lifetime in the environment and organisms. The values of DDT/DDE for bottom sediments from Amursky Bay were higher 1 at all stations excepted st. 2; the highest DDT/DDE values were found for the site C (11.5) and st. 6 (6.9), i.e. near Russky and Verkhovsky Islands. The data obtained suggest a recent input of DDT into the marine environment.

In 1990s, similar concentrations of DDTs (4.4–14.8 ng/g d.w.) have been found (Tkalin et al., 1997, 2000). In 1994 and 1996, "fresh" DDT predominated, and DDT/DDE ratio range was about 3–15 (Tkalin et al., 1997). In 1998, DDD and DDE comprised more than 90% of total DDTs in the sediments of Amursky Bay (Tkalin et al., 2000). However, quite a high proportion of DDT (13%) was registered in the mussel *Modiolus kurilensis* from the southern part of the bay.

Recently, a temporal trend of DDTs content in the bottom sediments of Amursky Bay from 1990 to 2001 has been analyzed, and no significant change in the level of sediment contamination with this pesticide was revealed (Belan et al., 2003). Analysis of mean values of DDT concentrations in 1980s–1990s (10.7±4.0 ng/g d.w.) and in 2001 (7.9±4.6 ng/g d.w.) revealed no significant difference ($p > 0.05$). Thus, the data obtained provide evidence of significant contamination of Amursky Bay ecosystem with DDT. It is worthy to note the absence of influence of the Razdolnaya River discharge on the distribution of DDT in bottom sediments of Amursky Bay while the influence of sewage outfalls as well as a city landfill located on the shore of Ussuriisky Bay was evident (Tkalin et al., 1993; Belan et al., 2003).

Heavy metals. Analysis of the concentrations of heavy metals (HM) in the sediments of the "near city" zone of Amursky Bay showed that in 1999–2002 concentrations of Fe, Mn, Zn and Cu were very close to those found in 1980s–the beginning of 1990s (Table 5).

Table 5. Concentrations of heavy metals in bottom sediments of Amursky Bay

Fe, mg/g	Mn, µg/g	Zn, µg/g	Cu, µg/g	Pb, µg/g	Year, reference
38–50	134–464	63–210	20–106	12–32	1999–2002, Zhadan et al., 2005 (range of concentrations)
–	–	–	31.3	21.3	2001, Belan et al., 2003 (average concentrations)
31–43	230–350	70–257	17–68	19–82	1987–1991, Khristoforova et al., 1993 (range of concentrations)
44.1	321	121	25	28	1994, Tkalin et al., 1996 (average concentrations)

For comparative analysis of the level of HM contamination of bottom sediments in the "near city" and "island" zones of Amursky Bay in different years, we used not absolute values of HM concentrations but relative numbers. These relative numbers were obtained by means of dividing the each metal concentration in the sediment samples from different stations by the same metal concentration in the sediment from st. 6. Then the coefficients obtained were summarized, and the average values for each station were determined. Thus, the relative numbers in Fig. 13 show exceeding levels of HM contents in the sediments from st. 6.

Contents of HM in the sediments from the "near city" zone (stations 1–3) and the nearest "island" st. 4 were significantly higher compared to the "island" st. 6. The highest exceeding levels (1.2–18) were found in 1999 as far as total sediment samples were analyzed, and at st. 6, the sediment was slightly dirty sand. In the "near city" zone, stations 2 and 3 were the most polluted. The highest concentration gradients were found for technogenic metals Pb, Cu and Zn.

In 2000, fine fraction of the sediment (< 100 µm) was analyzed, and exceeding levels were lower (1.2–4), though a general tendency was the same. In 2002, both total sediment and its fine fraction were analyzed. Content of the particles with size < 100 µm in the silted sediments from stations 1–3 was over 80%; portion of fine fraction in the sediment samples from "island" stations 4 and 6 was also significant – about 60 and 50%, respectively. Therefore, exceeding levels obtained for total sediment and its fine fraction did not differ significantly. In Fig. 13, the data for total sediment is presented. As in previous years, it is evident considerable contamination with Cu, Zn, Fe and Pb of the sediments from stations 2 and 3 and, to a lesser extent, st. 4.

Thus, the data obtained does not permit to make a conclusion about significant decrease in level of HM contamination of the sediments in Amursky Bay in 2000s compared to 1980s and 1990s. Analysis of spatial distribution of heavy metals in bottom sediments of Amursky Bay has revealed elevated concentrations of heavy metals near the sewage outfalls (Tkalin et al., 1993; Belan et al., 2003). The effect of the Razdolnaya River discharge on heavy metal distribution was quite limited. Analysis of temporal trends of heavy metal contents in the sediments of the bay from 1990 to 2001 revealed statistically significant decrease in Cd concentrations in 2001. Analysis of mean values of heavy metal concentrations in 1980s–1990s and in 2001 revealed significant difference for Cd (1.08±0.89 and 0.16±0.63, respectively, $p < 0.05$) but not for Pb and Cu.

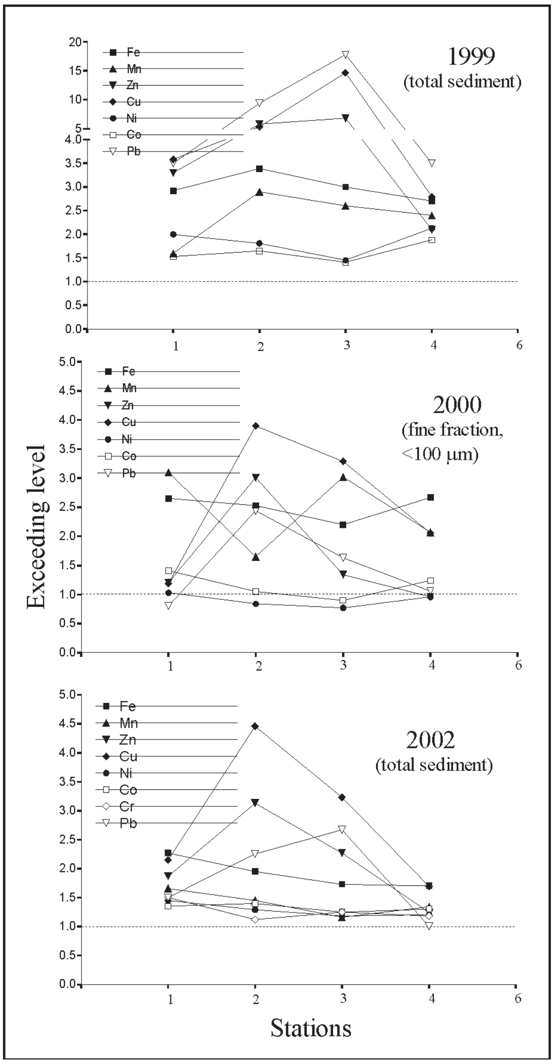


Fig. 13. Exceeding levels of HM contents in coastal zone of Amursky Bay (stations *1–4*) compared to station *6* (Verkhovsky Islands) in 1999, 2000 and 2002.

The state of benthos communities. The state of benthos communities in Amursky Bay has been studied since the first hydrobiological expedition in Peter the Great Bay carried out in 1925–1933 under the direction of K.M. Deryugin (Deryugin and Somova, 1941). In 1970s, 1980s, 1990s and the beginning of 2000s, long-term changes in the state of bottom communities have been investigated by a number of authors (Klimova, 1971, 1974, 1976, 1988; Belan, 2001, 2003; Belan et al., 2003; Oleynik and Moshchenko, 2004; Oleinik et al., 2004). It should be noted that principal attention had been paid to inhabitants of soft grounds – silts, sands and silted sands, i.e. infauna. The major representatives of infauna in Amursky Bay are polychaetes, bivalve mollusks and echinoderms, mainly ophiuroids. As to benthic inhabitants of rocky and boulder grounds, only limited information about long-term changes in their state is available.

In Fig. 14, sampling stations in Amursky Bay in the studies on the

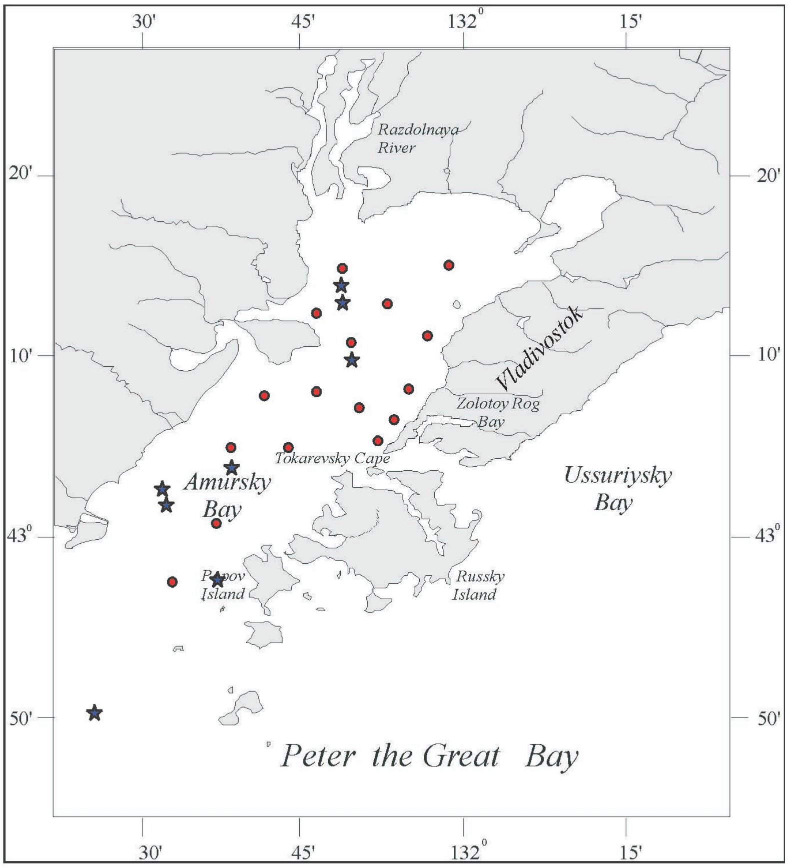


Fig. 14. Sampling stations in Amursky Bay in the studies on the state of benthic communities. Blue stars – stations in the hydrobiological expedition of K.M. Deryugin, 1925–1933; red circles – stations in the monitoring surveys of Far Eastern Regional Hydrometeorological Research Institute, 1986–1989 and 2001.

benthic biocenosis are shown. Analysis of published data allowed us to make several conclusions on long-term changes in the state of bottom communities in Amursky Bay.

In 1930s, benthos samples were taken from 8 stations at the depth from 14 to 40 m. The sediments were represented by silted sand. At almost all stations, the polychaetes were the most abundant and created the majority of biomass (Table 6). The polychaete *Maldane sarsi* predominated. Another abundant species were small bivalve mollusk *Nucula tenuis*, ophiuroid *Ophiura sarsi* and, at two stations, hydroid *Obelia longissima*.

The expeditions carried out in 1970s, 40 years later, have demonstrated significant changes in composition of bottom communities. In particular, a sharp decline in the abundance of dominant species (*M. sarsi, Scoloplos armiger, O. longissima*) was revealed.

In 1986–1989, the following significant changes in composition of bottom communities have been recorded (Table 6):

– The average benthos biomass decreased by a factor of 2, the value of 74 g/m^2 was created mainly by polychaetes;
– Sharp reduction of the habitat areas of ophiuroid *O. sarsi* and hydroid *O. longissima* took place, and they lost their dominant position;
– Decrease in abundance of the polychaete species *M. sarsi* and *S. armiger* which were the dominant species in 1930s and 1970s;
– Tolerant to pollution species of the polychaetes such as *Tharyx pacifica* and *Dipolidora cardalia* became widespread with high density in the most polluted areas;
– Among bivalve mollusks, several dominant species were revealed including *Raeta pulchella* which is common inhabitant of black silts adapted to extreme environmental conditions.

Table 6. Long-term changes in benthic communities in Amursky Bay

1925–1933	1986–1989	2001
Average biomass 150 g/m^2 Dominant species (ind/m^2): Polychaetes Maldane sarsi (800–2200) *Scoloplos armiger* (170–300) *Lumbrineris minuta* (250) *Anobothrus* (=*Sosane*) *gracilis* (150–800) Bivalve mollusks *Nucula tenuis* (250–1000) Ophiuroids *Ophiura sarsi* (120–735) Hydroids *Obelia longissima*	Average biomass 73.9 g/m^2 Dominant species (ind/m^2): Polychaetes Tharyx pacifica (1872, up to 8100) *Dipolydora cardalia* (up to 2100) *Lumbrineris* sp. (339.6) *Maldane sarsi* (333.6) *Schistomeringos japonica* (132.0) Bivalve mollusks *Raeta pulchella* *Callithaca adamsi* *Yoldia* sp. *Axinopsida* o. *subquadrata* *Leonucula tenuis tenuis* (=*Nucula tenuis*)	Average biomass 157.5 g/m^2 Dominant species (ind/m^2): Polychaetes Tharyx pacifica (604.6) *Lumbrineris* sp. (190.2) *Sigambra bassi* (85.9) *Maldane sarsi* (82.9) Bivalve mollusks *Theora lubrica*

In 2001, the average benthos biomass was almost 2 times higher than in 1980s; the value of 157.5 g/m^2 was formed mainly by large bivalves and polychaetes (Table 6). Abundance of pollution-tolerant species such as *Tharyx pacifica* decreased by a factor of 3 compared with the data of 1980s, and non-tolerant species such as *Sigambra bassi* appeared. Nevertheless, *Th. pacifica* reserved its dominant position. Among bivalve mollusks, only one species tolerant to black silts and to extreme environmental conditions was determined as dominant species, this was *Theora lubrica*. Investigation of the bivalve molluscan fauna in Amursky Bay has revealed that *R. pulchella* and *Th. lubrica*, the species tolerant to silt enriched in organic matter, are widespread in the north and central zones of Amursky Bay (Lutaenko, 2003).

Table 7 represents some qualitative parameters of the state of benthic communities in Amursky Bay in 1980s and 2001. Average benthos biomass has been increased in 2001 while the average abundance decreased due to a sharp decrease in the density of tolerant polychaete species. It is worthy to note that mean number of species and index of richness in 2001 have significantly decreased ($p < 0.05$).

Table 7. Benthic community parameters in Amursky Bay In 1980s and 2001 (according to: Belan et al., 2003)

Index	1986–1989	2001
Biomass, g/m^2	73.9±41.4	157.5±427.6
Abundance, ind/m^2	5104.6±4106.9	1556.1±1751.6
Number of species per station	21.6±9.9	13.0±8.1
Margalef richness index	1.7±0.8	1.2±0.7
Shannon–Wiener diversity index	2.3±0.9	2.1±1.2

Severe changes in the biodiversity and abundance of bivalve mollusks which are an important component of benthic communities in Amursky Bay took place in the period from 1980s to the beginning of 2000s. As is obvious from Table 8, despite the average biomass has not significantly decreased in 2001 compared to data of 1980s, the average density and number of species has decreased by a factor of 2. Significant decrease in the value of Shannon–Wiener diversity index was also revealed.

Table 8. Parameters of the state of bivalve mollusk fauna in Amursky Bayin 1980s and 2001 (according to: Oleynik, Moshchenko, 2004)

Index	1986–1989	2001
Biomass, g/m^2	60.2±38.5	73.1±16.0
Density, ind/m^2	934.1±501.1	95.3±57.0
Number of species per station	5.8±1.0	3.1±0.5
Shannon–Wiener diversity index	1.427±0.236	0.719±0.182

Based on the analysis of long-term data on the density of microalgae in the water, the level of the sediment contamination with oil hydrocarbons, heavy metals and organochlorine pesticides, and the state of benthic communities, no positive conclusion about improvement of the state of coastal ecosystems in Amursky Bay in 2000s compared to 1980s and 1990s can be made. Decreasing trends have been revealed for concentrations of oil hydrocarbons and cadmium in the sediments, while concentrations of other metals and total DDTs remained rather a high. Moreover, input of "fresh" DDT in the ecosystem of Amursky Bay including its island zone has been registered in 2001–2002. The Razdolnaya River runoff has contributed to the enrichment of adjacent waters of the bay in organic matter and oil hydrocarbons but not technogenic heavy metals and DDT. Biodiversity of the species forming bottom communities of soft sediments has significantly decreased in 2001 compared to 1986–1989. We believe that chronic pollution of the bay is the major cause of negative changes in the state of its biota.

New data on the ecosystem of Razdolnaya River estuarine zone based on results of expedition in June–September, 2005

According to the APN project schedule, Russian team conducted field-works in the Razdolnaya (Suifun) River mouth and adjacent areas of Amursky Bay. On the first stage, on June 6–13, 2005, a research expedition into the mouth area of the Razdolnaya River took place. A small research vessel *Professor Nasonov* was used to take samples of sediments, water, benthic invertebrate organisms, phyto- and zooplankton in accordance with the program developed by researchers from the Institute of Marine Biology FEB RAS. The main objective of the program was to study the influence of the Razdolnaya River runoff on the estuarine ecosystem.

The research team consisted of 11 specialists from the Institute of Marine Biology and the Far Eastern Regional Hydrometeorological Research Institute, including 3 junior researchers, and 2 students from Far East State Technical University of Fisheries.

Water and phytoplankton samples were taken at a depth of 0 to 18 m using 5-liter batometers, and sea water temperature was measured. Quantitative samples of macrobenthos were collected with van-Veen grab (0.05 m^2) and scuba-diver's core samplers, and microbenthic infauna was taken with 20 ml plastic syringes. 5-cm surface bottom sediments were sampled for chemical analysis. Zooplankton was collected with a Juday net. All stations are shown on Fig. 15.

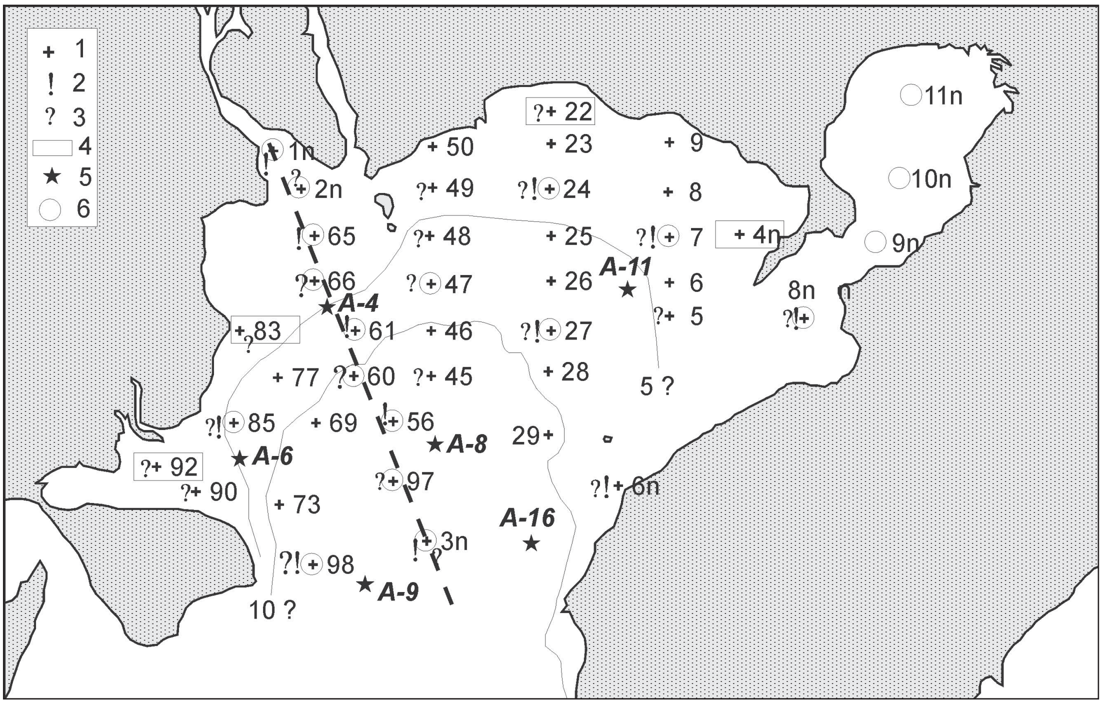


Fig. 15. Schematic map showing sampling sites in the mouth area of the Razdolnaya River. The following kinds of work have been done: *1*– water samples were taken for hydrological and hydrochemical analysis; *2* – zooplankton was sampled; *3* – phytoplankton was sampled; *4* – additional samples of ostracodes were taken; *5* – asterisks denote monitoring stations of the State System Control where bottom sediments and benthos were sampled for comparison of available long-term data; *6* – sediment samples for determination of granulometric composition and pollutant contents and micro- and macrobenthos samples were taken.

Sea water samples were analyzed to determine the following parameters:

- salinity;
- density;
- pH;
- dissolved oxygen;
- concentrations of nutrients (phosphates, nitrites, nitrates, and silicates).

Sediment samples were analyzed to determine the following parameters:

- granulometric composition;
- concentration of organic carbon;
- concentrations of pollutants (phenols, oil hydrocarbons, organochlorine pesticides DDT and hexachlorocyclohexane, and heavy metals Fe, Mn, Zn, Cu, Pb, Cr, Ni, Co, Cd).

Qualitative and quantitative analysis of macrobenthic and microbenthic infauna were performed in order to study their diversity, biomass, abundance, and the species structure of bottom communities.Qualitative and quantitative analysis of phyto- and zooplankton were performed in order to study species composition and density.

Intertidal group of the Amursky Bay expedition worked in estuarine zone of the bay from August 16 to September 21, 2005. In the tidal zone, 15 hydrobiological sections were made, 51 quantitative and about 20 qualitative samples of macrobenthos, and 49 quantitative samples of meiobenthos were collected. In Amursky Bay, the following areas were examined: Ugolny Cape, Tikhaya Lagoon, Tavrichansky Estuary in the area of Rechnoy Cape, Rechnoy Cape, Deviaty Val, De-Freez Peninsula, five points in Uglovoy Bight, the area of railway stations Vesenniaya, Okeanskaya, and Chaika (Figs. 16, 17). The following parameters were estimated on the studied area during the period of work: salinity in the range from 1‰ (Tikhaya Lagoon) to 29‰ (Tavrichanka Coast), water temperature from 16ºC (Ugolny Cape, September 21) to 30ºC (Tikhaya Lagoon, August 22). The collected material is treated by specialists in various taxonomic groups. At present, 11 Bivalvia species, 10 Gastropoda, 7 Decapoda species, 5 Polychaeta species, 4 Isopoda species, 2 Cirripedia species and 2 Pisces species have been identified. The found benthic species are typical for low-boreal region of the Far-Eastern seas of Russia.

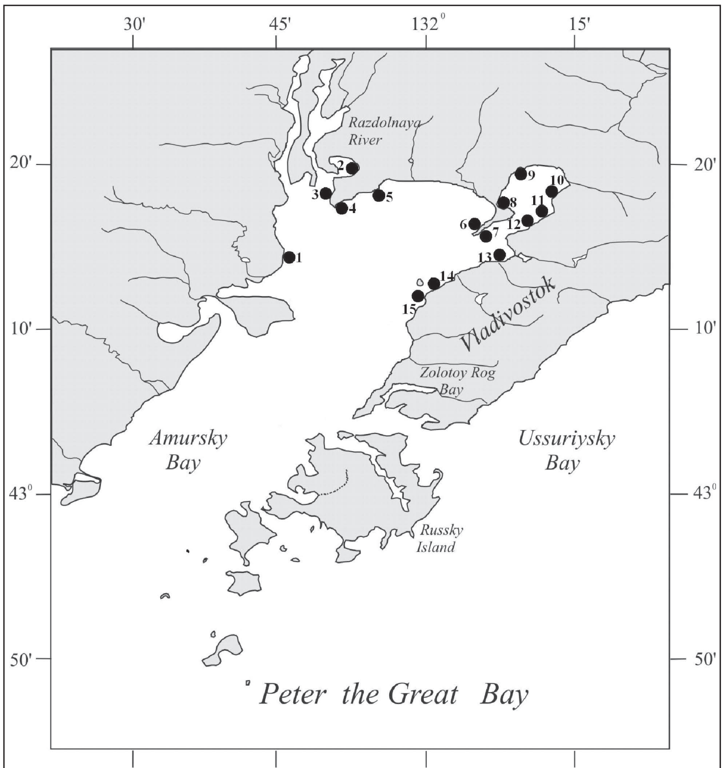


Fig. 16. The map of intertidal collecting sites in Amursky Bay.

Fig. 17. Intertidal zone of the Amursky Bay.

Some results of the studies carried out inluding comparison with long-term observations in Amursky Bay are presented below.

Near-bottom enviromental conditions and macrobenthos of inner part of Amursky Bay (Peter the Great Bay, East/Japan Sea)

The results of oceanographic and hydrobiological survey in the inner part of Amursky Bay in June, 2005 are briefly presented (Figs. 18, 19). More than 130 benthic species including phytobenthos were identified on soft substrata at the area studied. Biota was presented by typically marine, fresh-water and brackish-water organisms, which amounted 61, 20 and 19% of number of identified species, correspondingly. The most important taxa in terms of species abundance and frequency of occurrence were polychaetes, bivalve mollusks, amphipod crustaceans and gastropods. Average biomass and density of bottom macrofauna made up 566.4 g/m^2 and 3083 inds./m^2, respectively. Bivalve mollusks (26.7%), barnacles (21.5%) and sea anemones (16.1%) were prevalent in biomass and polychaetes dominate in abundance. According to the species composition and abundance three benthic communities were revealed. First of them is located in shallow and desalinated Uglovoy Bay and characterized by the presence of fresh- and brackish-water species. Two other communities are situated in more open part of the area, and are differentiated mainly by depth, sediment type and salinity limits. Statistically significant influence of water salinity, granulometric composition and organic carbon content in bottom sediments on structure, abundance and distribution of benthic communities is shown.

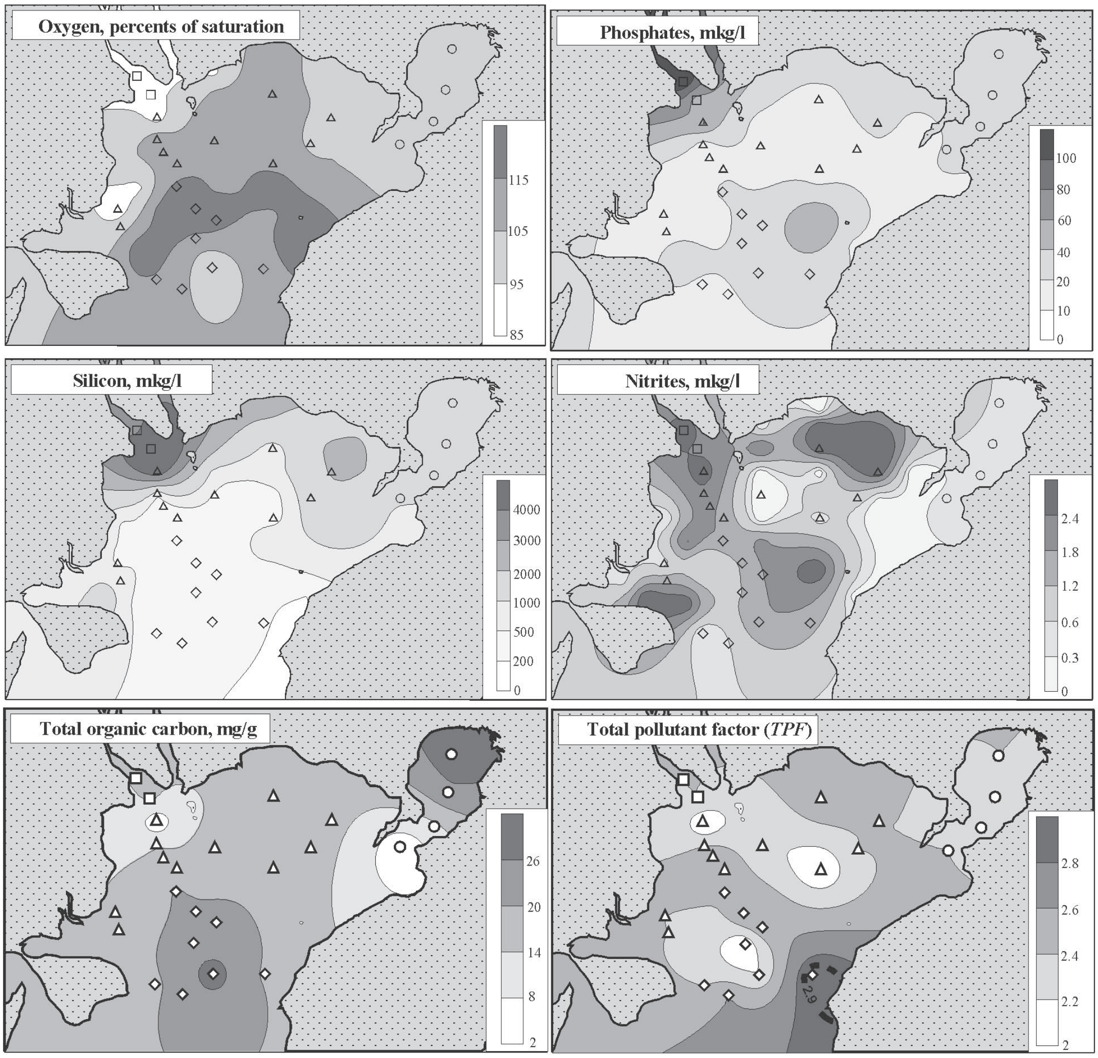


Fig. 18. Distribution of some oceanographic elements and bottom sediment characteristics over the region studied (area of the beginning of progressive degradation of benthic communities – ERL_q-zone – is confined by dotted line).

Health of plaice in Amursky Bay

In course of the project, available information and new evidence on the health of plaice from Amursky Bay (Sea of Japan) were reviewed with involvement of the data on contents of heavy metals and chlororganic compounds. Detected spectrum of histomorphological alterations in the gills and liver of flatfish from Amursky Bay testifies to metabolic disturbances and enhancement of protective-compensatory processes, it reveals appreciable signs of chronic intoxication, resulting, evidently, from an influence of polluted water discharged to the bay. Pathological damages in the structure of inner organs provide evidence for deterioration of health of flatfishes in Amursky Bay and can lead to different diseases, disturbances of reproduction processes and, consequently, to a decrease in a population abundance of these species. Pathological alterations in flatfish liver are recognized as biomarkers of sea environmental pollution and are used in international and state programs of sea monitoring in many countries.

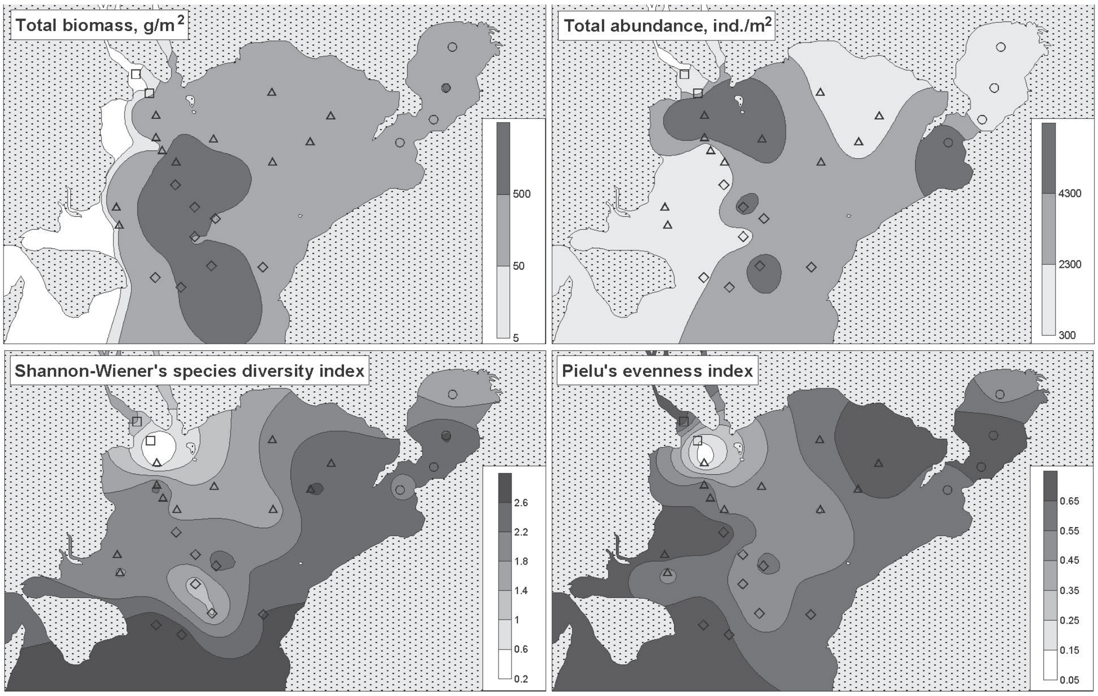


Fig. 19. Distribution of values of some bottom population characteristics over the area studied.

The International Council for the Exploration of the Sea (ICES) has elaborated instructions on the use of pathological states of liver of several flatfish species for sea monitoring. In the flounders and plaice of Amursky Bay, vacuolization of hepatocytes (hydropic dystrophy), necrosis of hepatocytes and epithelial cells of bile ducts, the presence of foci of cellular alterations, and nuclear pleomorphism in hepatocytes are recognized as histopathological markers. Two of 5 studied flatfish species – *P. obscurus* and *P. pinnifasciatus* – were recommended for use as indicator species for further biomonitoring of the state of marine environments in the coastal zone of Peter the Great Bay. These species do not migrate at long distances and are more sensitive to pollution than other flatfishes. The program of ecological monitoring accepted for the State System of Ecological Monitoring in Russia does not include usage of histopathological biomarkers. Our results support the opinion that estimation of the ecological state of the marine environment degraded by pollutants requires a complex use of biological indications, including a few biomarkers for fish and mollusks. This approach has been successfully applied by a scientific team of the Institute of Marine Biology (Far East Branch, Russian Academy of Sciences) in surveys of the state of marine environments in the zone of discharge of the Tumen River in 1996–2002. In this connection, elaboration of the regional system of ecological monitoring (RSEM) of the coastal sea waters in Primorsky Kray region requires special attention to the use of biological characteristics, in particular, histopathological markers of pollution of marine environments. The results obtained on pathology of the liver and other flatfish organs testify that Amursky Bay is a prospective area for organization of the system of ecological monitoring of marine environments that would correspond to the world standards. This study of pathological changes in flatfishes from Amursky Bay is important also for the estimation of the biological effects of pollution and the determination of the ecological risks and damage resulting from recently enhanced frequency of extraordinary discharges of pollutants to the sea.

The Razdolnaya River impact on the composition of meiobenthos in the Northern part of Amursky Bay

The impact of the Razdolnaya River on the quantitative and qualitative composition of meiobenthos was studied in the inner part of Amursky Bay. Meiobenthos density was not uniform over bottom sediments. It was highest (371±194 thous. ind/m^2) in pelite sediments, and lowest in fine silty sand (76.2±6.81 thous. ind/m^2). The correlation analysis revealed the dependence between the median diameter of sediment particles and the density of meiobenthic communities. In the inner part of the bay 11 taxonomic groups with nematodes as dominants were found and in the desalinated area 7 taxonomic groups were found. Correlation between nematode density and salinity was only slightly expressed. A total of 70 species of nematodes was found, *Anoplostoma cuticularia*, *Sabatieria intacta*, *Paracanthonchus macrodon, Dorylaimopsis peculiaris*, and *Paracanthonchus* sp_2 dominated. Five taxocenes of nematodes were allocated based on the results of cluster analysis and species domination in density. It turned out that in the zone affected by the Razdolnaya River various factors cause quantitative and qualitative changes in the meiobenthic communities, viz.: low density and reduced number of the groups of meiobenthos, as well as low diversity in the species composition of nematodes.

Phytoplankton resting stages in the recent sediments of Razdolnaya River mouth and surroundings waters of Amursky Bay (the Sea of Japan)

A qualitative and semi-quantitative study of viable phytoplankton resting stages has been undertaken in the Razdolnaya river mouth and surroundings waters of Amursky Bay. This is the first survey of its kind from the area of study. Forty eight different resting stage morphotypes belong to dinoflagellate, raphidophytes and diatoms were found. The most diverse geneses were those of *Protoperidinium, Gonyaulax* и *Scrippsiella*. Resting stages were found over the whole sampling area with concentrations ranging between 56–5012 cells/cm^3 with an average 1320.3 cells/cm^3. Both high densities and diversity of resting stages were observed in the area outermost from the river mouth. Resting stage assemblages are typical for marine coastal environments affected by anthropogenic eutrophication. Cysts of potentially toxic dinoflagellates *Alexandrium tamarense* as well as *A.* cf. *minutum* capable of producing paralytic shellfish poisoning and *Protoceratium reticulatum* (essotoxin producing species) were observed in the study area. Cysts of *Alexandrium* spp. were widely distributed and abundant with concentrations ranging between 14–994 cells/cm^3. The cysts raphidophyte cf. *Heterosigma akashiwo,* whose vegetative cells cause harmful algal blooms were dominated in Uglovoi bay with maximum concentration of 4676 cells/cm^3. The finding of toxic and bloom-forming species highlight the need for monitoring of the coastal waters both in shellfish and recreation areas: moreover it is preferable that monitoring programmes should include also cyst community studies for early warning purposes.

Summer phytoplankton in the area of Razdolnaya River mouth and adjacent waters of Amursky Bay, Sea of Japan

The qualitative and quantitative composition of the phytoplankton in the area of Razdolnaya River mouth and adjacent areas of Amursky Bay in June 2005 was studied. 124 species and intraspecies taxons of microalgae were found. The latter were dominated by an abundance of diatoms (64%) and cryptophytes (27%). River run-off affects the phytoplankton in the area of Razdolnaya River mouth. Here, increased numbers of freshwater diatoms, chlorophytes and cyanophytes, as well as benthic diatoms were found. In the inner and central parts of Amurskii Bay, exposed to considerable anthropogenic influence total numbers and biomass of phytoplankton, as well as numbers of eutrophic level indicator species and potentially toxic microalgae were increased.

Composition and distribution of intertidal communities in the estuarine zone of the inner part of the Amursky Bay (Peter the Great Bay, Sea of Japan)

It was shown that distribution of the sea biota of the area is characterized by a low aggregation of a majority of communities, and accordingly, by a relatively low biomass of dominant and subdominant forms. Within the meyobenthos, a portion of pseudomeyobenthos was significantly higher against the portion of eumeyobenthos, both in biomass and in population density (Fig. 20). Basing on a biogeographic analysis of intertidal macrobenthos of the area, the estiarine zone of the inner part of Amursky Bay was assigned to the Amuro-Japanese Subregion of the Sino-Indian Brackish Water Region.

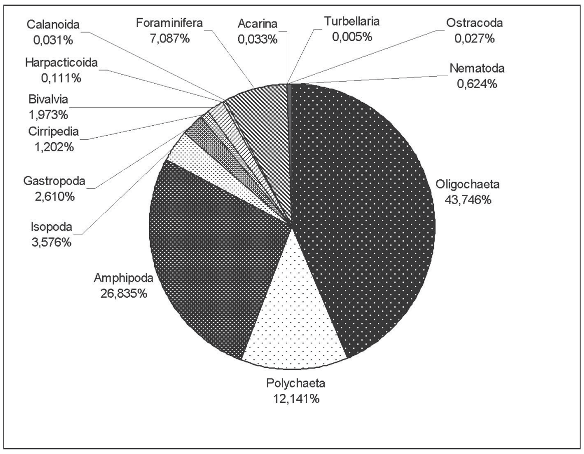


Fig. 20. Percentage of the meiobenthic groups by average biomasses in the intertidal zone of Amursky Bay.

Seasonal and interannual variability of the spring-summer zooplankton in the northern part of the Amurskiy Bay, Sea of Japan (River Razdolnaya estuary)

The pattern of distribution, seasonal and interannual dynamics of zooplankton abundance were studied for the spring-summer period in the northern part of the Amurskiy Bay of the Sea of Japan. In the period studied, eleven main taxonomic groups of holo-, ichtyoplankton and benthopelagic organisms were detected; 18 species of copepod crustaceans (Copepoda) were identified. Holoplankton constituted the basic 70% of zooplankton in the northern part of the Amurskiy bay in June–August. Its relative content was higher in the central section (St. 1n–3n), and at the south-western and north-western coasts than at the eastern coast of the inner part of the bay (St. 5, 7, 6n, and 7n). The mean density of holoplankton was minimal in August (17.5x10^3 spec./$m^{3)}$ at a temperature of 22–24^0C and maximal in June (46.6x10^3 spec./m^3) at a temperature of 15–19^0C. Dominant copepod species were represented in June by boreal-Arctic *Acartia* aff. *clausi* (55.7%), *Pseudocalanus newmani* (8%), *Centropages abdominalis* (7%) and nauplii of Copepoda (19.7%) and inn August by subtropical and low-boreal *Oithona brevicornis* (40%), tropical-subtropical *Acartia pacifica* (17%) and cosmopolitic *O. similes* (26%) and nauplii of Copepoda (9%). It was shown that peculiarities of water heating and salinity fluctuations affected the rates of seasonal and interannual variability of plankton distribution, species composition, and abundance. In spring-summer period 2005, distribution of the density of Copepoda population and the number of holoplankton groups was not determined by changes in the level of pollutants in the sea (nitrate and nitrite compounds, suspended forms of heavy metals etc.

Benthic flora of the inner part of Amursky Bay

In 2005, the researches of benthic flora were carried in topmost part of Amursky Bay (Peter the Great Bay, Sea of Japan). The thirty-six species of macroalgae belonging to three phyla and five species of Magnoliophyta were founded. The total species number of macrophytes decreased in 1.5 times in compare with 70–80 years of the last century. The greatest qualitative and quantitative changes of flora have taken place in the zones testing anthropogenic press and direct influence of a drain Razdolnaya River (Tavrichanka estuary, a site from cape Ugolny up to cape Atlasov, a site from cape Rechnoy up to the De-Frieze peninsula). Thickets with domination of kelps and sargasses have reduced, and extensive thickets of seagrasses have disappeared in these sites. The species number reduction, biomass decreasing, replacement of dominants in communities, alongside with increasing of importance of green algae testify to anthropogenic transformation of vegetation aside its degradation.

Ecological state of the Tumen River

Tumen River is the largest one in the basin of the Sea of Japan. It is 516 km long, and its water collection area equals 33,168 km^2**.** The river runs from the eastern slopes of the extinct Pectusan Volcano located on the Changbaichan Plateau. The Tumen River basin is generally hilly or mountainous, with river valleys accounting for less than 10% of the watershed (Yu, 1999). It determines the pronounced mountain pattern of the river and rather high velocity (Pyao, 1997). Most of sediments from the Tumen River, especially bed load sediments, are deposited in the river mouth and estuary (Transboundary..., 2002).

Tumen River acts as a border in Northeast Asia, between China, the Democratic People's Republic of Korea (DPRK) and the Russian Federation. As such, the Tumen River is an international waterway. More than 70% of the watershed is owned by China (Yanbian Korean Autonomous Prefecture) and about 30% belongs to Democratic People's Republic of Korea (North Hamgyong Province). The Russian portion of the watershed (less than 1% near Tumen River mouth) includes a small area of the Khasan District in Primorsky Territory (Yu, 1999; Kasyanov and Pitruk, 2001).

The total population in the drainage area is around 2.2 million, with 1,710,000 (more than 75%) living in China's part and around 500,000 in DPRK's part. Yanbian Prefecture is highly urbanized; in 1996, its non-agricultural population accounted for 60% of the total population. North Hamgyong Province is a heavy industry base of DPRK. Less than 5,000 people reside in the Russian Portion of watershed (Yu, 1999).

Water quality of the Tumen River is assessed on the basis of data from 29 Chinese monitoring stations, which have operated for about 20 years (United Nations..., 1997, after Yu, 1999). Therefore, data concerning water quality and discharges in the Chinese portion of the watershed are reasonably complete. According to Chinese water quality records, there were no serious signs of pollution of the Tumen River until the 1960s. The situation deteriorated in the 1970s and later (Yu, 1999).

The key ecological threats in the Tumen River basin are industrial pollution, the negative impacts of urban growth and agriculture, poor water and land management, unsustainable forest exploitation, forest fires, transportation corridors, poor management of protected areas and species, and the impact of tourism. All of these factors contribute to a loss and modification of inland, wetland and marine ecosystems, water and air pollution, hydrological changes, and land and soil degradation. In the Tumen River basin various types of contamination from industry, agriculture and human settlements accumulate and flow into the sea waters of the DPRK and Peter the Great Bay in the Russian Federation. With population in this region urban wastes have become one of the major polluters of surface water (Transboundary..., 2002).

Serious environmental damage has accompanied the rapid growth of industry. Approximately two-thirds of total Tumen River watershed pollutant originates from industrial emission. Although more than half of industrial wastewater is treated, only 17% of emissions are treated in a manner that meets national standards (Yu, 1999).

The chemical fiber and paper mills account for 95% of total industrial pollutants discharged into the Tumen River from Chinese sources. Two pulp and paper mills on the China side of the Tumen River built more than 60 years ago, with filters and evaporators that are now outdated and insufficient (Yu, 1999; personal observations). Musan Iron Mine on the DPRK side is a world class deposit which has been worked since 1937, but still contains 2.2 billion (B) tons of proven reserves grading 24% Fe, with another 3B tones of resource identified at the same grade. Waste to ore ratio is approximately 3.3:1. The mine discharges tailings into the river without or with little treatment. The tailings are not toxic, but cause severe damage to the river environment as they settle and choke the river bed and degrade the quality of the water. Additional sediments are carried into the river by uncontrolled run-off from the mining operations and waste dump (TumenNET Musan iron ore mine..., 2001).

The main sources of domestic sewage are settlements, the largest of wich are the Chinese cities Yanji and Hunchun. There are almost no sewage treatment plants there. Studies of Chinese scientists (Zhu et al., 1998) showed a high degree of pollution in the tributaries of the Tumen River except Hunchun River, which is only slightly polluted. An especially unfavorable situation arose in the basin of the Burhatong River (Fig. 21), where the level of pollution consistently increases. Long-term observation of the runoff of the Burhatong River showed that the quantity of discharged non-treated sewage waters in the summer period (when the water level in the riverwas the lowest) of 1997 was almost five times greater than the river runoff itself. By 2010 this index might turn two times greater. The pollution patterns of the four largest tributaries of the Tumen River may be classified as follows: Tumen River – organic pollution; Burhatong River – pollution by nitrogen compounds; Gaya River – pollution by suspensions and organic substances; and Hunchun River – pollution by suspensions (Zhu et al., 1998).

The agricultural potential of the area is relatively limited, due to the mountainous terrain. Cultivated land per capita in Chinese territory (for beginning of 1990s) was 0,26 ha, which is slightly higher than the national average (0,22 ha) (Li et al., 1997, after Yu, 1999). The agricultural potential on the DPRK side of the watershed is even more limited, as 94% of the area is mountainous (DPRK EWG, 1998, after Yu, 1999). Because of the agricultural limitations, extensive areas of the wetlands are being converted to agricultural use. Also, marginal lands on steep slopes are being cultivated, contributing to serious soil erosion and degradation of the waterway. Agricultural production on irrigated areas decreases by 1–2% every year due to the very low quality of the water (Cleaning..., 2000).

Soil erosion is serious in the watershed, which are exacerbated by farming on slopes. Almost 30% of the total land area of Yanbian Prefecture suffers from soil erosion. Within the Tumen River watershed, the percentage of land area affected by soil erosion ranges from 47% in the middle reaches to 3% in the lower reaches. It is estimated that 10.3 million tons of soil was lost in Yanbian Prefecture in 1988, or approximately 2% of the topsoil. Between 1965 and 1988, the capacity of the river channel was reduced by more than 30% (The Encyclopedia..., 1996). Soil erosion near the estuary of Tumen River is especially severe because of the fragile structure of the riverbank. Siltation is raising the riverbed in the lower reaches by 3–5 cm per year (The Encyclopedia..., 1996).

Deforestation or degradation of the forest and over-cultivation are the two most important causes of soil erosion. The basin of Tumen River was heavily logged during 1931–1945 (Yu, 1999). Since then, Yanbian Prefecture has been a major wood supplier for China. Although forest cover in China's portion of the Tumen watershed is approximately 77%, mature forest accounts for less than 50%. Along the river bank there is even less mature forest (less than 205), which significantly reduces its soil and water conservation function (Li et al., 1997, after Yu, 1999). Over-cultivation with farming on marginal lands and converting forest to farmland, is another cause of soil erosion.

Fig. 21. Map of the Tumen River basin. Chinese sources of pollution: *1* – Kaishantun Chemical Fiber Pulp Factory; *2* – Shixian Paper Factory; *3* – Longjing Paper Factory; *4* – Hunchun Power Station; *5* – Hunchun Mining Area Building Headquarters; *6* – Wangqing Forestry Office; *7* – Yushuchun Power Station (halt production). Korean sources of pollution: *8* – Musan Iron Mine; *9* – Undok (Awudi) Chemical Fertilizer Plant; *10* – Hoeryong Paper Mill. After: Transboundary Diagnostic Analysis, 2002.

The ecological costs of water pollution in the Tumen Region is significant. The Tumen River area is a globally important reservoir of rich biodiversity providing habitats for over 50 species of mammals including globally endangered and threatened species such as the Amur Tiger and the Far Eastern Leopard and about 360 species of birds, both settled and migratory ones. The lower reaches and the estuary of the Tumen River is a vast wetland complex serving as important place on East Asian-Australian Migratory Flyway. It supports about 200 species of migratory birds including 36 globally endangered species that are listed in the IUCN (The World Conservation Union) Red Data Book (Trans-boundary cooperation..., 2002).

Two thirds of the area's wetlands are on Russian territory and comprise the famous Khasan wetlands. There wetlands stretch to north from the Tumen River and the Russian-DPRK border and are included in Khasan Nature Park. Immediately south of the Tumen River the Korean peninsula's largest complex of natural lakes (Manpo and Bonpo) is located. These lakes are known as the Bonpo Wetland Reserve in Rajin-Sonbong area, DPRK. Other parts include the Jingxin Wetlands in China, where there are seven freshwater lakes and one reservoir. Ones of them are lakes in Fangchuan, which are rich in water chestnuts and lotus, attracting large number of tourists in the peak of summer (Lower..., 2004).

The fish stock of the Tumen River has been nearly decimated by pollution and overfishing. In the 1930s, fish catch in Tumen River was more than 2,000 tons annually. However, in the 1980s, the fish catch dropped to less than 10 tons annually (The Encyclopedia..., 1996, after Yu, 1999). According to investigations of Russian ichthyologist L.S. Berg (1914), fish fauna of the Tumen River included 43 species, but majority of these species was euryhaline and typical marine fishes: sardine, Japanese horse mackerel, Pacific mackerel, Japanese anchovy, sculpin and some others. Only a relatively small number (12) of typical fresh water species were observed. Currently, the Tumen River is essentially "dead" (Cleaning..., 2000), particularly in its middle reaches. However two tributaries Gaya and Hunchun Rivers are less seriously polluted and still yield some fish catch (Yu, 1999). In recent years the pollution caused a decrease of the stock of such commercially valuable fishes as redfin, striped mullet, haarder, herrings (Sokolovsky et al., 2001).

In the same time with decreasing of fish stock in the Tumen River, there is a tendency of increasing of fish species number. As a result of a multi-year investigation of fish fauna of the Tumen River, a current list of fish fauna of the Tumen River includes 76 freshwater, anadromous and euryhaline species (Chyung Moon-Ki, 1997; Zhen Baoshan et al., 1980; Kim Ri et al., 1990; Reshetnikov et al., 1997; Sokolovsky et al., 2001; Sokolovsky and Oksyuzyan, 2001, and others). It could be deduced that during this period an increase in the list of fishes occurred under the influence of the anthropogenic activities. The development of pond fish culture in the water bodies of the river enriched its fish fauna during the last two decades with such fishes as carp, grass carp, silver carp, bighead, snakehead. Some cyprinid fishes, such as Korean sawbelly, three-lip, spiny bitterling were introduced in the Tumen River with the fry of cultivated fishes (Sokolovsky et al., 2001).

Having been transported to the coastal waters of Peter the Great Bay, the pollutants affect the quality of the marine environment. The negative effects of pollution are recorded at different trophic levels from primary producers to mammals and humans and at different levels of organization of living matter from molecular-biochemical to community and ecosystem levels. In connection with pollution following phenomena are the most dangerous to the marine biota:

– Oxygen deficiency in the near-bottom water layer, as a result of dissolved oxygen consumption for the oxidation of organic compounds;

– Disturbance of the nutrient balance due to the input of large amounts of organic and mineral nitrogen and phosphorus compounds into the coastal waters, i.e. eutrophication of the water;

– Bioaccumulation of toxic substances by marine organisms. Capability of hydrobionts to accumulate pollutants in their organs and tissues in concentrations 10^3–10^5 times greater than their level in the environment, is a real threat to both a health of bioaccumulators themselves and the representatives of higher trophic levels, including humans.

Less contaminated southern part of Peter the Great Bay, including the area of Far Eastern State Marine Reserve (FESMR), located close to the Tumen River mouth, was used for a long time as a background area. However, doubling of the concentrations of Cd, Ni and Zn in brown algae during the recent 15 years is established. In the organs of three fish species from Sivuchya Bight, the presence of DDT (up to 6 ng/g) and HHC (up to 3.7 ng/g) was revealed. These facts are the evidence of anthropogenic effects.

– Fish pathology. In the mouth of Tumannaya River and adjacent marine coastal zone, considerable quantity of pathological alterations of external covers and interior organs of fishes was established. The prevalence of some histopathological changes in the liver and gills of the dark place from Sivuchya Bight was at the same level or higher than that in fishes from waters closed to Vladivostok, for example the Amursky Bay (Syasina et al., 2001).

To protect the unique marine biodiversity in Peter the Great Bay, the Far East State Marine Reserve was established in 1978. It remains recently as the alone marine reserve in the Russia. In 2003 the Reserve was included into the UNESCO World Network of Biosphere Reserves. In the Reserve more than 1,200 marine species, including 162 fish species, 274 crustacea species and 207 mollusc species have been identified (more than any other area in Russia) (Lower..., 2004).

Scientists of the Institute of Marine Biology FEB RAS propose some approaches for the biomonitoring optimization in the area of Tumen River mouth, including Marine Reserve. The major principle is that the monitoring has to be performed according to the observation rules established in advance and strictly maintained; the environmental monitoring has to be performed at the same time.

Expedition of the Institute of Marine Biology to the Amur River in July, 2005

From July 6 to 26 a group of specialists of the Institute of Marine Biology went on an expedition on the R/V *Professor Gagarinsky*. They explored the shallow-water Amur River estuary, the Tatar Strait of the Sea of Japan, and Sakhalin Bay of the Sea of Okhotsk. The expedition's main task was to make comprehensive analysis of the present state of the Sea of Japan and Sea of Okhotsk coastal marine ecosystems locating in the areas subject to the Amur River run-off.

Over the last several years environmental situation in the Amur River catchment-basin has been critical as a result of an uncontrolled and inappropriate nature management, mainly in China and Russia. This situation initiated new ecological problems in the region and aggravated the existing ones.

There are biogeochemical barriers on a boundary between a river and a sea. These zones are known as marginal filters. A whole range of processes take place here: river flow slows down, big fractions of suspended materials settle out, clay particles coagulate, river and sea water mix and dilute each other, substances interact physically and chemically (flocculation and coagulation of organic substances and metals, sorption and desorption), and biological processes intensify. All these processes are exposed to the effects of climatic and anthropogenic changes in a river run-off. They also depend on density structure of water and on hydrodynamic conditions. Dynamics and correlations between different barriers make a paramount impact on marine ecosystems functioning.

Taking into consideration that the anthropogenic effect on the Amur River ecosystem has increased and the environment changed owing to diminution of water discharge in the river-bed, it seems reasonable to try to estimate the ability of the Amur River estuary to make changes in the Amur River run-off, as well as the estuary's influence on the adjacent sea waters.

In this connection the expedition faced the tasks:

1. To investigate the spatial variability of hydrological and hydrochemical parameters in the zones where river and sea water mix: the Amur River, Amur River estuary, Sakhalin Bay of the Sea of Okhotsk, and the Tatar Strait of the Sea of Japan.

2. To study the peculiarities of the distribution of biogenic elements (mineral forms of phosphorous, ammonia and nitrate nitrogen, silicon and calcium) in areas with different hydrological conditions. An amount of chlorophyll *a* in the water surface layer was adopted as an index of productivity in the investigated areas.

3. To determine species composition, density (cells/liter), and biomass (mg/m^3) of phyto- and zooplankton in the investigated areas.

4. To study quantitative and qualitative characteristics of benthic communities.

5. To collect samples of suspended materials from the water surface layer for the purpose of determining its amount and chemical composition. This enables us to draw conclusions on the removal of various substances with the river run-off, on the intensity of sedimentation and production processes, as well as to make assessment of possible anthropogenic effect.

6. To make granulometric and chemical analysis of all types of grounds and bottom sediments to determine pathways of transport of matter discharged by the river and possible anthropogenic effect on different water areas.

7. To evaluate the effect of economical activity in the Amur River catchment-basin on the concentration and distribution of dissolved and suspended forms of metals (Pb, Cd, Cu, Zn, Fe, Mn, Ni) in the adjacent sea waters.

8. To determine the peculiarities of microelement composition of water surface layer plankton in connection with the kinds and concentration of metals in the environment.

Research Manager of the project: the Academician Kasyanov, V.L., Director of the IMB, FEB RAS; the Leader of the Expedition: Nekrasov, D.A., Cand.Sc. (Biol.), Researcher of the IMB.

The expedition was organized in cooperation and with participation of:

• A group of researchers from the Pacific Oceanological Institute, FEB RAS, who conducted investigations of hydrological characteristics of the terrigenous run-off and evaluated its effect on the Far Eastern seas ecosystems.

• A group of researchers from the Pacific Institute of Geography, FEB RAS, who studied the biogeochemical transformations of heavy metals in the coastal waters.

The Executives-In-Charge and the main participants of the project: Shulkin, V.M., Cand.Sc. (Geog.), Head of the Laboratory of the PIG, and Zhabin, I.A., Cand.Sc. (Geol.-Min.), Senior Researcher of the POI.

The research staff of the expedition comprised 8 members of the Institute of Marine Biology, 5 members of the Pacific Oceanological Institute and 2 members of the Pacific Institute of Geography – 15 people in all, including 5 Candidates of Sciences.

Hydrological, hydrochemical, geochemical, and hydrobiological work was made in the open-sea areas and in coastal zones. The researchers of the expedition were divided into three groups.

A group of hydrology and hydrochemistry made physical mensuration of water mass and collection of water samples for the purpose of evaluation hydrological and hydrochemical characteristics of marine environment in the areas studied.

A geochemical group collected water and bottom sediment samples to study them and to analyze heavy metal concentrations in the ship and institute laboratories. The group also evaluated the range of suspended materials sedimentation.

A hydrobiological group collected benthic fauna samples from the board using dredgers and drags. SCUBA-divers carried out sampling of sea flora and fauna in coastal water areas. They collected water samples at different depths using bathometers, and fixed the samples to make qualitative and quantitative analysis of phytoplankton. They also carried out sampling of mero- and zooplankton with plankton nets. All the collected materials were sorted out and analyzed in the ship laboratory. The researchers made observations of sea mammals, too.

The information obtained in course of the expedition:

1. Main physical and chemical characteristics of marine ecosystems in the areas adjacent to the estuaries of big rivers.

2. Data on the species composition, number, biomass and distribution of pelagic and benthic communities of marine organisms in relation to climatic and oceanological factors.

3. Evaluation of the effect of the Amur River run-off on biological communities.

4. Data on the connection between the biodiversity of coastal flora and fauna and intensity and character of the river run-off and anthropogenic effect.

5. Data on the biota reaction to the terrigenous run-off and contaminants, transported by the river run-off.

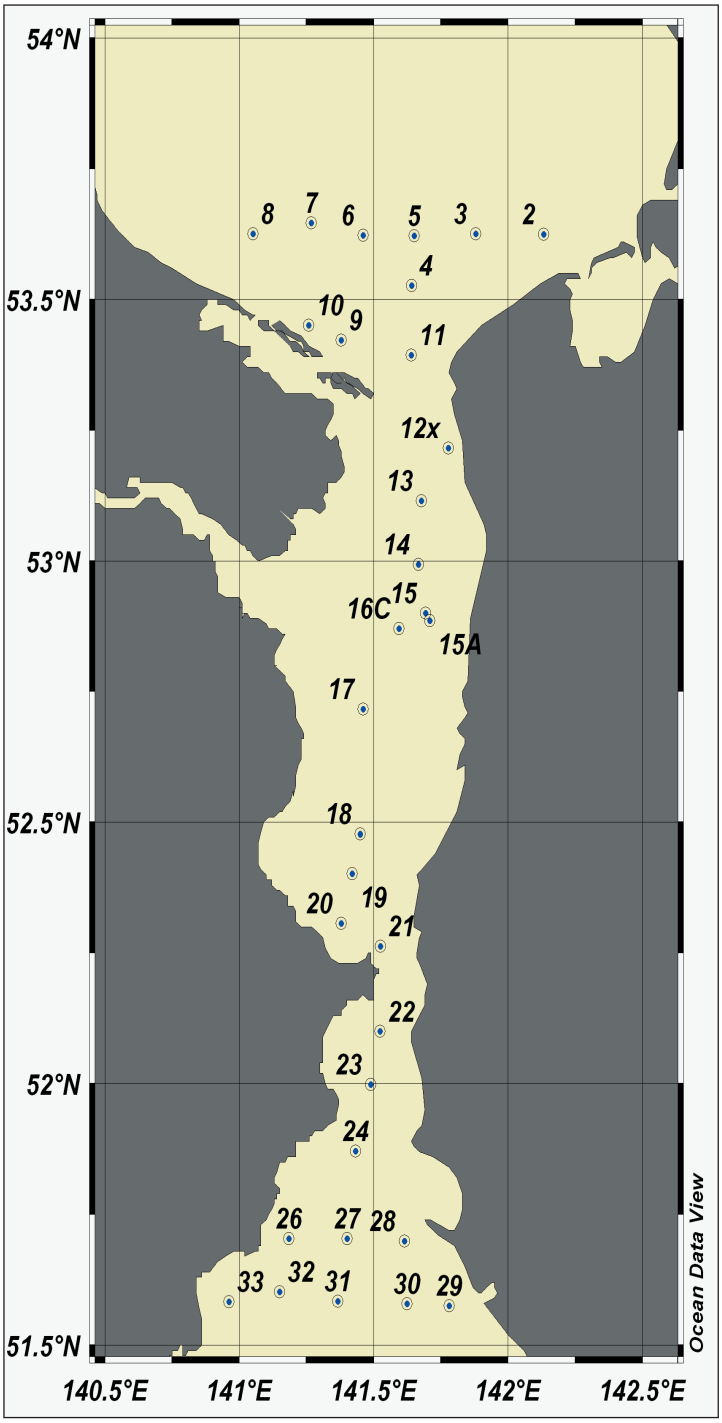


Fig. 22. Map of the stations of the expedition.

The expedition worked in the southern part of Sakhalin Bay (Sea of Okhotsk), in the Amur River estuary, the Tatar Strait and in the areas adjacent to the estuaries of the Tumnin and Koppi Rivers (Sea of Japan). The total length of rout was 1937 nautical miles. The voyage duration was 21 days.

36 sea stations for combined research to a depth of 30 m and 3 river stations were carried out (Fig. 22). Water samples were collected at these stations to further determine the concentrations of dissolved and suspended forms of metals. 40 profiles of temperature and salinity were obtained. 107 water samples including river water samples from the Amur, Tumnin and Koppi Rivers were analyzed to assess the amount of biogenic elements. 118 marine water samples were analyzed to determine carbonate parameters (pH, alkalinity), and equal number of samples were preserved for further analysis in the laboratories on shore to estimate calcium, magnesium, humic substances, and chlorophyll *a* concentrations.

More than 100 samples of macrobenthos, 99 quantitative and 34 qualitative samples of meiobenthos were collected. 35 bottom sediment samples were collected to determine granulometric composition of grounds, and equal number of samples was collected to determine the amount of organic substances and to evaluate the ratio of carbon C_{12}/C_{13} stable isotopes. 98 bathometric, 37 plankton net and 30 bottom samples of phytoplankton, as well as 104 samples of zooplankton were collected and mounted for further analysis.

Diving equipment, dredgers, automatic hydrologic probes, bathometers, plankton nets, meiobenthos drag, cold stores, binocular microscopes, personal computers, VHF radio stations, appliances for chemical analysis, chemicals, laboratory glassware, as well as an outboard motorboat and life saving equipment were in the disposal of the expedition.

All kinds of work were done in accordance with generally adopted methods.

The information obtained as a result of the expedition will make it possible to understand the spatial variability of hydrochemical, hydrological and hydrobiological parameters, processes of destruction and production of organic matter in the zone where river and sea water mix in the Amur River estuary, as well as in the adjacent water areas of the Sea of Okhotsk (Sakhalin Bay) and the Sea of Japan (Tatar Strait). Reconnaissance work was done in the estuaries of the Tumnin and Koppi Rivers, which are the largest rivers in the south of Khabarovsky Krai flowing into the Sea of Japan.

The material results of the expedition are: the preserved benthic and plankton samples, electron tables and notes in a research log-book. Data obtained will be worked up and realized as a scientific report and scientific publications in authoritative Russian and foreign journals.

All the scheduled programs of the expedition were performed. The unique hydrological, hydrochemical and hydrobiological information was collected on the effect of the Amur River run-off on the adjacent waters of the Sea of Okhotsk and Sea of Japan in relation to natural and anthropogenic environmental factors and climatic changes.

Environment Management Strategy for Han River Estuary in Korea

Han River Estuary is located on the west coast of Korea. Compared to highly developed upper part of the estuary (Seoul Metropolitan Area), the lower part of the estuary, which is a part of Demilitarized Zone (DMZ) and Military Facility Protected Area (MFPA) has been preserved well since the Korean War. Recently, however, concerns on the possible degradation and destruction of this precious estuary were raised in public because military tension and increased economic cooperation between South and North Korea began encouraging local developments in this border area. In this aspect, this study aims to develop environmental management strategy to protect the natural integrity, function and value of the Han River Estuary from the surging local development pressures and demands.

The estuary shows the natural abundance and biological diversity typically observed in macro-tidal environment and supports the local socio-economic needs. Total of 356.431 km^2 of estuarine wetlands support a wide range of internationally and nationally protected birds including 7 endangered species and 20 natural monuments such as White-naped crane, Chinese egret, and Black-faced spoonbill. In addition, rare plant species (*Grewia* sp., Leopard flower, *Crypsinus* sp., and etc.) and distinctive plant communities (Winter green and its relative species) are distributed in riparian or nearby terrestrial areas of the estuary. Several fishes such as River puffer, Horse-shoe crab and eel support the local commercial and recreational fisheries. At the same time, Panmunjeom and Mt. Odoo observation platform, which are historic sites of Korean War, draw many tourists from nearby Seoul Metropolitan areas.

Rapid expansion of the Seoul Metropolitan area, which is reflected in statistics (5% increase in urbanized area and 50% increase in number of industry for the last 5 years) resulted in various environmental problems in the Han River Estuary. Nutrient enrichment (eutrophication), sediment contamination, malformed fishes, and increased floating debris are major water quality problems in the estuary. In addition, several natural environmental problems are identified, such as destruction of environmentally sensitive habitats by estuary development, blocking wildlife pathways or corridors between rivers and riparian areas by the river banks and military fences, and negative environmental impacts by the Singok Submerged Weir. It is expected that implementation of “The DMZ Area Development Plan”, development of new towns in the Gimpo and Paju areas, connection of South-North Korea transportation networks, and increasing demands of local tourism will be major environmental stresses in the estuary.

This research suggested management vision, principles and strategies for the Han River Estuary based on the qualitative analysis by PSR and SWOT approaches and case studies. First of all, “Han River Estuary as a living place for naturally diverse and vivid, and socio-economically prosperous” was set as a management vision. Four management principles; sustainable, cooperative, ecosystem-based and integrated approaches were suggested to achieve the vision and eight management strategies were developed based on the principles: adaptation of precautionary policies and measures, encouragement of local stake-holder’s participation, development of institutional management frameworks and systems, development and implementation of environmental survey/research/monitoring programs, designation of substantial environmental protection zones, development of a comprehensive “Han River Estuary Environment Management Plan”, development of habitat restoration strategies, and establishment of secure funding sources to support the estuary management.

Management boundary of the Han River Estuary was defined as "the area from the down-stream watersheds of Jamsil Submerged Weir (landward) to the administrative boundary of Ganghwa and Ongjin counties in Gyeonggi Province (seaward)" based on the available scientific characteristics, demands of natural resources management, and substantial management conditions. Designation of the "Environmental Management District (EMD)" was suggested to effectively protect natural environment as well as to support site-specific environment-friendly land-use in the estuary. The EMD was divided into five classes based on the "National Environmental Assessment Criteria" which reflects regional environmental conditions. It is suggested that classes I and II are managed as conservation areas where local development is strictly regulated, class III, as an improvement area where only environment-friendly development is permitted, and classes IV and V, as restoration areas where local development is encouraged. According to the zoning, preservation areas occupy 57.7% (1.656 km^2) of the total area of the Han River Estuary. Although detailed regulations applicable to the individual areas have to be further developed based on local surveys, the EMD is expected to be a practical tool to support environment-friendly development.

Policies and countermeasures to solve the environmental problems and issues identified in five management sectors were suggested. Major recommendations are summarized as follows:

– Land/transportation: designation of the EMD to encourage the planned development, application of strict land-use regulations for the implementation of the "DMZ Area Development Plan", and development of detailed land-use guidelines in the EMD and DMZ area.

– Natural environment: development and implementation of basic estuary surveys and researches, development and implementation of estuary monitoring systems, and designations of the "Estuary Ecosystem Conservation Area" and the "Natural Reserved Area".

– Water environment: implementation of the "Total Pollution Load Management System" in the estuary, conducting post environmental impact assessment for the Singok Submerged Weir, and identification of exposure pathways of toxic chemicals.

– Landscape/tourism: designation of the "Natural Landscape Conservation Area" and development of the "Natural Landscape Management Plan" for downstream of the Singok Submerged Weir.

– Fisheries: improvement of the fishery management system, estimation of quantitative fishery stocks, and life cycle study of estuarine commercial fishes.

New institutional and noninstitutional management frameworks were suggested to support implementation of the suggestion and overcome current management problems such as fragmented government policies and schemes, uncoordinated management approaches, and lack of environmental knowledge and information.

– Establish "Han River Estuary Management Council (provisional name)" and related advisory committees, and develop a "Comprehensive Han River Estuary Environment Management Plan (provisional name)".

– Provide legal or institutional estuary management basis by either enactment of the "Special Act for Environmental Preservation and Utilization of Han River Estuary (provisional name)" or "Act for Integrated Watershed Management (provisional name)".

– Support establishment of non-institutional local or regional cooperative networks between government, local stake-holders, NGOs and military to facilitate environmental problems and disputes.

– Adapt and implement various non-institutional management measures such as voluntary agreement systems for biodiversity protection, cooperative educational programs for capacity building, and local monitoring programs for drawing stake-holder participation.

With all the suggested management strategies, selection of practical management measures and their effectiveness are uncertain at this point in time because of lack of knowledge and information on the estuary. In this aspect, this study also suggested spending over 8 billion Korean Won on the estuary surveys and research plan for the next 5 years, and presented 37 sustainable development indexes applicable to assess current status and to evaluate future management effectiveness based on the sustainable development concept.

Nature management within the Russian Far East coastal zones

In Russia, about 17 millions people live in the coastal zone (within a belt of 50 km from the coastline) and only 5 millions of them render habitable the coastal zones of the Far-Eastern seas – Bering, Okhotsk, Japan and open coasts of the Pacific Ocean. The Russian Far East is remarkable for the climate severity and heavy winter ice conditions; here, different violent natural phenomena are often observed. The Russia's coast is characterized by a rich natural-resource potential but its intensive development started only in the last 60 years. All of this coupled with remoteness from the country's center left their imprint on the development of the Far East which is characterized by sparse population and focal development of the infrastructure and a number of hard problems.

As a result, early in the 21 century, there are a number of challenges of the coastal zones of the Russian Far East required to be resolved where the legislative, social-economic, scientific and ecological ones can be identified:

Legislative:

- Imperfect legislative base.
- The absence of the governmental support system.

Social-Economic:

- The Far Eastern enterprises and those located in the western and central parts of the country do not have equal economic starting conditions.
- Investment unpleasantness.
- Little population and the drift from the land.
- Underdeveloped infrastructures.

Scientific problems are that there is no cadastre of the seacoasts.
Ecological problems:

- Depletion of more valuable biological resources.
- Conflicts between alternative types of nature use.
- Degradation of coastal ecosystems located near large maritime cities.

It is evident that for solving these problems, a system approach is necessary which consists in a developing and introducing the system of Integrate Coastal Area Management of the for the Russia's Far East making a good showing in the world practice (Fig. 23). It includes a continuous process of decisions making directed to a harmonization of the social-economic development of the coastal regions in an effort of sustainability of their development.

Construction of such system for the Far-Eastern region of Russia is based on the multilevel structuring of coastal zones as the specific contact structures (with determination of use priorities at each level) and includes an analysis of alternative use of natural resources of land and sea, determination of dynamic interconnections of natural processes and resources and kinds of human activities, evaluation of the stability of the coastal-marine and land ecosystems to natural and anthropogenic impacts; construction of thematic electronic maps and atlases based on GIS-technologies; component-wise division into districts and zoning of different scales (Figs. 24, 25).

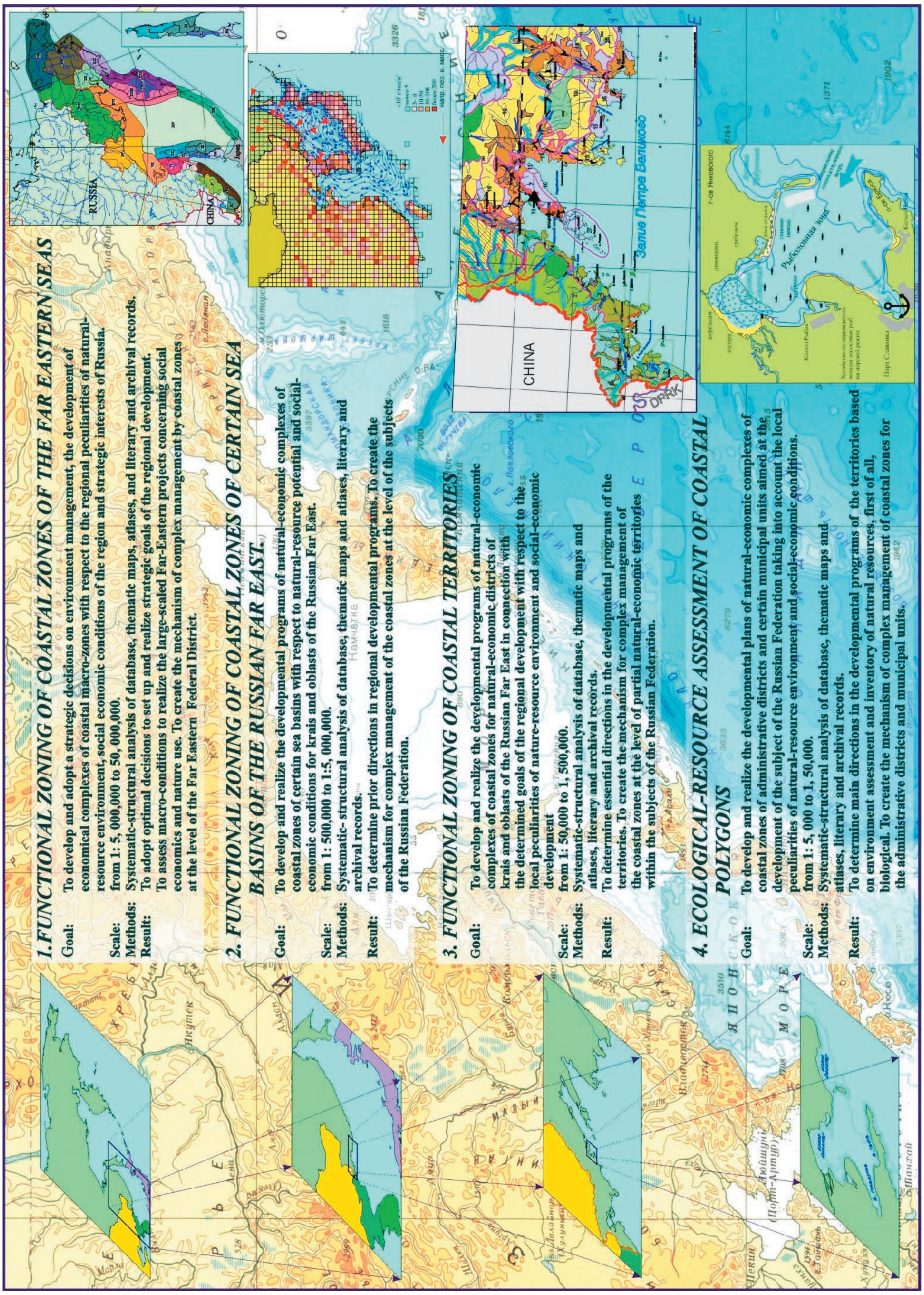


Fig. 23. The scheme of the functional zoning of different areas of the Russian Far East.

Fig. 24. Integrated coastal management of the Russian Far East.

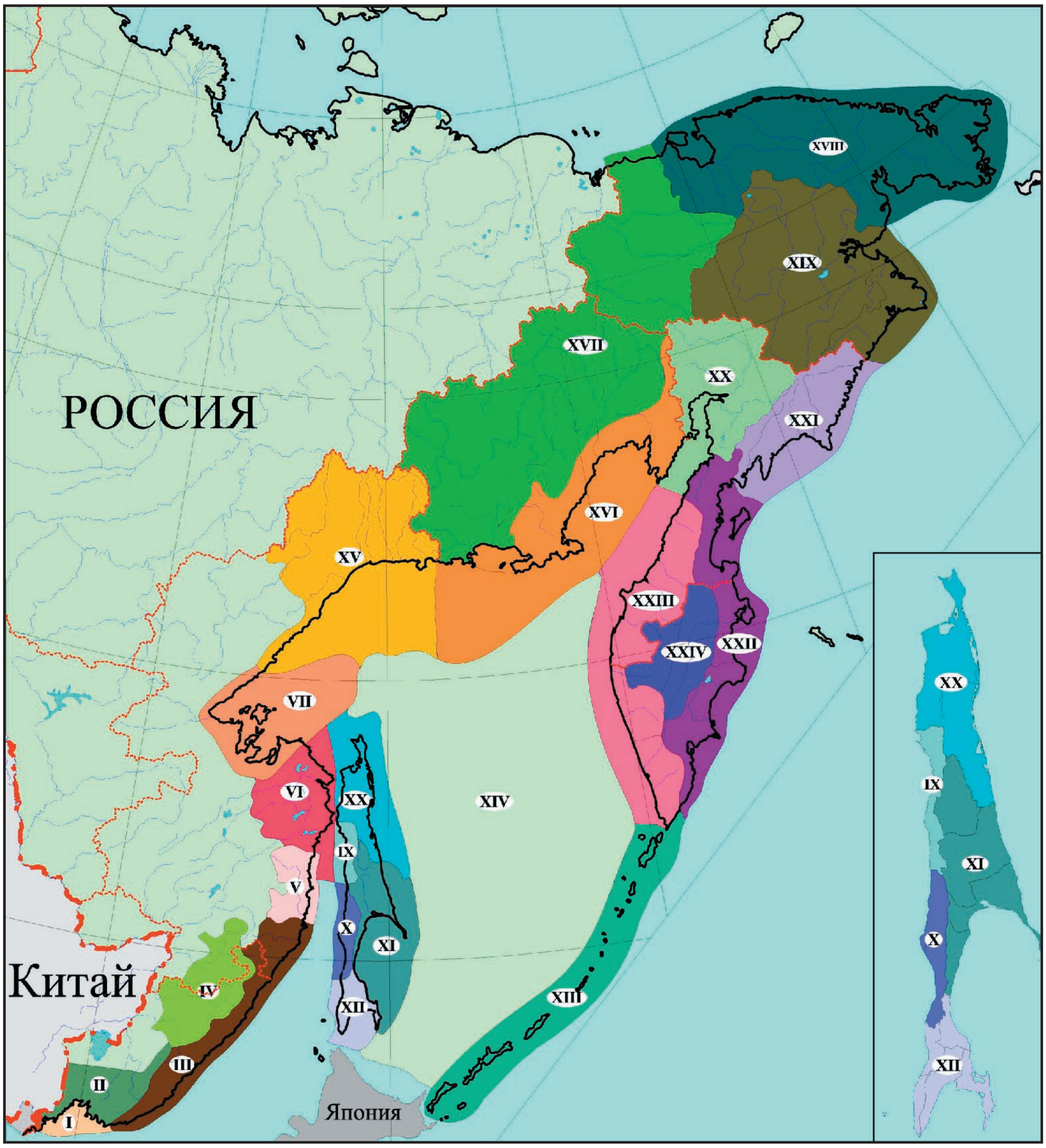


Fig. 25. Preliminary natural resources zoning of coastal part of the Russian Far East.

Coastal zone management in China

1. Background

The coastal zone of China comprises an area of more than three million square kilometers, and possesses an 18000-km coastline stretching across tropical, subtropical and temperate zones. More than 70% of large Chinese cities are located in the coastal areas, and coastal development in China plays a leading role in the national economy, accounting for 55% of its gross domestic productivity (GDP) (Wang, 1992). The coastal areas are characterized by rapid economic growth, with an annual increase in GDP by around 10% over the last decade. China has a population of more than 1.2 billion, and its land area per capita is far lower than the world's average. The Chinese government has begun to recognize the crucial role that the ocean's living and nonliving resources in China's energy and food security. However, the continuing increase in population coupled with economic growth, rapid urbanization and infrastructure development have resulted in conflicts among multiple groups, especially among terrestrially and marine based industrial sectors, e.g. tideland reclamation and coastal aquaculture, seaport/shipping development and wetland resource uses, coastal mining and protection against erosion, waste disposal and maintaining ecosystem and human health, offshore oil development and fisheries, coastal groundwater extraction and land uses (Yu, 1994). The increase in conflicts also has led to environmental degradation, e.g. pollution, deterioration of ecosystem health, habitat losses, resource depletion, and invasion of exotic organisms. To balance anthropogenic activities and ecosystem health and environmental protection, a comprehensive management scheme is urgently required in the coastal zone on a sustainable basis. Therefore, the objectives of this paper are to: (1) compile baseline information on the current status of coastal zone issues and management in China, and (2) review a pilot project on integrated coastal zone management in China.

2. Main issues in the coastal zone

The coastal zone is an interface between the land and sea, which comprised of a continuum of coastal land, intertidal area, aquatic systems including the network of rivers and estuaries, islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. A national programme of comprehensive coastal zone investigation has been carried out from 1980 to 86 throughout China, and the extent of coastal area, including the intertidal area, land area up to 10 km from the shoreline and landward water areas from the 10–15 m isobath was defined as coastal zone to build a baseline database towards better coastal zone management. This scope is adopted in this study due to the fact that most of anthropogenic activities influencing both land and sea environment occurred in this area (Fig. 26). Coastal ecosystems and environmental quality was degraded and deteriorated, and conflicts among terrestrially and marine based industrial sectors were already very common (Yu, 1994). However, with rapid economic growth and urbanization in the China's coastal zone in the recent years, new issues emerged, and coastal ecosystem degradation and environmental deterioration have been, to some extent, exacerbated.

2.1 Pollution

Pollution is one of the major challenges to sustainability of the coastal areas. Heavy pollution has been found very common in the Chinese river estuaries, bays and coastal

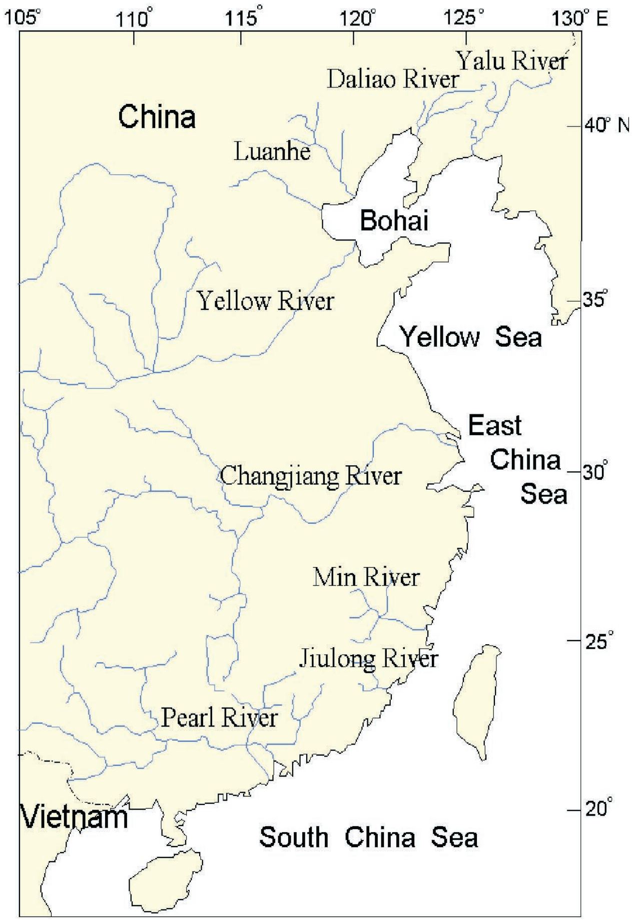


Fig. 26. Major coastal rivers in Mainland China.

areas, and this has resulted in a clear increase in both area and occurrence of red tides in the China's coastal sea (Table 9). The sources of pollution mainly come from the land and also from coastal waters by mariculture itself. Land-based pollution mainly includes riverine exports of agricultural chemicals from coastal catchments, domestic wastes and industrial wastes.

Agricultural diffuse sources are becoming a significant contributor to water pollution in the coastal zone in China. The excessive uses of commercial inorganic fertilizer for raising crop yield and meeting the demand of population growth in China has resulted in increased nutrient additions and subsequent losses from adjacent coastal catchments. In some regions where agriculture is productive, nutrient content in coastal water bodies increased over 10 fold during last two decades, and over 50% of the nutrients were contributed by diffuse agricultural activities (Cao et al., 2003). In the Changjiang River estuary, Zhang (1996) attributed a significant increase in riverine nitrogen fluxes to the increase in chemical fertilizer uses within the river catchment (Table 10), comparing to the previous estimate (Edmond et al., 1985). The more recent research by Shen et al. (2003) showed that agricultural diffuse sources in the Changjiang River catchment was the major N sources of riverine nitrogen fluxes. In the Jiulong River region, some areas in the coastal water have been deteriorated by eutrophication and excessive growth of benthic algae since mid-1980s, and 60.87% of total nitrogen was directly contributed by agricultural activities (Cao et al., 2005).

Table 9. Occurrence and area of red tides in coastal sea

Year	Occurrence	Area (km^2)
1999	13	–
2000	28	10650
2001	77	15000
2002	79	10140
2003	119	14550
2004	96	26630
2005	82	27070

Table 10. Riverine dissolved inorganic nitrogen fluxes in some Chinese rivers

Rivers	Drainage area (km^2)	Fluxes (t/yr)	Areal yield ($kg/km^2.yr$)	Data sources
Changjiang	1808500	625800	346	Zhang (1996)
		1746000	965	Shen et al. (2003)
Pearl River	442585	369600	835	Zhang (1996)
		179293	405	Huang et al. (2003)
Jiulong River	14741	6000	407	Chen et al. (1993)
		12600	855	Zhang (1996)

Livestock wastes. Many studies have shown that the diets of urban population in China were rapidly becoming diverse and shifting to what has been termed the Western-diet. This includes diets that are higher in meats, edible oils, and other fats and refined carbohydrates, but lower in fiber (Entwisle et al., 1995; Popkin, 1999). China has shown a very rapid increase in meat and egg consumption since 1960s. These changes in consumption patterns converted traditional land uses to livestock farms and orchards (Tanrivermis, 2003), and resulted in a great gap between increase in livestock wastes and lack of disposal facility, and consequent water degradation and eutrophication in receiving fresh water and coastal water bodies (Cao et al., 2006) in some areas.

Domestic sources. In 1998, 51 cities in the coastal region exceeded 0.1 million people. The largest of these are Shanghai (population 13.4 million), Tianjin (over 9 million), Hangzhou (1 million), and Guangzhou (4 million). As a consequence of limited sewage treatment and rapid urbanization and population growth, domestic wastewater and solid waste are another important pollutant sources. Domestic waste contributes organics, which increase biological oxygen demand (BOD), soluble nitrogen and phosphorus and suspended solids. Solid waste consists of suspended solids, organics including plastics, rubber and discarded building materials. These pollutants, domestic and solid wastes, contribute heavy metals to the marine environment. High concentrations of dissolved N and P can also lead to eutrophication, and finally result in decreases in species diversity, excessive alga growth (harmful algal blooms), dissolved oxygen reductions and associated fish kills.

Industrial sources. Industry mainly generates industrial wastewater, industrial solid and hazardous waste and waste gas. Oil pollution in the coastal zone comes from urban areas, i.e. runoff from city streets and from improper disposal of used sump oil. Industrial activity tends to be concentrated in highly industrialized cities, which densely located in the China's coastal zone.

Consequently, agricultural diffuse activities, urbanization, industrialization and population growth combines to greatly increase the environmental problems in coastal areas. The wastewater from above land-based sources either directly discharges or exports through river systems to coastal sea. The major Chinese river exports shows a clear increase in riverine pollutants fluxes (Table 11). Marine environmental pollution has become a more and more serious threat in the last several decades, creating problems such as chronic hypoxia, eutrophication, harmful algal blooms, toxicity in benthic fauna, reductions in species abundance, and stressed fisheries resources.

Table 11. The major pollutants from riverine exports in typical Chinese rivers

Rivers	COD (t)	Phosphate (t)	Heavy metal (t)	Arsenic (t)	Oil (t)
Year 2002					
Yalu River	67486	367	775	155	997
Daliao River	49802	495	390	–	227
Changjiang River	2479438	31482	15066	1547	49563
Min River	90000	1590	1784	43	2810
Jiulong River	123654	1056	8410	30	614
Pearl River	1154271	14614	3095	448	13674
Year 2003					
Luan River	5780	50	120	10	220
Yellow River	872140	220	200	60	1610
Changjiang River	2719470	70030	36340	3340	69890
Min River	172 340	1160	2530	160	7760
Jiulong River	232960	2020	370	30	420
Pearl River	1764030	24140	9170	2680	47120

Sediment pollution usually occurred in estuarine and seaport areas. The major pollutants are cadmium, arsenic, copper, mercury, zinc, lead, and organic compound (Yuan et al., 2001). This posed a health risk for human to consume seafood produced from such areas.

2.2 Ecosystem degradation

Mangrove areas, mainly distributed in southeast China, reduced from 5.5×10^4 ha in 1950s to less than 1.5×10^4 ha in 2002, i.e. 73% of mangrove areas were removed during about last fifty years, and the reduction mainly was occurred in the areas with strong economic expansions, such as Guangdong and Fujian province. Coral reef areas reduced by 80%, mainly due to destructively anthropogenic activities, such as excavations of reef rock for building materials and collections of coral skeletons for sale.

Up to 2002, twenty-six marine economic species (fish, shellfish and shrimp species) and three species of rice grass (*Spartina*) were introduced to China. Of which, *Spartina anglica* was intentionally introduced to China in 1963, owing to its special value in protecting coastal engineering (Tang and Zhang, 2003). However, the benefits of this exotic species have been overshadowed by the ecological, social and economic costs of its rapidly continued spread. *Spartina* has occupied the habitat of mangroves, invaded intertidal mudflats and saltmarsh and led to a great reduction in biological diversity in the areas where *Spartina* was first introduced.

The coastal zone in China supports a wide variety of fish and invertebrates that are of both fisheries and ecological interests. However, many species is losing habitats due to heavy pollution and anthropogenic coastal construction, such as the Chinese white dolphin (*Sousa Chinensis*), which considered as a highly endangered species.

2.3 Coastal reclamation

A significant consequence of economic expansion in coastal areas is extensive land reclamation. Cumulatively, reclamation has resulted in a conversion of 219 million ha from coastal wetland to other land uses until 2002, and the coastal wetland losses in area are about 50% of total coastal wetland in China. Negative environmental impacts of reclamation are inevitable. In Xiamen, 5791 ha of coastal areas have been reclaimed by filling in coastal wetlands, diking, and building dams since 1950s (Xue et al., 2004). The local reclamation has extensively changed water circulation system and resulted in accelerated erosion and contamination, shipping route siltation, losses of fish spawning sites. In Shanghai, 62% of the total land areas have been derived from land reclamation during the past 2000 years. In the last 45 years, 78700 ha of land have been reclaimed (Shi et al., 2001). Furthermore, the environmental impacts of reclamation include habitat losses of endangered species and losses of stepping-stones for transient birds.

2.4 Aquatic resource depletion

Environmental degradation, for instances, increases in occurrence of harmful algal bloom, exerted a significant influence on the coastal fauna and flora. In 1998, the coastal areas in China with water quality that was below the first class water quality standard reached 228000 km^2. This was a 100% increase over that recorded in 1992. Of these areas, about 40000 km^2 of the coastal sea were below the fourth class water quality standard. These areas could no longer satisfy the requirement for mariculture, swimming and coastal tourism. In 1998 alone, the occurrence of diseases in mariculture animals reached a high rate of 30%, and a high economic loss occurred.

Although marine fish catch increased 2.5 fold from 1981 to 1992, and to 13.85 million tons in 1997 due to greatly increased fishing vessels and vessel power, the catch has dramatically shifted from large high-valued species to small low-valued ones (Liu and Ye, 1998). The productivity of high-valued fisheries has greatly decreased due to the intensive human activity and over-fishing in China's coastal zone (Jin and Tang, 1996), and some species even become endangered, for example, a whitebait and lancelet.

2.5 Coastal erosion

Both anthropogenic (mining, deforestation) and natural (tides, storm surge, sea level rise) factors are responsible for coastal erosion. In coastal areas from Yingkou to Yantai, Shandong province, a continuous monitoring showed that as wide as fifty-one m of coastal land was eroded from December 1996 to August 2003, with an annual mean erosion rate of 1.4 m and maximum of 6.7 m. Together, as long as 28.9 km coastal land retreated in the monitoring area, and this posed a great threat to security of agriculture, mariculture and residence of local people.

3. Current scheme on coastal zone management in China

The UNCED Agenda 21, formulated at the United Nations Conference on Environment and Development in 1992, call for establishment of a comprehensive coastal management scheme in managing a nation's coastal affairs. Over the last decades, the Chinese government has made a significant effort in developing a better management scheme in coastal areas.

3.1 Institutional arrangements

The State Oceanic Administration (SOA) is the leading agency responsible for China's ocean policy making and overall management of ocean and coastal affairs. Due to high spatial heterogeneity (coastal land, intertidal area and aquatic systems) in the coastal areas, the management scheme is complex in China. However, the general management scheme for the coastal zone in China still remains sectoral.

The newly established (restructured) Ministry of Land Resources has been authorized to oversee the planning, management, conservation and rational utilization of land resources, mineral resources and marine resources.

The SOA is responsible for supervising activities in marine environment, and organizing the investigation, monitoring, surveillance and evaluation of the marine environment. It has a primary role in protection against marine pollution and damage caused by marine construction projects, such as offshore oil exploration and exploitation, and by waste dumping at the sea. The National Environmental Protection Bureau (NEPB) is responsible for directing, coordinating and supervising marine environmental protection work throughout the country. It possesses the authority to enforce the law relating to marine environmental protection against land-based pollutants and pollution from coastal construction projects. The Ministry of Transport is responsible for overseeing, investigating and dealing with vessel-source pollution, and keeping under surveillance the waters in the port areas.

Overall, there are about twenty or so related ministries and agencies, which responsible for agriculture, construction, flood control, environmental protection, transport, and natural resources exploitation in the coastal areas. Furthermore at provincial, city and county levels, there are similar horizontal sections having responsibilities for the management and planning at the corresponding level.

3.2 Legislation

China has also improved its legislation concerning maritime matters. A series of laws and regulations at national or local level have been formulated (Zou, 1999). Jurisdictional, zoning boundaries, and allocating use rights for coastal and marine resources have been essentially established (Table 12).

Table 12. Laws and regulations related to the coastal areas in China

Name of laws/regulations	Date of promulgation (d/m/y)
Law on the marine environmental protection	23-08-1982
Regulations concerning environmental protection in offshore oil exploration and exploitation	29-12-1983
Regulations concerning the prevention of pollution of sea areas by vessels	29-12-1983
Regulations concerning the dumping of wastes at sea	06-03-1985
Law on Fishery Resources (Amended on 21-10-2000)	20-01-1986
Law on Mineral Resources (Amended on 29-08-1996)	19-03-1986
Law on Land Resources Management (Amended on 29-08-1998)	25-06-1986
Regulations concerning prevention of environmental pollution by ship-breaking	18-05-1988
Law on Environmental Protection	26-12-1989
Regulations concerning prevention of pollution damage to the marine environment by coastal construction projects	25-05-1990

Regulations concerning prevention of pollution damage to the marine environment by land-based pollutants	25-05-1990
Measures for implementation of the regulations concerning the dumping of wastes at sea	25-09-1992
Implementing regulations on the protection of aquatic wild animals	05-10-1993
Law on the Territorial Sea and the Contiguous Zone	25-02-1992
Measures for implementation of the regulations concerning environmental protection in offshore oil exploration and exploitation	20-09-1992
Regulations of natural protected reserves	09-10-1994
Measures of management of marine natural reserves	29-05-1995
Regulations for the protection of wild plants	30-09-1996
Provisions governing the management of coastal forest belts under special state protection	09-12-1996
Provisions on the procedure for investigation and handling of accidents of pollution in fishing areas	26-03-1997
Measures on the protection of natural reserves of aquatic fauna and flora	17-10-1997
Law on the Exclusive Economic Zone (EEZ) and the continental shelf	26-06-1998
Measures of management on utilization of sea areas	27-10-2001
Law on Environmental Impacts Assessment	28-10-2002
Law on prevention of marine pollution and damage from marine construction projects	19-09-2006

The Law on Environmental Impacts Assessment which was passed at the Thirty Session of the Standing Committee of the Ninth National People's Congress of the People's Republic of China on 28 October 2002, and came into force on 1 September 2003. The promulgation of the law aimed to prevent environment (including coastal and marine environment) from pollution due to planning and construction. The Law on prevention of marine pollution and damage from marine construction projects was promulgated on 19 September 2006, and will take effect on 1 November 2006. It covers the legal monitoring and managing marine construction projects and their impacts, such as building artificial islands, bridges, and pipelines in the coastal areas. The law and regulations in Table 11 showed China's endeavor to protect the marine environment. There are a huge number of regulations and procedures, issued by the SOA and the NEPB, to direct or organize human activities in the coastal areas.

3.3 Actions and practices

From 1980s to 90s, a large-scale multidisciplinary investigation of resources in the Chinese coastal zone was carried out. The investigation aimed to establish an inventory of coastal resources including tideland, wetland, coastal hydrology, chemistry, environment, climate, geology and biology. A large volume of first hand data was obtained and has been published. The survey uniquely collected the baseline data and information in the coastal zone, paved a way for implementing of follow-up planning and management projects.

At national level, the overall marine functional zonation scheme has been promulgated on 22 October 2002. To protect and improve the coastal environment, the marine functions for a zone is determined depending upon zonation, natural resources and environmental condition. The sectoral sea-uses are optimized according to a comprehensive planning. Ten marine functional types, including seaport areas, fishery conservation areas, mineral resources areas, tourism areas, water use areas, marine energy use areas, natural reserves, engineering use areas, special use areas, and preserving use areas, are categorized to reflect coherent management requirements and dominant uses within the China's coastal areas. Under these functional types, a total of 3663 marine sub-zones have been spatially divided. Furthermore, the SOAs in coastal provinces were also formulating strategic marine function zonation schemes across their jurisdictions as supplementary systems under the national scheme.

Overall, the pollution-monitoring network has been significantly established, improved and strengthened by satellites, ships and offshore monitoring stations since 2002. The "polluters-pay" policy has been adopted for pollution control and coastal environmental protection. A preliminary legal system on the use and administration of the coastal areas has been promulgated, and the marine functional zonation scheme has published for comprehensive marine development and protection.

3.4 Establishment of natural reserves

Establishment of natural reserves is an effective way to protect coastal biological diversity and ecosystems. Up to 2002, twenty-one natural reserves at national level, together with fifty-five at local level have been established to protect endangered species and typical coastal ecosystems in China's coastal zone.

4. Integrated coastal management in China

Integrated coastal management (ICM) is a continuous and dynamic process by which decisions are taken for the sustainable use, development, and protection of coastal and marine areas and resources (Cicin-Sain and Knecht, 1998), and ICM was recommended as a sustainable approach for coastal and marine management.

A project on ICM in southeast coast of China at local level has been implemented with an international financial support. Since 1994, ICM has been implemented in Xiamen for the prevention and management of marine pollution in the East Asian Seas (MPP-EAS) with joint efforts by the Chinese government and the GEF/UNDP/IMO Regional Programme. The project provided the local government with both the timely opportunity and the challenge to address its marine environmental problems (Chua et al., 1997).

The ICM activities include that an interagency Executive Committee (EC) was established and chaired by the executive vice-mayor. The EC comprised representatives from twenty-two agencies, and the representatives met periodically to review progression of planned activities, and consider recommendations (Chua et al., 1997). A leading agency, the Marine Management Division, was designated to manage and coordinate the ICM activities in Xiamen.

A Marine Experts Group, comprised marine scientists, legal experts, economists, engineers and urban planners, was established. The group provided an advisory role to policymakers on scientific, technical and socioeconomic issues and provided the best available information that will minimize the costs and maximize the benefits associated with proposed development projects, and the group facilitated to increase support from local government to environmental projects and application of ICM, and enhanced the institutional collaboration among various sectors.

A fundamental management requirement is the availability of a reliable and scientific database that could be used by the coastal managers to develop appropriate coastal policies and corresponding management interventions for mitigating any adverse environmental change (Chua, 1997). The role of scientists and their contributions in Xiamen proved to be crucial in the implementation of the ICM program.

The ICM project in Xiamen is managed and conducted by the local government with minimal community involvements, and is also characterized as "decentralization or bottom-up" (McCleave et al., 2003; Lau, 2005) approach in decision-making process. Although the coastal catchment is a significant contributor to the coastal water quality in Xiamen, the catchment is not covered by the ICM program due to jurisdictional issues and a fact that the ICM program in Xiamen operated by local government. This approach may be more effective if the political unit implementing the ICM Program has more power and resources to implement the program within its jurisdiction than if the program included surrounding jurisdictions (McCleave et al., 2003).

5. Recommendations

Comprehensive coastal management in China is a big challenge facing with great difficulties such as shortage of baseline information, deficiency in scientifically sound planning and zonation scheme, lack of coordination amongst resource users and governance, lack of public involvement, insufficient local intelligence, lack of monitoring and evaluation, and poor financial support. Therefore, recommendations for tackling these problems in ICM are proposed.

5.1 From sectoral to integrated management

Overall, management scheme of the coastal zone in China still remains sectoral. The sectoral management systems are not necessarily equipped to cope with the adverse consequences of multiple resources-use and space interactions across sectoral jurisdictions and administrative boundaries. Where institutional capacity is lacking and inter-agency conflicts dominate, formalizing institutional structures is first priority (Olsen et al., 1997). However, overlapping jurisdiction is very common in China. The inter-agencies conflicts and overlapping jurisdiction, to some extent, can be alleviated by coordination and power re-allocation among the many agencies of government with significant roles in management of coastal ecosystems.

For example, the NEPB is granted the leading role in overall marine environmental management, but marine environmental research, surveys, monitoring and surveillance, as well as the designation of marine protected areas, are under the mandates of other coastal- and ocean-related agencies (Yu, 1997). This posed an overlapping jurisdiction among related government agencies. The amended Law of Marine Environmental Protection, promulgated on 25 December 1999 and effective on 1 April 2000, has not changed the jurisdiction between the agencies. As an alternative, it is recommended that different departments should conduct law enforcement at sea jointly when necessary. Apparently, the new law encourages the relevant departments to take joint and co-operative actions.

Furthermore, environmental protection and resource conservation call for concerted efforts across sectors and disciplines. However, sectoral laws and regulations were not necessarily consistent with others, and usually were single type or single region oriented. Therefore, a close working relationship between related agencies is necessary for an improved institutional and authoritative mechanism that can effectively address these cross-agency management issues.

5.2 Enhance a mechanism for public participation

Planning in China has been traditionally conducted in a top-down, hierarchical manner. Although a lot of strict environmental legislation is being implemented in the past decades, the trend of environmental improvement was not as obvious as expected. This is also a consequence of generally “top-down” or “centralizing” approaches in resources management, and of lack of environmental awareness among general public. It is worth for government considering further measures to step up necessary programs for public involvement.

5.3 Capacity building

A successful ICM application for addressing the complex environmental and resource management issues in the China’s coastal areas is depending upon the competence of local managers and developers who has sufficient knowledge on the integrated management. The competence is vital for implementation of integrated management. The lack of capacity became a serious impediment to the successful implementation of ICM programmes in many parts of the world (Yu and Chua, 1998). In China, the intelligence related to coastal science and technology is mainly from research institutes, universities, and other academic agencies. These institutes mainly located in some large cities, therefore, insufficient intelligence at county level is a major challenge to implement ICM across the whole China. However, successful ICM projects, such as demonstrative project in Xiamen, can be used for ICM training.

5.4 Implementing integrated catchment/coastal zone management

Given the substantial impact of riverine contaminant fluxes from adjacent catchments on coastal water quality, and increasing conflicts among terrestrially based production sectors with freshwater users and with coastal users, and conflicts between upstream and downstream resource users, it is essential to consider coastal catchment and coastal zone as a whole continuum, and to take an integrated management approach to address those multi-faceted issues within a legislative framework, although, the two geographical areas usually lie within various jurisdictions.

An European research project (EUROCAT) funded by the European Commission has been launched in 2000, to promote adaptive management that focuses on coupling integrated river catchment management with integrated coastal zone management in the Elbe river catchment. It can be especially helpful as a means to tackle the complex dynamics and issues and also a good example for coastal areas in China.

4.0 Conclusions

The APN-supported 2-year project, *Climate Variability and Human Activities in Relation to Northeast Asian Land-Ocean Interactions and Their Implications for Coastal Management*, united more than 30 scientists from three countries – Russia, Korea and China. Our main objectives were to identify estuarine and coastal changes in terms of hydrology, hydrochemistry, geochemistry, geomorphology, ecosystem and material cycling patterns of the Northeastern Asia region, with special reference to the Amur, Tumen and Razdolnaya Rivers; to evaluate the sensitivity of regional changes in relation to anthropogenic processes and climate change; and to provide recommendations for management of sustainable coastal development of the region and to provide assistance to policy/decision makers.

The results obtained deal with climatic changes, riverine and coastal modifications, environmental changes in the coastal zone and state of bottom and plankton communities, as well as practical recommendations for coastal zone management. It was shown that surface air temperature anomalies in Okhotsk Sea area and SSTs in the subarctic North Pacific are very sensitive to the extratropic ENSO signal. Changes in the water regime of the Amur River in the last 100 years have led to the disturbance of the ecological equilibrium in the valley of the lower Amur. These changes are fairly dynamic and occur not only in the floodplain of the Amur River, but also in the neighboring flat and mountain territories and in the adjacent areas of the Okhotsk and Japan seas. At the same time, despite obvious and significant anthropogenic influence on metal concentration in solution and suspended solids of Razdolnaya River, self-cleaning ability of the river is sufficient and in the downstream concentration of the dissolved metals is reduced close to basic level. Concentration of metals in downstream of Tumen River does not show heavy anthropogenic press, but dissolved Cu, Zn and Cu in suspended matter are higher as compared to downstream of Razdolnaya River and unpolluted rivers of the southern Russian Far East. Within the catchment basin of the Changjiang River, the construction of more than 48000 dams within the river valley has led to sediment discharge reduction by 40% over the last 20 years. In contrast, the discharge of nutrients (N and P) of the river has been increasing, due to the extensive use of chemical fertilizers and the large output of industrial and domestic sewage. These changes modify the coastal and shelf oceanographic conditions. The enhancement of nitrogen input and the biological productivity give rise to red tides, with a possibility that in the future red tides will occur more frequently when the freshwater discharge and the suspended sediment concentration in the estuarine waters are reduced.

Based on the analysis of long-term data on the density of microalgae in the water, the level of the sediment contamination with oil hydrocarbons, heavy metals and organochlorine pesticides, and the state of benthic communities, no positive conclusion about improvement of the state of coastal ecosystems in Amursky Bay and estuarine zone of Razdolnaya River in 2000s as compared to 1980s and 1990s can be made. Decreasing trends have been revealed for concentrations of oil hydrocarbons and cadmium in the sediments, while concentrations of other metals and total DDTs remained rather high. The Razdolnaya River runoff has contributed to the enrichment of adjacent waters of the bay in organic matter and oil hydrocarbons but not technogenic heavy metals and DDT. Biodiversity of the species forming bottom communities of soft sediments has significantly decreased in 2001 compared to 1986–1989. Chronic pollution of the bay is the major cause of negative changes in the state of its biota. In the near-estuarine zone of Tumen River, negative effects of pollution are recorded at different trophic levels from primary producers to mammals and humans. In connection with pollution following phenomena are found to be the most dangerous to the marine biota:oxygen deficiency in the near-bottom water layer, as a result of dissolved oxygen consumption for the oxidation of organic compounds; disturbance of the nutrient balance due to the input of large amounts of organic and mineral nitrogen and phosphorus compounds into the coastal waters, i.e., eutrophication of the water; bioaccumulation of toxic substances by marine organisms. Hydrochemical, oceanological and ecological data from the mouth area of Amur River are still in processing.

Social-economic and environmental issues recently emerged in China's coastal zone were identified and examined. Comprehensive coastal management in China is a big challenge facing with great difficulties such as shortage of baseline information, deficiency in scientifically sound planning and zonation scheme, lack of coordination amongst resource users and governance, lack of public involvement, insufficient local intelligence, lack of monitoring and evaluation, and poor financial support. For Han River estuary in Korea, major recommendations were proposed as follows: development and implementation of basic estuary surveys and researches, development and implementation of estuary monitoring systems, and designations of the 'Estuary Ecosystem Conservation Area' and the 'Natural Reserved Area'; implementation of the 'Total Pollution Load Management System' in the estuary, conducting post-environmental impact assessment for the Singok Submerged Weir, and identification of exposure pathways of toxic chemicals; designation of the 'Natural Landscape Conservation Area' and development of the 'Natural Landscape Management Plan' for downstream of the Singok Submerged Weir; improvement of the fishery management system, estimation of quantitative fishery stocks, and life cycle study of estuarine commercial fishes. For the Russian coast, a system approach is necessary which includes developing and introducing the system of Integrate Coastal Area Management of the for the Russia's Far East. It includes a continuous process of decision- making directed to a harmonization of the social-economic development of the coastal regions in an effort of sustainability of their development.

Capacity building was part of our project through involvement of young scientists, sharing of knowledge and scientific information within Northeastern Asia region. Meetings held in frames of the project were successful in this respect, especially for training of young scientists and providing information and recommendations for national policy-makers and, more broadly, improving communications between scientists and society. The collaboration between Russian, Korean, and Chinese scientists was strengthened during the project activities and will be continued through personal contacts, participation in new projects and preparation of joint publications.

5.0 Future Directions

Future programmes for capacity-building and management strategies will be developed in the Russian Far East. A series of papers on the state of the environment in Amur River estuary is planned to be submitted to both international and national journals. Planned collective monograph under preliminary title *Global Change in Northeast Asia: Climate Variability, Land-Ocean Interactions, Coastal Zone Management* will be prepared in 2007, and a book (in two parts), *Ecological Studies and State of the Ecosystem of Amursky Bay and Razdolnaya River Mouth,* will be published by Russian team in the same year. A new project was developed, *Biodiversity of the coastal zones in the NW Pacific: status, regional threats, expected changes and conservation*, and submitted to APN for evaluation.

Appendix 1

PROGRAMME

Workshop on Climate Variability and Human Activities in Relation to Northeast Asian Land-ocean Interactions and Their Implications for Coastal Zone Management (4–9th December 2004, Nanjing, China)

VENUE AND SCHEDULE

3rd December: Arrival of the participants from Russia (accommodation at *New Era Hotel*, near the University).

4th December: Arrival of the participants from Korea and China (accommodation at *New Era Hotel*, near the University). Business meeting about the implementation of the APN Project 2004 NMY in the afternoon (14.00–17.00). Reception at *New Era Hotel* in the evening, starting from 18.30.

5th December: Scientific presentations the workshop at the Lecture Room, Science and Technology Building, the Gulou Campus of Nanjing University (for the list of presentations see below). The morning session (09.00–12.00) will be chaired by Shu Gao, and the afternoon session will be chaired by Konstantin A. Lutaenko.

6th December: Meeting to discuss the science plan and implementation strategy stryc-ture of the APN Project 2004-18-NMY "Climate variability and human activities in relation to Northeast Asian land-ocean interactions and their implications for coastal zone management", at the Meeting Room of the Monistry of Education Key Laboratorty, Nanjing University.

7th December: City tour (Changjiang River and the historical sites).

8th December: Excursion to the Apex areas of the Changjiang River delta – a one day trip to the city of Zhenjiang.

9th December: Participants departure.

LIST OF PRESENTATIONS ON 5TH DECEMBER

Morning Session:

09.00–09.05: Welcome speech, by Shu Gao

09.05–09.25: What is APN, by Yang Ying

09.25–09.45: Big problems of the big river (ecological state of the Tumen River), by V. L. Kasyanov and D. L. Pitruk

09.45–10.05: Good aquaculture practice for sustainable coastal management, by M. H. Wong

10.05–10.25: Nature management within the Russian Far East coastal zones, by A. N. Kachur and P. Ya. Baklanov

10.25–10.40: Coffee break

10.40–11.00: Study of the state of coastal ecosystems in Amursky Bay (Peter the Great Bay, Sea of Japan): comparative analysis of the data of 1980s, 1990s and 2000s, by M. A. Vaschenko and P. M. Zhadan

11.00–11.20: Changes in the growth rates and degree of shell bioerosion of the Yezo scallop inhabiting Razdolnaya River estuary for two decades, by A. V. Silina
11.20–11.40: Environment Management Strategy for Han River Estuary in Korea, by Chang-Hee Lee, Taeho Rho, Hyunjoo Moon, Sungwoo Jeon, Kyeongmi Heo and Seong Hwan Pae
11.40–12.00: Long-term changes in the hydrological regime of the Amur River, by A. N. Makhinov

12.00–14.00: Lunch

Afternoon Session:
14.00–14.20: Concentration of metals in the rivers of the south part of Primorski Krai, Russia, by V. M. Shulkin and N. N. Bogdanova
14.20–14.40: River delta growth in relation to sediment retention, by Shu Gao
14.40–15.00: Scales in the variability of the lithological and biogeochemical processes within the Razdolnaya River estuary, by O. V. Dudarev, A. I. Botsul, A. N. Charkin and L.V. Utkin
15.00–15.20: The impact of climate variability and human activities on flood and drought disaster in the Yangtze Valley, by Ruihong Yu, Youpeng Xu and Zongwei Ma
15.20–15.40: Seasonal and annual variability of the concentration and output of nutrients by the Razdolnaya River (Primorski Krai), by V. M. Shulkin and G. I. Semykina

15.40–16.00: Coffee break

16.00–16.20: Nutrients, primary production and carbonate system in Razdolnaya River estuary, by V. I. Zvalinsky and P. Ya. Tishchenko [to be presented by Dr. O. V. Dudarev]
16.20–16.40: Deposition modes and the possible dynamic mechanism during evolution of the Pearl River delta since 6000 BP, by C. Y. Wu, J. Ren, Y. Bao, Y. P. Lei and Z. G. He
16.40–17.00: Multiscale oscillation of Razdolnaya (Suyfun) and Amur Rivers discharge affected by climate variability in the northeast Asia, by V. I. Ponomarev and N. I. Rudykh
16.40–17.00: Rare earth elemental compositions of the Changjiang and Huanghe sediments and its applications for tracing the river origins and uplift history of the Tibetan Plateau, by Shouye Yang, Jingong Cai, Congxian Li and Daidu Fan
17.00–17.20: Change in Changjiang suspended load after completion of the Three–Gorges Dam and its impacts on the delta evolution, by Congxian Li, Shouye Yang, Daidu Fan and Juan Zhao
17.20–17.40: Physico-chemical modeling of behavior of trace elements in the mixing zone of Razdolnaya River and Amursky Bay, by L. M. Gramm-Osipov and A. V. Savchenko [to be presented by O. V. Dudarev]
17.40–18.00: The changes of sediment concentration and discharge in recent five years from the Pearl River to the Pearl River Delta, China, Qingshu Yang, Ping Xie

Appendix 2

List of the participants of the Workshop on Climate Variability and Human Activities in Relation to Northeast Asian Land-ocean Interactions and Their Implications for Coastal Zone Management (4–9th December 2004, Nanjing, China)

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Appendix 3

P R O G R A M M E

Training Course for Young Scientists in Global Change, Vladivostok, Institute of Marine Biology FEB RAS, October 24–28, 2005

Monday, 24 October 2005. Institute of Marine Biology		
9:00 10:00	Registration	Institute of Marine Biology, entrance hall
10:00 10:40	**Konstantin A. Lutaenko**, Institute of Marine Biology Far Eastern Branch of Russian Academy of Sciences Vladivostok, 690041 RUSSIA	What is global change?
10:40 11:20	**Linda Anne Stevenson**, Programme Manager for Scientific Affairs Asia-Pacific Network for Global Change Research JAPAN	Asia-Pacific Network for Global Change Research: Effectively Bridging Science and Policy.
11:20 11:40	Break. Coffee and Tea	
11:40 12:20	**Aleksei A. Korotky** Pacific Institute of Geography Far East Branch of Russian Academy of Sciences Vladivostok, 690041 RUSSIA	Comparative analysis of environmental changes of Tumen River and Razdolnaya River and character of their changes for the last 2000 years.
12:20 13:00	**Natalia I. Rudykh,** Pacific Oceanological Institute Far East Branch of Russian Academy of Sciences Vladivostok, 690041 RUSSIA	Climate variability in the northeast Asia.
13:00 14:00	Lunch. Dining room of Institute of Marine Biology	

14:00 14:40	**Anatoly A. Kachur** Pacific Oceanological Institute Far East Branch of Russian Academy of Sciences Vladivostok, 690041 RUSSIA	Complex management problems within the coastal zones of the Far-Eastern seas.
14:40 15:20	**Soh Kuh Kang** Principal Research Scientist Korea Ocean Research and Development Institute, Ansan City, Seoul 425600 KOREA	Sea Level Rise in the East/Japan Sea and Practical Aspects.
15:20 15:30	Break. Coffee and Tea	
15:30 16:10	Excursion to the Museum of Institute of Marine Biology	
Tuesday, 25 October 2005. Recreation department		
10:00	Departure of houseboat	
12:00	Arrival to the recreation department. Walking-tour	
13:00 14:00	Lunch	
14:40 15:20	**Marina A. Vaschenko** Senior Research Scientist Institute of Marine Biology Far East Branch of the Russian Academy of Sciences Vladivostok, 690041 RUSSIA	Ecological state of Amurskii Bay.
15:20 16:00	**Iraida G. Syasina** Senior Research Scientist Institute of Marine Biology Far East Branch of the Russian Academy of Sciences Vladivostok, 690041 RUSSIA	Biomarkers of marine environment contamination.
19:00 20:00	Dinner	

<table>
<tr><td>20:00
22:00</td><td colspan="2">Sauna</td></tr>
<tr><td>22:00
23:00</td><td colspan="2">Slide-show. Dance. Wine, soft drinks, light snack</td></tr>
<tr><td colspan="3">Wednesday, 26 October 2005. Recreation department</td></tr>
<tr><td>9:00
10:00</td><td colspan="2">Breakfast</td></tr>
<tr><td>10:00
10:40</td><td>Richard Cheung,
Associate Professor
Department of Biology and Chemistry, City University of Hong Kong, Hong Kong, P.R. CHINA</td><td>Long- term Changes in the Coastal Zone / Marine Environment of Hong Kong, CHINA.</td></tr>
<tr><td>10:40
11:20</td><td>Nadezhda K. Khristoforova
Head of the General Ecology Department, Far Eastern National University, Vladivostok, RUSSIA</td><td>Chemical and microbiological monitoring of marine environment.</td></tr>
<tr><td>13:00
14:00</td><td colspan="2">Lunch</td></tr>
<tr><td>15:30</td><td colspan="2">Return to Vladivostok</td></tr>
<tr><td colspan="3">Thursday, 27 October 2005. Svetlanskaya str.</td></tr>
<tr><td>10:00
17:00</td><td colspan="2">Workshop for policy-makers</td></tr>
<tr><td colspan="3">Friday, 28 October 2005. Institute of Marine Biology</td></tr>
<tr><td>10:00
17:00</td><td colspan="2">Reports of young scientists</td></tr>
<tr><td colspan="3">Saturday, 29 October 2005.</td></tr>
<tr><td colspan="3">Final Departures for Airport</td></tr>
</table>

Appendix 4

P R O G R A M M E

Workshop for Policy-Makers, Vladivostok, October 27, 2006

Venue – Conference Hall of the Presidium of the Far-Eastern Branch of RAS
Date of the meeting – October 27, 2005 (Thursday)
Time of the meeting – 10.00 a.m.

10.00 Opening of the Workshop. Speech of the Chairman of FEB RAS Academician V.I.Sergienko

10.10 Opening address of Adrianov A.V., Correspondent Member of RAS, Acting Director of the Institute of Marine Biology FEB RAS.

10.25 Lutaenko K.A., Secretary of the Russian National Committee on International Geosphere-Biosphere Program.
Asian Pacific Network (APN) and its activity

10.40 Mahinov A.N., Deputy Director of the Institute of Water and Ecological Problems FEB RAS (Khabarovsk), Doctor of Sciences
Ecological problems of the Amur River and ways of their solution

10.00 Vyshkvartsev D.I., Senior Research Officer of the Institute of Marine Biology FEB RAS, Cand. Biol.Sci.
Transboundary transport of pollution by the biggest rivers of Primorye

11.20 Vaschenko M.A., Cand. Bio. Sci, Head of the Laboratory of Cytophysiology of IMB FEB RAS
Ecological condition of the Amursky Bay

11.40 Pitruk D.L., Cand. Bio. Sci, Deputy Director of IMB FEB RAS
Ecological Condition of southwestern part of Peter the Great Bay

12.00 Coffee break

12.20 Khristoforova N.K., Doctor of Biology, Professor, Head of the Department of Ecology of AEMBBT FESU;
Buzoleva L.S., Doctor of Biology, Professor of FESU
Chemico-ecological and microbiological stat control of the Amursky Bay waters

12.40 Sokolovsky A.S., Cand. Biol. Sci., Senior Research Officer of the Laboratory of Ichthyology of IMB FEB RAS
Long-term changes in composition and structure of commercial ichthyofauna of Peter the Great Bay

13.00 Baklanov A.Y., Academician, Director of the Pacific Institute of Geography FEB RAS
Problems of rational nature management in the basin of the Tumen River

13.20 Kachur A.N., Cand. Sci., Deputy Director of the Pacific Institute of Geography
Problems of rational nature management in the basin of the Razdolnaya River

13.40 Kubay B.V., Director of Primorsky Administration of Hydrometeorology and Monitoring of the Environments;
Semykina G.I., Head of the Center of Monitoring of Primorsky Administration of Hydrometeorology and Monitoring of the Environments
State of monitoring system of Primorsky Administration of Hydrometeorology and Monitoring of the Environments

14.00 Richard Cheung, Associate Professor of Department of Biology and Chemistry, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, CHINA Member of Centre for Coastal Pollution and Conservation.
Coastal Management, Marine Pollution Control and many other problems in the Coastal Marine Environment of Hong Kong, CHINA

14.10 – 15.00 Lunch

15.00 Round Table Discussion

17.00 Fourchette

Appendix 5

List of the lecturers of the Training Course for Young Scientists in Global Change, Vladivostok, Institute of Marine Biology FEB RAS, October 24–28, 2005 and Workshop for Policy-Makers, Vladivostok, October 27, 2006

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Appendix 6

P R O G R A M M E

WORKSHOP *GLOBAL CHANGE IN NORTHEAST ASIA: CLIMATE VARIABILITY, LAND-OCEAN INTERACTIONS, COASTAL ZONE MANAGEMENT,* Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok, May 24–26, 2006

May 24 (Venue – Conference Hall of the IMB)

Morning Session

9.30 – 10.00 am

Konstantin A. Lutaenko (Institute of Marine Biology FEB RAS, Vladivostok, Russia)

APN Project 'Climate variability and human activities in relation to Northeast Asia land-ocean interactions and their implications for coastal zone management' in 2003–2006: an overview

10.00 – 10.30 am

Vladimir I. Ponomarev, N.I. Savelieva, E.V. Dmitrieva, N.I. Rudykh, P.V. Novorotskii, A.N. Makhinov and A.S. Salomatin (Pacific Oceanological Institute FEB RAS, Vladivostok and Institute of Water and Ecological Problems FEB RAS, Khabarovsk, Russia)

Multiscale climate variations in the atmosphere-land-sea ice-ocean system of the north-western Pacific

10.30 – 11.00 am

Shu Gao (Nanjing University, Nanjing, China)

Catchment - coast interaction of the Changjiang River system

11.00 – 11.20 am

Coffee break

11.20 – 11.50 am

A.V. Moshchenko, T.A. Belan, **Irina R. Levenets**, A.V. Skriptsova, M.B. Ivanova, A.P. Tsurpalo and L.S. Belogurova (Institute of Marine Biology FEB RAS, Vladivostok, Russia)

Benthic communities of the Razdolnaya (Suifun) River estuary

11.50 am – 12.20 pm

Valentina V. Kasyan, Valentina A. Kulikova and Victoria A. Omelyanenko (Institute of Marine Biology FEB RAS, Vladivostok, Russia)

Composition, peculiarities of distribution and interannual variability of zooplankton in the northern part of Amursky Bay, Sea of Japan

12.20 – 12.30 pm – Collective photo in front of the IMB

12.20 – 14.00 pm – Lunch

Afternoon Session

14.00 – 14.30 pm

Ming H. Wong (Hong Kong Baptist University, Hong Kong, China)

Environmental and health impacts of aquacultural activities around the Pearl River delta, south China

14.30 – 15.00 pm
Tatyana Yu. Orlova (Institute of Marine Biology FEB RAS, Vladivostok, Russia)
Harmful algal blooms on the Russian East coast
15.00 – 15.20 pm
Coffee break
15.20 – 15.50 pm
Mariya A. Zenina and E.I. Schornikov (Institute of Marine Biology FEB RAS, Vladivostok, Russia)
Ostracods of the northern part of Amursky Bay, Sea of Japan
15.50 – 16.20 pm
Concluding remarks and discussion

May 25 (Venue – Conference Hall of the IMB)

Morning Session

9.30 – 10.00 am
Anatoly N. Kachur (Pacific Institute of Geography FEB RAS, Vladivostok, Russia)
Complex management problems within the coastal zones of the Far-Eastern seas
10.00 – 10.30 am
Dmitry A. Nekrasov (Institute of Marine Biology FEB RAS, Vladivostok, Russia)
The influence of the Amur River on the coastal marine ecosystems of Japan and Okhotsk Seas
10.30 – 11.00 am
Marina S. Selina, I.V. Stonik, T.Yu. Orlova, T.Yu. Morozova and O.G. Shevchenko (Institute of Marine Biology FEB RAS, Vladivostok, Russia)
Phytoplankton of the Amur River estuary and adjacent areas
11.00 – 11.20 am
Coffee break
11.20 – 11.50 am
Larisa S. Shkoldina and A.G. Pogodin (Institute of Marine Biology FEB RAS, Vladivostok, Russia)
Zooplankton of Sakhalin Bay and Amur Estuary: influence of discharge of Amur River
11.50 am – 12.20 pm
Dmitry L. Pitruk and D.A. Nekrasov (Institute of Marine Biology FEB RAS, Vladivostok, Russia)
Comparative analysis of influence of Tumen, Razdolnaya and Amur Rivers on the coastal zone **12.20 – 14. 00 pm** – Lunch

Venue – Director's Office of the IMB

Afternoon Session

14.00 – 17.00 pm (with coffee break)
Business Meeting on the implementation of the APN project and discussion on the collective monograph
(invited persons)
17.20 pm – bus departs for Acfes-Seiyo Hotel
18.00 pm – Reception in Acfes-Seiyo Hotel (invited persons)

Appendix 7

List of the participants of the Workshop Global Change in Northeast Asia: Climate Variability, Land-Ocean Interactions, Coastal Zone Management, Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok, Russia, May 24–26, 2006

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Appendix 8

Abstracts and CVs of the lecturers for Training Course for Young Scientists in Global Change, Vladivostok, Institute of Marine Biology FEB RAS, October 24–28, 2005

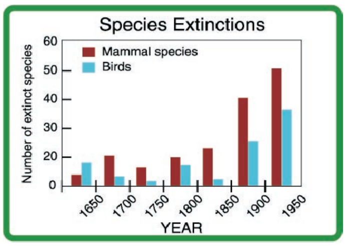
Dr. **Konstantin A. Lutaenko**, Ph.D. in Biology, Senior Research Scientist of the Institute of Marine Biology (IMB) FEB RAS, Laboratory of Benthos Ecology. President of the Russian Far East Malacological Society. Educational Background: Far East State Univ., Vladivostok, Russia, M.Sc., Hybrobiology, 1992; Ph.D., Paleoecology, Far East State Univ., 1999. Appointments: Junior Research Scientist, IMB, 1993–1994; Senior Museum Officer and Head of the Institute Museum, IMB, 1994–2001; Visiting Scientist, Korea Ocean Research and Development Institute, Ansan, Republic of Korea, November 1996–February 1997; Senior Research Scientist, IMB, 2001–present; Visiting Curator, Muséum National d'Histoire Naturelle, Paris, France (March–May 2004). Research Interests: Malacology, taxonomy, Quaternary paleontology and paleoclimatology, taphonomy of shelly faunas, biogeography, global change studies, zoology collections management. Teaching Activity: Lecturer, TMMP Training Course in *Molluscan Taxonomy*, Research Institute of Aquaculture No. 3, Nha Trang, Vietnam (1999); Lecturer, TMMP Training Course in *Molluscan Taxonomy*, Department of Fisheries, Sihanoukville, Cambodia (1999); Lecturer, TMMP Training Course in *Biodiversity of Marine Molluscs*, Research Institute of Aquaculture No. 3, Nha Trang, Vietnam (2001); Senior Lecturer, *Introduction to Paleoecology*, Department of Ecology, Far East State University, Vladivostok, Russia (1999–2001). Editorial Work and Membership: Editorial Board, *Bulletin of the Russian Far East Malacological Society* (1996–2003, Secretary; 2000–up to present – Editor); Editorial Board, *TEACOM Publications* (2001–2005); Editorial Board, *Bulletin of the Russian National Committee for the International Geoshpere-Biosphere Programme* (2003–up to present); Publications: Author and co-author of 72 papers (without abstracts).

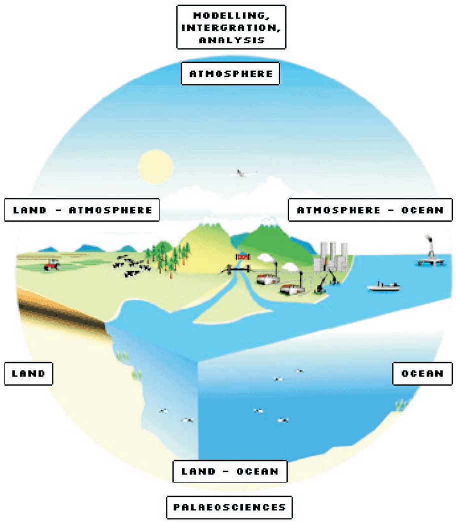
WHAT IS GLOBAL CHANGE?

Konstantin A. Lutaenko
A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, RUSSIA

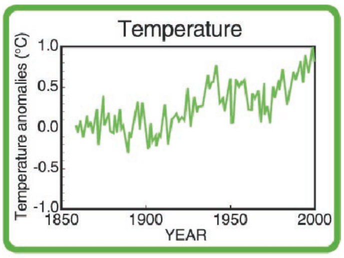
The Nature of Global Change

Humans have always interacted with the natural world around them. But over the last several centuries, the changes that have occurred in the human-nature relationship are complex and profound. To the best of our knowledge, they are unprecedented in the history of Earth. The expansion of mankind, both in numbers and per capita exploitation of Earth's resources, has been astounding. During the past three centuries human population increased tenfold to 6000 million. Concomitant with this population increase, the rate of consumption has risen even more sharply. Human activities are now so pervasive and profound in their consequences that they affect the Earth System at a global scale in complex, interactive and apparently accelerating ways. Humans now have the capacity to alter the Earth System in ways that threaten the very processes and components, both biotic and abiotic, upon which humans and our societies depend. Acquiring the scientific understanding to answer these questions is well beyond the scope of individual countries and regions. It is also well beyond individual disciplines, and beyond the traditional divide between the natural and the social sciences.





Gaining the knowledge base needed to underpin the transition to global sustainability demands an unprecedented international and interdisciplinary scientific research effort.**The International Geosphere-Biosphere Programme (IGBP)** was established by the International Council for Science (ICSU) in 1986 to help meet this challenge.



IGBP's integrating activities add value by:

- Developing common international frameworks for collaborative research based on agreed agendas.
- Forming research networks to tackled focused scientific questions.
- Promoting standardised methodologies.
- Guiding and facilitating construction of global databases.
- Undertaking model intercomparisons and comparisons with data.
- Facilitating efficient patterns of resource allocation.
- Undertaking analysis, synthesis and integration activities on broad Earth System themes.

What is IHDP?

Global Environmental Change (GEC) is the set of biophysical transformations of land, oceans and atmosphere, driven both by human activities and natural processes. These transformations take place on local, regional and global levels, and affect the quality of human life and sustainable development on a worldwide scale. Therefore, research on the **Human Dimensions of Global Environmental Change** puts people into the center of the analysis. It also takes into account that global environmental change is driven by and takes influence on processes of socio-economic, political and cultural globalization.

Why DIVERSITAS?

The goal of DIVERSITAS is to provide accurate scientific information and predictive models of the status of biodiversity, to find ways to support a more sustainable use of the Earth's biotic resources, and to build a world-wide capacity for biodiversity science.

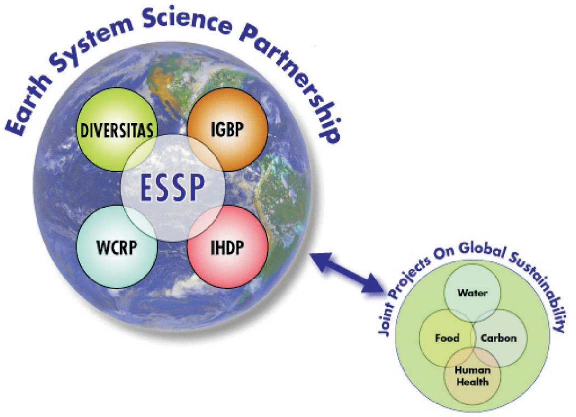
What is WCRP?

The World Climate Research Programme (WCRP) was established in 1980, under the joint sponsorship of International Council for Science (ICSU) and the World Meteorological Organization (WMO), and has also been sponsored by the Intergovernmental Oceanographic Commission (IOC) of UNESCO since 1993. The **objectives** of the programme are to develop the fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicted and the extent of human influence on climate. WCRP activities address forcefully outstanding issues of scientific uncertainty in the Earth's climate system including:

- *transport and storage of heat by the ocean,*
- *the global energy and hydrological cycle,*
- *the formation of clouds and their effects on radiative transfer,*
- *the role of the cryosphere in climate.*

Why ESSP?

Global change is not restricted to climate change and greenhouse gas emissions, nor can it be understood in terms of a simple cause-effect paradigm. Recent studies of the Earth's land surface, oceans, coasts and atmosphere, of the biological diversity, the water cycle and biogeochemical cycles make it clear that human activity is generating change that extends well beyond natural variability and at rates that continue to accelerate. Earth System dynamics are characterized by critical thresholds and abrupt changes. Global change research over the last decade shows that the Earth System is currently operating well outside the normal state exhibited over the past 500,000 years.



The presentation also deals with START and PAGES activities, and regional projects on global changes in the Russian Far East, including SPN and START-supported meetings and projects.

Dr. **Linda Anne Stevenson**, a native of Scotland, graduated from Glasgow University in 1990 with an Honours Degree in Pure Chemistry; Jordanhill College of Strathclyde University in 1991, with a Postgraduate Certificates in Education; and in 1997 graduated from Strathclyde University, Department of Pure and Applied Chemistry, with a PhD. Her thesis entitled "Membranes from Novel Polymer-Polymer Complexes" was based on synthesizing hollow-fibre membranes with superior separation properties from novel polymer complex systems. She also holds a PGCE in Secondary Education. Dr. Stevenson moved to Japan in 1996 and worked as Quality Assurance Inspector for major Clients such as British Nuclear Fuels, Mitsubishi Heavy Industries, Sumitomo Corporation, BP, Shell, etc., and from 1999 as a Technical and Scientific Writer at Kobe University and National Panasonic. Dr. Stevenson joined the APN Secretariat in January 2002 as Programme Manager for Scientific Affairs. Dr. Stevenson manages all of the APN's scientific activities including the Annual Regional Call for Proposals (ARCP) in global and climate change research; and the WSSD Type II initiative for Scientific Capacity Building for Sustainable Development, otherwise known as the CAPaBLE Programme. Part-time lecturing at a Japanese University on "Global Environmental Systems," further allows Dr. Stevenson to pursue her other interests, particularly eLearning as a tool for scientific capacity building and education in the areas of climate and energy effects (through anthropogenic forcing) at local, national, regional levels and global levels. For more information check APN's website **www.apn-gcr.org** or e-mail Dr. Stevenson at **lstevenson@apn-gcr.org**.

LECTURE: **EFFECTIVELY BRIDGING SCIENCE AND POLICY**

Linda Anne Stevenson
Asia-Pacific Network for Global Change Research (APN), Kobe, JAPAN

APN and its Second Strategic Phase

The mission of the Asia-Pacific Network for Global Change Research (APN) is to enable investigation of change in the Earth's life support systems as it occurs in the Asia-Pacific region to:

1. Identify, explain and predict changes in the context of both natural and anthropogenic forcing,

2. Assess potential regional and global vulnerability of natural and human systems, and

3. Contribute, from the science perspective, to the development of policy options for appropriate responses to global change that will also contribute to sustainable development.

APN's Definition of Global Change

"The APN defines "global change research" as "research regarding global change (the set of natural and human-induced changes in the Earth's physical and biological systems that, when aggregated, are significant at a global scale) and its implications for sustainable development in the Asia-Pacific region."

APN's Core strategies

The core strategies of the APN are to:

1. Encourage and promote research that has the potential, in addition to improving

understanding of global change and its implications in the region, to contribute to the establishment of a sound scientific basis for policy-making with regard to issues for which global change is an important factor.

2. Identify, in consultation with policy-makers and practitioners, the present and future needs for such research.

APN's Vision

Changes in the Earth system are clearly impacting the societies and economies of the countries within the Asia-Pacific region. These countries support more than half of the world's population. Recent research and supporting observations have provided new insights into some of these changes and their impacts, but have at the same time opened a number of new and challenging scientific issues.

The APN seeks to identify such emerging issues and to promote and encourage regional cooperative research to address these. In doing so, the APN assures that the results of this research contributes to the development of a sound scientific basis for policy- and decision-making related to issues for which global change is an important factor.

The APN strives to enable the developing countries of the region to participate increasingly in, and to benefit fully from, cooperative research in the region. Finally, recognising the interactive role of regional processes in the overall Earth system, the APN also seeks to link the research it sponsors with research conducted in other regions and under the aegis of global-scale programmes.

APN Science Agenda

The Asia-Pacific Network for Global Change Research (APN) enables activities that generate and transfer knowledge on the physical and human dimensions of change in the Earth system with a focus on:

1. **Climate,**
2. **Ecosystems, biodiversity, and land use,**
3. **Changes in the atmospheric, terrestrial and marine domains, and**
4. **Use of resources (food/water/energy/materials) and pathways for sustainable development.**

The APN serves scientific and decision-making communities and other users in the Asia-Pacific region. The APN will invest in identification of existing methods and the development of new methodologies and tools to improve the effectiveness of transfers of the necessary scientific knowledge to the decision-makers in Asia-Pacific communities.

Global Change and Climate Change

(1) The planet has a delicate climate system where its energy balance is essential for survival;

(2) Climate change covers two areas: natural climate change (variability) and anthropogenic (human-induced) climate change;

(3) Natural climate change can be as frequent as season to season or as infrequent over thousands of years glacial/interglacial as noted from Vostok Ice Core Research; but anthropogenic climate change has caused temperatures to rise dramatically since the start of the industrial revolution (mid-1900s);

(4) While there remain uncertainties about "anthropogenic" effects of climate change, essentially something is wrong: this can be viewed simply by reinforcing climate change

impacts such as “global warming,” “water and food security” “sea-level rise,” “extreme weather events such as

- Heat waves causing 15,000 deaths in France in 2004
- 10 typhoons in Japan in 2004
- Major hurricanes in the US in 2005
- Snow storms in Vladivostok, Russia in mid-October, 2005
- Forest fires, floods, heat waves, etc.
- Underlying vulnerabilities, particularly in the largely underdeveloped regions of the world (Asia) that house more than 60% of the world’s population

(5) Contributing Factors to Global Change:

- Greenhouse Gas concentrations (GHGs), CO_2, CH_4, SO_4^{2-}, N_2O – essentially released at a time where the impacts were not altogether apparent
- Global Warming and Increasing Intensity of Extreme Weather Events
- Urbanisation
- Deforestation
- Unsustainable Development
- Pollution
- Unsustainable use of resources (energy/food/water/materials)

(6) The importance of development: but GREEN economic growth and sustainable development;

(7) Effective Global Policy Responses to Global Environment and Climate Change:

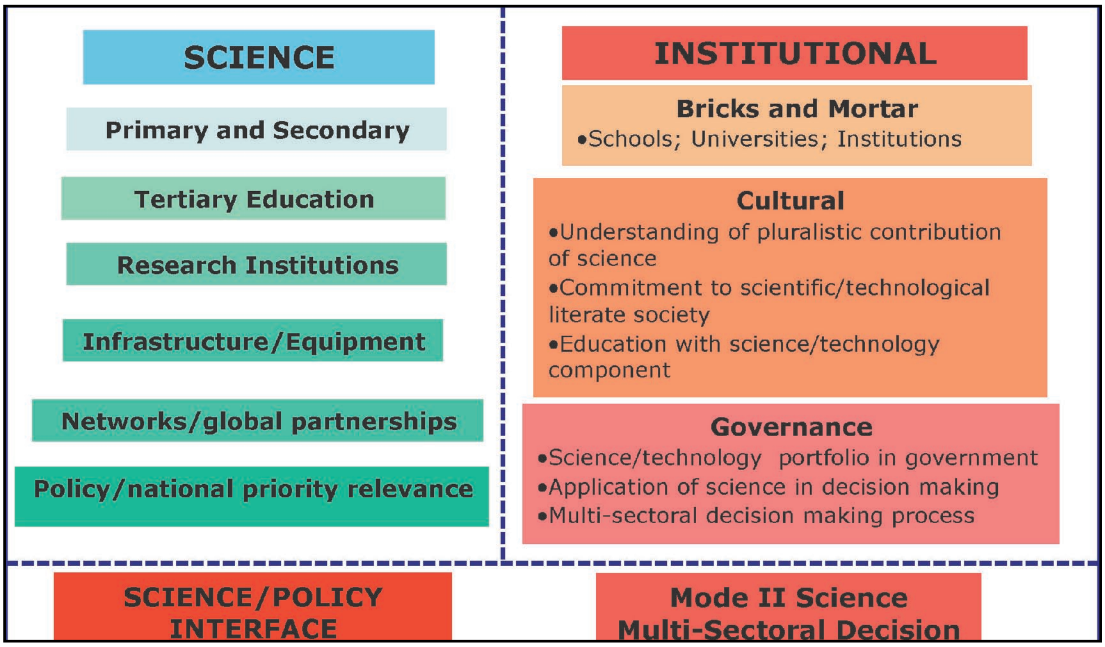
- Inter-governmental Panel for Climate Change (IPCC)
- Millennium Ecosystem Assessment (MEA)
- United Nations Framework Convention on Climate Change (UNFCCC)
- World Summit for Sustainable Development (WSSD)

(8) Effective Global Change and Climate Change Mechanisms:

- Adaptation and Mitigation Strategies
- Research, Syntheses and Assessments
- Scientific Capacity Building
- Education at all levels, Awareness Raising, Dissemination
- Sustainable development
- Increased dialogue between natural/social scientists and policy- and decision-makers.

Effectively Bridging Policy and Science

- More should be done to interface science and policy; this is different for each country and a complicated process
- Need to seek a method of converting knowledge-based interactions in terms of policy relevancy
- The IPCC has been a huge experiment in global coupling of science and policy. In many ways it has been very successful
- To convince policy-makers of the usefulness of APN (and other global change bodies) in the “GC” and “policy” communities is to make a significant difference to the IPCC through APN activities
- Activities can contribute to UNFCCC and IPCC in a different way, through GHG inventories, etc.
- Policy-makers and financial authorities are impatient; we need tangible outputs that appeal to the financial authorities



• Policy-science interfacing and improvement of decision-making: Should we invite a research proposal in terms of how sustainable development legislation gets into major projects? This is an idea that has been placed on the table of many a meeting

• Governments in developed countries are putting environmental legislation on their agenda but there are still no real linkages

• Awareness raising activities are/can be effective mechanisms

• Some ways for APN Science-Policy interface development would be to disseminate its activities at specific fora such as

  • the Pacific Islands Forum,
  • ECO ASIA,
  • the Asia-Pacific Seminar on Climate Change,
  • COP/MOP, IPCC, UNFCCC, etc.

• Although relevant to an extent, is this the best way to create the policy-science interface? This is a very complicated process that needs a great deal of consideration

• APN effectively brings its network policy and science people by holding joint SPG/IGM sessions annually (since 1994)

• Bring together a group of scientists and policy-makers that could discuss how best to interface.

  • Develop activities based on the outcome which might include:
  • Fora for APN dissemination
  • Involvement of APN national Focal Points
  • Mode II Science (knowledge generation)
  • Civil society (perhaps difficult due to too many differences at each country-level)

• Questions to consider:

  • How should we define capacity building for APN?
  • How can we ensure that scientific results receive full credence in the policy process?

Prof. **Richard Cheung** got his BSc in Biology and Biochemistry and MPhil in Environmental Biology from the Chinese University of Hong Kong. He got a Commonwealth Scholarship for his PhD in Pollution and Environmental Control from the University of Manchester, England. He also got a Certificate in Environmental Studies from the Manchester Polytechnic, England. After finishing his PhD, he worked as a Research Scientist in the Environmental Impact Group of the Water Research Centre, England. Then he returned to Hong Kong and worked as a Lecturer in the Department of Biology of the Hong Kong Baptist College and an Environmental Protection Officer (Water Science) in the Water Policy Group of the Environmental Protection Department of the Hong Kong Government. He is a Chartered Biologist, Chartered Water and Environmental Manager, Fellow Member of Hong Kong Institution of Environmental Impact Assessment, Member of Hong Kong Society of Quality Management, Member of Hong Kong Marine Biological Association. He sits in Appeal Boards Established Under Water Pollution Control Ordinance and Waste Disposal Ordinance, Laws of Hong Kong and Environmental and Conservation Fund Research Projects Vetting Subcommittee Established Under the Environment and Conservation Ordinance, Laws of Hong Kong. He is now an Associate Professor at the Department of Biology and Chemistry and a Member of the Centre for Coastal Pollution and Conservation, City University of Hong Kong.

LECTURES

Richard Cheung
Department of Biology and Chemistry, City University of Hong Kong,
Hong Kong, CHINA

LECTURE 1: **ENVIRONMENTAL MONITORING OF MARINE WATER QUALITY IN MARINE PARKS, MARINE RESERVES AND OTHER MARINE ECOLOGICAL SIGNIFICANT AREAS IN HONG KONG**

Since the designation of marine parks and marine reserve in 1996, water quality monitoring has been carried out by the Country and Marine Parks Authority of HKSAR Government. To further excel the management, visitor services and environmental monitoring in marine parks and marine reserve and to provide pre-designation monitoring of the potential marine parks at Soko Islands and Southwest Lantau, Agriculture, Fisheries and Conservation Department, HKSAR Government appointed City University of Hong Kong to undertake water quality monitoring of marine parks, marine reserves and other marine ecological significant areas in Hong Kong during the fiscal year of 2003/04. Such areas include Tung Ping Chau Marine Park, Hoi Ha Wan Marine Park, Yan Chau Tong Marine Park, Sha Chau and Lung Kwu Chau Marine Park, Cape D'Aguilar Marine Reserve, Soko Islands and Southwest Lantau Island. In-situ water quality monitoring of physico-chemical parameters was conducted by AFCD. Water samples at two depths were collected by CityU. Biochemical oxygen demand, suspended solids, ammonical nitrogen, unionised ammonia, nitrite nitrogen, nitrate nitrogen, total inorganic nitrogen, total nitrogen, orthophosphate phosphorus, total phosphorus, chlorophyll a, *E. coli* and faecal coliforms were determined in the samples collected. Data collected by CityU during the fiscal year of 2003/04 will be presented.

LECTURE 2: **BACTERIOLOGICAL CONDITION OF HONG KONG COASTAL WATER: A CASE STUDY ON ITS SUITABILITY FOR USE IN AQUARIA HOLDING SEAFOOD**

Using contaminated seawater in holding seafood is prohibited. As natural seawater is free of charge and easy to collect, seafood stall owners may collect natural seawater from coastal area to hold seafood, no matter it is contaminated or not. In this project, *Escherichia coli*, *E.coli*, in seawater collected from 5 selected sites (Aberdeen, Lei Yue Mun, North Point, Sai Kung and Sai Wan) were monitored in both summer and winter months. Only two samples collected in winter month from Lei Yue Mun and Sai Kung met the bacteriological standard. In order to find out the suitability of contaminated seawater for use in aquaria holding seafood in bacteriological aspect, fecal contaminated seawater was used in holding orange-spotted grouper, Epinephelus coioides, under different conditions. The effects of different filtration materials, including sand, coral bit and activated carbon, temperature (18°C, 25°C, 30°C), UV-light disinfection and fishes densities (8 fishes/50 L, 32 fishes/50 L) on *E.coli* density in contaminated seawater were tested. The results showed that there was no significance difference among different filtration materials in *E.coli* reduction. Based on the water temperature, the highest efficiency in *E.coli* reduction (91.1%) was found in keeping the water temperature around 18°C. 99% *E.coli* removal was recorded when water is circulating with UV-light for 60 min and 30 min with different circulation rate to achieve 20 min/cycle and 5 min/cycle respectively. If fish density increase, *E. coli* concentration of holding water would also increase. Apart from orange-spotted grouper, mussels, Perna viridis, were hold in fecal contaminated seawater. As mussels are filter feeders, bacteria in seawater would be filtered and accumulated in their bodies. The ability of accumulating *E. coli* by mussels was also investigated in this study. The results showed that mussels holding in water with different level of contamination (9.667 and 64.333 CFU of *E. coli*/100 ml) for 24 hr would accumulate 19.500 CFU of *E. coli* /100 g in their bodies. It must be treated or completely cooked before consumption. In conclusion, seawater in coastal area is highly contaminated. Continuous recirculation of water with UV-light for disinfection is necessary to meet the bacteriological standard of holding water. When holding mussels in contaminated seawater, *E. coli* would accumulate in their body in a short period of time.

LECTURE 3: **BODY BURDEN OF ENVIRONMENTAL CONTAMINANTS IN OYSTERS AND MUSSELS COLLECTED FROM THE PEARL RIVER DELTA (GANGDONG PROVINCE, CHINA)**

Pearl River is the largest river system in southern China. Sediments deposited at the mouth of this river created a composite delta. Economic development in Pearl River Delta (major cities: Guangzhou, Foshan, Shenzhen, Hong Kong and Macao) was substantial during the last few decades. It creates tremendous environmental pressure to the coastal waters of PRD. Coastal waters of Guangdong Province receive significant quantities of industrial effluents, domestic sewage and agricultural runoffs. Oysters and mussels are well established for their ability to bio-accumulate environmental contaminants from their living environment. They have been used as bio-monitors in various parts of the world for many years. Environmental contaminants accumulated in oysters and mussels collected from environmental monitoring locations represented integrated records of bio-available contaminants in the living environment of the collected oysters and mussels over their growing period. In year 2003, oyster and mussel samples were collected from 31 monitoring locations along the coast line of Jiangmenshi, Zhuhaishi, Macau SAR, Guangzhoushi, Dongguanshi, Hong Kong SAR and Shenzhenshi of Gangdong Province. Samples collected were analysed for heavy metals, petroleum hydrocarbons, organo-chlorine pesticides, polycyclic aromatic hydrocarbons and polychlorinated biphenyls. Results of this survey will be compared with previous similar studies and presented.

LECTURE 4: **DEVELOPMET OF A SEDIMENT ASSESSMENT PROTOCAL USING AN AMPHIPOD IN HONG KONG**

An investigation was conducted to study the feasibility of using Melita koreana Stephenson, an indigenous marine benthic amphipod species in Hong Kong, as a test species for the assessment of sediment toxicity in Hong Kong. The survivorship of the test organisms after a 10-day exposure period was used as the test endpoint. The test species was exposed to various physical and chemical parameters of seawater and marine sediments to determine its application limits and sensitivity. Results showed that the test species had over 90% survivals in seawater of salinity 25–35 ppt, 10–25^{o}C and 4.0–7.5 mg/L dissolved oxygen. It also had over 90% survival in sediments with ammonia up to 32 mg/L, 10–70% sand and 0.1–3.6% organic matter. This study indicated that the test species could survive in a broad range of physico-chemical parameters. The test organisms were then subjected to sediments spiked with various representative contaminants including silver, polycyclic aromatic hydrocarbons (PAHs) and acid volatile sulphides (AVS). The median lethal concentrations (LC_{50} values) found were 10.2 mg/kg for silver, 1247 µg/kg for low molecular weight PAHs, 2998 µg/kg for high molecular weight PAHs and 7.1 µmole/g for AVS. The responses of the test species to representative sediments of different levels of contamination collected from Hong Kong coastal waters were also investigated. The amphipod survivals in the control and reference sediment were over the 90% acceptable limit. The amphipod survivals in Category L and Category M sediments were high (over 90% survivals), whilst those in the Category H sediments were relatively low (47–80% survivals). Results of this study suggested that Melita koreana had potential to be adopted as a test species for sediment toxicity assessment for Hong Kong.

LECTURE 5: **BIO-REMEDIATION OF CONTAMINATED SEDIMENTSIN SHING MUN RIVER,HONG KONG SPECIAL ADMINISTRATIVE REGION, CHINA**

Hong Kong SAR Government is currently conducting bioremediation work in Shing Mun River a major watercourse in the New Territories of Hong Kong. In 2003, a sediment quality monitoring study was conducted independently to evaluate the effectiveness of this particular project. This study was divided into two parts. In the first part of this study, monitoring locations were visited in the study area and surface sediments were sampled. This part focused on the effectiveness of the bioremediation work on various sediment parameters (such as acid volatile sulphide, redox potential, nitrate, sulphate and organic matter content) in the project area. Result of this study showed that insufficient injection of nitrate and high metal toxicity of the contaminated sediment could lead to the re-occurrence of sulphide under optimal pH conditions. In the second part of this study, sediment samples were collected selectively at difference depths (0–15 cm, 15–30, 30–45 and 45–60 cm). This part focused on the effectiveness of the bioremediation works at difference sediment depths. Results of this study showed that the bioremediation works can alter sulphide level and Redox potential of the sediment from surface down to 60 cm deep. Detailed results of this 5 month study will be presented.

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MONITORING OF HARMFUL ALGAE IN THE AREA OF MOLLUSK FARMS IN THE PETER THE GREAT BAY, SEA OF JAPAN

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1. Introduction

Russia is facing a significant increase in aquacultute in the next few years. In its biogeographical features, the Peter the Great Bay is thought to be one of the most favorable areas for commercial cultivation of aquatic organisms in the Russian Far East. The planktonic microalgae are critical food for filter-feeding bivalve shellfish, such as scallops and mussels. Usually, the proliferation of planktonic algae is beneficial for aquaculture. However, in some cases, algal blooms caused by harmful or toxic species may have a negative effect causing losses to aquaculture. Every year, the number of species known to be toxic increases in Far-Eastern Russian waters.

2. Locations

The monitoring of harmful algae has been carried out in three mariculture regions in the Peter the Great Bay: station 1 – Minonosok Bay, the area of the oldest scallop farm in Russia, the monitoring has been carried out since 1997; stations 2, 3 – Kitovii Bay, the area of a new, yet the largest scallop farm in Russia, the monitoring has been carried out since 2000; station 4 – Vostok Bay, the area of an experimental mussel farm, the monitoring has been carried out since 1985, in this study data of 2001–2004 was used.

3. Methodology

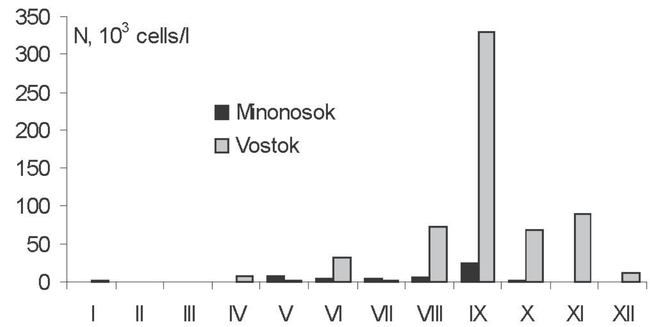
The samples were collected once to three times a month (weekly in summer). One-liter bathometric samples were collected at different depths with sampling intervals of 2–5 m. Plankton net with the mesh size of 20 mkm was used only for qualitative analysis. Samples were fixed immediately after the collection with Utermöhl's solution. The numbers of nanoplankton (2.0–20 mkm) were counted using Nojotta type Cell (0.05 mL) at total magnification of 300–400, and those of microplankton (> 20.0 mkm), using Sedgewick Rafter Cell (1 mL) at 100 X under a light microscope. The cell biovolume was calculated based on cell linear dimensions using appropriate geometric formulae. HABs monitoring data were stored using standard forms including the following fields: sampling site, sampling depth, data, volume of sample, counting cell type, ID of the responsible person.

4. Results

No potentially toxic species were found in Kitovii Bay. The study of phytoplankton samples in Minonosok and Vostok bays revealed 4 species, which caused water blooms in the surveyed areas: the diatoms *Skeletonema costatum* and *Thalassionema nitzschioides*, cryptophyta *Plagioselmis punctata*, and the cyanophyta *Synechocystis* sp. The most significant bloom (19.2 million cells/l) was caused by *Synechocystis* sp. in June 1997 in Minonosok Bay. The numbers of three other species didn't exceed 6.5 million cells/l. In addition, 15 species known to be toxic were found: the diatoms *Pseudo-nitzschia multiseries, P. pungens, P.* cf. *pseudodelicatissima;* dinoflagellates *Alexandrium acatenella, A. tamarense, A. pseudogonuaulax, Dinophysis acuminate, D. fortii, D. norvegica, D. rotundata, Karenia brevis, Prorocentrum minimum, Protoperidinium crassipes;* raphidophytes *Chattonella marina, Heterosigma akashiwo.* The species of the genera *Pseudo-nitzschia, Alexandrium,* and *Dinophysis* were relatively abundant, with their numbers exceeding the harmful concentration in summer.

4.1. Causative organisms of domoic acid poisoning (DAP)

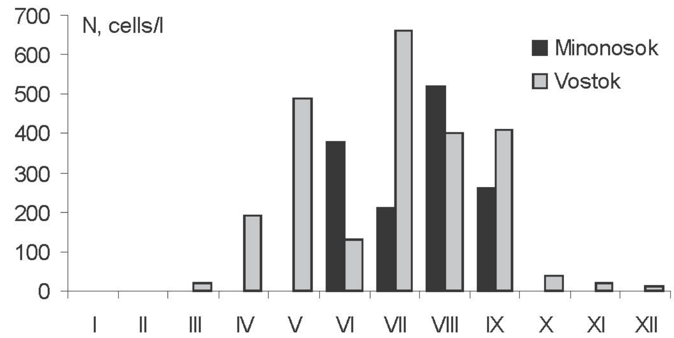
Diatoms of the genus *Pseudo-nitzschia* are known as domoic acid producing species. *Pseudo-nitzschia* species are common in the Peter of Great Bay. Potentially toxic species of the genus *Pseudo-nitzschia* were most abundant in Vostok Bay. In this bay, the total number of *Pseudo-nitzschia multiseries, P. pungens,* and *P. pseudodelicatissima* reached 330000 cells/l.



Changes in the numbers of *Pseudo-nitzschia* species (N) in Minonosok and Vostok bays (interannual maxima).

4.2. Causative organisms of diarrhetic shellfish poisoning (DSP)

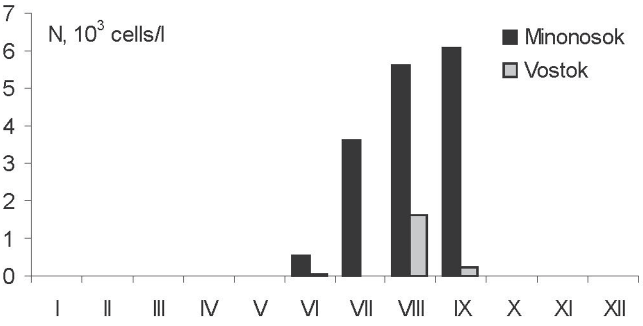
Dinoflagellates of the genus *Dinophysis* are known as species producing ocadaic acid and other DSP-toxins. Out of four species observed in the Peter the Great Bay (*D. acuminata, D. acuta, D. fortii,* and *D. rotundata*), *D. acuminata* was the most common toxic species in the Sea of Japan. The total numbers of *Dinophysis* spp. reached 520 cells/l in Minonosok Bay and 660 cells/l in Vostok Bay.



Changes in the numbers of *Dinophysis* species (N) in Minonosok and Vostok bays (interannual maxima).

4.3. Causative organisms of paralytic shellfish poisoning (PSP)

Dinoflagellates of the genus *Alexandrium* may produce PSP-toxins. In the Peter the Great Bay, three potentially toxic species of the genus *Alexandrium* (*A. tamarense, A. acatenella,* and *A. pseudogonyaulax*) were found. *A. tamarense* was most widespread. The total number of *Alexandrium* spp. reached 6000 cells/l in Minonosok Bay and 1600 cells/l in Vostok Bay.



Changes in the numbers of *Alexandrium* species (N) in Minonosok and Vostok bays (interannual maxima).

Cases of human poisoning or any damage were not recorded. There are no data on mitigation activity and its effectiveness in Peter the Great Bay. But due to the presence of potentially toxic microalgae, regular monitoring of phytoplankton in the Sea of Japan is a necessity.

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PHYTOPLANKTON PRACTICAL TRAINING. IDENTIFICATION OF HARMFUL AND BLOOM FORMING PHYTOPLANKTON SPECIES

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The Phytoplankton practical training "Identification of Harmful and Bloom Forming Phytoplankton Species" was held at Portovik recreation department (Vladivostok, Russia) 26 October, 2005. The main goal of these course was to train and upgrade the qualified young scientists to identify the phytoplankton species under the light microscope (LM).

The Course included the studies of the general morphology and taxonomy of the marine phytoplankton harmful and bloom forming species; the practical training including the examination of fixed and live specimens. Samples were shown by light microscope for each young scientist. Relevant techniques were presented aimed at collecting phytoplankton specimens and displaying taxonomic characters essential for identification. Training included a field trip to collect samples from the coastal waters of Amursky Bay.

Marine phytoplankton include about 300 can at times occur in such high numbers that they obviously discolour the surface of the sea (so-called "red tides"), while only 40 species have the capacity to produce potent toxins that can find their way through fish and shellfish to humans. Species of *Alexandrium* and *Pseudo-nitzschia* can produce neurotoxins dangerous for marine vertebrates and human health. Their classification and correct identification are the aim of an open and actively developing field of research.

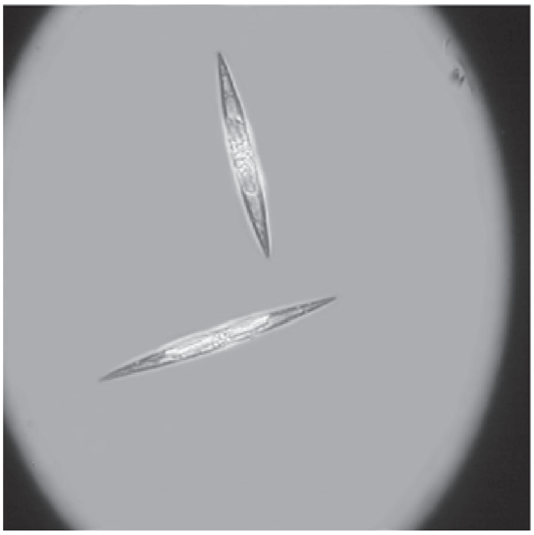
The knowledge of phytoplankton species from the taxonomic point of view is a tool that cannot be renounced for any ecological or ecophysiological work on marine phytoplankton. Due to its small scale response to environmental changes, phytoplankton community composition and its shifts represent an excellent tool to interpret the dynamics of the pelagic ecosystem and detect variations induced by river discharges, eutrophication and unusual climatic phenomena.

The practical training included the following activities:

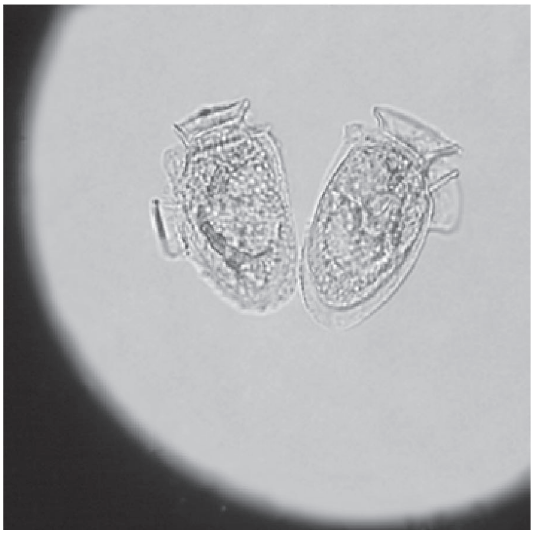
– Practical classrooms on the identification of selected HAB species under the light microscope.

A wide selection of fixed or living samples were available to each participant to be observed and identified under the light microscope. Bloom species and harmful species belonging to the different groups were given special attention and shown in comparison to

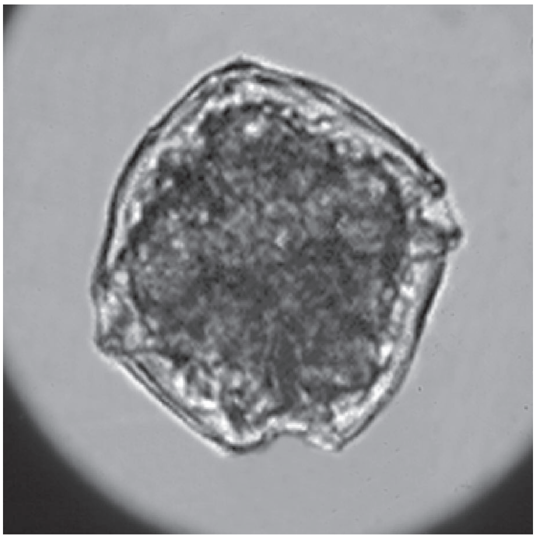
Species identifying during practical training



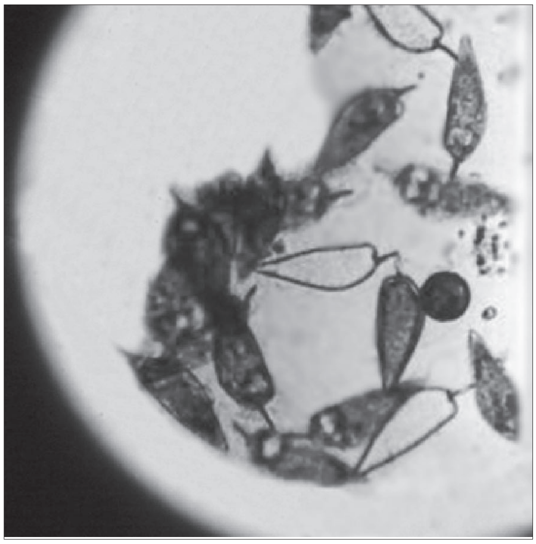
***Pseudo-nitzschia pungens*, LM**



***Dinophysis acuminata*, LM**



***Alexandrium tamarense*, LM**



***Prorocentrum triestinum*, LM**

related non-harmful species. Ultrastructural features of cells not visible under the light microscopy were illustrated by electronmicroscopical pictures.

– Field trips with demonstration of sampling techniques. Collection of phytoplankton samples was conducted with plankton nets.

Dr. **Iraida Syasina** is a senior researcher at the Laboratory of Cytophysiology, Institute of Marine Biology, Russian Academy of Sciences, Vladivostok, Russia. She has worked at this institute for more than 20 years. She earned an MS in Biology/Education from the Far Eastern State University and a PhD in Histology, Cytology and Embryology from the Institute of Marine Biology (Vladivostok). Her fields of study include biomonitoring in the marine environment, pathology of fishes and mollusks inhabiting polluted areas, histopathological biomarkers of contaminant exposure and effects in fishes and mollusks, as well as surveys for tumors in wild fish populations/experimental fish. She has more than 50 publications in Russian and international journals. She has been a visiting professor (October 2002–September 2004) at the Korea Maritime University (Pusan, Korea) and a lecturer (2005) at the Far Eastern State University. She is a member of the Russian Hydrobiological Society and the European Association of Fish Pathologists.

BIOMARKERS OF MARINE ENVIRONMENT CONTAMINATION

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Most independent states have regional and national monitoring programmes. International monitoring programmes such as the OSPAR Joint Assessment and Monitoring Programme (JAMP) and Biological Effects Monitoring Programmes have been undertaken by a number of ICES Member Countries for many years. Several biomarkers are currently used to determine chronic exposure of marine organisms to environmental contaminants. Implementation of new biomarkers is a very important problem for improving and upgrading of contaminant biomonitoring programmes.

Biological Markers (biomarkers) are measurements at the molecular, biochemical, or cellular level in either wild populations from contaminated habitats or in organisms experimentally exposed to pollutants that indicate that the organism has been exposed to toxic chemicals, and the magnitude of the organism's response to the contaminant. **Histopathological biomarkers** are cellular, tissue and organ lesions caused by the toxic effects of chemical compounds (Hinton et al., 1992).

Liver of fish is the primary organ for biotransformation of organic xenobiotics and sensitive to environment contaminants because many contaminants tend to accumulate in the liver, making this organ exposed to a much higher levels than in the environment. Some lesions in the liver of flatfish are well-established as histopathological biomarkers of contaminant effects in fish and show strong evidence of a **contaminant-associated etiology** based on previous field and laboratory studies (Hinton et al., 1992; Au, 2004). Owing to increasing evidence of the existence of a cause-effect relationship between environmental contaminants and the occurrence of toxicopathic liver lesions in fish, studies on histopathological liver lesions in flatfish have been recommended repeatedly as one of the techniques to be used for contaminant-specific and general biological effects monitoring. In order to achieve quality assurance of data obtained in such programmes, there is a

techniques developed by ICES for international standardization and intercalibration in collection, processing, examination, and reporting of histopathological findings. Liver lesions which were recommended as histopathological biomarkers include: early non-neoplastic toxicopathic lesions (hepatocellular nuclear pleomorphism, hydropic vacuolation of biliary epithelial cells and/or hepatocytes, phospholipidosis, fibrillar inclusion, peliosis and spongiosis hepatic); foci of cellular alteration (FCA); benign neoplasms; malignant neoplasms.neoplasms.

Using fish, we have been conducting biological effect **monitoring investigations in Peter the Great Bay**, Sea of Japan, since 1995. The main aim of the study was to reveal histopathological biomarkers of pollution in several organs of fish from Peter the Great Bay for assessment of biological effects of contaminants. Out of 120 flatfish belonging to six species and studied histologically, hepatic tumors were found only in two individuals: the black plaice *Pleuronectes obscurus* and the longsnout flounder *P. punctatissimus* from Sivuchya Bay (1.6%), it is not so high as it was in fishes from polluted coastal areas in other regions, for examples, Deer Island, Boston Harbor in years 1987–1993 (up to 11%). Foci of cellular alteration, which are preneoplastic lesions, in the liver of different flatfish species from Peter the Great Bay were occurred more frequently than neoplastic growth. Apart them a variety of histopathological changes were found in the liver of flatfish: vacuolization of hepatocytes and epithelial cells of biliary ducts, disturbance of blood circulation, pigment accumulation in melanomacrophage centres, and necrosis. The vacuolization of hepatocytes, resulting from hydropic and lipid dystrophy, was the most common liver pathology in the flounders; it has been detected in 60–80% of the specimens examined. Hydropic dystrophy is recognized in three stages: 1. Centrotubular (isolated groups of 1–2 vacuolated cells in the center of the hepatic tubule); 2. Tubular (linear arrays of vacuolated cells); 3. Focal (foci of 30 to several hundred vacuolated cells). Focal hydropic vacuolation have been described as preneoplastic lesions. We didn't found tumor and focal hydropic dystrophy in flounders from Amursky Bay, only tubular hydropic dystrophy.

The liver of barfin plaice *P. pinnifasciatus* sampled from Amursky Bay in August 2001 was examined for the presence of histopathological changes, which are known to be the biomarkers of marine environment contamination. Only a few of the variety of histopathological markers of marine environment pollution mentioned above were revealed in the plaices from sites A (inner part of Amursky Bay) and B (middle part of Amursky Bay), i.e. vacuolization of hepatocytes (occurrence 48 and 36%), coagulative necrosis of hepatocytes (8 and 9%), necrosis of epithelial cells of bile ducts (0 and 23%), and inflammatory reaction (24 and 16% respectively). The liver neoplasms as well as foci of cellular alterations were not found. In the fishes from both sites, the vacuolization of hepatocytes was more common than other pathologies.

This study has successfully applied histopathology to a pollution monitoring programme, both for the recording of toxicopathic lesions in the liver, and for the detection of tumors. Histopathological analysis provides a powerful integrative tool for the assessment of biological effects of contaminants in Peter the Great Bay.

During the last few years the problem referred to as **endocrine disruption in wildlife** has became very important. Contaminant-related endocrine disruption was found in some representatives of mammals and birds. Particularly numerous are examples of endocrine disruption in seawater and freshwater fishes from many countries. Much less is known regarding endocrine disruption in marine invertebrates, the key structural and functional components of marine ecosystems. Detecting endocrine disruption *in situ* might be achieved using biomarkers. The known examples of endocrine disruption in marine organisms *in situ* are **intersex** and **imposex** condition.

Imposex is the occurrence of induced male sex characteristics superimposed on normal female gastropods, with the development of male sex organs, the penis and/or the vas deferens. Imposex was first reported in the early 1970s for the common dog whelk *Nucella lapillus* found along the coastline of the United Kingdom (Blaber, 1970). *N. lapillus* remains the most thoroughly studied species in relation to imposex, although the phenomenon has now been observed and studied in many other species of gastropods worldwide. In a series of studies of the intertidal mud snail *Nassarius obsoletus* (=*Ilyanassa obsoleta*), the imposex condition was linked firstly to pollution in marinas, then antifouling bottom paints, and finally the chemical tributyltin (TBT), a major component of the antifouling paints (Smith, 1981). This was confirmed by long-term field and laboratory experiments with *N. lapillus* (Gibbs and Bryan, 1986; Bryan et al., 1987), which showed that the bioaccumulation of tin within the female correlated with increase in the development of imposex. Gastropods bioaccumulate TBT and its endocrine disruptive effects result in elevated testosterone levels giving rise to imposex (Matthiessen and Gibbs, 1998).

The significance of imposex is the adverse biological effects of the superimposed male sex characteristics on females. In some species, the vas deferens interferes with the oviducts leading to infertility and population decline. Measurement of imposex can provide a relatively rapid and inexpensive indication of pollution by TBT in a given ecosystem.

This lecture reports the comparative data on imposex occurrence in northeast Asia. In Japan, marine pollution by organotin compounds is serious and imposex occurs in marine gastropods. The first country-wide survey on imposex in Japanese gastropods was carried out in 1994 (Horiguchi et al., 1995). 30 species (24 neogastropods and 6 mesogastropods) were found to be affected by imposex in the 38 species of Japanese gastropods surveyed (as of October 1993). Occurrence rates of imposex in rock shells, *Thais clavigera* and *T. bronni* (Muricidae: Neogastropoda) were 100% at almost all the stations surveyed (32 sites in Japan). The percentage occurrence of imposex in the rock shell, *T. clavigera,* was 100% at all sites surveyed (7 sites in the **Sanriku region** and 22 sites from **the Seto Inland Sea**). The percentage occurrence of sterile individuals whose oviducts were blocked by vas deferens formation was changed between 0–100%.

Few studies have been conducted along the **Taiwan coastal area**. Samples of rock shells (*T. clavigera*) were collected from northern (Shingsan), central (Lukang) and southern (Chiku) Taiwan western oyster mariculture areas during August and November 1998 and January 1999 (Hung et al., 2001). Imposex at Shiangsan, Lukang and Chiku increased from 67.1, 59.3 and 36.7 in summer to 100, 100 and 80% in winter respectively.

Frequency of imposex in the *T. clavigera* from the **coast of the Korean peninsula** was 0% at the reference sites, but at 47 out of 61 sites was recorded as 100%. Tributyltin and tripheniltin concentrations in *T. clavigera* ranged from 5 to 508 ng/g and from 3 to 2460 ng/g, respectively. A significant positive relationship was found between degree of imposex and organotin concentration.

In **Russian Far East**, studies concerned with TBT contamination and imposex occurrence are totally lacking. **Intersex,** the presence of both male and female gonads and/or ovotestis, the presence of eggs in the testes in one individual, is currently studied across the world. Some evidence suggests that the incidence of intersex is linked with discharges of pollutants called **endocrine disruptors** into aquatic environment and this change has been suggested as a marker for exposure to these substances.

The presence of specimens with intersex gonads (ovotestis) is well documented in wild population of gonochorist teleost (Allen et al., 1999) and molluscs (Horiguchi et al., 2000) living in polluted environments. This kind of gonadal abnormality was registered among examined species of Peter the Great Bay in pecten *Mizuhopecten yessoensis* in 1996 (Syasina et al., 1996) and in sea urchins in May–August 2000. Sea urchins with intersex gonads were found at five stations: Sport Harbor, Alekseev Bight, Reinike Island, Verkhovskii Island, and Sivuchya Bay. The percentage of intersex was low in the areas investigated at the present time.

A number of chemicals and mixtures are implicated in endocrine disruption in invertebrates (Depledge and Billinghurst, 1999), and they are detected in marine environment Peter the Great Bay such as metals (Cd, Se, Zn, Pb), DDT and sewage effluent, others (organotins, estrogens, androgens) have been never measured at all. Organotins, in particular tributyltin (TBT) and triphenyltin (TPT), are considered to be toxic chemicals. However, there are no regulations in most countries of the Asian-Pacific Region and effects of organotins upon marine life in that area have not yet been well documented.

Therefore, until recently no systemic survey has been conducted on occurrence of intersex, imposex and other reproductive abnormalities in invertebrates and fish from Russian coastal water in Far East and it is important for us to obtain more information on endocrine disruptor effects. On the other hand, inexpensive, easy to use, ecotoxicological tools are also required everywhere to detect and monitor endocrine disruption in invertebrates and other organisms *in situ*.

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ECOLOGICAL STATE OF AMURSKY BAY

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The basin of Amursky Bay is the most developed area in Primorye Region. In this area, there are large cities such as Vladivostok (the largest seaport in Russian Far East and Ussuriysk. Numerous mining enterprises exploit different kinds of minerals in the basins of the rivers entering the bay. Intensive farming is developed in the basin of the Razdolnaya River, which feeds into the bay in the north. This river is the largest (after the Tumen River) of the rivers of southern Primorye, and it greatly influences hydrological and hydrochemical regimes of the bay.

Economic development of the region from the 1960s through the 1990s was not accompanied by construction of sufficiently powerful and effective treatment facilities, and the coastal waters of Amursky Bay were used as a receptacle of almost untreated sewage. There are 6 major sewage disposals located on the Vladivostok territory, they account for about 60% of total waste waters entering the bay; the rest of waste waters is carried out to sea by the Razdolnaya River (Nigmatulina, 2005). Together with the Razdolnaya River, the most important waste discharges are "Pervorechensky" (30% of total waste waters), "Vtoraya Rechka" (16%), and "De-Friz" (9%).

According to the expert estimations, in 1988 the annual volume of wastewater discharged into Amursky Bay was about 120 million m^3 that was 0.6% of total water masses of the bay (Ogorodnikova et al., 1997). About 90% of wastewater was not purified at all before discharge.

During the last decade, in the Primorye Region both industrial and agricultural activity has sharply decreased. This gave rise to hope for improvement of the ecological situation in Amursky Bay. The aim of the present paper is to review the data of the monitoring surveys conducted in the period from 1980s to 2000s, and to assess the dynamics of the state of marine environment and biota in Amursky Bay. The next items are under discussion:

– annual wastewater volume and composition;
– eutrophication of the bay;
– contamination of bottom sediments;
– the state of benthos communities.

Annual wastewater volume and composition. The major contamination sources in Amursky Bay are 12 water utility enterprises which account for 90% of annual volume of waste waters. Analysis of long-term data (1988, 1990, 1991, 1996, 1999, 2000) on the waste water volume and composition showed that in 2000 the volume of waste waters was lower than in 1988 for 44%, and a mass of contaminants discharging into the bay has decreased about 6 fold (Nigmatulina, 2005). During this period, a portion of untreated sewage was from 78 to 98%, and wastewater compositions were very similar. Quantitative analysis of the wastewater composition showed that in 2000 organic matter (33.5%), suspended solids (30.6%) and biogenic elements such as nitrogen and phosphorus (11.7%) predominated. Portion of heavy metals (Al, Fe, Zn, Cu, Pb, Ni, Cr, Ti) was much lower and accounted for only 0.4%.

Eutrophication of the bay. The enrichment of coastal waters of the bay with biogenic elements which are necessary for photosynthesis in unicellular algae results in increase in phytoplancton production. With decreasing distance from the sources of eutrophication (the Razdolnaya River water flow and sewage outfalls) the following trends in the phytoplankton composition were revealed: 1) total density and biomass increased; 2) the density of the diatom alga *Sceletonema costatum,* which is known from the literature as an indicator of organic pollution, increased significantly; and 3) the density of the non-diatom component of the phytoplankton increased (Stonik, Orlova, 2004). Long-term study (1991–2000) of the phytoplankton in Amursky Bay showed that in the end of 1990s, a tendency has arisen for a decrease in density of *S. costatum,* compared with the level of 1991 and 1996. Nevertheless, the authors concluded that there was no significant decrease in the level of organic pollution in Amursky Bay over recent years because the density of this alga remains rather a high (up to 3 million cells/l).

Contamination of bottom sediments. The concentrations of pollutants in bottom sediments are significantly higher than in water column; therefore, the chemical composition of the upper (2–5 cm) layer of bottom sediments allows us to judge the degree and pattern of anthropogenic disturbance in the coastal water areas.

<u>Oil hydrocarbons (OH).</u> Analysis of long-term data suggest a decrease in the level of sediment contamination with OH in the beginning of 2000s compared with the level of 1980s–1990s (Belan et al., 2003). Mean values of OH concentrations in 1980s–1990s (0.62±0.72) were significantly ($p < 0.05$) higher than in 2001 (0.10±0.07). The influence of the Razdolnaya River discharge and sewage outfalls on the distribution of OH concentrations in bottom sediments of Amursky Bay was evident both in 1980s–1990s and in 2001(Tkalin et al., 1993; Belan et al., 2003).

<u>Organochlorine pesticides.</u> Only two of a great variety of organochlorine compounds has been monitored in Amursky Bay, namely hexachlocyclohexane and DDT. The data obtained provide evidence of significant contamination of Amursky Bay ecosystem with DDT. In 2001–2004, concentrations of this toxic pesticide in bottom sediments from “near city” zone varied from 1.7 to 47 ng/g d.w. (Vaschenko et al., 2003; Zhadan et al., 2005).

Analysis of temporal trend of DDT content in the bottom sediments of Amursky Bay from 1990 to 2001 revealed no significant change (Belan et al., 2003). In June 2005, DDT was found in the sediments from all stations near the Razdolnaya River mouth.

Heavy metals (HM). Analysis of long-term data testify that the sediments from "near city" zone contain significantly higher concentrations of HM than the sediments from the open "island" zone of the bay (Belan et al., 2003; Shulkin, 2004; Zhadan et al., 2005). The highest concentration gradients were found for technogenic metals Pb, Cu and Zn. Analysis of mean values of heavy metal concentrations in 1980s–1990s and in 2001 revealed significant difference for Cd (1.08±0.89 and 0.16±0.63, respectively, $p < 0.05$) but not for Pb and Cu (Belan et al., 2003). In 2001 and 2005, the effect of the Razdolnaya River discharge on heavy metal distribution was quite limited.

The state of benthos communities. The state of benthos communities in Amursky Bay has been studied since the first hydrobiological expedition in Peter the Great Bay carried out in 1925–1933 under the direction of K.M. Deryugin (Deryugin and Somova, 1941). In 1970s, 1980s, 1990s and the beginning of 2000s, long-term changes in the state of bottom communities have been investigated by a number of authors. It should be noted that principal attention had been paid to inhabitants of soft grounds – silts, sands and silted sands, i.e. infauna. The major representatives of infauna in Amursky Bay are polychaetes, bivalve mollusks and echinoderms, mainly ophiuroids. As to benthic inhabitants of rocky and boulder grounds, only limited information about long-term changes in their state is available.

Long-term changes in benthic communities in Amursky Bay

1925–1933	1986–1989	2001
Average biomass 150 g/m^2 Dominant species (ind/m^2): Polychaetes *Maldane sarsi* (800–2200) *Scoloplos armiger* (170–300) *Lumbrineris minuta* (250) *Anobothrus* (=*Sosane*) *gracilis* (150–800) Bivalve mollusks *Nucula tenuis* (250–1000) Ophiuroids *Ophiura sarsi* (120–735) Hydroids *Obelia longissima*	Average biomass 73.9 g/m^2 Dominant species (ind/m^2): Polychaetes *Tharyx pacifica* (1872, up to 8100) *Dipolydora cardalia* (up to 2100) *Lumbrineris* sp. (339.6) *Maldane sarsi* (333.6) *Schistomeringos japonica* (132.0) Bivalve mollusks *Raeta pulchella* *Callithaca adamsi* *Yoldia* sp. *Axinopsida* o. *subquadrata* *Leonucula tenuis tenuis* (=*Nucula tenuis*)	Average biomass 157.5 g/m^2 Dominant species (ind/m^2): Polychaetes *Tharyx pacifica* (604.6) *Lumbrineris* sp. (190.2) *Sigambra bassi* (85.9) *Maldane sarsi* (82.9) Bivalve mollusks *Theora lubrica*

The Table demonstrates long-term changes in benthic communities in Amursky Bay. Analysis of qualitative parameters of the state of benthic communities in Amursky Bay in 1980s and 2001 (Belan et al., 2003) showed that average benthos biomass has been increased in 2001 while the average abundance decreased due to a sharp decrease in the density of tolerant polychaete species. It is worthy to note that mean number of species and index of richness in 2001 have significantly decreased ($p < 0.05$).

Severe changes in the biodiversity and abundance of bivalve mollusks which are an important component of benthic communities in Amursky Bay took place in the period from 1980s to the beginning of 2000s (Oleynik, Moshchenko, 2004). Despite the average biomass has not significantly decreased in 2001 compared to data of 1980s, the average density and number of species has decreased by a factor of 2. Significant decrease in the value of Shannon–Wiener diversity index was also revealed.

Conclusion. During the period from 1988 to 2000, the 44% decrease in the volume of wastewaters and 6-fold decrease in the mass of contaminants discharging into Amursky Bay has been registered. Nevertheless, based on the analysis of long-term data on the density of microalgae in the water, the level of the sediment contamination with oil hydrocarbons, heavy metals and organochlorine pesticides, and the state of benthos communities, no positive conclusion about improvement of the state of coastal ecosystems in Amursky Bay in 2000s compared to 1980s and 1990s could be made. Decreasing trends were revealed for concentrations of oil hydrocarbons and cadmium in the sediments, while concentrations of other metals and DDT remain rather a high. The Razdolnaya River runoff contributed to the enrichment of adjacent waters of the bay in organic matter and oil hydrocarbons but not technogenic heavy metals (Zn, Cu, Pb). Biodiversity of the species forming bottom communities of soft sediments has significantly decreased in 2001 compared to 1986–1989. Chronic pollution of the bay appears to be the major cause of negative changes in the state of the biota.

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Glossary of Terms

A – abundance
ADK – Amur River Discharge in Khabarovsk
AAS – atomic-absorption spectrophotometry
APN – Asia-Pacific Network for Global Change Research
B – total biomass
BOD – biological consumption of oxygen
CAS – Chinese Academy of Sciences
COD – chemical consumption of oxygen
DDT – organochlorine pesticides
DMZ – Demilitarized Zone (between Republic of Korea and DPRK)
DPRK – Democratic People's Republic of Korea
e – Pielou evenness index
EMD – Environmental Management District (in Republic of Korea)
ENSO – El Nino – Southern Oscillation
FEB RAS – Far East Branch of the Russian Academy of Sciences
FESMR – Far Eastern State Marine Reserve (in Russia)
H – Shannon–Wiener diversity index
HCN – α- and γ-isomers of hexachlorocyclohexane
HM – heavy metals
H_r – entropy
IGBP – International Geosphere-Biosphere Programme
IMB FEB RAS – Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences
IUCN – The World Conservation Union
LOICZ – Land-Ocean Interactions in the Coastal Zone (IGBP)
MFPA – Military Facility Protected Area (in Republic of Korea)
OH – oil hydrocarbons
OSI – Okhotsk Sea Ice Extend
PHC – petroleum hydrocarbons
PHE – phenols
R – Margalef richness index
RAS – Russian Academy of Sciences
SD – standard deviation
Si – Simpson domination index
SS – suspended solids
SST – sea surface temperature
START – Global Change System for Analysis, Research and Training