4th PICES Workshop on "*The Okhotsk Sea and Adjacent Areas*"

by Makoto Kashiwai

The 4th PICES Workshop on "*The Okhotsk Sea and adjacent areas*" was held from August 27–29, 2008, at the Okhotsk Campus of the Tokyo University of Agriculture (TUA) in Abashiri, Japan. 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 workshop brought together a team of international scientists interested in the region and the marine ecosystems embraced by them. Recognizing the concerns for increasing impacts of climate change, participants reviewed "what is known", and identified key scientific questions and necessary approaches to answer these questions. Convenors of the workshop were Prof. Makoto Kashiwai (TUA) and Dr. Gennady Kantakov (Sakhalin Research Institute of Fisheries and Oceanography).

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The list of participants included 64 scientists (Japan–45; Russia–17; Canada–1; PICES–1) and 8 students. Many of the Russian scientists came to Abashiri by a ferry, crossing La Perouse (Soya) Strait. Perhaps the choice was a consequence of marine scientists preferring a sea route, but it meant that the limited travel funds could be allocated to a larger group of researchers. Some participants came from Hakodate after attending the PICES Summer School on "*Ecosystem-based Management*" at Hokkaido University. It was a special honour to have a Wooster Award winner, Prof. Yutaka Nagata (Emeritus, University of Tokyo), in attendance. He was a leading convenor of all previous PICES Okhotsk Sea workshops.

Abashiri is the southernmost port and fisheries base in the Okhotsk Sea. In winter, the coast is inundated by sea ice so tourists can enjoy sea ice scenery from the comfort of an icebreaker. The Abashiri Campus of TUA is on a hilltop located about a 20-minute drive (at legal speeds) from downtown. It offers a fine distant view of the mountains of the Shiretoko Peninsula and other isolated volcanoes, and the lakes of Abashiri and Notoro.

The workshop began with welcome addresses by Prof. Michinari Yokohama (Dean, Faculty of Bioindustry, TUA) and Mr. Koji Kamada (Director, Abashiri Construction and Development Department Office, Hokkaido Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism). Three plenary sessions were held on the first day and two parallel sessions on the second day. A total of 46 papers were presented including one by Dr. Skip McKinnell (Deputy Executive Secretary of PICES) on the status and trends of FUTURE implementation.

The first plenary session PS1 on *Climate/Ocean Dynamics* (Chairs: A. Andreev and K.I. Oshima) produced 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*.), and seawater temperature, salinity and chemical parameters (Oshima *et al*.; Andreev) in the Okhotsk Sea. Future research should involve: (1) monitoring 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 region to detect the climate change impact on physical and chemical parameters of the seawater; and (3) modelling to compare with observations and to study the impact of tides on the spatio-temporal variations of the nutrient fluxes, chlorophyll (Chl) concentrations and primary production in the Okhotsk Sea and Kuril Straits area.

In the plenary session PS2 on *The Amur River and Geo-chemical Cycles* (Chairs: M. Kishi and A. Peña), five papers were given by scientists from Japan, Russia and Canada. Presentations included: 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 last two papers focusing on the effect of sea ice on nutrient fluxes (Nomura

et al.) and material fluxes (Hiwatari *et al*.) in the Okhotsk Sea. In the future, a joint Japan-Russia-China project on the Okhotsk Sea will provide information on the role of iron/OSIW on biogeochemical cycles. A bio-geochemical model embedded within a high resolution 3-D physical model must play an important role in improving our understanding of the transport of iron and material cycles. These research activities will facilitate predictions of future ecosystem states, including higher trophic levels. Field observations must be extended to cover the annual cycle, especially variables measured under ice during winter. Icebreaker expeditions focusing on biogeochemical studies will aim to clarify winter time processes.

The plenary session PS3 on *Primary Production – Zooplankton – Marine Mammals* was chaired by S. Saitoh, A. Trukhin, M. Kobayashi and A. Shiomoto. It was noted that high primary production at a scallop farming area in the southern 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 enforcement of the East Sakhalin Current in autumn. The summer bloom occurs as a result of instability of the SWC, contributing >50% of annual total primary production in the area (Muzzneena and Saitoh). Offshore from there, the maximum concentration of Chl-*a* was found in the surface layer in spring, but shifted to ~20 m depth in summer and autumn (Kasai *et al*.). Seasonal variability of integrated primary production within the euphotic layer was low. Although no significant relationships were found between photosynthetic parameters and temperature or nutrients, the surface primary production during August and September was correlated significantly with Chl-*a* concentrations. This suggests that primary production in summer depended basically on the biomass, and not on their photosynthetic physiology or the light intensity (Isada *et al*.).

A remarkable increase in the abundance of spotted seals near northern Hokkaido has occurred, significantly expanding their range of inhabitation (Trukhin). With global warming, the ice area where seal pups are born is declining, which seems to have had a negative impact on the entire regional population. Seven species of pinnipeds inhabit the Okhotsk Sea, but the Steller sea lion and harbour seal are rare. Of 14 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 Tuleniy Island near Sakhalin (Terpeniya Bay). Examination of 19 mitochondrial DNA haplotypes found in harbour porpoises near Japan indicates that this population was established relatively recently (Taguchi *et al*.). Cooperative studies in the Okhotsk Sea between Russia and Japan will be important for sharing biological samples and data on pinnipeds and other marine mammal species.

Future research on these topics 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 the high primary production (Okhotsk Sea Coastal Green Belt), especially the role of

Workshop participants at the venue entrance.

advection of the SWC (Cold Belt); (4) improve the local algorithm of determining Chl-*a* and primary productivity by remote sensing in the Okhotsk Sea and develop an algorithm to determine integrated Chl-*a* concentration within the euphotic zone, and likewise (5) develop an ice thickness algorithm to evalutate ice thickness changes in the Okhotsk Sea; (6) examine contributions of oceanic heat on sea ice melting/freezing/motion analysis and oceanic/ atmospheric 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/bio-chemical parameters (ocean circulation, mixed layer depth, light/nutrients) using a 3-D coupled Ice-Ocean-Ecosystem Model; and (9) understand zooplankton dynamics and population structure in the Okhotsk Sea.

Professors Sei-Ichi Saitoh, Michio Kishi and Akira Taniguchi continue their scientific discussion during the coffee break.

The topic session A1 (Chair: T. Nakanowatari) considered studies on *Current Dynamics* by numerical models and observations. Ocean Global Climate Model (OGCM) experiments provide good representations of oceanic structure and currents in the Okhotsk Sea. 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. One of the presentations (Uchimoto *et al.*) described a model of the circulation of the intermediate layer in the Okhotsk Sea. The 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 to westwardly propagating Rossby waves from the central North Pacific, as has been previously reported by several studies. A linear trend in OSIW temperature 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 Island 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).

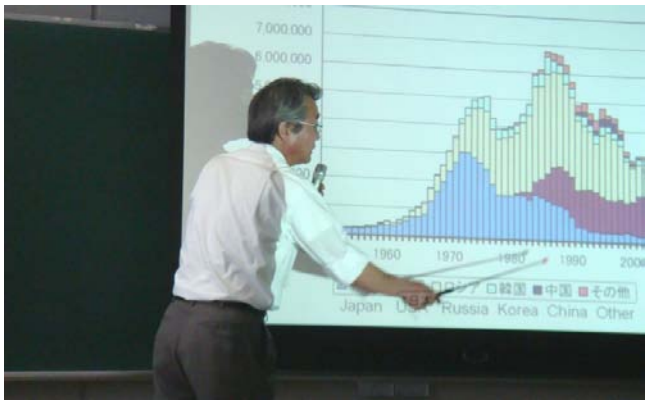
Future current dynamics research should focus on: (1) estimation of the effect of the multi-decadal scale changes in the Oyashio on material circulation and ecology of the North Pacific; (2) realistic simulations of OSIW dynamics; (3) variability of the vertical movements of water masses in the Okhotsk Sea (possibly a part of the FUTURE program due to obvious impacts of those phenomena on marine biota, especially at the early ontogenetic stages), climate oscillations and Okhotsk Sea hydrography.

The topic session A2 on *Sea Ice, Watermass and Freshwater Processes – Coastal Lagoons* was chaired by Y. Tachibana and A. Abrosimova. A study of sea-ice flow from the Okhotsk Sea through Nemuro Strait in 2008 (Motoi *et al.*) 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. Data obtained by the Hokkaido Kushiro Experimental Station indicated that outflow water from the Okhotsk Sea influences coastal Hokkaido (Nagata). Evidence of deep convection in the Okhotsk Sea was found (Kashiwai). This winter convection at 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 during a spring–summer flood found that a mesoscale lens of Amur River water is formed during a spring–summer flood (Abrosimova *et al.*). Re-analysis data was 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 studies should focus on: (1) paths of outflow of Okhotsk Sea water; (2) mechanisms and frequencies of deep convection; (3) dynamics, conditions of formation, and evolution of the Amur River plume; and (4) oceanography and ecosystems of lagoons, as well as their influence on biochemical processes in the adjacent marine areas.

The topic session A3 on *New Technology* (Chairs: N. Ebuchi and A. Romanov) heard six reports on topics ranging from HF radar, ionosphere monitoring, diagnostics for earthquakes, spectro-ellipsometry for ecological monitoring, radiometry for ecosystem bio-complexity assessment, and airborne lidar for registration of fish schools and plankton. In the future, these 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. Inviting technical specialists from various fields to future Okhotsk Sea workshops should be considered to enhance our monitoring technologies.

Presentations in the topic session B1 on *Biological Processes – Disturbance by Oil and Gas Development* (Chairs: A. Yamaguchi and V. Labay) dealt with 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). Five points are summarized as 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 species 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 will be needed in the future; and (5) Since sampling and analytical procedures vary by country, making it difficult to make direct comparisons, establishing standard sampling and analytical methods for biological processes should be considered.



Prof. Yasunori Sakura describes the variation in walleye pollock catches.

Finally, the topic session B2 on *Walleye Pollock* (Chairs: Y. Sakurai, A. Varkentin and V. Kulik) heard that despite such a long period of walleye pollock study in the Okhotsk Sea, new information is still emerging about its biology. It has been established recently that Okhotsk Sea waters off the northern Kuril Islands and southwestern Kamchatka area is the traditional region of spawning by animals from East Kamchatka (Buslov and Varkentin). Future studies 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 and 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 – until then statistical analysis of strong and significant multivariate, canonical and other analyses may lead to unacceptable biological nonsense; (3) 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; and (6) explore how the extent of ice cover affects the fate of walleye pollock around the Okhotsk Sea.

The final day was held in plenary to develop session reports and proposals for FUTURE. After the announcements for the preparation of workshop proceedings, the co-conveners provided closing remarks. The results of the workshop will be published in the PICES Scientific Report Series in early 2009.