# Preface

Being one of the most productive marginal seas in the world, the region where sea ice is formed at the lowest latitudes in the World's oceans, and the formation area of North Pacific Intermediate Water, the Okhotsk Sea has attracted attention of PICES scientists since the inception of the Organization. The very first Working Group established by PICES in 1992 was on *The Okhotsk Sea and Oyashio Region* (under the Physical Oceanography and Climate Committee). The final report of this Working Group 1, edited by Drs. Lynne Talley (U.S.A.) and Yutaka Nagata (Japan) was published as PICES Scientific Report No. 2 in 1995.

Built on this activity, the first PICES Workshop on "*The Okhotsk Sea and Adjacent Waters*" was held on June 19–24, 1995, in Vladivostok, Russia, and was co-convened by Drs. Yukata Nagata, Vyacheslav Lobanov (Russia) and Lynne Talley. Its purpose was twofold: to promote international cooperation in discussions of physical oceanography, fisheries and data exchange of the region and, in view of the importance of Russian contributions to the understanding of the area, to facilitate the incorporation of Russian information in the review of past work. A total of 144 scientists from 5 countries (Canada, Japan, Korea, Russia and U.S.A.) attended the workshop and presented 97 talks and 44 posters. The workshop proceedings were published as PICES Scientific Report No. 6 in 1996. In addition, the "*Multilingual Nomenclature of Place and Oceanographic Names in the Region of the Sea of Okhotsk*", prepared by Drs. Yutaka Nagata and Vyacheslav Lobanov, was published as PICES Scientific Report No. 8 in 1998.

The considerable interest generated from the first workshop led to a second one which took place from November 9–12, 1998, in Nemuro, Japan, and was co-convened again by Drs. Yukata Nagata, Vyacheslav Lobanov and Lynne Talley. The focus was mainly on physical oceanography, and the purpose was to exchange new findings and recent research results, and to review on-going and in-planning international and domestic projects in order to improve international cooperative research. There were 42 participants from 3 countries (Japan, Russia and U.S.A.) who presented 38 talks and 10 posters. The workshop outcome was published as PICES Scientific Report No. 12 in 1999.

A third workshop was held on June 4–6, 2003, again in Vladivostok, and was co-convened by Drs. Vyacheslav Lobanov, Yukata Nagata, Stephen Riser (U.S.A.) and Sei-Ichi Saitoh (Japan). The themes covered by this workshop were broadly based for the purpose of integrating physical, chemical and biological observations in the area. A novel element in the program was an attempt to synthesize the major findings in a discussion session at the end of the presentations. Almost 100 scientists from 3 countries (Japan, Russia and U.S.A.) attended the workshop and presented 38 talks and 45 posters. The workshop results were published in PICES Report No. 12 in 2004, and contributed significantly to the first PICES North Pacific Status Report (PICES Special Publication No. 1, 2004).

This report is the outcome of the fourth PICES Workshop on "*The Okhotsk Sea and Adjacent Waters*" held August 27–29, 2008, in Abashiri, Japan. The Co-convenors and participants of the workshop hope that these proceedings will contribute to future marine scientific research and stimulate international cooperation in the region.

## 1. Outline of the Workshop

The fourth PICES Workshop on "*The Okhotsk Sea and Adjacent Waters*" was held on August 27–29, 2008, at the campus of the Tokyo University of Agriculture (TUA) in Abashiri, the southernmost city and fisheries base in the rim of the Okhotsk Sea. The goal of the workshop was to develop an Okhotsk Sea component of the new PICES integrative science program, FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and

**R**esponses of North Pacific Marine **E**cosystems). The intention was to bring together a team of international scientists interested in the Okhotsk Sea and adjacent areas, and their marine ecosystems, to better understand the increasing impacts of climate change in the region, to review and exchange "what is known", and to identify key scientific questions and necessary approaches to answer these questions. Co-convenors of the workshop were Prof. Makoto Kashiwai (TUA) and Dr. Gennady Kantakov (Sakhalin Fisheries and Oceanographic Research Institute). A total of 75 participants attended the workshop: 63 scientists (Japan 44; Russia 17; Canada 1; PICES 1), 1 journalist and 11 auditing students (Appendices 1 and 2).

The workshop began with welcome addresses by Prof. Michinari Yokohama (Dean of Faculty of Bioindustry, TUA) and Mr. Koji Kamada (Director of Abashiri Construction and Development Department Office, Hokkaido Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism). Then, the Co-convenors reviewed the workshop objectives, structure and expected outcome. Three plenary sessions (PS) were held on the first day and two concurrent sessions (A and B) on the second day as follows:

Plenary Sessions:
- PS1: Climate / Ocean dynamics
- PS2: Amur River / Geochemical cycle
- PS3: Primary production / Zooplankton / Marine mammals

Concurrent Session A:
- A1: Current dynamics
- A2: Sea ice, watermass and freshwater processes / Coastal lagoons
- A3: New technology

Concurrent Session B:
- B1: Biological processes / Marine ecosystem disturbances by oil and gas development
- B2: Walleye pollock

A total of 47 papers were presented at these sessions, including one by Dr. Skip McKinnell (Deputy Executive Secretary of PICES) on the status and trends of FUTURE Implementation planning. The schedule of presentations is provided in Appendix 3.

The third day was held in plenary to develop session reports and identify proposals for FUTURE. The reports by session Co-chairs, including a brief summary of presentations and future research plans, can be found in the next section of the Preface. After the announcements for the preparation of the workshop proceedings, the Co-convenors provided closing remarks.

Associated with the workshop, the fourth day was dedicated to the TUA program, the Okhotsk Practical Learning Open Seminar on "*How can we develop resilience of ecosystem and fishery of the Okhotsk Sea against global warming?*". This program was composed of (1) two keynote lectures based on the PICES workshop summaries, "*Possible changes in oceanographic conditions of the Okhotsk Sea with global warming*" by Dr. Vyacheslav Lobanov (Deputy Director, Pacific Oceanological Institute, Russia) and "*Impacts of changes of oceanographic conditions and ecosystems associated with global warming on fisheries in the Okhotsk Sea*" by Dr. Gennady Kantakov (Deputy Director, SakhNIRO, Russia); (2) two keynote reports on "*Effect of the rise in summertime water temperature associated with global warming on the survival of the scallop fishery*" by Dr. Yuji Nishihama (Visiting Professor, TUA) and "*Influence of global warming on northern fish populations*" by Prof. Michio J. Kishi (Hokkaido University); and (3) a panel discussion on *"In order for the fisheries of the Okhotsk Sea to be able to tolerate severe changes due to global warming, what subjects should be addressed by marine sciences?"* with problems posed by the leaders of fisheries cooperatives, students from a practical learning class on the Okhotsk Sea Rim Program, and young TUA scientists. The citizens and fisheries people of Abashiri, workshop participants and students were invited to participate in this program aided by Russian/Japanese sequential translations.

## 2. Session Reports

**PS1: Climate/Ocean dynamics** (Co-chairs: Andrey Andreev and Kay-Ichiro Ohshima)

*Summary of presentations*

In this session, results of the studies concerning long-term changes of the climatic regime (Glebova *et al.*), sea ice coverage (Tachibana and Ogi; Muktepavel and Shatilina), Dense Shelf Water formation (Sasajima *et al*.), seawater temperature, salinity and chemical parameters concentrations (Ohshima *et al.*; Andreev) in the Okhotsk Sea were discussed.

*Future research should involve:*

1. Monitoring of the long-term changes of heat and moisture fluxes, wind regime and Amur River discharge and its influence on the water temperature, salinity stratification, circulation and ice coverage in the Okhotsk Sea;
2. Organization of time-series observations and research vessel expeditions in the Okhotsk Sea to detect the climate change impact on physical and chemical parameters of the seawater, and a comparison with the results of numerical models;
3. Study (observations and ecological models simulation) of the impact of tides on the spatio-temporal variations of the nutrient fluxes, chlorophyll concentrations and primary production in the Okhotsk Sea and Kuril Straits area.

**PS2: Amur River / Geochemical cycle** (Co-chairs: M. Angelica Peña and Michio J. Kishi)

*Summary of presentations*

In this session, five presentations were made including a review of the Pacific Oceanological Institute program on the Amur River estuary and adjacent areas (Lobanov *et al.*), a study of the link between biogeochemical cycles in the Amur River and the western subarctic Pacific, in particular the transport of iron in Okhotsk Sea Intermediate Water (OSIW) to the western subarctic Pacific (Nakatsuka *et al.*), a study of factors controlling biogeochemical cycles in coastal waters using a biogeochemical model (Peña), and the two papers focused on the effect of sea ice on nutrient fluxes (Nomura *et al.*) and on material fluxes (Hiwatari *et al.*) in the Okhotsk Sea.

*Future research should include:*

1. A joint Japan-Russia-Canada project on the Okhotsk Sea to provide information on the role of iron/OSIW on biogeochemical cycles;
2. Development of a biogeochemical model embedded within a high resolution 3-D physical model to improve our understanding of the transport of iron and material cycles and to facilitate predictions of future ecosystem states, including higher trophic levels;
3. Extended field observations to cover the full annual cycle, especially variables measured under ice in winter;
4. Icebreaker expeditions focusing on biogeochemical studies and aiming to clarify wintertime processes.

**PS3: Primary production / Zooplankton / Marine mammals** (Co-chairs: Sei-Ichi Saitoh, Alexey M. Trukhin, Mari Kobayashi and Akihiro Shiomoto)

*Summary of presentations*

Presentations for this session were grouped into the following two classes:

*Primary production*

Prolonged high primary production in the scallop farming area (southern part of the Okhotsk Sea) was sustained after the spring bloom by the development of a frontal area (Cold Belt) along the Soya Warm Current (SWC) in summer and by forcing of the East Sakhalin Current (ESC) in autumn. The summer bloom occurs due to instability of the SWC, contributing >50% of annual total primary production in the area (Muzzneena and

Saitoh). In the offshore region of the southern Okhotsk Sea, the maximum concentration of chlorophyll *a* (Chl-*a*) was found in the surface layer in spring, but shifted to ~20 m depth in summer and autumn, forming the subsurface chlorophyll maximum (SMC). Seasonal variability of integrated primary production within the euphotic layer was low (Kasai *et al.*). Although no significant relationships were found in the Okhotsk Sea between photosynthetic parameters and temperature or nutrients, the surface primary production during August and September was significantly correlated with Chl-*a* concentrations. This suggests that primary production in summer basically depended on the biomass and not on their photosynthetic physiology or light intensity (Isada *et al.*).

*Marine mammals*

A remarkable increase in the abundance of spotted seals near northern Hokkaido has occurred, significantly expanding their range of inhabitation southward. With global warming, the ice area where seal pups are born and spend early stages of their lives is declining, which seems to have had a negative impact on the entire regional population (Kobayashi *et al.*). Seven species of pinnipeds inhabit the Okhotsk Sea, but the Steller sea lions and harbour seals are rare. Of the14 Steller sea lion rookeries, 11 are located in the Okhotsk Sea. The abundance of sea lions has stopped decreasing recently. During the last 10 years, increasing abundances of northern fur seals have been observed at Tuleny Island (Terpeniya Bay) near Sakhalin (Trukhin). Analysis of 19 mitochondrial DNA haplotypes found in harbour porpoises near Japan indicates that this population was established relatively recently (Taguchi *et al.*).

*Future research should:*

1. Summarize and evaluate the available information on the responses of marine organisms of the Okhotsk Sea (from phytoplankton to marine mammals and seabirds) to variability in physical attributes of the ocean, such as seasonal sea ice cover, ocean temperature, stratification, and circulation;
2. Clarify the contribution of ice-algae to the total primary production in the Okhotsk Sea;
3. Understand the physical mechanism responsible for maintaining high primary production in the Okhotsk Sea (Coastal Green Belt), especially the role of advection of the SWC (Cold Belt) and upwelling zones in the Kuril Straits and inside the Okhotsk Sea;
4. Improve a satellite ocean color algorithm of Chl-*a* and primary productivity in the Okhotsk Sea and develop an algorithm to determine integrated Chl-*a* concentration within the euphotic zone;
5. Develop an ice thickness algorithm through remote sensing to evaluate ice thickness changes in the Okhotsk Sea;
6. Examine contributions of oceanic heat on sea ice melting/freezing/motion analysis and ocean–atmosphere heat flux relating to ice variation in relation to marine habitat;
7. Collect *in situ* bio-optical measurements of the phytoplankton community in the Okhotsk Sea;
8. Understand detailed responses of phytoplankton to sea ice dynamics in conjunction with other physical/biochemical parameters (ocean circulation, mixed layer depth, light/nutrients) using a 3-D coupled Ice-Ocean-Ecosystem Model;
9. Develop a plan for the study of zooplankton dynamics and population structure in the Okhotsk Sea;
10. Promote joint Japan-Russia studies on pinnipeds and other marine mammal species in the Okhotsk Sea for sharing biological samples and data.

**A1: Currents dynamics** (Chair: Takuya Nakanowatari)

*Summary of presentations*

This session considered studies on currents dynamics in the Okhotsk Sea and North Pacific by numerical models and observations. One of the presentations (Uchimoto *et al.*) described a model of the circulation of the intermediate layer in the Okhotsk Sea. Their Ocean Global Climate Model (OGCM) reproduced features on the 26.8$\sigma_\theta$ surface reasonably well, despite a relatively coarse resolution. Tracers injected at the model sea surface in the northwestern part of the Okhotsk Sea are transported to the Pacific *via* the Kuril Straits in the intermediate layer. In these experiments, the tidal mixing effect was essential for the realistic simulation of water mass property and circulation in the Okhotsk Sea. Using observational and hindcast data from an

OGCM experiment, a model was developed to successfully represent the observed multidecadal-scale cooling in the western North Pacific (Nakanowatari *et al.*). This cooling is related to increased cross-gyre transport of the western boundary current. Since the change in potential temperature originates from the western boundary, this indicates that the mechanism is different from the response of westward propagating Rossby waves from the central North Pacific, as has been previously reported by several studies On the other hand, a linear trend in the Okhotsk Sea Intermediate Water was not well simulated. Vertical movements of water masses in the western Okhotsk Sea are evident in observational data (Kantakov). Temperature inversions inside the dichothermal layer are located at convergence zones and/or close to the thermal fronts in the sea. There are at least two types of convection, one connected with salt transport by the SWC in the warm months and another with cooling and brine rejection during fall and winter. The characteristics of tidal and residual currents for the Shmidt Peninsula, Okhotsk Sea shelf of Urup and Kunashir islands were shown from observational mooring data (Shevchenko *et al.*). The energetic characteristics of tidal and residual sea level oscillations in the Okhotsk Sea were also examined from satellite altimetry data (Shevchenko and Romanov). In summary, OGCM experiments provide good representation of oceanic structure and currents in the Okhotsk Sea. However, the interannual variations and current mesoscale structure, including tidal currents, are not simulated well by models. The key components of realistic simulations of physical processes in the region involve tidal mixing and sea ice formation. Incorporating feedback from observational data to a numerical model is important to improve the simulation of the ocean circulation in the Okhotsk Sea.

*Future research should focus on:*

1. Estimation of the effect of the multi-decadal scale change in the Oyashio on material circulation and ecology in the North Pacific;
2. Realistic simulations of OSIW dynamics;
3. Variability of the vertical movements of water masses in the Okhotsk Sea (possibly a part of FUTURE due to obvious impacts of those phenomena on marine biota, especially at the early ontogenetic stages), climate oscillations and hydrography.

**A2: Sea ice, watermass and freshwater processes / Coastal lagoons** (Co-chairs: Yoshihiro Tachibana and Anastasiya Abrosimova)

*Summary of presentations*

A study of sea-ice flow from the Okhotsk Sea through Nemuro Strait in 2008 revealed that in addition to wind drift, the southwestward flow of the Coastal Oyashio and Oyashio currents are important factors controlling sea-ice drift along the southern coast of Hokkaido and result in ice blocking of some bays (Motoi *et al*.). Data obtained by the Hokkaido Kushiro Experimental Station indicated that outflow water from the Okhotsk Sea influences the eastern coastal ecosystem of Hokkaido (Nagata). Evidence of deep convection in the Okhotsk Sea was found (Kashiwai). This winter convection at the open ocean polynya can be an important process, along with the progress of global warming. A study of the influence of Amur River discharge on hydrological conditions of the estuary area indicated that a mesoscale lens of Amur River water is formed during a spring–summer flood (Abrosimova *et al*.). Re-analysis data were used to investigate the relationship of Amur River discharge with vertically-integrated atmospheric horizontal moisture flux (Oshima *et al*.). It was shown that variations in the Asian monsoon and Arctic circulation play an important role in the freshening of the Okhotsk Sea. A review of the coastal lagoons of the Okhotsk Sea found high biodiversity and important species for mariculture (Brovko).

*Future research should concentrate on:*

1. Paths of outflow of the Okhotsk Sea water;
2. Mechanisms and frequencies of deep convection;
3. Dynamics, conditions of formation, and evolution of the Amur River plume;
4. Oceanography and ecosystems of lagoons, as well as their influence on biochemical processes in adjacent marine areas.

**A3: New technology** (Co-chairs: Alexander Romanov and Naoto Ebuchi)

*Summary of presentations*

In this session, six reports were presented on topics ranging from HF radar (Ebuchi *et al.*), ionosphere monitoring (Romanov *et al.*), diagnostics for earthquakes (Romanov *et al.*), spectro-ellipsometry for ecological monitoring (Mkrtchyan *et al.*), radiometry for ecosystem bio-complexity assessment (Krapivin and Mkrtchyan), and airborne lidar for registration of fish schools and plankton (Chernook *et al.*).

*Future research*

1. Described technologies should be verified and improved by international cooperation under the umbrella of PICES, and new technologies should be developed to: (1) monitor ice-covered oceans in winter; (2) provide stable isotope analyses of sea water and biological samples; (3) assess biodiversity by DNA analyses; (4) improve remote sensing technology, and (5) create tools and methods for biological process studies, especially for monitoring the environment in the Okhotsk Sea.
2. Inviting technical specialists from various fields to future Okhotsk Sea workshops should be considered to enhance our monitoring technologies.

**B1: Biological processes/ Disturbances by oil and gas development** (Co-chairs: Atsushi Yamaguchi and Vyacheslav S. Labay)

*Summary of presentations*

This session dealt with presentation on phytoplankton (Shimada *et al.*), zooplankton (Asami *et al.*; Yamaguchi *et al.*), river fish communities (Kanaiwa *et al.*) and benthos (Kashiwai and Kantakov; Samatov and Labay).

*Future research*

The following points were included in a future research plan:

1. Remote sensing provides only the total amount of phytoplankton (pigment), but to understand spatial and temporal changes in phytoplankton community structure, detailed species composition is needed, especially for toxic species like *Alexandrium tamarense*;
2. The zooplankton community in the Okhotsk Sea is classified into a coastal community (dominated by *Pseudocalanus* spp.) and open sea community (dominated by *Metridia okhotensis*). Since *M. okhotensis* is the predominant component in the open part of the Okhotsk Sea, this copepod is considered a key species in this region. To evaluate its quantitative role in the biogeochemical cycle in this region, its ecology, especially its life cycle, should be studied;
3. Liquid natural gas (LNG), oil and gas activities on the east coast of Sakhalin Island, Magadan and western Kamchatka demand that the impact of such human development on marine ecosystem, especially benthos, should be addressed;
4. Since the characteristics of the Okhotsk Sea differ among locations (*e.g.*, depth, water masses, sea ice) affecting the spatial distribution of biota, cooperative research between Russia and Japan are needed in the future;
5. Since sampling and analytical procedures vary by country, making direct comparisons difficult, establishing standard sampling and analytical methods for biological processes should be considered.

**B2: Walleye pollock** (Co-chairs: Yasunori Sakurai, Alexander Varkentin and Vladimir Kulik)

*Summary of presentations*

This session showed that despite such a long period of walleye pollock study in the Okhotsk Sea, new information is still emerging about its biology. (Kulik; Ovsyannikov *et al.*; Yamamoto *et al.*). In particular, it has been established recently that Okhotsk Sea waters off the northern Kuril Islands and the southwestern Kamchatka area is the spawning region of walleye pollock of East Kamchatka origin (Buslov and Varkentin).

*Future research should:*

1. Summarize and evaluate available information on the responses of marine organisms of the Okhotsk Sea (from phytoplankton to marine mammals and seabirds) to variability in physical attributes of the ocean, such as seasonal sea ice cover, ocean temperature, stratification, and circulation;
2. Assemble existing biophysical datasets and time series from the Okhotsk Sea ecosystem to facilitate joint comparative studies of future climate change issues;
3. Conduct ecosystem studies of the Okhotsk Sea every year at the same time periods and at the same area polygons to ensure that statistical analysis of strong and significant multivariate, canonical and other analyses will not lead to unacceptable biological nonsense;
4. Improve ichthyoplankton survey methods in view of new knowledge about walleye pollock biology in the Okhotsk Sea waters off the northern Kuril Islands and in southwestern Kamchatka to clear up the rates and reasons of walleye pollock migrations to the Okhotsk Sea, and investigate in detail the hydrological conditions in this region;
5. Examine interannual walleye pollock reproductive strategy changes depending on climate and food conditions, stock level and other factors;
6. Explore how the extent of ice cover affects the fate of walleye pollock around the Okhotsk Sea.

## 3. Acknowledgements

All of the workshop achievements you find in these proceedings are due to the efforts of scientists who spared their precious time and traveled a long way to Abashiri to make valuable presentations and contribute to fruitful discussions. On behalf of all the participants, the workshop Co-convenors would like to acknowledge the Local Supporting Committee, consisting of young staff and students of the TUA campus in Abashiri, for their efforts in making the workshop a success. We thank TUA for providing the workshop venue and transportation not only for daily access to and from the campus but also between the campus and Wakkanai ferry terminal. We would also like to express our sincere gratitude to PICES, TUA, and the Abashiri Construction and Development Department Office for their financial support which made this workshop possible.

*Makoto Kashiwai and Gennady Kantakov*