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Keynote Address

PICES XV
Biological production, animal migration and ecosystem regime shifts in the Kuroshio and Oyashio Currents: Perspectives for sustainable use

Akihiko **Yatsu**

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The poleward-flowing Kuroshio and the equatorward-flowing Oyashio are western boundary currents that transport heat, nutrients, and planktonic animals, including fish larvae from the subtropical/subarctic gyres, to the coastal areas of the Japanese archipelago. They converge east of Honshu Island to form an oceanographically complex Transition Zone that is an important area for the recruitment of some pelagic fishes of commercial interest. These species have developed life history traits and horizontal migration patterns by adapting to the seasonality of biological production and oceanography. Climatic and ecosystem regime shifts are key factors affecting the population dynamics of species in this region and need to be considered for the sustainable use of the region's ecosystem services, including fish harvests. Proper understanding of how ecosystem dynamics are linked to both climate and human activities are essential for wise management, which recognizes ecosystem factors and various uncertainties. The most plausible mechanisms for sardine/anchovy cycles in the Kuroshio/Oyashio system are discussed to highlight the importance of these interconnections. Perspectives for sustainable use of ecosystem services, including fishing, will be discussed more generally in relation to case studies involving: 1) reclamation effects on a coastal ecosystem, 2) mitigation efforts, 3) successful adaptive co-management in a coastal fish stock, and 4) failure of fisheries management due to an overcapitalization that resulted from a mismatch between investment to fishing fleets and ecosystem regime shifts.

PICES XV

Abstracts

S1 Science Board Symposium
Boundary current ecosystems

Co-Convenors: Kuh Kim (SB), Michael J. Dagg (BIO), Gordon H. Kruse (FIS), John E. Stein (MEQ) Michael G. Foreman (POC), Harold P. Batchelder (CCCC), Suam Kim (CCCC), Jeffrey M. Napp (MONITOR), Igor I. Shevchenko (TCODE), Fangli Qiao (China) and Yukimasa Ishida (Japan)

The North Pacific is surrounded by boundary currents (*e.g*., Kuroshio, Tsushima, Oyashio, California, Alaska, Bering Slope) that support a diversity of ecosystems. These ecosystems are highly variable in space and time due to combinations of climate change, decadal "regime" shifts, ENSO and other interannual variability, seasonal and event mesoscale dynamics. This variability has led to dramatic changes at both low and high trophic levels, including productivity, range extensions, and species dominance. This theme will provide opportunities to address questions such as: 1) How will climate variation and projected climate change influence the dynamics and variability of boundary currents? 2) How will boundary current ecosystems respond to these physical property and transport changes? 3) How does human activity (*e.g*., fishing, hatcheries) alter the sensitivity of boundary current ecosystems to natural environmental forcing? and 4) What are appropriate management strategies to maintain healthy, sustainable living marine resources in boundary current systems that experience large environmental variations? Presentations that describe, compare and/or contrast physics, biology, fisheries, and geochemistry of boundary currents and the ecosystems they support are encouraged.

Monday, October 16, 2006 11:00-17:50

11:00-11:40 **Akihiko Yatsu** (Keynote)
Biological production, animal migration and ecosystem regime shifts in the Kuroshio and Oyashio Currents: Perspectives for sustainable use

11:40-12:10 **Ichiro Yasuda** (Invited)
The Kuroshio and Oyashio current system: Variability and impact on the ecosystem (S1-2788)

12:10-12:30 **Robert M. Suryan, Fumio Sato, Gregory R. Balogh, Noboru Nakamura, Paul R. Sievert and Kiyoaki Ozaki**
Kuroshio and Oyashio boundary currents: Critical foraging habitat for the short-tailed albatross (*Phoebastria albatrus*), one of Japan's natural monuments (S1-3121)

12:30-12:50 **Sanae Chiba, Hiroya Sugisaki and Toshiro Saino**
Decadal changes of the Oyashio and Kuroshio affected spatio-temporal variation of the copepod community in the western North Pacific (S1-2812)

12:50-14:10 ***Lunch***

14:10-14:40 **Edmundo Casillas and William T. Peterson** (Invited)
The Northern California Current Ecosystem: Variability, indicator development, and an ocean condition index for fishery management (S1-2820)

14:40-15:00 **John A. Barth and John M. Bane**
Intraseasonal wind oscillations and their influence on northern California Current coastal ecosystems (S1-3054)

15:00-15:30 **Arthur J. Miller** (Invited)
Long-term changes in the climate of the California Current, with biological impacts (S1-3059)

15:30-15:50 ***Tea/Coffee Break***

15:50-16:10 **Emanuele Di Lorenzo and Niklas Schneider**
Intrinsic oceanic decadal variability in the North Pacific generated in the Eastern Boundary Current System (S1-3093)

16:10-16:30 **James Christian**
The North Equatorial Countercurrent: An anomalous boundary current with biologically significant upwelling and a predictable response to climate forcing (S1-3055)

16:30-17:00 **J. Anthony Koslow, Ming Feng, Stephane Pesant and Peter Fearns** (Invited)
The biophysical oceanography of the Leeuwin Current, a poleward-flowing eastern boundary current off the west coast of Australia (S1-2999)

17:00-17:30 **Kenneth F. Drinkwater and Svein Sundby** (Invited)
The response of North Atlantic boundary currents and their ecosystems to climate change and variability - Contrasts and comparisons with the North Pacific (S1-3164)

17:30-17:50 **Juergen Alheit**
Synchronous ecological regime shifts in the Kuroshio and Humboldt Currents (S1-2894)

PICES XV S1-2894 Oral
Synchronous ecological regime shifts in the Kuroshio and Humboldt Currents

Juergen **Alheit**

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Decadal-scale dynamics of the Kuroshio and Humboldt Current ecosystems are controlled by shifts between alternating sardine and anchovy regimes that restructure the entire ecosystem. The transition from an anchovy to a sardine regime occurred in both systems between 1969 and 1971. The reversal back to an anchovy regime was observed in both systems in the mid-1980s. The causes for these dramatic, abrupt changes of major biological components in both ecosystems and their striking synchrony are a puzzle. However, the synchrony of events in both systems might be the key to solving the regime shift problem as it points to an external forcing mechanism which drives both systems. Recent work has drawn attention to subsurface processes which might be involved in the regime shift mechanisms. Changes in mixed layer depth in the Kuroshio Current Extension (KCE) region and associated changes in biological production coincide with the population changes observed in the KCE. Similarly, interdecadal changes of thermocline depth off the coast of Peru and Chile which are well correlated with interdecadal SST anomalies occurred at the time of transitions from anchovy to sardine and back to anchovy regimes. The coincidence of the timing of physical processes and ecosystem regime shifts in both ecosystems which are thousands of miles apart from each other raises the question whether both systems are governed by basin-wide climatic teleconnection patterns. This contribution will describe the ecological regime shifts in the two Pacific ecosystems and discuss commonalities, differences and possible teleconnection patterns.

PICES XV S1-3054 Oral
Intraseasonal wind oscillations and their influence on northern California Current coastal ecosystems

John A. **Barth**[1] and John M. Bane[2]

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Intraseasonal oscillations (ISOs) are fluctuations in the atmosphere-ocean-climate system with periods between 20 and 40 days which is longer than the typical 2- to 6-day “weather-band” wind fluctuations that drive coastal upwelling and downwelling. We show how wind ISOs directly influence the coastal ocean ecosystem in the northern California Current System, the eastern boundary current of the North Pacific. During summer 2001 in the Oregon coastal upwelling system, ecosystem variations were due to 20-day ISOs in wind stress. Upper-ocean temperature, phytoplankton and zooplankton varied principally on the 20-day time scale and correlated with the stress, showing the importance of the stress ISOs in driving the oceanic ecosystem. The stress ISOs were driven by variations in the north–south position of the atmospheric Jet Stream, which were generated by an interaction between the Jet Stream and the western U.S. mountain ranges. In 2005, the spring transition to upwelling-favorable wind stress was delayed by over a month in the northern California Current Large Marine Ecosystem by 20- to 40-day wind ISOs associated with a southward shift of the Jet Stream. Early in the upwelling season (May–July) off Oregon, the cumulative upwelling-favorable wind stress was the lowest in 20 years, nearshore surface waters averaged 2°C warmer than normal, surf-zone chlorophyll-*a* and nutrients were 50 and 30% less than normal, respectively, and mussel and barnacle densities were reduced by 83 and 66%, respectively. The negative impact of these changes propagated up the marine food web.

PICES XV S1-2820 Invited

The Northern California Current Ecosystem: Variability, indicator development, and an ocean condition index for fishery management

Edmundo **Casillas** and William T. Peterson

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Since 1997, we have been monitoring the coastal ocean environment of Washington and Oregon, including an assessment of the Columbia River plume, its interaction with the California Current, and how it affects the abundance, distribution, and growth of juvenile salmon as a means to assess their survival as they enter the marine landscape. Our observations indicate the northern California Current is a dynamic large marine ecosystem whose features vary widely at daily to decadal time scales. The ocean conditions we have observed are a measure of the interaction of the physical forces (*e.g.*, temperature, winds, water mass) and the biological features and responses to these physical drivers (*e.g.*, food resources, predator populations). The result of these physical-to-biological interactions is that growth, abundance and survival of fish in the pelagic ecosystem varies each year. Fisheries experts recognize that our ability to manage fishery resources will depend in part on forecasting the impact of changing ocean conditions as a result of the natural variability inherent in the ecosystem and the directed change as a function of impending global climate change. However, until now the region has lacked a clear set of tools that provide this information. I will discuss the physical and biological metrics we have evaluated and our results to date. Our goal is to communicate the status of the Northern California Current Ecosystem annually through a technical report, and in real time by posting the state of the California Current to our website for managers to use.

PICES XV S1-2812 Oral

Decadal changes of the Oyashio and Kuroshio affected spatio-temporal variation of the copepod community in the western North Pacific

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The KOE region, consisting of the Kuroshio, Oyashio and Transition zone, shows the highly variable, complex environments, where dynamics of those currents greatly influence biological production. We report the decadal change in geographical distribution pattern of copepods in the Oyashio and Transition zone using the historical zooplankton collection (Odate Collection). Temporal variation of the copepod community was examined by the principal component analysis (PCA). PC1 time-series mirrored interannual variation of the abundance of "Oyashio assemblage." The "jumps" of the PC1 value were detected in 1976 and 1988, both of which coincided the years of the major and minor climatic Regime Shifts in the North Pacific. On the other hand, PC2 time-series mirrored the variation of small-sized, warm-water species, defined as the "Transition zone assemblage" copepods, and a jump year was observed in 1982. The distribution of the Oyashio assemblage shifted southwestward after 1976, responding to the southern intrusion of the Oyashio. It further shifted west toward the Japanese coast after the 1988, presumably due to the northern intrusion of the Kuroshio. Although there was no clear change in the geographical distribution of the Transition zone assemblage before and after 1982, increase in its abundance was manifest. Considering that geostrophic transport of the Kuroshio increased in the early 1980s, several years after the southward shift of the Oyashio, it is suggested that distribution pattern of the copepod community was determined by the combined effects of lagged and un-lagged hydrographic variations, which are closely related to the Pacific Decadal Oscillation.

PICES XV S1-3055 Oral

The North Equatorial Countercurrent: An anomalous boundary current with biologically significant upwelling and a predictable response to climate forcing

James **Christian**

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The North Equatorial Countercurrent (NECC) forms the southern boundary of the North Pacific Ocean. Meandering ocean currents are known to generate significant upwelling, but the biological significance of this upwelling is not well understood. In the NECC during the 1997-98 El Niño event, satellite images showed a "river of dark water" formed by phytoplankton blooms in a narrow meandering current against a backdrop of oligotrophic waters. These blooms are closely related to the basin-scale dynamics of ENSO (El Niño Southern Oscillation), *i.e*., the chlorophyll anomaly is predictable from real-time observations of *e.g*., tropical Pacific sea surface temperature, or from an ENSO prediction model if the model itself has predictive skill. This region contains some of the world's largest underexploited oceanic fish populations and is a prime candidate for using satellite data and climate models to engineer a sustainable fishery in an underdeveloped region.

PICES XV S1-3093 Oral

Intrinsic oceanic decadal variability in the North Pacific generated in the Eastern Boundary Current System

Emanuele **Di Lorenzo**[1] and Niklas Schneider[2]

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[2] International Pacific Research Center, University of Hawaii at Manoa, 1680 East West Road, Honolulu, HI, 96822, U.S.A.

Decadal variations in the North Pacific have profound implications on the marine ecosystems, which are characterized by nonlinear, and regime-like, responses to changes in the physical environment. Previous studies of the mechanism of North Pacific decadal variability focus on the existence of midlatitude coupled ocean–atmosphere modes, or on the ocean response to atmospheric stochastic variability. However, sources of intrinsic ocean variability, which arise from ocean internal dynamics without atmospheric coupling and stochastic forcing, have not been explored.

In this study we investigate the role of the Eastern Boundary Current System in generating intrinsic decadal variations in the North Pacific. Specifically we show how the intrinsic mesoscale eddy field that develops in the California Current leads to decadal variations in the temperature (T) and salinity (S) properties of the eastern subtropical mode waters (ESMW). The subducted TS anomalies are density compensated and may ultimately lead to a delayed feedback on the tropical coupled ocean–atmospheric system when the ESMW are ventilated by equatorial upwelling.

The findings of this study rely on a multi-century long integration of an eddy-resolving ocean model of the Northeast Pacific. The model is forced either with monthly climatological forcing or with a 50 year-long forcing cycle derived from the National Center for Environmental Prediction (NCEP) reanalysis. A comparison of the model output with the long-term California Cooperative Fisheries Investigations (CalCOFI) TS dataset is also presented. Surprisingly, the model intrinsic variations capture the amplitude and periodicities of the CalCOFI salinity time series, which have been previously unexplained.

PICES XV S1-3164 Invited

The response of North Atlantic boundary currents and their ecosystems to climate change and variability - Contrasts and comparisons with the North Pacific

Kenneth F. **Drinkwater** and Svein Sundby

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Like the North Pacific, the North Atlantic is surrounded by numerous boundary currents (*e.g.*, Gulf Stream, Labrador Current, West Greenland and East Greenland Currents, Norwegian Atlantic Current, Norwegian Coastal Current, *etc*.) with a diversity of ecosystems. Also, like the North Pacific, these ecosystems have been shown to respond to changes in climate from short-term events such as wind storms to long-term multidecadal oscillations and climate warming trends. The responses depend in large degree on the frequency of forcing and various examples from the North Atlantic will be given to highlight these differences. Future climate scenarios will be discussed in terms of the possible changes to these boundary currents and their implications for the marine ecosystems. Discussion will also be presented on the effects of fishing on the sensitivity of fish species to climate forcing. Finally, we ask the question, can we obtain additional insights into the effects of climate forcing on marine ecosystems by comparing and contrasting responses between the North Atlantic and North Pacific?

PICES XV S1-2999 Invited

The biophysical oceanography of the Leeuwin Current, a poleward-flowing eastern boundary current off the west coast of Australia

J. Anthony **Koslow**, Ming Feng, Stéphane Pesant and Peter Fearns

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The Leeuwin Current is a uniquely poleward-flowing eastern boundary current (EBC) off the west coast of Australia. Because it is driven by a pressure gradient established by the Indonesian Throughflow, the primary link between the Pacific and Indian Oceans, its dynamics are closely coupled with variability in the North Pacific circulation, notably the El Niño Southern Oscillation (ENSO) cycle. But unlike other EBCs, the Leeuwin is a warm, nutrient-poor current that suppresses upwelling. As a consequence, the waters off Western Australia are generally oligotrophic. Interestingly, however, recruitment to the region's (and Australia's) most valuable single-species fishery, the western rock lobster (*Panulirus cygnus*), is *positively* correlated with interannual variability in the flow of the Leeuwin Current. The annual phytoplankton bloom also coincides with the period of strongest Leeuwin flow in late autumn, when the current spins up eddies just beyond the shelf break. The eddy kinetic energy of the Leeuwin is greater than that of other EBCs. Recent biogeochemical studies have generated several hypotheses that link the dynamics of the Leeuwin with regional productivity. These hypotheses suggest a mechanism underlying the apparently paradoxical correlation between the strength of the Leeuwin Current and western rock lobster recruitment.

PICES XV S1-3059 Invited

Long-term changes in the climate of the California Current, with biological impacts

Arthur J. **Miller**

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The CalCOFI dataset in the southern California Current reveals a significant surface-intensified warming and stratification (buoyancy frequency) change across the 1976-77 climate regime shifts. However, the average depth of the thermocline, defined as the maximum gradient of temperature, did not change significantly across the regime shift. But as the surface heating changed the strength of stratification, it also changed the slope of the nitrate-temperature relation for the mid-depth waters (roughly 30m to 200m). This may have affected the quality of upwelled water and the depth from which it is drawn. These historical changes can be useful in anticipating the potential impact of global warming on the oceanic circulation off the coast of California. For example, an eddy-permitting ocean model forced with wind stresses, heat fluxes and open boundary conditions obtained from a global climate model forced by increased greenhouse gases predicts increased upper-ocean

temperatures, and increased stratification along the coast. The vertical structure of the thermal response is similar to recent studies of global warming trends.

PICES XV S1-3121 Oral

Kuroshio and Oyashio boundary currents: Critical foraging habitat for the short-tailed albatross (*Phoebastria albatrus*), one of Japan's natural monuments

Robert M. **Suryan**[1], Fumio Sato[2], Gregory R. Balogh[3], Noboru Nakamura[2], Paul R. Sievert[4] and Kiyoaki Ozaki[2]

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The Kuroshio-Oyashio current region is a physically dynamic system supporting rich biological productivity and important foraging habitat for upper trophic level predators, including the short-tailed albatross (*Phoebastria albatrus*). We integrated satellite tracking of albatrosses and oceanographic remote sensing data to identify physical and biological features important to albatross foraging habitat. Nineteen albatrosses were tracked from their breeding colony on Torishima (Izu Islands) for three years, between 2002 and 2006. Primary foraging areas included prominent chlorophyll and sea surface temperature fronts, generally within the 17°C isotherm off the continental shelf break and slope domains. Geographically, these areas were off the northern Izu-Ogasawara Ridge, northeastern Honshu, eastern Hokkaido, and the Kuril Islands. In particular, a cool water tongue of the Kuroshio-Oyashio convergence off northeastern Honshu (35°–40°N) was a consistent foraging destination for albatrosses in all years. Albatrosses foraged progressively northward with the warm water intrusion of the Kuroshio Current during spring and summer. Most satellite-tagged albatrosses had migrated out of the Kuroshio-Oyashio current region by August. Despite the well documented eddy formation and elevated productivity of the Kuroshio extension and bifurcation regions, short-tailed albatrosses made relatively little use of these areas, other than transiting its northern boundary en route to the Aleutian Islands, Alaska. Our results identify prominent features of this boundary current system that are important to foraging for an upper trophic level marine predator, an endemic breeder, and designated natural monument of Japan.

PICES XV S1-2788 Invited

The Kuroshio and Oyashio current system: Variability and impact on the ecosystem

Ichiro **Yasuda**

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Recent studies are changing our view of the Kuroshio and Oyashio current system and water-mass formation in the western boundary currents. Large diapycnal tidal mixing expected around the Kuril and the Aleutian Straits enhances sinking in the Okhotsk Sea, and diapycnal upwelling could promote Oyashio and North Pacific Intermediate Water formation. These processes may have an influence on the Kuroshio and the Kuroshio Extension. Furthermore, large diapycnal mixing changes in the 18.6-year period because the diurnal tidal flow amplitude changes up to 20%. Sea surface temperatures (SSTs) around the Kuril and Aleutian Straits, and the surface to intermediate waters in the North Pacific subarctic region, show evidence of ocean-originated bi-decadal variability. This process may influence atmospheric bi-decadal variability. We also find long-term variability in zooplankton in the Oyashio waters and species replacement of small pelagic fishes among Japanese sardine and Pacific saury. We discuss possible mechanisms behind these long-term changes.

S2 BIO/FIS Topic Session
The human dimension of jellyfish blooms

Co-Convenors: Richard D. Brodeur (U.S.A.), Juahua Cheng (China), Hiroshi Iizumi (Japan) and Won Duk Yoon (Korea)

Large high-density jellyfish blooms are becoming increasingly common in many marginal seas in the North Pacific and in other regions of the world's oceans, and may be important regulators of marine ecosystems. These blooms may have direct effects on fish recruitment through predation on vulnerable early life stages of marine fishes, or indirect effects competing for limited food resources with exploited species. In addition, high concentrations of jellyfish influence humans in other ways like economic losses in tourism through beach closures, impeding commercial fishing through net clogging, and loss of energy production through clogging of power plant intakes. If jellyfish populations continue to increase in the coming decades, their impacts on human populations are also likely to increase. This session seeks to understand the causes of the proliferation and expansion of jellyfish blooms in coastal waters and whether climatic or anthropogenic changes have led to the recent blooms. In particular, studies examining the impacts of these blooms on humans and the economies that sustain them, and ways to predict their occurrence and spread are encouraged. The convenors are planning a *special issue in a primary international journal* (to be determined) so contributors to this session should express their interest in submitting a full manuscript during abstract submission.

Friday, October 20, 2006 09:00-17:30

09:00-09:10 **Introduction by Convenors**

09:10-09:50 **Jennifer E. Purcell** (Invited)
Interactions of multiple factors contribute to infestations of jellyfish (S2-3142)

09:50-10:30 **Shin-ichi Uye** (Invited)
Bloom of the giant jellyfish *Nemopilema nomurai*: A threat to the East Asian Marginal Seas fisheries sustainability (S2-2776)

10:30-11:00 ***Tea/Coffee Break***

11:00-11:40 **Tamara A. Shiganova** (Invited)
Comparative analyses of invasive gelatinous species blooms in the Black, Azov, Caspian and Aegean Seas and their effect on ecosystems and fisheries (S2-3228)

11:40-12:00 **Hitoshi Iizumi, Osamu Katoh, Tatsuro Watanabe, Naoki Iguchi, Koh Nishiuchi, Toru Hasegawa, Kosei Komatsu, Kazufumi Takayanagi and Masaya Toyokawa**
Mass appearance of the giant jellyfish, *Nemopilema nomurai*, along the coastal area of Japan (S2-3223)

12:00-12:20 **Joon-Yong Yang, Soo-Jung Chang, Jae Hong Moon, Won Duk Yoon and Donghyun Lim**
Distribution of *Nemopilema nomurai* in Korean waters in 2005 and its possible origin (S2-3151)

12:20-14:00 ***Lunch***

14:00-14:20 **Jia-Hua Cheng, Feng-Yuan Ding, Sheng-Fa Li and Hui-Yu Li**
Study on the quantitative distribution pattern of macro-jellyfish in the East China Sea (S2-3241)

14:20-14:40 **Jason S. Link, Michael D. Ford and Elizabeth Fulton**
Widespread and persistent increase of Ctenophora in the Northeast U.S. shelf ecosystem: Evidence from spiny dogfish (*Squalus acanthias*) and implications for large marine ecosystems (S2-3051)

14:40-15:00 **Hye Eun Lee, Won Duk Yoon and Donghyun Lim**
Predator on polyps of *Nemopilema nomurai* (Scyphzoa, Rhizostomeae) (S2-2997)

15:00-15:20 **Kristin Cieciel, Lisa Eisner, Angela Feldmann and Mary Courtney**
Size structure, distribution, and interaction characteristics of dominant jellyfish from surface trawls in the Eastern Bering Sea (S2-3053)

15:20-15:40 **Haruto Ishii**
Adaptation to coastal environmental changes in the polyp stage in relation to jellyfish blooms in Tokyo Bay (S2-3117)

15:40-16:00 ***Tea/Coffee Break***

16:00-16:20 **Richard D. Brodeur, Cynthia Suchman, Doug Reese, Todd Miller, Jim Ruzicka and Elizabeth Daly**
Spatial overlap and trophic interactions between fish and large jellyfish in the northern California Current (S2-2931)

16:20-16:40 **Jing Dong, Chun-Yang Liu, Yang-Qing Wang and Bin Wang**
Laboratory observations on the life cycle of *Cyanea nozakii* (Semeostomida, Scyphozoa) (S2-2856)

16:40-17:00 **Miyuki Hirose, Tohru Mukai, Kohji Iida and Doojin Hwang**
Acoustic observations on the jellyfish *Nemopilema nomurai* in the East China Sea (S2-2817)

17:00-17:30 **Discussion and Summary**

Posters

Naoki Fujii, Akiko Fukushima, Yuta Nanjo and Hidetaka Takeoka
Aggregations of *Aurelia aurita* in Uwa Sea, Japan (S2-3005)

Hye Eun Lee, Won Duk Yoon and Donghyun Lim
The prey passage of *Nemopilema nomurai* (Scyphozoa, Rhizostomeae) (S2-3000)

Seok Hyun Lee, Won Duk Yoon and Dong Hyun Lim
Effect of heavy metals on polyps of the *Aurelia aurita* (S2-2990)

Xiancheng Qu, Masaya Toyokawa, Ying Liu and Yasuaki Nakamura
Molecular biological analysis of jellyfish (*Nemopilema nomurai kishinouye*) mitochondrial 18S ribosomal RNA (S2-3104)

James J. Ruzicka, Thomas C. Wainwright and Richard D. Brodeur
Trophic interactions within the pelagic community of the Oregon and Washington upwelling ecosystem: A modeling study of the role of large jellyfish (S2-3045)

Jun Shoji
Quantitative and qualitative changes in predator-prey relationship between moon jellyfish and fish larvae in summer hypoxia: Possible increase in trophic flow to jellyfish in coastal ecosystems (S2-3028)

Euikyung Kim, Seunghwan Lee, Jong-Shu Kim, Won Duk Yoon, Donghyun Lim, Andrew J. Hart and Wayne C. Hodgson
Cardiovascular effects of *Nemopilema nomurai* (Scyphozoa, Rhizostomeae) jellyfish venom in rats (S2-2896)

PICES XV S2-2931 Oral

Spatial overlap and trophic interactions between fish and large jellyfish in the northern California Current

Richard D. **Brodeur**[1], Cynthia Suchman[2], Doug Reese[3], Todd Miller[4], Jim Ruzicka[5] and Elizabeth Daly[5]

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Due to dramatic explosions of jellyfish populations that have been increasing in frequency and expanding in geographic coverage, researchers have become concerned that their presence may affect coastal fish populations. We have conducted multi-year trawl surveys in the northern California Current and documented a substantial biomass of jellyfish consisting primarily of four species (*Chrysaora fuscescens*, *Aurelia labiata*, *Aequorea* spp., and *Phacellophora camtschatica*). The total biomass of these species in spring (April-June) is around 0.5-0.7 of the small pelagic fish biomass, whereas by summer (July-September), their biomass exceeds that of small pelagics by 6-10 fold due primarily to exponential individual growth of jellyfish. Spatial overlap of these jellyfish with pelagic fishes including salmon is minimal, but there are regions of intense overlap where trophic interactions may be occurring. We compared feeding ecology of jellyfish and pelagic fishes using diet analysis and stable isotope composition and found that trophic overlap can be high with planktivorous species such as Pacific sardines and herring that consume copepods and euphausiid eggs. We found no indication of predation by jellyfish on the early life stages of marine fishes. However, isotope and diet analyses suggest that jellyfish occupy a trophic level similar to small pelagic fishes such as sardines and northern anchovy and have the potential, given their substantial biomass, of competing with these species especially in years of low plankton production. We constructed Ecopath models of the coastal pelagic ecosystem to examine seasonal and interannual variations in the relative consumption of jellyfish and fish.

PICES XV S2-3241 Oral

Study on the quantitative distribution patterns of macro-jellyfish in the East China Sea

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Based on the investigations of macro-jellyfish resources carried out in the central and northern parts of the East China Sea during April and June 2004, the species composition, quantitative distribution, relationships to temperature and salinity, and the growth differences among the major jellyfish species were analyzed. The dominant species in April were *Aequorea* sp. (about 85%), *Cyanea* sp. (about 10%) and *Stomolophus meleagris* (about 5%). However in June, the dominant species were *Stomolophus meleagris* (about 60%), *Aequorea* sp. (about 25%), and *Cyanea* sp. (about 10%). *Stomolophus meleagris* and *Aequorea* sp. are the species that have caused major jellyfish eruptions in the East China Sea in the past. *Stomolophus meleagris* is a low-temperature and high-salinity species with an optimal temperature range of 12~17°C, and is distributed mainly in northern regions where the front of the Yellow Sea cold water mass extends to the East China Sea. Their biomass catch rate is around 10t h^{-1} in the high-density distribution area. *Cyanea* sp. is warm-water, high-salinity species with a preferred temperature range of 20~25°C, and is found in high density in the warm region in the north part of East China Sea. The Yellow Sea cold water mass can be used as an important reference factor for examining the distribution of *Stomolophus meleagris.* Among the dominant species of macro-jellyfish in the East China Sea, *Stomolophus meleagris* grows the fastest, followed by *Cyanea* sp., whereas *Aequorea* sp. grows more slowly and reaches a smaller terminal size.

PICES XV S2-3053 Oral

Size structure, distribution, and interaction characteristics of dominant jellyfish from surface trawls in the Eastern Bering Sea

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Due to increasing research interest in gelatinous zooplankton, the Bering Aleutian Salmon International Survey (BASIS) trawl surveys conducted in late summer/fall 2004, 2005, and spring/summer 2006, targeting epipelagic fish in the Eastern Bering Sea, were used opportunistically to sample gelatinous bycatch. All medusae caught in the surface trawl were sorted by species, and subsampled for bell diameter and wet weight (Suchman and Brodeur, 2005). Oceanographic data was collected before each tow, using a CTD and water sampler. The most abundant gelatinous species were analyzed for biomass with associated water mass characteristics (temperature, salinity, nutrients and Chlorophyll-*a*), volume (wet weight) to length (bell diameter) ratios, size structure, spatial distribution (south vs. north shelf), and temporal variation (summer vs. fall). Comparisons were also made between the most abundant fish and medusae species. Gelatinous zooplankton was present at nearly every station for each year, but the majority of the biomass was concentrated at only a small number of stations. Chrysaora melanaster had the highest density for all years, followed by: *Aequorea* sp., *Cyanea capillata*, *Starophora mertensi*, *Aurelia labiata*, and *Phallocephora camstichatica*. Information from this study will provide baseline data on biometrics and ecosystem interactions for the less studied medusae in Alaskan waters and strengthen it for the more known species, *C. melanaster* and *A. labiata*. Data collection will continue in late summer/fall 2006, and possibly onward, allowing future interannual comparisons.

PICES XV S2-2856 Oral

Laboratory observations on the life cycle of *Cyanea nozakii* (Semeostomida, Scyphozoa)

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The life cycle of the scyphozoan *Cyanea nozakii* Kishinouye was described from the fertilized-egg to the ephyra stage for the first time. Embryogenesis from fertilized egg and cleavage of the zygote to blastula stage took place in the water column and planulae formed after 14 hours at 20.8-21.4°C. Planulae formed plano-convex cysts (planulocysts) on attachment prior to forming scyphistomae. In addition to planulocysts, scyphistomae of *Cyanea nozakii* also produced podocysts and tendrils, which could be involved in formation of new cysts and development of new scyphistomae. Strobilation was typically monodiscous, although strobilae liberated two ephyrae occasionally. Newly liberated ephyrae had 8 marginal lobes, 8 rhopalia and 8 pairs of blunt-shaped lappets, although some aberrant specimens had maximum of 12 and minimum of 6 marginal lobes. The interaction between mature individuals was important for spawning and fertilization.

PICES XV S2-3051 Oral

Widespread and persistent increase of Ctenophora in the Northeast U.S. shelf ecosystem: Evidence from spiny dogfish (*Squalus acanthias*) and implications for large marine ecosystems

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Changes detected in the prey composition of the stomachs of opportunistic feeding fishes can provide information on various ocean ecosystem dynamics. During 1981-2000, stomach samples of the spiny dogfish,

Squalus acanthias, showed a major increase in the overall occurrence and hence implied abundance of Ctenophora - gelatinous zooplankton that range throughout the ecosystem. There have been a few such major increases in ctenophores in enclosed (*e.g.*, Caspian Sea) and semi-enclosed (*e.g.*, Mediterranean Sea) ecosystems, where there have been concomitant significant effects on those ecosystems and the productivity of their fishery resources. We show the first such increases in ctenophores in an open ecosystem, persistent over two decades. Distribution of the occurrence of ctenophores has also expanded. We briefly explore the energetic ramifications of ctenophores in the spiny dogfish diet, inferring that the presence of these gelatinous zooplankton represents an ambient feeding strategy. We also examine the utility of using spiny dogfish as a gelatinous zooplankton sampling device. Given some basic calculation assumptions, we provide bounds on potential biomass estimates of ctenophores in the Northeast U.S. shelf ecosystem. We then contextualize these findings relative to the large implications for the productivity of the fishery resources in any large marine ecosystem.

PICES XV S2-3005 Poster
Aggregations of *Aurelia aurita* in Uwa Sea, Japan

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Moon jellies, *Aurelia aurita*, usually form aggregations in the coastal surface waters of Uwa Sea, western Shikoku, Japan, in the summer. Using a video monitoring system set up on a hill with a full view of Hokezu Bay (a part of Uwa Sea) during the summer and autumn of 2005, we observed that moon jellies occurred in dense aggregations between mid-August and late-September. By mid-August, seawater temperature was rising suggesting that the physical transport of moon jellies by a swift intrusion current from offshore to inshore (called "Kyucho" in Japan) was primarily responsible for this increase. When moon jellies formed aggregations, planula larvae were increasing in the coastal area. These aggregations might be advantageous for their fertilization success.

PICES XV S2-2817 Oral
Acoustic observations on the jellyfish *Nemopilema nomurai* in the East China Sea

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Jellyfish abundance has been increasing worldwide which could have a negative effect on fisheries because jellyfish prey on zooplankton, fish eggs, and juvenile fishes. Thus, jellyfish are now recognized as an important predator and competitor in marine ecosystems. Information on the abundance of jellyfish can be used to help manage fisheries and identify changes in marine ecosystems. Acoustic techniques are commonly used to study the distribution and abundance of fish and zooplankton because these techniques can survey large areas of the ocean in relatively short periods. However before such surveys can be conducted, the acoustic characteristics of the target species must be known. The purpose of this study was to determine the acoustic characteristics of live individuals of the jellyfish, *Nemopilema nomurai*, which commonly occurs in the Yellow Sea and the Sea of Japan, to make such acoustic surveys possible. Data were collected by the training ship *Dong Baek* of Yosu National University, South Korea, in June 2005 at a station where many jellyfish were observed. Acoustic data were collected using 38 and 120 kHz scientific echosounders (EK500, SIMRAD) and the jellyfish were collected using a square mid-water frame trawl and a bottom trawl. The acoustic characteristics of jellyfish were obtained, and our results suggest that acoustic methods can be used to accurately estimate the distribution and abundance of jellyfish.

PICES XV S2-3223 Oral

Mass appearance of the giant jellyfish, *Nemopilema nomurai*, along the coastal area of Japan

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Giant jellyfish, *Nemopilema nomurai*, appeared in massive numbers along the Japanese coastal area from August 2005 until February or March in the following year, causing severe damages to local fisheries. This phenomenon previously occurred in 1958, 1995, 2002 and 2003, showing that the mass appearance occurred more frequently in the last several years than in previous times. This jellyfish also appeared to some extent in other years but the number of the jellyfish was not so large as in those in years mentioned above. Differences in the numbers of jellyfish among years are large. There appears to be at least two factors, both of which should be fulfilled, to cause these mass appearances along the Japanese coast. One is a biological/ecological factor; mass generation of free-swimming ephyras (and then medusae) from scyphistomae. So far, areas of the jellyfish polyp generation are not confirmed yet. However, a survey in China suggests that the jellyfish biomass, including not only *N. nomurai* but also other large jellyfish species to some extent, in East China Sea and Yellow Sea has increased in recent years, and that, even in 2004 when the mass appearance did not occur in Japan, total biomass of jellyfish was similar to that in 2003. This biological factor could control long-term trends in jellyfish production. The other factor to consider is a physical one; transportation from East China Sea and Yellow Sea, where the main population of this jellyfish grows, to Japanese coastal waters through Tsushima Strait. This factor could control short-term trends. To elucidate the relative importance of these factors, we have started collaboration between Japan, China and Korea.

PICES XV S2-3117 Oral

Adaptation to coastal environmental changes in the polyp stage in relation to jellyfish blooms in Tokyo Bay

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The influence of environmental changes such as eutrophication may result in serious problems in many coastal waters. Tokyo Bay is one of the most eutrophicated bays in Japan, and jellyfish blooms have often been observed in association with eutrophication. *Aurelia aurita* is often the dominant scyphomedusan species in coastal waters, and particularly in summer, mass occurrences of this medusa causes serious problems as they clog intake pipes of power plants. To elucidate the mechanism involved in the mass occurrence of jellyfish, we studied the adaptation behavior to coastal environmental changes in the polyp stage. In coastal environments, settling substrate for polyp has been increasing by reclamation, and dense aggregation of polyps in dysoxic bottom-layer waters resulting from eutrophication have been found during summer. This layer is characterized by low recruitment and low growth of other benthic organisms such as *Mytilus galloprovincialis*, resulting in an abundant settlement and high survival in polyp stage. Apparent growth of polyps and production of daughter polyps by asexual budding were observed even in the polyps cultured in hypoxic waters. We need to understand the relationship between the abundance of polyps with various jellyfish species in eutrophic coastal waters and their adaptation to dysoxic bottom-layer waters resulting from eutrophication.

PICES XV S2-2997 Oral
Predator on polyps of *Nemopilema nomurai* (Scyphzoa, Rhizostomeae)

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The life cycle of Scyphozoa is composed of a sexual medusoid stage and an asexual polypoid stage. The number of polyps can increase exponentially and the abundance of medusae greatly depends on the success of that polyp stage. We report, for the first time, predation on polyps of *Nemopilema nomurai* by an invertebrate worm and by *Aurelia aurita* polyps. The invertebrate worm has oval shape with a length between 200μm and 1000μm. The worm used pleated appendages, located vento-laterally at the end of the body, for feeding. The worms were only observed with polyps of *N. nomurai*, but not with *A. aurita* polyps. A series of predation experiments were carried out: worm - *N. nomurai* polyp, worm - *A. aurita* polyp, and polyps of *N. nomurai* - *A. aurita*. In the worm - *N. nomurai* experiment, the worms attached their appendages to the surface of the polyp and began to feed after several touches with the head part. In worm - *A. aurita* experiment, *A. aurita* polyps elongated their tentacles and captured the worm. In polyps only experiment of *N. nomurai* - *A. aurita*, *A. aurita* polyps captured *N. nomurai* polyps in a typical manner. We noted that although the polyps of *N. nomurai* are larger than those of *A. aurita*, polyps of *A. aurita* swallowed them slowly, gradually attaching their mouth to the surface of *N. nomurai* polyp. These results showed the highly voracious feeding behaviour of *A. aurita* polyps and suggested the possible control of *N. nomurai* at the early stage using their predators.

PICES XV S2-3000 Poster
The prey passage of *Nemopilema nomurai* (Scyphozoa, Rhizostomeae)

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The giant jellyfish, *Nemopilema nomurai*, mainly occurs in the East China Sea, Yellow Sea, South Sea, and East/Japan Sea from the late spring to the beginning of winter. *N. nomurai* feed on zooplankton including fish eggs and larvae, affecting from the bottom to the top the regional marine ecosystem. To elucidate the food passage of this species, *N. nomurai* was fed with *Artemia* naupli (within 24 hours after hatching) in excess concentrations. *N. nomurai* used their tentacles, cirri, oral arms, scapulets simultaneously and independently for feeding. Numerous cirri are located around small holes which are merged into one main canal extending into each oral arm. Each main canal joins at manubrium and is connected to the central stomach, where food is digested by gastric filaments. The diameter of terminal canal of oral arms and scapulets is about 1mm. *N. nomurai* adults do not have a mouth, as the polyp and ephyra stages do Metephyra have cirri for feeding as the adults, but have not developed any hole or canal yet. The ephyra is much smaller than the adult, but could capture and ingest prey of similar size as the adult. At the end of ephyral stage, the central mouth fuses and leaves 4 slits where holes and tubes are formed.

PICES XV S2-2990 Poster
Effect of heavy metals on polyps of the *Aurelia aurita*

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Aurelia aurita are widespread in the world and biological studies and information on this species are abundant. However, the relationship between this species and water pollution is relatively scarce and interpretation of field data, especially in where that species occurs abundantly, is rather speculative. Therefore, in the present studies we investigated the tolerance of *A. aurita* polyps to the varying concentration of three heavy metals. Polyps of *A. aurita* were exposed to varying concentration of Cu, Cd and Pb, and their survival, asexual reproduction and resettlement rate were followed. Heavy metals concentration was 0.01268, 0.1268, and 1.268 mg l^{-1} for Cu,

0.130, 1.30, 13.0 mg l^{-1} for Cd, and 0.100, 1.00, 10.0 mg l^{-1} for Pb. The mid concentrations were taken as references that were extracted from field data within Masan Bay, Korea. The results showed that the survival rates were, respectively for 3 concentrations, 100%, 80% and 0% for Cu, 100%, 87% and 0% for Cd, and 100%, 84%, 57% for Pb. Asexual reproduction started on the third day in the 0.100 mg l^{-1} level of Pb, continued and reached 200% at the end of experiment. Asexual reproduction in the control group was 140%, and similar rates were recorded for 0.01268 mg l^{-1} of Cu and 0.130 mg l^{-1} of Cd. The rates in the higher concentration were not null, indicating high tolerance to heavy metals. Resettlement rates were 93% in control and was similar to that of the lowest Cu, Cd and Pb concentrations. However, increasing concentrations decreased the resettlement rate down to 40% in Pb (10.0 mg l^{-1}).

PICES XV S2-3142 Invited
Interactions of multiple factors contribute to infestations of jellyfish

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Many human activities may simultaneously contribute to increases in jellyfish populations in coastal waters. The effects on jellyfish populations may be direct, through aquaculture of jellyfish and providing new substrates (aquaculture pens, harbors, oil rigs) for benthic polyps and hydroids of jellyfish, or indirect, by increasing the amount of food available through nutrient enrichment (sewage, fertilizers), which can increase small zooplankton, turbidity and hypoxia, conditions that favor jellyfish over fish. Similarly, fishing can remove fish predators of jellyfish (*e.g.* mackerels) as well as zooplanktivorous fish competitors (*e.g.* anchovies). Global warming may have both direct (increased jellyfish production) and indirect effects through the food web on jellyfish populations. Accidental introductions of jellyfish via shipping have had serious ecological consequences. Dramatic increases in jellyfish usually have occurred where multiple factors could have been responsible. At times, the ecosystem disruptions have resulted in replacement of fish by jellyfish. Large populations of jellyfish, in turn, directly interfere with human industries, including fishing (net clogging), aquaculture (killing fish), power plant operations (intake clogging), and tourism (stinging). Indirect interference by jellyfish, such as eating ichthyoplankton and zooplankton, which harms fish populations, is ubiquitous, but difficult to document. I will summarize evidence for factors that may increase jellyfish populations and the incidence of problem jellyfish blooms.

PICES XV S2-3104 Poster
Molecular biological analysis of jellyfish (*Nemopilema nomurai kishinouye*) mitochondrial 18S ribosomal RNA

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In this study, the genomic DNA of jellyfish (*Nemopilema nomurai kishinouye*) sampled from the Sea of Japan and East China Sea was extracted by Qiagen DNA extraction kit, CTAB, UNIQ-10 Spin Column and phenol/chloroform precipitation methods respectively, from the gonad, oral arm and umbrella tissues. Then, PCR was carried out to amplify a fragment of nuclear 18S ribosomal RNA. The results showed that DNA extraction by CTAB method from gonad is feasible for DNA analysis of this species. Electrophoresis of the PCR product showed a band at about 1.6kb, and it also showed that *Nemopilema nomurai kishinouye* nuclear DNA decomposed easily. We conducted a nuclear DNA 18S ribosomal RNA sequence analysis of several dominant jellyfish species (including *Nemopilema nomurai kishinouye*) sampled from the Bohai Sea, Yellow Sea and East China Sea using CTAB and PCR methods and compared differences in *Nemopilema nomurai kishinouye* 18S ribosomal RNA among different sea areas, as well as differences among all the sampled species in a same sampling location. Following this, we analyzed *Nemopilema nomurai kishinouye* genomic DNA gene using other methods such as RAPD and AFLP to investigate the polymorphism of this species.

PICES XV S2-3045 Poster

Trophic interactions within the pelagic community of the Oregon and Washington upwelling ecosystem: A modeling study of the role of large jellyfish

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The Northern California Current (NCC) off Oregon and Washington is a seasonally productive and open ecosystem. During the upwelling season it is home to a diverse endemic community including the juveniles of important salmon stocks and to transient species migrating from the south. Ecosystem productivity and food-web structure vary on seasonal to decadal time scales due to timing and strength of seasonal alongshore winds and forcing by climate-scale physical processes (El Niño, Pacific Decadal Oscillation, longer-term climate trends). This affects the survival and productivity of all members of the pelagic fish community. Jellyfish, in particular, can obtain a high biomass and may become an important energy pathway diverting zooplankton production away from pelagic fishes. We develop a quantitative, mass-balance food-web model for the upwelling season of the NCC ecosystem within the Ecopath framework. The model is based upon the coupled benthic and pelagic model developed by Field *et al*., 2006 [Prog. Oceanogr. 68:238-270] expanded to provide additional detail to the pelagic community. In particular, we investigate the importance of large jellyfish and their role as potential competitors for zooplankton prey with coastal pelagic fish including juvenile salmon. Information about fish and jellyfish biomass, distribution, and diet is provided by pelagic trawl surveys, and information about lower trophic-level production is provided by time-series zooplankton surveys. This static model provides the framework for future dynamic simulation studies of food-web response to various physical and ecological perturbations.

PICES XV S2-3228 Invited

Comparative analyses of invasive gelatinous species blooms in the Black, Azov, Caspian and Aegean Seas and their effect on ecosystems and fisheries

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At present time due to anthropogenic and climatic effects, zooplankton communities are changing towards an increasing share of harmful gelatinous plankton, particularly in semi-closed and closed seas. Anthropogenic eutrophication in these coastal areas creates favorable conditions for gelatinous zooplankton blooms. Fishing efforts continue to rise, and removal of valuable species from ecosystems may increase prey concentrations for gelatinous animals that are successful competitors for the same food as many fish and consumers of fish eggs and larvae. Inflating populations of gelatinous species in their native habitats affect local ecosystems, raising the probability of spreading to other non-native areas with ballast waters, where they may explode due to their previous disturbances.

Such an accidental introduction was an invasion of *Mnemiopsis leidyi* in the Black Sea, where it had an explosive outbreak starting in 1988 and then expanded to the Azov, Marmara, and eastern Mediterranean through the straits, and in 1999 into the Caspian Sea with ballast waters. *M. leidyi* is a polymorphic species with wide environmental tolerance and high phenotypic variability which likely aided its establishment in different environmental conditions of each of these seas. Environmental conditions determined its morpho-physiological features in its possible range of phenotypic alternative development. The most sensitive effects on the ecoyststem were in the productive Black, Azov and Caspian Seas. No remarkable effects were recorded in the oligotrophic Aegean Sea. The functioning of the Black and Caspian ecosystems was changed after *M. leidyi* outbreak. Cascading effect occurred at high and low trophic levels in both top down and bottom up manners. But with appearance of the ctenophore *Beroe ovata,* another gelatinous invader and a predator of *M. leidyi* , the Black Sea ecosystem began to recover. *B. ovata* spread via straits to the Sea of Azov, Marmara and Aegean. The Mediterranean basin and the Caspian Sea examples provide yet another illustration that a gelatinous alien carnivore, well adapted to rapid expansion, can suppress whole ecosystems and their functioning.

PICES XV S2-3028 Poster

Quantitative and qualitative changes in predator-prey relationship between moon jellyfish and fish larvae in summer hypoxia: Possible increase in trophic flow to jellyfish in coastal ecosystems

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The moon jellyfish *Aurelia aurita* has increased in abundance in coastal waters around Japan during recent decades. Since the moon jellyfish is highly tolerant of low dissolved oxygen concentrations, predation impacts by moon jellyfish on zooplankton can increase during summer hypoxia in the coastal waters caused by anthropogenic effects such as increase in nutritional loading from the land. We conducted laboratory experiments in order to test the hypothesis that summer hypoxia leads to quantitative and qualitative changes in trophic flow to moon jellyfish by affecting predator-prey relationships between moon jellyfish and larval fish. Larvae of a common coastal fish, the red sea bream *Pagrus major* (3, 4, 6 and 9 mm SL), were used for the experiments. Predation rates (% of larvae predated by a moon jellyfish per 10 min.) were examined at four oxygen concentrations (1, 2 and 4 mg L^{-1} and saturation) in 10 L tanks (4 replications). Size-selective predation was observed at the two highest oxygen concentrations: half of 6 and 9 mm larvae survived the 10 min. trials while more than 90% of 3 and 4 mm larvae were predated upon. Larval size did not affect the predation rates at the two lowest oxygen concentrations: more than 90% of larvae at all size classes were consumed. These results indicate that trophic flow from ichthyoplankton to moon jellyfish increases during summer hypoxia in coastal waters and a qualitative change in predator-prey interaction (*i.e.*, a shift from size-selective to non-size-selective predation) occurs at < 2 mg L^{-1}.

PICES XV S2-2776 Invited

Bloom of the giant jellyfish *Nemopilema nomurai*: A threat to the East Asian Marginal Seas fisheries sustainability

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The rhizostome jellyfish, *Nemopilema nomurai*, endemic in the East Asian Marginal Seas (*i.e.*, the Bohai, Yellow, East China and Japan Seas), is unique by both enormous body size (maximum bell diameter and wet weight: 2 m and 200 kg, respectively) and population outburst. The massive bloom used to occur once per *ca*. 40 years (*i.e.*, in 1920, 1958 and 1995), but became increasingly frequent recently (*i.e.*, in 2002, 2003 and 2005). Our recent experiment revealed some life cycle characteristics of this species *e.g.*, 1) asexual reproduction by means of podocyst formation, 2) induction of strobilation by thermal increase, and 3) ephyrae liberation occurrence in April-June. Both knowledge on the spatiotemporal distributions of medusae and physical modeling show that the meduae are originated in the Yellow and East China Seas and transported by the Tsushima Current to the Japan Sea. The bloom in 2005 was perhaps the largest ever in history, as 300-500 million medusae were transported through the Tsushima/Korea Straits per day in late July and there were total of >100,000 complaints from fishermen about nuisance to fisheries, particularly net-fisheries. Causes for the recent blooms of *N. nomurai* are still under investigation, but may be response to environmental changes, such as increased water temperature and eutrophication, habitat modification, and over-fishing in the seeding and nursery ground of *N. nomurai*, or Chinese coastal waters. Proliferation of jellyfish is apparently a threat to the fisheries sustainability of the East Asian Marginal Seas, the world top level productive fisheries ground.

PICES XV S2-3151 Oral
Distribution of *Nemopilema nomurai* in Korean waters in 2005 and its possible origin

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Recently, there has been a dramatic increase in biomass of *Nemopilema nomurai* causing fisheries damage in the marginal seas of the northwest Pacific. Environmental factors such as food abundance, temperature, salinity, and light are recognized as important factors in the developmental stage of jellyfishes. However, the aggregation and movement of the population depend on oceanic currents and winds. Blooms of *N. nomurai* have been recorded in the East China Sea (ECS), the Yellow Sea, and the East/Japan Sea. According to a recent study, the northeastward Taiwan-Tsushima current is psotulated to play a pivotal role in appearance of this jellyfish in Korean and Japanese waters.

We investigated the distribution of *N. nomurai* from a survey made in 2005 in waters around Korean Peninsula and speculated its possible origin using SeaWiFS ocean color images, surface salinity distribution by shipboard CTD, and a numerical model. This jellyfish was found west of Jeju Island and the West Sea of Korea in August. SeaWiFS ocean color images and surface salinity distribution showed that the Changjiang Diluted Water (CDW) flowed northeastward towards Jeju Island, in accordance with the jellyfish distribution. This was reinforced by Chinese surveys that report that the highest density of jellyfishes was in the northern part of the ECS near the Changjiang River. These data strongly suggest that the jellyfishes around Jeju Island were transported along with the CDW. In addition, numerical simulation of the migration of that jellyfish in 2005 explained part of the variation of *N. nomurai*'s population structure

PICES XV S2-2896 Poster
Cardiovascular effects of *Nemopilema nomurai* (Scyphozoa, Rhizostomeae) jellyfish venom in rats

Euikyung Kim[1], Seunghwan Lee[1], Jong-Shu Kim[1], Won Duk **Yoon**[2], Donghyun Lim[2], Andrew J. Hart[3] and Wayne C. Hodgson[3]

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Over the past few years populations of the giant jellyfish *Nemopilema nomurai* (Scyphozoa, Rhizostomeae) have increased dramatically in the waters of China, Korea, and Japan without any definitive reason. This has resulted in severe damage to fisheries in the areas. The urgent concern in public health especially for fishermen and recreational swimmers prompted us to investigate the biological effects and the mechanism of action of the venom. Results from a previous pilot study indicated that the venom of *N. nomurai* produced a severe functional cardiac depression in mice. However, the mechanism of action was not examined. In the present study, we investigated the cardiovascular effects of nematocyst-derived venom from *N. nomurai* in anesthetized rats. Venom (0.1-2.4 mg protein/kg, i.v.) produced dose-dependent hypotension and bradycardia. At the highest dose, this was characterized by a transient decrease in blood pressure (phase 1) followed by a return to basal level and then a slower decrease in blood pressure (phase 2). Heart rate showed a similar pattern. The venom also produced a decrease in rate and force of contraction in the rat isolated atria. These results suggest that the negative inotropic and chronotropic effects of the venom of *N. nomurai* are due to a direct effect on the heart.

S3 BIO Topic Session
Interactions between biogeochemical cycles and marine food webs in the North Pacific

Co-sponsored by IMBER (Integrated Marine Biogeochemistry and Ecosystem Research)
Co-Convenors: Angelica Peña (Canada), Hiroaki Saito (IMBER/Japan) and Sinjae Yoo (Korea)

Marine food webs and their components influence and respond to the abundance and distribution of biogenic elements in the ocean. Organic matter produced by phytoplankton is continuously transferred from lower to higher trophic levels, and transferred back to constituent elements through decomposition and re-mineralization by detritivores and microbes. Changes in microbial and phytoplankton activity, due to changes in the availability of macro- and micronutrients, can alter the composition, production and transfer of organic matter to upper trophic levels and its subsequent degradation. A better understanding of the fundamental interactions between biogeochemical cycles and food webs is necessary to advance our understanding and prediction of the responses of marine ecosystems to natural and anthropogenic perturbations, such as changes in physical dynamics and carbon cycle chemistry, dust events, eutrophication and marine harvest. The North Pacific and adjacent seas include a wide range of ecosystems and some unique environmental conditions, providing opportunities to investigate and compare the role of biological processes on biogeochemical cycles in different systems. In this session, we encourage presentations that expand our understanding of the interactions between biogeochemical cycles and marine food webs in the North Pacific Ocean, and the sensitivity of biogeochemical cycles, ecosystems and their interactions to global change.

Thursday, October 19, 2006 09:00-17:00

09:00-09:05 **Introduction by Convenors**

09:05-09:35 **Kon-Kee Liu, Chun-Mao Tseng, I-I Lin, Hong-Bin Liu and Anond Snidvongs** (Invited)
Effects of photoaclimation of phytoplankton and benthic-pelagic coupling on primary production in the South China Sea: Recent observations and modeling (S3-2824)

09:35-09:55 **Kazuaki Tadokoro, Tsuneo Ono, Akihiro Shiomoto and Hiroya Sugisaki**
Trends and bidecadal oscillations in PO_4 concentration in the Oyashio and Kuroshio-Oyashio mixed waters (S3-3116)

09:55-10:15 **Hernan E. Garcia, Tim P. Boyer, Sydney Levitus, Ricardo A. Locarnini, John I. Antonov, Daphne Johnson and Alexey Mishonov**
Climatological annual cycle of inorganic nutrient content anomaly in the Pacific Basin (S3-2876)

10:15-10:35 **Andrew L. King and Kathy Barbeau**
Macro- and micronutrient limitation of phytoplankton standing stock in the southern California Current System (S3-3048)

10:35-10:55 ***Tea/Coffee Break***

10:55-11:15 **Sinjae Yoo, Man-Sik Choi, Sang-Hwa Choi, Jung-Ho Hyun, Hyung-Ku Kang, Dongseon Kim, Hyun-cheol Kim, Chang Rae Lee, Jeong-Ah Lee, Taehee Lee, Jae Hoon Noh, Chang-Woong Shin and Eun Jin Yang**
Productivity and structure of lower trophic level communities and carbon flux in the Ulleung Basin in the JES in the summer of 2005 (S3-3069)

11:15-11:35 **TaeKeun Rho, Sei-ichi Saitoh, Akihiro Shiomoto, Takahiro Iida and Toshiyuki Konish**
Variability of summer primary production in the Subarctic North Pacific and the southeastern Bering Sea shelf (S3-3189)

11:35-11:55 **Hiroaki Saito, Takashi Ota, Koji Suzuki, Jun Nishioka and Atsushi Tsuda**
Role of heterotrophic dinoflagellate *Gyrodinium* sp. in biogeochemical cycles (S3-2973)

11:55-12:15 **Koji Omori, Hidejiro Ohnishi, Toru Fukumoto, Shunsuke Takahashi, Hideki Hamaoka, Miyuki Ohnishi, Kenji Yoshino, Motomi Kato and Todd W. Miller**
Two sources of primary production of sand bank ecosystems in Seto Inland Sea, Japan (S3-2929)

12:15-12:35 **Masahiko Fujii, Yasuhiro Yamanaka, Yukihiro Nojiri, Michio J. Kishi and Fei Chai**
Comparison of seasonal characteristics in biogeochemistry among the subarctic North Pacific stations described with a NEMURO-based marine ecosystem model (S3-2935)

12:35-14:00 ***Lunch***

14:00-14:30 **George A. Jackson** (Invited)
Using coagulation theory to predict maximum particle concentrations and fluxes from the surface ocean (S3-2771)

14:30-14:50 **Akira Kuwata**
Resting spore formation and sinking of bloom forming diatoms in the Oyashio region of the western subarctic Pacific Ocean (S3-3229)

14:50-15:10 **Toru Kobari, Deborah K. Steinberg, Atsushi Tsuda and Minoru Kitamura**
Active carbon transport by the ontogenetically migrating copepods in the western subarctic gyre (S3-2851)

15:10-15:30 **Atushi Yamaguchi, Yuji Watanabe, Hiroshi Ishida, Takashi Harimoto, Kazushi Furusawa, Shinya Suzuki, Joji Ishizaka, Tsutomu Ikeda and Masayuki M. Takahashi**
Taxonomic and size composition of plankton community down to the greater depths in the western North Pacific Ocean (S3-2785)

15:30-15:50 ***Tea/Coffee Break***

15:50-16:10 **Angelica Peña, M. Foreman and J. Morrison**
Modeling summer nutrient and phytoplankton dynamics off the entrance of Juan de Fuca Strait (S3-3226)

16:10-16:30 **Lei Gao, Dao-Ji Li, Yan-Ming Wang, Li-Hua Yu, Ding-Jiang Kong, Mei Li and Yun Li**
Nitrogen and silicon cycling in sediment and porewater of Dongtan tidal flat in the Changjiang (Yangtze River) estuary (S3-2884)

16:30-16:50 **David Checkley, Russ Davis, Alex Herman, George Jackson, Brian Beanlands, Jesse Powell and Lloyd Regier**
Simultaneous assessment of particles, including plankton, in the North Pacific by use of the SOLOPC (S3-3243)

Posters

Satoshi Kitajima, Fuminori Hashihama, Shigenobu Takeda and Ken Furuya
Nitrogen fixation in the subtropical and tropical western North Pacific (S3-3027)

Taehee Lee and Dongseon Kim
The cycling of organic carbon at the Ulleung Basin sediments, the East/Japan Sea (S3-2871)

Yuri Yu. Nikonov
Numerical analysis of chlorophyll-*a* modification in the south-east region of Sakhalin Island (S3-3115)

Takeshi Okunishi, Michio J. Kishi, Ryuichiro Shinohara and Toshihiko Yamashita
Impact of tidal mixing in the Kuril Strait on the surface nitrate distribution in the Okhotsk Sea and North Pacific during summer (S3-2959)

PICES XV S3-3243 Oral

Simultaneous assessment of particles, including plankton, in the North Pacific by use of the SOLOPC

David **Checkley**[1], Russ Davis[1], Alex Herman[2], George Jackson[3], Brian Beanlands[2], Jesse Powell[1] and Lloyd Regier[1]

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We present the simultaneous assessment of particles, including plankton, 0.1-mm to 2-cm equivalent spherical diameter (esd) by use of a novel autonomous, profiling instrument, the SOLOPC. This instrument combines a SOLO float, Laser-Optical Plankton Counter (LOPC), and fluorometer. During descent at ca. 25 cm sec^{-1}, pressure, the size and distribution of particles and plankton, and chl-*a* fluorescence are measured. During ascent at ca. 15 cm sec^{-1}, pressure, temperature, and conductivity are measured. At the surface, position, from GPS, and profile data are telemetered ashore via Iridium. First deployment was in autumn 2005. 63 dives were made over three days with measurements between the surface and 100 m. Particle and plankton size, transparency, and abundance (number and volume concentration) varied with time and depth. Particle abundance in the surface mixed layer was maximal at dusk and minimal at dawn. Particle size increased with depth. The abundance of late-stage *Calanus pacificus* was inferred from volume size spectra and compared favorably with estimates from a ship-deployed plankton net. The results are consistent with the daylight formation of particles by plant growth and subsequent lost due to aggregation and grazing with implications for the biological pump. Two SOLOPCs are scheduled for deployment in eu- and oligotrophic waters off Southern California in September 2006. Results from those deployments and plans for future deployments will be described.

PICES XV S3-2935 Oral

Comparison of seasonal characteristics in biogeochemistry among the subarctic North Pacific stations described with a NEMURO-based marine ecosystem model

Masahiko **Fujii**[1,2], Yasuhiro Yamanaka[3,4], Yukihiro Nojiri[5], Michio J. Kishi[4,6] and Fei Chai[1]

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A NEMURO-based sixteen-compartment marine ecosystem model is applied to Stations A7 (41.5°N, 145.5°E) and KNOT (44°N, 155°E) in the subarctic western North Pacific and Station PAPA (50°N, 145°W) in the subarctic eastern North Pacific. Model results show significant west-east differences in seasonal characteristics of physical environmental conditions and biogeochemistry, such as the larger seasonal amplitudes and higher primary productivity, at Stations A7 and KNOT than at Station PAPA. The modeled annual-mean e-ratios are higher at Stations A7 (0.32) and KNOT (0.33) than at Station PAPA (0.27) due to higher plankton biomass and mortality in the western North Pacific. Modeled annual-mean f-ratios are systematically higher than e-ratios under the influence of nitrification. The f-ratios are lower at Stations A7 (0.57) and KNOT (0.58) than at Station PAPA (0.64) because of higher ammonium concentrations in the western North Pacific. The e-ratio increases and f-ratio decreases with primary productivity, and the relationships can be described by exponential functions at any of the sites. Phytoplankton growth is severely limited by light at any of the stations throughout the year. Diatom growth is regulated by silicate rather than nitrate and ammonium at each site, particularly in late summer and early autumn at Stations A7 and KNOT. We conclude that the west-east differences in the biogeochemistry are primarily caused by differences in the physical environmental conditions. The biogeochemical differences are also suggested to be caused by differences in the ecosystem dynamics resulting from differences in the iron bioavailability among the stations.

PICES XV S3-2884 Oral

Nitrogen and silicon cycling in sediment and porewater of Dongtan tidal flat in the Changjiang (Yangtze River) estuary

Lei **Gao**, Dao-Ji Li, Yan-Ming Wang, Li-Hua Yu, Ding-Jiang Kong, Mei Li and Yun Li

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Monthly observations were carried out to investigate the nutrient profiles of SiO_3^{2-}, NH_4^+, and NO_2^-+NO_3^- concentrations in sediment porewater of three typical locations of Dongtan tidal flat in the Changjiang (Yangtze River) estuary during March 2005 to February 2006. In addition, nitrogen contents, biogenic silicon (BSi), and stable isotope ratio of $\delta^{15}N$ (‰) were also measured in solid fraction of sediment columns sampled in March 2005. The results showed that porewater concentrations of SiO_3^{2-} and NH_4^+ were in the range between 100 μM and 500 μM, and exhibited different patterns of variation at high, middle, and low marshes in general, which could be attributed to the intrusion of overlying water, production via organic matter degradation, and their relative importance. Moreover, seasonal variation could also draw its influence on nutrient concentrations, especially for SiO_3^{2-}, as was reflected by the significant correlations between average temperatures of sampling days and average SiO_3^{2-} concentrations in sediment porewater. Comparisons of nutrient concentrations between porewater and overlying water indicated significant NH_4^+ release and a less extent SiO_3^{2-} release from sediment to overlying water based on diffusive flux calculations, however, when it came to NO_3^-, fluxes of opposite direction in sediment-water interface could be expected.

PICES XV S3-2876 Oral

Climatological annual cycle of inorganic nutrient content anomaly in the Pacific Basin

Hernan E. **Garcia**, Tim P. Boyer, Sydney Levitus, Ricardo A. Locarnini, John I. Antonov, Daphne Johnson and Alexey Mishonov

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The most abundant dissolved inorganic nutrients (phosphate, nitrate, and silicate) play a central role in upper ocean biological production. We present a preliminary quantitative description of the observation-based climatological annual cycle of each of the nutrients in the upper layers of the Pacific Basin. The description is based on Fourier analysis of objectively analyzed monthly content anomaly values on a 1° grid (70°S-70°N) based on the recently released NODC World Ocean Database and Atlas 2005. We show that the largest seasonal changes in nutrient content anomalies occur in the extra-tropics in the 30° to 60° latitude belt of each hemisphere. The annual (C_1) and semi-annual (C_2) harmonics account for most of the annual cycle. The magnitude of C_1 is largest in the upper ~75 m depth except in the tropics and high latitudes. In the tropics, nutrients show a subsurface C_1 likely associated with the equatorial current system. The annual harmonic accounts for >80% of the variance of the zonally integrated monthly nutrient content anomaly. The annual signal is subject to uncertainty resulting from data coverage, data quality, variability, and other factors which are difficult to quantify. The World Ocean Database and Atlas 2005 are available from http://www.nodc.noaa.gov.

PICES XV S3-2771 Invited

Using coagulation theory to predict maximum particle concentrations and fluxes from the surface ocean

George A. **Jackson**

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Coagulation is an important process accelerating the sinking of particles and creating microhabitats. Its rate increases with particle concentration. Spring blooms and iron fertilization experiments provide useful situations to test the predictions of simple coagulation models. The predicted properties include particle (phytoplankton) concentration, size distribution, and settling flux. The models show, among other things, the importance of mixed layer depth in controlling the average particle settling speed. Predictions of maximum particle concentrations and particle fluxes made using coagulation theory are consistent with the observations resulting

from iron fertilization experiments. Observed patterns in high-latitude spring blooms are also very similar to predicted concentrations. Aggregate dynamics also provide insight into Th activity and microbial diversity.

PICES XV S3-3048 Oral

Macro- and micronutrient limitation of phytoplankton standing stock in the southern California Current System

Andrew L. **King** and Kathy Barbeau

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The mesotrophic southern California Current System (CCS), notable for its vigorous biological and chemical mesoscale variability, has been studied by CalCOFI (the California Cooperative Oceanic Fisheries Investigations) since 1949, and has recently become part of the California Current Ecosystem Long-Term Ecological Research (CCE-LTER) program. While not inclusive of trace metals, the CalCOFI program, over the years, has compiled a comprehensive and detailed dataset of southern CCS biological, chemical, and hydrographical parameters. During survey cruises between 2002 and 2005, and on a spring 2006 CCE-LTER Process cruise, trace metal clean samples were intermittently collected and Fe-addition grow-out bottle incubation experiments were conducted in an effort to examine variability and influence of micronutrient iron relative to macronutrient biogeochemistry and phytoplankton distribution and community structure. We found that although phytoplankton standing stock in the mixed-layer was generally correlated to and limited by nitrate, iron was also a limiting factor for phytoplankton growth. While iron is typically viewed as a biomass-limiting micronutrient in high-nutrient, low-chlorophyll (HNLC) regimes (typically 6-25+ µM nitrate), our studies in the southern CCS (typically <6 µM nitrate) suggest that while nitrate is a biomass-limiting nutrient, at times iron could control the rate of phytoplankton growth and macronutrient utilization in mesotrophic upwelling regimes.

PICES XV S3-3027 Poster

Nitrogen fixation in the subtropical and tropical western North Pacific

Satoshi **Kitajima**, Fuminori Hashihama, Shigenobu Takeda and Ken Furuya

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Nitrogen fixation rate was determined along meridian transects in the western North Pacific in November to December 2004 from 34°N to the equator on 155°E and May to June 2005 from 33°N to 3°N on 149°20'E. Nitrogen fixation showed a distinct aerial difference during both periods; significantly higher activity in the north of North Pacific Equatorial Current than in the south. This meridian difference largely reflected the activity of <10 µm fraction, with exceptions of patchy high activity at 8°N, and between 26°30' and 31°10'N, where *Trichodesmium* spp. and *Richelia intracellularis* were major nitrogen fixers. Thus, nitrogen fixers of <10µm were substantially important in the study area with sporadic contribution of *Trichodesmium* spp. and *R. intracellularis*. *Trichodesmium* spp. and *R. intracellularis* contributed to 0.5% of the horizontally integrated surface nitrogen fixation of the study area during the 2004 survey, and 28% during the 2005 observation. Flowcytometry of phytoplankton revealed that the activity of <10 µm fraction was significantly correlated with abundance of nanoplanktonic unicellular cyanobacteria, suggesting these organisms were responsible for the nitrogen fixation. The meridian difference likely controlled nutrient concentration at the surface; phosphate was depleted in the north of North Pacific Equatorial Current, but not exhausted in the south varying from 50 to 100 nM. Concentration of nitrate + nitrite was generally low in the both areas fluctuating below 15 nM. These observations show the importance of nitrogen fixation in controlling primary production in the tropical and subtropical western North Pacific.

PICES XV S3-2851 Oral

Active carbon transport by the ontogenetically migrating copepods in the western subarctic gyre

Toru **Kobari**[1], Deborah K. Steinberg[2], Atsushi Tsuda[3] and Minoru Kitamura[4]

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In the past decade it has become apparent that diel and ontogenetic migrating zooplankton contribute to carbon flux through their respiration, excretion, and mortality at depth. However, there is little information on the active exported carbon in the subarctic Pacific. Here we report vertical distribution of the ontogenetically migrating copepods collected from summertime day-night pairs of zooplankton samples in the western subarctic gyre and evaluate functional roles to carbon flux. The copepod community concentrated their abundance and biomass near surface over the study period. Non day-night migrants segregated the depth distribution, which *N. plumchrus* appeared near surface and *N. cristatus* and *E. bungii* were abundant in the 50-100 m layer. A consistent diurnal migration was evident for *M. pacifica* as they migrated above 50-m depth at night. *N. flemingeri* occurred below the permanent halocline over the study period showing dormancy. Although the community feeding rate above 150 m accounted for 52 to 74% of primary production, non-phytoplankton materials composed more than 99% of the ingested carbon. The feeding rate in each sampling layer was much larger than particulate carbon flux estimated from primary production and their fecal pellets were important as additional resource (i.e. repackaging). Exported carbon by diel (*M. pacifica*) and ontogenetic migrants (*N. flemingeri*) was estimated to be 4.4 mgC m^{-2} day^{-1} and 328 mgC m^{-2} $year^{-1}$, respectively. These results suggest that the copepod community have roles accumulating non-phytoplankton materials in the surface layer and transporting below permanent halocline through the diurnally and ontogenetically vertical migrations.

PICES XV S3-3229 Oral

Resting spore formation and sinking of bloom forming diatoms in the Oyashio region of the western subarctic Pacific Ocean

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An intensive phytoplankton bloom forms every spring in the Oyashio region of the western subarctic Pacific Ocean. This bloom is dominated by coastal diatom species, most of which are known to form resting spores. Resting spores have been recognized as a resting survival stage under unfavorable conditions with a large amount of carbon of storage products and a rapid sinking rate due to heavily silicified frustules. From viewpoint of carbon cycling, resting spore formation and sinking of diatom in the Oyashio region could be an important carbon transport process from surface to deep layer. To examine this possibility, observation of diatom flux using sediment trap and analysis of resting spore formation process by culture experiments were carried out. At 41°12' N,144°41'E in the Oyashio region, the annual diatom flux at water depth of 1100m was 1 x 1010 cells $m^{-2}yr^{-1}$. Diatom flux from April through May was dominated by bloom forming diatoms in surface water, *Thalassiosira*, *Chaetoceros*, *Odontella* and *Flagilariopsis* species, and contributed 80% of the annual diatom flux. At the beginning of the bloom period, flux of resting spores of bloom forming diatoms was 10% of the total flux and increased to 70% at the end of this period. Annual flux of the resting spores contributed 40% of that of total. Culture experiments revealed that three dominant bloom forming diatoms, *T. nordenskioeldii, C. furcellatus and C. debilis* form resting spores under N and/or P limitation. *C. debilis* also shows resting spore formation under light limitation.

PICES XV S3-2871 Poster

The cycling of organic carbon at the Ulleung Basin sediments, the East/Japan Sea

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The cycling of organic carbon fluxes was investigated based on a chamber experiment, porewater and geochemical analyses at the Ulleung Basin sediments in the 2005 summer. Sediment samples were collected using a box corer at the southern slope (B4), the western slope (D1), and the basin (D2 and D4). The burial flux of organic carbon was calculated by multiplying the sediment accumulation rate (SAR) and organic carbon contents. The recycling flux of organic carbon was estimated from the oxygen consumption rate (OCR) by applying an organic carbon: O_2 ratio of 106/138. Assuming the steady-state at the Ulleung Basin sediments, input flux of organic carbon is equal to the sum of burial flux and recycling flux. Burial fluxes of organic carbon ranged from 2.4 to 8.3 gC m^{-2} yr^{-1} with the highest value at station D1 and the lowest at station D4. OCR measured by the oxygen microelectrode were 6.88, 8.58, 5.27, and 5.48 mmol O_2 $m^{-2}yr^{-1}$ at station B4, D1, D2, and D4, respectively. On the other hand, OCR measured at station D2 by a chamber experiment was 2.1 mmol O_2 m^{-2} yr^{-1}, which was less than an half of that measured by the oxygen microelectrode. Recycling fluxes of organic carbon estimated from the OCR measurements by the oxygen microelectrode varied from 15.9 to 25.9 gC m^{-2} yr^{-1}. Input fluxes of organic carbon were calculated to be 27.6, 35.5, 18.4, 18.9 gC $m^{-2}yr^{-1}$ at station B4, D1, D2, and D4, respectively. About 4~9% of the primary production in the surface waters is deposited in the Ulleung Basin sediments. About 80% of organic carbon deposited in the Ulleung Basin sediments is regenerated in the sediment column, and about 20% is permanently buried in the sediments. The Ulleung Basin may play an important role for the deposition and/or removal of organic carbon.

PICES XV S3-2824 Invited

Effects of photoaclimation of phytoplankton and benthic-pelagic coupling on primary production in the South China Sea: Recent observations and modeling

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The South China Sea (SCS) is the largest marginal sea in the world aside from the ice-covered Arctic Ocean. Driven by the alternating monsoons, the biogeochemistry of SCS is very dynamic and potentially sensitive to climate change. Such a premise has inspired new biogeochemical observations and modeling work. A better understanding of the SCS biogeochemistry is essential for the interpretation of paleo records in the SCS obtained during paleoceanographic expeditions, which have flourished in the last decade. The primary production in the South China Sea (SCS) has been assessed by a coupled physical-biogeochemical model with a simple NPZD ecosystem. In recent years there have been an increasing number of observations in the SCS that may be used to check the validity of the previous approach. The coupled model of the SCS mentioned above employs a photo-adaptation scheme for the phytoplankton growth and uses the simplest bottom boundary condition of an inert benthic layer. These adopted schemes are checked against observations at the South-East Asia Time-series Study (SEATS) Station in the northern SCS and in the Gulf of Thailand. Numerical experiments with or without photo-adaptation or active benthic processes are carried out in this study. Additional experiments are performed with different parameters used for these processes. The observations at the SEATS Station provide direct evidence for the variable chlorophyll-to-nitrogen ratio in phytoplankton as required by photo-adaptation. It is concluded that the photo-adaptation scheme is critical to the phytoplankton growth, especially for the development of the subsurface chlorophyll maximum. However, the modeled subsurface chlorophyll maximum occurs at depths shallower than observations. Increasing of the upper limit of the chlorophyll-to-nitrogen ratio, as suggested by observations, enhances chlorophyll level in the lower part of the euphotic zone and raises primary productivity in areas with rich nutrient supply. The observed values of the vertically integrated primary production (IPP) in the Gulf of Thailand clearly demonstrate the importance of the benthic-pelagic coupling to the nutrient cycle. Without benthic nutrient regeneration the model grossly

underestimates primary production due to failure to build up the nutrient reserve in the Gulf. On the other hand, a fully regenerated flux of particulate organic nitrogen at the seafloor without denitrification produces too strong a primary productivity. The improved model uses a higher upper limit for the chlorophyll-to-phytoplankton ratio of 3.5 g Chl/mol N and adopts benthic processes of a coupled nitrification-denitrification scheme with denitrification consuming 14% of the detritus flux at the bottom. The model predicts a mean annual IPP value of 406 mgC mmgC $m^{-2}d^{-1}$ for the SCS, which may be broken down as 390 mgC $m^{-2}d^{-1}$ for the basin region (>200 m) and 429 mgC $m^{-2}d^{-1}$ for the shelf region (<200 m). The modeled monthly mean IPP values for the shelf and basin regions compare favorably with observed mean values in different seasons. The model also predicts a mean nitrogen removal flux of 0.16 mmol N $m^{-2}d^{-1}$ during denitrification for the shelf region.

PICES XV S3-3115 Poster
Numerical analysis of chlorophyll-*a* modification in the south-east region of Sakhalin Island

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In this paper present to study of changing concentration chlorophyll-*a* in the south-east region Sakhalin Island by numerical method. We used the three-dimensional prognostic Princeton ocean model (POM) for calculating. The algorithm of ecological POM was based on the algorithm of an ecologic-physic model for the PAPA-KKYS station. Chlorophyll-*a* concentration calculated with using hydrodynamic (temperature, salinity, radiation, water circulation and speed of currents and others) and biological (ammonium, phosphorus, DON, PON, DOP, POP, zooplankton and others) characteristics. Probabilistic space with chlorophyll-*a* accumulation was calculated by the south-east water area Sakhalin Island.

PICES XV S3-2959 Poster
Impact of tidal mixing in the Kuril Strait on the surface nitrate distribution in the Okhotsk Sea and North Pacific during summer

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The Kuril Straits are the significant generation regions of the K_1 tide. A 3-D hydrostatic model (Princeton Ocean Model) is applied to the Okhotsk Sea and northwestern Pacific Ocean. The simulation was conducted for 30 days at August by forcing K_1 tidal elevation along the open boundaries and monthly heat flux in the surface boundaries. The influence of tidal stirring on the distribution of nitrate has been investigated using the numerical model. Nitrate concentration is controlled by the physical process without the biological process. The initial nitrate concentration is used the climatological data from World Ocean Atlas 2001 except for the surface layers (0-30m), which are the depleted condition. K_1 tidal forcing causes intense vertical mixing all along the Kuril Island Chain to levels of a maximum vertical diffusivity exceeding 10^3 cm^2 s^{-1}. This strong vertical mixing leads to the increase of nutrients in the surface layers around the Kuril Straits. Model calculations indicate that the vertical nitrate flux to the surface layers is an average of 1.4 mmol-N m^2 day^{-1} in the region along the Kuril Straits. The high nitrate water spread to the surface layers in the North Pacific rather than in the Okhotsk Sea. After 30 days calculation, the total stock of nitrate in the surface layers (0-30m) in the North Pacific is about 1.14 times larger than that in the Okhotsk Sea. This is because that the low density water (<26 $\sigma\theta$) in the surface layers in the Okhotsk Sea prevent the spread of the high nitrate water.

PICES XV S3-2929 Oral
Two sources of primary production of sand bank ecosystems in Seto Inland Sea, Japan

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Primary production in the Seto Inland Sea shows one seasonal peak during the summer months, occurring primarily from many well-mixed waters around straits that are adjacent to more stratified waters. The well-mixed waters provide continuous nutrient supply to the photic zone, however the high turbidity within these waters also limits solar radiation for phytoplankton growth. In contrast, within adjacent more-stratified waters, phytoplankton in the warm surface layer are more limited by nutrients. Adding to this dynamic is the presence of sand banks between the two water types, which arise from sediment deposition following the sudden decrease in water velocity between the strait and adjacent more-stratified waters. The depth of these sand banks are typically more shallow than the phytoplankton compensation depth, negating the disadvantage of low solar irradiance from high turbidity in the well-mixed areas and providing nutrients for primary production. This condition therefore leads to relatively high primary production of phytoplankton around the sand banks. Moreover, the shallow waters of sand banks often get sufficient light to the bottom surface and high nutrients through tidal mixing, promoting bottom primary production by benthic algae. These two sources of primary production may make sand banks one of the most productive areas in coastal waters. Our intensive research on sand bank ecosystems in the Aki-Nada from one spring tide to the next spring tide elucidates some of the dynamics of primary production within this unique habitat and adjacent waters within the Seto Inland Sea.

PICES XV S3-3226 Oral
Modeling summer nutrient and phytoplankton dynamics off the entrance of Juan de Fuca Strait

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Large phytoplankton blooms are often found on the continental shelf off Vancouver Island during summer associated with the Juan de Fuca Eddy situated off Vancouver Island and Washington coasts. Results from a biological/circulation model (ROMS) developed to study factors influencing bloom dynamics will be presented. The biological model includes two size classes of phytoplankton and zooplankton, nitrate, ammonia and silicate. Model results are analyzed to explore the influence of the eddy on the growth of phytoplankton and biogeochemical cycles. We seek to understand the effect of the eddy on the (i) planktonic ecosystem structure and function, and (ii) the macronutrient fields of N and Si. The sensitivity of the model results to the grazing parameters and to the uptake ratio by diatoms of silicic acid and nitrogen will be presented. We discuss the main factors influencing the fate of the organic matter produced. This study is part of ECOHAB-PNW, a project funded by the Ecology and Oceanography of Harmful Algal Blooms program to investigate factors influencing the formation and toxicity of *Pseudo-nitzschia* spp. bloom in the Juan de Fuca Eddy.

PICES XV S3-3189 Oral
Variability of summer primary production in the Subarctic North Pacific and the southeastern Bering Sea shelf

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To understand variability of summer primary production in the Subarctic North Pacific and the southeastern Bering Sea shelf, nutrient and chlorophyll-*a* concentrations, and primary production were measured along the 165°E and 165°W lines in the north Pacific, along the Aleutian chains, and the southeastern Bering Sea shelf during summer 2005. Primary production ranged between 0.13 g Cm^{-2} d^{-1} and 0.54 gC m^{-2} d^{-1}. Primary

production were similar in the western and the eastern North Pacific between 40°N and 50°N along the 165°E line and the 165°W line although there were differences in the surface nitrate concentrations. Primary production were higher along the Aleutian chain and the shelf break region of the southeastern Bering Sea shelf than the southeastern Bering Sea shelf and along the 165°E and 165°W lines. Along the 165°W line, primary production gradually decreased toward the south between 50°N and 40°N, then increased around 40°N. The relative contribution of phytoplankton in >10 μm showed strong positive relationship with the total chlorophyll-*a* and primary production within the euphotic layer, but other size fractions (< 2 μm and between 2 μm and 10 μm) showed negative or no relationship.

PICES XV S3-2973 Oral
Role of heterotrophic dinoflagellate *Gyrodinium* sp. in biogeochemical cycles

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Large feeds on small is a fundamental rule of marine ecosystem and this rule characterizes the structure of marine food webs. Heterotrophic dinoflagellates (HDFs) are exceptions of this rule. They can feed on larger prey than their body size by phagotrophy or pallium feeding. Although their feeding behaviour has been studied well by the interest in their unique biology, the biogeochemical role of HDFs is still unknown. During *in situ* iron-enrichment experiment in the HNLC subarctic Pacific (SEEDS-I), chain forming diatoms such as *Chaetoceros debilis*, *Pseudonitzschia turgidula* responded to the iron-enrichment and formed an intensive diatom bloom. In response to the diatom bloom, the heterotrophic dinoflagellate *Gyrodinium* sp. increased and phagotrophically fed on the diatoms up to 12 times their length. Mathematical simulations show the carbon fixed by diatoms is mostly respired by *Gyrodinium* sp. in the sea surface. The emergence of initially rare species and their key biogeochemical roles were unexpected due to our limited understanding of food-web components. This indicates that the prediction of ecosystem responses to natural or anthropogenic perturbation remains a challenging issue. Effective carbon sequestration as a geoengineering technique may not be accomplished by purposeful iron-enrichment, at least in the western subarctic Pacific where rapid-growth diatom grazers stand by. On the other hand, faecal pellets or cells of HDFs are observed in sediment trap samples from world oceans. Further studies are needed on the biogeochemical roles of HDFs, especially in the regions where diatom bloom occur.

PICES XV S3-3116 Oral
Trends and bidecadal oscillations in PO_4 concentration in the Oyashio and Kuroshio-Oyashio mixed waters

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We studied long-term variations in surface (0m) and subsurface (26.7-26.8 sigma-t isopycnal) PO_4 concentration in the Oyashio and Kuroshio-Oyashio Mixed (below: Transition) waters by using archived oceanographic dataset from *e.g.* A-line and biological information from the Odate project. In the surface layer, PO_4 concentration represented the bidecadal oscillations superimposed on the liner decrease trends in both waters. These trends decreased in 26% and 36% of PO_4 concentrations from 1958 to 1999 in the Oyashio and Transition waters, respectively. On the other hand, PO_4 of subsurface had bidecadal oscillations superimposed on liner increase trends in both waters. After removing the trend components, PO_4 had significant positive relationship between surface and subsurface layer in both waters. These indicated that trend component of the variations were inverse relationship, however the components of bidecadal oscillation were synchronous between surface

and subsurface layer in both waters. The Oyashio water is formed water of the Okhotsk and western Subarctic Gyre throughout the mixing around the Kuril Island. The tidal mixing would be related to the formation process of Oyashio around Kuril Islands. The bidecadal components of PO_4 were synchronous with the 18.6-year period nodal cycle. The relationships suggested that the bidecadal oscillation of PO_4 concentrations related to the change in formation process of Oyashio waters due to 18.6-year period nodal cycle. The inverse trends suggested the diminishing in water exchange between the layers, however we have no evidences. *Neocalanus plumchrus* is a dominant mesozooplankton in the North Pacific. The biomass had significant positive relationship with surface PO_4 in both waters. Variations in PO_4 might affect the biomass of *N. plumchrus* due to change in productivity of phytoplankton.

PICES XV S3-2785 Oral

Taxonomic and size composition of plankton community down to the greater depths in the western North Pacific Ocean

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Taxonomic structure and size spectrum of plankton organisms were studied down to greater depths (2000-5800 m) at four stations (44°N; 39°N; 30°N; and 25°N, all in 137-155°E) in the western North Pacific Ocean during 1997-2001. The plankton organisms were divided into four taxonomic groups (bacteria, phytoplankton, protozooplankton, and metazooplankton) and their biomasses were quantified. The total plankton biomass in the water column increased toward northern stations, ranging from 8,179 (25°N) to 32,820 mg C m^{-2} (44°N). At the subarctic (44°N) and transitional station (39°N), metazooplankton dominated (ca. 80%) in the meso- and bathypelagic zones, while their composition decreased with increasing depth and bacteria increased in the abyssopelagic zone instead. An appreciable contribution of dormant copepods (subarctic *Neocalanus* spp.) to metazooplankton biomass was noted at the subarctic station, but *Neocalanus* copepods were less at the transitional station and almost absent at the subtropical stations (30°N and 25°N). At the subtropical stations, bacteria (ca. 60%) and protozooplankton (30%) were the two dominant taxa in plankton biomass throughout the water column, and there observed little changes in community structure with increasing depth. The water column-integrated size distribution patterns of plankton communities were characterized by three marked peaks [pico, micro (20 μm), and meso (2000 μm) size] at the subarctic station, the same three peaks, but with less marked in the micro- and meso sizes at the transitional station, and only one peak (pico size) at the subtropical stations. These size distribution patterns in planktonic community may reflect of the nutrient condition, relatively high nutrient concentration at the northern stations induced dominance of micro size phytoplankton and transferred organic matter to meso size zooplankton within minimum loss, while extremely low nutrient concentration at the southern stations induced dominance of pico size phytoplankton and lower transfer efficiency of organic matter to meso-size since the number of trophic levels are greater at those stations. Biomass each plankton group decreased with increasing depth, and their declining patterns below 100 m depth were well described by a negative power function with different slopes between groups and also between stations. Within these stations, the slope was the greatest for mesozooplankton, followed by phytoplankton and bacteria or protozooplankton.

PICES XV S3-3069 Oral

Productivity and structure of lower trophic level communities and carbon flux in the Ulleung Basin in the JES in the summer of 2005

Sinjae **Yoo**[1], Man-Sik Choi[2], Sang-Hwa Choi[1], Jung-Ho Hyun[3], Hyung-Ku Kang[1], Dongseon Kim[1], Hyun-Cheol Kim[1], Chang Rae Lee[1], Jeong-Ah Lee[1], Taehee Lee[1], Jae Hoon Noh[1], Chang-Woong Shin[1] and Eun Jin Yang[1]

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The Ulleung Basin, located in the southwestern part of JES, is a complex environment which is characterized by different types of waters: the North Korean Cold Water from north; the Tsushima Current, a branch of the Kuroshio, which carries diluted water from the Changjiang River; and the coastal current flowing northward along the eastern Korean Peninsula which carries freshwater as well as up-welled intermediate water from depths. Frequently eddies also formed from the Tsushima Current reflecting the bottom topography of the Ulleung Basin. In July 2005, a cruise conducted surveys of hydrography, structure and productivity of lower trophic communities, and flux of carbon in a region between 35.5~37.5N and 129.5~ 132E. A strip of high chlorophyll concentration was formed in the entrained coastal waters along the west side of an anti-cyclonic eddy in the center of the Ulleung Basin. Community structure of the lower trophic level components in the area was different from other areas. Partial pressure of carbon dioxide in the surface water was also lower than that in the air while in other areas the reverse was true. Primary production ranged 281~772 mg C m^{-2} d^{-1} over the whole study area. The export production at 100m depth based on sediment traps was estimated 36~44 mg m^{-2} d^{-1} inside the eddy, while estimates based on POC/Th methods gave lower values. We discuss how the different structure in the lower trophic level communities might influence the carbon flux in the region.

S4 BIO Topic Session
Synthesis of *in situ* iron enrichment experiments in the eastern and western subarctic Pacific

Co-Convenors: Maurice Levasseur (Canada), Shigenobu Takeda and Atsushi Tsuda (Japan)

Three successful meso-scale iron enrichment experiments have been conducted in the subarctic North Pacific (SEEDS-I & II and SERIES) over the last four years. This session will synthesize the key findings of these experiments and initiate the development of a common database. We invite contributions specifically comparing and contrasting these three experiments. In addition, the unpredicted response of a recent meso-scale iron enrichment experiment (SEEDS-II) highlights our limited understanding of how iron affects biogeochemical cycles, and the complexity of ecosystem responses to iron in HNLC (High Nutrient Low Chlorophyll) waters. We also encourage papers investigating how iron influences, and is in turn, influenced by ocean-atmospheric exchanges, plankton activities and community structure, micronutrient chemistry, and other processes in the subarctic North Pacific.

Tuesday, October 17, 2006 09:00-18:00

09:00-09:30 **Philip W. Boyd** (Invited)
Mesoscale iron enrichments - A valuable tool to understand how Pacific HNLC waters function (S4-2963)

09:30-10:00 **Atsushi Tsuda, Shigenobu Takeda, Hiroaki Saito, Jun Nishioka, Yukihiro Nojiri and Isao Kudo**
SEEDS I summary (S4-2880)

10:00-10:30 **Paul Harrison, Maurice Levasseur, Philip Boyd, C.S. Wong, Richard Rivkin and Tom Pedersen**
Mesoscale Fe enrichment produces a large diatom bloom, draws down CO_2, but with limited production of DMS and carbon export in the NE Subarctic Pacific (S4-3236)

10:30-11:00 ***Tea/Coffee Break***

11:00-11:30 **Hiroaki Saito and SEEDS II participants**
SEEDS II summary (S4-2972)

11:30-11:50 **Daisuke Tsumune, Jun Nishioka, Akifumi Shimamoto, Yutaka Watanabe, Shigenobu Takeda and Atsushi Tsuda**
The physical behavior of the iron patches detected by SF_6 tracer during SEEDS-I and SEEDS-II (S4-3213)

11:50-12:10 **S. Takeda, J. Nishioka, C.S. Wong, W.K. Johnson, M. Kinugasa, Y. Kondo, K. Kuma, S. Nakatsuka, H. Obata, E. Roy, M. Sato, N. Sutherland, Y. Sohrin, H. Takata, H. Tani, A. Tsuda and M.L. Wells**
Iron geochemistry of SEEDS-I, -II and SERIES (S4-3030)

12:10-12:30 **Jun Nishioka, Tsuneo Ono, Hiroaki Saito, Takeshi Nakatsuka, Shigenobu Takeda, Takeshi Yoshimura, Koji Suzuki, Kenshi Kuma, Shigeto Nakabayashi, Humio Mitsudera and Atsushi Tsuda**
Iron supply to the western subarctic Pacific: Importance of lateral iron transport from the Sea of Okhotsk and winter mixing (S4-2883)

12:30-14:00 ***Lunch***

14:00-14:30 **Yukihiro Nojiri, Keiri Imai and Takafumi Aramaki**
Analysis of changes in water and particulate material chemistry during iron-enrichment experiments in the subarctic North Pacific (SEEDS, SERIES and SEEDS-II) (S4-3071)

14:30-14:50 **Takeshi Yoshimura, Hiroshi Ogawa, Keiri Imai and Jun Nishioka**
The dynamics of dissolved organic matter during *in situ* iron enrichment experiments in the subarctic North Pacific (S4-2966)

14:50-15:10 **Koji Suzuki, Hiroaki Saito, Akira Hinuma, Hiroshi Kiyosawa, Akira Kuwata, Kyoko Kawanobe, Toshiro Saino and Atsushi Tsuda**
Comparison of community structure and photosynthetic physiology of phytoplankton in two mesoscale iron enrichment experiments in the NW subarctic Pacific (S4-2889)

15:10-15:30 **Charles G. Trick, William P. Cochlan, Mark L. Wells and Julia N. Betts**
Complexity of grow-out experiments: Further iron stimulation of planktonic communities from the iron-fertilized mesoscale patch during SEEDS (S4-3199)

15:30-16:00 ***Tea/Coffee Break***

16:00-16:20 **Isao Kudo, Yoshifumi Noiri, Jun Nishioka, Yousuke Taira, Hiroshi Kiyosawa and Atsushi Tsuda**
Phytoplankton community response to Fe and temperature gradients in the NE (SERIES) and NW (SEEDS) subarctic Pacific Ocean (S4-3015)

16:20-16:40 **Mark L. Wells, Charles G. Trick, William P. Cochlan and Julian Herndon**
The persistence of iron limitation during the SEEDS-II mesoscale iron enrichment experiment (S4-3203)

16:40-17:00 **Atsushi Tsuda, Hiroaki Saito and Akash R. Sastri**
Meso- and microzooplankton responses in the iron-enrichment experiments in the subarctic North Pacific (SEEDS, SERIES and SEEDS-II) (S4-2881)

17:00-17:20 **Maurice Levasseur, Anissa Merzouk, Martine Lizotte, Michael Scarratt, Sonia Michaud, Yvonnick Le Clainche, Chi Shing Wong and Richard Rivkin**
Impact of iron enrichment on DMS cycling in the subarctic Pacific: A synthesis of SERIES and SEEDS-II (S4-3041)

17:20-17:40 **Ippei Nagao, Shinya Hashimoto, Shuji Toda, Shungo Kato, Yoshizumi Kajii, Yasushi Narita, Mitsuo Uematsu, Atsushi Tsuda, Hiroaki Saito and Koji Suzuki**
Seawater and atmospheric DMS concentrations during SEEDS-II (Western North Pacific) (S4-3177)

17:40-18:00 **Yoko Iwamoto, Yasushi Narita and Mitsuo Uematsu**
Single particle analysis of oceanic suspended matters during SEEDS-II (S4-3073)

Posters

Takafumi Aramaki, Yukihiro Nojiri and Keiri Imai
Variations in total mass flux, nutrients and particulate matters during SEEDS-II (S4-3023)

Yoshiko Kondo, Shigenobu Takeda, Jun Nishioka, Hajime Obata, Ken Furuya, William Keith Johnson, Agnes Sutherland and C.S. Wong
Behavior of organic iron (III) complexing ligands during SEEDS-II experiment (S4-2872)

Isao Kudo, Yoshifumi Noiri, T. Aramaki, William P. Cochlan, Koji Suzuki, Tsuneo Ono and Yukihiro Nojiri
Primary production, bacterial production and nitrogen assimilation dynamics during the SEEDS-II experiment (S4-3016)

Seiji Nakatsuka, Masatoshi Kinugasa, Yoshiki Sohrin, Jun Nishioka, Shigenobu Takeda and Atsushi Tsuda
Dynamics of bioactive trace metals during the mesoscale iron enrichment in the Subarctic Western North Pacific Gyre (SEEDS-I and -II) (S4-3132)

Yasushi Narita, Yoko Iwamoto, Kentaro Yoshida, Masaki Kondo and Mitsuo Uematsu
Contribution of biogenic sulfur to the marine lower atmosphere in the Northwestern Pacific (S4-3145)

Hajime Obata, Yasuko Hara, Takashi Doi, Yayoi Hongo, Toshitaka Gamo, Shigenobu Takeda and Atsushi Tsuda
Rare earth elements during an iron fertilization experiment in the western subarctic North Pacific (SEEDS-II) (S4-2945)

Mitsuhide Sato, Shigenobu Takeda and Ken Furuya
Responses of pico- and nano-phytoplankton to artificial iron infusions during SEEDS-II (S4-2986)

PICES XV S4-3023 Poster
Variations in total mass flux, nutrients and particulate matters during SEEDS-II

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After iron fertilization during SEEDS-II, chlorophyll-*a*, nutrients, particulate organic carbon (POC) and particulate organic nitrogen (PON) in the water column were monitored and drifting sediment traps (DST) were moored at 40, 70 and 100 m depth inside and outside the iron patch for a month as an indicator for biological response. In SEEDS-II, the maximum chlorophyll-*a* concentration reached inside the patch was less than 3 mg m^{-3}, a value ca. 1/6 of the level reached during SEEDS-I. In SEEDS-II, the biomass peaked on days 8-14, and then decreased gradually. In response to the increase in chlorophyll-*a*, nutrients concentrations decreased slightly. POC and PON concentrations in surface water increased from 0.19 mg L^{-1} to 0.29 mg L^{-1} and from 0.03 mg L^{-1} to 0.06 mg L^{-1} between day 2 and day 14, respectively. The total mass flux at 40 m depth estimated by DST began to increase after days 15-18 and the maximum flux (1585 mg m^{-2} d^{-1}) was measured during days 21-24. The maximum flux was tow time higher than at the onset of the experiment and two time smaller than the maximum flux measured during SEEDS-I. Variations in the composition of the particulate matter caught by DST will also be discussed.

PICES XV S4-2963 Invited
Mesoscale iron enrichments - A valuable tool to understand how Pacific HNLC waters function

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High Nitrate Low Chlorophyll (HNLC) waters are widespread in the Pacific and are found in the subarctic, equatorial, subantarctic and polar waters. In the last decade, 8 of the 12 mesoscale iron-enrichment experiments have been conducted in Pacific waters. These experiments have been conducted across a wide range of environmental conditions - such as –1ºC to > 24ºC waters and 15 m to 65 m mixed layers - resulting in a wide range of bloom dynamics and biogeochemical signatures. Here, I will present a summary of the main findings of these experiments, and their implications for better understanding ecosystem function and associated biogeochemistry in Pacific water masses, as discussed and synthesized at a recent SOLAS-sponsored workshop. Recommendations of future experimental and modelling studies will conclude this presentation.

PICES XV S4-3199 Oral
Complexity of grow-out experiments: Further iron stimulation of planktonic communities from the iron-fertilized mesoscale patch during SEEDS

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Complimentary studies associated with the SEEDS-II iron enrichment experiment in the western subarctic Pacific Ocean indicate that the resultant ambient phytoplankton community remained iron-limited, despite the presence of elevated dissolved iron concentrations (> 0.5 nM) from infusions. The growth potential of the planktonic community was monitored using deck-board incubation “grow-out” experiments conducted aboard the R/V *Kilo Moana* where both strong and weak iron-complexing ligands were employed, and the photosynthetic capacity and efficiency of the resulting communities were assessed using short-term, photosynthesis versus irradiance (PE) experiments. Multi-day grow-out experiments were designed to consider: (1) if additional iron would allow for additional and/or accelerated biomass accumulation, and (2) if altered forms of the iron-ligand complex added to the community would change the Fe-enhanced phytoplankton community structure. Our experiments indicated that the community in the iron-infused patch remained iron-

limited throughout the entire *in-situ*, mesoscale experiment. Addition of iron in shipboard grow-out flasks alleviated the iron stress, presumably in a fashion not chemically identical to the re-addition of iron *in situ*. We also consider how the resulting grow-out communities varied physiologically both as a function of time, and in relation to the in-situ community. In other words, did iron infusion merely influence biomass accumulation, or were more dramatic changes in cell physiological state and community composition discernable during the > 30 day mesoscale enrichment experiment?

PICES XV S4-3236 Oral
Mesoscale Fe enrichment produces a large diatom bloom, draws down CO_2, but with limited production of DMS and carbon export in the NE Subarctic Pacific

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The Subarctic Ecosystem Response to Iron Enrichment Study (SERIES) was conducted in the NE subarctic Pacific, one of the three major high nitrate low chlorophyll (HNLC) regions of the world where Fe limits primary productivity. SERIES is part of the Canadian SOLAS network project. During the first phase of the bloom, small phytoplankton (mainly prymnesiophytes) increased and there was a record increase in dimethylsulphide (DMS). During the second phase, the bloom was dominated by large pennate and centric diatoms and chlorophyll-*a* was 8-fold higher than initial values. The fugacity of CO_2 (fCO_2) decreased from 340 to 260 μatm and DIC from 2010 to 1970 μmol kg^{-1}. In contrast, DMS decreased and often became undetectable due to the metabolism of DMSP by bacteria. There was no significant difference in the zooplankton community dominated by small copepods inside the patch and outside. The bloom was terminated on Day 20 by silicate and low Fe concentrations, while sufficient nitrate and phosphate remained. Using sediment trap information and other data, it was estimated that <5% of the carbon associated with the Fe-induced bloom, was exported below the mixed layer depth during this 30 day experiment. About 25% of the Fe-enhanced primary production in the mixed layer was channeled through the microbial food web, thus reducing the amount of organic carbon for export. Hence large scale Fe 'fertilization' may not be a viable solution to drawing down CO_2 and offsetting global warming.

PICES XV S4-3073 Oral
Single particle analysis of oceanic suspended matters during SEEDS II

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Electron probe X-ray micro analyzer was used to characterize shapes and chemical compositions of individual suspended particles in surface seawater collected during the SEEDS II iron fertilization experiment. Analyzed particles with 0.4-10 μm in diameter were classified into five groups according to their chemical compositions: Al-Si, Si-rich, Ca-rich, Organic and Others. Most of particles were classified as Si-rich, Ca-rich and Organics during the experiment. Based on observations made with an electron microscope, Si-rich and Ca-rich particles were mainly detritus of phytoplankton that have opal or calcium carbonate shell. In the iron-fertilized patch, variation in Chl-*a* concentration corresponded to the changes in dry weight, number concentration and volume concentration of the suspended particles. At 20 m depth, the number concentration of Organic particles (characterized by two size modes: 1.1 μm and 0.65 μm in diameter) increased immediately after the iron fertilization, and then gradually increased with time. It is suggested that the increase in suspended particles corresponded to the increase in primary production. In the Si-rich and Ca-rich particles, weight percents of Si and Ca in the coarse particles tended to be higher than those in the fine particles. From the appearance frequency of elements in Si-rich, Ca-rich and Organic particles, biolimiting elements, such as Si, P, S and Ca, were detected more often than crustal elements. These results suggest that aggregation and adsorption may occur between small fragments of biogenic shell material and organic particles.

PICES XV S4-2872 Poster
Behavior of organic iron (III) complexing ligands during SEEDS-II experiment

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Field observations were conducted during a mesoscale iron enrichment experiment in the western subarctic North Pacific (SEEDS-II) to investigate complexation of Fe(III) with natural organic ligands through the development and decline of phytoplankton bloom induced by artificial iron supplies. Rapid increase in ligands concentration was observed after the first iron infusion, and the concentration decreased to the pre-infusion level within 5 days. After the second iron infusion, similar increase and following decrease in the ligands concentration were observed again. It has been reported that iron-limited phytoplankton may release Fe(III) complexing ligands following iron addition, but it is possible that the actual ligand Fe-binding capacity was partly influenced by surface active amorphous colloids formed after the iron infusions. Dilution of the iron-enriched water mass and photochemical degradation in the surface water could contribute the rapid decreases of the ligands concentrations. Weaker-class ligands with conditional stability constant of ~10^{20} M^{-1} showed a large (>75%) contribution to the increases in the total ligands concentration. However, dissolved iron in the iron-enriched surface water was estimated to be complexed by stronger-class ligands with conditional stability constant of ~10^{22} M^{-1}. During the bloom decline phase, ligands concentration increased again. Phytoplankton cell lyses, zooplankton grazing on phytoplankton or siderophore release from iron-limited bacteria could be a source of the ligands during the decline phase. These results suggest that chemical speciation of iron was strongly affected by the Fe(III) complexing organic ligands and their source varies during the development and decline of iron-induced phytoplankton bloom.

PICES XV S4-3015 Oral
Phytoplankton community response to Fe and temperature gradients in the NE (SERIES) and NW (SEEDS) subarctic Pacific Ocean

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Ship-board iron enrichment bottle experiments were carried out in the subarctic NW Pacific (SEEDS) and NE Pacific (SERIES). The iron concentration in the incubation bottles ranged from 0.1 to 2.0 nM by adding $FeCl_3$ solution. Incubation temperature varied from 5 to 18°C to elucidate the interactive effect of Fe and temperature on phytoplankton growth in these regions. The increase in Chl-*a* in the micro (>10 μm) and nano-sized (2^{-10} μm) fraction was observed as a function of the added iron As a hyperbolic relation was found between iron concentration and specific growth rate for the micro and nano-sized fraction, the Monod equation was fit to obtain a maximum growth rate (μ_{max}) and a half-saturation constant for iron (K_{Fe}). The μ_{max} values at the SERIES study site were 0.72 and 0.48 d^{-1} for the micro and nano-sized fraction, respectively. The K_{Fe} values were 0.10 and 0.08 nM for the micro and nano-sized fraction, respectively. The μ_{max} agreed with the rate of increase in Chl-*a* observed in the SERIES experiment. The μ_{max} value for the micro-sized fraction at 12°C was half the value measured at the SEEDS site, indicating that the potential growth rate was much higher in SEEDS than that in SERIES. The K_{Fe} values were much lower than that in SEEDS, suggesting that the phytoplankton community in the NE subarctic Pacific was acclimated to a lower ambient Fe concentration. These differences in K_{Fe} between SERIES and SEEDS may reflect an east-west gradient in Fe eolian deposition in the subarctic North Pacific Ocean.

PICES XV S4-3016 Poster

Primary production, bacterial production and nitrogen assimilation dynamics during the SEEDS II experiment

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Primary productivity and uptake rates of nitrate and ammonium were measured during an iron enrichment-experiment in the western subarctic Pacific Ocean (SEEDS II) using stable ^{13}C and ^{15}N isotope methods with simulated, on-board, 24-h incubations. Heterotrophic bacterial production was measured using the ^{3}H-leucine method. Nitrate, phosphate and silicate before the iron enrichment in the surface mixed layer (0–10 m) were abundant at 19, 1.6 and 38 µM, respectively. These concentrations were similar than those measured at the beginning of SEEDS I in 2001. Primary productivity in the upper 20 m was 30 mgC m^{-3} d^{-1} on Day 2 and did not change outside the iron patch during the 30 days of the observation. Primary productivity in the iron patch increased 3-fold after Day 8 and the maximum of 110 mgC m^{-3} d^{-1} was observed on Day 8. During the 25 days observation, total primary production was 22.4 gC m^{-2}, which is 1.5 times higher than that in the out-patch. Bacterial production in the patch increased two hold after Day 7, indicating that the heterotrophic activity was stimulated by the increase in primary production. The total bacterial production during the observation period was 3.4 gC m^{-2}. Assuming a bacterial growth efficiency of 30%, bacterial carbon demand was 11.3 gC m^{-2}, which accounted for 45% of the total primary production in the patch. Export production was 7.7 gC m^{-2}, which accounted for 31% of the total production and almost 100% of the new production as estimated from the *f*-ratio. The remaining production seemed to be consumed by the meso-zooplankton.

PICES XV S4-3041 Oral

Impact of iron enrichment on DMS cycling in the subarctic Pacific: A synthesis of SERIES and SEEDS-II

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Ocean production of the climate active gas dimethylsulfide (DMS) contributes to climate regulation via the formation of aerosols that scatter solar radiations and increase the albedo of clouds. DMS emissions thus alter the radiative balance of the Earth and can potentially exert a cooling effect on climate. DMS is produced from the degradation of its algal precursor dimethylsulfoniopropionate (DMSP). Few microalgae have the capability to directly produce DMS, but most of DMSP degradation is believed to occur indirectly, through the release of algal DMSP and its subsequent uptake by bacteria. The strong dependency of DMS cycling to the structure and functioning of the planktonic food chain makes it sensitive to nutrient limitation, including iron. Accordingly, iron enrichment consistently resulted in increase (up to 6 times) in DMS concentrations in High Nutrient - Low Chlorophyll (HNLC) waters of the southern ocean and equatorial Pacific. In contrast, the addition of iron in the subarctic Pacific HNLC waters during SERIES and SEEDS-II had no stimulating effect on DMS. We will investigate the cause(s) for this unexpected response, with a special focus on microbial food chain processes.

PICES XV S4-3177 Oral

Seawater and atmospheric DMS concentrations during SEEDS-II (Western North Pacific)

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During SEEDS-II, simultaneous measurements of DMS in the seawater and the atmosphere were carried out to determine the impact of iron (Fe) fertilization on DMS production and flux in Western North Pacific HNLC waters. Maximum Chl-*a* concentration was observed on day 13 in the Fe-patch and was about 3 times higher than that in the surrounding area. Prymnesiophyceae, major DMSP producers, were slightly more abundant in the patch than outside. However, the seawater DMS concentration in the patch did not show any significant increase during the first 15 days of the experiment. Average DMS concentrations in the surface waters were 3.8 nM in the patch and 3.2 nM in the surrounding waters. Then, DMS concentrations significantly increased to 6.2 nM on day 18 in the patch and 9.3 nM on day 22 in the surrounding area, while phytoplankton biomass gradually decreased except for Cryptophyceae. During the same period, meso-zooplankton biomass abruptly increased by about a factor 3 inside and outside the patch. Results from a simple DMS budget analysis suggest that the increase in DMS resulted from a stimulation of the net biological production of DMS. In the atmosphere, DMS concentration showed a large variation (10~600 pptv) compared to that of the seawater. Variations in atmospheric DMS levels resulted from changes in sea-to-air flux, and in the oxidation rate in the gas-phase. We will discuss how changes in seawater DMS concentrations may affect DMS concentration in the atmosphere.

PICES XV S4-3132 Poster

Dynamics of bioactive trace metals during the mesoscale iron enrichment in the Subarctic Western North Pacific Gyre (SEEDS-I and -II)

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Two Mesoscale iron-enrichment experiments (SEEDS-I and -II) were conducted near the center of the Western subarctic gyre. The dynamics of trace elements was studied over 13 days in SEEDS-I, and 26 days in SEEDS-II. In SEEDS-I, dissolved (< 0.2 μm) and acid-dissolvable (unfiltered) Mn, Fe, Co, Ni, Cu, Zn and Cd were measured. Dissolved iron in the surface mixed layer was originally depleted (< 0.13 nM) and acid-dissolvable iron was 4.7 nM. Iron in this fraction was dominated by particulate species and hardly available to phytoplankton. After the iron enrichment, Chl-*a* increased to ~20 μg/L in SEEDS-I. All dissolved trace metals decreased exponentially, and the drawdown ratio was similar to the elemental ratio of phytoplankton. In contrast, acid-dissolvable Mn, Co, Ni, Cu, Zn and Cd did not change, suggesting that the metals accumulated by phytoplankton stayed in the surface mixed layer. In SEEDS-II, there was a threefold increase in Chl-*a* (~3 μg/L). Dissolved and particulate (> 0.2 μm) Co, Ni, Cu, Zn, Cd and Pb were measured. Dissolved Cd decreased by ~20 % in the iron patch. The concentrations of particulate Co, Ni, Cu and Cd on days 8 to 10 in the iron patch were ~1.5 times higher than those on day 0, but we found no significant increase below the surface mixed layer. Results from SEEDS-I and -II confirm that iron enrichment alters the physiochemical species of trace metals in the surface mixed layer, depending on the accumulation of phytoplankton biomass.

PICES XV S4-3145 Poster

Contribution of biogenic sulfur to the marine lower atmosphere in the Northwestern Pacific

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Sulfate, nitrate and ammonium of anthropogenic origin, and major elements such as silicon, aluminum and iron of crustal origin are transported from the Asian continent over the North Pacific. Dimethyl sulfide (DMS) is produced by phytoplankton in the water column, and oxidized to sulfuric acid and methane sulfonate (MSA) in the marine atmosphere. The origin of airborne sulfate over the Northwestern Pacific is thus both anthropogenic and biogenic. It is necessary to understand how much and how anthropogenic and crustal aerosols affect the biota and radiative forcing in and over the Northwestern Pacific. The aim of this study was to separate airborne sulfate into an anthropogenic and biogenic fraction and to estimate the relative contribution of the biogenic source. To do so, aerosol samples were collected during the SEEDS-II cruise on the R/V *Hakuho-maru*, KH04-3 (13 July – 27 August, 2004). Episodes of high Al concentrations and results from the backward trajectory analyses associated with these episodes suggested that the air masses originated from the Asian continent and that these air masses may contain substantial load of crustal aerosols even during the summer period. It was expected that anthropogenic sulfate was also transported with crustal aerosols from the Asian continent. The contribution of biogenic sulfate was obtained using the Bates *et al.* (1992) equation using MSA, NH_4^+, NO_3^- and air temperature. The molar ratio of biogenic sulfate to nss-SO_4^{2-} was about 0.4 in the fine mode (<2.5um). Our results indicate that variations in marine biological activity may affect climate by increasing aerosols production as well as by controlling atmospheric CO_2 concentration.

PICES XV S4-2883 Oral

Iron supply to the western subarctic Pacific: Importance of lateral iron transport from the Sea of Okhotsk and winter mixing

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The Western Subarctic Pacific (WSP) is known as a highly biologically productive region of the world ocean where iron can limit primary production. The supply of iron to this region is believed to come primarily from deposition of atmospheric dust. Our results suggest that other sources of iron may have been underestimated. We found extremely high concentrations of dissolved and particulate iron in the Okhotsk Sea Intermediate Water (OSIW) and in the North Pacific Intermediate Water (NPIW). Both water masses are affected by water ventilation process caused by sea ice formation in the northwestern coastal-shelf region of the Sea of Okhotsk. Additionally, results from our time-series in the Oyashio region show that the seasonal change in dissolved iron concentration in the surface mixed layer was similar to that of macronutrients, and that deep vertical mixing results in higher concentrations of iron in the surface in winter. These data suggest that iron is transported from the coastal-shelf region of the Sea of Okhotsk to a wide area of the WSP via intermediate water layer, and is supplied to surface by winter vertical mixing in the Oyashio region. This source of iron supports the spring biological production, especially in the Oyashio region, and should be considered in current attempts to understand and model the biogeochemical cycles in the subarctic Pacific and the role of the marginal sea.

PICES XV S4-3071 Oral

Analysis of changes in water and particulate material chemistry during iron-enrichment experiments in the subarctic North Pacific (SEEDS, SERIES and SEEDS II)

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During these iron-enrichment experiments, we conducted vertical and horizontal measurements of pCO_2 and dissolved/particulate nutrient in and around the iron-enrichment patch. The integration of the changes in these water properties helps to estimate the formation and export flux of particulate organic carbon during the experiments. The ratio of silica and nitrate consumption in surface waters in the iron-patch increased toward the end of the iron-induced phytoplankton bloom, a period coinciding with an increase of the sinking rate of the particulate material and higher concentrations of particulate silica in sub-surface waters. Data from the floating sediment traps were use to calculated the export flux inside and outside the iron-patch during the three experiments. The analysis of the chemical composition of the exported material was carried out by C-N analyzer and ICP emission spectrometry including carbon, nitrogen, phosphorus, silica and other metallic elements. The elemental composition of the particulate material collected in the traps varied in phase with the development stages of the iron-induced bloom. We examined the change in the ratios of organic and inorganic carbon, and macro nutrients. During SERIES, a large increase of the export flux at 50 m and below was measured in the iron-patch area one week after the chlorophyll maximum. We will discuss the relationship between the changes in the water and particulate chemistry and the development stages of the iron-induced phytoplankton bloom during the three experiments.

PICES XV S4-2945 Poster

Rare earth elements during an iron fertilization experiment in the western subarctic North Pacific (SEEDS-II)

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Rare earth elements (REE) have been used as chemical tracers in the ocean because of their consistent behavior and small but systematic variation of particulate affinities. During an iron fertilization experiment in the western subarctic North Pacific (SEEDS-II), REE were determined in seawaters in order to study the removal process of trace metals. Within the iron-enriched patch, the composition of REE in seawater changed systematically according to the phytoplankton growth. The La/Yb ratios showed minimum values at Day 11 when the chlorophyll-*a* content in seawater reached almost a maximum in the patch. These results are consistent with the systematic feature of REE in the ocean that the lighter REE are preferentially removed by the settling particle. Interestingly, the same fractionation of REE was observed in a natural phytoplankton bloom taking place near the iron patch. Within the natural phytoplankton bloom, characterized by low surface water pCO_2, the North Pacific Deep Water (NPDW) normalized REE pattern showed a clear depletion of lighter REE. Such a rapid composition change of REE in seawater during the phytoplankton bloom indicates that REE are useful chemical tracers for the particle scavenging process.

PICES XV S4-2972 Oral
SEEDS-II summary

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In the first mesoscale iron-enrichment experiment conducted in the HNLC region of the western subarctic Pacific (SEEDS-I, 2001), the phytoplankton assemblage initially dominated by the centric diatom *Chaetoceros debilis* responded dramatically to the iron enrichment, and chlorophyll-*a* concentration in the surface mixed layer increased from 0.8 mg m^{-3} to 20 mg m^{-3}. The second iron-enrichment experiment in the WSP (SEEDS-II) was carried out in 2004. Although the location and timing of both experiments were identical, there were several differences in the initial conditions. SEEDS-II had: 1) a deeper pycnocline, 2) a lower enriched-iron concentration, 3) no seed population of *C. debilis*, 4) and a higher mesozooplankton biomass. In SEEDS-I and II, chlorophyll-*a* increased and peaked after 8-14 days from the iron-enrichment. The magnitude of phytoplankton bloom in SEEDS II was however ca. 1/6 of the one reached during SEEDS-I (3 mg m^{-3} of chlorophyll-*a*) and, accordingly, the drawdowns of pCO_2 and macronutrients were less. In SEEDS-II, the mesozooplankton was dominated by the copepod *Neocalanus plumchrus*, and the biomass was one-order higher than in SEEDS-I at the beginning of the experiment. In contrast to SEEDS-I, we also measured an increase in copepod biomass (from 3.5 to 5.4 gC m^{-2} in the top 20-m) in SEEDS-II. Their potential ingestion rate reached 0.9-1.4 mmol N m^{-3} d^{-1}. After the phytoplankton bloom, the assemblage became dominated by picophytoplankton and the abundance of microzooplankton decreased. Here we suggest that copepod grazing was the main factor preventing the development of the phytoplankton bloom and controlling the microbial succession during SEEDS-II.

PICES XV S4-2986 Poster
Responses of pico- and nano-phytoplankton to artificial iron infusions during SEEDS-II

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How pico- and nano-phytoplankton responded to artificial iron infusions was investigated using flow cytometry during SEEDS II. Cell concentration, forward light scatter, and chlorophyll fluorescence were measured for four phytoplankton groups: *Synechococcus*, cryptophytes, picoeucaryotes, and nanoeucaryotes. The two iron infusions caused remarkable increase in the cellular chlorophyll fluorescence and cell size of all four phytoplankton groups investigated. The cellular content of labile iron of the nanoeucaryotes measured using a fluorescent probe Phen Green SK also increased after the second iron infusion. One day after the second iron infusion, cryptophytes abundance started to increase and became ca. 4 times higher that prior the enrichment. Two days after the cryptophyte peak, picoeucaryotes started to increase exponentially. When the concentration of dissolved iron in surface waters decreased to its initial level, the chlorophyll fluorescence of all four groups returned to pre-infusions level and cell concentrations of pico- and nanoeucaryotes declined below initial conditions. In contrast, cell concentration of cryptophytes remained high. *Synechococcus* started to increase after the concentration of surface dissolved iron started to decrease, reaching levels 6 times higher than before the infusions. This peak in *Synechococcus* was not observed in SEEDS I and SERIES. The abundance of nanoeukaryotes was not affected by the iron infusions. Responses in chlorophyll fluorescence indicate that the iron infusions alleviated physiological stress of all the four phytoplankton groups. As a result, the iron infusions resulted in the dominance of cryptophytes and *Synechococcus* which, in contrast to the nanoeucaryotes, escaped zooplankton grazing.

PICES XV S4-2889 Oral

Comparison of community structure and photosynthetic physiology of phytoplankton in two mesoscale iron enrichment experiments in the NW subarctic Pacific

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Two mesoscale iron (Fe) enrichment experiments (SEEDS and SEEDS-II) were conducted in the NW subarctic Pacific during the summers of 2001 and 2004, respectively. In SEEDS, the chain-forming centric diatom *Chaetoceros debilis* formed a massive bloom after a single Fe fertilization. As a result, surface chlorophyll-*a* concentrations reached a maximum of ca. 20 mg m^{-3} and large phytoplankton (>10 μm in diameter) contributed to >90% of the surface chlorophyll-*a*. The photochemical quantum efficiency (F_v/F_m) and the functional absorption cross-section of photosystem II for the phytoplankton community increased and decreased, respectively, after the Fe enrichment, suggesting that the photosynthetic physiology of the phytoplankton was improved by the Fe addition. However, at the end of the experiment, F_v/F_m and the functional absorption cross-section decreased and increased, respectively. These results indicate phytoplankton growth may have been limited by either light and/or Fe at the end of the experiment. In SEEDS-II, the Fe addition resulted in a smaller bloom, with maximum chlorophyll-*a* concentrations reaching ca. 3 mg m^{-3} in surface water. In this experiment, the Fe-induced bloom was dominated by small phytoflagellates (cryptophytes, prasinophytes, chlorophytes, and prymnesiophytes), while diatoms abundance remained unchanged. The maximum level of F_v/F_m for the surface phytoplankton community during SEEDS-II was equivalent to that during SEEDS, indicating that the photosynthetic competence of phytoplankton in SEEDS-II were almost the same as SEEDS. These results suggest that the stocks and community structure of phytoplankton during SEEDS-II were controlled by herbivorous zooplankton grazing.

PICES XV S4-3030 Oral

Iron geochemistry of SEEDS-I, -II and SERIES

Shigenobu **Takeda**[1], Jun Nishioka[2], C.S. Wong[3], Wm. Keith Johnson[3], Masatoshi Kinugasa[4], Yoshiko Kondo[1], Kenshi Kuma[5], Seiji Nakatsuka[4], Hajime Obata[6], Eric Roy[7], Mitsuhide Sato[1], Nes Sutherland[3], Yoshiki Sohrin[4], Hyoe Takata[5], Heihachiro Tani[5], Atsushi Tsuda[6] and Mark L. Wells[7]

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Mesoscale iron-enrichment experiments were performed in the western (SEEDS-I & -II) and eastern (SERIES) subarctic Pacific in order to verify whether iron supply controls the magnitude of phytoplankton production in these high-nitrate, low-chlorophyll waters. Prior to the iron infusion, dissolved (<0.2 μm) iron concentrations in the surface seawater were extremely low both in the western and eastern experimental sites, although high concentrations of acid dissolvable particulate iron were observed at the SEEDS site. Additions of an acidified ferrous sulfate solution resulted in increases of the dissolved iron concentration to nanomolar levels and a large portion of the dissolved iron was observed in the colloidal fraction. Most of the soluble (<200 kDa or <0.03 μm) iron was in the Fe(II) form at the surface. The dissolved iron concentrations decreased rapidly in the SF_6-labelled patch via aggregation of colloidal iron and dilution of the patch. The half-life of dissolved iron in the surface mixed layer was estimated to be 20-70 hours. Transformation of dissolved (mainly colloidal) iron to labile particulate (>0.2 μm) iron by aggregation and/or physical adsorption to suspended particles as well as biological utilization seemed to be a key process determining the fate of added iron. In SEEDS-II, the iron infusions enhanced production of Fe(III)-complexing organic ligands and most of the dissolved iron was estimated to be complexed with these ligands. Construction of biogeochemical budgets for iron was difficult due to change in vertical mixing and horizontal heterogeneity of iron distribution.

PICES XV S4-2881 Oral

Meso- and microzooplankton responses in the iron-enrichment experiments in the subarctic North Pacific (SEEDS, SERIES and SEEDS-II)

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Three mesoscale iron-enrichment experiments were conducted in the subarctic Pacific between 2001 and 2004. The iron-patches were tracked 14 days after the fertilization (D14) in SEEDS and 26 days in SERIES and SEEDS II. Dominant zooplankton species in the upper 200-m depth were *Neocalanus* spp., *Eucalanus bungii* and *Metridia pacifica*. Mesozooplankton grazing on phytoplankton was not significant in SEEDS and during the first half of SERIES, but was significant in SEEDS II and during the diatom-declining phase in SERIES. No variation in the vertical distribution and diel vertical migration of mesozooplankton was observed for all species and stages in SEEDS and SEEDS-II. On the other hand, an upward shift of the vertical distribution of *E. bungii* in the iron-patch was measured during SERIES, resulting in a significant increase of the development rate of this species. Mesozooplankton biomass (wet weight) did not change significantly in SEEDS and SEEDS-II, but significantly increased in SERIES. The abundance of the first copepodite stages of *N. plumchrus* and *E. bungii* increased several times in the fertilized patch during SEEDS and SERIES. The increase in the abundance of both species is attributed to a lower mortality rate inside the patch during the egg and nauplius stages.

Microzooplankton grazing significantly increased after the development of diatom bloom in SEEDS, reflecting an increase of the heterotrophic dinoflagellates. The observed growth rate and reported grazing rate predict that most of the fixed carbon should be respired in the surface layer after our observation period. In contrast, microzooplankton grazing and phytoplankton growth rates were almost in equilibrium throughout the experimental period in SEEDS-II.

PICES XV S4-2880 Oral

SEEDS-I summary

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To test the iron hypothesis, an *in situ* iron-enrichment experiment (SEEDS) was performed in the western subarctic Pacific in summer 2001. About 350 kg of iron and the inert chemical tracer sulfur hexafluoride were introduced into a 10-m deep surface mixed layer over an 8 x 10 km area. During SEEDS, we observed iron-mediated increases in chlorophyll a concentrations (16 mg/m^3), primary production, and photosynthetic energy conversion efficiency relative to the surrounding waters. The rapid and very high accumulation of phytoplankton biomass was caused by a floristic shift from open-ocean pennate diatoms to fast-growing centric diatoms. The blooming of diatoms resulted in a marked consumption of macronutrients and dissolved inorganic carbon. The export flux between day 2 and day 13 was 12.6% of the integrated primary production in the iron-enriched patch. Most of the carbon fixed by the blooming diatoms remained in the surface mixed layer as biogenic particulate matter. Our findings support the hypothesis of a 'bottom up' control of phytoplankton growth and biomass in this HNLC area, but the fate of the algal carbon remains unknown. Modeling study predicted that 40% of the fixed carbon would be exported by sinking between day 0 and day 40. In contrast, the abundance of heterotrophic dinoflagellate increased in the second half of the experiment and their observed growth and grazing rates predict that most of the fixed carbon would be respired in the surface layer between day 10 and day 18.

PICES XV S4-3213 Oral

The physical behavior of the iron patches detected by SF_6 tracer during SEEDS-I and SEEDS-II

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Sulfur hexafluoride (SF_6) tracer release experiments were carried out to track the iron (Fe)-fertilized water masses during the Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study (SEEDS and SEEDS-II) in 2001 and 2004, respectively. A solution of Fe and SF_6 tracer was released into the mixed layer over a 8 x 8 km area, and the fertilized patch was tracked and mapped by on-board SF_6 analysis for 12 days in each experiment. A Lagrangian frame of reference was maintained by the use of a GPS buoy released at the center of the patch to minimize the effect of advection on our observations. Horizontal diffusivities were determined by the changes in SF_6 concentrations. The horizontal diffusivity was about 4.9×10^1 m^2 s^{-1} in SEEDS-II, a value five times higher than during SEEDS. The mixed layer depth varied between 8 and 10 m in SEEDS, and between 20 and 33 m in SEEDS-II. The higher horizontal diffusivity and deeper mixed layer depth during SEEDS-II combined to rapidly reduce the concentration of Fe in the surface layer during that experiment. Detailed patch structures and behavior were obtained in SEEDS-II. Following the iron infusion, the patch moved along the contour of a sea surface height (SSH) of a clockwise mesoscale eddy for 4 days. After day 4, a strong westward wind dragged the patch across the contour of the SSH. The behavior of the patch was thus affected by both the mesoscale eddy and surface winds.

PICES XV S4-3203 Oral

The persistence of iron limitation during the SEEDS II mesoscale iron enrichment experiment

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The SEEDS-II iron enrichment experiment was conducted in the western subarctic Pacific to study the effects of iron additions on community structure and carbon export. As observed during SEEDS-I, iron additions stimulated diatom growth, however the response was substantially less than in SEEDS I and more similar to that observed in the eastern subarctic Pacific iron enrichment experiment (SERIES). Deckboard incubation "grow-out" experiments during SEEDS-II demonstrated that diatom growth remained iron-limited in the patch despite elevated dissolved iron concentrations (> 0.5 nM). Total chlorophyll biomass in the large (> 20 μm) fraction increased progressively with picomolar level iron additions, indicating that the added iron had been rendered largely unavailable to the large diatoms. A likely explanation for this condition is the presence of strong Fe(III)-complexing organic ligands released by the biota because analogs for these suspected ligands limit diatom growth. Diatoms of the genus *Pseudo-nitzschia* were among those responding within the enriched patch, and there is evidence that some members of this genus possess copper dependent, high affinity iron uptake systems that can access iron bound to strong organic ligands. Low-level copper additions to enriched patch waters stimulated the growth of large phytoplankton during grow-out experiments, and the combination of iron and copper generated a greater response than did iron alone. Our findings suggest that dynamics of strong Fe(III)-complexing ligands can overwhelmingly regulate ecosystem responses to natural (low level) atmospheric iron deposition events in high latitude, HNLC regions.

PICES XV S4-2966 Oral

The dynamics of dissolved organic matter during *in situ* iron enrichment experiments in the subarctic North Pacific

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The dynamics of dissolved organic carbon (DOC) was investigated during three in situ iron enrichment experiments in the western (SEEDS in 2001 and SEEDS-II in 2004) and the eastern (SERIES in 2002) subarctic North Pacific. Although the magnitude of the phytoplankton blooms induced by single or double addition of iron was different in each experiment, significant portion of the organic carbon production was observed as DOC during the iron-induced phytoplankton blooms. Net DOC production increased with increasing magnitude of the phytoplankton bloom. At the peak of the phytoplankton abundance, net DOC productions were 131 mmol/m^2 in SEEDS (0-20m on Day 13), 107 mmol/m^2 in SERIES (0-20m on Day 17), and 48 mmol/m^2 in SEEDS-II (preliminary value; 0-30m on Day 12). While the ratio of net DOC production to net Chl-*a* production (mmol DOC / mg Chl-*a*) was 0.7-1.1 during the growth phase of the centric diatom dominated bloom in SEEDS and pennate diatom dominated bloom in SERIES, preliminary result from SEEDS-II indicated a relatively high ratio of 2.3 during the bloom dominated by small non-diatom phytoplankters during SEEDS-II. Extracellular release by phytoplankton and grazing of zooplankton generally can be important mechanisms for DOC production. The size structure of the phytoplankton assemblage would thus have an impact in regulating the extracellular release and fate of the carbon flow through the planktonic food web.

S5 BIO Topic Session
Advances in epi- and meso-pelagic ecosystem research

Co-Convenors: Alexei M. Orlov (Russia), Evgeny A. Pakhomov (Canada) and Orio Yamamura (Japan)

Micronekton is an important component of epi- and meso-pelagic ecosystems linking mesozooplankton and higher trophic levels. Due to their intermediacy and mobility, quantitative sampling of micronekton has long been regarded as virtually impossible. Recent advances in acoustic devices and efforts in standardizing sampling gear have made the sampling of micronekton more precise. In the PICES area, various ongoing projects such as BASIS (NPAFC), US-GLOBEC and DEEP (Japan FRA) are studying micronekton. The session will synthesize new knowledge on micronekton biology including distribution, life history and vertical migrations, relationships with commercial species and its functional role in the North Pacific boundary current and open ocean ecosystems. Presentations on quantitative sampling are also welcome.

See related presentations at the MIE-AP workshop (W9)

Wednesday, October 18, 2006 09:00-15:30

09:00-09:30 **Richard D. Brodeur** (Invited)
Micronekton and their importance in the northern California Current Ecosystem (S5-2904)

09:30-09:50 **Andrey V. Suntsov**
Adaptive radiations in mesopelagic fishes: The role of key innovations (S5-3043)

09:50-10:10 **Vladimir I. Radchenko**
Ratio of myctophid and bathylagid fish biomasses as an index of mesopelagic fish community status (S5-3147)

10:10-10:30 **Michael J. Miller and Katsumi Tsukamoto**
Distribution and ecology of leptocephali in the western North Pacific gyre ecosystem (S5-3178)

10:30-10:50 ***Tea/Coffee Break***

10:50-11:10 **Hiroshi Kubota, Yoshioki Oozeki and Ryo Kimura**
Factors responsible for the differences in feeding habits of mesopelagic fishes (Myctophidae and Gonostomatidae) and larval and juvenile Japanese anchovy (S5-2924)

11:10-11:30 **Todd W. Miller, Richard D. Brodeur and Greg H. Rau**
Trophic relationships of nekton and zooplankton in the northern California Current: Insights from diet and stable isotope analysis (S5-2942)

11:30-11:50 **Hiroya Sugisaki, Masatoshi Moku, Kazuhisa Uchikawa, Kotaro Tsuchiya, Yuji Okazaki and Makoto Okamoto**
Vertical distribution and feeding habit of mesopelagic fishes and squids off northeastern Japan (S5-2985)

11:50-12:10 **Oleg N. Katugin, Gennady A. Shevtsov and Mikhail A. Zuev**
Distribution and life cycle patterns of the squid *Gonatopsis octopedatus* and *Gonatopsis japonicus* (Cephalopoda: Gonatidae) in the northwestern Pacific Ocean (S5-2842)

12:10-12:30 **Kaori Takagi, Akihiko Yatsu, Hiroshi Itoh, Masatoshi Moku, Ken Mori and Hiroshi Nishida**
Distribution and prey composition of juvenile small epipelagic fishes and myctophids in the Kuroshio-Oyashio Transition Zone in spring, 2002-2004 (S5-2947)

12:30-14:00 ***Lunch***

14:00-14:30 **Hiroaki Saito** (Invited)
Dynamic linkage between epipelagic and mesopelagic ecosystems by horizontal and vertical migrations of myctophids (S5-2970)

14:30-14:50 **Alexei M. Orlov and Anatoly K. Gruzevich**
Distribution of micronekton within lower mesopelagic layers of the Sea of Okhotsk and the Bering Sea in relation to hydrological and hydrochemical environmental parameters (S5-2806)

14:50-15:10 **Galina V. Belova and Vadim F. Savinykh**
Reproductive biology of the mesopelagic fishes *Tarletonbeania crenularis* and *Ceratoscopelus warmingii* (Osteichthyes: Myctophidae) from the northwestern Pacific (S5-2848)

15:10-15:30 **Jun Yamamoto, Mio Tateyama Yoshihiko Kamei, Keiichiro Sakaoka Naoto Kobayashi and Yasunori Sakurai**
Interannual variability of the community structure of epipelagic nekton along 155ºE longitude in early summer (S5-2866)

Posters

Yoshinari Endo and Fuhito Yamano
Diel vertical migration of *Euphausia pacifica* in relation to molt and reproductive processes, and feeding activity (S5-3181)

Oleg A. Ivanov and Vitaly V. Sukhanov
Species structure of epipelagic nekton in the northwestern part of the Japan/East Sea (S5-2887)

Gennady A. Shevtsov, Oleg N. Katugin, Mikhail A. Zuev and Gennady V. Khen
Distribution of cephalopods in the western Subarctic Boundary in the autumn of 2001 (S5-2843)

Natalia S. Kosenok and Vladimir V. Sviridov
Feeding behavior and vertical migration of some common mesopelagic fish species in the Bering Sea during autumn of 2004 (S5-2784)

Vladimir A. Shelekhov and Vadim F. Savinykh
Age and growth of the Highsnout bigscale, *Melamphaes lugubris* (S5-2979)

Vadim F. Savinykh
The micronekton community of the epi- and mesopelagic layers of the Kuroshio Current zone (S5-2978)

Boyoung Sung, Hyoung-Chul Shin, Donhyug Kang and Suam Kim
Characterizing krill aggregations and linking them to some environmental factors in the Southern Ocean: Relevant to other krill-bearing marine ecosystem studies? (S5-3086)

Masanori Takahashi, Noritaka Mochioka, Sekio Shinagawa, Hiroshi Nishida and Akihiko Yatsu
Fluctuations of epipelagic leptocephalus assemblages in the Kuroshio-Oyashio transition region (S5-3218)

Naoki Tanimata, Orio Yamamura, Yasunori Sakurai and Tomonori Azumaya
Relationship between the inhabited environment and the distribution of *Stenobrachius leucopsarus* in the Bering Sea (S5-2981)

Masaya Toyokawa, Hiroya Sugisaki and Hiroshi Morita
Vertical distribution of cnidaria and ctenophores in the A-Line (S5-2933)

Anatoliy Ya. Velikanov, Dmitriy Yu. Stominok and Alexander O. Shubin
Interannual changes in fish communities of the Aniva Bay upper epipelagic zone (Sakhalin Island) and adjoining areas of the Okhotsk Sea in summer (S5-2787)

Hikaru Watanabe, Tsunemi Kubodera and Masatoshi Moku
Diel vertical migration of squid in the Kuroshio-Oyashio transition region (S5-3002)

Oleg G. Zolotov
Atka mackerel, *Pleurogrammus monopterygius*, larvae and fry in the upper epipelagial of the north-western Pacific Ocean (S5-2882)

Mikhail A. Zuev
Squids of the family Enoploteuthidae in the epipelagic layer of the Kuroshio Current (S5-3119)

PICES XV S5-2848 Oral

Reproductive biology of the mesopelagic fishes *Tarletonbeania crenularis* and *Ceratoscopelus warmingii* (Osteichthyes: Myctophidae) from the northwestern Pacific

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Tarletonbeania crenularis (Jordan et Gilbert, 1880) and *Ceratoscopelus warmingii* (Lütken, 1892) belong to different faunistic complexes, boreal and subtropical, respectively. Reproductive biology of these species has not been investigated. Samples of *T. crenularis* (375 individuals) and *C. warmingii* (458 individuals) have been collected off the Kuril Islands and in open waters of the western North Pacific (region «A») in November 2001, July-August 2002 and November 2005, and in the subtropical waters (region «B») in April 1984 and February 1990.

T. crenularis is a boreal eurythermal species. It spawns in both areas: in the region «A» mass spawning occurs in July-August, and some individuals possibly spawn in November; in the region «B» the fish spawn in April-May. This species had a size range of 40–90 mm (Standard length, SL). Females mature at 60 mm SL. In the region «A», *T. crenularis* spawns and forages, while in the «B» region, only spawning of this species occurs.

C. warmingii spawning was observed in the region «B» during winter-spring. Most likely, spawning continues all the year round, like in many other subtropical species. In the region «B», females had SL of 70-85 mm. In the region «A» females were smaller – 50-80 mm. Females mature at 70 mm SL. *C. warmingii* spawn in the region «B» and forage in the region «A».

Both species are intermittent spawners. *T. crenularis* have twice as many oocytes at all developmental phases in stage IV gonads as *C. warmingii*. The portional fecundity of *T. crenularis* is 5150±2905, *C. warmingii* 2283±1186. The potential individual fecundity of *T. crenularis* is 51379±7282 and *C. warmingii* 21698±6500.

PICES XV S5-2904 Invited

Micronekton and their importance in the northern California Current Ecosystem

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The micronektonic fauna of the northern California Current has been extensively studied since the pioneering work of Aron and Pearcy starting in the late 1950s. Although for a period in the 1980s and 1990s, little or no research on micronekton had been conducted, interest has renewed in the last decade in examining the importance of this disparate but highly abundant group of organisms in this ecosystem, fueled by interest within the PICES community. Ichthyoplankton surveys indicate that mesopelagic fishes represent a high percentage of the total abundance collected and are dominated by the families Myctophidae and Bathylagidae but also include Phosichthyidae, Stomiidae, and Sternopthchidae. For adult stages, four species of myctophids (*Stenobrachius leucopsarus, Diaphus theta, Tarletonbeania crenularis,* and *Nannobrachium ritteri*) and one Bathylagid (*Leuroglossus* sp.) are dominant. Distribution of these species is generally well off the continental shelf though it shifts shoreward during winter and in areas subject to bathymetrically-induced upwelling (canyons). They appear to go through periods of sustained high or low abundance through time. Trophic studies based on stomach and stable isotope analyses indicate that most myctophids feed on copepods, euphausiids, pteropods and hyperiid amphipods and are in turn consumed by many species of fishes, birds and marine mammals. Relatively little is known about micronektonic crustaceans and cephalopods in this region.

PICES XV S5-3181 Poster

Diel vertical migration of *Euphausia pacifica* in relation to molt and reproductive processes, and feeding activity

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We investigated the diel vertical migration of *Euphausia pacifica* in relation to molt and reproductive processes and feeding activity in April and September 2001 at fixed stations off northeastern Japan. The vertical distribution of this species was shallower in April than in September during both day and night, which was partly explained by a high surface temperature (19°C) and the existence of a subsurface chlorophyll maximum in September. It has been demonstrated for the first time that diel vertical migration of this species is influenced by molt processes because upward migration of molting individuals was restricted compared with non-molting ones. Feeding activity of molting individuals was reduced throughout the day, being lower than or similar to the daytime feeding activity of non-molting ones. The percentage of molting individuals was least (2-4%) among the gravid females, which suggests that gravid females molt less frequently than other stages of females and males. Molt and reproductive processes therefore seemed to be coupled in this species.

PICES XV S5-2887 Poster

Species structure of epipelagic nekton in the northwestern part of the Japan/East Sea

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Nekton species structure of the northwestern Japan/East Sea was analyzed, based on data from trawl surveys conducted from 1981-2003. The structure of the nektonic community changes during the day and species diversity is maximum at night. Species diversity has two peaks during the year, in April and November. The rate of succession also has two maxima, in the spring (April) and in the autumn (October). Species diversity of the nektonic community showed high-frequency interannual fluctuations with a variable period and a weak positive trend. The correlation between rate of succession and species richness is shown. This correlation for fast intradaily processes is positive and statistically significant. For seasonal processes, correlation between rate of succession and number of species is somewhat lower and not statistically significant. For slow interannual processes, correlation between these parameters is still low. The rank curve of the nektonic species is well described by the so-called model of geometric series or the model of Motomura. Based on this model, potential species richness of these epipelagic nekton communities was 411 ± 11 species. A positive correlation between evenness of species structure and nektonic species diversity was found. The relationship between total biomass of a species in a trawling sample and evenness of species structure in a sample was negative. Correlation analyses suggest that monodominant communities have higher total biomass than polydominant communities.

PICES XV S5-2842 Oral

Distribution and life cycle patterns of the squid *Gonatopsis octopedatus* and *Gonatopsis japonicus* (Cephalopoda: Gonatidae) in the northwestern Pacific Ocean

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Patterns of spatial, vertical and seasonal distribution of two pelagic squid species of the family Gonatidae (*Gonatopsis octopedatus* and *Gonatopsis japonicus*) are considered, based on the data collected in 37 research cruises during 1979-2004 into the northwestern Pacific Ocean, Okhotsk and Bering seas.

G. octopedatus and *G. japonicus* were rare in the Bering Sea, and were relatively common in the Okhotsk Sea and in the Pacific Ocean off the Kuril Islands. These species occurred beyond the shelf zone in a wide depth range, from the surface layers down to as deep as 2,000 m, and were most abundant in the Okhotsk Sea deep basin.

In summer, *G. octopedatus* were distributed mainly in the epipelagic zone, where the catches were dominated by small young individuals. By autumn and winter, squid descended to deeper layers, where the catches were dominated by larger adult and maturing individuals. Our data suggest that juvenile squid are predominantly epipelagic, and immature individuals migrate to the deep layers, where they mature and breed.

In summer, autumn and winter, *G. japonicus* were distributed mainly in the epipelagic zone, where the catches were dominated by juveniles and immature adults. Squid were rather common in summer and rare in the latter two seasons. In contrast to *G. octopedatus*, the distribution of *G. japonicus* did not show any clear evidence for early ontogenetic migrations to the deep-water layers. Our data suggest that *G. japonicus* lead an active pelagic life until they attain advanced maturity, and only after that do they descend to the bathypelagic zone to spawn.

PICES XV S5-2843 Poster
Distribution of cephalopods in the western Subarctic Boundary in the autumn of 2001

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Rather scanty information exists about species composition and distribution of pelagic cephalopods inhabiting the western Subarctic Boundary area. We analyzed data on the occurrence of cephalopods collected on a midwater trawl survey conducted by the TINRO-Centre in open waters of the northwestern Pacific Ocean in November 2001. A total of 45 tows were made in the offshore oceanic area bounded by 39º-46ºN and 150º-160ºE. The sampling grid consisted of 35 trawling hauls, 32 within the upper 200 m and three at about 500 m. At one station, 10 tows were made over two days to as deep as 600 m.

In total, 77,525 individual cephalopods in 34 species, 25 genera and 12 families were collected. Of these, 32 species and 10 families (Enoploteuthidae, Ancistrocheiridae, Octopoteuthidae, Onychoteuthidae, Gonatidae, Histioteuthidae, Ommastrephidae, Chiroteuthidae, Mastigoteuthidae and Cranchiidae) represented the order Teuthida (squids), and only 2 species and 2 families (Ocythoidae and Alloposidae) represented the order Octopoda (octopuses). Most abundant were the squid families Enoploteuthidae (76,139 individuals), Gonatidae (576 individuals) and Onychoteuthidae (483 individuals).

The cephalopod fauna of the region was represented by both boreal and subtropical species, and was related to oceanographic structure. Several species occurred throughout the study area. Some of them were migrants from the south that normally spawn in the subtropics and forage in or north of the Subarctic Boundary. Others were migrants from the north that penetrated far south within the relatively cold, deep-water layers. A few species appeared to be widely distributed bathypelagic dwellers.

PICES XV S5-2784 Poster
Feeding behavior and vertical migration of some common mesopelagic fish species in the Bering Sea during autumn of 2004

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Stenobrachius leucopsarus, *S. nannochir* (Myctophidae family), *Leuroglossus schmidti* and *Lipolagus ochotensis* (Bathylagidae family) comprised the major share of fish biomass in the mesopelagic layer of the western Bering Sea. Euphausiids were the dominant food items of *L. schmidt*i and *S. leucopsarus*. *L. ochotensis* consumed primarily gelatinous plankton, and euphausiids were of secondary importance. *S. nannochir* consumed primarily deep-water shrimps and copepods. The highest feeding activity of *L. schmidti* and *S. leucopsarus* was observed in the upper epipelagic layer at night. During the day, feeding activity of these two species was significantly lower (especially that of *L. schmidti*). *L. schmidti* stomach content indices in both the upper and lower mesopelagic layers were significantly lower than indices for *S. leucopsarus*. *L. ochotensis*, (night only), was observed to feed in both the epipelagic and mesopelagic layers. Feeding activity of *S. nannoch*ir was quite low in all layers throughout the entire twenty-four hour period. *L. schmidti*, *L. ochotensis* and *S. nannochir* were located in the lower mesopelagic layer, while *S. leucopsarus* was found mainly in the upper mesopelagic layer. At night, most individuals of all species were located in the lower

mesopelagic layer. Body length of *S. leucopsarus* and *L. ochotensis* increased with depth, while the opposite pattern was observed in *L. schmidti*. No pattern was observed in *S. nannochir*.

PICES XV S5-2924 Oral

Factors responsible for the differences in feeding habits of mesopelagic fishes (Myctophidae and Gonostomatidae) and larval and juvenile Japanese anchovy

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Survival during the early life stages of pelagic fishes may be affected by food competition with mesopelagic fishes in the Kuroshio-Oyashio Transition Zone (KOTZ) of the western North Pacific. Gut contents of the dominant larval and juvenile fishes (Japanese anchovy *Engraulis japonicus* and 8 mesopelagic species) were analyzed from samples caught by a frame trawl (MOHT, 5 m^2 opening, 1.59 mm square mesh size) in KOTZ during 2001 and 2002. Feeding habits were compared by the volumetric ratio and body width frequency of items found in the gut, and both were considerably different between anchovy and mesopelagic fishes. Larval and juvenile anchovy fed mainly on copepods smaller than 0.4 mm in body width, while prey found in the gut content of mesopelagic fishes showed much greater size variability. Day/night differences in vertical distribution of prey copepods were also analyzed. Small copepods (< 0.4 mm in body width) had similar vertical distribution patterns throughout the day, while large copepods (> 0.4 mm) had considerably different patterns. The density of large copepods was 20-fold higher during nighttime than during daytime in the surface 30 m. It was suggested that mesopelagic fishes migrate and forage in the surface layer during nighttime, and possibly feed selectively on large mesopelagic zooplankton concurrently migrating into the surface layer. On the other hand, anchovy feed during daytime, but the low daytime density of large zooplankton in the surface layer does not allow selective feeding.

PICES XV S5-3178 Oral

Distribution and ecology of leptocephali in the western North Pacific gyre ecosystem

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Leptocephali, the leaf-like larvae of eels, have several characteristics that make them unique components of the epipelagic ecosystem, such as transparent bodies with a unique physiology, use of abundant marine snow-like organic material as a food source, a long larval duration, a large size increase before transformation into juvenile eels, and the ability to swim both forwards and backwards. Their large size and good swimming ability enables them to avoid standard sized plankton nets and this has made these often abundant larvae an almost unknown component of epipelagic ecosystems worldwide. Recent surveys in the Kuroshio, Kuroshio Extension and the western North Pacific using big plankton nets have suggested that many of these larvae are spawned along the Kuroshio in the East China Sea or along coastal Japan. Although many leptocephali are likely retained until recruitment, others are transported offshore by the Kuroshio. Large numbers of those transported offshore may enter the western Kuroshio gyre due to recirculation or countercurrents. Some species of congrids (*e.g. Ariosoma*) reach very large larval sizes (250–300 mm) and appear to be recirculated as far south as the North Equatorial Current (NEC). Although the Japanese eel spawns in the NEC and recruits back to East Asia, it is unknown if these other species recruit back to their continental shelf or slope habitats, because their biology is still poorly understood. Leptocephali may be ecologically important in marine ecosystems because they represent a potentially significant connection between the surface layer of the ocean and the continental shelf.

PICES XV S5-2942 Oral

Trophic relationships of nekton and zooplankton in the northern California Current: Insights from diet and stable isotope analysis

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The northern California Current (NCC) ecosystem is highly productive and exhibits seasonal, interannual, and interdecadal variation in pelagic productivity and community composition. To better understand the trophic relationships within this system, from 2000 and 2002 GLOBEC surveys we examined the diets of 25 nekton species and measured carbon and nitrogen stable isotopes of nekton and their prey. Nektons were placed into trophic groups using cluster analysis of diet (percent prey weight). Cluster analysis partitioned nekton into three trophic groups denoting lower (*e.g.* sardine, and juvenile fishes), mid- (*e.g.* herring, smelts, anchovy, juvenile salmon, and market squid) and upper (*e.g.* adult sharks, mackerel and salmon) trophic levels. Lower trophic nekton consumed euphausiids (eggs and juveniles) and copepods, mid-trophic consumed more adult euphausiids and decapod larvae, and upper trophic nekton consumed adult and juvenile fishes, although euphausiids were important as well. Comparison of cluster groups to stable isotopes showed the mid-trophic group had high overlap in $\delta^{15}N$ among species, indicating this group generally fed at the same trophic level. Higher and lower trophic levels were distinguishable by $\delta^{15}N$ but each overlapped with the mid-trophic group. The $\delta^{13}C$ of nekton and zooplankton showed a strong cross-shelf trend with nearshore organisms being heavier in ^{13}C, indicating delineation between onshore and offshore communities. The lower level of trophic connectivity observed here represents a relatively unstable condition where many species depend on a few abundant prey, particularly euphausiids. However, cross-shelf variations in $\delta^{13}C$ indicate a more spatially complex system that may be more resilient.

PICES XV S5-2806 Oral

Distribution of micronekton within lower mesopelagic layers of the Sea of Okhotsk and the Bering Sea in relation to hydrological and hydrochemical environmental parameters

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Micronekton plays an important role in oceanic ecosystems. It represents a significant component of various food webs and takes part in the transport of organic matter and energy between different trophic levels. Despite the large biomass and high biodiversity of micronekton species in the northwestern Pacific, their patterns of distribution are still poorly understood. Relationships between their distribution and abundance patterns and hydrological and hydrochemical environmental parameters are also poorly known.

On the basis of midwater trawl and oceanological surveys in deepwater regions (500-1000 m layer) of the Sea of Okhotsk (23 stations) and the Bering Sea (50 stations), spatial distributions of 19 taxa of midwater fishes and invertebrates (squids, hydrozoans, deepwater shrimps and mysids) were determined. Fish taxa included slender blacksmelt *Bathylagus pacificus*, northern smooth-tongue *Leuroglossus schmidti*, eared blacksmelt *Lipolagus ochotensis*, stout blacksmelt *Pseudobathylagus milleri*, barelleye *Macropinna microstoma*, Pacific viperfish *Chauliodus macouni*, northern pearleye *Benthalbella dentata*, paperbone *Scopelosaurus adleri*, California headlightfish *Diaphus theta*, brokenline lampfish *Lampanyctus jordani*, pinpoint lampfish *Nannobrachiun regale*, northern lampfish *Stenobrachius leucopsarus*, garnet lanternfish *S. nannochir*, silvery eelpout *Bothrocarina microcephala*, dreamers Oneirodidae, ridgeheads Melamphaeidae, and juveniles of three grenadiers (giant grenadier *Albatrossia pectoralis*, Pacific grenadier *Coryphaenoides acrolepis*, popeye grenadier *C. cinereus*). Survey indices are compared with hydrological and hydrochemical parameters such as water temperature, salinity, dissolved oxygen, phosphates, organic phosphorus, nitrates, ammonia, organic nitrogen, silicates, organic carbon and chlorophyll “a”. Relationships between micronekton survey indices and patterns of spatial distribution and hydrological and hydrochemical parameters listed above will be presented.

PICES XV S5-3147 Oral

Ratio of myctophid and bathylagid fish biomasses as an index of mesopelagic fish community status

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The biomass ratio of myctophids to bathylagids (RMB) was calculated using data from pelagic trawl surveys summarized in the series of "Atlases of quantitative distribution…", and "Nekton…" (Shuntov *et al*., 2003, 2005, 2006). Calculations were made for 18 statistical regions of the Okhotsk, Bering Seas, and north-western Pacific Ocean. Data from 668 trawl hauls were analyzed for the Bering Sea (1982-2004), 864 – for the Sea of Okhotsk (1984-2003), and 973 – for the Pacific Ocean (1979-2004). For representative data sets, RMB varied no more than 3.6 times in the northern Sea of Okhotsk while estimated myctophid biomass varied up to 38 times, and bathylagid biomass varied up to 30 times. In the Oyashio Current area, RMB displayed the greatest value (18.4) and variability, 12 times, while estimated myctophid biomass ranged up to 145 times. This wide range was caused by the presence of numerous subarctic species of myctophids. RMB values increased in the Pacific Ocean due to the increase of the subarctic species portion of total myctophids biomass ($r = 0.74$). Comparing selected regions, RMB increases from the northern Sea of Okhotsk to the northern Bering Sea. RMB is higher for offshore regions than for the near-slope ones in the southern Bering Sea and the Pacific Ocean off Kamchatka. The RMB index was compared for three periods: from 1979-1984 to 1990, 1991-1995, and 1996-2004 (2003). It only significantly changed when data sets consisted of less than 30 samples due to geographical or vertical limitation of sampling. RMB indicates the mesopelagic fish community is relatively stable in the long-term but varies gradually on the spatial scale.

PICES XV S5-2970 Invited

Dynamic linkage between epipelagic and mesopelagic ecosystems by horizontal and vertical migrations of myctophids

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The mesopelagic layer known as the "*twilight zone"* is situated between the euphotic and aphotic layers. As the mesopelagic ecosystem is fueled by organic matter produced in the euphotic layer, some organisms are adapted to sense and feed on sinking particles from the euphotic layer. They are often inactive in the dimly lit and cold mesopelagic layer compared with organisms in the sunlit and warm epipelagic region. On the other hand, many mesopelagic zooplankton and micronekton carry out vertical migration to the epipelagic layer for foraging. Myctophids are dominant mesopelagic micronekton and many species are diel vertical migrators across the boundary between the epipelagic and mesopelagic layers. They feed on prey in the epipelagic layer during nighttime and return to the mesopelagic layer during the day. Their prey species during the day are often zooplankton migrating down to the mesopelagic to avoid epipelagic predators. Myctophids as well as epipelagic fish in the temperate and boreal seas are also migrators across the subarctic and/or subtropical boundaries. Most myctophids spawn in the warmer region south of the boundaries and migrate to the colder region during summer for foraging. As the biomass of myctophids is greater than that of epipelagic fish, we can say that myctophids are the most active drivers connecting epipelagic and mesopelagic ecosystems and also connecting subtropical and subarctic ecosystems. This study is a part of the Deep-Sea Ecosystems and Exploitation Programme (DEEP), and the role of myctophids in North Pacific ecosystems will be summarized.

PICES XV S5-2979 Poster
Age and growth of the Highsnout bigscale, *Melamphaes lugubris*

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Highsnout bigscale is a common but not highly abundant species inhabiting the North Pacific Ocean. It is distributed from the Bering Sea down to northern Baja California, off the Japanese Islands and in the Okhotsk Sea. There is no data about age of this fishand therefore otoliths of 14 samples of fish (SL from 76 to 95 mm) were analyzed for age estimation. The sagitta is rather large, being 6.5-7% of the SL. Judging from the number of well-defined hyaline zones, the largest individuals (SL of 10 cm) were 2.5 years old. Those with 8-9 cm SL were aged at 1.5 years. We also used another method of age estimation for this fish. Microincrements were counted using equipment from the Ratoc System Engineering Co. Ltd. at a 100-fold magnification. The radius of the nuclear zone is about 9.2 mm. There are 3 or 4 unclear circles inside the nuclear zone. Width of microincrements gradually decreases in the nuclear-edge direction. However, there are regular changes of microincrement width and their duration is estimated to be about one year. The age of large-sized fish from Kuroshio Current waters was estimated to be from 2+ to 5+ years. The largest fish and juveniles of Highsnout bigscale were observed in the Kuroshio and California Currents whereas middle-aged fish were found in subarctic waters. It is suggested that the Subtropical gyre is the spawning and nursery ground of this fish whereas the Subarctic gyre is its feeding area.

PICES XV S5-2978 Poster
The micronekton community of the epi- and mesopelagic layers of the Kuroshio Current zone

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The micronekton community of the epipelagic (0-200 m) and mesopelagic (200-500 m) layers of the Kuroshio Current was studied in November 2001 and July 2002.

Only the upper layer was warm in July and subarctic (*Diaphus theta, Stenobrachius leucopsarus, Lipolagus ochotensis*), and transitional (*Lampanyctus regalis, Notoscopelus japonicus, Tactostoma macropus*) species of fishes and squid (*Watasenia scintillans* and *Chiroteuthis calyx*) dominated the mesopelagic layer. *W. scintillans* and the transitional myctophid *Diaphus gigas* dominated the epipelagic layer. Biomass was 3.7 ton/km^2 in the epipelagial and 5.6 ton/km^2 in the mesopelagial. The number of species was 21 and 39, respectively.

In November, there were 36 species of fishes and squids in the epipelagic layer and the biomass was 0.36 ton/km^2 during the night. Myctophids (*Ceratoscopelus warmingii, Symbolophorus californiensis, S. leucopsarus*) and small squids (*W. scintillans, Enoploteuthis chuni, Abraliopsis* sp.) were most abundant. The number of species and the biomass fluctuated during the day in the mesopelagic layer. Maximal values of species number (63) and biomass (0.95 ton/km^2) were observed at night, medium values were observed in the evening (56 species and 0.36 ton/km^2), and minimal values were observed near noon (44 species and 0.3 ton/km^2). The same small squids, myctophids and *Howella hoylei* were more numerous in the mesopelagic layer in the daytime but the proportion of bathypelagic species increased near sunset. The highest number of bathypelagic species and the maximal biomass were observed at night. Thus, there are three groups of micronekton in the investigated area. One of them migrates between the epi- and mesopelagic layers, the second between the epi- and bathypelagic layers, and the third between the meso- and bathypelagic layers.

PICES XV S5-2985 Oral

Vertical distribution and feeding habit of mesopelagic fishes and squids off northeastern Japan

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Seasonal micronekton sampling has been conducted for several years using a 4 m^2 MOCNESS and various midwater fishing gears at fixed stations off northeastern Japan. Seasonal variation of vertical distribution and feeding habit of various micronekton have been analyzed. Mesopelagic fishes and small squids were grouped into vertical migrant species and non-migrant species. The vertical migrant species *e.g. Diaphus theta*, ascended to near surface water during the night, where they mainly fed on vertical migrating herbivorous copepods, *e.g. Metridia* spp. This implies that primary production is quickly transported to mesopelagic micronekton through this food chain. Non-migrant deep-water species, *e.g. Stenobrachius nannochir*, mainly fed on *Neocalanus* copepods in the deep layers throughout the year. The feeding season of *Neocalanus* species is only during the spring bloom period, when they feed on phytoplankton near the surface. They reside in the deep layers during other seasons. Non migrant deep water species, therefore, may depend on sinking flux by biological processes such as this ontogenetic vertical migration of *Neocalanus*, for sustaining their high biomass in the deep layer. The feeding habits of micronektonic squids were also analyzed. *Watasenia scintillans*, a vertical migrant, mainly fed on vertical migrating herbivorous copepods, *e.g. Metridia* spp. Non migrant squids, *e.g. Gonatopsis borealis* and *Gonatus onyx*, often fed on crustacean zooplankton, mainly copepods and euphausiids. In addition, chaetognaths were often detected from the gut contents of these gonatiid squids. Difference of feeding habit between species of squids was clearly observed. This is the first report on the predator-prey relationship of squids in the mesopelagic ecosystem in the Pacific Ocean.

PICES XV S5-3086 Poster

Characterizing krill aggregations and linking them to some environmental factors in the Southern Ocean: Relevant to other krill-bearing marine ecosystem studies?

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Euphausiids, often a key trophic link in marine food webs around the globe, form near-monospecific aggregations in epipelagic zones. Hence, formation and dispersion of these aggregations are subject to a range of environmental conditions. Hydroacoustic techniques have been used extensively to determine krill biomass and also offer a tool to investigate various aspects of their ecology. In this study, we examined morphological characteristics of Antarctic krill aggregations using a scientific echosounder (38 and 120kHz) in the Southern Ocean. Based on the dB difference (2dB $<\delta Sv_{120\text{-}38}<$ 16dB) between mean backscattering strength (Sv) at 120 and 38 kHz, krill aggregations were delineated. Krill swarms were categorized into a number of groups by physical dimension, and the frequency of occurrence was calculated. Various parameters such as Svmean/Svmax, the depth, and the spacing between aggregations were extracted, and examined in relation to hydrography, sea ice distribution, and chlorophyll level and so on. Krill seem to form well-separated, dense aggregations close to the ice edge, and these tend to turn into layers that are more diffuse and interweaving in offshore waters. This may represent a response to a spectrum in food condition, from concentrated, pulsed to more dilute, well-spread supplies. In the Southern Ocean, this range corresponds to 'sea ice to open water'. A similar spectrum in terms of food condition, or at least part of the spectrum, may apply in other krill-bearing marine ecosystems including the North Pacific.

PICES XV S5-3043 Oral
Adaptive radiations in mesopelagic fishes: The role of key innovations

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Mesopelagic fishes usually constitute a dominant part in the heterogeneous assemblage of small pelagic animals collectively known as micronekton (fishes, cephalopods and crustaceans). The enormity of the mesopelagic ecosystems and the very high biomass of midwater biota, indicate the ecological significance of micronekton in open-ocean dynamics. However, numerous evolutionary aspects of the open ocean populations, such as modes of speciation, constraints on adaptation, speciation rates *etc*. have rarely been addressed. At the same time, such data are clearly needed to improve our understanding of the ecology of deep-sea pelagic fishes and other micronektonic animals, as well as general patterns and processes operating in oceanic midwaters. Even a brief survey of midwater fish diversity indicates a significant disparity in species richness between different taxa. It is intriguing to consider why some groups successfully radiated in the twilight zone of the World ocean, while others remained species poor. This presentation will address the species diversity trends in mesopelagic fishes and attempt to explain the observed patterns integrating morphological, physiological and ecological information. It is proposed that a number of key adaptations facilitated higher speciation rates in midwater ecosystems for selected teleost groups. The role of certain morphological features in deep-sea evolutionary dynamics, as well as some other adaptive mechanisms known in midwater fishes and contributing to greater success of particular groups, will be reviewed and discussed.

PICES XV S5-2947 Oral
Distribution and prey composition of juvenile small epipelagic fishes and myctophids in the Kuroshio-Oyashio Transition Zone in spring, 2002-2004

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The Kuroshio-Oyashio Transition Zone (KOTZ) is the key area for recruitment of the Pacific stocks of Japanese sardine, *Sardinops melanostictus*, anchovy, *Engraulis japonicus*, and mackerels, *Scomber* spp. In addition to these commercially important small epipelagic fishes, myctophids are also important components of oceanic ecosystems, including the KOTZ. Epipelagic fishes and myctophids were simultaneously collected by nighttime trawl tows at depths of 0-30 m in the KOTZ in May, during 2002-2004. In contrast to an increasing trend in density of epipelagic fishes, density of myctophids sharply declined in 2004, when the Kuroshio Extension axis moved south. Juvenile small epipelagic fishes showed scattered horizontal distributions, whereas myctophids were caught ubiquitously. Juvenile sardine and anchovy prey mainly on small copepods which are abundant at depths of 0-40 m, *Paracalanus parvus* and *Corycaeus affinis*, respectively. Juvenile mackerels prey mainly on large copepods such as *Neocalanus cristatus*. Myctophids prey upon *Euphausia pacifica*, Doliolida, Hyperiidea, and large copepods, such as *Pleuromamma piseki* and *Metridia pacifica* (abundant at depths of 40-150 m). These results suggest resource partitioning between juvenile small epipelagic fishes and myctophids in terms of habitat and prey, both of which are probably affected by year-to-year variations in oceanographic conditions.

PICES XV S5-3218 Poster

Fluctuations of epipelagic leptocephalus assemblages in the Kuroshio-Oyashio transition region

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The assemblages of leptocephali were studied in the epipelagic zone (upper 30 m) in the Kuroshio-Oyashio transition region from May to June 1998-2002 to determine their distribution and ecology, and examine the possible effects of ocean-atmospheric changes. A total of 3,336 leptocephali of at least 40 species (types) were collected during resource assessment research by the National Research Institute of Fisheries Science of Japan. The most abundant leptocephali were *Gnathophis nystromi nystromi* and *G. nystromi ginanago* of the eel family Congridae, which spawn in the East China Sea and along coastal Japan. The assemblages at each site were clustered into four groups using ordination and the fuzzy *c*-means method based on the similarity of species composition between sites. Species were also clustered by the same method into four groups. One group consisted of *G. nystromi nystromi*, which was the middle temperature group. Other groups contained species such as albuliform bonefish, *Pterothrissus gissu*, the 'lower temperature group', the mesopelagic eel, *Nemichthys scolopaceus*, the 'high temperature group', or a 'mixed group' of low and high temperature species. *G. nystromi nystromi* increased from 1998 to 2002, but the lower temperature group decreased from 2001 onwards. Regressions between fluctuations of leptocephalus assemblages and climate indices showed correlations between *G. nystromi nystromi* and the Southern Oscillation Index (SOI) and the North Pacific Index (NPI), and the lower temperature group was correlated with the Tropical Northern Hemisphere (TNH) pattern. These results suggest that the either spawning activity or the transport of leptocephali into the transition region was influenced by ocean-atmospheric factors.

PICES XV S5-2981 Poster

Relationship between the inhabited environment and the distribution of *Stenobrachius leucopsarus* in the Bering Sea

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Stenobrachius leucopsarus is one of the most abundant fishes in the Bering Sea and plays an important role in transporting organic matter from the productive epipelagic zone to the deep sea. Besides being an important prey item for higher trophic levels, *S. leucopsarus* is also a potential competitor for zooplanktivorous salmon, which utilize the Bering Sea as a nursery during summer. In the present study, we examined the distribution, density and feeding habits of *S. leucopsarus* and the distribution of zooplankton in the Bering Sea during summer. We collected micronekton and zooplankton in the central Bering Sea using an RMT net at night on board the R/V *Kaiyo Maru* during 3-18 September 2002, 28 June-17 July and 30 August-19 September 2003. *S. leucopsarus* was the most abundant micronekton collected in the Bering Sea. Although no clear patterns were found in the overall distribution, small individuals were abundant near the Aleutian Islands in waters influenced by the Alaskan Current System (ACS), suggesting they were transported from southern areas (perhaps the Gulf of Alaska) into the Bering Sea. Small *S. leucopsarus* fed heavily on *Metridia pacifica* around the Aleutian Islands, which suggests they were carried by the Alaskan stream and then found a favorable environment for feeding. High abundance of small individuals tended to be associated with high abundance of *M. pacifica*, suggesting the distribution of the main prey species affected the distribution of small *S. leucopsarus*. This study suggested the distribution of small *S. leucopsarus* was affected by inhabited environments.

PICES XV S5-2933 Poster
Vertical distribution of cnidaria and ctenophores in the A-Line

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Vertical distribution of cnidaria and ctenophores along the A-Line, off Kushiro, Hokkaido, Japan was investigated. Samples were collected in April 2002 by using MOCNESS2 net (mesh 2 mm) from 700-m depth to the surface: 700-500, 500-300, 300-150, 150-0 m. Four scyphozoan, 14 hydrozoan excluding 17 siphonophore, and 2 ctenophore species (or taxa) were identified. *Aglanthe digitale* was predominant at 150-0 m, while *Dimophyes arctica* was most abundant at 300-150 m. Twenty-one species among 37 did not occur shallower than 300 m. Combined biomass of cnidaria and ctenophores was most abundant at 150-0 m, because of high abundance of *Aglantha digitale*.

PICES XV S5-2787 Poster
Interannual changes in fish communities of the Aniva Bay upper epipelagic zone (Sakhalin Island) and adjoining areas of the Okhotsk Sea in summer

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The hydrological properties of Aniva Bay are derived from two ocean currents (the cold East-Sakhalin and the warm Soya currents) which vary interannually. The pelagic trawl surveys conducted by SakhNIRO in 2002-2004 showed that the upper-epipelagic ichthyofauna of Aniva Bay and adjoining waters of the Okhotsk Sea also undergoes significant interannual changes. Those changes in fish communities are manifested in different ways, including: species composition, ratio between abundance and biomass for different fish species, spatial distribution, and size composition. Interannual differences in distribution trawl catches and some biological parameters were observed for many marine fish species and for young pink and chum salmon. Our observations showed that Aniva Bay is an important nursery region for juveniles of many fish species of different ecological groups. There are anadromous fishes, which spawn in rivers; marine species reproducing in coastal and open waters of the Bay; and species which spawn in adjacent areas, sometimes far from the study area. Capelin, juvenile herring, arabesque greenling, some species of sculpins, deep smelts and, sometimes, Japanese anchovy were typically abundant in the trawl catches during our study. There was a marked tendency for increase in abundance of juveniles of 10 fish species, including walleye pollock and sand lance. At present, the two last species are not abundant in the study area.

PICES XV S5-3002 Poster
Diel vertical migration of squid in the Kuroshio-Oyashio transition region

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Knowledge about vertical distribution patterns of squid is essential when conducting quantitative sampling to evaluate their biomass. However, this knowledge is extremely limited for micronektonic and adult sized individuals larger than 30 mm in dorsal mantle length (DML) because they are strong swimmers and ordinary micronekton nets such as RMT and IKMT make them unsatisfactory for the quantitative sampling. Using commercial-sized otter trawls (mouth opening of ca. 500 m^2), we examined the diel vertical migration of squid (21-490 mm DML) in warm core ring (WCR) and cold water mass (CW) areas in the Kuroshio-Oyashio transition region. Three patterns of diel vertical migration were recognized for 6 of the squid species. (1) Migrant, in which day and night habitats are clearly separated with peak abundance deeper than 300 m during the day and shallower than 200 m at night: *Gonatopsis borealis*, *Watasenia scintillans*, and

Onychoteuthis banksii. (2) Semi-migrant, in which part of the population migrates to the upper 200 m at night from its daytime habitat of 500-600 m, while the remainder of the population mainly remains in the daytime habitat: *O. borealijaponica*. (3) Non-migrant, in which the habitat is consistently distributed below 400 m: *Histioteuthis dofleini* and *Belonella borealis*. Among the vertically migratory and semi-migratory species, nighttime distribution depth was similar between WCR and CW for *O. banksii*, but was deepened by upper layers of warm subtropical waters in the WCR for *G. borealis*, *W. scintillans*, and *O. borealijaponica*.

PICES XV S5-2866 Oral

Interannual variability of the community structure of epipelagic nekton along 155°E longitude in early summer

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The interannual variability of distribution and abundance of the epipelagic nekton and its community structure in the Kuroshio-Oyashio transition area were examined. Epipelagic nekton were collected by 22 years of gillnet surveys conducted from T/S *Hokusei-Maru* and T/S *Oshoro-Maru*, ships operated by Hokkaido University in Japan. Collections were made along 155°E longitude between 35-44ºN latitude, in early June of each year, from 1982 to 2004. In total, 47 species, 7 families and 1 genus were caught by 116 gillnet operations, and four species groups were recognized using cluster analysis based on the weighted mean CPUE, sea surface temperature and salinity, and latitude. These groups are characterized by variations in water temperature and salinity. Anomalies of SST were related to ALPI (41º00'-44º00'N), PDO (39º30'-44º00'N) and SOI (39º30'N), suggesting the distribution and abundance of the epipelagic nekton were affected by climate change. Interannual changes in species composition and latitudinal distribution were used to identify three types of community structure at the sampling stations. In particular, the species composition in community Type-B, which mainly occurred in the Subtropical and Transition Domain, showed variability that was apparently related to the regime shift and SOI. Further results will be discussed at the meeting.

PICES XV S5-2882 Poster

Atka mackerel, *Pleurogrammus monopterygius*, larvae and fry in the upper epipelagial of the north-western Pacific Ocean

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Atka mackerel, *Pleurogrammus monopterygius*, is a semi-demersal commercial fish species in the northern North Pacific, abundant near both the Asian and American coasts. During early life, from larval to juvenile stages, it has a pelagic phase and inhabits surface water, at first in the vicinity of reproductive areas, and later in the high seas. Oceanic currents and water mass circulation play a central role in the dispersion of larvae. Larvae of Atka mackerel are an important component of the ichthyoneuston in some areas adjacent to Kamchatka and the North Kurile Islands, and fry are a major part of the epipelagic fish community in the Bering and Okhotsk Seas. The principal features of this species' early life history are still insufficiently understood. We utilized diverse sources of data for the period since the mid 1960s: ichthyoplankton samples collected on cruises in waters around Kamchatka; samples from juvenile salmon trawl surveys in the epipelagial of the Okhotsk Sea and the north-western Pacific Ocean; incidental catch data from drift nets; data on stomach contents of Pacific salmon from the high seas; and scientific literature. We will discuss several biological features of pelagic Atka mackerel in the upper epipelagial region between the North Kurile Islands and the western Aleutians including the distribution of larvae and fry, growth and feeding and relationships with other fish species.

PICES XV S5-3119 Poster

Squids of the family Enoploteuthidae in the epipelagic layer of the Kuroshio Current

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Data on the distribution of the enoploteuthid squids (family Enoploteuthidae) were collected in the epipelagic Kuroshio Current in November 2005. These are highly abundant nektonic squids in the Kuroshio zone. Six species were encountered during the research: *Watasenia scintillans, Enoploteuthis chuni, Abraliopsis felis, Ancistrocheirus lesueurii, Abralia similis* and *Pterygioteuthis giardi*. The catches were highest at night, when squid migrate to the surface from deep layers.

Enoploteuthid squids are warm-water dwellers. Three species (*W. scintillans, A. felis* and *E. chuni*) formed the bulk of the squid biomass. The other three species (*A. lesueurii, A. similis* and *P. giardi*) occurred only in the subtropical waters and were much less abundant. *W. scintillans* were most abundant in the subarctic waters, where the species biomass peaked at 32.9 tons per square km, and averaged 3.2 tons per square km. The biomass of this species was assessed at 0.018 tons per square km in the subtropical waters, and averaged 1.8 tons per square km over the entire study area. *A. felis* occurred mainly in the subtropical and transitional waters, rarely entered the subarctic waters, and its biomass averaged 0.015 tons per square km of the study area. *E. chuni* occured in the subtropical waters was occasionally found in the transitional waters as well, and the biomass of this species averaged 0.005 tons per square km in the study area.

S6 CCCC Topic Session
Modeling and historical data analysis of pelagic fish, with special focus on sardine and anchovy

Co-Convenors: Shin-ichi Ito, Michio J. Kishi (Japan), Bernard A. Megrey and Francisco E. Werner (U.S.A.)

During the synthesis phase of the PICES CCCC Program, comparisons of life-history strategies in relation to climate change are recommended for pelagic species such as pollock, pink salmon, capelin, sardines, anchovies, saury, euphausiids and squid, among others. In this session we will focus on modeling and analyses of processes affecting growth, survival and recruitment of sardine and anchovy, and their relevance to management. We are calling for presentations on models and historical data analysis on the temporal and spatial variability of recruitment processes of sardine and anchovy, their linkages to changes in climate, human impacts and regional ecosystem structure. Advances in general modeling approaches that couple pelagic fish population dynamics with lower trophic ecosystems are also encouraged.

Tuesday, October 17, 2006 09:00-12:30

09:00-09:10 **Introduction by Convenors**

09:10-09:35 **Salvador E. Lluch-Cota, Daniel Lluch-Belda and Daniel Lluch-Cota** (Invited)
Eastern North Pacific sardine spawning through climate, latitudinal, and inshore-offshore gradients (S6-3171)

09:35-10:00 **Akinori Takasuka, Yoshioki Oozeki, Hiroshi Kubota, Hiroshige Tanaka, Ichiro Aoki and Salvador E. Lluch-Cota** (Invited)
Potential biological mechanisms of anchovy and sardine alternations: Species-specific temperature optima and synergistic factors (S6-3210)

10:00-10:25 **Kenneth Rose, Vera Agostini, Larry Jacobson, Carl van der Lingen, Salvador Lluch-Cota, Shin-ichi Ito, Bernard Megrey, Michio Kishi, Akinori Takasuka, Manuel Barange, Francisco Werner, Yunne Shin, Lucho Cubillos, Yasuhiro Yamanaka and Hao Wei** (Invited)
Towards coupling sardine and anchovy to the NEMURO lower trophic level model (S6-3212)

10:25-10:45 ***Tea/Coffee Break***

10:45-11:00 **Tadaaki Kuroyama, Akira Nihira and Sei-Ichi Saitoh**
Larval anchovy catch distributions in the Kashima-nada relative to environmental features observed by satellite remote sensing (S6-3088)

11:00-11:15 **Xiangxin Li**
Individual-based models of anchovy (S6-3099)

11:15-11:30 **Shin-ichi Ito, A. Takasuka, Y. Oozeki, A. Yatsu, M. Noto, M. Kishi, Y. Yamanaka, T. Hashioka, M. Aita, K. Rose, B. Megrey, F. Werner, C. Lingen, M. Barange, Y. Shin, L. Cubillos, L. Jacobson, V. Agostini, S. Lluch-Cota, G. Onitsuka and Y. Kamezawa**
A sardine growth model coupled with the NEMURO lower trophic level ecosystem model (S6-3079)

11:30-11:45 **Haruka Nishikawa and Ichiro Yasuda**
Species replacement between Japanese sardine and Pacific saury in relation to variations in feeding environment (S6-3148)

11:45-12:00 **Yury I. Zuenko and Svetlana V. Davidova**
Empirical modeling the stock fluctuations of sardine in the Japan/East Sea (S6-3176)

12:00-12:15 **Naoki Yoshie and Yasuhiro Yamanaka**
Development of a lower trophic ecosystem model representing prey of juvenile pelagic fish in the subtropical western North Pacific (S6-3188)

12:15-12:30 **Fumitake Shido, Yasuhiro Yamanaka, Shin-ichi Ito, Taketo Hashioka, Daiki Mukai and Michio J. Kishi**
A two-dimensional fish model simulating the biomass of Pacific saury (S6-3074)

PICES XV S6-3079 Oral

A sardine growth model coupled with the NEMURO lower trophic level ecosystem model

Shin-ichi **Ito**[1], Akinori Takasuka[2], Yoshioki Oozeki[2], Akihiko Yatsu[3], Masahiko Noto[2], Michio J. Kishi[4,5], Yasuhiro Yamanaka[5,6], Taketo Hashioka[6], Maki Noguchi Aita[5], Kenneth A. Rose[7], Bernard A. Megrey[8], Francisco E. Werner[9], Carl D. van der Lingen[10], Manuel Barange[11], Yunne Shin[12], Lucho Cubillos[13], Larry Jacobson[14], Vera N. Agostini[15], Salvador E. Lluch-Cota[16], Goh Onitsuka[17] and Yasuko Kamezawa[4]

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NEMURO.FISH consists of a fish bioenergetics model coupled to the NEMURO lower trophic model. The NEMURO.FISH integration for Pacific saury with realistic climate forcing suggested the importance of competition for zooplankton prey between saury and sardine in the Northwestern Pacific, and NEMURO.FISH was applied to Japanese sardine as a first step toward examining competition between these two species. Most of the biological parameters for Japanese sardine were determined from previous published studies, and although Japanese sardine expands its distribution at high biomass levels, we first concentrated on the lower biomass stage (current stage), and applied a two box model to represent the Kuroshio and mixed water regions. Sardine migration was defined by calendar date and the life span was defined as 8 years. Modeled sardine body length compared well with observed growth of Japanese sardine, with modeled fish reaching 20 cm within 4 years. The fish part of the sardine model will be applied to four current systems, namely the Humboldt Current, Benguela Current, California Current and Kuroshio-Oyashio Current systems, in order to compare sardine growth response to climate forcing between systems. Output water temperature and zooplankton density of the global NEMURO model, coupled with the general circulation models will be used for each system, and these results will be shown in the presentation.

PICES XV S6-3088 Oral

Larval anchovy catch distributions in the Kashima-nada relative to environmental features observed by satellite remote sensing

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Larval anchovy (*Engraulis japonica*), "shirasu" in Japanese, is one of the most important fish in the coastal fisheries of Kashima-nada off eastern Japan. There is a very remarkable interannual variability in larval anchovy catch. The objectives of this study are to clarify relationships between distribution of larval anchovy in the Kashima-nada and its relation to environment factors and to identify the cause of anchovy catch fluctuations. We employed the following environmental parameters: 1) NOAA/AVHRR sea surface temperature (SST), 2) the distance between the coast and the Kuroshio axis by detected NOAA/AVHRR, 3) SeaWiFS surface Chlorophyll-*a* concentrations and 4) TOPEX sea surface height (SSH). As biological data, we used the 1998-2002 length frequency of adult anchovy before the fishing season which takes place from November to March. When the percentage of adult anchovy over 12 cm length was over 60 percent, there was a strong positive

relationship between catch and SST and weak positive correlation otherwise. This suggests that there is a possibility to predict larval anchovy catch using length composition of adult anchovy and SST. When the Kuroshio axis moved north and intruded to the Kashima-nada coastal region, larval anchovy catch increased. Larval anchovy and eggs seem to be transported to the Kashima-nada coast by the Kuroshio and grew up with warm SST. When the Kuroshio axis moved to south, larval anchovy catch decreased. This suggests that the fluctuation of larval anchovy catch was affected by the position and behavior of the Kuroshio.

PICES XV S6-3099 Oral
Individual-based models of anchovy

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Anchovy in the East China Sea have nearly disappeared in recent years warranting an examination of processes that control the population. In this paper a model of anchovy is presented where we calculate phytoplankton and zooplankton densities on a two-dimensional grid as a background for the anchovy simulation. We used individual-based models (IBMs) to simulate the life history of anchovy. Two attributes of every individual anchovy (or egg) include genotype and phenotype. Individual activities include consumption, metabolism, movement, spawning, hatching and death. We assume an individual's genotype remain constant over its lifetime. The genotypes of eggs are inherited from their parents and little aberrance is considered in the model. Phenotype is time variable. Genotype and environment co-determine an individual's activities and then determines the future phenotype. There are two phases considered in this model. The aim of first phase is to train the each individual's genotype. In this phase, the mechanisms of the death were divided into three types, including forced death, natural death and death because of starvation. Abnormal individuals are forced to die, which means forced death. In the second phases, trained individuals are placed in a changing environment. The response of entire ecosystem is then simulated to determine the influence of environment changes.

PICES XV S6-3171 Invited
Eastern North Pacific sardine spawning through climate, latitudinal, and inshore-offshore gradients

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Historical data analyses and comparison of sardine and anchovy catch records from different regions of the world have resulted in the notion of synchrony occurring between remote systems, independently of the effect of fishing pressure and management strategies, and the oceanographic domain and local forcing. It has been proposed that mechanisms underlying abundance changes must be simple and controlled by the same background climate signal. In contrast we have faced several rejected or inconclusive hypotheses, and a failure of integration attempts. In this contribution we provide a brief review of some of these drawbacks, and identify a common problem in the lack of historical information. We realize modeling represents an alternative to test some of the main existing hypotheses. Based on studies of the eastern North Pacific sardine, we discuss: 1) the differences and changing rates in the spawning intensity (eggs and larvae abundance) and physical conditions between climate regimes, latitudinal, and inshore-offshore gradients, 2) a simple model that expresses advection of early stage individuals as a function of spawning ground location and temperature-dependent growth, and 3) climate scenarios proposed to be tested and compared using models and data analyses, after reviewing traditional criteria and definitions.

PICES XV S6-3148 Oral

Species replacement between Japanese sardine and Pacific saury in relation to variations in feeding environment

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In the 1980s, the dominant species of small pelagic fishes in the Northwestern Pacific was the Japanese sardine (*Sardinops melanostictus*). But the population decreased from 1988. On the other hand, Pacific saury (*Cololabis saira*) increased from 1988 and exceeded Japanese sardine in 1997 in terms of catches. Population fluctuations of Japanese sardine have been suggested to be related to winter sea surface temperature variations in the Kuroshio Extension (Noto and Yasuda, 1999). Tian *et al*. (2002) reported that the fluctuation of large-size Pacific saury was correlated with winter sea surface temperature in the Kuroshio south of Japan. However, the cause of this species replacement coincided with the change of environment in the Kuroshio Extension, and thus remains unclear. Using the NEMURO model, we carried out numerical experiments to estimate the feeding environment of sardine and saury. From the results obtained, we suggest a hypothesis for the species replacement between Japanese sardine and Pacific saury as follows. Since 1988, the winter shallow mixed layer depth in the Kuroshio Extension has led to early phytoplankton blooms, and zooplankton populations have occurred earlier in the year. Consequently, winter zooplankton increased while spring zooplankton decreased. Pacific saury that grows in the Kuroshio Extension in winter can take advantage of the early blooms, but the Japanese sardines that migrate to the Kuroshio Extension in spring could not survive because of low food density. This match/mismatch with the bloom may explain the late 1980s species replacement from Japanese sardine to Pacific saury in the Northwestern Pacific.

PICES XV S6-3212 Invited

Towards coupling sardine and anchovy to the NEMURO lower trophic level model

Kenneth A. **Rose**[1], Vera N. Agostini[2], Larry Jacobson[3], Carl van der Lingen[4], Salvador E. Lluch-Cota[5], Shin-ichi Ito[6], Bernard A. Megrey[7], Michio J. Kishi[8,9], Akinori Takasuka[10], Manuel Barange[11], Francisco E. Werner[12], Yunne Shin[13], Lucho Cubillos[14], Yasuhiro Yamanaka[9,15] and Hao Wei[16]

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Sardines and anchovies exhibit classic population cycles whose interpretation seems to get more complicated with each new examination. The NEMURO model has been developed by an international group of scientists as a template NPZ lower trophic model for regional comparisons. Single species bioenergetics models for herring and saury have been coupled to NEMURO and are known as NEMURO.FISH. This presentation describes the next step in the evolution of the NEMURO.FISH coupled modeling approach – namely the simulation of Sardine and ANchovy population dynamics (NEMURO.SAN). We first describe the general 2-dimensional framework of NEMURO.SAN, and how we use an individual-based approach for simulating the daily growth, mortality, reproduction, and movement of sardines and anchovy. Fish growth is based upon bioenergetics, with fish daily consumption dependent on the zooplankton and phytoplankton concentrations generated by NEMURO in each spatial cell. Fish consumption, in turn, is treated as an explicit mortality term on the plankton. By making mixed layer depth, nutrients, and other inputs to NEMURO specific to each model grid

cell, we can simulate spatial heterogeneity in fish habitat. Alternative hypotheses about climate conditions can be specified via changing the inputs to NEMURO, and the response of the anchovy and sardines predicted in terms of their growth, survival, and spatial distribution. Progress to date includes initial synthesis of available data for target locations, outlining of the general modeling framework, and the development of an initial computer code. We will present some preliminary multidecadal simulations that illustrate the general approach. Our goal is to next apply the NEMURO.SAN model to several locations, beginning with the California Current ecosystem.

PICES XV S6-3074 Oral
A two-dimensional fish model for simulating the biomass of Pacific saury

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We developed a two-dimensional fish model for Pacific saury (*Cololabis saira*) and applied it to the western North Pacific. We used the PICES NEMURO.FISH model (Ito *et al*., 2004), current fields (Sakamoto *et al*., 2005), and zooplankton and temperature data predicted by 3D-NEMURO (Hashioka and Yamanaka, 2006). We assumed that saury hatch in southern Japan (near 32ºN, 138ºE) in February 1, are advected by Kuroshio and Kuroshio extension during their larvae or juvenile stage, then during summer migrate west against the current in the young or adult stages, and then from fall to winter they migrate back to their original spawning area during the adult stage. The model successfully simulated the observed wet weight of saury during two years: 70g in the first summer and 140g in the second summer. The observed seasonal migration geographical distributions are also simulated well. Saury migrates to the north by several different routes, mainly through regions far from Japan during spring, staying off Hokkaido Island during summer, and back the along coastal area off Honshu Island during the fall. An Eulerian method was adopted because we will include two-way coupling between fish and zooplankton and predict their future biomass.

PICES XV S6-3210 Invited
Potential biological mechanisms of anchovy and sardine alternations: Species-specific temperature optima and synergistic factors

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Pelagic fish have exhibited cyclic population dynamics in complex marine ecosystems. However, biological processes have yet to be resolved to explain out-of-phase oscillations of anchovy and sardine and their synchrony/asynchrony among ecosystems. First, we explored simple and direct pathways to link climate changes and species alternations, focusing on species-specific temperature optimums. The initial idea was the "optimal growth temperature" hypothesis, based on differential optimal temperatures for larval growth rates of Japanese anchovy and sardine and temperature shifts between these values. To extend the theory and undertake a basin-scale comparison, spawning temperature optima of anchovy and sardine were examined using the long-term data set of egg and larval surveys. Contrasting spawning temperature optima of anchovy and sardine between opposite sides of the Pacific may provide a theoretical explanation to the synchronous alternations despite the reversed temperature regimes across the Pacific. In addition, spawning temperature optima reflected long-term population dynamics in terms of similarities and differences among anchovy, sardine, mackerel, and jack mackerel in the western North Pacific. Additional objectives include testing the generality of temperature-based hypotheses and seeking synergistic mechanisms based on other factors. Comparisons of feeding habits among co-occurring small pelagics suggested that differential feeding strategies are unlikely to regulate dominance shifts but might lead to inter-species competition. Temporal and spatial overlaps of eggs and larvae were described as a potential source of competition between anchovy and sardine in the western North Pacific. A series of analyses provide biological parameters for models to predict the future trends.

PICES XV S6-3188 Oral

Development of a lower trophic ecosystem model representing prey of juvenile pelagic fish in the subtropical western North Pacific

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The standing stocks of pelagic fish, anchovy and sardine, are affected by changes in climate through the direct link of physical process such as egg transport and/or the indirect link via dynamics of phytoplankton and zooplankton population's abundance and distribution. The processes affecting survival of juvenile pelagic fish are important for interannual variations of standing stocks of adult fish. These processes are controlled by the prey conditions of the juvenile fish around the spawning grounds. In the western North Pacific, the spawning grounds are in the subtropical region near Japan. A lower trophic level marine ecosystem model, NEMURO (North Pacific Ecosystem Model Used for Regional Oceanography) developed by CCCC/MODEL task team does not include key groups of plankton in the subtropical region. In this study, we have extended NEMURO by introducing the subtropical groups of plankton (*i.e.*, small-size phytoplankton, zooplankton, and bacteria), to simulate not only the subarctic but also the subtropical ecosystems. The extended NEMURO, eNEMURO, was applied to two stations A7 (41.5N, 145.5E) and B1 (30.0N, 138.0E) in the subarctic and subtropic western North Pacific. The eNEMURO model successfully simulated the seasonal changes in plankton biomass observed at the both stations, and those of the small size plankton at station. The eNEMURO results showed improved results compared to NEMURO. The fish growth model coupled with eNEMURO might be a useful tool for understanding the processes controlling the variations of fish standing stocks.

PICES XV S6-3176 Oral

Empirical modeling the stock fluctuations of sardine in the Japan/East Sea

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An empirical multiple regression model of the sardine stock in the Japan/East Sea is proposed:
$S_j = \Sigma_{i=3,4,5,6...}[S_{j-i} * (f + k_N T_{N(j-i-1)} + k_W T_{W(j-i)} + k_S T_{S(j-i)} + k_C D_{C(j-i)} + k_D S_{j-i}) * (1-m)^i]$, where S_j is a stock for a j year, $(f + k_N T_{Nj} + k_W T_{Wj} + k_S T_{Sj} + k_C D_{Cj} + k_D S_j) = F$ is a parameter of fecundity (taking into account the eggs and larvae survival), and m is a coefficient of fish mortality (constant, defined empirically). The fecundity depends on fish density and environmental conditions: f is a constant representing potential fecundity; k_N, k_W, k_S, k_C, k_D are empirical coefficients; and the following environmental factors are considered as predictors: T_N – SST on the feeding grounds (41-46°N) in spring-summer (negatively correlated with zooplankton abundance); T_W – SST on the spawning grounds (35-38°N) in winter; T_S – SST on the spawning grounds (35-38°N) in spring-summer (negatively correlated with zooplankton abundance); D_C – the Cushing match/mismatch factor defined as sum of the deviation of winter and spring SST anomalies from an "ideal" correlation determined empirically. The component $k_D S_j$ is a density factor and other components of F depend on environmental factors. According to D.H. Cushing's hypothesis, the winter SST determines by physiological mechanisms the time of the larvae's hatching, but the spring-summer SST determines the time of spring plankton bloom: a match of these terms is favorable for fish larvae survival and a mismatch is unfavorable.

Long-time data series on the total catch of sardine in the Japan/East Sea by Japan, Korea and Russia (since 1917) and SST data since 1950 were used. Correlation of the catch of sardine with its stock was estimated using the data of trawl surveys in the Japanese EEZ in 1986-2003.

The model describes 85% dispersion of the sardine catch in the period 1954-2003 and adequately simulates the stocks' collapses in 1960s and 1990s and their rise in 1970-1980s. The most important environmental factors are the match/mismatch ($k_C = -1.37$) and the feeding ground conditions ($k_N = -0.67$). Excluding environmental factors from the model (*i.e.*, transforming it to a simple reproduction density-dependent model) worsens it considerably to ~0.48 which is unsatisfactory for the stocks' forecasting. Generally, lowered SST both in winter and spring-summer are favorable for sardine because of the higher plankton abundance in the feeding grounds

and coincides with the times of larvae hatching and plankton bloom. These conditions were observed in the late 1970s – early 1980s and is suggested as the reason for the prominent rise of the sardine stock.

S7 FIS/CCCC Topic Session
Key recruitment processes and life history strategies: Bridging the temporal and spatial gap between models and data

Co-Convenors: Kerim Y. Aydin (U.S.A.), Shin-ichi Ito (Japan), Jacob Schweigert (Canada), Paul Spencer (U.S.A.), Akihiko Yatsu (Japan) and Yury I. Zuenko (Russia)

Stock-recruitment relationships for exploited fishery stocks quite often show large deviations from theoretical curves. This results from the tremendous variability in survival rates in the early life stages of marine species. In the synthesis phase of the PICES CCCC Program, comparison of life-history strategies in relation to climate changes are recommended for pollock, pink salmon, capelin, sardines, anchovies, saury, euphausiids, squids, and others. Among the potential causes of succession of different life-history strategists, recruitment variability is one of the most important factors. To perform scientific management for target species, appropriate modeling of recruitment processes, including environmental effects, is needed. Under this theme, we will review the temporal and spatial variability of recruitment processes of key species, their linkages to climate changes, human impacts and regional ecosystem structure. Moreover, we will explore new methodologies to plug the gaps between data and the current state of modeling.

Thursday, October 19, 2006 09:00-17:00

09:00-09:10 **Introduction by Convenors**

09:10-09:40 **Lorenzo Ciannelli and Kerim Aydin** (Invited)
Relating recruitment mechanisms to life-history strategies for Alaskan groundfish populations (S7-3246)

09:40-10:10 **Maki Suda, Tatsuro Akamine and Hiroshi Nishida** (Invited)
A population dynamics model for Japanese sardine, *Sardinops melanostictus*, off the Pacific coast of Japan, consisting of spatial early-life stage and age-structured adult sub-models (S7-2833)

10:10-10:30 **Brenda L. Norcross, Sean-Bob Kelly, Peter-John Hulson and Terrance J. Quinn II**
An early life history model for Pacific herring in Prince William Sound, Alaska (S7-3222)

10:30-10:50 ***Tea/Coffee Break***

10:50-11:10 **Oleg Bulatov**
The Ricker model and the pollock recruit abundance (S7-2804)

11:10-11:30 **Anatoly V. Smirnov**
Parent-progeny relationships in the Okhotsk Sea walleye pollock (S7-3224)

11:30-11:50 **Paul D. Spencer**
The effect of spawner age on stock productivity: Influences of life-history pattern and recruitment variability (S7-2855)

11:50-12:10 **Thomas C. Wainwright, Richard D. Brodeur, Robert L. Emmett, Peter W. Lawson, William T. Peterson, James J. Ruzicka and Laurie A. Weitkamp**
Climate variation and salmon recruitment: Comparing climate indices for predicting salmon marine survival in the Northern California Current ecosystem (S7-2932)

12:10-12:30 **Motomitsu Takahashi, David M. Checkley Jr., Akihiko Yatsu and Yoshiro Watanabe**
Growth of larval and early juvenile sardine (*Sardinops* spp.) and anchovy (*Engraulis* spp.) in the eastern and western North Pacific Ocean (S7-2939)

12:30-13:40 ***Lunch***

13:40-14:00 **R.J. Beamish, C.M. Neville and R.M. Sweeting**
Life history strategies of sea lice in the subarctic Pacific (S7-3058)

14:00-14:20 **Chih-hao Hsieh, Christian S. Reiss, John R. Hunter, John R. Beddington, Robert M. May and George Sugihara**
Fishing elevates variability in the abundance of exploited species (S7-2891)

14:20-14:40 **C. Tracy Shaw, Leah R. Feinberg, Hongsheng Bi and William T. Peterson**
Analysis of key recruitment processes for *Euphausia pacifica* off the Oregon coast (S7-2902)

14:40-15:00 **Yoshioki Oozeki, Ryo Kimura, Hiroshi Kubota and Hiroshi Hakoyama**
Patchiness structure and mortality of Pacific saury, *Cololabis saira*, larvae in the northwestern Pacific Ocean (S7-3009)

15:00-15:20 **Taro Ichii, Kedarnath Mahapatra, Mitsuo Sakai and Denzo Inagake**
Life cycle characteristics of the neon flying squid associated with the oceanographic regime in the North Pacific (S7-2863)

15:20-15:40 **Jae Bong Lee, Chang Ik Zhang, Anne Hollowed, Dong Woo Lee and Sang Cheol Yoon**
Variations in recruitment of small pelagic species around Korean waters (S7-3020)

15:40-16:00 ***Tea/Coffee Break***

16:00-16:20 **Yasunori Sakurai, Jun Yamamoto, Ken Mori, Tsuneo Goto and Hideaki Kidokoro**
Can we explain and predict stock fluctuations of Japanese common squid, *Todarodes pacificus*, related to climatic regime shifts? (S7-3081)

16:20-16:40 **Jie Zheng and Gordon H. Kruse**
Crab larval advection and recruitment in the Eastern Bering Sea (S7-2937)

16:40-17:00 **Chris J. Harvey**
Using bioenergetics models to estimate sensitivity of California Current groundfish to temperature anomalies (S7-3065)

Posters

Yasuko Kamezawa, Tomonori Azumaya, Toru Nagazawa and Michio J. Kishi
Bioenergetics model of Japanese chum salmon (*Oncorhynchus keta*) growth (S7-3106)

Hiroshi Kubota, Tatsuya Kaji, Nobuhiro Saito, Akinori Takasuka and Yoshioki Oozeki
Seasonal variability in feeding habits in the larval stage of three clupeoid species in Tosa Bay, southern Japan (S7-3017)

Daiki Mukai, Michio J. Kishi, Shin-ichi Ito, Yasuhiro Yamanaka and Fumitake Shido
Interdecadal variability on the growth and migration trajectory patterns of Pacific saury: A model-based study (S7-3105)

Sayaka Nakatsuka, Akinori Takasuka, Hiroshi Kubota and Yoshioki Oozeki
Predation on larval and juvenile anchovy by skipjack tuna in the Kuroshio - Oyashio transition region (S7-2991)

Kai Sugiyama, Tetsuya Takatsu, Yasuyoshi Fukui and Mikimasa Joh
Comparison of growth rate between hatching months of Pacific sandlance *Ammodytes personatus* in early life stages (S7-2926)

Yongjun Tian
Impact of the late 1980s regime shift on the abundance and distribution of loliginid squid *Loligo bleeker*i in the southwestern Japan Sea (S7-3163)

PICES XV S7-3246 Invited
Relating recruitment mechanisms to life-history strategies for Alaskan groundfish populations

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Mechanisms linking climate to fish recruitment involve nested scales of complexity; from local effects such as prey concentrations, turbulence, or light conditions to large-scale ecosystem effects such as food web shifts due to increases in long-lived predators. A single recruitment "mechanism" (for example, as hypothesized through correlations) may be a part of a larger pattern: a *regime shift* in climate may lead to a *phase change* in mechanism (for example, from bottom-up to top-down control, or from local to large-scale bottlenecks) making prediction via a single correlation-driven mechanism prone to error. Furthermore, the nature of the controlling mechanisms may vary from stochastic models governed by a multitude of difficult-to-measure variables to nonlinear models with few controlling variables but relatively unpredictable bursts of production. In spite of these issues, the evolutionary results of climate-induced challenges to recruitment are quite visible. The diversity of life history strategies among fishes may offer vital clues to the type of climate variation to which different species have been exposed and become adapted. Here, we review hypothesized mechanisms linking climate to the recruitment for several Alaskan groundfish stocks, and discuss analytical tools used to develop and test mechanistic linkages in a manner that captures possible phase changes and nonlinearities. In doing so, we pay specific attention to the relationships between analytical results, the scale of hypothesized mechanisms, and the life history of periodic, opportunistic, and intermediate strategists: to what extent can the recruitment patterns be inferred from a species' position within this range of strategies?

PICES XV S7-3058 Oral
Life history strategies of sea lice in the subarctic Pacific

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The sea louse, *Lepeophtheirus salmonis*, is commonly found on Pacific salmon that are rearing in the central North Pacific Ocean and adjacent seas (subarctic Pacific). Large numbers of sea lice have also been observed on all species of adult Pacific salmon when they return to coastal marine areas in the summer during their spawning migration. Juveniles of these species of Pacific salmon inhabiting the same areas at the same time as the returning adult salmon also have sea lice. Juvenile pink, chum and sockeye salmon will carry these sea lice into the open ocean when they migrate away from the coastal areas later in the year. Juvenile coho and chinook salmon that remain in the coastal areas can serve as hosts for the sea lice over the winter. The offspring of these sea lice on pink, chum and sockeye can infect juvenile Pacific salmon on the high seas and the sea lice on coho and chinook salmon can infect smolts and fry that enter the ocean in the early spring. We propose that the transport of sea lice into coastal areas is a strategy employed by *L. salmonis* to improve their productivity by improving the transmission potential of the infectious stage when host densities are decreased in the open ocean and increased in the coastal areas.

PICES XV S7-2804 Oral
The Ricker model and the pollock recruit abundance

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Many scientists believe that the Ricker model is most sensitive to the spawner-recruit relationship. Verification of this model has shown that for pacific salmons this relationship had very low significance (Kotenev *et al*., 2006). The Ricker model was used also to forecast the total allowable catch of Pollock in the Bering and Okhotsk Seas. We used information on the abundance (biomass) of spawners and the numbers of recruit from different authors (Wespestad, Traynor, 1988; Balykin, 1996; Ianelli *et al*., 2005) and examine the relationship between these estimates by linear regression. The correlation was weak and inverse (R= - 0,21, in 1965-2004)

for the eastern Bering Sea, and it was slightly stronger for the western Bering Sea (R= 0,38, in 1970-1990). For Okhotsk Sea Pollock no apparent relationship between the estimates was found (R= 0,09, Smirnov, 2005). We also relied on linear regression to examine the relationship between the solar activity and chlorophyll a concentration (R=0,6, for 1963-1994), the average water temperature (1 year before hatching) and the abundance of generations (R=0,7, for 1966-1984), the fishery biomass lagged by 5 years and the average temperature in July (R=0,6, for 1966-1984), and the fishery biomass lagged by 5 years and the solar activity (R=0,6, for 1977-1999).

PICES XV S7-3065 Oral
Using bioenergetics models to estimate sensitivity of California Current groundfish to temperature anomalies

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The California Current is an eastern boundary current ecosystem with a highly diverse community of groundfish, many of which are commercially and recreationally exploited. The groundfish assemblage is characterized by multiple life history strategies that can be distinguished by differences in growth, maturation rate, age, fecundity, egg size, and parental care. Because they co-occur in time and space, groundfish employing these different strategies are often exposed to the same perturbations, whether of natural origin (*e.g*., temperature changes) or human origin (*e.g*., fishing). A precautionary or ecosystem approach to managing diverse fish assemblages must be predicated on understanding the sensitivities of these life history types to perturbations so that their responses can be anticipated and accounted for. Bioenergetic modeling of fish energy budgets is one tool for generating quantitative estimates of the ecological impacts of ecosystem-level changes. Using previously and newly developed bioenergetics models for representatives of the major groundfish life history strategies in the Northern California Current ecosystem (rockfish, *Sebastes* spp.; Pacific hake, *Merluccius productus*; English sole, *Parophrys vetulus*; leopard shark, *Triakis semifasciata*; lingcod, *Ophiodon elongatus*), I am examining the responses of three variables (growth, consumption and reproductive output) to temperature anomalies consistent with basin-scale oscillations and global climate change. These models produce estimates of which life history strategies, and which size or age classes within each strategy, would be most sensitive to temperature anomalies, and thus may require the most directed management attention within the assemblage.

PICES XV S7-2891 Oral
Fishing elevates variability in the abundance of exploited species

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Separating the effects of environmental variability from the impacts of fishing on the dynamics of fish populations is essential for sound fisheries management. We distinguish environmental effects from fishing effects by comparing variability in the abundance of exploited versus unexploited species living in the same environments. Using the 50-year-long larval fish time series from the California Cooperative Oceanic Fisheries Investigations, we regard fishing as a treatment effect in a long-term ecological experiment. Here we present the first direct large-scale evidence from the marine environment that exploited species exhibit higher temporal variability in abundance than unexploited species. This remains true after accounting for life history effects, abundance, ecological traits and phylogeny. The increased variability of exploited populations is likely caused by fishery-induced truncation of the age structure, which reduces the capacity of populations to dampen environmental variability. Thus, to avoid collapse, fisheries must be managed not only to sustain the total viable biomass but also to prevent the significant truncation of age structure. A precautionary management approach is warranted not only because of normal uncertainties associated with estimates of stock size but also because fishing itself magnifies population variability.

PICES XV S7-2863 Oral

Life cycle characteristics of the neon flying squid associated with the oceanographic regime in the North Pacific

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Seasonal recruitment, growth, and migration patterns of the neon flying squid (*Ommastrephes bartramii*) were examined in relation to oceanographic conditions in the North Pacific. *O. bartramii* undertakes an annual round-trip migration between subtropical spawning grounds and subarctic feeding grounds, which is comprised of an autumn and winter-spring spawning cohort. The autumn cohort grows faster during northward migration whereas the winter-spring cohort grows faster during southward return migration. Males and females of the autumn cohort follow separate migration patterns whereas those of the winter-spring cohort follow an almost identical pattern. We addressed the following three questions: (1) Why is there a difference in growth patterns between the cohorts? (2) Why are there differences in migration and distribution patterns between the cohorts? (3) Why has the stock level of the autumn cohort been low since 1999? These issues can be explained using seasonal as well as interannual meridional movements of the following two oceanographic zones: (a) optimum spawning zone defined by the SST range: 21°C - 25°C; and (b) food-rich zone defined by position of Transition Zone Chlorophyll Front (TZCF). Lower stock size of the autumn cohort in the recent years can be attributed to the interannual variation in the TZCF position considering its possible contribution to the productivity in the spawning ground, the Subtropical Frontal Zone.

PICES XV S7-3106 Poster

Bioenergetics model of Japanese chum salmon (*Oncorhynchus keta*) growth

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In the 1990s, a reduction of Japanese chum salmon body size was observed. The change of zooplankton density as prey, and/or their population density effect are proposed by many studies. In order to investigate this body size reduction of Japanese chum salmon in the North Pacific, we developed a bioenergetics model for chum salmon. Our model was based on NEMURO.FISH (Ito *et al*., 2004) using respiration and consumption terms (Ware, 1978; Beauchamp *et al*., 1989) and assumed that SST and prey zooplankton density are the determining factors of the reduction of body size. SST and prey zooplankton density are obtained from the result of NEMURO embedded in 3-D physical model (Aita-Noguchi *et al*., 2006), along the migration root of chum salmon. The period of foraging migration is supposed to be four years and the life stage of Japanese chum salmon is divided into eight stages, *i.e.* four stages for summer and the other four for winter. The model reproduced the body size of the 1972 and 1991 year classes of chum salmon, respectively. Reproduced body size of the 1972 year class is larger than that of 1991 year class. This result shows a good agreement with the observations in the Bering Sea. Moreover, our model reproduces the trend of observations in l970-2000 well. The prey density, especially in the Eastern North Pacific, has a larger influence on the change of body size than SST does. This suggests that the size reduction of Japanese chum salmon in 1990s was partly affected by prey zooplankton density.

PICES XV S7-3017 Poster

Seasonal variability in feeding habits in the larval stage of three clupeoid species in Tosa Bay, southern Japan

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The links between fish species replacement and zooplankton dynamics owing to climatic regime shift are often complex. For instance, anchovy flourish and sardine often collapse in the same regime and in several ecosystems. Through gut content analysis, we tested the hypothesis that the difference in feeding habits among species would solve a part of this complexity. The study area was set in Tosa Bay, southern Japan, where Japanese sardine consistently spawned every early spring even after the collapse of the sardine stock. We collected larval fishes from the commercial fishery catch by a shirasu-patch net from November 2003 to April 2004, analyzed the gut content of 1,500 individuals and compared its composition among the dominant three clupeoid species (Japanese sardine *Sardinops melanostictus*, Japanese anchovy *Engraulis japonicus* and round herring *Etrumeus teres*) of 10–38 mm in SL. Gut content composition differed little between the three species when compared in the same season, but the dominant fish species and their main prey changed seasonally, *e.g.* *Paracalanus* spp., *Clausocalanus* spp., *Calanus* spp. and *Candacia* spp. in February and March. We conclude that food selectivity seldom varies among larvae of these species, and that their food changes synchronously with the seasonal variations in zooplankton fauna. Seasonal match-mismatch between the zooplankton bloom and larval feeding (or spawning) seasons of each species could be more important than food selectivity, as the zooplankton bloom and larval feeding may shift several weeks or months with the yearly fluctuations in water temperature.

PICES XV S7-3020 Oral

Variations in recruitment of small pelagic species around Korean waters

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Marine fish species with pelagic eggs or larvae often show substantial fluctuations in recruitment, which may be attributed to environmental factors affecting early life stage's abundance, growth and survival. Environment-recruitment relationships have been studied in highly productive areas such as shelf areas of the Northwestern Pacific, including Korean waters where environmental factors showed relatively clear patterns and there was general understanding of casual links between ocean physics, plankton productivity and recruitment success. Because small pelagic fishes are usually short-lived, any fluctuation in recruitment success translates rapidly into fluctuations in population size. Therefore, what may be a conservative level of exploitation during years with good recruitment may result in overfishing during unfavorable years. Recruitment success can be thought of as an integrated function of processes acting across a wide range of life-history stages, from the size and condition of the spawning population at one end to the pre-recruit survival rates at the other. The objective of this study is to investigate an abrupt shift, that is, a discontinuity in ocean environmental time series data of Korea and adjacent waters for 1968-2004. We hypothesized that successful recruitment was dependent on advection processes; specifically, eggs and larvae of small pelagics were transported from spawning grounds in the ECS to nursery grounds in the southwestern Korean peninsula. The recruitment of small pelagics is dependent on the abundance of spawning biomass in the previous year and advection during the spring.

PICES XV S7-3105 Poster

Interdecadal variability on the growth and migration trajectory patterns of Pacific saury: A model-based study

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Pacific saury is mainly located in North Pacific and is one of the important fisheries in Japan. Saury migrates widely in the North Pacific. However, saury growth and stock vary widely from year to year, and the cause for these fluctuations is unclear due to paucity of data. A modeling approach is useful to investigate physical and biological processes responsible for variation of saury biomass and growth rate. This modeling study focuses on interdecadal variability of Pacific saury growth and their migration trajectory patterns. The saury model is linked with 3-D lower trophic biological model consists of multiple phytoplankton and zooplankton. The model is based on a biomass-based model, NEMURO.FISH of PICES (Ito *et al*., 2004). The results show that saury growth rate tends to be higher after the 1976/77 Pacific climate shift due to the modeled zooplankton biomass increase after the 1976/77 climate shift, which correlate well with the Pacific Decadal Oscillation (PDO). During the positive PDO phase, the mixed water region tends to be colder with deeper mixing during the winter and early spring. Therefore spring phytoplankton productivity is higher, which result in higher zooplankton biomass. For saury migration trajectory patterns, our study results that most of saury are advected to the east of 160°E through their southward migration in winter because of strong eastward current and never back to near Japan. Conversely, few saury can migrate back to near Japan, and some of them are caught as one of important commercial fisheries in Japan.

PICES XV S7-2991 Poster

Predation on larval and juvenile anchovy by skipjack tuna in the Kuroshio - Oyashio transition region

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Daily ration of skipjack tuna (*Katsuwonus pelamis*) on larval and juvenile anchovy (*Engraulis japonicus*) was assessed using samples of skipjack tuna and anchovy captured simultaneously through a cooperative cruise comprising two research vessels in the Kuroshio–Oyashio transition region in May and June 2005. Young anchovy were sampled using a frame trawl (MOHT: 5 m^2 mouth opening), while skipjack tuna were captured with a drift net. To quantify the predation effect of skipjack tuna on young anchovy, the digestive tracts of 100 individuals (390–510 mm in SL) were divided into five parts (stomach, pylorus, duodenum, bowel, and rectum) and examined. The contents were sorted by stage of digestion and prey items were identified. We estimated the number of larval and juvenile anchovy ingested by counting otoliths as well as undigested individuals. Standard length and wet weight of anchovy found in the gut of skipjack tuna were reconstructed from the otolith radius. The larval and juvenile anchovy dominated 65% of stomach contents in number, and more than 98% of the contents of the other parts of the digestive tract. Estimated standard length of anchovy preyed upon by skipjack tuna were similar in range to those of anchovy captured by the trawls (n = 1382, 13.6–40.6 mm in SL), although the mean size of ingested anchovy was larger than the mean size obtained from the trawl. An individual skipjack tuna fed on 274 ± 175 (mean ± SD) larval and juvenile anchovy and 22.0 ± 14.1 g in weight per day. This corresponded to approximately 1.2% of the skipjack tuna's wet body weight.

PICES XV S7-3222 Oral
An early life history model for Pacific herring in Prince William Sound, Alaska

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Our modeling efforts support Hjort's concept of mortality in the larval stages as the most "critical period" in determining year-class strength of herring fisheries. Using published data, we integrated information about survival in egg, larval and juvenile life stages into a mathematical model that used means and standard deviations to characterize the early life history of Pacific herring (*Clupea pallasii*) in Prince William Sound (PWS), Alaska. The early life history model predicted survival after the first year to be 118 herring out of one million eggs and a 95% confidence interval of 5 - 2,822 herring. Survival estimates differed for all life stages in the first year, with survival the lowest in the larval stage. Estimates of survival of the egg stages, fall juveniles and winter juveniles were two orders of magnitude greater than the survival of larvae. The single-stage sensitivity analysis demonstrated that for age-0 herring the influence of altering daily mortality resulted in an estimated total survival that was not equivalent for each life stage. The largest influence to the total survival was by increasing or decreasing the daily mortality in the larval stage. The results of the interaction sensitivity analysis of all possible paired life stages affirmed the results of the single life stage sensitivity, *i.e.*, the larval life stage, in combination with any other life stage, contributed the most to total survival of first year herring. Environmental processes, including food availability, water temperature, and transport processes, act on the larval stage to determine survival of Pacific herring.

PICES XV S7-3009 Oral
Patchiness structure and mortality of Pacific saury, *Cololabis saira*, larvae in the northwestern Pacific Ocean

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Patchiness structure and mortality rate of Pacific saury, *Cololabis saira*, larvae were studied in the Kuroshio-Oyashio transition zone in May 2000 and 2001. Dense larval distribution areas were detected during preliminary surveys and were marked using GPS-buoys equipped with drogues. Random neuston-net (1.3 m mouth width, 0.45 mm mesh) sampling was repeatedly conducted at night in the 5 nautical square miles with tracking the buoys every other day. Nine data sets (a total of 221 net samples) provided four pairs for larval mortality analysis. Average density of larval patchiness was estimated as 1.4 patches 100 km^{-2} and the patch size was estimated as 23.7 km^2. The average distance between the gravity centers of patches was 8.4 km. These parameters of patchiness of the saury larvae remained consistent over the course of the study. Hence, larval mortality was estimated on every 5 mm knob length (KnL) intervals without considering the diffusion rate. Larval growth was examined through otolith increment analysis. The estimates of mortality ranged from 30 to 40 % for larvae of 10 to 40 mm in KnL and did not decrease during the larval and juvenile stage. Negative mortality rate, estimated on larvae smaller than 10 mm KnL, suggested a continuous hatching of saury larvae in this area.

PICES XV S7-3081 Oral

Can we explain and predict stock fluctuations of Japanese common squid, *Todarodes pacificus,* related to climatic regime shifts?

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Annual catches of Japanese common squid, *Todarodes pacificus*, decreased during a cool regime period from the late-1970s to late-1980s, and have increased during the recent warm regime period after the late-1980s. The catch fluctuations are similar to those of Jack mackerel and Japanese anchovy. *T. pacificus* produces gelatinous, nearly neutrally buoyant egg masses that contain many small eggs. The egg masses are thought to occur within or above the pycnocline at temperatures suitable for egg development. Recently, we estimated from laboratory studies that hatchlings (< 1mm ML) will ascend to the surface at temperatures between about 18-23ºC. After hatching, the paralarvae presumably ascend to the surface layer from the mid layer near the pycnocline above the continental shelf and slope and are advected into convergent frontal zones. We used this new reproductive hypothesis to explain and predict the stock fluctuations in relation to climatic regime shifts. During warm regime period after 1989, the inferred spawning areas of winter spawning group have occurred along the continental edge off the Kyushu Island and the Nansei Islands, and the inner flow of the Kuroshio has transported the hatchlings in the surface layer from the spawning areas to the nursery areas of northeastward along the continental edge. However, the spawning areas during the cool regime of the 1980s vanished along the continental edge, when winter wind stress was stronger, and air temperature at the sea surface was lower, and mixed layer depth at the spawning grounds was deeper than those after 1989. We conclude that prospective change of *T. pacificus* stock can predict by physical parameters such as wind stress, air temperature, SST, and MLD during the spawning period based on a new reproductive hypothesis.

PICES XV S7-2902 Oral

Analysis of key recruitment processes for *Euphausia pacifica* off the Oregon coast

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The euphausiid *Euphausia pacifica* is widely distributed throughout the Pacific Ocean. It is often the dominant species of euphausiid found throughout a wide range of ocean conditions, from warm inland seas to the cold and food-limited open ocean. We will investigate the recruitment processes of this species, including brood size, development time and growth rate, in relation to environmental conditions (*i.e.*: warm or cold ocean regime) to determine temporal variability in spawning and the subsequent effect on recruitment. Survivorship curves and development time measurements from work conducted in our laboratory show that the early developmental stages C1 and FIII are considerably slower than other stages. We will use these measurements to determine how varying the development time of particular stages affects recruitment. We will also investigate the effect of warm and cold ocean conditions on recruitment. Experiments on spawning, growth and larval development show high variability among individuals. *E. pacifica* seems to apply a plastic life history strategy of being highly variably in each of these vital rates under all environmental conditions. As a consequence, we suggest that modeling of euphausiids should be conducted using individual-based models to accurately represent this variability. This is a more complicated process, but will yield results that reflect the actual population dynamics of *Euphausia pacifica*.

PICES XV S7-3224 Oral
Parent-progeny relationships in the Okhotsk Sea walleye pollock

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Data on the number of spawning adults and the abundance of recruits of walleye pollock (*Theragra chalcogramma*) in the Okhotsk Sea, collected during 1984-2004, have been analyzed. It appears that the survival of walleye pollock during the first year of life is not correlated with the abundance of parents (r=0.09). It implies that, under equal conditions, the probability for the appearance of high-yielding generation is higher when the number of spawners is high. Such a relationship had statistical support (r=0.67). We may suggest that, for the rather large population of the Okhotsk Sea walleye pollock, the classical reproduction curve (Rickers's model) is not applicable. Mainly environmental factors and, to a lesser extent, the number of spawners, produce a measurable influence on walleye pollock survival in early ontogenetic stages. In particular, the higher the share of first-time spawning females, the lower the survival of their progeny. In certain years, high survival rates of the progeny were due to large mean size and high mean age of spawning females, and their lower relative abundance in a spawning stock. However, such a relationship appeared insignificant, when long-term data were taken into account. We suggest that a combination of favorable environmental factors, medium or high abundance, optimal size-age structure of the spawning stock and "quality" of spawners favor the appearance of strong generations in populations of walleye pollock.

PICES XV S7-2855 Oral
The effect of spawner age on stock productivity: Influences of life-history pattern and recruitment variability

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Marine fish stocks exhibit a wide variety of responses to oceanographic variability and harvesting, reflecting largely differences in reproductive biology and stock-recruitment relationships. In particular, for some stocks (Pacific rockfish and Atlantic cod) there is evidence that larval viability may be affected by the age of the spawner, thus potentially complicating stock-recruitment relationships. These maternal effects can be viewed as redefining the units of spawner output from eggs to "viable larvae", and for Alaska Pacific ocean perch (POP) this redefinition has produced increased estimates of resiliency by associating a given time-series of recruitment estimates with a diminished measure of spawner output. Additionally, harvesting would be expected to have a substantial role in the production of viable larvae via truncation of the stock age-structure. In this study, simulated "cod-like" and "rockfish-like" populations are used to further explore how estimates of stock productivity may be affected by life-history pattern, recruitment variability, and exploitation. Production of viable larvae may be affected by density-dependent and/or density-independent mortality, and traditional stock-recruitment functional forms will be modified to consider the effect of spawner age.

PICES XV S7-2833 Invited
A population dynamics model for Japanese sardine, *Sardinops melanostictus*, off the Pacific coast of Japan, consisting of spatial early-life stage and age-structured adult sub-models

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We constructed an individual-based life cycle model for the Japanese sardine, *Sardinops melanostictus*, off the Pacific coast of Japan, consisting of spatial early-life stage and age-structured adult sub-models. Japanese sardine has exhibited dramatic changes in its stock abundance. Our simulation approximately reproduced these fluctuations during 1978-2002, using this life cycle model. Stock fluctuations of Japanese sardine are thought to be caused mainly by differences among years in the mortality rate before recruitment. Our multiple cells model showed the population dynamics in the early life stages under heterogeneous environmental conditions, by

incorporating information on differences in the environment of each of the cells. Our model determined the natural mortality by using the information of the environmental conditions, interspecific-relationship and the density-dependent effects. Also in the age-structured adult sub-model, our model determined the number of surviving fish by using the natural mortality and the fishing mortality. That is, we considered the influence of environmental factors (water temperature and food density), interspecific relationship and fishing mortality to investigate the causes of the Japanese sardine stock fluctuation. Our simulation revealed that the decline of the sardine stock in the 1990s could not have been halted by catch regulations; however, the slope of the decline in the 1990s could have been mitigated by a reduction of the fishing mortality. Our approach allows flexibility and extensibility in the model. If more observed data are accumulated, the future versions will incorporate a more explicit spatial approach and a multispecies model.

PICES XV S7-2926 Poster

Comparison of growth rate between hatching months of Pacific sandlance *Ammodytes personatus* in early life stages

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To clarify the population fluctuation mechanism of Pacific sandlance *Ammodytes personatus*, we examined growth history by using an otolith back-calculation method of the pelagic larvae and settled juveniles collected in Mutsu Bay, Japan from January to May in 2003-2005. Pelagic larvae of Pacific sandlance were collected with a ring net and MTD closing nets mainly from February to April in the bay, and settled juveniles were obtained from commercial landings of dip nets individuals with fishing lamps from the coastal area of the bay mouth in May. Hatch date distributions for pelagic larvae and settled juveniles through the three years were 1% in number in January, 15% in February, 68% in March, and 16% in April, and 1% in January, 33% in February, 65% in March, and 1% in April, respectively. The logistic growth equations were obtained as follows: BL=82.00/(1+exp(2.530-0.031·age)), for the individuals hatched in February, BL=73.55/(1+exp(2.424-0.038·age)), for those in March, and BL=73.55/(1+exp(2.469-0.042·age)), for those in April. In all three years, early hatched individuals showed low growth rates and water temperature increased from March. Densities of copepod nauplii as the primary prey for small larvae and copepodites as prey for large larvae were roughly steady from February to April in these three years. Thus, growth rates in larval and early juvenile periods of Pacific sandlance might be mainly enhanced by high water temperature rather than by high prey abundance. Settled juveniles had relative wider otolith increments near the outer margins than pelagic individuals which showed similar body size.

PICES XV S7-2939 Oral

Growth of larval and early juvenile sardine (*Sardinops* spp.) and anchovy (*Engraulis* spp.) in the eastern and western North Pacific Ocean

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We hypothesize that both food and temperature control the growth of larval and juvenile sardine and anchovy. Growth rates of larval and early juvenile sardine and anchovy were estimated from daily increments of otoliths and examined in relation to sea surface temperature (SST) and the concentration of available copepods in the California Current and Kuroshio/Oyashio regions. Pacific sardine *Sardinops sagax* and northern anchovy *Engraulis mordax* were collected off California, Oregon, and Washington in spring, summer, and autumn. Japanese sardine *S. melanostictus* and anchovy *E. japonicus* were collected in the Kuroshio-Oyashio transition in spring. Otolith and somatic growth rates of *S. melanostictus* and *E. japonicus* were faster than those of *S. sagax* and *E. mordax*. We standardized the individual growth rate to remove the effect of fish size. Standardized recent growth rate (SRGR) for the five days before capture varied positively over 12-20°C SST for *S. melanostictus* and *E. japonicus*, while SRGR decreased over 17-20°C SST for *S. melanostictus*. SRGR for

S. sagax and *E. mordax* was in the lower range of SRGR for *S. melanostictus* and *E. japonicus*. SRGR of *E. mordax* was significantly less than that of *E. japonicus* over 13-16°C SST; there were insufficient data for this analysis for *Sardinops*. The concentration of copepods available to *E. mordax* in the California Current region was significantly lower than that for *E. japonicus* in the Kuroshio-Oyashio transition region. We conclude that both food and temperature affect the growth rate of larval and juvenile anchovy and sardine in the regions studied.

PICES XV S7-3163 Poster
Impact of the late 1980s regime shift on the abundance and distribution of loliginid squid *Loligo bleekeri* in the southwestern Japan Sea

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An oceanic regime shift, as indicated as an abrupt change from colder to warmer water in the Tsushima Warm Current (TWC), was identified in the late-1980s in the Japan Sea and largely associated with fish population dynamics. The loliginid squid *Loligo bleekeri* is a commercially important species for coastal fisheries in Japan. Catch from the southwestern Japan Sea reached the maximum of 13,700 tons in 1977, but has been decreased to less than 100 tons in recent years with large interannual fluctuations. Using monthly trawl catch data with a resolution of 30 minutes (longitude-latitude) for the southwestern Japan Sea during 1975-2004, we examined the impact of fishing and the late 1980s regime shift on the abundance and distribution of the squid.

The catch of loliginid squid shows decadal variations with a change from positive to negative anomalies occurring around the late 1980s. This pattern corresponds well with the changes in water temperature in TWC from cold to warm regime that occurred in late 1980s, strongly indicating that the decadal variability in loligind squid was largely affected by the late 1980s regime shift. DeLury analysis showed that fishing mortality averaged during 1989-2000 is about 3 times higher than that during 1975-1988, and the exploitation rate increased from 50% to 80% during the last three decades, indicating that intensified fishing mortality accelerated the collapse of the stock. GIS mapping showed that the distribution area in the south of Tsushima Is. almost disappeared, and the decreasing pattern in distribution and abundance corresponded with the warming and northward shift in winter sea temperatures front of TWC. These suggest that decadal variation patterns in the squid largely forced on the regime shift of TWC, while fishing has a large impact on the interannual variation and the collapse of the stock.

PICES XV S7-2932 Oral
Climate variation and salmon recruitment: Comparing climate indices for predicting salmon marine survival in the Northern California Current ecosystem

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Interannual to decadal scale climate fluctuations have a strong influence on recruitment of Pacific salmon (*Oncorhynchus* spp.), as evidenced by numerous studies linking various long-term climate indices (regional upwelling, local sea surface temperature, date of the spring transition, ENSO indices, PDO, *etc.*) with salmon commercial catch as a proxy for stock abundance. The anadromous life history of salmon complicates interpretation of these results. Researchers have recently focused on using these climate indices to directly explain variation in salmon marine survival for stocks where freshwater production, harvest, and adult escapement are adequately monitored to estimate marine-phase survival. To date, these studies have focused primarily on indices of the physical climate. However, during the past decade, increased biological sampling in the Northern California Current (NCC) has provided a number of biological indicators of ecosystem status (*e.g.*, plankton production, copepod community structure, and abundance estimates for juvenile salmon, forage fishes, and predaceous fishes). We compare the utility of various physical and biological indicators (including both

ocean and freshwater environments) as salmon forecasting tools by putting these various indicators in a consistent statistical framework and assessing their effectiveness as short-term forecast tools for three salmon production indices: Oregon Production Index (OPI) coho salmon marine survival, Oregon Coast natural (OCN) coho salmon recruits per spawner, and Snake River spring/summer Chinook salmon marine survival. We also propose a statistical "ensemble" forecast model that combines the various indices in a decision-support framework to provide integrated recruitment forecasts along with an assessment of uncertainty.

PICES XV S7-2937 Oral
Crab larval advection and recruitment in the Eastern Bering Sea

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Spatial distributions of red king and snow crabs in the eastern Bering Sea changed profoundly during the last three decades. The shifts of distributions to the northeast for mature female red king crabs occurred right after the 1976/77 regime shift, while the shifts of mature female snow crabs to the northwest occurred from the mid-1970s to early 1980s. Because distribution centers of small juvenile red king and snow crabs are generally located downstream of the mature females, advection may be an important process for red king and snow crabs. In this study, we used the OSCURS model to simulate annual larval drifts from 1967 to 2004 for red king crabs and from 1975 to 2004 for snow crabs. Larval durations were estimated to range from 44 days to 153 days for red king crabs and from 59 days to 153 days for snow crabs, with longer durations for the earlier hatching larvae. The northward shifts of spatial distributions of mature females made it difficult to supply larvae to the southern portions of their ranges. Larvae hatched in the north of their habitat might have greater chances of settling on unfavorable habitats than in those hatched in the south. Changes in settling locations over time might have affected recruitment strength for Bristol Bay red king crabs. However, simulated larval locations cannot consistently explain the strong and weak year classes for snow crabs. Larval advection may be one of many important factors influencing crab year class strengths.

S8 FIS/MEQ Topic Session
Aquaculture and sustainable management of the marine ecosystem

Co-Convenors: Toyomitsu Horii (Japan), Jie Kong (China) and Michael B. Rust (U.S.A.)

Activities associated with aquaculture can result in both positive and negative impacts on the marine ecosystem. The environmental, ecological and genetic capacities of the marine environment need to be considered to maintain sustainable aquaculture development and a healthy wild ecosystem. At various levels of aquaculture production, environmental hazards can be assessed and management measures developed to minimize those hazards to the marine ecosystem and/or their probability (risk) of occurrence. PICES WG 18 has begun to consider environmental and ecological impacts associated with aquaculture. These include ecological hazards associated with nutrient release, escaped or released cultured organisms (predation, competition), and the potential for disease transfer. In addition, the escape of genetic selected species used for aquaculture may have harmful effects on the genetics of wild populations of native species. Genetic risks should be evaluated based on potential impacts to biodiversity and ecosystem conservation using proper evaluation techniques. These techniques should be consistent among researchers where possible. Moreover, it is necessary to consider the influence on ecosystem and genetic diversity when artificially produced seedlings are released for stock enhancement or rebuilding. To promote responsible aquaculture in a healthy marine ecosystem, it is critical to continuously evaluate and manage the aquaculture activity. Clearly defining the potential hazards to the ecosystem, assessing the probability that hazards will occur and implementing mitigation strategies to reduce or eliminate hazards can facilitate this oversight. The goal of this session is to identify and establish evaluation techniques and models for potential hazards which aquaculture exerts on genetic diversity, ecosystem function and/or the marine environment. The potential for standardization of methods and models that deal with interactions between aquaculture and wild organisms will also be explored.

Thursday, October 19, 2006 09:00-17:00

09:00-09:10 **Introduction by Convenors**

09:10-09:40 **J.E. Jack Rensel, Dale A. Kiefer and Frank J. O'Brien** (Invited)
AquaModel: Mariculture model development and testing (S8-3038)

09:40-10:05 **Zhaohui Zhang, Zongling Wang and Mingyuan Zhu**
Ecosystem services valuation of marine aquaculture (S8-3251)

10:05-10:30 **Colin E. Nash and William T. Fairgrieve**
Ecological risk assessment of marine fish aquaculture in the coastal zone (S8-2766)

10:30-11:00 ***Tea/Cofee Break***

11:00-11:25 **Michael B. Rust**
Risk and risk management for feed and seed for carnivorous marine fish aquaculture (S8-3044)

11:25-11:50 **Galina S. Gavrilova**
Shellfish mariculture in the Russian Far East (S8-2969)

11:50-12:15 **R.J. Beamish, C.M. Neville and E. Gordon**
Sea lice production on farmed salmon – Not what you read in textbooks (S8-3060)

12:15-12:40 **Joseph S. Paimpillil**
Eco-friendly shrimp culture with Pokkalli paddy – Sustainable coastal resource management practice (S8-2791)

12:40-13:45 ***Lunch***

13:45-14:10 **Hee Won Park and Chang Ik Zhang**
A study on the ecosystem-based resource management system of self-regulatory community fisheries in Korea (S8-2831)

14:10-14:35 **Yoh Yamashita and Yutaka Kurita**
Carrying capacity of nursery grounds for Japanese flounder in relation to stocking densities (S8-2852)

14:35-15:00 **Tomohiko Kawamura, Hideki Takami and Toyomitsu Horii**
Factors affecting recruitment fluctuations of abalone – Assessment of the stock management and enhancement activities in the last 30 years in Japan (S8-2914)

15:00-15:25 **Naoaki Tezuka and Masami Hamaguchi**
Biological impacts caused by the release of the imported manila clam, *Ruditapes philippinarum*, in Japan (S8-3207)

15:25-15:45 ***Tea/Coffee Break***

15:45-16:10 **Tetsuo Fujii**
Conservation of the genetic diversity of Japanese flounder *Paralichthys olivaceus* under successive mass release of hatchery-reared juveniles (S8-3126)

16:10-16:35 **Graham E. Gillespie, Antan C. Phillips, Debbie M. Paltzat and Tom Therriault**
Distribution of non-indigenous intertidal species on the Pacific Coast of Canada (S8-3211)

16:35-17:00 **Vasily Radashevskiy**
Alien polychaete worms (Annelida, Polychaeta) in the North Pacific (S8-2922)

Posters

Eugene I. Barabanshchikov, Nikolay V. Kolpakov and Victor A. Nazarov
Invasion of non-indigenous animal species into the Russian Far East marine and estuarine ecosystems (S8-2910)

Motoyuki Hara and Hiroshi Hoshikawa
Genetic analysis for reproduced contribution of released hatchery-produced abalone (S8-2920)

Sergey I. Maslennikov and Victor V. Ivin
Environmental impact of scallop mariculture on coastal ecosystems in Russia (S8-3101)

Chul Won Kim, Dae Hee Kim, Kyung Hyun Park, Seock Jung Han and Choon Goo Jung
Technology development for intermediate rearing of the sulf clam, *Tresus keenae*, in Korea (S8-2858)

Dae-Hyun Kim, Jung Hwa Choi, Kwang Ho Choi and Sung Tae Kim
Relationship between nucleic acids and artificial gonad maturation of swimming crab (*Portunus trituberculatus*) by manipulating water temperature, photoperiod, and eyestock ablation (S8-3111)

Sung Il Lee, Hyung Kee Cha, Young Seop Kim, Sang Cheol Yoon, Jae Houng Yang and Kyunk Chan Know
Study on stock rebuilding plan for *Arctoscopus japonicus* in the East/Japan Sea of Korea (S8-2961)

Won Chan Lee, Hyun Taik Oh, Sung Eun Park, Jun Ho Koo, Sok Jin Hong and Rae-Hong Jung
Ecosystem modeling for improvement the water quality in a eutrophic marine environment of Chinhae Bay, Korea (S8-3072)

Xuezheng Lin, Kaoshan Chen and Xiaohang Huang
Advances in marine alien species invasion in China (S8-2943)

Kyung Hyun Park, Chul Won Kim, Dae Hee Kim, Seock Jung Han and Choon Goo Jung
Growth and survival of the sulf clam, *Tresus keenae*, larvae according to rearing condition in Korea (S8-2859)

PICES XV S8-2910 Poster
Invasion of non-indigenous animal species into the Russian Far East marine and estuarine ecosystems

Eugene I. **Barabanshchikov**, Nikolay V. Kolpakov, Victor A. Nazarov

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It is well known that non-indigenous species are penetrating into ecosystems by two ways; active and passive. Each of these ways can be from both natural and anthropogenic means. By active natural migrations into the far-eastern ecosystems the *Mugil cephalus* has proliferated but other indigenous animals are instilled by man into the western and northern marine and estuarine ecosystems of Russia such as *Liza soiuy, Oncorhynchus gorbuscha* and *Paralithodes camtschaticus.* Passive natural migrants use wind and currents. Examples include *Charybdis japonicus, Histrio histrio* and *Rhopilema asamushi* which have penetrated into the Russia Far East marine areas. Anthropogenic vectors include ship ballast water, ship biosedentaries, uncontrolled aquaculture *etc*. Examples of this type of introduction include *Eriocheir chinensis, Schmackeria inopina* and some Polychaeta which have appeared in far-eastern offshore areas and estuaries. Marine ecosystems of the Russian Far East are free from anthropogenic non-indigenous species now, but with the increase in shipping activity there is apprehension that species such as Ascidia, Cirrhipedia and Polychaeta species will be introduced and could establish. All natural invasions in the far-eastern seas both active and passive, took place during last spring-summer-early fall period. Migrating actively non-indigenous marine fishes such as *Mugil cephalus, Sardinops melanostictus, Engraulis japonicus, Konosirus punctatus, Strongylura anastomella, etc.* are included in the offshore fisheries resource. Passively shifting alien species are not dangerous for native communities but species introduced by-ships would be potentially dangerous for far-eastern offshore marine ecosystem biodiversity. China and Russia pisciculture activities have increased the number of non-indigenous fish species in southern transboundary river estuaries, such as *Hypophthalmichthys molitrix, Aristichthys nobilis, Ctenopharyngodon idella, Culter alburnus, Hemiculter leucisculus, Channa argus* and others. The further scientific monitoring of the influence of such species on the natural structure of estuaries is required.

PICES XV S8-3060 Oral
Sea lice production on farmed salmon – Not what you read in textbooks

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We monitored sea lice development on salmon in one fish farm during the two year production cycle. For the first 10 months there was no evidence of a natural progression of development stages. Complete life cycles did not occur until winter when surface salinities exceeded 30‰. We concluded that mobile stages of sea lice commonly are free swimming.

PICES XV S8-2766 Oral
Ecological risk assessment of marine fish aquaculture in the coastal zone

Colin E. Nash and William T. Fairgrieve

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The presentation summarizes the proceedings of an international workshop organized to develop "Guidelines for the Risk Assessment of Marine Fish Aquaculture" (see: http://www.nwfsc.noaa.gov to download proceedings). The international participants adopted the structural approach to risk assessment developed by the World Health Organization (WHO), and which is now widely used. For each risk, the WHO framework begins with problem formulation, and proceeds through problem analysis to characterize the exposure and ecological effects of the risk before the final risk characterization. It ends with risk management. In addition to explaining the Risk Assessment Framework and its application in a global marine aquaculture setting, the Guidelines include ten example templates. Each template applies the process to a risk currently perceived by scientists or the public to have possible impact on the coastal and marine ecosystems depending on specific ecological conditions of various biogeographical zones and in a variety of other circumstances. The ten risks are: increased organic and

inorganic loading, residual heavy metals in sediments, transmission of disease between wild and farmed populations, residual therapeutants in sediments, biological interactions of escapees with wild populations, physical interactions with marine wildlife, physical impacts on marine habitats, using wild juveniles for grow-out, and harvesting industrial fisheries for aquafeeds. Included in each risk template are sections on the current hypothesis for perception of the risk, the background experience or known information, the conceptual model of how the risk is manifest, its analysis and characterization, and finally a biological opinion regarding its possible incidence and management or prevention.

PICES XV S8-3126 Oral
Conservation of the genetic diversity of Japanese flounder *Paralichthys olivaceus* under successive mass release of hatchery-reared juveniles

Tetsuo **Fujii**

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The Japanese flounder *Paralicthys olivaceus* is one of the most important fish for the coastal fisheries in Japan and approximately 25 million hatchery-reared juveniles have been released annually to enhance the stock. As a result of the stock enhancement program, more than 10% of landed flounder is from released fish in some regions. It is necessary to consider how to conserve the genetic diversity of the wild population of Japanese flounder under successive mass releases of hatchery-reared juveniles. Genetic diversity, migration, and reproduction of released hatchery-reared flounder were investigated by DNA analysis. The genetic diversity of hatchery-reared juveniles was lower than that of wild population especially when cultured fish were used as parents. It was suggested that using enough (more than 100) fish from wild populations as a brood stock, collecting eggs at the middle of the spawning season, and collecting eggs more than 3 times in one season with more than 3 days interval were important. Released flounder tend to migrate against the ocean current as they grow and flounder from several hatcheries were caught at the same spawning area. The genetic diversity of recaptured flounder at a spawning area was as high as when they were released. This finding suggested that the genetic diversity of released juveniles was stable until they matured. Recent studies demonstrated the successful reproduction of released founder. Continuous investigations on genetic variability of both wild population and hatchery-reared juveniles are needed.

PICES XV S8-2969 Oral
Shellfish mariculture in the Russian Far East

Galina S. **Gavrilova**

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In the South of the Russian Far East (Peter the Great Bay, Japan Sea) shellfish mariculture is developed better than mariculture other species. Technologies for cultivation of 3 species (Japanese scallop, Pacific mussel and oyster) have been worked out and approved. Oyster cultivation hasn't developed widely because of unstable larvae numbers resulting in unprofitable sea farms. Experience with mussel culture in our region resulted in up to 100-4000 individuals from 1 running meter of substrate. But there is heavy elimination of mollusks in the bays with low water exchange. Extensive cultivation of Japanese scallop has developed most successfully. Average spat production in Peter the Great Bay is about 4 million individuals per hectare of mariculture plantation. High density has an influence on mollusks vital functions both in ponds and on bottom plantations. Decreased growth rates were observed when plantation density exceed 800 g/m^2. Our results will allow us to estimate farm capacity taking into account both biological and economic components.

PICES XV S8-3211 Oral
Distribution of non-indigenous intertidal species on the Pacific Coast of Canada

Graham E. **Gillespie**, Antan C. Phillips, Debbie M. Paltzat and Tom Therriault

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Aquatic invasive species are a significant issue globally. British Columbia (BC) has an extensive coastline, but much of it is difficult to access, so the presence of non-indigenous species has been difficult to determine. Surveys were undertaken for non-indigenous intertidal species in waters outside of the Strait of Georgia. A trapping program for European green crab, *Carcinus maenas*, was undertaken in conjunction with beach surveys. Pacific oysters, *Crassostrea. gigas*, were in Barkley, Clayoquot and Nootka Sounds and Esperanza Inlet on the west coast of Vancouver Island (WCVI). Belon oysters, *Ostrea edulis*, had successfully recruited in Barkley Sound, the first records of natural reproduction in BC, but specimens collected in Esperanza Inlet were deliberately placed there. Manila, *Venerupis philippinarum*, varnish, *Nuttallia obscurata*, and softshell clams, *Mya arenaria*, were abundant throughout WCVI. Japanese drills, *Ocinebrina inornata*, green mussels, *Musculista senhousia*, and mouse-ear snails, *Myosotella myosotis*, were collected in Barkley Sound; all first records for WCVI. Dwarf eelgrass, *Zostera japonica*, was in Clayoquot Sound, and wireweed, *Sargassum muticum*, and violet tunicate, *Botrylloides violaceus*, were in Barkley, Clayoquot and Esperanza. Green crabs were encountered throughout WCVI, with highest densities in Pipestem Inlet (Barkley), Holmes Inlet (Clayoquot) and Queen Cove (Esperanza). At least three year classes were present, which suggests successful local recruitment. While the ecological and economic impacts of some long-established species are known, it is uncertain what impacts recent invaders might eventually have. The results of these surveys are a first step in examining potential impacts by determining current distribution of non-indigenous species.

PICES XV S8-3207 Oral
Biological impacts caused by the release of the imported manila clam, *Ruditapes philippinarum*, in Japan

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Invasion by marine nonindigenous species (NIS) is a wide spread phenomenon in the world. Marine organisms have been moved around the world accidentally or intentionally. Aquaculture is now considered one of the major gateways for introduction of marine NIS. The case of invading mollusks has been studied for a long time because of their economic damage and disturbance, their impact on endemic faunas, or their role in the transmission of some pathogens. The manila clam, *Ruditapes philippinarum*, is widely distributed all over Japan and the most common and commercially important shellfish in the country. The census shows a rapid decrease in fisheries production of the clam in recent years. Thus, large numbers of the manila clams have been imported to Japan from China, Korea and North Korea for aquaculture seed as well as for human consumption. In 2003, total production of manila clam in Japan was 36179 metric tons and the total imported clam was 52242 metric tons. We have analyzed the morphological and the complete nucleotide sequences of mitochondrial DNA of native and imported manila clams (from China, Korea and North Korea). Two morphological and genetic forms were identified and we developed the discrimination method of both forms. We will discuss about ecological impacts (introgression, *etc.*) of foreign form to native form of manila clam in Japan.

PICES XV S8-2920 Poster
Genetic analysis for reproduced contribution of released hatchery-produced abalone

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The reproductive contribution of stocked organism is of interest in the context of management of enhanced fisheries and the discipline of conservation ecology. The Ezo-abalone (*Haliotis discus hannai*) is one of the most important molluscan fishery resources. The annual landing since about 1970 has been reduced by one-third, even though a lot of hatchery-produced abalone has been stocked intensively across Japan every year. We analyzed wild populations, naturally reproduced juvenile and stocked adult abalone populations in experimental areas based on highly variable genetic markers, and tried to assess stocking impact of released abalone to natural resources. The genetic population heterogeneity of populations among the juveniles were not significantly different, but combination between the juveniles and stocked abalone yielded highly significant differences. The genetic distance between the juveniles and wild populations were substantially smaller than those between the juveniles and stocked abalone. The genetic population relationship among those groups was divided into two major groups, one group was the naturally reproduced juveniles and the wild populations and the other was the stocked abalone. The assignment test of the juveniles revealed that relatively low proportions of individuals of the juveniles were from the stocked population, and high percentages were excluded from them, nevertheless the stocked abalone accounted for a high ratio in the study area. These results indicate that the stocked abalone were not as effective as broodstock for natural recruitment compared to wild abalone.

PICES XV S8-3101 Poster
Environmental impact of scallop mariculture on coastal ecosystems in Russia

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The main aquaculture species in the Russian seas are various species of pacific mussel *Mytilus trossulus*, Yesso scallop *Mizuhopecten yessoensis*, and Japanese kelp *Laminaria japonica*. All species are farmed in monoculture, mostly in semi-closed bays. The review considers effect of plantations for cultivation of bivalve mollusks on hydrological and chemical conditions of the marine environment and on communities of marine organisms in semi-closed bays of the seas of Russia. Due to eutrophication resulting from rearing mollusks in suspension, the species composition, structure and functional parameters of pelagic and benthic communities has changed. Moreover, the occurrence of the Harmful Algal Blooms becomes more frequent. The rate of eutrophication depends on the configuration of bays, intensity of water exchange and turbulence of the bottom layer of water. After removal of mariculture facilities the biological components of ecosystems of semi-closed bays is restored within 5-10 years.

PICES XV S8-2914 Oral
Factors affecting recruitment fluctuations of abalone – Assessment of the stock management and enhancement activities in the last 30 years in Japan

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Despite the release of millions of abalone seed annually in the last 30 years in Japan, abalone resources have not increased in many years mainly due to low natural recruitment. In the last 10 years, however, natural recruitment of the northern species *Haliotis discus hannai* has markedly increased in some areas, which is reflected by an increase in catch. The catch and natural recruitment of the southern species, *H. discus discus*, *H. madaka* and *H. gigantea*, have shown no sign of recovery. Why has the natural recruitment of *H. discus hannai* started increasing? Why has the recruitment of southern species remained low? Why has reseeding not contributed to an increase in abalone stocks? Relatively high seawater temperature in the winter since 1990's is

suggested as a main factor increasing natural recruitment of *H. discus hannai*. However, this increase has only been observed in restricted areas suggesting adult populations in other areas may have been reduced to a critical level. Dense patches of males and females appear to be important for fertilization success and post-larval survival in abalone species. Adult densities are generally much lower in southern species than in *H. discus hannai*. Juveniles released over a wide area may result in low densities, and these individuals may not contribute to further reproduction. Maintaining dense adult communities seems to be important. An increase in natural recruitment seems to be necessary for the recovery of stocks. And reseeding is not always effective, without appropriate management of stocks for successful reproduction.

PICES XV S8-2858 Poster

Technology development for intermediate rearing of the sulf clam, *Tresus keenae*, in Korea

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In Korea, the output of *Tresus keenae* decreased from 85,182 kg in 1999 to 32,272 kg in 2004, making it necessary to develop cultivation technology to aid in resource recovery. Generally, intermediate rearing technology has been reported as a very useful culture technology because it contributes to improved growth and survival rates. Accordingly, we examined the effect of intermediate rearing technologies for juvenile *T. keenaes* produced by artificial propagation, in terms of size, the depth of water, density, and the method of stocking. As for suitable size, stocking 12 mm clams resulted in a harvest length of 21.93 mm and a survival rate of 70.8%, indicating better results compared with the group stocked at 8 mm that resulted in a harvest length of 17.71 mm and a survival rate of 63.3%. As for the density, the highest length growth of 24.74 mm was found in the experimental group with 500 inds./m^2 but the highest survival rate of 58.8% was found in the experimental group with 1000 inds./m^2. Economically, the experimental group with 1000 inds./m^2 is thought to be most appropriate. As for the depth, the highest length growth of 24.84 mm was observed at 10 m and the highest survival rate of 63.3% was at 6 m. The water depth of 6m or more is thought to be most suitable for stocking. With an artificial intermediate rearing site, the stocked *T. keenaes* showed a favorable growth of 23.7 mm but the survival rate remained low at 24.5%, making it necessary to conduct further studies.

PICES XV S8-3111 Poster

Relationship between nucleic acids and artificial gonad maturation of swimming crab (*Portunus trituberculatus*) by manipulating water temperature, photoperiod, and eyestock ablation

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To evaluate effects of temperature and light on reproduction of swimming crab (*Portunus trituberculatus*), we induced maturation and spawning of two groups of females *(*with ablated *vs* unablated eyestock) under four temperature (natural, 10, 15, and 20°C) and two photoperiods (15h and 9h light) conditions. We examined gonad somatic indices, spawning rates, and nucleic-acid variations. The group with ablated eyestocks under 20°C temperature and longer (15h) photoperiod showed highest degree of ovarian maturation and spawning. Despite the non-ablated eyestock, the gonad did mature under 20°C temperature and 15h photoperiod. In the cases of low temperatures (10°C and natural temperature), the degree of gonad maturation did not significantly differ by the eyestock manipulation, or between the two photoperiods, and we were unable to induce spawning during the experiment. RNA: DNA ratio was significantly correlated with the degree of gonad maturation. It was highest in the group of ablated eyestock under 20°C temperature and 15h photoperiod. The increased RNA indicates smaller and higher number of cells, and gonad differentiation began two weeks earlier in the ablated eyestock group than the other groups. These results suggest that *P. trituberculatus* require not only higher temperature but also light-related stimuli for off-season maturation and spawning.

PICES XV S8-2961 Poster
Study on stock rebuilding plan for *Arctoscopus japonicus* in the East/Japan Sea of Korea

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In recent years the fisheries resources in Korea waters have become overexploited, and the necessity for stock rebuilding is stressed. For the East/Japan Sea, *Arctoscopus japonicus* is a commercially important species. The average catch of *Arctoscopus japonicus* was approximately 15,000 mt in the early 1970s, since 1988 catch started to decrease to below 5,000 mt. Catch is about 2,400 mt in recent years. So, we are going ahead with the Stock Rebuilding Plan for *Arctoscopus japonicus* in the East/Japan Sea of Korea. We conducted biological studies on maturity and spawning, and age and growth of *Arctoscopus japonicus* using samples collected in the East/Japan Sea from 2004 to 2005. And we investigated the distribution of fishing grounds by month and the catch per unit effort (CPUE) of Eastern Sea trawl from 1975 to 2005. The biomass of *Arctoscopus japonicus* was estimated by a virtual population analysis (VPA) and stock assessment was conducted using surplus production model (MSY and f_{MSY}), yield per recruit model (F_{max} and $F_{0.1}$) and spawning biomass per recruit model ($F_{35\%}$ and $F_{40\%}$). Finally, the strategies for the rational management and stock rebuilding of *Arctoscopus japonicus* were discussed and suggested.

PICES XV S8-3072 Poster
Ecosystem modeling for improvement the water quality in a eutrophic marine environment of Chinhae Bay, Korea

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This study focused on water quality response to land-based pollution loads and the appropriate pollutant load reduction in Chinhae Bay using an eco-hydrodynamic model. Land-based discharge from urban areas, industrial complex and sewage treatment plant was the greatest contributor to cause red-tide blooms and summer hypoxia. Tidal currents velocity of the ebb tide was about 10 cm/s stronger than that of the flood tide. A residual current was simulated to have a slightly complicated pattern ranging from 0.1 to 2.7 cm/s. In Masan Bay, pollutant materials cannot flow from the inner to the outer bay easily because of residual current flow southward at surface and northward at the bottom. The simulation results for COD distribution showed high concentrations over 3 mg/L in the inner part of Masan Bay related pollutant discharge, and lower levels less than 1.5mg/L in the central part of Chinhae Bay. To improve water quality in Chinhae Bay, it will be necessary to reduce the organic and inorganic loads from point sources by more than 50% and ameliorate severely polluted sediment.

PICES XV S8-2943 Poster
Advances in marine alien species invasion in China

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Many species of alien marine organisms have been introduced to China, either by intentional introduction for aquaculture and planting based on their economic, ecological and social significances or introduction by accidental activities such as casual import and discharge of ballast water. It has been widely perceived that the littoral biota in many regions has undergone rapid and profound changes caused by exotic species. Based on the research program of Ministry of Science and Technology, P. R. China (2004DIB3J085), more than 150 alien marine species have been identified (http://bioinvasion.fio.org.cn), including more than 20 species of seashell, 20 species of algae, 3 species of halophyte, 8 species of shrimp, and more than 60 species of fish. The rate of initiative introduction of marine alien species is accelerating in recent years without elaborate ecological and

economic cost-benefit assessment; these exotic species have brought to bear certain impacts to native diversity on a local scale, as well as contributing to the regional "homogenization" of marine biodiversity. Some negative impacts are even threatening human health and have negative economic impacts to the local fisheries, aquaculture, tourism and marine infrastructure. Alien species compete with local species, which may result in destruction of the ecological balance in the local niche. Second, exotic species can bring about genetic pollution through their hybridization with local species. Thirdly, pathogenic organism may be imported and imperil local species. Fourthly, many species of harmful alga bloom are believed to have been introduced by ship ballast water and are considered to be responsible for ecological disaster. The main noxious marine alien species in China are *Spartina anglica*, *Spartina alterniflora*, *Mgtilopsis sallei*, *Strongylocentrotus intermedius*, *Sciaemops ocellatus*, *Desmarestia ligulata*, *Taura syndrome* virus and so on. A management system is required to assess the different risks of marine alien species invasion, and then determine appropriate legislation and law enforcement actions. The design of policy should emphasize the following six points in the generic process of this issue: prevention, detection, quarantine, eradication, control and mitigation. Before an alien species is introduced, it is necessary to determine the risk of introduction, establishment and spread of marine species in the particular regions, and their potential impacts on the ecosystem, human health and economic activities. Successful mitigation and management of these threats by marine invasive species will be possible only if handled at a global and regional level. More and more attention is being paid to the marine alien species invasion in China. Research has been undergoing and several statutes on introduction of alien species have been enacting.

PICES XV S8-2791 Oral
Eco-friendly shrimp culture with Pokkalli paddy – Sustainable coastal resource management practice

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The market for organic products has expanded rapidly in recent years with organically farmed aquatic products earning premium prices over conventional products. One of the most eco-friendly of all farming practices is the Pokkalli paddy cultivation–cum- shrimp culture of south West Indian coast that relies on the symbiotic nature of shrimp and this paddy. The Pokkalli paddy is a saline, flood and acid resistant, wonder crop cultivated in marshy waterlogged coastal regions. The Pokkalli cultivation is less expensive due to low incidence of diseases in high saline environment. Farmers seem to be disinterested in cultivating Pokkalli as the market is not good for Pokkalli due to the lack of awareness by people that it is eco-friendly and organically grown. It is high time for socially and health conscious people to propagate the use of organic paddy and to encourage this farming practice to other wetland regions. This farming, a community-based coastal resource management, which is indeed healthier and sensible money wise, needs to be encouraged to protect the coastal wetlands. This alternative income-generating program contributes towards the improvement of the coastal environment and conserves the biodiversity of the ecosystem. These systems are less well placed to accommodate any unprecedented changes in climate and related environmental conditions that are anticipated to occur during the remainder of the current century. Failure to adapt to climate change now could lead to high social and economic costs in the future.

PICES XV S8-2831 Oral
A study on the ecosystem-based resource management system of self-regulatory community fisheries in Korea

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A self-regulatory community fisheries management program in Korea is designed to enhance fisheries resources, to protect fishing grounds of self-regulatory communities, and to manage their fisheries resources by their own regulations and knowledge. This study analyzed the status of present stock management systems of self-regulatory community fisheries, and explored the applicable ecosystem-based management plan based on scientific investigation and analysis. This study suggested objectives, indicators and reference points for an ecosystem-based resource management system which is applicable to self-regulatory community fisheries. The

objectives of the management system are to maintain sustainable fisheries production, to maintain optimum fishing intensity, to reduce by-catch, to conserve spawning ground and habitat, to maintain optimum habitat environment, to increase/maintain abundance of prey species, to increase/maintain stock biomass, and to conduct stock enhancement on the basis of scientific assessment. The improved methods for the assessment and management are introduced by demonstrating a self-regulatory fishery which targets on hen clam in Dong-ri fishing village in Busan. Finally, we developed a user-friendly computer program which could be used for fishermen to interactively conduct a simple stock assessment of target species when information and data on the fishery and the stock are limited.

PICES XV S8-2859 Poster
Growth and survival of the sulf clam, *Tresus keenae* larvae, according to rearing condition in Korea

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The sulf clam, *Tresus keenae*, is distributed only in Korea and Japan. In Korea, it is an endemic species of the southern coast of the Korean peninsula. Recently, the natural resource quantity of *T. keenae* decreased further due to overfishing and habitat destruction. As a result, this study was conducted to help establish artificial seedling production technology of *T. keenae*. This study investigated the optimum conditions for larvae culture. According to the results of larva rearing experiments to determine optimal water temperature, the highest survival rate of 37.5% was found at 20°C. In the experimental group reared at 25°C, the final length was 268.8 μm, showing the highest growth. For salinity, the highest growth rate was seen at 30 psu. with a final length of 213.3 μm. The highest survival rate of 52.9% was found in the natural sea water experimental group. For rearing density, the experimental group with 1 inds./ml showed the highest growth and survival rates of 257.0 μm and 70.0%, respectively. The experiment groups with 8 individuals or more showed decreased growth and survival rates. For feeding level, the highest growth with a length of 225.0 μm was found in the experimental group with 10.0×10^4cells/ml. The highest survival rate of 57.1 % was shown in the experimental group with 1.0×10^4cells/ml. But the experimental group with 20.0×10^4cells/ml showed poor growth and survival rates.

PICES XV S8-2922 Oral
Alien polychaete worms (Annelida, Polychaeta) in the North Pacific

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Lists of species of marine invertebrates introduced through human activity all over the world usually include polychaete worms (Annelida, Polychaeta). Polychaetes are frequently dispersed outward from their native regions by means of the commercial oyster industry, aquaculture in general, ballast water and hull fouling of ocean-going vessels. Attention is drawn to the fact that increasing interest in bioinvasions has been accompanied by decline in studies on the taxonomy of marine invertebrates, including polychaetes. Faunas of native polychaete species are poorly known for many Pacific countries, creating problems in recognizing alien species. This study summarizes the situation for polychaete bioinvasions in the North Pacific and provides ideas on its management.

PICES XV S8-3038 Invited
AquaModel: Mariculture model development and testing

J.E. Jack **Rensel**[1], Dale A. Kiefer[2] and Frank J. O'Brien[3]

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[3] System Science Applications, U.S.A.

Numerical models are increasingly important for planning and permitting of marine fish farms. Models range from simple one-box simulations to complex mainframe-oceanic models potentially capable of managing entire coastal systems. We have developed a GIS-based simulation model to visualize and quantify temporal and spatial effects of fish farms. AquaModel was designed for administrators, who establish regulations, for operators, who wish to plan farms and obtain permits and for investors, who wish to assess risks and opportunities. The model provides a real-time, three-dimensional simulation of the growth and metabolic activity of penned fish as well as the associated flow and transformation of nutrients, oxygen, and particulate wastes in adjacent waters and sediments. The farm model resides within the EASy Marine Geographic Information System (www.runeasy.com), and thus all environmental information from field measurements to satellite imagery are readily available for model development and use. AquaModel consists of a description of advective and turbulent flow, a PZN description of plankton dynamics, a carbon-based description of fish growth and metabolism within the farm, and description of benthic sedimentation distribution and resuspension. AquaModel has been applied to salmon (*Salmo salar*) and cobia (*Rachycentron canadum*) farms. AquaModel is relatively easy to operate, but the integrated GIS system allows the user to expand into complex analyses. Future directions include adaptation of AquaModel for integrated aquaculture and expansion into a real time farm operation tool through the use of feedback sensors or probes to optimize fish farm operations.

PICES XV S8-3044 Oral
Risk and risk management for feed and seed for carnivorous marine fish aquaculture

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The provision of feed and seed for marine fish aquaculture often occurs external to the actual fish culture operation. How those external activities are conducted and applied impacts the potential ecological risk for the entire industry. Up stream ecological risks associated with feed and seed from culture of carnivorous marine fish aquaculture include the potential for over-fishing due to demand for wild juveniles for grow-out, and harvesting industrial fisheries for aquafeeds. Downstream ecological risk associated with feed includes organic loading and benthic impacts. Downstream risks associated with seed are associated with the potential ecological and genetic impacts of escapes on conspecific wild stocks if the cultured fish is native or ecological impacts on native species if the escapees are non-native. For each risk, the WHO risk assessment framework may be applied to focus research and development on strategies that could be used to manage or eliminate the risk. I suggest that situations where economic gain and ecological risk reduction are in-line are preferred and have a much higher chance of resulting in meaningful improvements. In both up stream cases, proper fishery management can reduce risk at a low level of demand, however at some higher levels of demand, substitution (*i.e.* hatchery development and alternative feedstuffs) provides a better option. In both later cases, economic gain is in line with ecological risk improvements, making adoption more likely. The development and adoption of formulated feeds over raw fish diets greatly reduces the organic pollution associated with fed fish aquaculture. Further refinements in diet formulation and processing can further reduce the organic loads associated with fed fish aquaculture. Gains in feed technology are also in line with economic gains once a critical level of production is reached. Risk associated with escapes can be managed at the hatchery by either raising fish with the same genetic make-up as wild stocks, or by domestication of the farmed species to reduce escapees' fitness in the wild. In this case, economic gains would favor domestication and not maintaining a wild stock genotype. Governments can create win-win situations by fostering research and development where ecological risk and economic gains are in line and both considered. In the case of feed and seed, this would include development of high quality compound feeds and hatcheries with associated selective breeding programs for new and existing marine fish industries.

PICES XV S8-2852 Oral

Carrying capacity of nursery grounds for Japanese flounder in relation to stocking densities

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Stocking of Japanese flounder, *Paralichthys olivaceus*, has been extensively carried out in Japan. A total of ca 25 million hatchery-raised juveniles are released in Japanese coastal waters each year. The determination of the appropriate stocking density in relation to the carrying capacity of the nursery ground is a key factor affecting maintenance of a healthy marine ecosystem and stock enhancement success. We studied the nursery ground carrying capacity available for released hatchery-raised flounder juveniles. We found the market return rate of released flounder is clearly higher in northeastern areas than in southwestern areas. Also there was a clear tendency of lower wild juvenile flounder density and higher prey abundance in northeastern areas than in southwestern areas. As a result, feeding rates and growth rates were higher in northeastern Japan, resulting in greater productivity of flounder juveniles. Because there was no difference in stocking intensity between southwestern and northeastern areas in Japan, the higher surplus productivity of nurseries for released flounder appears to support higher survival after release leading to a higher return rate in northeastern Japan. We developed a sub-population production model for juvenile flounder with the basis of an ecophysiology model. The model predicted a higher productivity available for released flounder in northeastern Japan supporting the above latitudinal tendency. Effects of stocking of hatchery fish on the wild population can be studied by means of this model.

PICES XV S8-3251 Oral

Ecosystem services valuation of marine aquaculture

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As a main activity along the coasts of the world, marine aquaculture will not only provide seafood to human beings, but also make a contribution to the marine ecosystem services. A valuation study was conducted based on indicators modified from Millennium Ecosystem Assessment in Sanggou Bay, a typical and intensive marine aquaculture area in the Yellow Sea of China. The results show the total value of ecosystem services (VES) in Sanggou Bay is 6.07×10^8 RMB from 2003 to 2004, in which provision services, regulating services, and culture services account for 51.29%, 17.34%, and 31.37% respectively. The average value of marine aquaculture area is 4.24×10^6 RMB/km^2, 1.27 times the global average value in coast ($4052 USD/ha, concluded by Costanza *et al.*, 1997), which means that aquaculture activity could promote ecosystem services. Not including culture services, kelp (*Laminaria japonica*), was the main farming species, contribute the biggest part of ecosystem services (1.78×10^8 RMB), then followed by abalone (*Haliots discus hannai*) and sea cucumber (*Apostichopus japonicus*). However, the phytoplankton in the ecosystem only provides a small portion (8.01×10^6 RMB). These results indicate that farming species and aquaculture activities not only contribute to the local social economic (51.29%), but also contribute to the environmental regulation and social culture (48.71%). The results also suggest that the marine aquaculture activities are important to maintain and promote ecosystem services, especially the macroalgae farming. We should not only focus on the marine aquaculture production, we should also give more consideration to the environmental regulation and social culture services in the management.

S9 MEQ Topic Session
Harmful algal blooms in the PICES region: New trends and potential links with anthropogenic influences

Co-Convenors: William P. Cochlan (U.S.A.) and Ichiro Imai (Japan)

This session will highlight recent advances in the understanding of the ecology and physiology of harmful algal bloom (HAB) species in the coastal waters of the PICES region. Of particular interest will be laboratory and field research where anthropogenic factors have been studied in order to elucidate if links exist between the apparent increase in the duration, distribution and impact of HABs, and environmental factors associated with human activities, including urban and agricultural runoff, climatic change and mariculture. This session will complement the continuing series of annual MEQ workshops where two new HAB genera found in the PICES region are examined in detail, but encourages studies of other HAB genera of interest in the coastal waters of the North Pacific Ocean.

Wednesday, October 18, 2006 09:00-15:30

09:00-09:10 **Introduction by Convenors**

09:10-09:50 **Theodore J. Smayda** (Invited)
Harmful algal blooms: Global spreading or global synchrony? (S9-3180)

09:50-10:10 **Paul J. Harrison, Alvin Ho, Kedong Yin and Xu Jie**
Nutrient and phytoplankton dynamics in Hong Kong and their response to sewage abatement (S9-3035)

10:10-10:30 **Ichiro Imai, Mineo Yamaguchi and Yutaka Hori**
HAB occurrences and eutrophication in the Seto Inland Sea, Japan (S9-3032)

10:30-10:50 ***Tea/Coffee Break***

10:50-11:10 **Tatiana Yu. Orlova and Inna V. Stonik**
Long-term changes in the phytoplankton of the coastal waters off Vladivostok (the north-western part of the Japan/East Sea) (S9-2885)

11:10-11:30 **In-Seong Han, Hee-Dong Jeong and Ki-Tack Seong**
Physical oceanic conditions on summer time related with harmful algal blooms around the Korean Peninsula (S9-2958)

11:30-11:50 **Kanako Naito and Ichiro Imai**
Iron and harmful algal blooms (S9-3066)

11:50-12:10 **Tamiji Yamamoto and Gen Hatta**
Does dam construction induce harmful algal blooms? (S9-2998)

12:10-12:30 **Ken Furuya, Takuo Omura and Thaithaworn Lirdwitayaprasit**
Noctiluca scintillans with endosymbiont, successful red tide species in SE Asian waters (S9-2895)

12:30-14:00 ***Lunch***

14:00-14:30 **Janice E. Lawrence** (Invited)
The role of viruses on harmful algal bloom dynamics (S9-3091)

14:30-14:50 **Keizo Nagasaki, Yuji Tomaru, Hiroyuki Mizumoto, Yoko Shirai and Yoshitake Takao**
Viral impact on the population dynamics of HABs (S9-2950)

14:50-15:30 **Discussion and Summary**

Posters

Seung Ho Baek, Shinji Shimode and Tomohiko Kikuchi
The role of temperature, salinity, light intensity and photoperiod for dinoflagellates, *Ceratium furca* and *Ceratium fusus*, in the temperature coastal water of Sagami Bay, Japan (S9-2846)

Boris M. Borisov
Basic factors determinative phytoplankton bloom in the western subarctic Pacific and the adjacent deep area of the Bering Sea in spring of 2005 (S9-2798)

Lalit P. Chaudhari, A.G. Bhole, S.P. Yavalkar and N.K. Choudhary
Application of biotechnology for monitoring harmful algae in marine food resources (S9-2777)

Maureen E. Auro, William P. Cochlan and Vera L. Trainer
Growth and toxicity of *Pseudo-nitzschia cuspidata* from the U.S. Pacific Northwest (S9-3198)

Tomotaka Shiraishi, Kiyohito Nagai, Jyoji Go, Takashi Yamamoto, Michinori Yamakawa, Misa Inoue, Isao Kuriyama, Seiya Taino, Tetsu Ishikawa, Yoshihiro Hayashi, Shingo Hiroishi and Ichiro Imai
Population dynamics and overwintering of the shellfish killing dinoflagellate *Heterocapsa circularisquama* in the western coastal Sea of Japan (S9-3182)

Wataru Takahashi, Hiroshi Kawamura, Takuo Omura and Ken Furuya
Detecting red tides in the eastern Seto Inland Sea with satellite ocean color imagery (S9-2864)

PICES XV S9-2846 Poster

The role of temperature, salinity, light intensity and photoperiod for dinoflagellates, *Ceratium furca* and *Ceratium fusus*, in the temperature coastal water of Sagami Bay, Japan

Seung Ho **Baek**, Shinji Shimode and Tomohiko Kikuchi

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Seasonal changes of field populations and growth rates of two dinoflagellates, *Ceratium furca* and *Ceratium fusus*, were examined in the temperate coastal waters of Sagami Bay, Japan. Weekly field sampling was conducted from August 2002 to August 2003, and laboratory experiments carried out to investigate the effects of temperature, irradiance and photoperiod on the growth rates of the two species. In the field, both species increased significantly in abundance from April to August, and gradually decreased from November 2002 to January 2003. In February 2003, *C. fusus* increased its population even at lower temperatures (ca. 13ºC). In the laboratory, the two species did not grow at temperatures < 10ºC or > 32ºC. The highest specific growth rate of *C. furca* was 0.72 d^{-1} at 24ºC and 600 µmol $m^{-2}s^{-1}$. Optimum growth rates (> 0.4 d^{-1}) of *C. furca* were observed at temperatures from 18 to 28ºC and at irradiances from 216 to 796 µmol $m^{-2}s^{-1}$. On the other hand, the highest growth rate of *C. fusus* was 0.56 d^{-1} at 26ºC and 216 µmol $m^{-2}s^{-1}$. Optimum growth rates of *C. fusus* were observed at the same irradiance rage of *C. furca*, whereas its temperature range was narrower (26 to 28ºC). Growth curves of both species indicated saturation of growth rates above irradiance of 216 µmol $m^{-2}s^{-1}$, but no photoinhibition was also observed up to 796 µmol $m^{-2}s^{-1}$. Moreover, the specific growth rates of both *Ceratium* species were clearly decreased at L: D = 10:14, compared to those at L: D = 14:10 and L: D = 12:12. The present study clearly indicates that the two *Ceratium* species adapt to a wide-range of temperature and irradiance, implying that their adaptations make them one of the dominant species and allow their sustainance beyond normal growth seasons in the temperate waters in the world ocean.

PICES XV S9-2798 Poster

Basic factors determinative phytoplankton bloom in the western subarctic Pacific and the adjacent deep area of the Bering Sea in spring of 2005

Boris M. **Borisov**

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In spring of 2005, a plankton survey was carried out in the western subarctic Pacific Ocean and in the adjacent deep area of the Bering Sea. During the survey, an intense algal bloom occurred in the study area; the highest biomass of net-collected phytoplankton at the upper 50m layer was 2900mg m^{-3}. Mesozooplankton samples were represented mainly by fragments of large body-size species - salps and heteropods, typical inhabitants of the south boundary of the Western Subarctic Gyre. The composition of the remainder of zooplankton samples included typical warm water species: *Pleuromamma gracilis, P. abdominalis, Tessarobrachion oculatum*, and spawning stage of *Euphausia pacifica.* The species composition of mesozooplankton at the study area during the spring of 2005 suggests that the water supporting the intense algal bloom was observed penetrated from Western Subarctic Gyre. It is possible that during this time, the large amount of dead salps and heteropods provided a strong input of nutrients to the euphotic zone, which resulted in the observed algal bloom in the study area, although such a phenomena has not been detected previously in this area.

PICES XV S9-2777 Poster

Application of biotechnology for monitoring harmful algae in marine food resources

Lalit P. **Chaudhari**, A.G. Bhole, S.P. Yavalkar and N.K. Choudhary

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Phytoplankton blooms, micro-algal blooms, toxic algae, red tides, and harmful algae, are all terms for naturally occurring phenomena. About 300 hundred species of micro-algae are reported at times to form mass occurrences, these so called blooms. Nearly one fourth of these species are known to produce toxins. Harmful

algae and their toxins pose a growing global problem for human health, aquaculture, fisheries, seafood trade, tourism and recreation, and the aquatic environment at a time when human reliance on coastal zones for food, recreation and commerce is also expanding. In developing countries, seafood often constitutes an important or even the sole source of food and protein, especially in coastal areas. With the increasing problems of over fishing, aquaculture may become an increasingly important alternative for the supply of seafood. However, to minimize the risk of sea-food poisonings and the risk of major economic losses due to fish kills, it is important to establish adequate surveillance programmes, and to control the quality of the seafood products; this will often require expert assistance from countries which have longstanding experience in biotechnological applications in the marine sector. This study focuses on development of the plan for monitoring and management of harmful algal blooms in coastal waters for aquaculture using biotechnology from experiences in India. The study also evaluates taxonomy and biogeography of harmful algae for increasing aquaculture productivity. This study signifies that the application of biotechnologies is essential for aquatic food production with special focus on eco-physiology, biochemical and pharmacological aspects of algal toxins.

PICES XV S9-3198 Poster
Growth and toxicity of *Pseudo-nitzschia cuspidata* from the U.S. Pacific Northwest

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The toxigenic diatom, *Pseudo-nitzschia cuspidata*, is commonly found in the Juan de Fuca Eddy region of the U.S. Pacific Northwest. Isolates collected during Fall surveys of the ECOHAB-PNW project during 2004 and 2005 were examined in non-axenic, semi-continuous, batch cultures enriched with either 40 μM nitrate, 40 μM ammonium or 20 μM urea as the sole nitrogen source. Experiments conducted at high (120 $\mu E \cdot m^{-2} \cdot s^{-1}$) and low (40 $\mu E \cdot m^{-2} \cdot s^{-1}$) photosynthetic photon flux densities (PPFDs), demonstrate that *P. cuspidata* grew significantly faster at high PPFD, but showed no preference for one nitrogen source over the other. However at low PPFD, cells maintained on urea grew faster than those on either nitrate or ammonium. Exponential growth rates (determined using cell abundance over time) and particulate domoic acid (using ELISA) did not significantly differ as a function of the nitrogen growth substrate. In contrast to other *Pseudo-nitzschia* species where DA is generally enhanced during stationary phase, the particulate DA per cell for *P. cuspidata* averaged 51% greater during exponential growth on nitrate compared to stationary growth, regardless of PPFD. Growth on urea at low light showed a similar reduction in particulate DA during stationary phase. These results demonstrate the capability of this diatom to grow and produce DA on both oxidized and reduced N substrates. Our field observations have generally found greatest *P. cuspidata* abundances in the nitrate-rich, upwelled waters of the Juan de Fuca Eddy, whereas elevated urea concentrations have not been observed in this and adjacent coastal regions.

PICES XV S9-2895 Oral
Noctiluca scintillans with endosymbiont, successful red tide species in SE Asian waters

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Noctiluca scintillans containing the photosynthetic endosymbiont, *Pedinomonas noctilucae*, is the most frequent causative organism of red tides in Southeast Asian waters. Clonal cultures of *N. scintillans* isolated from Thailand and Philippine waters were of two types: one requiring an external food supply and the other not requiring an external food supply. The latter grew photoautotrophically for generations, but they also fed on foods. The *P-E* relationship was characterized by low light intensity of saturation and either absence or weak photoinhibition, showing efficient utilization of light. Thus, *P. noctilucae* assures a supply of organic matter to the host, and facilitates survival of *N. scintillans* under food limitation. The organism forms perennial red tides in Manila Bay, Philippines, and since 2003 occasionally covering almost the whole area. A field survey was conducted in March 2004, when *N. scintillans* formed red tides in the whole bay with surface chlorophyll-*a* reaching up to 522 $\mu g\ L^{-1}$. This predominance was not explained by growth activity or physical accumulation.

In-situ specific growth rate (0.16 d^{-1}), as determined by cell cycle analysis at a fixed station, was likely too low to account for its dominance in the bay, where potentially fast growing diatoms co-existed. Many cells of *N. scintillans* conducted active grazing, and preferred large particles mainly secondary dominant species. Based on these observations, we postulate a hypothesis that despite the low growth rate the endosymbiont provides competitive advantages for *N. scintillans*, and that once it becomes dominant, its active grazing prevents population growth of co-existing phytoplankton.

PICES XV S9-2958 Oral
Physical oceanic conditions on summer time related with harmful algal blooms around the Korean Peninsula

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Outbreaks of harmful algal blooms (HABs) have frequently occurred in the Korean waters, and have caused economic losses in the coastal breeding grounds. These annual outbreaks were usually accompanied by distinct physical, biological and environmental conditions in Korean waters. From the results of spatial scale, maximum density and duration, relatively large-scale outbreaks of HABs appeared in 1995, 1997, 1999, 2001, 2002 and 2003. To clarify the relationship between these HAB outbreaks and physical oceanic environmental factors, we examined the horizontal and vertical distribution of temperature, coastal temperature variation, behavior of low saline water, magnitude of Kuroshio volume transport at upstream areas and related factors. Relatively lower coastal temperature in August around the South Sea correspond with the outbreak of HABs. To clarify the relationship between HAB outbreaks and stratification around the South Sea, we also examined the temperature profiles in this region. Weaken stratification usually corresponded with HAB outbreaks. We also considered that relatively weaken stratification plays an important role in nutrient supply from lower layers. Moreover, we found that the relationship between the behavior of low saline water originated from Changjian, larger Kuroshio volume transported upstream and HAB outbreaks. There are surely some exceptions to this finding because HAB outbreaks have complex causes including biological, environmental and physical factors. To gain a better undertstanding of such HAB outbreaks, physical oceanographic factors must be included in HAB research.

PICES XV S9-3035 Oral
Nutrient and phytoplankton dynamics in Hong Kong and their response to sewage abatement

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The Hong Kong government has a 15-year time series of ambient nutrients and phytoplankton dynamics in Victoria Harbor and its vicinity. Ammonium and phosphate are good indicators of sewage inputs where screened, untreated sewage was discharged into the harbor until 2001. Total inorganic nitrogen, nitrate and chlorophyll have been increasing and dissolved oxygen has decreased during this 15-year period. The phytoplankton biomass was usually dominated by fast growing centric diatoms and chlorophyll ranged from 5 to 20 ug/L. During the last four years, 70% of the sewage is now receiving primary treatment at a sewage treatment plant located several kilometers away. We have been following the recovery in Victoria Harbor with a focus on nutrients, dissolved oxygen, chlorophyll and phytoplankton dynamics. Ammonium, phosphate and total inorganic nitrogen concentrations have declined since sewage treatment has begun. However, increasing Chl-*a* and decreasing dissolved oxygen in the bottom waters near the new sewage treatment plant indicates that the potential eutrophication problem may have been moved from the harbor to the vicinity of the sewage treatment plant.

PICES XV S9-3032 Oral
HAB occurrences and eutrophication in the Seto Inland Sea, Japan

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The Seto Inland Sea is the largest enclosed coastal sea in Japan and is also a major fishing ground including aquacultural farms of fish, bivalves and seaweeds. Incidents of red tides had dramatically increased in frequency and scale in the Seto Inland Sea along with serious eutrophication in 1960s and 1970s. The maximum annual incidents of 299 was recorded in 1976, and these incidents showed a clear decreasing trend reaching about 100 per year in late 1980s due to new regulations; this level has been subsequently kept with the level of nutrients supporting red tide occurrences. The "Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea" was legislated in 1973 and industrial loading was decreased to half of the level of 1972. The important red tide organisms causing huge fishery damages by fish-kill are *Chattonella antiqua*, *C. marina*, *C. ovata* and *Heterosigma akashiwo* (Raphidophyceae) and *Karenia mikimotoi* and *Cochlodinium polykrikoides* (Dinophyceae). The maximum fishery damage (death of 14.2 million yellowtails) was 7.1 billion yen (about $60 million US) caused by *C. antiqua* in Harima-Nada in 1972. In 1988, a novel red tide dinoflagellate species *Heterocapsa circularisquama* appeared for the first time, and has recurrently killed both free-living and farmed bivalves, with the highest damage of 3.9 billion yen attributed to cultured oysters in Hiroshima Bay in 1998. Among the important red tide organisms, *C. antiqua*, *H. circularisquama* and *C. polykrikoides* are rated to be extremely harmful species that can easily reach the warning level of fishery damages by consuming only small amounts of nutrients. In toxic blooms, the dinoflagellate *Alexandrium tamarense* has become dominant in the Seto Inland Sea in the spring season, and has made short-necked clams and cultured oysters toxic almost every year. The existence of abundant cysts of *Alexandrium* spp. in sediments indicates the establishment of this toxic species in the Seto Inland Sea.

PICES XV S9-3091 Invited
The role of viruses on harmful algal bloom dynamics

Janice E. **Lawrence**

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Viral infection has only recently been appreciated for its role in influencing the population dynamics of phytoplankton. It is now recognized that infections become especially important during bloom conditions since the rate of infection is dependent on the density of host cells. *Heterosigma akashiwo* is a harmful algal bloom-forming species against which numerous distinct viruses have been isolated. These lytic HaVs are unevenly distributed throughout marine ecosystems and therefore impose dynamic controls on host abundance, and spatial and temporal distribution. High abundances of HaVs are found in coastal sediments; evidence suggests they accumulate in the benthos via sinking, infected cells. The presence of infectious viruses in coastal sediments has several implications on past, present and future harmful algal blooms, all of which will be discussed. Each type of HaV is distinct with respect to lytic cycle length, host range and burst size. These infection characteristics interact with the physiology and ecology of the host alga to influence the rate of propagation of infection throughout a bloom. The result is a complex, dynamic role of viruses in shaping the formation, demise, and genetic compositions of harmful algal blooms. Isolating and characterizing more novel algal viruses is important for further developing our understanding of algal-virus interactions, and therefore phytoplankton population dynamics.

PICES XV S9-2950 Oral
Viral impact on the population dynamics of HABs

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Recently, viral infection is regarded as one of the most important factors controlling the population dynamics of phytoplankton. To scrutinize the ecological relationship between the bloom-forming dinoflagellate *Heterocapsa circularisquama* and its infectious viruses, we conducted field surveys in western Japan. About 88% of *H. circularisquama* cells harbored small virus-like particles at the peak of the bloom in summer 2001; then, it was followed by a sudden bloom termination. Further, occurrence of *H. circularisquama* blooms was accompanied with specific increases in abundance of its infectious viral agents. By northern dot-blot analysis, ~96% of the clonal viral agents isolated through the surveys positively reacted with a molecular probe specific to HcRNAV (*H. circularisquama* RNA virus); hence, viral impacts observed in these field surveys were considered to be largely due to HcRNAV infection. HcRNAV comprises two ecotypes having complementary intraspecies host ranges to each other (type UA and CY); they showed different dynamics presumably reflecting the fluctuation patterns of their suitable host ecotypes *in situ*. Recent studies revealed the intraspecies host specificity of HcRNAV is determined by the upstream events including specific binding of virus particle to host cell surface receptor. Another point of interest is that the amount of HcRNAV accumulated in the sediment just prior to the host's blooming season may be a significant factor in determining the size or term length of *H. circularisquama* blooms. Thus, HcRNAV infection is assumed to be one of the remarkable factors affecting the population dynamics of *H. circularisquama*; both its biomass and clonal composition.

PICES XV S9-3066 Oral
Iron and harmful algal blooms

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Iron is an essential element for the biochemical and physiological functioning of microalgae. However, the mechanism of iron uptake by eukaryotic microalgae is not yet fully understood because of the intricate iron chemistry of natural seawater and the difficulty in cultivation of axenic microalgae under uncontamination. Dissolved iron fractions consist largely of colloidal hydrolysis species and most of those are bound by organic ligands in natural waters. As a result of above-mentioned iron speciation, the concentrations of directly bioavailable iron species are extremely low in natural waters. The growths of the principal species of red tide microalgae including the harmful algal species were examined using a newly developed artificial synthetic medium in the presence of different iron species. The present study demonstrated that particulate $FePO_4$ and FeS were bioavailable for the growth of the dinoflagellates *Heterocapsa circularisquama* and *Karenia mikimotoi*, and the cryptophyte *Rhodomonas ovalis*. And the differences in concentration of organic ligands in each medium caused the changes of the growth (maximal growth yield and specific growth rate) of red tide microalgae examined. Furthermore, it is confirmed by Chrome azurol S assay that 14 species of red tide microalgae produced strong iron-binding ligands like siderophores (> 0.1 μM), at the early stationary growth phase under iron-limiting conditions. These results suggest that the iron speciation may be an important role in controlling the harmful algal bloom formation in coastal water. We here suggest that red tide microalgae have specific strategies to utilize iron under dissolved inorganic iron limitation.

PICES XV S9-2885 Oral

Long-term changes in the phytoplankton of the coastal waters off Vladivostok (the north-western part of the Japan/East Sea)

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The qualitative and quantitative compositions of phytoplankton, as well as analysis of the blooms caused by mass development of potentially toxic algae, have been carried out in the coastal waters off Vladivostok. This area is exposed to continuous anthropogenic influence due to input urban and agricultural runoff. The following trends in the composition and distribution of the phytoplankton were revealed: the total density and biomass increased; the density of diatom *Skeletonema costatum* increased, leading to a decrease in microalgae species diversity; the density of the non-diatom component of the phytoplankton increased. Twelve species causing red tides were observed; these species belong to four taxonomic groups of phytoplankton: dinoflagellates, diatoms, raphidophytes and euglenophytes. A total twenty-three red tide events were observed during the study period. Dinoflagellates were the most common bloom-forming algae, and caused more than half of the total red-tide events. *Noctiluca scintillans* has caused most of the visible red tides. Obtained data indicate that in the past two decades there has been an apparent increase in the frequency, intensity and duration of microalgal blooms in the coastal waters off Vladivostok. The algae that cause the most concern are the genera *Pseudo-nitzschia, Dinophysis, Prorocentrum* and *Heterosigma*, known for their toxicity and ability to cause harmful algal blooms.

PICES XV S9-3182 Poster

Population dynamics and overwintering of the shellfish killing dinoflagellate *Heterocapsa circularisquama* in the western coastal Sea of Japan

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In Japanese western coastal waters, *Heterocapsa circularisquama* is the most noxious dinoflagellate to shellfish aquaculture due to its formation of red tides and the accompanying mass mortalities of both natural and cultured bivalves such as oysters, short-necked clams, mussels and pearl oysters. In order to reduce the negative impacts by *H. circularisquama*, it is important to comprehend its population dynamics. Sensitive monitoring is presented here by employing the indirect fluorescent antibody technique using monoclonal antibody, and overwintering was investigated in southwestern waters. Samplings were made several times per month in Ago Bay, Mie, Japan from April 2001 to December 2005, once a month in two bays of Mie, from August 2003 to December 2005, and several times a month in Uranouchi Inlet, Kochi, Japan, from February 2004 to July 2006. Vegetative cells of *H. circularisquama* were generally detected from late spring to late autumn, and the cell density increased (maximum 2.33×10^6 cells l^{-1}) during summer in three bays of Mie. It is confirmed that *H. circularisquama* causes red tides in summer in western coast of Japan. Vegetative cells were not detected every year from winter to early spring. However in Uranouchi Inlet, Kochi, vegetative cells have been detected throughout the year. These detected cells were regarded to be overwintering and/or overwintered cells. Furthermore, the cultured strains isolated from Uranouchi Inlet in March 2004 were identified as *H. circularisquama*. These results indicate that *H. circularisquama* can overwinter in the stage of vegetative cell in warmer areas such as Uranouchi Inlet in Japan.

PICES XV S9-3180 Invited
Harmful algal blooms: Global spreading or global synchrony?

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A harmful algal bloom (HAB) epidemic is in progress in global coastal waters and inland seas characterized by remarkable and unusual parallel events relative to the historical record. Collectively, the patterns and impacts of this phenomenon suggest that a major change in phytoplankton bloom dynamics, flagellate species in particular, is occurring that may be symptomatic of an emergent and widespread disequilibrium in phytoplankton dynamics in the sea. Four theories have been proposed to explain the HAB epidemic, three of which deal with anthropogenic habitat modification - the 'changing environment' theories - while the fourth - the 'emigration' theory - attributes the HAB increase to the geographic dispersal of HAB species vectored in ballast water and shellfish transplantation. The nutrient stimulus theory posits that the increased frequency in HABs is being stimulated by anthropogenic nutrient enrichment of coastal waters, including changes in nutrient ratios which influence species selection. Harmful blooms at aquacultural and fish-farming sites, often resulting in severe financial loss, have been attributed to waste-nutrient excretions. Climate change by altering climatology and driving physical habitat modifications that favor HABs has also been invoked. The merits of the 'emigration' and 'changing environment' stimulation theories will be evaluated applying a comparative ecosystem analysis in combination with ecophysiological assessments of representative bloom-species. The question underlying the analysis will be whether the HAB epidemic is primarily the coincidence of isolated, regional blooms developing in response to different local causes, or whether there is a more profound global synchrony in this phenomenon.

PICES XV S9-2864 Poster
Detecting red tides in the eastern Seto Inland Sea with satellite ocean color imagery

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A multi-spectral classification scheme is proposed to identify areas with red tides through the satellite ocean color imagery by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). The eastern Seto Inland Sea, where serious red tides frequently occur in Japan, was studied. Colors of the water around a red tide or those of water before/after a red tide are referred to as "background ocean colors (BOCs)", and BOCs are estimated as the monthly mean of normalized water-leaving radiances (nLw) with 0.01 degree spatial resolution with SeaWiFS imagery. Criteria for detection of red-tide pixels are established from analyses of the characteristics of nLw (at 443, 490, 510, and 555nm) anomalies from BOCs and the nLw spectra together with the red-tide records in Osaka Bay. The criteria developed from the SeaWiFS data appear to be robust; the SeaWiFS data used for the criteria indicated 81% of water with a red tide, and 95% of water without it. Probability of red-tide detection is high in eastern Osaka Bay and in the coastal waters of the northern Harima Nada. In the innermost part of Osaka Bay, monthly probability of red-tide detection (MPRD) does not go below 20% in any month. On the other hand, in Harima Nada, MPRD is almost zero from November to April. These distribution patterns of identified red tides in time and space are well supported by previous biogeographic investigations. The results suggest that the scheme is appropriate to detect red tides for optically complex coastal water of the eastern Seto Inland Sea.

PICES XV S9-2998 Oral

Does dam construction induce harmful algal blooms?

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A numerical model was constructed to elucidate whether flattening of river discharge and trapping of silica by dam construction could induce harmful algal blooms. Two harmful algal bloom species, the paralytic shellfish poisoning dinoflagellate *Gymnodinium catenatum* and the fish-killing raphidophyte *Chattonella antiqua* were used as representatives of harmful algae, and a diatom *Skeletonema costatum* was used as a norm. *G. catenatum* showed the maximum cell yield in continuous nutrient supply mode and *C. antiqua* also showed less response to pulsed discharge mode, while *S. costatum* showed the maximum cell yield in pulsed discharge mode with large fluctuations. In simulations of mixed-species, a pulsed nutrient supply with an intermediate frequency interval led to a longer period of coexistence than continuous nutrient supply, showing consistency with the Intermediate Disturbance Hypothesis. Reduction of silicate supply depressed the *S. costatum* cell density and made the coexistence period of these three species much longer. These model calculations imply that flattening of river discharge and trapping silica by dam construction may induce harmful algal blooms. In other words, temporal heterogeneity in estuaries could be a factor maintaining phytoplankton species diversity.

S10 POC/MONITOR/CCCC Topic Session
Synchronous and asynchronous responses of North Pacific boundary current systems to climate variability

Co-Convenors: Jack Barth, Steven Bograd (U.S.A.), Shin-ichi Ito, Kosei Komatsu (Japan) and Vyacheslav B. Lobanov (Russia)

A number of hypotheses have attempted to explain the synchronous low-frequency fluctuations in sardine populations off California and Japan. One hypothesis proposes that since the Kuroshio Current (subtropical western boundary current) and California Current (subtropical eastern boundary current) are driven mainly by wind stress, their variability should be closely related through basin-scale atmospheric teleconnections. However, basin-scale climate signals may be modulated by regional meso-scale processes, and both systems are impacted by a range of variability from decadal (*e.g.*, regime shifts), to interannual (*e.g.*, ENSO), to seasonal and shorter time scales. This variable forcing may lead to divergent and asynchronous ecosystem responses. This session will provide a comparative review of the physical and ecosystem variability of the boundary currents, discuss the degree of synchronicity of this variability, and facilitate understanding of the connectivity between North Pacific boundary current systems. A more comprehensive understanding of the boundary current systems requires modeling approaches, although the data for model validation is often limited. This session will also provide consideration of observing system requirements and techniques for monitoring boundary current circulation and ecosystems, in particular the necessary combination of data and models.

Friday, October 20, 2006 09:00-17:30

09:00-09:05 **Introduction by Convenors**

09:05-09:35 **Masami Nonaka, Hisashi Nakamura, Youichi Tanimoto, Takashi Kagimoto and Hideharu Sasaki** (Invited)
Interannual-to-decadal variability in the Oyashio Current and its influence on the subarctic frontal region in an eddy-resolving OGCM (S10-2911)

09:35-09:55 **Harold P. Batchelder and Brie J. Lindsey**
Modeling interannual variation of spring-summer transport of plankton and juvenile salmon in coastal regions of the northeast Pacific (S10-3201)

09:55-10:15 **Elena I. Ustinova and Yury D. Sorokin**
Spring thermal conditions in the Northwestern Pacific boundary current systems (S10-2875)

10:15-10:35 **Steven J. Bograd, Roy Mendelssohn, Franklin B. Schwing and Cindy Bessey**
On the (a)synchrony of long-term sea surface temperature trends in the western and eastern North Pacific (S10-3172)

10:35-10:55 ***Tea/Coffee Break***

10:55-11:25 **Andrew Bakun** (Invited)
"Active opportunist" species and opportune multi-annual-scale events (S10-2819)

11:25-11:45 **Hiroshi Ichikawa and Xiao-Hua Zhu**
Relation between the quasi-biennial variations of northeastward volume transport southeast of Okinawa Island and the Aleutian Low Pressure Index (S10-3046)

11:45-12:05 **Shoshiro Minobe**
Anomalous SST warming over Kuroshio-Oyashio Extension from 1999 to 2001 and its possible ocean to atmosphere influence (S10-3154)

12:05-12:25 **George Shevchenko and Valery Chastikov**
The influence of East Sakhalin Current on the South Kuril Region ecosystem (S10-3004)

12:25-14:00 ***Lunch***

14:00-14:30 **Bo Qiu** (Invited)
Decadal variability of the Kuroshio Extension jet, recirculation gyre and mesoscale eddies, and its connection to PDOs (S10-2811)

14:30-14:50 **Shin-ichi Ito, Hiroshi Uchida, Yugo Shimizu and Shigeho Kakehi**
Synchronous and asynchronous variability of the North Pacific western boundary currents: Kuroshio and Oyashio (S10-3078)

14:50-15:10 **David L. Mackas, William T. Peterson, Mark D. Ohman and Bertha E. Lavaniegos**
Zooplankton anomalies in the California Current System before and during the warm ocean conditions of 2005 (S10-3173)

15:10-15:30 **Jin Woo Kim and Im Sang Oh**
A study of the Kuroshio in the South of Japan islands using remote sensing data (S10-3025)

15:30-15:50 ***Tea/Coffee Break***

15:50-16:20 **Igor A. Zhabin** (Invited)
Large-scale and meso-scale variability in the East Kamchatka Current/Oyashio Current region (S10-2952)

16:20-16:40 **William T. Peterson and Robert L. Emmett**
An investigation into time lags between recent high-frequency changes in the PDO and response of various components of the ecosystem in the northern California Current (S10-3096)

16:40-17:00 **Peter W. Lawson, Robert C. Francis, Steven R. Hare, Nathan J. Mantua and Laurie Weitkamp**
Patterns in salmon production in the Northeast Pacific: Inverse production regimes revisited (S10-3061)

17:00-17:20 **Kiyotaka Hidaka and Kaoru Nakata**
Climate effects on interannual variation in winter-spring plankton community in the slope water and Kuroshio (S10-2977)

17:20-17:30 **Summary by Convenors**

Posters

Gennady V. Khen, Elena I. Ustinova and Jury. D. Sorokin
Interannual variation of sea surface temperature in different areas of the northern Pacific (S10-2835)

Victor I. Kuzin, Aleksandr N. Man'ko and Aleksandr D. Nelezin
Diagnosis of the Kuroshio Current on the basis of hydrological measurements during 1980-1990 (S10-3183)

Ryan R. Rykaczewski
Decadal-scale **va**riability in upwelling processes in the California Current Ecosystem and potential biological responses (S10-2897)

PICES XV S10-2819 Invited
"Active opportunist" species and opportune multi-annual-scale events

Andrew **Bakun**

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Widespread multi-annual-scale synchronies in population abundance and/or productivity variations have been apparent in marine ecosystems, most notably in the 1970s to mid-1980s. Some manner of climatic synchronizing agent seems required. Indeed the period from the early 1970s to mid-1980s was a period of particularly steep decadal-scale trends in several important climatic indices. A remarkable aspect is that similar populations have seemed to react in a parallel manner in quite different regional circumstances where the local effects of the large-scale climatic variations should have been distinctly dissimilar. A parsimonious common explanation is sought in the notion of "active-opportunist" species (of which sardine might be a good example), as opposed to what might be termed "obstinate-efficient" species (perhaps well-exemplified by anchovy). Suggested characteristics of an active-opportunist would include a wide-ranging, migratory, "exploratory testing/tracking" mode of operation, a very broad spectrum of acceptable food sizes, *etc.*, that may afford competitive advantages over its "adversary species" during extended periods of disruption and rapid change. It will be argued that periods of steep multi-year change (either in environmental character or in exploitive pressure), such as occurred from the early 1970s through the early 1980s, or low system productivity (*e.g.*, El Niño dominated periods in the eastern or equatorial Pacific) may afford distinct advantages to active-opportunists, allowing them to temporarily break out from normal biological constraints. This set of considerations may be better able than conventional conceptual frameworks to parsimoniously rationalize evident patterns of decadal and multi-decadal ocean-basin-scale population synchrony.

PICES XV S10-3201 Oral
Modeling interannual variation of spring-summer transport of plankton and juvenile salmon in coastal regions of the northeast Pacific

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Plankton, and to a lesser extent, larval and juvenile fish, are subject to alongshore and cross-shore advection by near-surface flows over continental shelves. Near the west coast of North America, the westward flowing North Pacific Current bifurcates into the poleward flowing Alaska Current and the equatorward flowing California Current somewhere near central-southern British Columbia. The position of this bifurcation and the relative strengths of the poleward and equatorward components of the flow are thought to vary through time (interannually). The strengths of these flows are impacted by El Niño and La Niña events, and such variations will likely impact biological populations residing on and adjacent to the continental shelf. Lagrangian modeling is used to examine interannual variability in spring-summer transport from select locations assuming that the particles are passively transported by the flows. Pre- and post-1977 regime shift, El Niño – La Niña, and recent highly variable years 1997-2004 will be emphasized.

PICES XV S10-3172 Oral
On the (a)synchrony of long-term sea surface temperature trends in the western and eastern North Pacific

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We use state-space models to characterize and compare long-term trends in sea surface temperature (SST) within four large marine ecosystems (LMEs) of the North Pacific: the California Current System, the Gulf of Alaska, the Oyashio, and the Kuroshio. Monthly SST data in 1° boxes were obtained from the Hadley Centre for Climate Prediction and Research (1900-1993) and the NOAA-CIRES Climate Diagnostics Center

(1994-2005). Each LME has experienced an overall warming trend of similar magnitude over the past century, with relatively synchronous accelerations and decelerations in the trends. However, we find subregions within each LME in which the long-term warming trend has been enhanced or mitigated on shorter time scales. These signals suggest that local processes (intensity of upwelling, freshwater runoff, strength of boundary currents) are modulating a global signal asynchronously around the North Pacific rim. We speculate on the forcing and biological consequences of these long-term temperature trends.

PICES XV S10-2977 Oral
Climate effects on interannual variation in winter-spring plankton community in the slope water and Kuroshio

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We investigated interannual changes of climatic and biological factors in the slope waters and Kuroshio water off Japan. Wind stress, sea surface temperature, and sea surface chlorophyll concentration were derived from remote sensing or global data sets, and phytoplankton/zooplankton samples collected in field observations in winter-spring of 1990-2004 were analyzed. Phytoplankton blooms were found to occur in late winter to early spring in the area, reaching a peak in March. Some variables showed anomalies during the study period, including weak wind stress in 1990 and 1998, high SST in 1998, and an increase of large copepod biomass in the Kuroshio in 1999 and 2000. In contrast with these anomalies, winter copepod biomass in the slope waters was rather stable compared to that in the Kuroshio. Sea surface chlorophyll concentration fluctuated among years, but the flutuation was largest in late spring. The climate effects on the planktonic community in the area should be most apparent in late spring to early summer, when depletion of surface nutrients occurs. The fluctuation in winter to early spring may be due to another mechanism, *e.g.* fluctuation of the Kuroshio flow path and the consequent fluctuation in the transport of organisms from the slope waters to the Kuroshio.

PICES XV S10-3046 Oral
Relation between the quasi-biennial variations of northeastward volume transport southeast of Okinawa Island and the Aleutian Low Pressure Index

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The relation between the northeastward volume transport (NVT) southeast of Okinawa Island in the upstream region of the Kuroshio south of Japan and the Aleutian Low Pressure Index (ALPI) is examined for better understanding of the role played by NVT in the global climate system. From the 10-day interval time series of NVT from October 1992 to December 2004, the eddy-removed NVT (ER-NVT) is estimated by the third order Butterworth low-pass filer with 300-day period half-power gain, applied once forwards and once backwards, to eliminate phase error. As ALPI is the four-month mean value, the four-month mean of ER-NVT (ER-NVT4) is calculated every month from December 1992 to November 2004. As we are focusing on the quasi-biennial component dominant in the ER-NVT4, the HPALPI and HPER-NVT4 are estimated respectively from ALPI and ER-NVT4 by the third order Butterworth high-pass filter with 60-month period half-power gain. It is found that the HPER-NVT4 in November three years preceding (27-months ahead of the HPALPI) has the most statistically significant positive correlation with the HPALPI. It is also found that the volume transport of the Kuroshio south of Japan changes 16-months ahead of the HPALPI. These results suggest that the variation of Aleutian Low Pressure shorter than 5-year period is caused by the quasi-biennial variation of northward heat transport of the Kuroshio, the western boundary current of the North Pacific Subtropical Gyre.

PICES XV S10-3078 Oral

Synchronous and asynchronous variability of the North Pacific western boundary currents: Kuroshio and Oyashio

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The Oyashio Intensive observation line off Cape Erimo (OICE), set along an altimetry ground track, was used to estimate the Oyashio transport during 1998-2002. Repeated hydrographic observations and several mooring observations have been made along OICE. The geostrophic transport of the Oyashio was compared with sea surface height (SSH) from the satellite altimeter, and an equation to estimate the Oyashio transport from the SSH data was established. The SSH-derived annual mean transport of the Oyashio was estimated as 9.46 Sv. Also the time series of the Oyashio transport revealed the importance of both barotropic and baroclinic responses to the wind stress curl in the North Pacific. On the other hand, a similar type of observation, Affiliated Surveys of the Kuroshio off Cape Ashizuri (ASUKA), had been done to observe the Kuroshio transport during 1993-1995, in advance of the OICE observations. An equation to estimate the Kuroshio absolute transport from SSH data was also established using the ASUKA data. The barotropic components of these two transports should show a synchronous response to the wind stress curl in the North Pacific. However, the latitudinal difference and the baroclinic response caused an asynchronous response between them. The time series of the two transports will be compared in detail.

PICES XV S10-2835 Poster

Interannual variation of sea surface temperature in different areas of the northern Pacific

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The climate of the northern Pacific has changed appreciably during the past 5 decades. These changes have been associated with a deepening of the Aleutian Low, and with warming sea surface temperatures (SST). However, in different areas these interannual changes did not coincide, and in some areas the variations were out of phase. In the subarctic zone, including the Bering and Okhotsk Seas, from 1950 to the mid 1970s SSTs increased, reached maximum values during the 1980s, and have begun to drop since the 1990s. In contrast, SSTs fell from 1950 to the mid 1970s and have trended higher since the 1990s in the subtropic zone. In the transition zones (between 35-50^{o}N), the sea surface has cooled during the past 5 decades. Thus in this domain, interannual variability during the 1950s and 1960s corresponded with the subtropic zone, while variability during the 1990s corresponded to the subarctic zone. A southward widening of the subarctic zone could be reflected in the conditions of salmon feeding areas in the northern Pacific.

PICES XV S10-3025 Oral

A study of the Kuroshio in the South of Japan islands using remote sensing data

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It is well known that the Kuroshio path in the south of Japan Islands shows remarkable features, namely, the large meander (LM) path, off shore non large meander (oNLM) path and near shore non large meander (nNLM) path (Kawabe,1985). Many researches on the Kuroshio path have been done by using Sea Level Data in tidal stations, Sea Surface Height (SSH) in Topex/Poseidon and Simulated Numerical Model Results. For the present study, we analyzed the Kuroshio path and its relationship with SST and Ocean Color using remote sensing data; Sea Surface Temperature (Pathfinder ver 5.0) in 1985~2004, Ocean Color (SeaWIFS) in 1997~2004 and Satellite Tracked Drifter Data (NOAA/AOML) in 1990 ~ 2004. As a result, we could confirm the patterns of LM, oNLM and nNLM and figure out the correlation of SST and Chlorophyll with the Kuroshio path. We found that SST is high and Chlorophyll is low during nNLM period in whole region of the south of Japan

Islands. During LM and oNLM period, SST is lower and Chlorophyll is higher in upper border of the Kuroshio as compared with the mean SST and the mean Chlorophyll in the Kuroshio.

PICES XV S10-3183 Poster
Diagnosis of the Kuroshio Current on the basis of hydrological measurements during 1980-1990

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The main objectives of this paper are to continue the study of the Kuroshio Current behavior south of Japan. The observational data were obtained from 40 oceanographic cruises made by FERHRI vessels during the period 1980-1990. The measurements were interpolated to a regular grid and reached depths of 1500 m. Some of these periods were characterized by the onshore (shelf), non-large meander state, whereas during other periods a typical offshore, large-meander path was formed. The characteristics under analysis include: temperature and salinity distribution, potential vorticity behavior, and the horizontal and vertical velocity components. Reconstruction of 3D velocity fields was done using the P-vector approach. Using the P-vector method for the estimation of the absolute velocity field gives reasonable results, with regular velocity fields in the periods of the shelf or meander modes. The method needs an accurate data analysis to avoid instability of the ill-posed problem. The instability of the P-vector method arises in the winter season, which is associated with the mixed layer forming. To analyze the large meander formation the Q-vector technique was applied to the data.

PICES XV S10-3061 Oral
Patterns in salmon production in the Northeast Pacific: Inverse production regimes revisited

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Through most of the 20th century the North Pacific alternated between persistent warm and cold regimes at a frequency of 20 – 30 years. A warm regime dominated from 1927 – 1946, a cool regime from 1947 – 1976, and a warm regime from 1977 – 1998. Salmon abundance in Alaska and the Pacific Northwest during these regimes varied inversely, with higher abundance in Alaska during warm regimes and higher abundance in the Pacific Northwest and British Columbia during the cold regime – the "inverse production" regime. This pattern was closely related to northeast Pacific sea surface temperatures as indexed by the Pacific Decadal Oscillation. In the decade of the 1990s salmon harvest in Oregon was lowest on record, while Alaska experienced record harvests. For four years starting in 1999 a different pattern emerged, with high salmon abundances throughout the northeast Pacific and a different sea surface temperature signal dubbed the "Victoria Pattern." We reanalyzed patterns in salmon harvest using data through 2000, the most recent year available. From 1990 to 2000 the switching point in the inverse production regime had moved south so that British Columbia stocks were more closely aligned with Alaskan stocks. This could reflect a southward extension of the subarctic ecosystem along the coast, even though sea surface temperatures were warmer throughout the region.

PICES XV S10-3173 Oral

Zooplankton anomalies in the California Current System before and during the warm ocean conditions of 2005

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Zooplankton in the California Current had large anomalies in biomass and composition in 2005. The zone most strongly affected extended from northern California to southern British Columbia. Within this range, zooplankton biomass was low from spring through autumn, community composition showed reduced dominance by "northern" origin taxa, and life cycles of some species shifted earlier in the year. Although similar anomalies have previously been observed coastwide (*i.e.* over the entire California Current system) during strong El Niño events, the 2005 zooplankton anomalies were more localized, initiated by a combination of very warm temperatures (since 2002-2003), weak and late upwelling (spring and early summer 2005), and low phytoplankton productivity (at both time scales). However, the zooplankton anomalies persisted longer: through the remainder of 2005 and into 2006.

PICES XV S10-3154 Oral

Anomalous SST warming over Kuroshio-Oyashio Extension from 1999 to 2001 and its possible ocean to atmosphere influence

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A strong warming event in the Kuroshio/Oyashio extension region from 1999 to 2001 (Minobe 2002, Prog. Oceanogr.) is investigated in more detail, using satellite-derived high resolution datasets for sea-surface temperature (SST), sea-surface height (SSH) and associated geostrophic velocities, along with reanalysis data and satellite winds. AVHRR SST reveals that the SST warming in 1998/99 and cooling in 2001/02 were clearly sandwiched between the Kuroshio and Oyashio extensions over 35-43°N. The warming and subsequent cooling were accompanied by positive and negative anomalous heat fluxes toward the atmosphere, respectively, indicating that the atmosphere-ocean heat flux change was not the cause but probably the result of the SST change. Examination of the geostrophic current field derived from SSH suggests that the meridional migration of the Kuroshio extension, and associated transport changes including the eddy field, may play important roles in SST changes.

QuikSCAT winds, available since July 1999, are used to investigate possible ocean to atmosphere feedback. Wintertime southward wind speeds were stronger for the period of warmer SSTs than for the period of colder SSTs (2002–2004), and the meridional wind speed difference was also sandwiched between the Kuroshio and Oyashio extensions. The meridional wind changes in the NCEP2 reanalysis were limited from the surface to 850 hPa, but vertical wind anomalies, which were mainly due to convergence of the meridional wind anomalies, penetrated to 600 hPa. Therefore, quite strong SST anomalies and accompanying heat flux changes from 1999 to 2001 likely influenced the local atmosphere even above the atmospheric boundary layer.

PICES XV S10-2911 Invited

Interannual-to-decadal variability in the Oyashio Current and its influence on the subarctic frontal region in an eddy-resolving OGCM

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Using output of an eddy-resolving OGCM simulation that well represents the subarctic front (SAF) and the Oyashio Current (OC) in the western North Pacific, we investigate mechanisms for variability in the OC and its influence on the temperature field in the SAF region. Lagged correlation analyses indicate that simultaneous wind forcing in both basin scale and local regions induces variations in the OC via barotropic and baroclinic wave propagations, respectively. Three-year lead wind fields in the western basin can also impact the OC strength. Lagged correlation analyses between the SST field and the OC further indicate that enhancement of the OC is followed by eastward propagation and/or extent of cool anomalies in the SAF region. Sea surface height fields also show a similar eastward propagating signal, suggesting that the anomalies are associated with subsurface layer changes. Indeed, on an isopycnal surface in the lower thermocline, the enhanced OC transports low potential vorticity (PV) water southward to induce low PV anomalies extending eastward, likely by eastward currents in the SAF region. This makes the SAF region move southward slightly, given the meridional gradient of the mean PV field with low PV to the north. Additionally, we examine decadal variability in the boundary currents based on the Pacific Decadal Oscillation index. In the particular OGCM output, the Oyashio and Alaska Currents correlate positively with the index, but the California Current correlates negatively along Baja California. By contrast, correlations with the Kuroshio Extension Current suggest southward migration when the index is positive.

PICES XV S10-3096 Oral

An investigation into time lags between recent high-frequency changes in the PDO and response of various components of the ecosystem in the northern California Current

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Decadal variability in the climate of the North Pacific Ocean, as indexed by the Pacific Decadal Oscillation (PDO), has recently shown high-frequency variability: a 20-year warm phase which ended in 1998 was followed by a 4-year cold phase (1999-2002) and a 4-year warm phase (2003-2006), and now a switch back to cold phase. Shifts to cold (warm) phase in the northern California Current (NCC) resulted in increased (decreased) biomass of zooplankton and baitfish such as osmeriids, anchovies and sardines, dramatic increases (decreases) in survival rates of both coho and Chinook salmon, and increased (decreased) reproductive success of marine birds. This high-frequency climate variability has handed us a grand experiment that allows us determine in what ways and how quickly hydrographic properties, plankton, and fish respond to short term climate variability. We explore the time lags between PDO phase changes and changes in temperature, salinity, the spring transition, zooplankton, baitfish, salmon abundance and species composition in the NCC. We will also briefly review the biological impact of warm ocean conditions in the NCC observed in 2005: zooplankton stocks were reduced by half, baitfish stocks crashed, salmon returns declined, and seabird deaths were extraordinarily high for common murres, cormorants and Cassins' auklet populations. Evidence suggests that the 2005 oceanic warm event was as devastating to the NCC coastal marine ecosystem as the El Niño of 1998.

PICES XV S10-2811 Invited
Decadal variability of the Kuroshio Extension jet, recirculation gyre and mesoscale eddies, and its connection to PDOs

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Long-term sea surface height (SSH) data from multiple satellite altimeters are used to investigate the low-frequency changes and the interconnections of the Kuroshio Extension (KE) jet, its southern recirculation gyre, and their mesoscale eddy field. The dominant signal is characterized by the steady weakening of the KE jet/recirculation gyre from 1993 to 1996, followed by a gradual strengthening in 1997 to 2004, and by the recent weakening after 2005. During the weakening periods of 1993-1996 and 2005-present, the KE path migrated southward in general, and this path migration reversed in direction during the strengthening period of the KE jet in 1997-2004. When the KE jet and recirculation gyre were in a weak mode, the regional eddy kinetic energy level was observed to be higher than when the KE jet and recirculation gyre were in a strong mode.

By hindcasting the SSH signals using linear vorticity dynamics, we found that weakening (strengthening) in the KE jet and recirculation gyre is caused by westward propagation of negative (positive) SSH anomalies generating in the eastern North Pacific and strengthening during their westward propagation. Generations of the SSH anomalies in the eastern North Pacific are forced by wind-stress curl anomalies related to the Pacific decadal oscillations (PDOs).

PICES XV S10-2897 Poster
Decadal-scale variability in upwelling processes in the California Current Ecosystem and potential biological responses

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Upwelling of nutrient-rich deep waters in the California Current Ecosystem (CCE) is the result of two different atmospheric processes: alongshore wind stress and wind-stress curl. A 57-year time series of each upwelling process was created for the Central and Southern California region using a simple model of atmospheric forcing and ocean response. High vertical velocities are typical of coastal upwelling areas and are limited to a narrow region along the coast. Large spatial areas of low velocities are typical of wind-stress curl upwelling. The data show that the strengths of these two upwelling processes are out of phase at decadal and interdecadal time scales. I hypothesize that different ecosystem types result from the two upwelling processes. A pelagic ecosystem with relatively large primary and secondary producers is characteristic of regions with high levels of nutrient supply expected when coastal upwelling is high. Conversely, an ecosystem dominated by smaller organisms is likely when wind-stress curl upwelling is dominant and nutrient supply is low. Chlorophyll and nutrient measurements in the CCE since 1984 show correlation to the magnitude of upwelling in the region, supporting the idea that these winds have a bottom-up effect on production in the ecosystem. The influence of each upwelling process on the production of Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*) is also explored.

PICES XV S10-3004 Oral
The influence of East Sakhalin Current on the South Kuril Region ecosystem

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It is well known that the area of the South Kuril Islands is under the influence of the warm and salty waters of the Soya Warm Current in summer. The influence of the relatively fresh waters of the East Sakhalin Current (ESC) in winter time, however, is not well known. Seasonal changes of water salinity in the area of South Kuril reach 2‰ and more. We found the appearance of these waters (salinity about 32‰) in the Kunashirsky Strait in

the last half of December from CTD surveys. Usually low salinity waters in the southern part of the Okhotsk Sea are formed as a result of sea-ice melting. The origin of low salinity waters in autumn is Amur River discharge. Amur River waters are transported by the ESC along Sakhalin Island during October and November. They reach the South Kuril Islands in December. Thus, we observe the replacement of Soya Warm Current waters by ESC waters in the cold season. This phenomenon may be one of the causes of high productivity in the areas adjacent to the South Kuril Islands.

PICES XV S10-2875 Oral
Spring thermal conditions in the Northwestern Pacific boundary current systems

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It is known that the timing of the spring bloom, dynamics of zooplankton communities, seasonal fish migrations and other features of marine ecosystems are closely connected with variability of spring conditions. In this paper, various spring thermal parameters were analyzed: the timing of initial spring warming, rates of seasonal temperature changes, and SST anomalies in spring and early summer using the ten-day data of water temperature at the coastal meteorological stations and SST data from the Japan Meteorological Agency. A phase shift in the initiation of seasonal warming varied from year to year in the Northwestern Pacific boundary current systems: from 3 ten-day periods in the Subarctic frontal zone to 8 ten-day periods in the region to the east of Kamchatka. In the latter case the strong variability of the terms is connected to a known "double-humped" curve of ice cover seasonal cycle: maximal ice cover of the Bering Sea can be observed both in February and in April. Extremely high rates of spring warming are observed most often after anomalous cold winters. The rate of spring warming slowed down after warm winters with low ice cover from the end of the 1980s until 1997. The rates of warming are characterized by irregularity during spring and early summer. The warming rate is more variable from year-to-year in June. Since 1998, the warming rate from March to June has increased in the area of the Kuril Islands. This phenomenon may be associated with the "1998" regime shift.

PICES XV S10-2952 Invited
Large-scale and meso-scale variability in the East Kamchatka Current/Oyashio Current region

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The East Kamchatka Current (EKC) and Oyashio Current (OC) currents are western boundary currents of the North Pacific Subarctic Gyre. The EKC transports waters from the Bering Sea. Exchange between EKC waters and the Okhotsk Sea form the OC. The OC flows southwestward along the Kuril Islands and Hokkaido. These are among the most productive ecosystems in the world ocean. Data collected during the INPOC project (International North Pacific Ocean Climate Study) show considerable seasonal and year-to year variability in water characteristics in this region. INPOC data analyses also show that mesoscale variability and disturbances are fundamental aspects of EKC and OC variability. One objective of this study is to better understand how mesoscale physical processes force changes in the EKC and OC ecosystem. Satellite altimetry (TOPEX and Jason^{-1}), sea surface temperature (AVHRR and MODIS), and surface chlorophyll (SeaWIFS) data were used to investigate EKC and OC anticyclonic eddies and their influence on the spatial/ temporal variability of biological production in the study area.

CCCC Paper Session

Co-Convenors: Harold P. Batchelder (U.S.A.) and Suam Kim (Korea)

Papers describing patterns and processes of North Pacific ecosystem responses to physical forcing and climate change are invited.

Tuesday, October 17, 2006 14:00-18:00

14:00-14:20 **John A. Holmes and Kenneth D. Cooke**
Changes in the distribution of Pacific hake (*Merluccius productus*) in response to climate and ocean variability in the California Current (CCCC_Paper-2899)

14:20-14:40 **Hyoung-Chul Shin, Kang Hyun Lee, Kyung Ho Chung and Sung-Ho Kang**
Zooplankton distribution off Sakhalin Island during summer and comparison with other sub-arctic waters (CCCC_Paper-2810)

14:40-15:00 **Anne B. Hollowed, Elizabeth Logerwell, Rebecca Isquith and Chris Wilson**
The impact of regime shifts on the oceanography of the northern Gulf of Alaska and its influence on the species interactions between walleye pollock, capelin, and Steller sea lions (CCCC_Paper-3067)

15:00-15:20 **Jeffrey M. Napp, Lawrence E. Schaufler, George L. Hunt Jr. and Kathy L. Mier**
Summer food web structure in the eastern Bering Sea: Fatty acid composition of plankton, fish, and seabirds around the Pribilof Islands (CCCC_Paper-3049)

15:20-15:40 **Elena Dulepova and Svetlana Glebova**
An East-West comparison of plankton communities of the northern Okhotsk Sea (CCCC_Paper-2793)

15:40-16:00 ***Tea/Coffee Break***

16:00-16:20 Muzzneena Ahmad **Mustapha and Sei-Ichi Saitoh**
Interannual variations of sea ice and spring bloom occurrences at the Japanese scallop farming area in the Okhotsk Sea (CCCC_Paper-2869)

16:20-16:40 **Vadim Navrotsky, T. Zadonskaya, V. Darnitsky, V. Chuchukalo, L. Bokhan and V. Napazakov**
Hydrophysical and biological characteristics in the Kuril-Kamchatka Current and Oyashio region of the Northwestern Pacific (CCCC_Paper-3042)

16:40-17:00 **Hyejin Song and Young-shil Kang**
Variations in zooplankton and oceanographic condition in the southwestern East/Japan Sea after the late 1990s (CCCC_Paper-2996)

17:00-17:20 **Takashige Sugimoto, H-Y. Kim, K. Tadokoro, K. Kuroda and N. Nagai**
Stepwise increase of water temperature and zooplankton biomass after the mid-1980s in the East China Sea and their possible effect on the recovery of jack mackerel (CCCC_Paper-3084)

17:20-17:40 **Kyum Joon Park, Chang Ik Zhang, Zang Geun Kim, Seok Gwan Choi and Yong Rock An**
Abundance of finless porpoise (*Neophocaena phocaenoides*) and their role in the eastern Yellow Sea ecosystem (CCCC_Paper-2834)

17:40-18:00 **Andrei Krovnin and G. Moury**
The state of the climate system of the North Pacific and North Atlantic in 2000-2005 in comparison with the 2nd half of the XX century (CCCC_Paper-3166)

Posters

Young Seop Kim, Hyung Kee Cha, Sung Il Lee, Seon Jae Hwang, Sang Cheol Yoon, Kyunk Chan Know and Jae Houng Yang
Application of the ecosystem structure model (Ecopath) to the East/Japan Sea in Korea (CCCC_Paper-2968)

Kosei Komatsu and Akihide Kasai
Modeling annual variation of transport of eggs and larvae of jack mackerel in the East China Sea (CCCC_Paper-3139)

Kosei Komatsu, Kaoru Nakata and Takahiko Kameda
3D modeling of size-dependent variation of phyto- and zooplankton biomass caused by advective processes around the Kuroshio and the Kuroshio Extension (CCCC_Paper-3138)

Carol Ladd
Interannual variability of the Gulf of Alaska eddy field (CCCC_Paper-3040)

Jong Hee Lee and Chang Ik Zhang
Analysis of the lower trophic level of the northern East China Sea ecosystem based on the NEMURO model (CCCC_Paper-2830)

Ken-Ichi Sato, Atsushi Yamaguchi, Naonobu Shiga and Tsutomu Ikeda
Fine-scale vertical habitat separation among four grazing copepods (*Neocalanus cristatus*, *N. flemingeri*, *Eucalanus bungii* and *Metridia pacifica*) in the Oyashio region, western subarctic Pacific Ocean (CCCC_Paper-3075)

Yulia N. Tananaeva and Marat A. Bogdanov
Interannual variability in development of the seasonal processes and their influence on fishery resources of the North Pacific (CCCC_Paper-3152)

PICES XV CCCC_Paper-2793 Oral
An East-West comparison of plankton communities of the northern Okhotsk Sea

Elena **Dulepova** and Svetlana Glebova

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An analysis of zooplankton community structure and it is coupling with ice cover in the northern Okhotsk Sea was carried out for spring periods of 2000-2005. The years 2000 and 2001 may be referred to as "cold" type years, due to the significant extent of ice cover, and 2004 and 2005 can be referred to as "warm" years due to the decreased extent of ice cover area. "Cold" and "warm" years did not differ in zooplankton biomass. However, in the northeast Okhotsk Sea zooplankton abundance increased during "cold" years. This is probably connected with interannual differences in features of synoptic situation. On the other hand, significant differences in species composition and size structure of zooplankton community were noted. The spring period of "cold" years (2000 and 2001) had higher average biomass of small and medium-sized (body sizes less than 3.5 mm) zooplankton fractions, as compared with 2004 and 2005. For instance, the average relative biomass of these size fractions of zooplankton in 2000 and 2001 was 11 g/m^2, whereas in "warm" years it was only half that level (5.5 g/m^2). In addition, different year types had significantly different taxonomic structure of the macroplankton community. The abundance of copepods is higher in "warm" years, whereas chaetognaths (*Sagitta*) abundance rose sharply during "cold" types. These structural differences have an impact on functional characteristics of the zooplankton community (for instance, upon its productivity). This may be an explanation for the increase of non-predatory zooplankton during "warm" years, and predatory zooplankton during "cold" years.

PICES XV CCCC_Paper-3067 Oral
The impact of regime shifts on the oceanography of the northern Gulf of Alaska and its influence on the species interactions between walleye pollock, capelin, and Steller sea lions

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Recent studies of the oceanography of the eastside of Kodiak Island have revealed a complex system of pelagic ocean habitats. Acoustic surveys reveal that these habitats serve to partition marine fishes across the shelf. We hypothesize that the ocean conditions prior to the 1976/77 regime shift differed from the present resulting in a more diverse mix of forage species across the shelf. To test this hypothesis, we reconstructed the pre-regime shift ocean conditions using data collected during oceanographic surveys conducted in the region in 1961, 1973 and 1974 and compare the system to present day conditions. We reconstructed the distribution of walleye pollock in over the central GOA shelf from NMFS stock assessment surveys and other field research efforts. Physical oceanographic data were used to describe surface and subsurface temperature fields and ocean currents from current moorings placed in the region in the early 1970s and early 2000s. Results of this paper provide new insight into the impact of the regime shift on the availability and diversity of prey to top trophic level consumers. Our work also provides a baseline for understanding the processes controlling competition, resource partitioning, and other species interactions among forage species in the region.

PICES XV CCCC_Paper-2899 Oral
Changes in the distribution of Pacific hake (*Merluccius productus*) in response to climate and ocean variability in the California Current

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Pacific hake, *Merluccius productus*, is a transboundary species that moves annually from spawning areas off of southern California to summer feeding grounds off Oregon, Washington, and British Columbia. The northern extent of the summer distribution observed during joint Canada/U.S. surveys changes in response to high

frequency (ENSO events) and low frequency (regime shifts) climate variability. During warm ocean conditions (*e.g.*, El Niño), hake move north into Queen Charlotte Sound. In contrast, during periods of cool ocean conditions (*e.g.*, La Niña), hake exhibit a more southerly distribution. In 2005, hake were distributed well north to the Canada-Alaska border (54°N), but they were dispersed over a wide, shallow range inshore of the 250 m depth contour and thus, largely absent from their usual feeding grounds near the shelf edge. We hypothesize that the anomalously warm waters along much of the central and northern coastal regions through 2003 and 2004 coupled with the late onset of persistent upwelling off northern coastal regions in 2005, led to lower productivity and coincident changes in hake behavior and distribution. Hake were able to move further north because their migration was not physically or ecologically impeded and the timely appearance of food resources whose production is supported by upwelling did not occur until late in the summer resulting in an inshore feeding pattern. Our analysis has implications with respect to climate change: the latitudinal distribution of Pacific hake is expected to shift northward and the cross-shelf distribution may become shallower in future.

PICES XV CCCC_Paper-2968 Poster
Application of the ecosystem structure model (Ecopath) to the East/Japan Sea in Korea

Young Seop **Kim**[1], Hyung Kee Cha[1], Sung Il Lee[1], Seon Jae Hwang[2], Sang Cheol Yoon[1], Kyunk Chan Know[1] and Jae Houng Yang[1]

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We conducted trawl survey seasonally to study the distribution of fisheries resources in the coastal regions of the East/Japan Sea off Korea during 2002-2005. We analyzed the annual and seasonal changes in biomass density (mt/km^2). The dominant species in the ecosystem were *Dasycottus setiger*, *Glyptocephalus stelleri* and *Chionoectes opilio*. We calculated the species diversity and the evenness index by season and by area, and showed a dendrogram of the clustering by species. We collected ecological information on all organisms in the ecosystem (including biomass, production, consumption, mortality, catch and diet composition by species) for application of ecosystem model. Using the ecosystem structure model (Ecopath), we examined the structure of the ecosystem and analyzed ecotrophic levels of functional groups in the East/Japan Sea ecosystem. We showed predator and prey niche overlap index plot and Leontif matrix showing mixed trophic impacts in the East/Japan Sea ecosystem. The relative contributions of *Dasycottus setiger*, *Glyptocephalus stelleri* and *Chionoectes opilio* to the total flow of energy (throughput) in the ecosystem were calculated.

PICES XV CCCC_Paper-3139 Poster
Modeling annual variation of transport of eggs and larvae of jack mackerel in the East China Sea

Kosei **Komatsu**[1] and Akihide Kasai[2]

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In February and March eggs of jack mackerel (*Trachurus japonicus*) are estimated to be mainly spawned around Taiwan in the southern East China Sea (ECS) and transported through survival/growth processes into the Pacific, the Japan Sea and the coastal region off Kyushu, Japan. Annual variation of their recruitment is partly attributable to change of oceanic conditions in the ECS, however particulars about their transport process remain obscure because of a complex current system filled with mesoscale phenomena. To clarify the transport process of eggs and larvae of jack mackerel, particle transport experiments were conducted under realistic forcing, using an eddy-resolving OGCM assimilating satellite SSH/SST based on the adjoint ocean primitive equation model, C-HOPE, developed by Max-Planck-Institute. Pseudo-particles were released at 20 m depth around Taiwan in February of 2000 to 2005 and transported for 90 days, incorporating survival functions parameterized by modeled temperature and SeaWiFS chlorophyll concentration. Release points were specified from backward experiments and critical values for temperature and chlorophyll were set as 18.5°C and 0.35mg/m^3 from sensitivity analysis based on sampling data. Without survival processes, most of the particles were transported to the Pacific along the Kuroshio. Including mortality processes, however, showed that surviving particles were more populous in the Japan Sea, due to flows that detached from the Kuroshio and transported particles

northward on the shelf to the Japan Sea. The model indicated that high abundance in 2001 was caused by a high survival rate mainly due to good temperature condition.

PICES XV CCCC_Paper-3138 Poster

3D modeling of size-dependent variation of phyto- and zooplankton biomass caused by advective processes around the Kuroshio and the Kuroshio Extension

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Temporal and spatial variations of plankton biomass were calculated by a three-dimensional ecosystem model with focus on size dependent effects of advective processes in the frontal region of the Kuroshio and the Kuroshio Extension in the western North Pacific. The model consists of a lower trophic-level model based on the extended NEMURO (eNEMURO) coupled with an eddy-resolving OGCM assimilating satellite SSH/SST based on the adjoint ocean primitive equation model, C-HOPE, developed by Max-Planck-Institute, and it was driven by a surface forcing from January 1997 through April 2004. Downstream of the Kuroshio, high concentration region of phytoplankton (zooplankton) was distributed along the northern edge of the front, where variation of the biomass was controlled not only by local biological variation but also by advective process due to the strong jet in comparison between the primary production term (grazing term) and the advection term. Moreover local maxima were formed in convergence zones located downstream (upstream) of the meander ridge (trough), as observed by sampling. On the other hand, in the fringe areas of the Kuroshio the variation was affected mainly by *in situ* biological growth. Consequently in the frontal region, a small difference in initial growth rate between small and large-sized plankton induced a large difference in their biomass, coupled with advective process due to convergence and divergence, cross-frontal current and eddy-stream interaction.

PICES XV CCCC_Paper-3166 Oral

The state of the climate system of the North Pacific and North Atlantic in 2000-2005 in comparison with the 2nd half of the XX century

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We compared the current (2000-2005) climate of the North Pacific and North Atlantic with previous climate conditions in the second half of the XX century. A phase change of the North Atlantic Oscillation from positive to negative occurred in 2005-2006. In contrast to the 1950-1999, when the climate regime shifts were sharp (*i.e.* within one year), in the current decade a longer (3-4 year) transitional period is observed. The shift coincided with the dramatic widening and intensification of the Siberian anticyclone, which influence was traced in the Europe. In the North Pacific the processes were not so clear because of its widening. However, in the beginning of the century the role of the meridional component of the atmospheric circulation in the Northwest Pacific increased. In particular, in the western Bering Sea during 2000-2005 advection of air masses from the northwest along the Koryak and East Kamchatka coastal zones increased sharply, while in the 1990s the advection of air masses from the southeast prevailed over those regions. It seems that the relationships between climate and fish stocks (*e.g.* salmons) in the Northwest Pacific obtained during the earlier period may not hold for this more recent period. The corresponding analysis will be done.

PICES XV CCCC_Paper-3040 Poster
Interannual variability of the Gulf of Alaska eddy field

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Eddies formed in the eastern Gulf of Alaska have important consequences to the biology and physics of the gulf. Sea surface height anomalies from merged altimetry were used to calculate eddy kinetic energy (EKE) in the Gulf of Alaska. Regions of particularly high EKE denote formation regions and propagation pathways for Haida, Sitka, and Yakutat eddies. Time series of eddy kinetic energy amplitude in these regions illustrate an annual cycle (high in spring and low in autumn) as well as interannual variability. In the Haida and Sitka formation regions, EKE is particularly high in winter/spring of 1998, associated with high amplitude eddies whose formation has been associated with the strong 1997-98 El Niño. Eddies are also regularly observed northeast of Kodiak Island (in the northwestern gulf). These eddies form in the eastern Gulf of Alaska as Sitka or Yakutat eddies and propagate to the Kodiak Island region. They have been implicated in high offshelf chlorophyll concentrations observed from ocean color satellites. As opposed to the Sitka and Haida regions, EKE in the Kodiak Island region was not particularly high in 1998. Altimetry data show that while eddies in this region have occurred quasi-annually since 2000, they were less frequent prior to that time. Significant correlations between EKE and chlorophyll suggest that EKE may be a useful index for understanding and predicting biological variability in the Gulf of Alaska.

PICES XV CCCC_Paper-2830 Poster
Analysis of the lower trophic level of the northern East China Sea ecosystem based on the NEMURO model

Jong Hee **Lee** and Chang Ik Zhang

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The NEMURO model is aimed to efficiently understand the interaction among factors of lower trophic level of a marine ecosystem, using data on solar radiation and sea water temperature. In this study, we analyzed the seasonal pattern of nutrients and planktons, and estimated production and biomass of planktons from 2002 to 2005. Nutrients (NO_3, NH_4, and $Si(OH)_4$) which were used by phytoplankton showed a high concentration before the bloom of phytoplankton. Nutrients (DON, PON, and Opal) which were a byproduct of phytoplankton showed a high concentration in the same period as the bloom of phytoplankton. Both phytoplankton and zooplankton had two peaks in March and August. Estimated phytoplankton biomass from the NEMURO model showed a similar pattern with observed chlorophyll a concentrations. Biomasses of phytoplankton were bigger than those of zooplankton. Annual mean biomasses of small and large phytoplankton were estimated at $32.994\ell^{-1}$ and $18.120\ell^{-1}$ respectively. Annual mean biomass of predatory zooplankton was greater than those of small and large zooplankton.

PICES XV CCCC_Paper-2869 Oral
Interannual variations of sea ice and spring bloom occurrences at the Japanese scallop farming area in the Okhotsk Sea

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Sea ice extent in the Okhotsk Sea has large interannual variations and has been considered to play an important role in the high productivity at the ice edge. The coastal region of the Okhotsk Sea, Hokkaido, is an ideal habitat for the Japanese scallop, *Patinopecten yessoensis*, and has supported important fisheries for this species since the early 1900's. Understanding the dynamics of ice formation and phytoplankton bloom development is important in management of this benthic community. The objectives of this study are to clarify the interannual variability of sea ice cover and to determine the timing of the spring bloom at the scallop farming area in the Okhotsk Sea. Eight-day composites of remotely sensed data sets of sea ice (SSM/I) and Chlorophyll-*a* (SeaWiFS) from 1998 – 2004 were analyzed. There was variability in the length of the ice season at the scallop

farming area. Ice cover in 1999, 2001 and 2003 was prolonged with presence of ice until early April (over 90 days), while in 1998, 2000, 2002 and 2004 ice retreat occurred earlier, until early March (over 60 days). The timing of the spring bloom was determined by the timing of ice retreat. Early ice retreat (mid to end March) led to a later open water bloom, whereas later ice retreat (mid to end April) led to an ice edge bloom. Length of sea ice season and timing of spring blooms might play ecological significance on the growth rate of scallop.

PICES XV CCCC_Paper-3049 Oral

Summer food web structure in the eastern Bering Sea: Fatty acid composition of plankton, fish, and seabirds around the Pribilof Islands

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The eastern Bering Sea ecosystem supports high biomass of fish, seabirds, and marine mammals. The Pribilof Island archipelago has been identified as a "hot spot" or location of enhanced production and trophic transfer; however the actual mechanism(s) that sustain production during summer are undescribed. In 2004 a team of scientists sampled around the islands and at a series of "control stations" to discover the operative mechanisms. One hypothesis was that organisms from areas of sustained new production would show the highest levels of fatty acids (FA) associated with diatoms (*i.e.*, 16:1(n-7) and 20:5(n-3)), while those from highly stratified waters (production dominated by recycled nutrients) would have high levels of FA associated with small phytoplankton taxa (*e.g.*, haptophytes, chlorophytes, and cryptophytes; *i.e.*, 14:0, 18:3(n-3), and 18:4(n-3)). All particle-grazing taxa sampled (copepods, euphausiids, decapod larvae, pteropods) showed relatively high average percent mass of 16:1(n-7) and 20:5(n-3), however we could distinguish taxa based on FA signatures. Clustering of stations based on FA composition demonstrated strong regional differences. The FA composition of copepods, pteropods, and decapod larvae from the control stations (a strongly stratified region) were distinct from the Pribilof Islands samples. Euphausiids FA compositions were not different between the two regions. Within the island archipelago, copepods sampled at stations around the 100 m isobath and north of the islands were more similar than those sampled over Pribilof canyon. The results and interpretation of these data will be discussed with respect to hydrography, nutrient concentrations and estimates of phytoplankton production and community composition.

PICES XV CCCC_Paper-3042 Oral

Hydrophysical and biological characteristics in the Kuril-Kamchatka Current and Oyashio region of the Northwestern Pacific

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The information used for the analysis was taken from data bases of TINRO-Center and Pacific Oceanological Institute of Russian Academy of Sciences, as well as from Japanese cruises. The main hydrophysical features of the region are formed by the western boundary currents in the subpolar circulation of the North Pacific and closely related to the land and bathymetry - the chain of 30 islands 80 underwater volcanoes from Hokkaido to the Kamchatka peninsula. Interaction of tides and mesoscale and large scale processes with the heterogeneous bottom and coastline causes topographic upwellings and eddies, which are observed directly by measuring hydrologic parameters in the sea and remotely from satellites. Mixing of Kuril current waters with colder waters of the Okhotsk Sea south of the Bussol Strait leads to the destruction of the shelf-slope front and are partly responsible for Oyashio current formation. The resulting horizontal hydrographic and current structures are complicated and variable. The main parameter used to characterize the ecosystem state was plankton biomass (or concentration). Biomass of phytoplankton during the spring bloom in the open waters can reach values of 1500-2000 mg/m^3. In general, interannual variability of plankton is higher than seasonal variability in this region. Structure and distribution of plankton in space and time and its relation to the high diversity of oceanographic conditions in the region are analyzed.

PICES XV CCCC_Paper-2834 Oral

Abundance of finless porpoise (*Neophocaena phocaenoides*) and their role in the eastern Yellow Sea ecosystem

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Three line-transect surveys for studying the abundance and distribution of finless porpoise were conducted in the western sea of Korea from 2003 to 2005. The half-normal model was one of the robust models for estimating finless porpoise density and could be able to avoid a hazardous density overestimation. The abundance of finless porpoise was estimated to be 36,475 individuals. The structure of the western sea ecosystem was estimated using an ECOPATH model. The eastern Yellow Sea ecosystem consisted of primary producers, primary consumers, secondary consumers and terminal consumers. Finless porpoise was classified as terminal consumer with apex predator. The trophic level of finless porpoise was estimated to be 4.12. Relative contribution of finless porpoise at the trophic level and to the total flow of energy was 4.4%.

PICES XV CCCC_Paper-3075 Poster

Fine-scale vertical habitat separation among four grazing copepods (*Neocalanus cristatus, N. flemingeri, Eucalanus bungii* and *Metridia pacifica*) in the Oyashio region, western subarctic Pacific Ocean

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Stratified zooplankton sampling (9 strata between 0-1000 m) with a Vertical Multiple Plankton Sampler (mouth area; 0.25 m^{-2}, mesh aperture; 60μm) was made every 3 h for 24 h during 21-22 March 2005 at Site H in the Oyashio region to reveal fine-scale vertical distribution patterns of copepodid stages of *Neocalanus cristatus*, *N. flemingeri*, *Eucalanus bungii* and *Metridia pacifica*. As a unique hydrographic condition of Site H at this season, the water temperature was near homogenous from the surface down to 1000 m (1.5-3.4°C). Chlorophyll *a* concentrations were 1.5-2 mg m^{-3} in the top 40 m, and decreased rapidly downward. Most C1-C5 stages of *Neocalanus cristatus* occurred in the 100-200 m depth stratum day through night, showing a pattern of development "descent". Lipid deposition in the body of C5 varied from one individual to the next, but this was not related to their resident depth. Most C1-C5 of *N. flemingeri* inhabited 30-90 m both day and night, showing the pattern of developmental descent as observed in *N. cristatus*. Irrespective of day and night, C3-C6 *E. bungii* distributed largely at 200-400 m without the developmental descent pattern (C5 being the shallowest inhabitant). C1-C6 of *M. pacifica* showed a broad distribution ranging from 100 to 400 m, in which the C5 and C6 (females only) exhibited a diel migration pattern (nocturnal ascent). Among the four copepod species, the incidence of different copepodid stages suggests dissimilar species-specific life-cycles and ontogenetic vertical migration patterns. The present results are compared with those reported in the eastern subarctic Pacific, and discussed in the light of possible adaptive significance.

PICES XV CCCC_Paper-2810 Oral

Zooplankton distribution off Sakhalin Island during summer and comparison with other sub-arctic waters

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Plankton sampling was undertaken in association with oceanographic measurements along a transect roughly at the 1000 m contour off Sakhalin Island during early summer 2005. The NORPAC net-collected zooplankton assemblage was dominated by calanoid copepods. The distribution pattern of zooplankton did not necessarily match that of ambient chlorophyll level, although the overall abundance declined at the northern stations. The subsurface chlorophyll maximum tended to be more prominent at stations located further off the coast, and the

contribution of near pico size fraction (< 5 μm) appeared to be larger at these stations. At one station where the zooplankton abundance was far higher than elsewhere, chlorophyll concentration was also highly elevated with the contribution of smaller cells lower. Hydrographic control may well have been one of the major determinants of this case. Zooplankton distribution in this region at the time of investigation must be a product of interactions between hydrography and the distribution of potential food organisms. Comparison with our previous studies in other sub-arctic waters such as the Barents Sea and Bering Sea is presented. In general, zooplankton dynamics during summer is subject to a gradient of various environmental factors, and microzooplankton appears to play a greater role in the distribution and the diet of mesozooplankton during summer than in spring.

PICES XV CCCC_Paper-2996 Oral
Variations in zooplankton and oceanographic condition in the southwestern East/Japan Sea after the late 1990s

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Variations of zooplankton biomass and dominant zooplankton groups like copepods, amphipods, euphausiids and chaetognaths were studied in the southwestern East/Japan Sea to identify the knowledge on a different state or regime since the late 1990s. Zooplankton biomass was estimated as wet weight from 1965 to 2005 and abundance of four dominant zooplankton groups from 1978 to 2005. Temperature and salinity from 1965 to 2005 and Chlorophyll-*a* from 1995 to 2005 were used to analyze the oceanographic responses to the 1998 regime shift and an El Niño event in 2002/03. Zooplankton biomass trended upward after the mid-1990s with annual fluctuation. The increasing trend tended to be sharper since 2000. Especially, the years of 1998 and 2002 showed high values compared to the other years. Seasonal peaks shifted from winter (February) before 1998 to spring (April) and fall (October) after 1998. In dominant zooplankton groups, macro-zooplankton has continued to increase in their abundance and relative composition in four dominant groups. Sea surface temperature has continued to increase in winter (December and February) and early spring (April). Contrasted to before 1998, in more recent years high sea surface temperatures in some areas has extended to June. Sea surface salinity has continued to decrease, but the timing of the decrease has shifted from October and December before 1998 to February, April and June after 1998. It can be concluded that the timing of peak zooplankton biomass has changed, and peak biomass has increases since the late 1990s.

PICES XV CCCC_Paper-3084 Oral
Stepwise increase of water temperature and zooplankton biomass after the mid-1980s in the East China Sea and their possible effect on the recovery of jack mackerel

Takashige **Sugimoto**, H.-Y. Kim, K. Tadokoro, K. Kuroda and N. Nagai

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Long-term variations in the marine environment and ecosystem in the East China Sea and in the coastal water along the southern coast of Japan are affected not only by the decadal scale meteorological variations but also by the modal shift of the Kuroshio path. The relationship among these time series including the stepwise increase of water temperature, zooplankton biomass and jack mackerel's recruitment after the mid-1980s in the East China Sea are discussed.

PICES XV CCCC_Paper-3152 Poster

Interannual variability in development of the seasonal processes and their influence on fishery resources of the North Pacific

Yulia N. **Tananaeva** and Marat A. Bogdanov

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The beginning, duration and ending of the phenological seasons are important factors determining the development of production processes in the ocean. Analysis of weekly sea surface temperature (SST) and ice cover maps allowed us to distinguish a number of important features and regularities of interannual variability in the beginning and duration of cold and warm seasons in the North West Pacific, Bering and Okhotsk seas. We also analyze weekly satellite chlorophyll maps for this region to compare with seasonal thermal patterns.

Changes in the duration of the cold and warm seasons may strongly impact biological and fish productivity. Satellite chlorophyll records indicate that phytoplankton blooms occur earlier in "warm" years. Also we have examples of the influence of thermal regime on fish productivity (pacific salmons, saury, pollock). There is a significant correlation coefficient between ice conditions in the Bering and Okhotsk Seas and pollock harvest.

FIS Paper Session

Convenor: Gordon H. Kruse (U.S.A.)

Papers addressing various topics in fishery science and fisheries oceanography in the North Pacific and its marginal seas (excluding S7 topic) are invited.

Wednesday, October 18, 2006 9:00-15:30

09:00-9:20 **Churchill Grimes, Daniel Goodman, Peter Lawson, Richard Marasco, Andre Punt and Terry Quinn**
Ecosystem-based fishery management; A pragmatic approach (FIS_Paper-3094)

09:20-09:40 **Chang-Ik Zhang, Jae Bong Lee and Sun-Kil Lee**
Size-based indicators to evaluate ecosystem variations in Korean waters (FIS_Paper-3010)

09:40-10:00 **Doug Hay and Tom Therriault**
Climate change: Important impacts on unimportant species? (FIS_Paper-3245)

10:00-10:20 **Naoki Tojo, Gordon H. Kruse and Terrance J. Quinn II**
Environmental cues for herring spawning timing in northern Bristol Bay, Alaska (FIS_Paper-2808)

10:20-10:40 **Jong-Hun Na, Zang Geun Kim and Chang Ik Zhang**
Estimation of growth parameters of minke whale, *Balaenoptera acutorostrata*, in Korean waters (FIS_Paper-2845)

10:40-11:00 ***Tea/Coffee Break***

11:00-11:20 **Hidetada Kiyofuji, Evan Howell, Katsuya Saitoh, Sei-Ichi Saitoh and Jeffrey Polovina**
Spatial and temporal dynamics of albacore tuna (*Thunnus alalunga*) and blue shark (*Prionace glauca*) in the Kuroshio Extension area (FIS_Paper-2936)

11:20-11:40 **Evan A. Howell, Donald R. Kobayashi and Jeffrey J. Polovina**
Identifying critical habitat of swordfish and loggerhead turtles from fishery, satellite tag, and environmental data (FIS_Paper-2837)

11:40-12:00 **Nanami Kumagai, Hidetada Kiyofuji and Sei-Ichi Saitoh**
Distributions of squid fishing grounds and their relationship to sea surface temperature and chlorophyll-*a* concentration in the Japan Sea (FIS_Paper-2853)

12:00-12:20 **Gordon A. McFarlane and Jacquelynne R. King**
Migration patterns of big skate (*Raja binoculata*) based on a large-scale tagging study in northern British Columbia waters: Preliminary results (FIS_Paper-3127)

12:20-12:40 **Alexander I. Glubokov**
Status of fishes in the outer shelf and upper slope of the Northern and Western Bering Sea (FIS_Paper-2765)

12:40-14:00 ***Lunch***

14:00-14:20 **Kazushi Miyashita, Atsumu Watanabe, Saho Morioka, Yoshihiro Ikewaki, Ryu-ichi Matsukura and Hiroki Yasuma**
Acoustic monitoring of Japanese anchovy (*Engraulis japonicus*) post-larvae "shirasu" (FIS_Paper-2974)

14:20-14:40 **Min Ho Kang, Jung Youn Park and Suam Kim**
Genetic variations and differences of chum salmon (*Oncorhynchus keta*) collected from the Bering Sea and along the North Pacific region (FIS_Paper-2909)

14:40-15:00 **You Jung Kwon, Chang Ik Zhang, Dae Yeon Moon and Jeong Rack Koh**
Stock assessment of southern bluefin tuna (*Thunnus maccoyii*) using MULTIFAN-CL (FIS_Paper-2828)

15:00-15:20 **Elizabeth A. Logerwell, A.B. Hollowed, C.D. Wilson, P. Walline, P. Munro, M.E. Conners, S. McDermott, S. Neidetcher, D. Cooper and K. Rand**
Fish ecology plays a key role in understanding the potential for commercial fishing to impact prey fields of endangered Steller sea lions (FIS_Paper-2938)

Posters

Elena N. Andreeva, Svetlana V. Davidova and Anatoly V. Smirnov
Dynamics of the flounders spawning during the spring seasons 1984-2005 depending on hydrological conditions of the Okhotsk Sea (FIS_Paper-2849)

John R. Bower, Saya Shimura and Shuuichi Abe
Observations on the morphology and distribution of gonatid paralarvae in the northeast Pacific (FIS_Paper-2839)

Oleg Bulatov, Olga Moiseeva and Georgiy Moiseenko
The Okhotsk Sea pollock stock assessment using GIS "Fishery" (FIS_Paper-2805)

Jung Hwa Choi, Dae Soo Chang, Kang-seok Hwang, Young-yull Chun and Jong Bin Kim
Environmental effects on landings of penaeid shrimp in the Yellow Sea (FIS_Paper-3110)

Vladimir A. Belyaev, V.B. Darnitskiy, E.I. Ustinova and S.P. Bomko
Dynamics of oceanographic conditions near the Japanese Archipelago: Fluctuations, processes in ecosystems and mass pelagic species (FIS_Paper-3157)

Yurii P. Diakov
Geographic variations of seasonal spawning structure of *Pleuronectiformes* in the northern Pacific Ocean (FIS_Paper-2780)

Natalia T. Dolganova and A.E. Lazhentsev
Feeding of mass nekton species in the epipelagic waters of the northwestern Japan Sea (FIS_Paper-2797)

Maria V. Eletskaya, Vadim A. Shtrik and Minna I. Tarverdieva
Feeding of red king crab (*Paralithodes camtschaticus*) juveniles in the North Pacific and Barents Sea (FIS_Paper-2779)

Elena V. Gritsay
Geographical variability of walleye pollock maturation rate in the Bering Sea and Gulf of Alaska (FIS_Paper-2801)

Kazushi Kadomura, Makoto Sugihara, Sayaka Naruse, Takuji Nakashima, Kenichi Yamaguchi and Tatsuya Oda
ROS (reactive oxygen species) generation by several marine fish species during embryogenesis (FIS_Paper-2847)

Makoto B. Kashiwai
Challenge of Hanasaki Program; Toward management of Hanasaki crab including taste quality (FIS_Paper-2989)

Atsushi Kawabata
Distribution and biomass of the Japanese common squid, *Todarodes pacificus*, estimated by acoustic survey in the Pacific coastal waters off the northern Japan (FIS_Paper-2923)

Anastasia M. Khrustaleva, Alexander A. Volkov and Darya A. Zelenina
Study of the population structure of Asian sockeye salmon (*Oncorhynchus nerka*) using microsatellite polymorphism analysis (FIS_Paper-2927)

Hwa Hyun Lee, Min Ho Son and Suam Kim
Distribution of common squid, *Todarodes pacificus* (Cephalopoda: Ommastrephidae), larvae in the East China Sea in the early 2000s (FIS_Paper-3097)

Yeong Hye Kim, Kwang Ho Choi, Jin Goo Kim, Jong Bin Kim and Dong Woo Lee
Age, growth and maturity of shotted halibut, *Eopsetta grigorjewi*, in the southern coast of Korea (FIS_Paper-2993)

Toshiyuki Konishi, Hidetada Kiyofuji, Katsuya Saitoh and Sei-Ichi Saitoh
Predictability of Pacific saury fishing grounds using satellite remote sensing and a statistical model (FIS_Paper-2838)

Eugene V. Miheev and Nikolay N. Kovalev
Adaptation of Cephalopoda: A biochemical approach (FIS_Paper-2956)

Hideaki Kudo, Masakazu Shinto, Ikue Mio and Masahide Kaeriyama
Histological study of the olfactory system of immature and maturing chum salmon (*Oncorhynchus keta*) in the North Pacific Ocean (FIS_Paper-2822)

Sun-Kil Lee, Jae Bong Lee, Chang-Ik Zhang and Dong Woo Lee
Fish reproduction potential (FRP) index of marine ecosystems in Korea (FIS_Paper-3068)

Yong-Woo Lee
Bias in size distribution estimates for fish populations due to sampling gear selectivity and sample sizes (FIS_Paper-3052)

Pablo del-Monte-Luna, Salvador E. Lluch-Cota, Jesus Bautista-Romero and Daniel Lluch-Belda
Fishing down or just too many small pelagics? (FIS_Paper-3170)

Kazushige Oishi, Akira Nihira, Tadaaki Kuroyama and Sei-Ichi Saitoh
Predictable hotspots for Skipjack tuna, *Katsuwonus pelamis*, using multi-sensor satellite remote sensing off the east coast of Japan (FIS_Paper-2825)

Alexei Orlov and C. Binohlan
Length-weight relationships of deep-sea fishes from the western Bering Sea (FIS_Paper-3037)

Alexei M. Orlov and Vasily A. Ul'chenko
Seasonal changes of environmental conditions of the most abundant and common groundfish species in the Pacific off the North Kurils and South Kamchatka (FIS_Paper-2807)

Gennady V. Avdeev, Evgeny E. Ovsyannikov and Svetlana L. Ovsyannikova
Seasonal distribution of immature pollock in the northern Okhotsk Sea (FIS_Paper-2957)

Yosuke Sagawa, Hideaki Kudo and Masahide Kaeriyama
Feeding habits of Pacific salmon in the North Pacific Ocean in summer 2005 (FIS_Paper-2826)

Aida Sartimbul, Hideaki Nakata and Ikuo Hayashi
Analysis of time series of coastal fishery catches in the Tsushima Warm Current region in relation to temperature changes (FIS_Paper-2982)

Young Il Seo, Joo Il Kim, Sun Do Hwang, Taek Yun Oh, Sun Kil Lee, Won Seok Yang, Sung Tae Kim and Hyun Joo
Coastal ecosystem of the Yeo-Ja Bay in the southern sea of Korea (FIS_Paper-3083)

Kyung-Jun Song, Zang Geun Kim, Hawsun Sohn, Seok Gwan Choi, Yong-Rock An and Chang Ik Zhang
The feasibility of photo-identification techniques for bottlenose dolphin (*Tursiops truncatus*) in Jeju Island, Korea (FIS_Paper-3034)

Mikhail A. Stepanenko and Elena V. Gritsay
Effect of biological and physical factors on recruitment variability of eastern Bering Sea pollock (FIS_Paper-2802)

Naoki Tojo, Gordon H. Kruse and Fritz C. Funk
Migration dynamics of Pacific herring (*Clupea pallasii*) and response to spring environmental variability in the southeastern Bering Sea (FIS_Paper-2809)

Norio Yamashita, Masayuki Noto, Chikako Watanabe, Atsushi Kawabata and Hiroshi Nishida
Distribution and growth of juvenile chub mackerel, *Scomber japonicus*, in the Kuroshio-Oyashio transition region (FIS_Paper-2925)

Hak Jin Hwang, Yang Jae Im, Myoung Ho Sohn, Inja Yeon, Naek Joong Choi and Mi-young Song
Spatio-temporal distribution of Pacific cod, *Gadus macrocephalus*, in the western sea of Korea (FIS_Paper-3162)

Inja Yeon, Hak Jin Hwang, Yang Jae Im, Myoung Ho Shon, Sung Hyun Hong, Yoon-Seon Yang and Mi-Young Song
The reproductive biology of blue crab, *Portunus trituberculatus* (Miers), in the western sea of Korea (FIS_Paper-3161)

PICES XV FIS_Paper-2849 Poster
Dynamics of the flounders spawning during the spring seasons 1984-2005 depending on hydrological conditions of the Okhotsk Sea

Elena N. **Andreeva**, Svetlana V. Davidova and Anatoly V. Smirnov

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During 1984-2005, catches of fish eggs in the Okhotsk Sea were dominated (97%) by flounders (*Pleuronectes quadrituberculatus, Hippoglossoides (robustus* and *dubius)*, excepting the eggs of walleye pollock *(Theragra chalcogramma*). The eggs of flounders were widely distributed in the waters of the Okhotsk Sea above depths of 16-1000 m. However, highest egg densities were found in three areas. Average density of eggs near the western coast of the Kamchatka Peninsula changed year to year from 10 to 80 eggs per m². At the northern part of the Okhotsk Sea – the Pritauiskiy shelf and Schelikhov Bay - average density changed from 2 to 66 eggs per m². According to long-time observations, these areas were the main spawning grounds of flounders in March-July above depths of 40-170 m. Maximal catches of flounders were collected in "hydrological warm" spring seasons characterized by small area of ice cover (1984-1996). Since 1998 (1998-2005 - "hydrological cold" spring seasons) decreased of catches of flounders eggs was observed. On the decadal scale, a negative correlation exits between the number of flounder eggs and the degree of development ice cover (-0.67). During 1984-1996, eggs of flounders were widely distributed in the Okhotsk Sea, from the Schelikhov Bay to the southern coastal area of the Sakhalin Island, in general above depths of 50-100 m. During 1998-2005, the area of the egg distribution significantly decreased and eggs were caught in deeper areas, 100-200 m.

PICES XV FIS_Paper-2839 Poster
Observations on the morphology and distribution of gonatid paralarvae in the northeast Pacific

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Gonatid squid paralarvae in the North Pacific are difficult to identify because most species are undescribed. In this study, we used genetic techniques to identify and describe the paralarvae of several gonatid species, and then examined their distribution patterns. Paralarvae were collected during seven summer cruises (1999-2006) in the North Pacific aboard the Hokkaido University ship *Oshoro Maru*, and specimens were divided into morphotypes based on their physical characteristics. The PCR was then used to amplify and sequence the COI gene. Using this method, we positively identified the paralarvae of two important gonatid species in the North Pacific: *Gonatopsis borealis* and *Berryteuthis anonychus*. *B. anonychus* paralarvae occurred north of the Subarctic Boundary from the Subarctic Current to the Alaska Stream, and previously published size data from juveniles and adults in this region suggest that this species migrates northward during spring. These and other observations will be presented.

PICES XV FIS_Paper-2805 Poster
The Okhotsk Sea pollock stock assessment using GIS "Fishery"

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Data were obtained from large Russian fishering vessels in January-April 1998-2006. Pollock biomass was calculated for Kamchatka-Kuril, Western Kamchatka and Northern Okhotsk Sea areas. Software products of ESRI, ArcView GIS, and a server of database Oracle, Oracle9i, were used. Daily data (type of trawls and catch per one hour) from Russian fishering vessels provided the basis for the calculations. In each quadrangle (around 55x55km) biomass was estimated monthly. We found that pollock biomass fluctuated widely in each area both seasonally and interannually. Stock assessment dynamics of walleye pollock is discussed.

PICES XV FIS_Paper-3110 Poster
Environmental effects on landings of penaeid shrimp in the Yellow Sea

Jung Hwa **Choi**, Dae Soo Chang, Kang-seok Hwang, Young-yull Chun and Jong Bin Kim

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Korean fishermen catch penaeid shrimp in the Yellow Sea (middle of western coast of Korea) by using beam trawl and stow nets. During the past 40 years, the shrimp landings fluctuated with a cycle of about 10 years. Recently, landing decreased rapidly, possibly due to habitat loss and environmental degradation. Land reclamation projects have reduced spawning and nursery grounds in the coastal area, while climatic and hydrological changes could affect growth and survival of shrimps. To evaluate effects of environmental changes, time series of shrimp catch and environmental factors (seawater temperature, salinity, nutrient and precipitation of rainfall season) from 1993 to 2001 are being analyzed. Preliminary results indicated that shrimp catch is related to concurrent seawater temperature and salinity and to nutrient levels and annual precipitation with one-year time lag. We will eventually develop models to predict potential yield and landing of penaeid shrimp based on habitat loss and environmental conditions.

PICES XV FIS_Paper-3157 Poster
Dynamics of oceanographic conditions near the Japanese Archipelago: Fluctuations, processes in ecosystems and mass pelagic species

Vladimir A. Belyaev[1], Vladimir B. **Darnitskiy**[2], Elena I. Ustinova[2] and Svetlana P. Bomko[2]

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An understanding of the fluctuations in abundance of Far East sardine and others pelagic fishes require specification of their internal population dynamics and a detailed elaboration of oceanographic processes near Japan and Ocean regions. In recent years, catches of sardines by the Russian fleet in the southern portion of the Okhotsk Sea have been many times larger that earlier levels. Scientists from different countries process large amounts of data on near surface atmosphere and the upper and baroclinic layers of the ocean to identify step changes in the environment. This yields an objective picture of interannual variability of the oceanographic conditions. A published spectral analysis of EOF data from the last 50 years of 20th Century in the Japanese Sea identified 11-, 7-8- and 3-4-yr periodicity for the first component; 11- and 2-3-yr for the second and 19- and 2-3-yr periodicity for the third component. Another analysis of thermal conditions in the Japanese Sea in 1932-1941 and 1950-1958 revealed periodicity of warming and cooling for 7 years and 3-4 years, respectively. Yet, other authors have shown that water temperature anomalies in any decade or month are practically unrelated to the subsequent anomalies. We report on some features of the internal dynamics of sardine populations relevant to the 20th Century wave of high abundance.

PICES XV FIS_Paper-2780 Poster
Geographic variations of seasonal spawning structure of *Pleuronectiformes* in the northern Pacific Ocean

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Variability of spawning timing and several early ontogenetic characteristics were studied for 56 species of *Pleuronectiformes* in the Bering Sea, Okhotsk Sea and Sea of Japan. Two types of adaptive strategies were uncovered. The first type includes mechanisms to reduce the strength of potential competition for food during early ontogenesis. Given broad geographic diversity of flounder species from higher to lower latitudes and a decline in abundance of particular species from north to south, intraspecies competition is most likely in the north and interspecies competition is most likely in the south. This adaptive strategy implies the following north to south patterns: decline in average duration of spawning; increase in the number of the seasonal-spawning groups; increase in the hierarchical structuring of fauna in this number; increase in the seasonal differentiation of spawning of different species; increase in the number of batch-spawning species; and a decrease of age of

metamorphosis causing a reduction of exogenous feeding periods of larvae. The other type of adaptation is the adaptation to seasonal changes of environment, influencing food supply of fish in early ontogenesis. The period favorable for egg and larval development is shorter in the north than in the south. Mechanisms of adaptation include later displacement of spawning timing of some species with increasing latitude. This shortens the time lag between larval emergence and plankton blooms. Most northern species prefer the warm period of the year for spawning, whereas the spawning timing of southern flounder species is distributed more evenly throughout the year.

PICES XV FIS_Paper-2797 Poster
Feeding of mass nekton species in the epipelagic waters of the northwestern Japan Sea

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Feeding of five basic species of nekton (2500 stomachs) in the upper 50-meter layer of the Japan Sea in the Russia EEZ was investigated in autumn. Squids − *Todarodes pacificus* and *Watasenia scintillans* – make up more than 54% of the trawl catch. Prey of adult *T. pacificus* predominantly consists of nektonic species (63.5 %), and the prey of young squids largely consists of planktonic species (91%). The daily diet of *T. pacificus* is 3% and 9% of body weight, respectively. *Watasenia scintillans* eats amphipods, copepods and euphausiids, accounting for 4.3% of it's body weight on a daily basis. Three species of fish – juvenile *Oncorhynchus gorbuscha* and *Pleurogrammus azonus*, and also *Engraulis japonicus* – in aggregate account for 41.5% of the trawl catch. Planktonic prey accounts for 70%, and up to 96% of their diet, from 6.5 - 9.3% of body weight daily. There are some regional distinctions in the food spectrums and daily diets. Copepods, comprising one third of total zooplankton biomass, do not play an important role in the feeding of nektonic animals (except for an anchovy), but hyperiids, accounting for only one tenth of zooplankton biomass, are actively consumed by all species of fishes and squids.

PICES XV FIS_Paper-2779 Poster
Feeding of red king crab (*Paralithodes camtschaticus*) juveniles in the North Pacific and Barents Sea

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The population abundance of the red king crab, one of the most commercially important crustacean species, has drastically declined in the North Pacific. Larval culture under controlled conditions is currently considered as one way to restock its populations. Our data on feeding habits and rations of 0-4 year old juveniles both in the native area (Russian Far East) and the Barents Sea should become an important component of the final phase of culture cycle: release of the juveniles to the sea. Our studies demonstrated that in both areas the range of prey species expands as the juveniles grow and migrate to deeper waters. Juvenile diet varies in relation to season (summer/autumn). The range of prey species of the juveniles in the Barents Sea differs from that in the North Pacific. For example, in western Kamtchatka main prey species were hydroids, crustaceans, mollusks, echinoids, polychaetes, bryozoans, and sponges, while in the Barents Sea juveniles mainly consumed benthic algae, detritus and silt, echinoids, crustaceans, mollusks, and bryozoans. Interestingly, in Kamtchatka the percentage of juveniles with algae in the stomachs was 13.1%, and the amount of algae constituted less than 1% of all food consumed; at the same time, in the Barents Sea algae were found in 77.7/100% of specimens in autumn/summer, respectively, and constituted up to 100% of stomach contents. Therefore, selection of suitable sites and timing of release of juveniles of a certain age class should consider the depths and the availability of primary food objects.

PICES XV FIS_Paper-2765 Oral
Status of fishes in the outer shelf and upper slope of the Northern and Western Bering Sea

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Up to 4.5 million tons of seafood was harvested in the second half of the 1980s in the Bering Sea, an area of only 0.6% of the global ocean. This makes its productivity commensurable with that of the Peruvian and West African upwelling areas. Fish occupy upper trophic levels and can be regarded as an integrated indicator of the overall ecosystem condition. On the one hand, the status of fish stocks reflect seasonal and interannual climatic and oceanographic changes. On the other hand, it shows the effect of fishing. A gradual transfer to multispecies fisheries requires knowledge of succession regularities of biota in general and fishes in particular. Twenty eight research cruises were conducted in the northern and western parts of the Bering Sea during 1995-2004. The study examined species composition of fish communities, frequency of occurrence and distribution density of 67 fish species in the North and 62 in the Northwest Bering Sea. A qualitative and quantitative seasonal analysis of fish community structure allowed us to make the following conclusions. Density of other bottom fish and the role of dominant species increases when pollock biomass declines. At the present time the bottom fishes of the North and Northwest Bering Sea are dominated by cod and great sculpin, as well as Pollock. In terms of importance they are followed by region-specific community structures: northern rock sole and Alaska plaice in Navarin region; skates and Pacific halibut in Koryak region; and yellow Irishlord and darkfin sculpin in Karagin-Olutor region.

PICES XV FIS_Paper-3094 Oral
Ecosystem-based fishery management; A pragmatic approach

Churchill **Grimes**[1], D. Goodman[2], P. Lawson[3], R. Marasco[4], A. Punt[5] and T. Quinn[6]

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Ecosystem-based fishery management (EBFM) is ever more frequently the focus of fisheries management discussions. While EBFM means different thing to different people, the underlying concern is the overexploitation of fish stocks. Historically, ecology, fisheries biology, oceanography, and fisheries economics have not been well integrated in fisheries management. However, it is generally acknowledged that far more attention needs to be focused on a coupled understanding of many factors for more successful fisheries management. Information on physical, chemical and biological oceanography, population biology, community structure and dynamics, and the likely social and economic ramifications of management changes must be considered explicitly. Recognizing that the process of incorporating ecosystem consideration into fishery management is an evolutionary one, three issues related to EBFM are identified and discussed to facilitate the transition to EBMF. The issues are: (1) how to define EBFM for use by management bodies, (2) what characteristics are specific to an EBFM approach, and (3) what are the next steps that management bodies should take to move forward from the existing management approach that consider ecosystem interactions in an implicit and often peripheral way to one that considers these interactions explicitly.

PICES XV FIS_Paper-2801 Poster

Geographical variability of walleye pollock maturation rate in the Bering Sea and Gulf of Alaska

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Geographic variability in the rate of walleye pollock maturation was examined in the Bering Sea: Karaginskiy and Olyutorskiy Bays, Koryak coast (170°30' - 176°00' E), Navarin area (176°00' E – Convention line Russia – U.S.A.), eastern Bering Sea, Commander Islands area and the Gulf of Alaska in 1981-1990. Length of 50% maturity of Gulf of Alaska and southeastern Bering Sea pollock mature is less 35 cm. Mean length of first maturing fish increases towards the western and northwestern Bering Sea − 40.1 cm in the Navarin area, almost 41 cm in the Karaginskiy and Olyutorskiy Bays, and 43.8 cm in the Commander Islands area. The youngest first maturing pollock in the Bering Sea occurs in the southeast near Unimak Island, where about 50% pollock mature by 3.5 years old. Age of first maturity increases with increasing fish length. Pollock in the northern Bering Sea shelf (Russian EEZ) and Commander Islands region reach maturity 1.9-2.0 years later than other areas of the Bering Sea and Gulf of Alaska. Results of cluster analysis showed that growth and maturation rates of pollock of the Commander Islands region are close to fish of the western Bering Sea population. Growth and maturation rates of pollock of the Navarin area are close to the eastern Bering Sea population fish. The length of first maturing pollock does not depend on the abundance of adjacent year-classes (n-1, n+1); the coefficient of correlation is less than 0.5.

PICES XV FIS_Paper-3245 Oral

Climate change: Important impacts on unimportant species?

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Major climate-related change may occur in commercially unimportant species, including smelts (Osmeridae). In the coastal waters of British Columbia, a small, unique, fall-spawning population of capelin (*Mallotus villosus*) disappeared in the 1970s. They re-appeared in the late 1990's but in different areas and as spring spawning fish. In the mid-1990's the anadromous eulachon (*Thaleichthys pacificus*) declined synchronously in BC and adjacent areas in the U.S.A. A partial recovery in 2000 has now diminished. Eulachons were relatively abundant but have now declined throughout their range. Surf smelt (*Hypomesus pretiosus*) has suffered major declines in the last three decades in BC. Concurrently, the distribution and abundance of some clupeids has changed. Sardines (*Sardinops sagax*) have recovered from a collapse and now enter Canadian waters. Anchovy *(Engraulis mordax*) occur only in southern Canadian areas but undergo local distributional change. Herring (*Clupea pallasi*) exhibit continuous small changes in distribution and abundance. There has been a reduction in spawning areas in the last three decades, but not spawning biomass. Most osmerid and clupeid species are small and relatively short-lived. Probably few of the observed changes are a result of fisheries. Some of the changes appear to be synchronous among species. One important question is whether some of these changes share a common cause. Comparative life history analyses shows that inter-specific synchrony probably develop in marine waters during their first year of life.

PICES XV FIS_Paper-2837 Oral

Identifying critical habitat of swordfish and loggerhead turtles from fishery, satellite tag, and environmental data

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Incidental takes of sea turtles in fisheries are a concern globally as well as locally in the Hawaii-based longline fishery for swordfish. New regulations in addition to an annual quota of turtle-longline interactions place additional pressures on this fishery to limit the bycatch of loggerhead turtles from swordfish sets. In this study

satellite derived sea surface height, sea surface temperature, and ocean color were used in conjunction with commercial fishery and satellite tag position data to identify the critical habitat of swordfish and loggerhead turtles in the central North Pacific during winter months. Available daily positions from satellite tags and fishery set locations were matched in time and space with environmental data, and then analyzed. A generalized additive model was constructed to quantify the maximum effects of environmental parameters on swordfish and turtle habitat. Output from this model was then used to build spatial habitat maps for these two species. From these habitat maps potential areas of interaction between the swordfish fishery and loggerhead turtles can be identified. The usefulness and limitations of these maps for use in an operational fishery and management decisions is discussed.

PICES XV FIS_Paper-2847 Poster
ROS (reactive oxygen species) generation by several marine fish species during embryogenesis

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One important aspect of the aquacultural industry is the development of new seed production of valuable fish. Devil stinger (*Inimicus japonicus*) is considered to be one such promising fish species. However, the establishment of the stable seed production has not succeeded yet because of sudden mass mortality during the larval rearing stage. Although rearing conditions, egg quality, feeding conditions, and infectious diseases are suspected as causes for the mass mortality, our recent studies have suggested that reactive oxygen species (ROS) produced by larvae of devil stinger themselves may be a factor affecting the survival rate of larvae. Several lines of evidence suggested that the larvae of devil stinger may produce ROS as an innate immune defense system against invading pathogens. In the study, we employed chemiluminescence analysis using L012, a highly sensitive ROS specific chemiluminescence probe. By this method, we found that the larvae of black rockfish (*Sebastes inermis*) and marbled rockfish (*Sebastes marmoratus*) produce even higher levels of ROS than that of devil stinger. Furthermore, lower but significant levels of ROS were also detected in the larvae of sevenband grouper (*Epinephelus septemfasciatus*), red seabream (*Pagrus major*), and spotted halibut (*Verasper variegatus*). These results suggest that ROS generation by larvae of marine fish species may be a common biological feature at least among the species tested. Based on these findings, we would like to propose that ROS level in larval stage should be taken into consideration as an important factor influencing survival rate of larva during rearing marine fish species.

PICES XV FIS_Paper-2909 Oral
Genetic variations and differences of chum salmon (*Oncorhynchus keta*) collected from the Bering Sea and along the North Pacific region

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We examined the genetic variations and differences of chum salmon (*Oncorhynchus keta*) collected from the western Bering Sea and hatcheries in Korea, Russia, and Alaska using mitochondrial (mtDNA) DNA analysis. Nucleotide sequence analysis of about 500 bp in the variable portion of the 5′end of the mtDNA control region revealed 20 variable nucleotide sites, which defined 30 haplotypes of 3 genealogical clades (A, B and C). In a total of 820 fish examined, (66 from Korea, 40 from Alaska, 14 from Sakhalin and 700 from the Bering Sea), the sequence comparison indicated 12 variable sites, comprising 14 haplotypes in the examined fish. The A-1 and C-1 haplotypes characterized the Korean population and the clade B haplotypes Alaska/Russian populations. In the Bering Sea populations, the clade A and C haplotypes were widely distributed. The estimates of F_{st} revealed that Russian and Alaskan chum salmon are genetically more distinguishable among the regional groups (Korea, Russia and Alaska), and Asian stocks were dominant at most survey areas of the Bering Sea in 2004.

PICES XV FIS_Paper-2989 Poster

Challenge of Hanasaki Program; Toward management of Hanasaki crab including taste quality

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The Hanasaki crab (spiny king crab), *Paralithodes brevipes*, is an important species in local crab fisheries of Nemuro and is the symbol of Nemuro City, a town of seafood and sight-seeing. The habitat of Hanasaki crab is the shallow waters of rocky coast around Nemuro peninsula, Kurilsky Islands, Sakhalin Island, and Kamchatka Peninsula. Management of Hanasaki crab fishery around Nemuro involves fishing seasons, allowable size and quotas, determined by survey every year. In spite of management efforts by local fisheries managers and limited catches far below the quota, the stock level continues at low level and moreover the size of crabs has become smaller. The price of Hanasaki crab at Nemuro Fish Landing Market is kept low by a large amount of imported Hanasaki crab caught in the Kurilsky waters, just neighboring to the Nemuro water, almost by illegal fishing. Under present lower price, the value of local crab resource is not realized in the market and cannot cover the cost of harvesting. In order to breakthrough this bottle-neck situation, a scientific program, Hanasaki Program, was initiated in 2003 as a joint study between SakhNIRO and Nemuro City to cope with problems on Hanasaki crab. The Program consists of the following research themes: 1) characteristics of the fisheries and population dynamics; 2) ecology and population structure; 3) enhancement techniques; 4) techniques for preservation and improvement of taste quality; and 5) design of a sustainable fishery system. In the early part of implementation, the priorities were placed on population structure analyses by DNA markers, which have revealed that the crab stocks in Nemuro Water and Kurilsky water belong to the same local population but different from populations of Sakhalin Island and Kamchatka Peninsula. A joint field study on planktonic larvae and a joint modeling study on larval transport using ecosystem model is under way. A subsequent part of program will prioritize on taste quality.

PICES XV FIS_Paper-2923 Poster

Distribution and biomass of the Japanese common squid, *Todarodes pacificus*, estimated by acoustic survey in the Pacific coastal waters off the northern Japan

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Spatial distribution and biomass of Japanese common squid, *Todarodes pacificus*, in summer of major fishing season were examined by echo sounding, ROV observations, squid jigging and bottom/mid-water trawling in the Pacific coastal waters off northern Honshu Island on the major fishing ground in Japan. *T. pacificus* concentrated around the continental shelf edge where the cold water of Oyashio was distributed under the warm water gyre of the Tsugaru Warm Current. The maximum density of squid was 3-4 individuals/m^2. Squid showed obvious diurnal vertical migration beginning at about one hour before the sunset/sunrise in relation to distribution of prey. Squid were distributed near the seafloor at 100-200 m depth at 5-10°C in the daytime and in the mid-water layer of 50-100 m at 12-18°C near the weak thermocline in the nighttime, though some squid ascended to near the sea surface of about 20°C or remained near the seafloor. Squid were thought to be preying efficiently on euphausiid forming aggregations in cold water near the seafloor in the daytime. Squid biomass estimated by acoustic transect survey fluctuated annually between 238,000 (1996) and 17,000 (1998) tons in the coastal fishing ground of 3,600 km^2 in August-September during 1996-2002. Biomass estimates seem to be adequate for commercial catch of squid (33,000-9,000 tons) after the surveys. Annual change of the biomass strongly correlates with the CPUE of squid jigging fishery (R^2=0.89). Acoustic estimation of *T. pacificus* biomass is considered to be accurate and applicable to appropriate stock assessment.

PICES XV FIS_Paper-2927 Poster

Study of the population structure of Asian sockeye salmon (*Oncorhynchus nerka*) using microsatellite polymorphism analysis

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A comparative study of the structure of the largest Asian sockeye salmon populations was carried out for estimation of the stock composition and identification of individuals in mixed sea catches. Microsatellite DNA variation at three microsatellite loci (One-111, OtsG253b, OMM-1082) was examined in approximately 430 sockeye salmon collected between 2003 and 2004 from seven stocks on the east and west coasts of Kamchatka, Chukotka, North Kuril Islands, and the west coast of the Sea of Okhotsk. All surveyed loci were highly polymorphic and Hardy-Weinberg equilibrium was observed in the most of the groups. The microsatellite polymorphism analysis revealed well-defined genetic differentiation among local populations. Significant differences in allele frequencies were found between Chukotka, Okhota River, North Kuril populations, and Kamchatka populations as well as between east and west Kamchatka populations. Assignment tests of simulated mixed-stock samples showed that three well-chosen microsatellite loci would enable relatively accurate individual identification.

PICES XV FIS_Paper-3097 Poster

Distribution of common squid, *Todarodes paificus* (Cephalopoda: Ommastrephidae), larvae in the East China Sea in the early 2000s

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To reveal the spatio-temporal distribution of common squid larvae, *Todarodes pacificus*, in relation to the ocean environment, we examined zooplankton samples collected by Bongo and MOCNESS samplers in the northwestern East China Sea during April to October 1999-2005. Common squid larvae were caught in all sampling cruises. T-S plots were developed at 39 stations out of 171 stations. Over 90% the common squid larvae were found in mixed waters southeast of Jeju Island in water temperatures of 10.7-24.3°C and salinity of 33.4-34.6 psu. Common squid larvae were distributed mainly from 20 to 80 m in depth. Mantle length (ML) of the larvae gradually decreased with increasing water depth. Average ML of the larvae was 4.47 mm at 0-20 m and 3.68 mm ML at 80-100 m depth. The specimen's size gradually decreased as sample date approached October. Average ML of the larvae was 7.60 mm in April and 2.96 mm in October.

PICES XV FIS_Paper-2993 Poster

Age, growth and maturity of shotted halibut, *Eopsetta grigorjewi*, in the southern coast of Korea

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Age, growth and maturity of shotted halibut, *Eopsetta grigorjewi* in the southern coast of Korea were studied by examination of otoliths and gonads. Marginal increments of otoliths formed annual rings from May to June. The growth of this fish was expressed by von Bertalanffy's equation as follows: $L_t = 531.6\ (1\text{-}e^{-0.16(t-2.47)})$ for females and $L_t = 58.70\ (1\text{-}e^{-0.12(t-2.41)})$ for males, where L_t was total length in mm and t was age in year. The growth of males and females were significantly different ($P< 0.05$). The age composition ranged mostly between ages 3-5 yr. The spawning period of this population was considered to take place from March to May (mainly April). The minimum size at maturity was 307.8 mm TL and the age at which 50% of the fish reached maturity was 3 yr for females.

PICES XV FIS_Paper-2936 Oral

Spatial and temporal dynamics of albacore tuna (*Thunnus alalunga*) and blue shark (*Prionace glauca*) in the Kuroshio Extension area

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Albacore tuna (*Thunnus alalunga*) and blue shark (*Prionace glauca*) catch data from the Japanese longline fishery between 1998 and 2001 were analyzed in conjunction with satellite remote sensing data to examine and detect potential habitat areas for both species in the Kuroshio extension area. Total catch of both species showed opposite seasonal variability, albacore catch tended to be high in fall and winter (October–March), while blue shark catch was high in summer. Geographical distributions of both species also showed significant seasonal variation. Albacore appeared around the Emperor Seamount in August and moved southward so by March they were at 28°N. Generally albacore catches were east of 155°E longitude and blue shark catches by contrast were distributed broadly between 140°E and 180°E. These species might be competitors in the Kuroshio Extension Bifurcation Region (KEBR). Both species seemed to move along the satellite-derived chlorophyll 0.2 mg/m^{-3} isopleth, indicating that movement of the chlorophyll front can be one habitat indicator for both species. Positive sea surface height anomaly around fishing areas suggests that both species may be influenced by warm core eddies. The spatial correlations and links to mesoscale eddy activities will be presented. Although multi-species distributions and their interactions are not fully understood in the Kuroshio extension area, our study will begin developing an approach to multi-species habitat prediction and management.

PICES XV FIS_Paper-2838 Poster

Predictability of Pacific saury fishing grounds using satellite remote sensing and a statistical model

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Pacific saury, *Cololabis saira*, is one of the most important commercial fishes in the northwest Pacific Ocean. This study investigates the relationship between saury caught in Japan and the daily oceanographic variables obtained by satellite remote sensing to predict daily saury fishing grounds. The saury fishery data from southeastern Hokkaido area to eastern Honshu area during 1998-1999 were used in this study. The catch per unit of effort (CPUE) was calculated from the catch per net. Satellite data such as NOAA/AVHRR sea surface temperature (SST), Orbview2/SeaWiFS chlorophyll-*a* concentration (Chl-*a*) and DMSP/SSM/I Surface Wind Speed were employed to examine the oceanographic condition at the fishing grounds. Gradients of SST and Chl-*a* were determined by the histogram analysis within 11x11 pixels window. The generalized additive models (GAM) were applied to analyze the relative influence of various factors on the saury CPUE. The GAM indicated five significant variables (p-value< 0.05) that were important in the order of SST, Chl-*a*, SST gradient, wind speed, and Chl-*a* gradient to predict saury fishing grounds. However, the order of important variables varied by month. SST was the most important variable for saury fishing grounds in September and October (p-value< 0.001), but the other variables were more important in August and November. This study suggested that the relative importance of various environmental conditions was different in each migration stage of Pacific saury. It will be necessary to add different weight (such as p-value) to variables in each month to predict daily saury fishing grounds more accurately.

PICES XV FIS_Paper-2956 Poster
Adaptation of Cephalopoda: A biochemical approach

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One of the directions of modern ecological research is the investigation of the impact of existence conditions on the functioning of living systems. Molecular processes, and first of all enzymes activity, are the basis of all changes of biological systems. The maintenance of high level of locomotion is carried out due to the high speed of the nervous pulse transfer. Therefore, the parameter of the cholinesterase (ChE) activity level can be a biochemical marker of animals' adaptation level to habitat. The nervous tissue of squid *Ommastrephidae* (*O. bartrami* and *T. pacificus*) is characterized by the greatest ChE activity. The resultant data coordinate with existing data on biology of these squid species, which testifies to the greater extent of squid *O. bartrami* migrations. ChE of komandor squid (*B. magister*) is intermediate in enzyme specific activity. Octopus **(***Octopus dofleini***)** nervous tissue has the least ChE activity characterized. However, octopus enzyme has the greatest affinity to substrate, which implies the high speed of short-term motor reactions. Cephalopoda evolution from bottom species to species making significant migrations first affects ChE activity. The strategy of squid feeding behavior, as active predators, is expressed as high speed of cholinergic reactions and high enzyme affinity with substrate. More expressed substrate specificity and high degree of substrate affinity with enzyme is the biochemical base of octopus adaptation to the short term reaction of prey behavior.

PICES XV FIS_Paper-2822 Poster
Histological study of the olfactory system of immature and maturing chum salmon (*Oncorhynchus keta*) in the North Pacific Ocean

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Olfactory sense plays an important role in salmon behavior, such as homing migration, feeding, and social interaction. It is generally accepted that anadromous salmon discriminate the natal stream using their olfactory sense for homing migration, at least during their final riverine stage. On the other hand, it seems reasonable to suppose that salmon on the high seas use olfactory sense for feeding and/or social interaction. However, no intensive physiological studies on olfactory sense (*i.e.*, the olfactory system) have been performed in high seas salmon. Olfactory sensory information about the chemical environment, including food odors, is transmitted to the central nervous system (*i.e.*, brain) through the olfactory receptor cells in the peripheral olfactory system (*i.e.*, olfactory epithelium). Recently, we have developed a technique for detecting two olfactory receptor cell types in salmon olfactory epithelium using light microscopic immunohistochemistry. In this paper, we carried out histological and immunohistochemical analyses of the olfactory epithelium of immature and maturing chum salmon (*Oncorhynchus keta*) along the transect 165°W (45.5-50°N, July, four stations) in 2006 aboard the T/S *Oshoro maru*, Hokkaido University, in the North Pacific Ocean. In addition, we will compare in the olfactory epithelium among young, high seas, and adult chum salmon.

PICES XV FIS_Paper-2853 Oral
Distributions of squid fishing grounds and their relationship to sea surface temperature and chlorophyll-*a* concentration in the Japan Sea

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The Japanese common squid, *Todarodes pacificus*, is one of the most important commercially fished species in Japan. The objectives of this study are to clarify the relationship between squid fishing grounds and their oceanographic conditions in the Japan Sea and to estimate potential fishing grounds using satellite remote sensing. Nighttime visible images by DMSP/OLS (Defense Meteorological Satellite Program, Operational Linescan System) were used to detect distributions of squid fishing fleets from May to October 2002-2004. To

understand spatial and temporal oceanographic characteristics of the fishing fleet positions, NOAA/AVHRR sea surface temperature (SST), Orbview-2/SeaWiFS chlorophyll-*a* concentration (Chl-*a*) and bathymetry data by JODC (Japanese Oceanographic Data Center) were analyzed. Squid fishing grounds were mainly recognized along the east coast of Korea, around Tsushima Strait, around Yamato Rise, along the coast of Honshu, and off northwest Hokkaido. The fishing grounds along the east coast of Korea and around Tsushima Strait were characterized by higher Chl-*a* area (0.25-1.25 mgm^{-3}) and wide SST range (14-26ºC) from May to July, while the areas along the coast of Honshu and in the waters off northwest of Hokkaido were formed in water with lower Chl-*a* (0.15-0.3 mgm^{-3}) and narrow SST range (16-22ºC). In addition, these fishing grounds were limited to the depth of 100-400 m from May to July. The potential fishing grounds are estimated from parameters for each month and each area based on these results. We suggest that this estimation procedure contributes to improved accuracy of predicted fishing grounds.

PICES XV FIS_Paper-2828 Oral
Stock assessment of southern bluefin tuna (*Thunnus maccoyii*) using MULTIFAN-CL

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Southern bluefin tuna (*Thunnus maccoyii*; SBT) is one of the most important tunas in the world ocean. Since the commercial fishery for SBT developed in 1952, the longline fishery expanded rapidly. Largest catches of 85,000 mt were taken in 1961, but catches declined substantially with falling catch rates. Recent studies indicated that there were large declines in both spawning biomass and recruitment. For the conservation of SBT, management procedures (MPs) based on the Fox surplus production model were recently developed by Australia, Japan and Taiwan, contracting parties to CCSBT (Commission for the Conservation of Southern Bluefin Tuna). A variety of data such as, annual catch, catch per unit effort (CPUE), catch at age and recent total allowable catch (TAC) were used as input data. The MPs involve various uncertainties because input data were obtained from Japanese longline fisheries only. Therefore, the necessity of MPs to use more input data and an objective analytical method has become important. In this study we conducted stock assessment of SBT using the age-structured MULTIFAN-CL model. Catch, effort, length-frequency and tagging data from 1965 to 2003 for three model regions and three fisheries were used in this analysis. Results showed that total biomass and spawning biomass of SBT had significantly declined.

PICES XV FIS_Paper-3010 Oral
Size-based indicators to evaluate ecosystem variations in Korean waters

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Size-based indicators (SBI), fish reproduction potential (FRP) and fish community health (FCH), were used to quantify the reproductive probability and trophic level of fish communities, and to foster development of ecosystem-based fisheries management (EBFM) in Korean waters. At a population level, the FRP index was estimated using data on adult fish compositions to total catch, catch (in metric tons) by species, and fishing effort (in horse power per metric ton). At the level of a community, the FCH index was developed by adding trophic level of the catch by species group into FRP. We distinguished FRPs from FCHs in three ecosystems in Korean waters, the East Sea (ESE), Yellow Sea (YSE), and the East China Sea (ECSE) ecosystems. Reference directions of changes (RD), analogous to single-species reference points (RP), under heavy fishing pressure and damaged trophic structure, declined since the base year, 1975. Regime shift analysis of FCH indices showed three regimes. The first decrease to 0.45, 0.89, and 0.60 occurred simultaneously in 1985 in the ESE, YSE, ECSE, respectively. Timing of the second decline varied by ecosystem; in the ESE and ECSE they decreased to 0.40 and 0.17 in 1994, respectively, while in the YSE they declined to 0.55 in 1992. Patterns of variations between FRPs and FCHs in the three ecosystems were similar with correlation coefficients of 0.93 – 0.98, while the magnitude between the two indices differed. SBIs can explain underlying processes to policy makers and non-scientists, by integrating multiple data to summarize the state and functioning of exploited ecosystems cost-effectively.

PICES XV FIS_Paper-3068 Poster
Fish reproduction potential (FRP) index of marine ecosystems in Korea

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We developed an ecosystem indicator (EI) describing the response of fish populations to exploitation in coastal and offshore waters off Korean. Fish reproduction potential (FRP) was defined as an ecosystem indicator describing the reproductive probability of adult fish resources in Korean waters. The FRP indices were estimated using data of adult fish compositions to total catch, catch (in metric ton) by species and by ecosystem, and fishery efforts (in horse power per metric ton). All of the FRP indices of the East Sea ecosystem (ESE), Yellow Sea ecosystem (YSE), and East China Sea ecosystem (ECSE) started to decrease after the mid 1980s and the current indices further decreased to 0.63 in the ESE, 1.22 in the YSE, and 0.68 in the ECSE, respectively, compared to the indices of year 1975 when their catch amounts between two periods were similar. Lower FRPs in the Korean marine ecosystems represent a higher proportion of immature fish resources in the catch. The FRP indices can be used as an important tool to diagnose the status of marine ecosystems in quantity as well as in quality.

PICES XV FIS_Paper-3052 Poster
Bias in size distribution estimates for fish populations due to sampling gear selectivity and sample sizes

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Unbiased estimation of fish size distributions from samples is an important activity in fishery science, as these distributions are used to determine age and growth, mortality, and stock structure of the population. However, a certain portion of a population may not be sampled effectively due to sampling gear selectivity and insufficient sample size. In this study, the effects of gear selectivity and sample size on the estimation of size distributions were examined using computer simulation experiments. For simulations, a finite population of individual fish weights (n=50,000) was generated based on the distributional characteristics of channel catfish samples collected from a commercial aquaculture pond in Arkansas, US. Four different scenarios of gear selectivity were examined; equal catch probability, reduced probability for either end and for both ends of the size distribution. Each end of the size distribution comprised of about 3% of total population. The effects of six different sample sizes were also examined, ranging from 0.1% to 5% of population size. Nonparametric Kolmogorov-Smirnov tests were used to statistically compare the distributions of samples-to-population and samples-to-samples. The results indicated that uneven selectivity for only a small fraction of the size classes could bias the distribution estimates. Small sample size could lead to false positive conclusions. Interestingly, increase in sample size did not reduce the discrepancy in distributions between samples and population, when sampled under uneven selectivity. Careful examinations on the characteristics of gear selectivity appear to be more critical than increasing sample size to obtain unbiased estimates of size distribution.

PICES XV FIS_Paper-3170 Poster
Fishing down or just too many small pelagics?

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The fishing down marine food webs concept (FD) has been widely used to denote ecosystem overfishing. However, it seems that for boundary current systems (Humboldt, California, Kuroshio) it may not be adequate. Such areas are likely dominated by small pelagics whose relative contribution to total landings determines the mean trophic level (MTL) evolution. Here, we show that this proportion of sardine and anchovy in major

productive marine ecosystems is strongly (r^2 >0.7 – 0.85) and inversely related to historical records of MTL, implying that: 1) given the close relationship between climate and worldwide small pelagics abundances, historical trend in MTL, at least for the mentioned areas, is chiefly dominated by a global signal independent of fishing pressure; and 2) FD should not be used indiscriminately to assess ecosystem health.

PICES XV FIS_Paper-2938 Oral

Fish ecology plays a key role in understanding the potential for commercial fishing to impact prey fields of endangered Steller sea lions

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The Fishery Interaction Team (FIT) at the Alaska Fisheries Science Center was formed in 2000 to investigate the potential ecosystem effects of commercial fishing. FIT researchers are presently interested in interactions between commercial fisheries and endangered Steller sea lions. The research activities of FIT currently focus on three commercially fished groundfish species in Alaska: Pacific cod, Atka mackerel and walleye pollock. To investigate whether fishing impacts Steller sea lion prey fields, we conducted at-sea experiments that used a before-after, treatment-control type design to compare the change in fish abundance within heavily-trawled areas during the fishing season to the change within adjacent no-trawl zones. These studies focused on Pacific cod and walleye pollock. To evaluate the efficacy of trawl exclusion zones at maintaining sufficient quantities of prey for sea lions, we used tag release-recovery methods to estimate local fish abundance and movement rates inside and outside the zones. This study focused on Atka mackerel. In addition, fish food habits, reproductive biology and pelagic habitat selection were studied during field research experiments. Results to date indicate that fish ecology (movement, feeding, habitat selection and reproduction) plays an important role in understanding the potential for commercial fishing to cause localized depletions of fish. Fish ecology is also key to assessing the role of trawl exclusion zones at maintaining local concentrations of fish for foraging sea lions.

PICES XV FIS_Paper-3127 Oral

Migration patterns of big skate (*Raja binoculata*) based on a large-scale tagging study in northern British Columbia waters: Preliminary results

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Since 1996, catches of big skate have increased dramatically in British Columbia waters in response to increased market demand. Major fisheries occur in Queen Charlotte Sound and Dixon Entrance in Northern Hecate Strait. Concern about exploitation of this species led to questions regarding stock structure northern waters. Since 2003, approximately 12,000 big skate were tagged and released in these two areas combined. This program is the most extensive tagging study on any skate species and allows examination of big skate migration patterns. As of May 2005, 549 tagged skate have been recaptured with reliable recovery location information. Generally, big skate were recaptured close to their release site, within 20 km. Approximately 18% of the recaptured big skate moved 20-100 km from their release location. Some (5 % of those recaptured) moved between the two main fishing areas (> 100 km). Five extensive migrations (> 1000 km) were observed. One skate released in March 2003 in Dixon Entrance was recaptured in the Bering Sea, just north of the Aleutian Chain in November 2004. Two big skate released in August 2003 in Queen Charlotte Sound were recaptured in April 2004 in Prince William Sound. An additional two skate released in August 2003 in Queen Charlotte Sound were recaptured in April and May 2005 in Prince William Sound and near Kodiak Island, respectively. Although 76% of recaptured big skate were recovered very close to their release location, movement of the remaining 24% illustrates that big skate migration may be more complex than previously thought.

PICES XV FIS_Paper-2974 Oral
Acoustic monitoring of Japanese anchovy (*Engraulis japonicus*) post-larvae "shirasu"

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The post-larval stage of the Japanese anchovy *(Engraulis japonicus)*, called "shirasu", is widely distributed in inshore and offshore areas in Japan, and is an important commercial target in Japan. It is also an important prey for nekton, seabirds, and marine mammals, and plays an important role in the ecosystem. Therefore, quick biomass estimates of shirasu are an essential to conduct cosystem-based management. An acoustic method is the most practical way to quantitatively investigate a wide area in a short time. In this study, we tried to accurately identify the echoes of shirasu using a quantitative echosounder at two frequencies (38 and 120 kHz), and then to estimate the horizontal distribution characteristics of shirasu. Acoustic surveys and net sampling were carried out in October and December 2003 and January to July 2004 in the Kii Channel, Japan. Echoes of the shirasu school were identified by the volume back-scattering strength difference method, and were overlaid on maps of surface temperature using GIS software. In the fishering seasons (October 2003, April to July 2004), a large number of shirasu schools were observed, but in the non-fishering seasons (December 2003, January and February 2004), few shirasu schools were observed. These results suggest that shirasu can be identified quantitatively using the acoustic method.

PICES XV FIS_Paper-2845 Oral
Estimation of growth parameters of minke whale, *Balaenoptera acutorostrata*, in Korean waters

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Population dynamics of minke whale is important for fisheries management because minke whales have the largest biomass of all cetaceans of marine ecosystems. In this study, we sampled North Pacific minke whales, *Balaenoptera acutorostrata* that were bycaught in Korean waters, from April 2002 to May 2004. Age determination was carried out using baleen plates. One hundred twenty-six baleen plates and eleven ear plugs were analyzed to age. There was a 2-year difference between growth layer groups of baleen plates and those of ear plugs. Maximum age was estimated at 12 years with 810 cm from baleen plates, and maximum age estimated from an ear plug was 7 years with a length of 740 cm. Mean length by age was estimated at 408.8 cm for age 0 to 810 cm for age 12. The von Bertalanffy growth parameters estimated from a non-linear regression were L_∞ = 878.25 cm, K = 0.1774/yr and t_0 = -3.36. For females, the von Bertalanffy growth parameters were estimated as L_∞ = 946.02 cm, K = 0.137/yr and t_0 = -3.93. For males, they were estimated as L_∞ = 842.3 cm, K = 0.21/yr and t_0 = -3.05.

PICES XV FIS_Paper-2825 Poster
Predictable hotspots for Skipjack tuna, *Katsuwonus pelamis*, using multi-sensor satellite remote sensing off the east coast of Japan

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Skipjack tuna, *Katsuwonus pelamis*, is widely distributed in the Pacific Ocean between 40°S and 40°N latitudes. In spring, this species migrates for foraging from an equatorial area to the waters off Joban-Tohoku area, one of the world's most biologically productive regions where two currents mix. The objectives of this study are to (1) explore potential hot spot habitats for skipjack tuna; and (2) analyze migration patterns for skipjack tuna using

an integration of satellite-based observations and GIS. To describe hot spots for skipjack tuna, we used remotely sensed data from multi-sensor satellite images of NOAA/AVHRR sea-surface temperature (SST), SeaWiFS chlorophyll-*a* concentration (Chl-*a*), fisheries catch data. We employ a simple prediction model and an environmental probability model to generate predictable hotspots. The simple prediction model is constructed from the significant and favorable ranges of the two environmental variables (SST, Chlorophyll-*a*) based on the confidence limits (mean ± standard deviation). The environmental probability model is used to identify hot spots, and takes into account both CPUE and frequency of fishing effort in relation to the biophysical environmental variables (SST, Chlorophyll-*a*). SST in hotspots tended to change from warm to cold and Chl-*a* in hotspots tended to change from low to high during August to November, 2004. Predictable hot spots using these two models were in good agreement with actual skipjack fishing grounds.

PICES XV FIS_Paper-3037 Poster
Length-weight relationships of deep-sea fishes from the western Bering Sea

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Length-weight relationships are useful to obtain estimates of biomass, as may be needed for ecosystem modeling, when only length-frequency distribution of specimens is reported. For deep-sea fishes, few studies on length-weight relationships have been published. This work presents the analysis of length-weight measurements of deep-sea fishes from samples taken during pelagic trawl surveys in 1990 and bottom trawl surveys and commercial cruises in 1995-1998 in the western Bering Sea. The study covers a range of small and large midwater and bathydemersal fishes, comprising 43 species and 20 families. Many of these species are commercially exploited. The estimates obtained here are compared with available length-weight estimates from the literature.

PICES XV FIS_Paper-2807 Poster
Seasonal changes of environmental conditions of the most abundant and common groundfish species in the Pacific off the North Kurils and South Kamchatka

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The Pacific waters off the northern Kuril Islands and southeastern Kamchatka are characterized by complicated oceanographic conditions caused by climatic features, complex bottom relief, current dynamics, and tidal events. Nineteen bottom trawl surveys (about 1,500 hauls) and 21 oceanographic surveys (over 1,500 stations) were conducted during 1993-2000. Patterns of fish distribution, their physiological condition and fluctuations of abundance are well known to be closely related to changes of climatic and oceanographic conditions. Yet, until now few studies have investigated the relationships between the distribution of fishes in study area and environmental parameters. The analysis of relationships between maximum catches of 14 commercial fishes and red squid *Berryteuthis magister* and depth, bottom temperature, salinity and water masses and also relationships between patterns of distribution of some groundfishes and quasi-stationary, anti-cyclonic eddies are exceptions. We investigated seasonal changes in bathymetric distributions of 60 most abundant and common groundfish species in the study area (6 skate species Rajidae, walleye pollock *Theragra chalcogramma*, Pacific cod *Gadus macrocephalus*, 2 grenadiers Macrouridae, 2 morid cods Moridae, 3 eelpouts Zoarcidae, prowfish *Zaprora silenus*, 2 rockfishes *Sebastes* spp., 2 thornyheads *Sebastolobus* spp., sablefish *Anoplopoma fimbria*, 2 greenlings Hexagrammidae, 11 sculpins Cottidae, 2 fatheads Psychrolutidae, 4 poachers Agonidae, smooth lumpsucker *Aptocyclus ventricosus*, 12 snailfishes Liparidae and 7 flatfishes Pleuronectidae), as well as their distributions with respect to bottom temperature and salinity. This analysis is based on data obtained during 6 spring (453 stations), 9 summer (702 stations), 5 autumn (327 stations) and 1 winter (44 stations) surveys.

PICES XV FIS_Paper-2957 Poster
Seasonal distribution of immature pollock in the northern Okhotsk Sea

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Immature pollock usually concentrate in the northeastern and western Okhotsk Sea – the area of TINRO and Derugin Basins. We compared seasonal distribution of immature pollock 1999-2003 year classes. Data collected in autumn 2003 and spring 2004 were used in the analysis. 0+ year old pollock inhabit the shelf near the spawning ground at a depth < 100 m. 1- year old pollock were distributed deeper (100-300 m) in autumn. 1+ year old pollock inhabit the shelf, but basically concentrate on the continental slope (200-300 m). This year class (2-years old fish) concentrated at depths 200-500 m in spring. These data suggest that, 0+ - 2-year old pollock gradually migrate from the spawning ground to the TINRO and Derugin Basins. Migratory activity of recruits (2+ to 5-years old) increased, and they were distributed more widely at depths 100-500 m and deeper. Their distribution is connected with seasonal variability of hydrological conditions in the northern Okhotsk Sea. Immature 2-5 year old fish avoid cold shelf waters and concentrate in area the TINRO and Derugin Basins in the winter and early spring. They disperse and distribute at shallower depths, when the spring warming of shelf waters begins.

PICES XV FIS_Paper-2826 Poster
Feeding habits of Pacific salmon in the North Pacific Ocean in summer 2005

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Results of many studies on feeding ecology of Pacific salmon show that: 1) Pacific salmon are extremely adaptable to changes in the marine environment, 2) salmon have a wide diversity of prey, and 3) their prey selectivity is related to inter- and intra-specific interaction. We examined the feeding habits of Pacific salmon collected by non-selective drift gillnets aboard the T/V *Oshoro maru* (Hokkaido University) in the Western Subarctic Gyre (WSG; 45-50ºN165ºE, 3 stations) and the Gulf of Alaska (GA; 45-47.5ºN165ºW, 4 stations) in summer 2005. Sockeye and pink salmon mainly fed on amphipods, copepods, and euphausiids in the WSG, and fed on amphipods and squid in the GA. Chum salmon mainly consumed copepods, gelatinous zooplankton, and amphipods in the WSG, and copepods and amphipods in the GA. Thus, Pacific salmon show different feeding habits between the WSG and the GA. Although euphausiids, amphipods, and copepods were common prey of Pacific salmon in both gyres, the dominant food differed among species such as squids in coho salmon, amphipods in sockeye and pink salmon, and gelatinous zooplankton in chum salmon.

PICES XV FIS_Paper-2982 Poster
Analysis of time series of coastal fishery catches in the Tsushima Warm Current region in relation to temperature changes

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The fish community in Japan Sea is characterized by diverse fishes from warm water pelagic species and cold water demersal species. Water temperature is one of the primary factors in determining this characteristic. Recent water temperature change due to global warming has significantly affected coastal fishery composition in Tsushima Warm Current region. In order to clarify the impact of water temperature change on structure of fish community, we analyzed time series of gillnet fishery data and water temperature data from 1995 to 2004 together. The result shows that the trend of total catch has followed trend of water temperature; total catch is low when water temperature low and vice versa. There are three dominant species during 10 yr of study; (1) *Turbo cornutus*, non migrating rocky shore organisms, are dominant during cold year (1996) and decrease as water temperature increases; (2) *Gadus* spp., demersal migrating species originating from northern regions,

show an increasing trend in recent years; and (3) *Seriola* spp., pelagic migrating species originating from southern regions, seem to respond positively to the water temperature. The large change in dominant fish species in 1997-1998 may be related to the water temperature increase during this period.

PICES XV FIS_Paper-3083 Poster
Coastal ecosystem of the Yeo-Ja Bay in the southern sea of Korea

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The Yeo-Ja Bay ecosystem (YBE) is located in the southern sea of Korea and is surrounded by the Yeo-Su and Go-Hung Peninsula. It is a typical coastal embayment that has an area of 318 km^2 and average depth of 10 m. While the YBE is most important area for habitat and spawning ground of organisms inhabiting the southern sea of Korea, fish stocks have been decreasing due to overfishing and environment pollution. Therefore, it is necessary to implement management for rebuilding for the YBE. In this study, we conducted seasonal survey every three months in 2005 using the small trawl gear and analyzed seasonal change of dominant species and abundance. The dominant species in the YBEs were crustaceans, such as *Thalamita sima*, *Oratosquilla oratoria* and *Crangon hakodatei*, and dominant fishes were *Argyrosomus argentatus* and *Muraenesox cinereus*. We collected the ecological information and divided groups by self-organized mapping (SOM) for all organisms. Using the ecosystem model, ECOPATH, we constructed the structure of the YBE and analyzed ecotrophic levels of functional groups. Also, we conducted a comparative study of origin of the prey that analyzed composition of stable isotopes for major species in the YBE. Finally, considering the ecosystem and commercial fishing intensity, a management and rebuilding plan for the YBE was suggested and discussed in this study.

PICES XV FIS_Paper-3034 Poster
The feasibility of photo-identification techniques for bottlenose dolphin (*Tursiops truncatus*) in Jeju Island, Korea

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The feasibility of using photo-identification techniques for bottlenose dolphin in Jeju Island of Korea and the possibility of whale watching using this species were evaluated. We observed a population of bottlenose dolphins, which is composed of approximately 30 individuals, on the southwestern coastal area of Jeju Island. We took a total of 246 photographs of bottlenose dolphins, and 35 photographs were sufficiently suitable for identification of individuals. Among 35 suitable photographs, we identified and cataloged a total of 5 individuals from unique nicks and notches on their dorsal fins. Consequently, we confirmed the feasibility of photo-identification techniques for bottlenose dolphin in Jeju Island. Furthermore, this population of bottlenose dolphins in Jeju Island appears as a suitable species for a long-term population biology study using photo-identification techniques because of their small group size and high possibility of stable home ranges around Jeju Island throughout the year. On the other hand, they showed the behavior of approaching to boat and riding bow waves without avoidance of the boat. Consequently, we thought that the possibility of whale watching using bottlenose dolphins in Jeju Island is very high if we have more information on the seasonal distribution, movement and residency of this population of bottlenose dolphins in Jeju Island in a future study. This study is the first report on the comprehensive sighting survey and photo-identification survey of bottlenose dolphins in Jeju Island, Korea.

PICES XV FIS_Paper-2802 Poster
Effect of biological and physical factors on recruitment variability of eastern Bering Sea pollock

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Recruitment of Bering Sea pollock shows high interannual variability. Among the last 30 years, abundant year-classes pollock appeared only in 1978, 1982, 1984, 1989, 1992, 1996 and 2000. Year-classes strength does not depend on total population biomass nor female spawning biomass. Also there is no direct dependence of strength pollock year-classes on water temperature nor ice distribution in the Bering Sea. Generally, pollock eggs, larvae and juveniles are advected from main spawning grounds in the southeastern Bering Sea for long distances, but there is no relationship between the year-class strength and the distribution of juveniles or 1-year old pollock. Pollock juveniles were abundant in 1997, 2000, 2003, 2004 but only the 1996 and 2000 year classes were strong. Recent data show that juvenile survival varies widely in winter. Surveys demonstrate that survivals of juveniles in different areas of the Bering Sea in winter are often very similar despite significant differences of regional physical condition. Most data show that the feeding environment of juvenile pollock could affect survival in winter and eventual recruitment. In spite of a diversity of plankton species in the Bering Sea, just 1-2 species predominate in pollock feeding and often production of zooplankton is low in autumn. During the 1980-1990s high zooplankton production was observed in the Bering Sea only in 1989, 1992 and 1995. These observations support the hypothesis that poor feeding habitats for pollock juveniles in autumn and winter could be the cause of their low survival.

PICES XV FIS_Paper-2808 Oral
Environmental cues for herring spawning timing in northern Bristol Bay, Alaska

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Spawning timing of Pacific herring (*Clupea pallasii*) varies by up to one month interannually in northern Bristol Bay. Fisheries in this region depend on availability of herring with mature roe, which are available during limited fishing opportunities just prior to the spawning season. The fishing industry and fishery managers mobilize for this remote fishery from other areas of the state. To reduce risks of foregone harvests or higher operating costs associated with unexpectedly early or late spawning, we developed prediction models based on relationships between herring spawning and air-sea-ice environmental variables in northern Bristol Bay. Multiple regressions formed these models through spatio-temporal analyses with ArcGIS. Statistical relationships between the timing of both school arrival and spawning with air-sea-ice environmental conditions are most significant ($P< 0.001$) in April. Spawning timing was most strongly correlated ($P< 0.05$) with both surface air temperature (SAT) and sea surface temperature (SST) in the southwestern offshore area and with observed sea ice total concentration along the eastern sea ice edge extending toward shore. Predictive models include sea ice total concentration in the migration corridor and Cape Newenham SAT near coastal spawning sites. Pre-spawning herring respond to thermal structure over the southeastern Bering Sea shelf driven by the atmospheric pressure gradient over the North Pacific and Arctic regions. An effect herring body size on spawning timing was not detected, but an underlying effect of body size may be masked by herring school responses to local thermal conditions or by a coarse spatial sampling of catches.

PICES XV FIS_Paper-2809 Poster

Migration dynamics of Pacific herring (*Clupea pallasii*) and response to spring environmental variability in the southeastern Bering Sea

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Pacific herring (*Clupea pallasii*) undergo large-scale migrations in the southeastern Bering Sea involving over-wintering near the Pribilof Islands and spawning along the Alaska coast in spring. The location of fish and timing of pre-spawning migration is important for management of a nearshore commercial fishery that targets roe-bearing fish just prior to spawning. Also, herring bycatch is managed by time and area closures triggered by bycatch caps in groundfish trawl fisheries. The goal of our study was to determine the seasonal migration pattern of Pacific herring and its spatial and temporal variability to improve fisheries management. Using herring bycatch data collected by NMFS observers aboard groundfish vessels since the 1970s, we conducted a retrospective analysis to achieve the goal. Observed changes in herring catch per unit of effort (CPUE) were compared with variability in climate and oceanographic conditions in ArcGIS. Seasonal migration patterns are more complex than evidenced by past findings, and annual shifts in migration pathways and a possible northward shift of the over-wintering grounds were identified. Pre-spawning herring concentrated in distinctly different areas, depending on whether annual spawning was early or late. The thermal structure around the ice edge appears to affect herring migration timing and route, as well as spawning timing. Given recent large shifts in sea-ice extent and duration, the herring bycatch savings area based on 1980s data should be revised to reflect prevailing conditions.

PICES XV FIS_Paper-2925 Poster

Distribution and growth of juvenile chub mackerel, *Scomber japonicus*, in the Kuroshio-Oyashio transition region

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Distribution and growth rate of juvenile of chub mackerel, *Scomber japonicus*, in the Kuroshio-Oyashio (35-40°N, 142-164°E) transition region were investigated by mid-water otter trawl surveys during May 2003-2006. Mid-water trawls were towed in the Kuroshio-Oyashio transition region in 2003-2006. The radii of each daily growth ring on otoliths were measured and growth trajectories were back-calculated using the biological intercept method for 204 specimens (30-95 mm FL) of juveniles. Juveniles were widely throughout the survey area in 2004 and 2005, but those collected in 2003 and 2006 were restricted to the areas of 35-40°N, 154-156°E, and 36-38°N, 147-150°E, respectively. Annual mean growth rates up to 25 days old were 1.04±0.17 in 2003, 1.37±0.24 in 2004, 1.06±0.16 in 2005, and 0.91±0.15 mm/day in 2006. Mean growth rate of the 2004 cohort of high RPS (recruitment per spawning) was significantly higher than those of 2003, 2005 and 2006 cohorts of low RPS. This result suggests that the growth rate up to 25 days old in chub mackerel has an influence on their survival process.

PICES XV FIS_Paper-3162 Poster

Spatio-temporal distribution of Pacific cod, *Gadus macrocephalus*, in the western sea of Korea

Hak Jin Hwang, Yang Jae Im, Myoung Ho Sohn, Inja **Yeon**, Naek Joong Choi and Mi-Young Song

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Landings of Pacific cod, *Gadus macrocephalus*, from the western sea of Korea have increased recently. This study, focuses on spatial-temporal density distribution variations in this species, using 2002 to 2005 bottom trawl data to identify stock fluctuations. Fish resources management is based on stock trends. Overall, highest densities appeared offshore of Kyunggi Bay during the four years. Seasonal densities were highest from November to December, and lowest from February to March. In winter, the main area of abundance expanded to the east to Eocheong Island, and was limited by both the warm thermal front from the Kuroshio Current in the south part of the sea and by water below 10ºC in the middle of the Yellow Sea. We plan further study to assess stock size and to determine the optimum catch level for sustainable harvest of this population.

PICES XV FIS_Paper-3161 Poster

The reproductive biology of blue crab, *Portunus trituberculatus* (Miers), in the western sea of Korea

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Landings of blue crab, *Portunus trituberculatus* (Miers), in Korean waters have declined from 32,000 t in 1988 to 4,000 t in 2005. Therefore, additional management measures are necessary to conserve and to rebuild the stocks. Improving our understanding of this species' reproductive biology is being studied to help develop more optimum management. Our study looked at 2040 specimens that were collected from monthly samples in the western sea of Korea from March 1995 to December 1997. Biometric data analysis of reproductive biological characteristics of this species indicated that the main spawning period was from April to October with a peak from June and July; and that mating was from July to November with a peak from July to October. Female copulation happened after spawning from July to August in crabs older than one year, and after the molt to maturity from September to October in younger crabs. The estimated size at 50% maturity was 10.8 cm carapace width, excluding the spines. We recommend that the closed fishing period be changed from July ~ August to May ~ July, that the minimum legal size dimension be changed from carapace length to carapace width, and that the minimum size limit be increased from 9.2 to 11 cm carapace width (5 to 6.5 cm carapace length) to improve recruitment to the population.

POC Paper Session

Convenor: Michael. G. Foreman (Canada)

Papers are invited on all aspects of physical oceanography and climate in the North Pacific and its marginal seas

Tuesday, October 17, 2006 9:00-18:00

09:00-09:20 **William R. Crawford**
Transport and mixing of continental margin waters into mid-basin by anticyclonic eddies: An example from the Gulf of Alaska (POC_Paper-3200)

09:20-09:40 **Masatoshi Sato and Tokihiro Kono**
Seasonal variation of current structure in the subarctic North Pacific from Argo data (POC_Paper-3214)

09:40-10:00 **Young-Gyu Park, Chang-Hwan Park and Sang-Wook Yeh**
The formation of the Tsushima Warm Current in a high resolution ocean circulation model (POC_Paper-2984)

10:00-10:20 **Ye Yuan, Wen-Sheng Jiang and Liang Zhao**
Estimating suspended sediment concentration using ADCP, LISST-100 and OBS in Jiaozhou Bay and Laizhou Bay, China (POC_Paper-2832)

10:20-10:40 **Svetlana Yu. Glebova**
Features of atmospheric circulation over the Asian-Pacific region in 2000-2006 (POC_Paper-2800)

10:40-11:00 ***Tea/Coffee Break***

11:00-11:20 **Liqi Chen**
China's international polar year 2007-08 projects and CHINARE's SOLAS in polar regions (POC_Paper-3248)

11:20-11:40 **Pavel Ya. Tishchenko, Sergey G. Sagalaev, Vyacheslav B. Lobanov, Alexander P. Nedashkovskiy, Galina Yu. Pavlova and Lynne D. Talley**
Peculiarities in distribution of the N:P ratio in seawater of the Japan/East Sea (POC_Paper-2955)

11:40-12:00 **Melissa Chierici, Agneta Fransson and Yukihiro Nojiri**
Evolution of the surface water carbon dioxide in relation to the annual trends in salinity and temperature in the Oyashio region (POC_Paper-3022)

12:00-12:20 **Agneta Fransson, Melissa Chierici and Yukihiro Nojiri**
Comparison of interannual trends in the surface water pCO_2, salinity and temperature in the subarctic North Pacific (POC_Paper-3029)

12:20-12:40 **Shigeho Kakehi, Kazuyuki Uehara, Shin-ichi Ito, Kosei Komatsu, Hiroaki Saito and Miwa Nakamachi**
The processes of AOU change in the North Pacific (POC_Paper-2967)

12:40-14:00 ***Lunch***

14:00-14:20 **Konstantin Rogachev**
Cooling at hot spots: Amplification of tidal currents over banks and 18.6-year tidal cycle in the Oyashio and Sea of Okhotsk (POC_Paper-2818)

14:20-14:40 **Michael G. Foreman, Patrick Cummins, Josef Cherniawsky and Phyllis Stabeno**
Tidal energy and the 18.6-year cycle in the Bering Sea (POC_Paper-2796)

14:40-15:00 **Satoshi Osafune and Ichiro Yasuda**
Bidecadal variations of water properties around the Bering Sea and the relation with the 18.6-year period nodal tidal cycle (POC_Paper-3150)

15:00-15:20 **Fangli Qiao and Xingang Lv**
The upwelling system in the East China Sea in winter and summer (POC_Paper-3215)

15:20-15:40 **Ig-Chan Pang, Jae-Hong Moon, Takeshi Matsuno, John M. Klinck, Jin-Young Kim, Hee-Dong, Jeong, Ki-Tack Seong and In-Seong Han**
Distribution mechanism of Changjiang diluted water in the East China Sea (POC_Paper-3160)

15:40-16:00 ***Tea/Coffee Break***

16:00-16:20 **Se Han Lim, Chan Joo Jang and Im Sang Oh**
Spatial and temporal variations of the mixed layer depth in the East Sea (POC_Paper-2857)

16:20-16:40 **Olga O. Trusenkova, Sergey V. Stanichny and Yuri B. Ratner**
Variability modes and typical patterns of surface wind over the JES and adjacent land (POC_Paper-2890)

16:40-17:00 **Tokihiro Kono, Tomonori Hamatsu, Keizo Yabuki, Kazutoshi Watanabe and Michael G. Foreman**
Transport of walleye pollock (*Theragra chalcogramma*) eggs between 1989 and 1995 and its causes on the southwest coast of Hokkaido, Japan (POC_Paper-3140)

17:00-17:20 **Fan Wang**
Long-term variability of temperature in the Yellow Sea and the East China Sea in the past 40 years (POC_Paper-3098)

17:20-17:40 **Jae-Yul Yun, Kuh Kim, Kyung-Il Chang, Yang-ki Cho and Lorenz Magaard**
The El Niño teleconnection to the isopycnal fluctuations in the southwestern East Sea/Japan Sea (POC_Paper-3128)

17:40-18:00 **Changshui Xia, Fangli Qiao, Yongzeng Yang and Yeli Yuan**
The development of a wave-tide-circulation coupled model and its application in the Yellow Sea and the East China Sea (POC_Paper-2873)

Posters

Tatyana V. Belonenko and Alexey V. Koldunov
Rates of steric sea-level variation for the Kuril area in the North Pacific (POC_Paper-2770).

Yongli Chen, Yongping Zhao, Fan Wang and Aiming Wu
The pathway of interannual and interdecadal variability of the Pacific subsurface ocean temperature anomaly (POC_Paper-2954)

Yang Ho Choi, Young Jae Ro and Chang Su Jeong
Development of a hydrodynamic and eutrophication model of the west coast of Korea (POC_Paper-2907)

Shan Gao, Fan Wang, Mingkui Li, Yongli Chen, Changxiang Yan and Jiang Zhu
Application of altimetry data assimilation on mesoscale eddies simulation (POC_Paper-2919)

Hitoshi Kaneko, Hiroji Onishi and Ichiro Yasuda
Formation processes of temperature inversions in the subarctic North Pacific (POC_Paper-3130)

Eung Kim, Young-Jae Ro, Yu-Hwan Ahn and Kwang-Young Jung
Estimation of sea surface current vectors based on satellite images around the Korean Marginal Sea (POC_Paper-3133)

Yun-Bae Kim, Kyung-II Chang, Jae-Hun Park, Jong-Jin Park, D. Randolph Watts, Jae-Hak Lee and Kuh Kim
Low-frequency deep flow variability in the Ulleung Basin (POC_Paper-3165)

Viktor V. Koldunov
Research of interannual variability of the mean sea level in the North Pacific (POC_Paper-2795)

Kosei Komatsu, Takashi Setou and Yasumasa Miyazawa
Abrupt change of mixed-layer structures caused by horizontal intrusion of the warm water mass from the Kuroshio into the coastal region off Enshu-nada, south of Japan (POC_Paper-3134)

Kosei Komatsu, Yasumasa Miyazawa and Takashi Setou
Effects of wind and waves on the jet-leaving transport of surface materials around the Kuroshio and the Kuroshio Extension (POC_Paper-3136)

Kosei Komatsu, Yasumasa Miyazawa and Takashi Setou
Modification processes of intermediate water around the Kuroshio region (POC_Paper-3135)

Mingkui Li, Fan Wang, Yongli Chen, Shan Gao and Fangli Qiao
Parameterization of tidal current-induced vertical eddy viscosity (POC_Paper-2948)

Vyacheslav Lobanov, Vladimir Zvalinsky, Anatoly Salyuk, Pavel Tishchenko, Sergey Zakharkov, Svetlana Ladychenko, Boris Lee, Kyung-Ryul Kim, Jae-Young Lee and Victoria Nadtochiy
Physical, chemical and biological structure of an anticyclonic eddy in the northwestern Japan Sea (POC_Paper-3219)

Valentina V. Moroz and Konstantin T. Bogdanov
Variability of water characteristics in the Kuril-Oyashio Current system (POC_Paper-2870)

Hanna Na, Kuh Kim and Kyung-II Chang
Application of high-frequency radar to the east coast of Korea (POC_Paper-2928)

Masayuki Noto and Ichiro Yasuda
Bi-decadal variations in SST relating to a tidal cycle of 18.6-year periods around the Kuril and Aleutian Islands (POC_Paper-2921)

Sachiko Oguma, Tsuneo Ono, Akira Kusaka and Yutaka W. Watanabe
Stable isotopes as chemical tracers in the coastal region around eastern Hokkaido (POC_Paper-3001)

Jong Jin Park and Kuh Kim
Kinetic energy flux of inertial frequency motion out of the mixed layer and its balance with wind energy input in the global scale ocean (POC_Paper-3107)

Natalia I. Rudykh, Vladimir I. Ponomarev and Elena V. Dmitrieva
Linkages of oceanographic characteristic variability in the Tatarskii Strait with the Amur River discharge (POC_Paper-2953)

Yugo Shimizu, Hiroaki Tatebe, Ichiro Yasuda, Shin-ichi Ito, Shigeho Kakehi, Akira Kusaka and Tomoharu Nakayama
Southward Oyashio intrusion revealed by profiling floats set to drift in the intermediate layer (POC_Paper-3174)

Miyuki Tatesawa, Shin-ichi Ito, Yugo Shimizu and Shigeho Kakehi
Seasonal variation of dissolved oxygen in the Oyashio (POC_Paper-2912)

Shuichi Watanabe, Masahide Wakita, Vyacheslav B. Lobanov and Igor Zhabin
Distributions of chemical species in the subarctic North Pacific and the western Bering Sea during 2004 summer cruise (POC_Paper-3225)

Masahiro Yagi and Ichiro Yasuda
Vertical eddy diffusivity at the Bussol' Strait in the Kuril Islands from CTD data (POC_Paper-3129)

PICES XV POC_Paper-2770 Poster
Rates of steric sea-level variation for the Kuril area in the North Pacific

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Various approaches are taken to estimate steric sea-level fluctuations, however, they all recognize that steric sea-level in the Pacific reaches the greatest values (50-70 mm) in an average range of 20-45°N latitude in dynamically active areas. In cold waters of the Oyashio Current and the Kamchatka Current steric sea-level values are insignificant (10-20 mm). The steric sea-level contribution dominates during seasonal variability in the North Pacific and is caused mainly in response to seasonal changes in heat and advective inflows.

We offer a different method to estimate steric sea-level. In the beginning we estimate the speed of steric sea-level changes for every month and then the absolute values are computed.

Rates of change of the steric sea-level variation are present for the Kuril area in the Pacific according to calculations by hydrodynamic motion equations and mass continuity equation.

The Generalized Digital Environmental Model GDEM data set is used to compute monthly-averaged temperatures and salinities at standard depths at the nodes of a regular grid. At 24 points in the open Pacific Ocean we obtained values of the steric sea-level oscillations and their rates of change as well as coefficients of pair-correlation and cross-correlation with the sea surface temperature and their respective time lags. The sea surface temperature (SST) is shown to be a good predictor for forecasting steric sea-level oscillations, including operative forecasts, taking into account that steric sea-level oscillations are lagged by the change in SST.

PICES XV POC_Paper-3248 Oral
China's international polar year 2007-08 projects and CHINARE's SOLAS in polar regions

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Under the leadership and in appreciation of the International Council for Science (ICSU) and the World Meteorological Organization (WMO), over 200 programs have been accepted for initiation during the International Polar Year (IPY) 2007-08. China will develop a network of observation stations from Prydz Bay, Larsemann Hills, Zhongshan-Dome A transect, Amery Ice Shelf, the Glove Mountains to Dome A (PANDA). The project will cover five major themes: sea ice, circulation and water masses in Prydz Bay; interaction between the ice shelf and the ocean; multidisciplinary observations at Zhongshan Station; East Antarctic glaciological exploration; and Dome A multidisciplinary observations. During IPY 2007-08, China will dispatch the R/V *Xuelong* to conduct cruises, respectively during the summertime in 2008 and 2009 in the Arctic Ocean to study the Ocean-Atmosphere-Sea ice System (OASIS), and in the austral summertime from 2007 to 2009 in the Southern Ocean for the Southern Ocean Observing System (SOOS).

CHINARE (Chinese National Arctic and Antarctic Research Administration) has been conducting a SOLAS program in the polar oceans since the 1980s, especially for carbon cycles in the Southern Ocean, Bering Sea and the Chukchi Sea. China's State Oceanic Administration (SOA) and the U.S. National Oceanographic and Atmospheric Administration (NOAA) will cooperate to conduct a program to compare air–sea pCO_2 fluxes between the Southern Ocean and the Arctic Ocean (CFCSOA), using NOAA's developed underway pCO_2 measurement system on board the R/V *Xuelong* for the tracking survey, and applying China's innovated analytic system for new biological production, dissolved inorganic carbon (DIC), pCO_2 for the section investigation. Chinese scientists will also participate in an IPY project for Polar Aerosol Optical Depth (Polar-AOD) to study and assess impacts of anthropogenic chemical species by the atmospheric transport to polar regions using data collected from Chinese polar stations respectively located in Antarctica and Ny-Alesund of the Svalbard Islands.

PICES XV POC_Paper-2954 Poster

The pathway of interannual and interdecadal variability of the Pacific subsurface ocean temperature anomaly

Yong-Li **Chen**[1], Yong-ping Zhao[1], Fan Wang[1] and Ai-ming Wu[2]

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Based on Simple Ocean Data Assimilation (SODA) and expendable bathythermograph (XBT) data sets, the distribution of the thermocline depth in the Pacific was estimated. Letting the ocean temperature anomaly at the thermocline depth surface be representative of the subsurface ocean temperature anomaly (SOTA), the pathway of its interannual and interdecadal variability in the Pacific is investigated. The results show that the interannual variability in the tropical Pacific has a special pattern with 57 and 44 month periods, a west-east SOTA seesaw with a cross-axis in the middle Pacific and a south-north SOTA seesaw with the longitudinal axis along 6-8ºN. Mid-high latitude areas of the South and North Pacific have a weak SOTA in phase with patterns in the tropical western Pacific. During the El Niño Southern Oscillation (ENSO) cycle, a strong SOTA center in the western tropical Pacific propagates mainly eastward along the equator, strengthens, and moves northward after it reaches the eastern equatorial Pacific, and causes El Niño or La Niña events. In the meantime, a weak SOTA signal propagates northeastward and southeastward from the western tropical Pacific to the mid-high latitude areas of the North and South Pacific, respectively. Meanwhile, a strong SOTA center with contrary sign located in eastern tropical Pacific propagates westward along 10-15ºN, strengthens and moves southward after it reaches the western tropical Pacific, and prepares for the next La Niña or El Niño events. In the meantime, it isolates and weakens the SOTA in mid-high latitude area of the North Pacific. Repeating the above processes will complete the ENSO cycle. The interdecadal variability with 17 and 11 years periods has a similar spatial distribution and signal pathway as interannual variability, but the SOTA center in the eastern tropical Pacific shifts westward by about 10° longitude, and the signals propagating northeastward and southeastward from the western tropical Pacific are more evident. The latter may be closely connected to the Pacifc Decadal Oscillation (PDO) and the interdecadal variability in the South Pacific. The above results reveal a new mechanism of the ENSO phenomenon and new aspects of the SOTA signal pathway in the Pacific.

PICES XV POC_Paper-3022 Oral

Evolution of the surface water carbon dioxide in relation to the annual trends in salinity and temperature in the Oyashio region

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We examined the annual trends in the carbon dioxide system and surface water hydrography in the Oyashio region (145°E to 155°E, 42°N to 48°N) for a period of 6 years (1995 to 2001). We use data on partial pressure of carbon dioxide (pCO_2) in both surface water and air, as well as data on sea surface temperature and salinity obtained from the Japanese–Canadian joint Volunteer Observing Ship program. The annual trends on seasonally detrended data showed increasing surface water pCO_2 at an annual rate of 5.3 µatm yr^{-1}, and the atmospheric pCO_2 showed an increase of 2.1 µatm yr^{-1}. We also observed a clear trend towards saltier (0.055 yr^{-1}) and colder (-0.29°C yr^{-1}) surface water conditions which suggested increased mixing of subsurface waters to the surface layer in the end of the 1990's.

PICES XV POC_Paper-2907 Poster
Development of a hydrodynamic and eutrophication model of the west coast of Korea

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This study focuses on the development of a hydrodynamic and eutrophication model of Chunsu Bay, on the west coast of Korea. To investigate the characteristics of water quality distribution and variability in the study area, monthly hydrographic surveys were carried out at 10 stations, in which temperature, salinity and water quality parameters were collected for the period of 2001-2002. In addition, simultaneous time series records of water quality parameters were collected by a realtime monitoring system with a 10-minute sampling interval. The observational results show the characteristic patterns of dissolved oxygen (DO) and formation of hypoxia in the bottom water in the vicinity of the embankment and aquaculture fish farm in summer. A three-dimensional Hydrodynamic Eutrophication Model (HEM-3D), using real oceanographic forcing, was used to reproduce the distribution of water quality parameters in the study area. The hydrodynamic model results were in good agreement with observation data. The model was able to reproduce tidal elevations and currents with more than 90% accuracy for four major tidal constituents. The Eulerian tidal residuals show that a lot of eddy structures developed around islands and central parts of the study area due to the complex coastline and irregular bottom topography. The water quality model was successful in reproducing the distribution of water quality parameters in the study area. The horizontal distribution of salinity showed that low salinity water extends southward to the mouth of the bay at low tide, while it is limited to the northern part of the bay at high tide. The lowest salinity water mass resides in the area adjacent to the embankment due to the low flow pattern of less than 0.1 m/s. The horizontal distribution of DO showed that the vicinity of the embankment and aquaculture fish farm had low DO concentrations, less than 5.0 mg/l, while high concentrations, greater than 7 mg/l, were characteristic of the central part of the bay. A sensitivity analysis using the calibrated model was performed to study the controlling processes for hypoxia in the study area. It shows the DO consumption by sediment oxygen demand (SOD) is more effective in changing the water quality than that due to chemical oxygen demand (COD) of freshwater discharges. However, more detailed model studies will be needed to understand the physical and biogeochemical processes of water quality variables in the study area. Among those, the influence of the freshwater runoff, pollutant loading from aquaculture fish farms, and bottom sediment flux will be the main focuses in the development of a water quality prediction model.

PICES XV POC_Paper-3200 Oral
Transport and mixing of continental margin waters into mid-basin by anticyclonic eddies: An example from the Gulf of Alaska

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Mesoscale eddies form along the eastern boundary of the Gulf of Alaska and drift westward for several years. In their cores are nutrient-rich coastal waters that provide needed nutrients for primary production at the sea surface. The near-surface, excess micro- and macro-nutrients are normally depleted by late spring of their natal year by phytoplankton growth, yet SeaWiFS imagery reveals that phytoplankton concentrations in these eddies are usually higher than in surrounding gulf waters for most of their first year and even into their second year. This enhanced primary production is attributed to advection and mixing processes that transport excess nutrients in sub-surface eddy waters up to the euphotic layer of the ocean. Some of these processes are unique to anticyclonic eddies and others to the Gulf of Alaska: (a) Sub-surface cores of anticyclonic eddies upwell as these eddies decay. If upwelling is insufficient to bring these nutrients all the way to the surface, the nutrients can mix up to the ocean surface during storms. (b) Eddies that remain close to the continental margin deflect coastal nutrient-rich waters far into mid-gulf to mix with nutrient-depleted waters there. (c) As eddies drift into mid-gulf they encounter denser waters at all depths; nutrients advecting along constant density surfaces out of eddies will upwell toward the surface. (d) The turbulence generated by decaying eddies mixes nutrients toward the nutrient-depleted near-surface waters.

PICES XV POC_Paper-2796 Oral
Tidal energy and the 18.6-year cycle in the Bering Sea

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Tidal harmonics computed from TOPEX/Poseidon altimetry are assimilated into a barotropic, finite element model of the Bering Sea. The model is used to estimate energy fluxes through each of the Aleutian Passes and Bering Strait and to construct an energy budget for the major tidal constituents. Though the M_2 constituent is estimated to have the largest net energy flux into the Bering Sea, at 31.2 GW, the K_1 constituent is not far behind at 24.9 GW and the sum for the three largest diurnal constituents is found to be greater than the sum for the largest three semi-diurnals. Samalga and Amutka Passes are found to be the primary conduits for influx of semi-diurnal energy while Amchitka Pass is the primary conduit for diurnal energy. A significant portion of the diurnal energy is seen to exist in the form of continental shelf waves trapped along Bering Sea slopes. The effect of the 18.6-year nodal modulation is estimated and found to cause basin-wide variations of approximately 19% in the net incoming tidal energy flux. Larger variations in the dissipation occur in subregions that are strongly dominated by the diurnal constituents, such as Seguam Pass and south of Cape Navarin. These variations should correlate with tidal mixing and may have important consequences for biological productivity, similar to those found for Pacific halibut (*Hippoglossus stenolepis*) recruitment.

PICES XV POC_Paper-3029 Oral
Comparison of interannual trends in the surface water pCO_2, salinity and temperature in the subarctic North Pacific

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We investigated the interannual variability of the partial pressure of surface water carbon dioxide (pCO_2), salinity and temperature in the surface water in the Western Subarctic Gyre (WSG), the Alaska Gyre (AG) and the southern Bering Sea for a period of 6 years (1995 to 2001). All areas showed increasing surface water pCO_2, with the largest annual rate in pCO_2sw of 9 µatm yr^{-1} in the southern Bering Sea. In the WSG, the pCO_2 in the surface water increased by about 1.5 µatm yr^{-1}, and in the AG by 3.6 µatm yr^{-1}. Sea surface temperature showed a cooling trend in all areas for the studied period and salinity increased in the southern Bering Sea and the WSG. We discuss the importance of different processes and ocean-atmosphere coupling to explain the differences between the areas.

PICES XV POC_Paper-2919 Poster
Application of altimetry data assimilation on mesoscale eddies simulation

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The phenomenon of mesoscale eddies plays an important role in the ocean circulation. In order to improve the simulation accuracy of mesoscale eddies in the western Pacific Ocean, a three-dimensional variation (3DVAR) data assimilation system named Ocean Variational Analysis System (OVALS) is applied to a Princeton Oceanographic Model (POM) model. In this system, the sea surface height anomaly (SSHA) data measured by T/P and ERS1/2 altimetry are assimilated and translated into pseudo temperature and salinity profile data. Meanwhile, along with the XBT and ARGO observations, these profile data are assimilated again to produce a three-dimensional analysis T-S field. According to the character of mesoscale eddies and the model setup, the most appropriate assimilation parameters are chosen and tested.

A set of ten years' worth of mesoscale eddy simulation tests with and without altimetry data assimilation are made. The results of the comparison to the observed data show that the simulation efforts of the test with assimilation is much better than that of the test without assimilation. This indicates that the altimetry data assimilation can improve the simulation accuracy of mesoscale eddies dramatically and demonstrates the potential of the OVALS on the mesoscale assimilation.

PICES XV POC_Paper-2800 Oral
Features of atmospheric circulation over the Asian-Pacific region in 2000-2006

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Atmospheric circulation over the Asian-Pacific region has a well expressed seasonal character. A northern wind transfer (a winter monsoon) is formed over the Far East Seas in the cold season by the interaction of the Aleutian Low and Siberian High. A southern wind transfer (a summer monsoon) develops in spring and summer by the interaction of the Far East Low and Hawaiian High.

A change in intensity and location of the atmospheric action centers causes variations in monsoonal circulation (and, as a whole, of the climatic conditions) in the Far East Seas.

Charts of sea level atmospheric pressure, averaged for the cold and warm seasons, were used to analyse synoptic conditions over the Far East Seas in 2000-2006. To quantitatively estimate the intensity of northern and southern wind transfer over the Japan, Okhotsk and Bering Seas (as indicators of monsoon intensity), Katz's meridional indices of atmospheric circulation were calculated.

It is established that the Aleutian Low was gradually shifting towards the southwest in 2000-2004 (from the eastern areas of the Bering Sea to its western part). As a result, the winter monsoon weakened over the Far East Seas. The greatest weakening of the monsoon was noted over the Bering Sea in the winter 2003-2004. After that, the Aleutian Low turned towards the east, and the winter monsoon was amplified over the all seas (especially over the Bering Sea during the cold season of 2005-2006).

In summer, the atmospheric action center (Far Eastern Low) was gradually shifting towards the northeast (from the continent towards the Sea of Okhotsk). Here, the summer monsoon amplified over the Japan and Bering Seas, having reached its greatest intensity in 2003. At the same time, it was weakening over the Sea of Okhotsk. After 2003 the Far Eastern Low began to be displaced back towards the continent, and the intensity of a summer monsoon began to decrease over the all three seas.

On the basis of the weakening winter and strengthening summer monsoons, climatic warming occurred in the Far East Seas. For example, ice cover decreased in 2002-2005. Changes in the character of atmospheric circulation which occurred after 2004 (strengthening winter and weakening summer monsoons) can be thought of as a harbinger of climatic cooling in the Asian-Pacific Region.

PICES XV POC_Paper-2967 Oral
The processes of AOU change in the North Pacific

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The three processes of Apparent Oxygen Utilization (AOU) change by water mixing, biological activities and air-sea exchange in the mixed water regions were investigated using hydrographic data on 155, 160, 167.5 and 175 degrees E lines from 35 degrees to 45 degrees N which were obtained for the period from May to June, 2004. Changes in AOU by water mixing were defined as isopycnal mixing between pure Oyashio and Kuroshio waters. Changes in AOU by biological activities were estimated by the Redfield ratio and nutrient

concentrations. The influence of air-sea exchange on the change in AOU was assumed to be related to the residuals from observed AOU to AOU change predicted by mixing and biological activities. Water mixing is the dominant process of AOU change in the whole water column. Both biological activities and air-sea exchange decrease AOU in the layers above the depth of 26.7 σ_θ. This means O_2 is produced by photosynthesis and dissolves from air in the upper layer. In the layers below the depth of 26.7 σ_θ, the AOU changes by them are negligible. These indicate that AOU and nutrients can be used as a conservative tracer in these layers. The change in AOU ratios by water mixing, biological activities and air-sea exchange are estimated as 50-80, 20-50 and less than 10 percent, respectively.

PICES XV POC_Paper-3130 Poster
Formation processes of temperature inversions in the subarctic North Pacific

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In the subarctic North Pacific, temperature inversions (TIs) are common oceanographic structures. It has been thought that TIs are caused predominantly by sea surface cooling in the wintertime mixed layer (WML) under strong salinity stratification and that the TI remains at subsurface in the warming season as a vertical temperature minimum. However, direct comparison between the winter mixed layer and TI has not been fully performed because ship observations are difficult in severe winter. We then analyze hydrographic data from Argo floats to investigate the formation process of TIs and their relation to the WML in several sub-regions in the western subarctic North Pacific and the Bering Sea. We find that there are two kinds of TIs: shallow and deep TIs. The former exists around 26.6σ_θ and has a relatively large vertical scale (~100m). Temperature and salinity at the TI correspond well to those of the WML in the previous winter. It is thus confirmed that the shallow TI is mainly formed in the previous WML. The latter distributes in the density around 26.8σ_θ; the deep TI thus cannot be formed in the WML. The deep TI occurs around the subarctic front, the mixed water region and along the southern coasts of the Kuril Islands where different kinds of water form water mass fronts, whereas a deep TI is not seen in the Bering Sea. This implies that the deep TI results from lateral exchange caused by eddy and/or double-diffusive interleaving in the frontal zone.

PICES XV POC_Paper-3133 Poster
Estimation of sea surface current vectors based on satellite images around the Korean Marginal Sea

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One of the most difficult parameters to measure in the sea is current speed and direction. Recently, many efforts are being made to estimate the ocean current speed and direction by utilizing sequential satellite imageries. In this study, we have estimated sea surface current vectors (sscv) by using ocean color imageries of SeaWIFS satellites around the Korean Peninsula. This ocean color image data has a 1-day sampling interval and the spatial resolution of the data is 1×1 km. The maximum cross-correlation method is employed which is aimed at detecting similar patterns between sequential images. The estimated current vectors are compared to the surface geostrophic current vectors obtained from altimetry data of sea level height. In using the color imagery data, some limitations and drawbacks exist so that in warm water regions, where phytoplankton concentration is lower relative to cold water regions, estimation of sscv is poor and unreliable. On the other hand, two current vector fields agree well for the Korean South Sea region where a high concentration of Chlorophyll-*a* and a weak tide exist. In the future, when we have more ocean color data with shorter sampling period from the Communication, Ocean and Meteorological Satellite (COMS), the algorithm and methodology developed in the study will be useful so that the supply of information for the ocean currents around Korean Peninsula will be feasible.

PICES XV POC_Paper-3165 Poster
Low-frequency deep flow variability in the Ulleung Basin

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From 2002-2004, the variability of deep flows was analyzed from five moored current meter measurements, including one full water column mooring in the Korea Gap located northeast of the Ulleung Basin. The Korea Gap is about 90 km wide, and serves as a main passageway for the exchange of deep waters below 1500 m depth between the Ulleung Basin and the Japan Basin. The 16-month mean deep flows with variability of periods of 10-60 days are directed to the south or southwest at three moorings in the western side of the channel, and to the north at two moorings on the eastern side, with the strongest mean flow of 4.5 cm/s near Dokdo. The results show that the deep flows near Dokdo have a significant effect on the deep water exchange between the Ulleung Basin and Japan Basin. Deep flow variability with a period of 13-20 days is strengthened with a bottom-intensified character during the warming event in the upper layer. Using linear topographic Rossby waves (TRW) theory, we compared observation and estimated results. These measurements are consistent with the model for 13- to 20-day periods.

PICES XV POC_Paper-2795 Poster
Research of interannual variability of the mean sea level in the North Pacific

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The interannual variability of the mean sea level at 63 tide-gauge stations in the North Pacific and its relationship with climate indices were analyzed. Sea level data were obtained from the Joint Archive for Sea Level (JASL) with different measurement time intervals from 22 to 103 years (1901–2005). Climate indices were obtained from publicly available sources and include: ENSO (El Niño/La Niña + Southern Oscillation), Pacific Decadal Oscillation index (PDO), Arctic Oscillation index (AO), North Atlantic Oscillation index (NAO), North Pacific index (NP), Aleutian Low Pressure Index (ALPI). Linear and nonlinear sea level trends were mapped. Spectral analysis of these sea level variations indicates significant low-frequency peaks for the 18.6-year lunar nodal cycle, for 11 years (period of solar activity), 7 years (the component nutational period), 5 years, 3.5 years, 14 months (period of the speed of Earth's rotational change – nutational tidal), and annual and semi-annual cycles which are allocated as characteristic scales of the variability. A multiple linear regression model was used to derive the relationship between sea level variation and climate indices fluctuations. It showed significant correlations with the ENSO, NP and the PDO indices. This work is supported by a grant of the Russian Foundation for Basic Research.

PICES XV POC_Paper-3134 Poster
Abrupt change of mixed-layer structures caused by horizontal intrusion of the warm water mass from the Kuroshio into the coastal region off Enshu-nada, south of Japan

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Warm water intrusion from the Kuroshio into the coastal area is a familiar phenomenon off Enshu-nada south of Japan. However, the effect of the intrusion on the variation of hydrographical structures is unclear. Repeated conductivity-temperature-depth (CTD) observations captured an abrupt change of water structures in the mixed-layer off Enshu-nada in October 2004, when the Kuroshio took a large meander path and a large cold core was formed in the Slope Water region inshore of the Kuroshio. At the station (33°N, 138°E) located in the Slope Water region, CTD observations were conducted at local time 16:13 h October 30, 17:11 h October 30 and 00:09 h October 31. Consequently, the third observation indicated a 30-m deepening of the mixed layer depth

and a 4.66°C warming at 79db in 7 hours, in comparison with the first and second observations. This deepening speed of the mixed layer depth, 4.3m/h, was one-order larger than the speed estimated from vertical processes determined by the air–sea heat exchange and water entrainment from the lower layers. The T/S vertical profiles obtained by the third observation were similar to the profiles obtained at the stations in the Kuroshio, when a shipboard acoustic Doppler current profiler (ADCP) observed a westward current more than 0.2m/s at 84m depth and the satellite sea surface temperature image indicated a westward spread of the warm water region from the Kuroshio to the coastal area off Enshu-nada. These observations conclude that the abrupt change of hydrographical structures in the Slope Water was caused mainly by horizontal intrusion of the warm water mass from the Kuroshio.

PICES XV POC_Paper-3136 Poster
Effects of wind and waves on the jet-leaving transport of surface materials around the Kuroshio and the Kuroshio Extension

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Some larval fish are well known to leave the jet during the transport process by the Kuroshio and the Kuroshio Extension (KE). However, detailed mechanisms of the leaving are unknown. In order to clarify the jet-leaving process, the Lagrangian current was observed by drifting GPS-buoys in the region around the Kuroshio and KE in 2001-2006. During the observation some buoys left the jet of the Kuroshio and KE and drifted toward the subarctic or subtropical regions after drifting along the jet. Comparison with the wind field estimated from QuikSCAT indicated that southerly (northerly) winds blew when the buoys left the jet northward (southward). The effect of currents induced by wind and waves on the leaving was demonstrated by particle transport experiments using reanalyzed currents calculated by the Japanese Coastal Ocean Predictability Experiment (JCOPE) ocean forecast system. The experiments with additional induced-currents estimated from existing theoretical analyses properly reproduced most of particles to leave the jet corresponding to the buoy trajectories. On the other hand, the experiments without the induced-currents transported most of particles along the jet. Moreover, the buoy observations conducted in February 2001 and March 2003 revealed that the transport effect of wind and waves was dependent on the depth where the materials were located. Two buoys deployed at the same position on the shelf of the East China Sea indicated different trajectories: the buoy drogued at 10 m depth drifted northward to the Japan Sea, whereas the buoy without drogue drifted southward to the Pacific in response to northerly winds.

PICES XV POC_Paper-3135 Poster
Modification processes of intermediate water around the Kuroshio region

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Recent observations have appreciably clarified the spatial distribution and transport budget of the North Pacific Intermediate Water (NPIW) characterized by a salinity minimum widely distributed in the layers around $26.8\sigma_\theta$ off Japan. However, particulars about modification processes of NPIW caused by advection, diffusion and mixing remain obscure. In order to clarify the NPIW modification processes around the Kuroshio region, firstly we analyzed conductivity-temperature-depth dissolved oxygen (CTD-DO) data obtained in the cruises crossing the Kuroshio along three TOPEX/Poseidon tracks south of Japan and secondly we analyzed 4-D hydrographic data simulated by the Japanese Coastal Ocean Predictability Experiment (JCOPE) ocean forecast system (Frontier Research Center for Global Change). In the region under the Kuroshio current axis, the observed salinity minimum decreased from upstream to downstream, additionally the simulation indicated that saline anomaly propagated downstream at a speed of 0.3 m/s along the Kuroshio on the $26.8\sigma_\theta$ surface. The propagation speed corresponded to the current speed under the Kuroshio current axis, which indicated that the saline, old NPIW was transported downstream along the Kuroshio. On the contrary, in the subtropical side of

the Kuroshio current axis, the observed salinity minimum increased from upstream to downstream in the cruise Sep. 2001. In this case a large anticlockwise eddy located south of the Kuroshio was likely to lure the fresher, new NPIW recirculated from the eastern region around the Kuroshio Extension. The simulation indicated clearly that the fresher water was lured northward at the western side of the eddy into the upstream-subtropical side of the Kuroshio on the 26.8σ_θ surface.

PICES XV POC_Paper-3140 Oral
Transport of walleye pollock (*Theragra chalcogramma*) eggs between 1989 and 1995 and its causes on the southwest coast of Hokkaido, Japan

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Walleye pollock, *Theragra chalcogramma*, is one of the most important fishery resources in Japan and the southwest coast of Hokkaido is the most important spawning ground of the Japanese Pacific stock (Honda *et al*., 2003). The influence of the ocean environment on walleye pollock reproduction and recruitment has been investigated and the importance of water temperature and currents in Funka Bay and at its mouth has been pointed out (Isoda *et al*., 1998; Hamatsu *et al*., 2004). We analyzed time-dependent changes in the egg numbers for each spawning stage observed along this coast and in the bay from 1989 to 1995. We formulated a conservation equation for eggs in the observational area by considering egg development and removal from the area, and by estimating the numbers that spawned and hatched. The ratio of hatched to spawned eggs was large in 1994 and 1995 but small in 1992 and 1993. A regression analysis showed that the ratio tended to be large when salinity decreased rapidly along the coast. This suggests that the westward movement of the cold and less saline Coastal Oyashio along the coast may be important for recruitment. It has been pointed out that this water is controlled by bottom topography and current structures off the coast as well as by the wind (Kono *et al*., 2004). We have simulated current fields in the observational periods using a numerical model and will discuss how this movement was controlled.

PICES XV POC_Paper-2857 Oral
Spatial and temporal variations of the mixed layer depth in the East Sea

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In the East Sea, a semi-enclosed marginal sea of the northwest Pacific, seasonal variations of the mixed layer depth (MLD) show a typical pattern of shallowing during the warm (summer) season and deepening during the cold (winter) season, respectively. As commonly known, the MLD is originally formed by the action of turbulent mixing of the water mass due to monsoon wind stress and intensive seasonal heat exchange variations at the sea surface.

The objective of this study is to compute spatial and temporal variations of the MLD in the whole domain of the East Sea. We estimated monthly MLD from oceanic profile data, *i.e.*, NODC, KODC, JODC and ARGO float data produced by the French Research Insititute for Exploitation of the Sea (IFREMER). Results show typical seasonal variations; however, significant spatial differences of the MLD are also observed. The spatial variances are larger in the near and off-shore regions of Vladivostok and the southeastern part of the East Sea, and deepening of the MLD appears about 1 month earlier in the southern region than in the northern region of the East Sea.

PICES XV POC_Paper-2948 Poster
Parameterization of tidal current-induced vertical eddy viscosity

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Based on the Mellor-Yamada turbulence closure scheme of POM (Princeton Ocean Model), a series of ideal tests were designed to calculate the tidal current-induced vertical eddy viscosity. Through analyses on the thickness of the bottom mixed layer and distribution of vertical eddy viscosity with different water depths and amplitudes of the tidal current, a formula is obtained to parameterize the tidal current-induced vertical eddy viscosity. By applying this formula to calculate the tidal mixing in the ideal test area instead of using the tidal current boundary condition, the simulated temperature structures are in great accord. When we apply the parameterization method to simulate the vertical thermohaline structure of the East China Seas, the results agree well with the collected observations.

PICES XV POC_Paper-3219 Poster
Physical, chemical and biological structure of an anticyclonic eddy in the northwestern Japan Sea

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Mesoscale eddies are an essential component of the Japan Sea circulation and should play an important role in water mass formation and fluxes. Detailed physical, chemical and biological observations of an anticyclonic eddy with diameter of around 110 km located south of the Peter the Great Bay was done on May 2004 in the cruise of the R/V *Akademik M. A. Lavrentyev*. The central part of the eddy showed a distinct anomaly of water mass properties in comparison with surrounding waters with a greater thickness, and extreme values of a subsurface high salinity layer and underlying low and high salinity intermediate waters. A high content of dissolved oxygen (>260 umol/kg) was observed down to 1000 m in the eddy center indicating recent ventilation down to this depth. Thus winter convection and subduction processes result in the accumulation and trapping of lenses of subsurface and intermediate waters in the eddy. A lens-like structure of the eddy core causes a splitting of main pycnocline with an upward shift of its upper portion and a deepening of its lower boundary down to 200-300 m in comparison with 75-100 m depth outside the eddy. Similarly, a gradual intensification and deepening of backscatter layers were observed by underway acoustic soundings, as well as high values of Chl-*a*, primary production, zooplankton biomass and increased number of seals and whales. Thus the eddies in the northwestern Japan Sea are hot spots where the anomalous structure of water masses and dynamics creates favorable conditions for biological processes and the attraction of marine organisms which are not observed in the outside areas.

PICES XV POC_Paper-2870 Poster
Variability of water characteristics in the Kuril-Oyashio Current system

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One of the most dynamical places in the Pacific Ocean is the area adjacent to the Kuril Island occupied by the Kuril-Oyashio Current system. To what extent does water exchange between the Sea of Okhotsk and the Pacific Ocean predetermine the thermohaline characteristics of the current waters?

The given studies are based on the resources of the Pacific Oceanological Institute of the Far Eastern Branch of the Rusian Academy of Sciences (POI FEBRAS) data bank including the materials of the national research

cruises in the Kuril area for the period from 1988 to 1993, and the global array of the average long-term (more than 50 years) hydrological data of the U.S. Naval Oceanographic Office (Washington) covering the whole area of the NW Pacific.

These available materials were the basis for our investigation of the structure and variability of thermohaline fields in the current area. Oceanographic mapping of the Kuril-Oyashio Current area was made and characteristic differences of various water formations in the current area were shown. The evolution of characteristics of the current system in the area is determined to a significant extent by climatic factors – a seasonal reconstruction of atmospheric processes (their monsoon character). For the Kuril-Oyashio Current system, the seasonal variations are well expressed. They are related both to the seasonal variability of the wind over the ocean field, and the seasonal variations of the waters coming to the current zone through the straits. The dependence of the water structure formation in the current zone on the variability of water exchange through the straits and atmospheric circulation variability was analyzed. New information about the role of the Kuril Island Straits in the formation of water characteristics of the Kuril-Oyashio Current area and its variability was obtained. As the water circulation in the sub-strait areas varies, it also varies the thermohaline and dynamic characteristics of the particular zones of the Kuril-Oyashio Current system. Such variability is both seasonal and interannual. It was revealed that while the main quantitative features of the water circulation is preserved, particular parts of the current system in some years can possess different quantitative characteristics. These results can be used to develop forecasts of variability for the hydrological conditions in the given area.

PICES XV POC_Paper-2928 Poster
Application of high-frequency radar to the east coast of Korea

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Three SeaSonde High-Frequency (HF) radar stations have been installed on the east coast of Korea and some preliminary results are presented. These standard-range systems, operating near 13 MHz, provide surface current maps to 70 km offshore with range resolution of 3 km. The coverage of near-real time maps contains the area where the East Korea Warm Current (EKWC) separates to the east. These maps are used to analyze the temporal and spatial characteristics of the surface current off the coast and also represent an approach for a spectrum of coastal ocean applications related to fisheries, ecosystems, and search and rescue operations. The surface current velocity observed by the HF radars is compared with Acoustic Doppler Current Profiler (ADCP) data from the East Sea Real-time Ocean Buoy (ESROB). The HF radar-derived current velocity is found to exhibit reasonable agreement with the ADCP data.

PICES XV POC_Paper-2921 Poster
Bi-decadal variations in SST relating to a tidal cycle of 18.6-year periods around the Kuril and Aleutian Islands

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We find that the long-term sea surface temperature (SST) anomaly deviations, which are the residuals after removing the influence of the atmosphere, seem to be related with the 18.6-year period modulation of diurnal tides along the straits of the Kuril and Aleutian Islands. For example, in the periods of strong diurnal tide in the middle of the 1910's and 1930's, in the beginning of the 1950's and 1970's, and in the late 1980's, tide-induced mixing made the summer SST lower and the winter SST higher. It can be explained that SST in summer decreases due to stronger tidal mixing with cold dichothermal water in the period of strong tides in spite of intense solar heating. On the other hand, SST in winter increases because warm subsurface water is entrained into the surface by stronger tidal mixing, where it is cooled at the surface from the atmosphere. These analyses support evidence that tidal mixing with the 18.6-year period cycle really happens around the Kuril and Aleutian Islands.

PICES XV POC_Paper-3001 Poster
Stable isotopes as chemical tracers in the coastal region around eastern Hokkaido

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In this study, we tried to discriminate the mixing of three water masses, the Soya Warm Current water, Okhotsk Sea water, and Oyashio water, in the coastal region off southeastern Hokkaido shallower than 200 m. Instead of temperature and salinity, we applied isotopic tracers, δ^{13}Cas and δ^{18}O, for water mass classification to estimate the mixing ratio of these three water masses. δ^{13}Cas–δ^{18}O plots showed a clear isotopic difference between the littoral water and the offshore Oyashio water. While T-S plots of the littoral water showed minimal difference to the offshore Oyashio water in the summer-autumn, δ^{13}Cas–δ^{18}O plots indicated a notable effect of the Soya Warm Current water from the Okhotsk Sea on the littoral water. We also discussed the seasonal variations of the mixing process and mixing ratio in the coastal region off southeastern Hokkaido between the water masses from the Okhotsk Sea and the Oyashio. In the summer-autumn season, the Soya Warm Current water flows out via the Nemuro Strait and other straits along the southern Kuril Islands. The mixing ratio of the Soya Warm Current water was estimated as about 60 % in the littoral current region, and around 20 % in the offshore Oyashio region. On the other hand, in spring, there were two possible sources from the Okhotsk Sea; one was the water mass entering alongshore via the Nemuro Strait, and the other was the mixture of the Soya Warm Current water and the Okhotsk Sea water flowing out from the Kunashiri and Etorofu Straits. The mixing ratio of the former source was overestimated (>100 %), however, that of the latter source was estimated as more than 80 %.

PICES XV POC_Paper-3150 Oral
Bidecadal variations of water properties around the Bering Sea and the relation with the 18.6-year period nodal tidal cycle

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Bidecadal variability is a prominent feature of the ocean and climate around the North Pacific and must be important to the ecosystem. We found bidecadal variations of water properties synchronized with the 18.6-year period nodal tidal cycle around the Bering Sea. When the diurnal tide is strong, upper layer salinity averaged in the top 100 m is high, isopycnal potential temperature around the intermediate temperature maximum (*e.g.* mesothermal structure) is low, and thickness of the intermediate layer is large in the continental shelf region of the Bering Sea. Similar variations of upper layer salinity and layer thickness can be seen in the region south of the Aleutian Islands. Around the continental shelf and the Aleutian Islands, strong tidal mixing is suggested, and tidally induced vertical mixing can transport subsurface high salinity water to the surface layer and weaken the intermediate temperature maximum structure. Thus, it may be reasonable to attribute these variations to the modulation of vertical mixing in the nodal tidal cycle.

PICES XV POC_Paper-3160 Oral
Distribution mechanism of Changjiang diluted water in the East China Sea

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Changjiang Diluted Water (CDW) is created by outflow of the Changjiang River and can penetrate eastward in summer. The distribution of CDW is quite different every year and the cause of these differences is not clear. In order to clarify the cause of these differences, the dominant mechanism underlying the seasonal variations in the flow path of CDW and the salinity distribution is examined by numerical model calculations. Numerical experiments reveal the wind to be the major force driving CDW eastward to Cheju Island in summer. The wind

is also primarily responsible for salinity distribution. Different routes and salinities for CDW occur in different years due to variations in wind forcing. We can reproduce the different flow routes in 1996 and 1998 and the salinity distribution in 2000 by monthly and daily satellite winds, respectively. The large-scale motion of the buoys in 2003 is reasonably well represented; however, the small-scale structure of the locations is not well represented due to the influence of higher frequency flow variation on buoy position. Through this study, we found that the northward expansion of high salinity water around Cheju Island in winter, which comprises the distinct seasonal circulation with the eastward movement of CDW in summer, is driven by the monsoon wind. We also found that a significant part of CDW flows into the Yellow Sea in summer and fall, driven by southerly winds. In winter, CDW withdraws to the Chinese coast and then drifts southward driven by northerly winds. In spring, some of CDW returns northeastward in the reversed coastal current. Therefore, low salinity water rotates counterclockwise with season driven by monsoon winds, as reported from recent observations.

PICES XV POC_Paper-3107 Poster
Kinetic energy flux of inertial frequency motion out of the mixed layer and its balance with wind energy input in the global scale ocean

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In order to quantify the flux of inertial energy out of the mixed layer, the decay timescale (how fast the inertial motion loses its energy in the mixed layer) has been estimated using satellite tracked drifter data. The decay timescale is defined as the *e*-folding time of the temporal correlation function computed from the drifter data. The spatial patterns of the timescale show some remarkable differences not only between the North Pacific and the North Atlantic but also between seasons. The decay time usually gets much longer in high latitudes and in summer, especially in the North Pacific. The theoretical model study, together with climatology data, exhibits the large-scale variation of inertial motion decay rate that would be determined primarily by the mixed layer depth even though the overall model results provide overestimated timescales of more than 30%. The wind energy power input to the mixed layer inertial motion averaged in the North Atlantic (Park *et al.*, 2006) is comparable to the energy flux out of the mixed layer computed from the basin-averaged inertial kinetic energy (Park *et al.*, 2005) and the decay timescale. However, in the North Atlantic, it is remarkable that the wind energy input is not balanced with the energy transfer to the deep ocean.

PICES XV POC_Paper-2984 Oral
The formation of the Tsushima Warm Current in a high resolution ocean circulation model

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From 0.1 OFES (OGCM for the Earth Simulator) results provided by the Japan Marine Science and Technolgy Center (JAMSTEC) (Masumoto *et al.*, 2004), we investigated the East China Sea circulation while focusing on the origin of the Tsushima Warm Current. The simulated sea surface temperature is cooler than the observations. The volume transport of the simulated Tsushima Warm Current is 1.7 Sv and is weaker than the observations. The Kuroshio Current, however, is reproduced well, as is the Taiwan Warm Current of about 1.5 Sv. Considering that this global model is not optimized for the East China Sea, and these flows are not determined by the lateral boundary conditions but by the internal dynamics, the model results are good enough for the purpose of this study. The model results are analyzed while focusing on the interaction between the Taiwan Warm Current and the Kuroshio to determine the major source of the Tsushima Warm Current, and compare it with earlier studies.

PICES XV POC_Paper-3215 Oral
The upwelling system in the East China Sea in winter and summer

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The mechanisms of upwelling off the Changjiang River Estuary and in the adjacent waters in summer and winter are studied using numerical modeling. First, the persistent feature of these phenomena is confirmed using cruise observations, satellite sea surface temperature (SST), and SST climatologic data. Then, the MASNUM (Marine Science and Numerical Modeling) wave-tide-circulation coupled numerical model is employed to simulate the upwelling patterns. Based on the simulation, a set of numerical experiments is designed to explore the main mechanisms inducing the upwelling.

In summer, numerical results suggest that tidal mixing plays a predominant role in inducing the upwelling. In offshore waters, strong tidal mixing results in a considerable horizontal density gradient across tidal fronts. Upwelling is induced as a branch of the secondary circulation, which is stimulated by the cross-frontal density gradient. Topography also exerts profound effects on upwelling by steering bottom currents to ascend upward and by regulating tidal fronts in both location and intensity. Besides the tides and topography, other dynamical factors also alter the strength of upwelling locally. The Yangtze River discharge and Taiwan Warm Current account partly for the upwelling off the Changjiang River Estuary and near Zhoushan Islands, respectively. The influence of winds on upwelling is small. In the coastal waters near Zhoushan Islands, the wind forcing exerts negative influences on upwelling by weakening the encroachment of the Taiwan Warm Current (TWC) onto the continental shelf, which may exceed the positive effects of Ekman pumping.

In winter, numerical results suggest that the density (or salinity) front, which separates the inshore Low Salinity Coastal Water and the offshore TWC, is the primary inducement for the upwelling. Owing to a strong density gradient, the baroclinic pressure gradient force is quite large near the frontal zone, and this pressure gradient force elicits an upwelling branch along the topography slope. Wind, Taiwan Warm Current, and tide affect the density front in extension and intensity, thus exerting subsidiary influences on the upwelling. According to Ekman's theory, the northerly monsoon is downwelling favorable. However, the net effects of wind on the upwelling off the East China Sea coast in winter are positive because it drives the Changjiang River Diluted Water flowing southward and forms the density front. Similarly, the resultant effects of TWC on the upwelling are negative for obstructing the pathway of the Changjiang River Diluted Water. The tide contributes to the upwelling because tidal mixing facilitates the expansion of the Changjiang River Diluted Water.

PICES XV POC_Paper-2818 Oral
Cooling at hot spots: Amplification of tidal currents over banks and 18.6-year tidal cycle in the Oyashio and Sea of Okhotsk

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The dissipation of tidal energy in shallow and coastal regions and attendant mixing is an important process that affects the sea surface temperature. The Oyashio, near the Kuril Islands and Sea of Okhotsk, is a region of particularly strong tidal mixing. Examples of the impact of tidal currents on water temperature are the persistent tidal mixing above Kruzenshtern and Kashevarov Banks. Drifter observations were used to understand the characteristics of tidal currents over Kruzenshtern Bank (KB). The velocity was dominated by a diurnal signal with strong fortnightly modulation. The K_1 and O_1 tidal ellipses are clockwise with a nearly circular shape. To interpret the physical mechanism of the amplified diurnal currents over KB, a shelf-wave model was applied. The frequency of shelf waves around KB is close to the diurnal tidal frequencies for a steep slope of the bank. It is proposed that the amplified diurnal currents over KB are caused by the resonance with diurnal shelf waves. The observed fortnightly variability in tidal currents suggests that cold spots in summer are due to the vertical mixing with subsurface cold intermediate water caused by strong tidal currents. From values of tidal harmonics it is clear that $K_1 + O_1$ currents are large and their 18.6-year modulation is significant. The evidence of air temperature variability in the Sea of Okhotsk associated with the 18.6-year nodal cycle is presented. The mechanism of these bi-decadal variations of temperature is conceivably linked to nodal modulations of tidal current amplitudes.

PICES XV POC_Paper-2953 Poster

Linkages of oceanographic characteristic variability in the Tatarskii Strait with the Amur River discharge

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The Amur River fresh waters penetrate to Tatarskii Strait and have an influence on the variability of salinity, ice extent and sea surface temperature (SST). The long-term variability of Amur River discharge was analyzed. It is shown that the seasonal and annual Amur River discharge anomalies affecting Tatarskii Strait salinity are in agreement with the sun's activity.

The sun's magnetic field reverses sign every 11 years. Consequently, every 11 years a zonal baric type of atmospheric circulation alternates with the meridian type so that the North Asia monsoon weakens or strengthens. When the north wind intensity decreases, the south Japan Sea waters reach the top of Tatarskii Strait and the oceanographic characteristics change in comparison with normal atmospheric circulation years. Then the correlation coefficient sign and value depend, to a considerable extent, upon the hydrometeorological time series length. If the term of the series is set in accordance with even years and 11 years' of the sun spot period are added, the correlation doubles. This is shown by the example of the Amur River discharge, SST and the Tatarskii Strait salinity.

Thus, the impact of the seasonal Amur River discharge on the spring-summer SST and salinity and winter ice extent in the Tatarskii Strait is manifested. The sun has an influence on Amur River discharge and other oceanographic characteristics in this region.

PICES XV POC_Paper-3214 Oral

Seasonal variation of current structure in the subarctic North Pacific from Argo data

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The structure of the subarctic gyre and its temporal change has been investigated mainly from historical data and satellite altimetry. In this study, we analyzed synoptic data from Argo floats drifting in the subarctic North Pacific from October 2005 to April 2006 to show bimonthly variation in current structure. Wind stress curl increased remarkably in December 2005 and decreased in February 2006 north of 45°N. However, patterns of geopotential anomalies at the sea surface referred to 1000db are similar to each other except for April 2006 in which Alaskan Gyre was slightly strengthened. The northward Sverdrup transport crossing the parallel of 45°N varied from -60 to 57 Sv, whereas relative transport referred to 1000db moved steadily northward at 7 to 10 Sv. Since the subarctic gyre is wind-driven, the vertical current structure should be changed in the observational period. We estimated current structure from the sea surface to 1000db depth under the constraints of the Sverdrup relation and the mass continuity in boxes of 5° by 5° in longitude and latitude between the isopycnal surfaces for the bimonthly data. The western subarctic gyre was strengthened at the sea surface from December to February in which the Sverdrup transport increased. At 1000m depth the current tended to flow southwestward from the Gulf of Alaska to the east off Japan for all the data except for November to January, in which the southwestward current was shifted north to the south coast off the Aleutian Islands.

PICES XV POC_Paper-3174 Poster
Southward Oyashio intrusion revealed by profiling floats set to drift in the intermediate layer

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The southward Oyashio intrusion from the Oyashio area to the mixed water region (MWR) was examined using twelve profiling floats (isopycnal APEX, Webb Research Co., U.S.A.) set to drift on isopycnal surfaces of 26.6, 26.7, 26.8 and 27.2 σ_θ. The Oyashio water mainly consists of the Okhotsk Sea Mode Water (OSMW) with low potential vorticity (PV) and the East Kamchatka current water (EKCW) with high-PV in an intermediate layer of 26.7-26.9 σ_θ. We deployed these floats separately into the low-PV and high-PV parts in the southwestward Oyashio current in May 2001, September 2003 and July 2005, and then traced their movements in order to reveal the OSMW contributions to the southward Oyashio intrusion and the formation of the North Pacific Intermediate Water in the MWR. As a result, 6 of 7 floats deployed in the low-PV Oyashio moved to the MWR, while 3 of 5 floats deployed in the high-PV Oyashio stayed in the Oyashio area after a year. It is suggested that the water with OSMW properties tends to be transported southward into the MWR whereas the water with EKCW properties tends to stay in the Oyashio area. We will show the details of the float movements and the comparison with numerical models in the presentation.

PICES XV POC_Paper-2912 Poster
Seasonal variation of dissolved oxygen in the Oyashio

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Seasonal variations of dissolved oxygen (DO) in the southwestward Oyashio current were revealed by an analysis of bottle and CTDO (conductivity-temperature-depth-oxygen) sensor data from the two repeat hydrographic observation sections called OICE (Oyashio Intensive observation line off Cape Erimo) and A-line during 2000-2004, both of which extend southeastward from the Hokkaido coast. We examined the seasonal variation of the water properties isopycnally averaged at the stations in the southwestward Oyashio current. The DO has a maximum in spring at densities 26.6-26.9 σ_θ and in winter at densities 27.0-27.3 σ_θ, with a possible correlation with temperature and salinity variations. Thus we calculated DO, assuming an isopycnal mixture of the two Oyashio sources, which are the East Kamchatka current and the Okhotsk Sea waters, and compared them to the observed values. As a result, the calculated DO coincides well with the observed DO, especially at densities 26.6-26.9 σ_θ. It suggests that the seasonal variation of DO in this layer is caused mainly by seasonal variations in the occurrence or transport of these two source waters.

PICES XV POC_Paper-2955 Oral
Peculiarities in distribution of the N:P ratio in seawater of the Japan/East Sea

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A basin-scale oceanographic survey of the East/Japan Sea in summer 1999 on the R/Vs *Roger Revelle* and *Professor Khromov* revealed distinct peculiarities of the nitrogen/phosphate ratio distribution in seawater of the East/Japan Sea. It was found that the surface waters had very low nitrogen/phosphate ratios ranging between 1 and 3 for most parts of the Sea. A distinct maximum in the N:P ratio equal to 19-20 corresponds to 60-80 m depth. The distribution of the N:P ratios in the main body of the Sea is very uniform and ranges between 12-13, which is less than the Redfield ratio. There are two local areas where near bottom waters reveal low N:P ratios.

One of them is situated on the southwestern slope of the Ulleung Basin and another one is on the continental slope of the Primorye area, Russia at 46°N. These areas are characterized by low near bottom concentrations of oxygen and high concentrations of inorganic phosphates and dissolved inorganic carbon in comparison with surrounding waters. Distinct features of these areas are geochemical evidence of sedimentary denitrification that occurs there. The annual denitrification rate for the Japan/East Sea was estimated as 3.4×10^{12} gN/year using primary production of organic matter equal to 2.6×10^{14} g/year. Depletion of oxygen, release of carbon dioxide and phosphate and denitrification are proof of strong geochemical activities. It is suggested that observed geochemical activity is caused by high productivity as well as by allochtonic and terrigenic materials supplied from the Korean and Tatar Straits into the Japan/East Sea.

PICES XV POC_Paper-2890 Oral
Variability modes and typical patterns of surface wind over the JES and adjacent land

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The Japan/East Sea (JES), located in the monsoon region of Northeast Asia, is subject to intensive wind and thermal forcing, key factors that influence the physical environment of marine ecosystems, in particular through the sea circulation. Modeling studies have revealed that there is a substantial impact of wind stress and curl patterns, specific for different datasets, on the simulated JES circulation. The effect of strong and relatively stable winter winds is usually emphasized, while highly changeable summer winds are underestimated when averaged on monthly timescales, despite numerous strong synoptic events. To investigate wind variability over the JES, the complex empirical orthogonal function (CEOF) analysis is applied to the NCEP/NCAR 1°x1°-gridded 4 times daily fields for 1998-2005. Three first modes account for the general wind direction, its zonal and meridional modulation, and cyclonic (C) and anticyclonic (AC) vortex component. To reveal typical wind stress and curl patterns, initial fields are combined using the prevailing wind aspects derived from CEOF1. For the summer monsoon, the SW1 pattern, most frequent in May and July, is characterized by a C (AC) curl over the western (eastern) JES, while the SW2 pattern, occurring in June and August, is characterized by an AC curl over the central JES. From April through September, the Western (Eastern) pattern is characterized by an AC (C) curl over the central JES, the NE pattern by AC (C) curl over the western (eastern) part of JES, and the Southern – SE pattern reveals mostly a C curl. Circulation features simulated by the MHI numerical model (Shapiro, 1998) forced by the specific wind patterns are discussed.

PICES XV POC_Paper-3098 Oral
Long-term variability of temperature in the Yellow Sea and the East China Sea in the past 40 years

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Global warming is known as a remarkable phenomenon of the atmosphere-ocean system, which has been intensively studied on global and basin scales. However, variability of temperature in continental margins, especially in the Yellow Sea (YS) and the East China Sea (ECS), has been rarely studied and is poorly understood. Based on historical data from 1957 through 2001, coastal station data from 1960 through 1999 and pathfinder sea surface temperature (SST) data from 1985-2002, the long-term variability of temperature in the YS and the ECS is studied. In summer, SSTs showed a warming tendency in the north YS and in most parts of the ECS, including the Kuroshio and Taiwan Warm Current (TWC) regions, while there was a cooling tendency in the south YS and north edge of the ECS. Warming rates exceeding 0.02°C/a occupied the coastal zones of the north YS and the western ECS, and cooling rates exceeding -0.02°C/a were found in the south YS. Warming rates in the Kuroshio region were less than 0.02°C/a. In winter, temperature in most parts of the YS and the ECS warmed up with rates greater than 0.04°C/a in the central YS and greater than 0.08°C/a in the western ECS. The two warming centers correspond to the regions of the TWC and the Yellow Sea Warm Current (YSWC), respectively. As the origin of the TWC and YSWC, the Kuroshio warmed too. Interdecadal fluctuations of temperature were found in the representative regions with troughs in the 1970's, and peaks in the 1960's and 1990's, although the amplitudes were quite weak.

PICES XV POC_Paper-3225 Poster

Distributions of chemical species in the subarctic North Pacific and the western Bering Sea during 2004 summer cruise

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Time series observations and analysis of historical data in the northern North Pacific have given us a lot of knowledge related to climate change and/or global warming. It is found that dissolved inorganic carbon (DIC) has been increasing at Station KNOT since 1990. Material transport in the adjacent sea and the coastal area off the Kamchatka Peninsula can affect those changes. Distributions of several chemicals, dissolved oxygen, nutrients, chlorofluorcarbons (CFCs) and others were obtained during the R/V *Mirai* MR04-04 cruise to study the transport in the western North Pacific. Some results obtained during this cruise are shown in the following:

1) Dissolved silicate in deep water (potential density 27.75–27.78) is increasing from the western North Pacific subarctic region to the Bering Sea through the Kamchatka Strait. The bottom water in the Kamchatka basin has no CFCs, but CFCs are detectable in the Aleutian basin. This indicates that deep water in the western North Pacific is flowing to the western Bering Sea through the Kamchatka Strait and is spreading on the bottom of the Bering Sea.

2) Silicate content of upper deep water (near potential density 27.7 surface) in the Kamchatka Strait and Kamchatka basin is over 200 mol/kg and higher than that in the western North Pacific.

3) Intermediate water (potential density 27.0 surface) is classified as containing three water masses (out-flowing waters from the Bearing Sea, the Okhotsk Sea, and Alaskan Current water along the Aleutian Islands), from analyes of dissolved oxygen and CFC saturation.

PICES XV POC_Paper-2873 Oral

The development of a wave-tide-circulation coupled model and its application in the Yellow Sea and the East China Sea

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Common problems of ocean circulation models using the Mellor-Yamada turbulence vertical mixing scheme are an overestimation of sea surface temperature (SST) and an underestimation of upper mixing layer in summer, when the temperature stratification is stable. One possible reason for this is that surface wave induced mixing is not considered or is underestimated in these models. Yuan *et al.* (1999) suggested developing a wave-current coupled model. Qiao *et al.* (2004) postulated a wave-induced mixing term, Bv, as a function of the wave number spectrum. Following the theory of Yuan and Qiao, a wave-tide-circulation coupled model is established based on the Princeton Ocean Model (POM) and a numerical wave model. An additional wave-induced mixing Bv is computed by the wave model and added to the vertical viscosity K_M and diffusivity K_H calculated by the Mellor-Yamada turbulence mixing scheme in POM. The model is used to simulate the climatological temperature structure seasonal variation in the Yellow Sea and the East China Sea. The model result shows good agreement with the observation data. The result shows the wave-induced mixing controls the formation of the upper mixing layer in summer while the tide-induced mixing controls the formation of the bottom mixing layer and the temperature front in the Yellow Sea and the East China Sea. Compared with the original POM the coupled model solves the problem of overestimated SST and an underestimated upper mixing layer in summer when the temperature stratification is stable.

PICES XV POC_Paper-3129 Poster

Vertical eddy diffusivity at the Bussol' Strait in the Kuril Islands from CTD data

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The Bussol' Strait is one of the straits that has water exchange between Okhotsk Sea and North Pacific in Kuril Straits and it is speculated that there is strong vertical turbulent mixing because of strong tides. The Okhotsk Sea water mixed vertically in this strait flows out to North Pacific and has an important role in the formation of Oyashio Water, but it is not clear how strong the vertical turbulent mixing in a cross-section of this strait is. We estimate the temporal and spatial distribution of vertical eddy diffusivity indirectly, using the relation between the Ozmidov scale, the overturning thickness which causes vertical mixing, and Thorpe scale obtained by density inversions in conductivity-temperature-depth (CTD) profile data. The result suggests that the turbulence is largely influenced by tide. Mean cross-strait vertical eddy diffusivity is estimated to be 323cm^2/s in spring tide and 126cm^2/s in neap tide. Averaged vertical eddy diffusivity at the Bussol' Strait is then 222cm^2/s.

PICES XV POC_Paper-2832 Oral

Estimating suspended sediment concentration using ADCP, LISST-100 and OBS in Jiaozhou Bay and Laizhou Bay, China

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For more than a decade, acoustic Doppler current profilers, ADCPs, have been in common use for measuring current profiles. In recent years it has been recognized that after careful calibration procedures, echo intensity, a parameter recorded by ADCP when measuring current velocity, can also be used to quantitatively estimate suspended sediment concentration (SSC). Acoustic intensity weakens as it moves through water column because of sound spreading and absorption. In addition to considering losses from spherical spreading and water absorption, calculations of acoustic transmission losses caused by attenuation from suspended sediment and correction for nonspherical spreading in the near-field of the acoustic transducer are included in the present work. Also, the procedure to calculate SSC is improved by integrating the particle size information obtained from the Laser in-situ Scattering Transmissometer (LISST100).

In the current experiments conducted in Jiaozhou Bay and Laizhou Bay, China, RDI 600-kHz ADCP, LISST-100 and Optical Backscatter Sensor (OBS) are deployed to assess the potential of ADCPs to measure the suspended sediment concentration. Regression analysis shows that good correlation exists between the bottle samples and calibrated echo intensity. Turbulent characteristics through the tidal cycle are then calculated to explain SSC variation.

PICES XV POC_Paper-3128 Oral

The El Niño teleconnection to the isopycnal fluctuations in the southwestern East Sea/Japan Sea

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In this study we propose a teleconnection between strong El Niños and the isopycnal fluctuations of 27.0-27.2σ_θ in the Ulleung Basin in the southwestern East (or Japan) Sea and aim to determine the teleconection mechanism. To this end, we compute the cross-spectrum between Niño-3 and the isopycnal depths, between Niño-3 and European Centre for Medium range Weather Forecasting (ECMWF) reanalysis data, and between the isopycnal depths and sea surface temperatures (SSTs) at a period of 17.2 years. The resulting coherencies are significant at the 95% confidence level and the phases are nearly opposite between Nino-3 and the isopycnal depths, indicating that during the mature phase of strong El Niños, the isopycnal depths in the Ulleung Basin become shallow. The coherencies and phases between Niño-3 and SSTs, and between the isopycnal depths and SSTs,

indicate that the isopycnal fluctuations there are attributed to SST fluctuations in the northwestern East Sea. The results of analysis on the causal mechanism indicate that the warm and humid air column becomes thick in the western Indian Ocean during the mature phase of strong El Niños and the lower density air is transported into the Siberian High region. This air pushes the existing cold air of the Siberian High to the east and makes it penetrate southward to the East Sea. The SST decrease due to this penetration, the formation and southward flow of the cold, relatively fresh water, and the convergence of this water in the Ulleung Basin appear to cause the teleconnection between El Niños and isopycnal fluctuations in the southwestern East Sea.

BIO Poster Session

Convenor: Michael J. Dagg (U.S.A.)

Posters on various aspects of biological oceanography in the North Pacific and its marginal seas (excluding S2-S5 topics) are welcome.

Thursday, October 19, 2006 18:00-20:30

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Distribution of macrozoobenthos in the North-West part of the Japan/East Sea in 2006 (BIO_Poster-2790)

Andrew A. Bobkov and Kirill M. Petrov
Bionomic criteria for large marine ecosystem identification (BIO_Poster-2900)

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Biological transport and survival of larval pelagic fishes in the Kuroshio system region estimated with Lagrangian drifters (BIO_Poster-2786)

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Increase in salp abundance during 1983-1993 in the western subarctic North Pacific (BIO_Poster-2944)

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Phytoplankton of the Amur River estuary and adjacent areas in July 2005 (BIO_Poster-2951)

Yugo **Shimizu**, Kazutaka Takahashi, Shin-ichi Ito, Shigeho Kakehi, Akira Kusaka and Tomoharu Nakayama
Southward carbon transport of large subarctic copepods by the Oyashio current (BIO_Poster-2886)

Dong Hyun Shon
Differentiation of phytoplankton groups using in-water optical techniques (BIO_Poster-3175)

Vladimir I. Zvalinsky and Pavel Ya. Tishchenko
Natural and anthropogenic eutrophication of Amursky Bay (East/Japan Sea) (BIO_Poster-2965)

Keiko Yamada, Sang-Woo Kim, Hee-Dong Jeong and Woo Jin Go
Typhoon effects on the short-term variation of chlorophyll-*a* in the East/Japan Sea, derived by satellite remote sensing (BIO_Poster-2865)

PICES XV BIO_Poster-2790
Distribution of macrozoobenthos in the North-West part of the Japan/East Sea in 2006

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The results of a benthic survey in the NW part of the Japan/East Sea (43-47°N; 134°30'-141°30'W) in 2006 are presented. Benthic samples were taken from 15sites ranging in depth from 125-2180m. Eighty benthic species were identified from soft substrata within the area studied. The most abundant in terms of number of species were polychaetes (37 species) and bivalve molluscs (21). Total benthic biomass ranged from 0.04g/m^2 (1400m depth) to 86.8g/m^2 (176m). Total density ranged from 4 to 700ind/m^2. Average biomass and density of bottom macrofauna were 23.4g/m^2 and 193.4ind/m^2, respectively.

The most important contributors to total biomass came from five benthic faunal groups: Brachiopoda, Asteroidea, Ophiuroidea, Polychaeta and Bivalvia. Over the depth range of 125-250m, the brachiopod *Laqueus vancouveriensis* dominated the biomass. At stations deeper than 500m, biomass was dominated by the starfish *Ctenodiscus* sp.

PICES XV BIO_Poster-2900
Bionomic criteria for large marine ecosystem identification

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The Oceanosphere is organized as a set of multiple chorological subsystems of miscellaneous rank. Most generally, it is possible to speak about biomes of local, regional, etc range. Any natural complex of marine communities represents a single unit, characterized by horizontal and vertical properties and controlled by azonal factors. Apparent linkages of hydrbiont distributions with water masses, derived from stations and biotopes, allows comparison of biogeographic and oceanographic classifications for establishment of joint biooceanographic zones. Specific properties of oceanic waters identify the vital space of marine organisms. Dynamics of these waters principally control the concentration and migration of passively and actively floating hydrobionts. Boundaries of water masses do not have strictly fixed locations and a difficulty exists in choosing optimal bionomic criteria to describe most fully the features of each concrete region. By characterizing such boundaries, a system of three-level operational units can be used, namely units of zonal (belt-sector-zone latitudinal-province); azonal (marine basin-area/subarea- district-region); and, vertical (stage-layer-zone vertical) properties. This system reflects the biotope hydroclimate which, together with relief and processes of sedimentation, predetermine the species composition and the distributions of the biohydrocenosis. Bionomic criteria, taking into consideration an inner non-uniformity of water, are used to identify biocenosis with characteristic sets of indicator species, which correspond to specific properties of regional water masses.

PICES XV BIO_Poster-2786
Biological transport and survival of larval pelagic fishes in the Kuroshio system region estimated with Lagrangian drifters

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Biological transport and survival of larval pelagic fishes in the Kuroshio system region were studied using Lagrangian drifter data from 1990–2003. Subseasonal movement from the Kuroshio area is presented. Lagrangian temperature, measured during transport, was applied to an optimal temperature model for growth and mortality to estimate survival of larval patches. The majority of drifters from the Kuroshio area south of Japan, where there are dense spawning grounds of Japanese sardine and Japanese anchovy, spread around the Kuroshio Extension up to 170°E. Due to a recirculation gyre, ome of the other drifters moved southward to the

offshore area of the Kuroshio. A recirculation gyre in the Kuroshio Extension region also plays a significant role for retention and dispersion of drifters. We show that these recirculation gyres enhance seasonal amounts of warming and cooling, apparently through horizontal mixing. Results of the survival model suggest that surface water during the observational period was too warm for the Japanese sardine to increase, while temperature and transport conditions were ideal for larval Japanese anchovy from an area around the Izu islands, Japan in April–June.

PICES XV BIO_Poster-3087
Secondary production of *Jassa slatteryi* (Amphipoda, Ischyroceridae) on a *Zostera marina* seagrass bed in Southern Korea

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On the basis of monthly samples, we measured the secondary production of the amphipod *Jassa slatteryi* Conlan 1990, on a seagrass bed (*Zostera marina* L.) in Gwangyang Bay, southern Korea. The standing crop of seagrass showed 2 peaks in spring and fall, with maximum biomass in May. Biomass distribution of *J. slatteryi* is positively correlated with the standing crop of seagrass ($p<0.05$), suggesting that there is a biological interaction between these 2 species. *J. slatteryi* displays 2 main breeding periods during the year; in spring (March to May) and in fall (October to December). The biomass of *J. slatteryi* and standing crop of seagrass in the spring was much higher than in the fall. The annual secondary production of *J. slatteryi* in the Gwangyang Bay seagrass bed (20.07g dry weight m^{-2} yr^{-1}) is the highest reported in amphipods inhabiting seagrass beds. However, the annual production biomass (*P:B*) ratio, at 5.21, was lower than recorded previously in both temperate and tropical seagrass beds because the number of generations decreases the *P:B* ratio. The combination of high abundance and secondary production suggests an important role for *J. slatteryi* in the seagrass-bed ecosystem as a trophic link from primary producers to higher consumers.

PICES XV BIO_Poster-2988
Zooplankton distribution, abundance and biomass relative to oceanographic conditions in the Yellow Sea

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The spatial distributions of important zooplankton groups and biomass were compared to oceanographic conditions in the Yellow Sea to understand the status of basin ecosystem. Zooplankton abundance and biomass were estimated in October~November 2003 and 2005 by both Korea and China. Seawater temperature, salinity and chlorophyll-*a* concentration were also measured. Zooplankton biomass was higher in 2005 than in 2003. The high zooplankton biomass was mainly concentrated in the southeastern coastal region in 2003 and the southwestern coastal region in 2005. Zooplankton was composed of 21 taxa in 2003 and 17 taxa in 2005. Even though the numbers of identified taxa were different between years, the dominant taxa were similar. The dominant taxa were as follows: Copepoda, Chaetognatha, Thaliaceae, Euphausiid, Amphipoda and Appendicularia. The spatial distribution of Copepoda was similar to that of total zooplankton biomass. Fish larvae and eggs were found in 2005, while not in 2003, mainly in the northwestern coastal region. Chlorophyll-*a* concentration was also higher in 2005 than in 2003, and distributed similarly to zooplankton biomass. Sea surface temperature decreased towards the northern area and ranged between 15~20ºC in both years. Sea surface salinity was lower in 2005 than in 2003, in particular in the most southeastern area. In contrast to surface salinity, salinity at 50m was higher in 2005 than in 2003. The high saline water was mainly concentrated near the western coast. We concluded that zooplankton production is closely related to the coastal area and to low salinity water in the Yellow Sea.

PICES XV BIO_Poster-2816
Composition, distribution and interannual variability of zooplankton in the inner part of Amursky Bay (Japan/East Sea)

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Zooplankton density in the spring-summer period was much higher in the central part of Amursky Bay (50,000 ind/m^3) and near the southwestern and northwestern coasts (63,000 ind/m^3), than near the eastern coast of the northern part of Bay (25,000 ind/m^3). Dominant copepod species were the boreal-arctic *Acartia aff. clausi* (55.7%), *Pseudocalanus newmani* (8%) and nauplii of Copepoda (19.7%) in June and the subtropical *Oithona brevicornis* (40%), the cosmopolitic *O. similis* (26%) and the tropical-subtropical *A. pacifica* (17%) in August. Copepodid stages I-III of all species were rare or absent in the eastern coast waters of the northern part of Bay. Indices of specific richness and diversity were also lowest in this region. These data are evidence of adverse conditions in this part of the Bay, because indices of specific diversity decrease in stressful environments and increase in favorable environments, according to Tinemanna's principle. For the last 25 years, zooplankton density and taxonomic diversity have increased but lowest values were seen in 1991. Perhaps, this was caused by pollution of water in that part of the Bay, as the highest anthropogenic loading was recorded in early 1990.

PICES XV BIO_Poster-2971
Maturity and spawning of *Glyptocephalus stelleri* in the East/Japan Sea, Korea

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The maturity and spawning of *Glyptocephalus stelleri* was studied using samples collected in the East/Japan Sea of Korea from 2004 to 2005. We analyzed monthly changes in gonad weight (GW) and gonadosomatic index (GSI), histological changes of ovary in female and of testis in male, fecundity, total length at 50% group maturity and sex ratio. The spawning period was April to June, and the main spawning period was estimated to April to May. Annual reproductive cycles of female could be divided into six successive stages (immature stage: July-August, nucleolus stage: September-October, yolk vesicle stage: October-November, vitellogenic stage: December-January, ripe stage: February-April, spent stage: May-June) and male could be divided into four successive periods (recovery period: May-June, spermatog onial proliferation period: July-September, spermatogenic period: October-December, functional maturation period: January-April). The relationship between fecundity (F, eggs) and total length (TL, cm) was $F=2.246TL^{3.0143}$ (R^2=0.6364). The total length at first maturity was 17.6cm and at 100% maturity, 24.8cm. The total length at 50% group maturity was estimated to be 22.2cm. The sex ratio was similar between female and male as 52:48, respectively, but female was a little predominant in large size more than 23cm.

PICES XV BIO_Poster-2983
Plankton distribution during the spring bloom in Asan Bay in the Yellow Sea, Korea

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To understand the spatial and temporal distribution of phytoplankton and mesozooplankton during the spring bloom period in Asan Bay, Yellow Sea, we sampled plankton at about 2 weeks' intervals at 5 stations from mid February to the beginning of June. Maximum Chl-*a* concentration was 44.32 μg/ℓ and occurred in the inner part of the bay during mid February. Concentrations of Chl-*a* in the middle part of the bay were similar to those in the inner bay. In the outer bay, the concentration of Chl-*a* was less than 10 μg/ℓ during the study period. The phytoplankton bloom in the inner bay lasted for about 1 month and was more intensive than in the outer bay.

The abundance of mesozooplankton was highest in the middle part of the bay (st. 3) in the beginning of April and lowest in the inner part (st. 1) in mid February. Chl-*a* and phytoplankton abundance were well correlated. Mesozooplankton increased about 1 month after the phytoplankton bloom. This indicates that phytoplankton abundance affected zooplankton after a certain period of time. We concluded that the *in situ* distribution of phytoplankton during the bloom was affected primarily by the concentration of nutrients rather than zooplankton grazing in Asan Bay.

PICES XV BIO_Poster-2980
Seasonal distribution of siphonophores in and near the Kuroshio Current off eastern Taiwan

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This study describes the seasonal variation in species composition and abundance of siphonophores in relation to hydrographic conditions in and near the Kuroshio Current off eastern Taiwan from May 2000 to July 2001. In total, 54 siphonophoran species belonging to 21 genera and six families were recognized. The six most predominant species, which constituted 75% of the total siphonophores, were, in order of abundance, *Chelophyes contorta*, *Abylopsis tetragona*, *Bassia bassensis*, *A. eschscholtzi*, *Eudoxoides mitra*, and *Diphyes chamissonis*. The abundance of siphonophores showed an apparent seasonal change, higher in autumn and lower in winter and summer. The mean abundance of siphonophores was significantly higher in the Kuroshio waters than in coastal waters, although species number was the same. Non-metric multidimensional scaling revealed clear seasonal and spatial variations of siphonophoran assemblages. Different dominant species showed different seasonal distribution patterns and different relationships with water temperature and salinity.

PICES XV BIO_Poster-2944
Increase in salp abundance during 1983-1993 in the western subarctic North Pacific

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Salps are filter-feeding gelatinous macrozooplankton and their periodic blooms in response to 'favorable' environmental conditions have often been reported from various parts of the world ocean. However, little is known about the biological/physical factors that enable salps to achieve rapid population growth. In addition, decadal - or multi-decadal variations of marine ecosystems have been studied in various regions in the subarctic Pacific. While increases of scyphozoan jellyfish such as *Chrysaora* and *Nemopilema* on decadal scales have been intensively studied, little attention has been given to salps, especially in the western part of subarctic Pacific. Net samples were collected from 47-107 stations from mid-May to June during an 11 year period from 1983-1993 in the area of 37-40ºN, 142-180ºE. We examined the occurrence patterns of total and dominant salp species. Total salp abundance in the area ranged from 432 ind.m^{-2} (in 1989) to 37244 ind.m^{-2} (in 1993), and increased exponentially within the research period. Salps occurred at 18-77% of sampling stations. Among 9 species found, two species, *Thalia democratica* and *Salpa fusiformis* dominated numerically. Significant correlations were obtained between salp abundance and the percentage of the sampling stations where salps of both species occurred, suggesting that an increase of abundance in more recent years is not due to the higher abundance at specific stations but rather is due to the wider horizontal occurrence of salps in the research area. Possible causes for an overall increase of salp abundance during the 11–year survey will be discussed.

PICES XV BIO_Poster-2951
Phytoplankton of the Amur River estuary and adjacent areas in July 2005

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Phytoplankton of the Amur River estuary and adjacent areas of the Sea of Okhotsk and the Sea of Japan was investigated in July, 2005 at 33 stations. The study revealed 195 species of microalgae from 8 divisions. Microalgae varied most in Sakhalin Bay - 122 species - and less in Tartar Strait - 98 species. Phytoplankton total density ranged from 0.031 to 9.7 million cells/L, and biomass varied from 0.2 to 6.2 g/m^3. Average density of microalgae was 241 thousand cells/L and average biomass was 1.5 g/m^3 in Tartar Strait, 288 thousand cells/L and 1.9 g/m^3 in the Amur River estuary, and 1.4 million cells/L and 2.1 g/m^3 in Sakhalin Bay. Diatoms dominated everywhere. They comprised 43-84% of total density and 93-99% of total biomass of phytoplankton. Many freshwater species were found in the northern part of the Amur River estuary and in the southern part of Sakhalin Bay, indicating river water influence. Freshwater algae were represented by Cianophyta - 10 species, Diatoms – 8 species, and Chlorophyta – 16 species. High concentrations of freshwater algae were observed in the northern part of the Amur River estuary (up to 460 thousand cells/L), and in the central part of Sakhalin Bay (up to 345 thousand cells/L). Freshwater species comprised 23-93% of phytoplankton density in the Amur River estuary and 10-54% of phytoplankton density in Sakhalin Bay. A bloom of *Skeletonema costatum* was recorded in the central part of Sakhalin Bay, where density exceeded 9 million cells/L, indicating a strong eutrophic influence of Amur River water on this area.

PICES XV BIO_Poster-2886
Southward carbon transport of large subarctic copepods by the Oyashio current

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The lateral carbon transport of the four large subarctic copepods (*Neocalanus cristatus, Neocalanus flemingeri, Neocalanus plumchrus, Eucalanus bungii*) was estimated by integrating seasonal observation data in the Oyashio area off Hokkaido Island, Japan. This transport was compared to copepod production and vertical ontogenetic migration and mortality in deeper layers. We analyzed seasonal observation data during 2001 to 2002 on a repeat section called OICE (Oyashio Intensive observation line off Cape Erimo), which extends southeastward from Hokkaido. In these observations, we sampled the copepods in four layers above 500 m depth with a vertical multiple plankton sampler (VMPS) and deployed a conductivity-temperature-depth sensor from 0-1500 m. Multiplying the copepods' carbon by the geostrophic current and integrating over time and space, we estimated the net southwestward carbon mass of these four copepods across OICE to be 561 kilo tons (kt) per year. Based on the results of other experiments deploying isopycnal floats in the Oyashio current, 435 kt of these copepods are considered to traverse the Oyashio front and reach the mixed water region, where copepod reproduction does not occur because of excess temperature. From previous studies, estimates of annual copepod production and vertical transport in the Oyashio area are 10 mega tons (Mt) and 2.2 Mt respectively. Therefore, lateral transport is about 5 % of total copepod production and 20 % of total vertical transport.

PICES XV BIO_Poster-3175
Differentiation of phytoplankton groups using in-water optical techniques

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The detection of an algal bloom from ocean colour sensors depends on the concentration of phytoplankton pigments because pigments, such as chlorophylls, produce a significant change in the optical properties of water. The pigment composition results in a characteristic colour, which can be measured using absorption spectra and spectral reflectance signatures. Each individual phytoplankton group contains a number of accessory

pigments and has its own characteristic composition. Several of these pigments are restricted to 1 or 2 phytoplankton classes. As these marker pigments have distinctive absorption spectra, which determine a characteristic spectral signature, they can be used as indicators of different phytoplankton classes. Using the High Performance Liquid Chromatography (HPLC) system, major accessory pigments contained in phytoplankton samples were analysed. *In situ* measurements of remote sensing reflectance were obtained at wavelengths coincident with the SeaWiFS visible wavebands using a Profiling Reflectance Radiometer (PRR600, Biospherical Instruments Inc). Group specific absorption spectra were generated according to the proportion of one of the marker pigments, fucoxanthin, in the sum of pigments measured by HPLC. Remote sensing reflectance was modelled based on phytoplankton group specific absorption spectra and compared to the *in situ* remote sensing reflectance signatures.

PICES XV BIO_Poster-2965
Natural and anthropogenic eutrophication of Amursky Bay (East/Japan Sea)

V.I. Zvalinsky and Pavel Ya. **Tishchenko**

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The Razdol'naya River and associated sewage drains Vladivostok city and are the main sources of natural and anthropogenic nutrient enrichment for Amursky Bay (East/Japan Sea). In our study, macronutrient concentrations (nitrogen, phosphorus, and silicon), oxygen, chlorophyll, primary production and water transparency were measured. Annual total loading of macronutrients into Amursky Bay were: 4000 - 7100 tons of nitrogen, about 320 tons of phosphorus and 12,000 tons of silicon. Measured primary production varied between 0.4 and 1.2 g $C*m^{-2}*day^{-1}$ and 0.6 - 2 g $C*m^{-2}*day^{-1}$ in wintertime and summertime, respectively. During summertime, the total primary production of the northern part of Amursky Bay (500 km^2) is about 100,000 tons of carbon. Using Redfield ratios (C:N:P=106:16:1), it was estimated that this ecosystem can assimilate up to 15,000 tons of nitrogen and 1,000 tons of phosphorus. Thus, the current capacity of the Bay is three times higher than observed average primary production. At present, the ecosystem of Amursky Bay satisfactorily treats existing fluxes of macronutrients. Available data do not permit separate identification of natural and anthropogenic impacts in Amursky Bay. Further investigations are needed for clarification of this matter.

PICES XV BIO_Poster-2865
Typhoon effects on the short-term variation of chlorophyll-*a* in the East/Japan Sea, derived by satellite remote sensing

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The objectives of this study were to derive the short-term variation of sea surface temperature before and after typhoons during summer in the East/Japan Sea, and to determine the increase in chlorophyll-*a* concentration that accompanies the typhoons. Five day averages of SST and surface chlorophyll-*a* concentration before and after typhoons were calculated from satellite images in the study area (34-50ºN, 127-143ºE) by NGSST (0.05 degree resolution, daily, Tohoku University) and SeaWiFS (9km resolution, daily, NASA), respectively. Four typhoons in 2004 (NAMTHEUN, MEGI, CHABA and SONGDA) and one typhoon (NABI) in 2005 passed over the East/Japan Sea. Decreases in SST were associated with all five typhoons, but the magnitude of decrease varied (1-5ºC). Chlorophyll-*a* increases (0.1-5.0 μg l^{-1}) were observed after each typhoon expect NAMTHEUN, and the area affected was approximately included within the area cooled by the typhoons. The magnitude of chlorophyll-*a* concentration increases seemed to depend on the typhoon path. Increased chlorophyll-*a* concentration was greater in southern areas than northern areas and in coastal areas than in offshore areas. We suggest that increase of chlorophyll-*a* concentration is related to the amount of nutrients supplied to the upper layer by typhoon induced mixing.

MEQ Poster Session

Convenor: John E. Stein (U.S.A.)

Posters on various aspects of marine environmental quality in the North Pacific and its marginal seas (excluding S8 and S9 topics) are welcome.

Thursday, October 19, 2006 18:00-20:30

Tatyana A. Belan and Alexander V. Moshchenko
Near-bottom environmental conditions and state of benthos at the inner part of Amursky Bay (Peter the Great Bay, Japan/East Sea) (MEQ_Poster-2762)

Andrey P. Chernyaev and Alexander A. Vostroknutov
Determination of n-nonylphenol in the sea water (MEQ_Poster-2975)

Minkyu Choi, Gui-Young Kim, Hyo-Bang Moon, Hee-Gu Choi, Jun Yu and Jong-Soo Park
Behavior and contamination of estrogenic nonylphenols in Masan Bay, Republic of Korea (MEQ_Poster-3123)

Yoon seok Choi, Jong hui Kim, Chang su Jeong and Hyeon Seo Cho
Distribution and origins of PCBs and PAHs in sediments of Yellow Sea (MEQ_Poster-3100)

Daoji Li, Lei Gao and Ping Wang
Nutrient exchange fluxes between water-sediment interface in tidal flat of Dongtan, Changjiang (Yangtze River) estuary (MEQ_Poster-2905)

Tatyana S. Lishavskaya and Alexander V. Moshchenko
Contamination level and distribution of some pollutants in bottom sediments of the north-west part of the Japan/East Sea in 2006 (MEQ_Poster-2813)

Renyan Liu, Daoyan Xu, Yuhua Dong, Bingjun Chen, Bing Liang, Yubo Liang and Sai Ye
Preparation of monoclonal antibody against okadaic acid and development of ELISA to detect diarrhetic shellfish poisoning in shellfish from China (MEQ_Poster-3254)

Olga N. Lukyanova, Svetlana A. Aleshko and Sergey A. Cherkashin
Mysids as sensitive bioindicators for coastal ecosystems monitoring (MEQ_Poster-2850)

Tatiyana V. Pavlova, Vasiliy F. Mishukov and Larisa C. Buzoleva
Dynamics of number of oil oxidizing microorganisms in Golden Horn Bay of the Sea of Japan (MEQ_Poster-3070)

Dariush Mowla and Majid Ahmadi
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Long-range transport of polycyclic aromatic hydrocarbons and nitropolycyclic aromatic hydrocarbons from China to Japan (MEQ_Poster-3131)

PICES XV MEQ_Poster-2762

Near-bottom environmental conditions and state of benthos at the inner part of Amursky Bay (Peter the Great Bay, Japan/East Sea)

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The results of an ecological survey of the inner part of Amursky Bay in June, 2005 are presented. More than 130 benthic species including phytobenthos were identified on soft substrata at the area studied. Average biomass and density of bottom macrofauna was 566.4 g/m^2 and 3083 ind/m^2, respectively. Bivalve molluscs (26.7%), barnacles (21.5%) and sea anemones (16.1%) were prevalent in biomass, while polychaetes dominated in abundance. The main factors affecting structure, abundance and distribution of benthic communities were: water salinity, sediment type and organic carbon content in bottom sediments.

Statistically-significant relationship between total pollution level (*PHC+Phenols+Pb+Cu+∑DDT*) and distribution of benthic communities was not detected. However, strong alterations of species composition in 2005, compared with 1970-1980s, were detected. The high abundance of some species (alga *Ulva fenestrata*, polychaete *C. capitata,* phoronid *Ph. harmeri,* bivalve *Theora fragilis* and sea anemone *Edwardsia japonica*) can be evidence of progressive euthrophication of Amursky Bay.

PICES XV MEQ_Poster-2975

Determination of n-nonylphenol in the sea water

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Recently specialists in the field of ecology and medicine have taken great interest in chemical substances which have a negative impact on the endocrine system and development of vertebrates and invertebrates. Among such substances, n-nonylphenol is especially significant because of its high concentration in the environment. This substance is marked by its sharply negative influence on endocrine system of invertebrates, fishes and mammals. Monitoring of alkylphenol in the environment has revealed its connection with numerous problems, including the non-availability of standard methods of detemination in Russia. For estimation of potential for n-nonylphenol extraction from model environment, extraction of n-nonylphenol was carried out using two extractions by 50 ml of dichloromethane. The associated extracts were dried by waterless sodium sulfate and evaporated untill dry under reduced pressure. The dry residuum was dissolved in acetonitrile. The exhaustiveness of extraction was 80 %.

Separation of the obtained extracts was carried out by high-performance liquid chromatograph, HP 1100, supplied with diode-matrix and mass-selective detectors. The type of ionization is API-ES Negative. The column is “Zorbax ODS” 25cm x 4.6mm. The limit of detection and minimum detected quantity of the substance was (5 ng) was calculated as (50 ng/l).

As a result of the experiment, a method of n-nonylphenol extraction from the sea water with its following chromatography and mass-spectrometric determination was worked through, and the process enables us to develop and put into practice a monitoring program of n-nonylphenol concentration in coastal sea water.

PICES XV MEQ_Poster-3123

Behavior and contamination of estrogenic nonylphenols in Masan Bay, Republic of Korea

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We measured the amounts of estrogenic nonylphenols in 42 seawater, 40 sediment, and 24 creek water samples from Masan Bay to investigate the status and source of contamination and conduct a risk assessment on aquatic life. Nonylphenol (NP) and nonylphenol (1-2) ethoxylates [NP(1-2)EOs] were detected in all samples in the range of 56-24,374 ng/L for water and 15-4,944 ng/g dry weight for sediment, respectively. The levels of these compounds in seawater decreased with distances from terrestrial sources. However, the nonylphenols seemed to be transported at least several tens of kilometers into Masan Bay. The highest concentrations were found in the samples collected from creeks and the mouth of the bay, indicating that one of the contamination routes in the bay is creek discharge. Relatively high concentrations were observed at stations near the outfall of sewage treatment plants. However, those levels were comparable to or lower than those previously reported in other foreign locations. Based on water quality guidelines proposed by some countries, approximately 41% of water samples exceeded the guideline. These results suggest that nonylphenols can be a cause of chronic and reproductive toxic effects on various marine organisms from these areas. We also estimated the load of nonylphenols through the creeks into the Masan Bay. The results indicated that considerable amounts of these compounds are discharged through the creeks, which receive discharges from industrial complexes. To efficiently manage nonylphenols in the bay, it would be best to improve the connection rate of the sewage system in industrial complexes.

PICES XV MEQ_Poster-3100

Distribution and origins of PCBs and PAHs in sediments of Yellow Sea

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To assess the status of polycyclicaromatic hydrocarbon (PAH) contamination and polychlorinated biphenyl (PCB) in surface sediments of Yellow Sea, we analyzed sediment samples of 33 stations by gas chromatography mass spectrometry (GC-MS). In this study total concentration of PAHs ranged from 2201.54 to 15432.42 ng/g dry weight. The average total PAHs concentrations were 6256.43 ± 3516.34 ng/g dry weight. The estimated total PCBs concentrations for 23 congeners ranged from 2837.74 pg/g dry weight to 13740.03 pg/g dry weight with the average of 7431.18 ± 2868.21 pg/g dry weight. Very high concentrations of PAHs appeared for the central area of Yellow Sea, and this pattern was similar to the spatial distribution of PCB concentration of the 33 sites collected in the Yellow Sea. Highest concentrations of PCBs and PAHs typically occur in sediments having a large fraction of clays, organic matter, or micro-particulate, and the amount of PCBs sorbed to particles tends to increase as the TOC content of sediment rises. It has also been reported that the concentration of total PCBs and PAHs in sediments were significantly correlated with the organic carbon content, and both contents were affected by grain size distribution. In addition to total organic carbon, Al, Fe and Mn were possible normalisers. In the present study, different sediments had different grain size distribution and the high PCB concentration also had a very high TOC content, with a significant correlation coefficient (R = 0.306) between total PCBs and TOC concentration.

PICES XV MEQ_Poster-2905

Nutrient exchange fluxes between water-sediment interface in tidal flat of Dongtan, Changjiang (Yangtze River) estuary

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The sediment-water exchange fluxes of nutrients (*i.e.* NH_4^+, NO_2^-, NO_3^-, PO_4^{3-}, and SiO_3^{2-}) and dissolved oxygen were investigated monthly in the tidal flat of Dongtan, a turbidity maximum zone area in Changjiang (Yangtze River) estuary, in an annual cycle from March 2005 to February 2006. The results indicated that (1) except for NH_4^+, there seemed to be significant influxes from overlying water into sediment for other four nutrients and (2) the high and middle marshes, covered with vegetation, showed a more significant tendency of assimilating nutrients than low marsh without vegetation growth and (3) the temperature and nutrient concentrations present in overlying water could both draw their significant effects on the fluxes. According to the numerical model provided by Christensen *et al.* (1990), the denitrification was estimated to be in a range from -16 μmol h^{-1} m^{-2} to 193 μmol h^{-1} m^{-2} (average 63 μmol h^{-1} m^{-2}, n=18) in the study area, of which both coupled nitrification production (D_N) and overlying water input (D_W) were important pathways to provide the NO_3^- needed. Moreover, the results also implied that denitrification could take a significant contribution for the organic carbon mineralization in Dongtan intertidal flat sediments in Changjiang estuary.

PICES XV MEQ_Poster-2813

Contamination level and distribution of some pollutants in bottom sediments of the north-west part of the Japan/East Sea in 2006

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Investigations of the state of the deep sea environment are extremely irregular. In addition, our knowledge of the processes in such zones remains poor and demands more detailed study. Contents of petroleum hydrocarbons, metals and organochlorines in bottom sediments of the northwestern area of the Japan/East Sea (43-47ºN; 134º30'-141º30'W) have been investigated. The samples were taken at the depths of 117-3600 m in March 2006. For comparison the data obtained by FERHRI specialists in 1987-1989 along century transects (between Zolotoy and Slepikovskogo Capes and between Terney and Kamui Capes) were used.

Contamination level of sediments in the region studied was shown to be rather low, and it was notably dropped from the 1980s to 2006. Effects of several factors determining input and accumulation of different contaminants – the system of currents, fraction composition of sediments, etceteras – are displayed in their distribution patterns.

PICES XV MEQ_Poster-3254

Preparation of monoclonal antibody against okadaic acid and development of ELISA to detect diarrhetic shellfish poisoning in shellfish from China

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Monoclonal antibody against OA (okadaic acid, diarrhetic shellfish poisoning, DSP) was prepared using the technique of cell fusion. This antibody was used in developing a idc-ELISA (indirect competition enzyme-linked immunosorbent assay) for OA detection. With the carbodiimide method, the hapten OA is coupled with the carriers hemocyanin and ovalbumin, respectively, to obtain immune antigen and coating ligand. Using OA-KLH as the immunogen to immunize BALB/c mice several times, the titer of antibody in serum was measured.

When the titer was greater than the required value, splenocytes from the immunized mice were fused with murine myeloma cells. Using OA-OVA as the coating ligand, culture media were screened for adopting an ELISA method. Three positive hybridoma cells strains that could secrete steadily anti-OA monoclonal antibody were obtained after several times of cloning. The minimum detectable limit is 0.781ng/ml OA using the idc-ELISA method developed by 1#OA monoclonal antibody.

PICES XV MEQ_Poster-2850
Mysids as sensitive bioindicators for coastal ecosystems monitoring

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To describe all aspects of the ecosystem state, a suite of indicators, covering different changes of the environment and biota, is needed. Taken together, indicators can provide a quick evaluation of the state of marine ecosystems. They should be used simultaneously to understand the mechanisms and processes that are acting. Mysid shrimps (Crustacea, Mysidacea) are common in shallow coastal waters and form vital links in aquatic food webs. Besides, mysids are sensitive to the chemical contaminants, so some species are suitable organisms for estimation of ecotoxicological conditions in coastal areas. Such aspects of their physiology as growth, reproduction, development and the activities of antioxidant and biotransformation enzymes were used for bioindication of pollution influence in the Peter the Great Bay (Japan/East Sea). Our studies have shown the changes in the size and sexual structure of populations from coastal areas with different levels of anthropogenic pressure. There were specific and spatial differences in the activity of glutathione-S-transferase and other biomarkers of oxidative stress in stenobiotic (*Paracanthomysis* sp.) and eurybiotic (*Neomysis mirabilis*) species. These metabolism alterations should be linked to the effects at higher levels of biological organization (*i.e.* reproductive success). It is concluded that mysids are appropriate indicators of responses of coastal ecosystems to pollution.

PICES XV MEQ_Poster-3070
Dynamics of number of oil oxidizing microorganisms in Golden Horn Bay of the Sea of Japan

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In 2003-2004, scientists at the V. I. Il'ichev Pacific Oceanological Institute and Far Eastern National University conducted seasonal monitoring of a number of oil oxidizing microorganisms in Gold Horn Bay in the Sea of Japan. The basic sources of oil pollution are the ship-repair enterprises, the largest city ports, and city wastewater.

The results shown in the table below indicate a seasonal change in the number of microorganisms in the bay, with minimum concentrations in the cold season. The greatest number of aerobic heterotrophic organisms is observed in the area of input of the Ob'yasneniya River in Gold Horn Bay, where warm waters from the cooling system of the largest thermal power station of Vladivostok enter the marine environment.

The mineral environments, distinguished from each other only by additives of different kinds of oil, show various numbers of oil oxidizing microorganisms in seawater for each sampling point. The results indicate that only some kinds of bacteria can actively develop and decompose petroleum in conditions of moderate petroleum pollution, while the others show more selective activity. Experiments on agar firm environment with addition of each kind of mineral oil have allowed us to allocate 42 types of oil oxidizing microorganisms in waters of Gold Horn Bay, but only four types of bacteria and two types of mushrooms steadily developed on all used mediums down to the maximal concentration of mineral oil.

Seasonal number of microorganisms (cells on ml of sea water) in sea water of Gold Horn Bay in 2003-2004

Stations	Season	Heterotrophic microorganisms, cells/ml	Oil oxidizing microorganisms, cells/ml			
		YK medium	Organic nutrient medium			
			Black oil after separation	Diesel fuel	Black oil	Phenol
St.1 Churkin cape	Autumn (October)	4200	45	140	95	95
	Winter (February)	950	950	15000	75	95
	Spring (March)	2500	1600	170	200	25
	Summer (July)	91000	150	45000	950	40
St. 2 Maltzevskaya ferry	Autumn (October)	15000	95	750	450	4
	Winter (February)	9500	4500	450	4500	0
	Spring (March)	9500	950	150	2500	0
	Summer (July)	95000	165	1150	650	25
St. 3 Mouth of Ob'yasneniya River	Autumn (October)	20000	95	4500	200000	30
	Winter (February)	9500	9500	4500	1150	250
	Spring (March)	200000	150	95	95	25
	Summer (July)	450000	1500	2500	4500	450
St. 4 36 mooring	Autumn (October)	9500	9000	250	1150000	40
	Winter (February)	165	250	2500	95	0
	Spring (March)	2500	25000	0	25	25
	Summer (July)	95000	950	4500	95	45
Trading port	Autumn (October)	20000	4500	2500	15	45
	Winter (February)	2500	950	4500	9	0
	Spring (March)	95000	450	45	25	25
	Summer (July)	43000	1500	11500	750	40

PICES XV MEQ_Poster-3089

Theoretical and experimental investigation of biodegradation of hydrocarbon polluted water in a three phase fluidized-bed bioreactor with PVC biofilm support

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The aerobic treatment of hydrocarbon-polluted groundwater was performed experimentally in a three phase fluidized-bed bioreactor (FBBR) using mixed culture of living cells immobilized on PVC particles. The characteristic of the living cells immobilized in FBBR were identified and the kinetic parameters of the biochemical reaction were evaluated. A steady state biofilm model was developed based on porous pellet model which considers the diffusion and reaction of organic matters within biofilm, axial dispersion coefficient in bioreactor and external mass transfer resistance between biofilm and completely-mixed liquid phase. The developed model assumes a first-order biochemical reaction within biofilm. Experimental results were used to test the validity of the proposed model. A reasonable agreement between the experimental and theoretical results was found.

PICES XV MEQ_Poster-2976

Selenium accumulation in trophic net of the Japan/East Sea

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Selenium concentrations were determined in marine organisms of the Peter Great Bay (Japan/East Sea). Average selenium concentration is 0.6 mkg/g d.w. in marine algae and sea grasses; 4 mkg/g d.w. in soft tissues of mollusks; less than 5 mkg/g d.w. in digestive organs and gonads of echinoderms: and up 6 mkg/g d.w. in fish.

Selenium accumulation was estimated in trophic net of Japan/East Sea. Selenium accumulation coefficient (CA) in each trophic level was calculated as a ratio of selenium concentrations of the next and previous trophic

levels. Results show that processes of accumulation and migration in trophic food chains for selenium and other microelements (iron, zinc, cadmium, cobalt and *etc*.) are fundamentally distinct. The mean CA for 1st trophic level (sea water/phytobenthos) was 7000; for 2nd level (algae/echinoderms and algae/mollusks) was 10; and for 3rd level (mollusks/starfish and crustaceans/ fish) was 1. Selenium concentrations in predator and prey organisms in Japan/East Sea ecosystems do not differ significantly. Therefore, we observed a reduction of the mean CA and its dispersion in the higher trophic levels.

The selenium accumulation type can serve as an indicator of local biogeochemical province, and CA is specific parameter of marine organisms of different trophic levels.

PICES XV MEQ_Poster-3076

Partition of polycyclic aromatic hydrocarbons (PAHs) between the river water and bottom sediments at the estuary of rivers in Kanazawa, Japan

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Understanding the behavior of chemical substances in the estuary is important for the coastal marine environmental quality management because there is a concern that a significant amount of chemical substances may flow into seas from rivers, either accidentally or regularly. Hydrophobic organic pollutants such as PAHs often exhibit a complicated partitioning in the water-bottom sediment environment system. This partition affects the existence and the transport of pollutants in environment. We have been monitoring the concentration of polycyclic aromatic hydrocarbons (PAHs) in the two main rivers of Kanazawa City, Asano and Sai rivers, together with concentrations in the bottom sediments at the estuary. The bottom sediments were classified into three fractions of different sizes, smaller than 75, between 75 and 250, and larger than 250 micrometers; PAHs concentration and the level of organic carbon (f_{oc}) in each fraction were measured. Based on the assumption that PAHs in water and bottom sediments are in equilibrium, we estimated the bottom sediment-water partition coefficients, K_d, and found a correlation between K_d and the organic carbon contents of sediments. No significant correlation was found between K_d and the sediment particle size. Calculated organic carbon normalized partition coefficients K_{oc} (*e.g.* $K_{oc}=K_d/f_{oc}$) values were fitted to the well known relationship $\text{Log}K_{oc}=\text{Log}\ K_{ow}+C$, and we found that the 3-ring PAHs in both estuaries are approximated with C=1.8, whereas 4 and 5-ring PAHs except for Benzo[k]fluoranthene are represented with C=1.2. These results suggest that the river water and the sediments were nearly in equilibrium, and the organic carbon content, not the particle size, controls the sediment-water partition coefficient. Also, the characteristics of the organic carbon in the sediments in the estuaries of two rivers are similar in the partition of PAHs.

PICES XV MEQ_Poster-3250

Status of combined heavy metal and POP pollution in Razor clam from coastal areas of Quanzhou, China

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In this study, the status of combined heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) and organo-chlorine pesticide (OCPs; *i.e.* HCHs, and DDTs) pollution was investigated by determining the residue level of HCHs, DDTs and heavy metals in razor clam collected from coastal areas of Quanzhou City, Fujian Province China. OCPs and trace metals are measured by GC and GFAAS, respectively. Concentration ranges of HCHs and DDTs were 0.62-2.54, and 43.1-309.5 ng/g dry wt., respectively; while concentration ranges of Cd, Cr, Cu, Ni, Pb and Zn were 0.0105-0.112, 0.0256-0.192, 12.2-38.5, 2.20-6.33, ND-0.0529 and 5,78-20.4 ug/g dry wt, respectively. The results indicated the presence of combined pollution by heavy metals and POPs in the marine bivalve mollusks. The concentrations of DDTs and Cu in the samples were significantly higher than those of HCHs and other metals, indicating that DDTs and Cu can be considered the typical factors for combined pollutants in the survey areas.

PICES XV MEQ_Poster-3158

Existence of background dust in the free troposphere over an Asian dust source region

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Asian dust particles, known as "KOSA" (literally, "yellow sand") in Japan, originated in arid and semi-arid regions of the Asian continent and are often transported to the North Pacific. Asian dust particles not only have direct and indirect climate effects through radiative processes in the atmosphere, but also have influences on the oceanic environment due to deposition of the dust particles onto the marine surface. The dust particles may facilitate oceanic primary productivity, since the Asian dust contains nutrients like iron. Most of the research on KOSA has been made near the ground or sea surface when relatively strong KOSA events were observed. Recent measurements over Japan, however, suggested that 'weak KOSA' events are frequently passed in the free troposphere over the Japanese islands throughout the year. The weak KOSA may contribute to radiative impact in the atmosphere as well as on the oceanic environment, because the weak KOSA appears frequently, even though the magnitude is not so large.

To reveal the origin of weak KOSA events, we systematically observed free tropospheric aerosols over Duhunag, China, located in the east end of the Taklamakan Desert. The measurements were conducted using a balloon-borne aerosol sampler, a balloon-borne Optical Particle Counter (OPC), and LIDAR. From these measurements, we revealed that mineral particles constantly exist in the free troposphere over an Asian source region, and can suggest that the nutrients in dust particles are constantly supplied to the ocean by weak KOSA.

PICES XV MEQ_Poster-3131

Long-range transport of polycyclic aromatic hydrocarbons and nitropolycyclic aromatic hydrocarbons from China to Japan

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In East Asia, with the rapid increase of population and economic development, large amounts of pollutants are released into the air and water. Among the pollutants in the atmosphere, several polycyclic aromatic hydrocarbons (PAHs) and nitropolycyclic aromatic hydrocarbons (NPAHs) are carcinogenic, mutagenic, or have endocrine disrupting activity. PAHs and NPAHs are released from the combustion of petroleum and coal. Coal consumption in China is the largest in the world and represents over 75% of the energy source in China. However, in spite of the much higher concentration of atmospheric PAHs in China than that in Japan, there has been no report concerning the long-range transport of atmospheric PAHs and NPAHs from China to Japan.

Airborne particulates were collected at Wajima, in the Noto Peninsula, Ishikawa, Japan by a high volume air sampler with a quartz filter every week from September 17, 2004 to September 16, 2005. Polycyclic aromatic hydrocarbons (PAHs) were analyzed by HPLC with fluorescence detection. The atmospheric concentrations of PAHs at Wajima were higher during the heating period of China (from mid October to mid April) than during the no-heating period. A meteorological analysis indicated that the air samples collected in this period at Wajima were transported mainly from Northeast China over the Japan Sea. Principal Component Analysis of nine PAHs indicated a Chinese origin of the PAHs. These results strongly suggest that the atmospheric PAHs detected at Wajima, Japan were transported from China.

Observers **Poster Session**

Posters providing general information and highlighting scientific objectives and recent activities of scientific organizations, programs and monitoring efforts of regional and global scale that are presented by observers at PICES XV are invited.

Thursday, October 19, 2006 18:00-20:30

Norio Baba
Current activities and future plans of Northwest Pacific Action Plan (NOWPAP) (Observer_Poster-3012)

John A. Barth, Jan A. Newton and NANOOS Colleagues
Northwest Association of Networked Ocean Observing Systems (NANOOS) (Observer_Poster-3095)

Kenneth F. Drinkwater and George L. Hunt
Ecosystem Studies of Sub-Arctic Seas (ESSAS) (Observer_Poster-3102)

Julie Hall and Sylvie Roy
IMBER: Integrated Marine Biogeochemistry and Ecosystem Research (Observer_Poster-2940)

George L. Hunt Jr. and K. David Hyrenbach
The Bering Ecosystem Study Program (BEST): A new program for the eastern Bering Sea (Observer_Poster-3039)

Molly McCammon, G. Carl Schoch and Mark Johnson
AOOS: Implementing an Ocean Observing System in Alaska (Observer_Poster-3194)

Clarence Pautzke and Francis Wiese
Bering Sea and Aleutian Islands integrated ecosystem research program of the North Pacific Research Board (Observer_Poster-3242)

Howard J. Freeland, Nobuyuki Shikama and the Argo Steering Team
Argo – An ocean observing system for the 21st century (Observer_Poster-3167)

Usha Varanasi, William Fox, Elizabeth Clarke, Jonathan Phinney, Jack Barth, Russ Davis, John Hunter and Dolores Wesson
The Pacific Coast Ocean Observation System: A new approach to integrating ecosystem-based science observations for management (Observer_Poster-3263)

PICES XV Observer_Poster-3012
Current activities and future plans of Northwest Pacific Action Plan (NOWPAP)

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Northwest Pacific Action Plan (NOWPAP) was established in September 1994 as a part of the Regional Sea Programme of the United Nations Environment Programme (UNEP) with four member states: the People's Republic of China, Japan, the Republic of Korea and the Russian Federation. The overall goal of NOWPAP is "the wise use, development and management of the coastal and marine environment so as to obtain the utmost long-term benefits for the human populations of the region, while protecting human health, ecological integrity and the region's sustainability for future generations". In order to support the implementations of its priority projects, four Regional Activity Centres (RACs) were established in the member states during 2000-2002:

CEARAC (Toyama, Japan), Special Monitoring and Coastal Environment Assessment RAC;
MERRAC (Daejeon, Korea), Marine Environmental Emergency Preparedness and Response RAC;
DINRAC (Beijing, China), Data and Information Network RAC; and
POMRAC (Vladivostok, Russia), Pollution Monitoring RAC.

Until the establishment of a co-hosted Regional Coordinating Unit (RCU) in Toyama, Japan and Busan, Korea in 2004, NOWPAP was coordinated by the interim secretariat located in the UNEP Headquarters in Nairobi, Kenya. The 10th NOWPAP Intergovernmental Meeting held in Toyama, Japan, in November 2005 agreed:

- To start the Marine Litter Activity (MALITA) in the region;
- To expand the geographical coverage of the NOWPAP Oil Spill Regional Contingency Plan; and
- To initiate new directions of work for the RACs (including, among others, Integrated Coastal Zone and River Basin Management; State of Marine Environment Reporting; and Chemical Spill Preparedness and Response), in addition to the present NOWPAP activities.

PICES XV Observer_Poster-3095
Northwest Association of Networked Ocean Observing Systems (NANOOS)

John A. **Barth**[1], Jan A. Newton[2] and NANOOS Colleagues

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NANOOS, the Northwest Association of Networked Ocean Observing Systems, serves the Washington, Oregon, and northern California region. The region includes the eastern Pacific Ocean and California Current, the Strait of Juan de Fuca, Puget Sound, the Columbia River, and several smaller estuaries in each of the states. Chartered in 2003, NANOOS has an established Memorandum of Agreement and a diversity of membership including tribal, state, and local governments, industry, academic and research institutions. Focused workshops have afforded NANOOS a venue to prioritize user needs, to focus outreach to industry partners, and begin to address system design elements and issues. At present, NANOOS' observational capability is largely through a pilot grant funded by NOAA Coastal Services Center, focused on integrating existing sub-regional observational capability in estuaries and shorelines and delivering web access to a variety of data products. In the upcoming year, NANOOS will be formulating a business plan, enhancing its website and database capabilities, and establishing a focused outreach and education program.

PICES XV Observer_Poster-3102
Ecosystem Studies of Sub-Arctic Seas (ESSAS)

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Ecosystem Studies of Sub-Arctic Seas (ESSAS) is a regional programme of GLOBEC whose principal object is to compare, quantify and predict the impact of climate variability on the productivity and sustainability of Sub-Arctic marine ecosystems. The area includes the Bering Sea, Sea of Okhotsk and the Oyashio Shelf Region in the Pacific and the Barents Sea, Iceland region, Greenland shelves, Newfoundland/Labrador shelves, Gulf of St. Lawrence and Hudson Bay in the Atlantic. Several factors make these Sub-Arctic seas unique: exchange with the Arctic Ocean, seasonal ice cover, freshwater from ice-melt, dramatic seasonality, reduced sunlight, low biodiversity; large commercial fish stocks, and vast numbers of marine birds and mammals. Recently, changes in species abundance or distribution have been observed within several Sub-Arctic marine ecosystems, which appear to correlate with fluctuations in the physical environment. Subarctic comparisons are expected to help determine the fundamental processes controlling the structure and function of their marine ecosystems. ESSAS held its kick-off Symposium in Victoria in Canada during 2005 and recently held a workshop to facilitate comparative studies that resulted in the formation of 3 international working groups. National ESSAS programs have been established in Iceland, Japan, Norway, and the U.S.A. and other countries such as Canada, Russia, and Korea have been involved in ESSAS activities. ESSAS is heading an International Polar Year (IPY) consortium called ESSAR (Ecosystem Studies of Subarctic and Arctic Regions) containing 20 projects with participation from 12 countries. Extensive fieldwork to back ESSAS objectives will take place within ESSAR.

PICES XV Observer_Poster-2940
IMBER: Integrated Marine Biogeochemistry and Ecosystem Research

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Human activities are rapidly altering Earth System processes that directly and indirectly influence society. Informed decisions require an understanding of which parts of the Earth System are most sensitive to change, and the nature and extent of anticipated impacts of global change. In response to this need, the new IGBP-SCOR Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project has been formed, to focusing on ocean biogeochemical cycles, ecosystems and there interactions. The IMBER vision is to; "provide a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society". To achieve this, the IMBER Science Plan and Implementation Strategy is structured around four major research themes. Theme 1 focuses on identifying and characterising interactions of the key biogeochemical and ecosystem processes that will be impacted by global change. Central to IMBER goal, Theme 2 will develop a predictive understanding of how marine biogeochemical cycles and ecosystems respond to complex forcings, such as large-scale climatic variations, changing physical dynamics, carbon cycle chemistry and nutrient fluxes, and the impacts of harvesting. Theme 3 investigates the roles of ocean biogeochemistry and ecosystems in impacting the larger Earth System through direct and indirect feedbacks. Finally, Theme 4 integrates natural and social sciences, drawing on information from the previous three themes to investigate key interactions with the human system and the options for mitigating or adapting to the impacts of global change on marine biogeochemical cycles and ecosystems

PICES XV Observer_Poster-3039
The Bering Ecosystem Study Program (BEST): A new program for the eastern Bering Sea

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Information is presented on a new research program in the eastern Bering Sea, the Bering Ecosystem Study Program (BEST), that will go in the field in Spring 2007. The goal of the BEST Program is to develop a fundamental understanding of how climate change will affect the marine ecosystems of the eastern Bering Sea, the continued use of its resources, and the economic, social and cultural sustainability of the people who depend on it. BEST was conceived as an integrated, collaborative, interdisciplinary study of the eastern Bering Sea shelf between the Alaska Peninsula and St. Lawrence Island and will also address the social implications of the anticipated ecosystem changes. Fieldwork will occur in 2007, 2008 and 2009, with 2010 as a year for synthesis and write-up. The focus of the fieldwork planned for 2007-2009 is to understand the role of changing sea-ice conditions on the chemical, physical, and biological characteristics of the ecosystem, and the impact of these changes on human resource use activities. Thus, an important component of BEST focuses on social science issues, and was developed in collaboration with Alaskan Native Community participation. During the next several years, many organizations and programs in addition to BEST will be investigating the eastern Bering Sea and the effects of climate variability on its resources and people. It is expected that, through close cooperation and integration of effort, a much stronger program will emerge than could have been sustained by any one agency alone.

PICES XV Observer_Poster-3194
AOOS: Implementing an ocean observing system in Alaska

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The Alaska Ocean Observing System (AOOS) is the regional association developing a regional integrated coastal and ocean observing system - as part of the national Integrated Ocean Observing System - for the large marine ecosystems of Alaska. These span the Gulf of Alaska, the Bering Sea and Aleutian Island regions, and the Arctic Ocean, Beaufort and Chukchi seas. Planning and implementation efforts have been underway for three years. Challenges include Alaska's remoteness, harsh weather, lack of infrastructure including transportation, power, and communications, and most especially, its length of coastline. Two key efforts will be highlighted: the Prince William Sound pilot project and the Data, Modeling and Analysis Group, and their scientific and management contributions.

PICES XV Observer_Poster-3242
Bering Sea and Aleutian Islands integrated ecosystem research program of the North Pacific Research Board

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The North Pacific Research Board (NPRB) is developing a Bering Sea and Aleutian Islands Integrated Ecosystem Research Program (BSIERP) that will be a significant component of the Board's request for proposal (RFP) to be released on October 6, 2006. To date, the Board has released five RFP's which have resulted in combined funding of $24 million for 137 projects over a wide range of topics including general ecosystem studies, fish and invertebrates, habitat, humans, marine mammals, salmon, and seabirds. All projects are browsable on NPRB's website at www.nprb.org. The top twelve organizations funded by NPRB include NOAA, University of Alaska, University of Washington, Alaska Department of Fish and Game, Oregon State University, U.S. Fish and Wildlife Service, U.S. Geological Survey, Moss Landing Marine Laboratories, PRBO

Conservation Science, University of California-Scripps, Alaska SeaLife Center, and the Prince William Sound Science Center.

NPRB's science plan, published in 2005, strongly promotes integrated ecosystem research. The BSIERP is expected to last from 2007-2013 and be supported by $12-13 million. It will focus on questions such as (1) how the Bering Sea and Aleutian ecosystem is responding to climate variability and change, (2) what processes regulate the production, distribution and abundance of upper trophic level organisms such as commercial/subsistence fish species and marine mammals, (3) how well can these processes be quantified and can we separate the natural variability of the system from impacts of climate change and/or human intervention, and (4) can we quantitatively tie together the lower and upper food webs? The BSIERP envisions one spin-up year, three major field seasons, and two years for analysis, synthesis and reporting. It will examine vertical integration up through the food web, including human impacts and will be completed by a multi-disciplinary and multi-agency research team with academics and agency scientists and managers. The NPRB anticipates that the BSIERP will be just the first in a long series of 6-year integrated research programs, each informed by the previous programs. The approximate schedule is as follows, but may change by the Board meeting in September: BSIERP pre-proposals will be due on November 22, invitations for full proposals will go out on December 15, and full proposals will be due March 2, 2007. Board decisions on full proposals will occur on April 23-26, 2007. More information will be available at www.nprb.org

PICES XV Observer_Poster-3167
Argo – An ocean observing system for the 21st century

Howard J. Freeland, Nobuyuki **Shikama** and the Argo Steering Team

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This poster is designed to describe the progress of the international Argo array.

Argo is an international venture designed to install a global array of profiling floats in all oceans of the world, with deployments starting in 2001 and continuing. This poster will summarize progress towards full implementation of a globally homogeneous array of devices. By the time the poster is displayed at the PICES meeting Argo will be operating 2500 floats reporting data every 10 days from every ocean basin on the planet. The object is to make data freely available in near-real time and we are almost achieving this objective. Currently 90% of all profiles are available for download from the Global Argo Data Centres within 24 hours of their acquisition. So far 25 nations have deployed floats in support of Argo and this is likely to grow in the near future.

Argo now permits mapping of the physical oceanography of the top 2000 decibars of the ocean in real-time. This should be of particular interest to scientists attempting an ecosystem approach to the management of ocean resources. To date Argo has focused on its primary mission of describing the distribution of heat and fresh water in the oceans and the advection of those. However, in rapidly increasing numbers floats are being deployed with sensors designed to observe dissolved oxygen. This opens the way to a wide area of new applications.

PICES XV Observer_Poster-3263

The Pacific Coast Ocean Observation System: A new approach to integrating ecosystem-based science observations for management

Usha **Varanasi**[1], William Fox[2], Elizabeth Clarke[1], Jonathan Phinney[2], Jack Barth[3], Russ Davis[4], John Hunter[4], and Dolores Wesson[1,4]

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The Pacific Coast Ocean Observing System (PaCOOS) is a U.S. West Coast federation to develop an ecological observing system and includes NOAA, other federal and state conservation-based agencies, universities, and not-for-profit organizations. The mission of PaCOOS is to provide information for the sustained use of the California Large Marine Ecosystem (CCLME) under a changing climate. It is the backbone for the ecosystem-related objectives of the Integrated Ocean Observing System (IOOS), and the enabler of the national backbone for the full set of seven objectives identified for the CCLME.

The geographic area covered by PaCOOS is the California Current and includes portions of Canada, the United States and Mexico and their respective Exclusive Economic Zones (EEZs). This area encompasses about 811,000 km^2 and is home to many managed species. As a result, collaboration with Canada and Mexico's marine observation efforts is essential to achieve the desired goals. The North Pacific Marine Science Organization (PICES) and other organizations serve as avenues for international collaboration on issues related to PaCOOS.

PaCOOS' vision is to implement an operational system of observations; data management and modeling that will rapidly detect ecological change in the CCLME and its living resources, and provide forecasts tailored to specific management decisions. PaCOOS will improve the accuracy and precision of science advice for management, provide key information required for ecosystem-based management decisions, and for understanding the roles played by climate and humans (*e.g.*, fisheries) in the CCLME.

W1 IFEP/MODEL Workshop
Modeling iron biogeochemistry and ocean ecosystems and IFEP-AP Meeting

Co-sponsored by SOLAS (Surface Ocean - Low Atmosphere Study)
Co-Convenors: Fei Chai (U.S.A.) and Jun Nishioka (Japan)

Synthesis of data from three successful meso-scale iron enrichment experiments in the subarctic North Pacific (SEEDS-I & II and SERIES) has been underway, which helps development of ocean ecosystem models. This workshop will enhance communication between experimentalists and modelers working on iron biogeochemistry and modeling. The workshop will focus on a couple of key questions: 1) What have we learned regarding iron biogeochemistry in the ocean from natural observation and iron-enrichment experiment? and 2) How can ocean models be improved with detailed iron dynamics to better represent ocean ecosystems? The workshop will provide an opportunity for experimentalists and modelers to share their latest results and understanding on iron biogeochemistry and ocean ecosystems, and make recommendations for future iron cycle observations and ocean ecosystem modeling in the subarctic Pacific.

Friday, October 13, 2006 09:00-18:00

09:00-09:10 **Welcome and introductions**

09:10-09:50 **Marie Boye, Olivier Aumont, Constant M.G. van den Berg and Hein J.W. de Baar** (Invited)
The organic complexation in modeling the iron geochemistry and bioavailability (W1-3036)

09:50-10:15 **Atsushi Ooki, Jun Nishioka and Tsuneo Ono**
Determination of iron solubility of Asian dust in the surface seawater (W1-3146)

10:15-10:40 **Daisuke Tsumune, Keith Lindsay, Gokhan Danabasoglu, Scott C. Doney, Jun Nishioka, Takeshi Yoshimura, Frank O. Bryan and Nakashiki Norikazu**
Phosphate and iron concentrations in an ocean carbon cycle model (W1-3208)

10:40-11:00 ***Tea/Coffee Break***

11:00-11:25 **Fei Chai, Lei Shi, M-S Jiang, Yi Chao, Francisco Chavez and Richard T. Barber**
Modeling responses of iron enrichment in the equatorial Pacific Ocean (W1-3186)

11:25-11:50 **Masahiko Fujii and Fei Chai**
Influences of initial plankton conditions and mixed layer depth on the outcome of iron-fertilization experiments (W1-2934)

11:50-13:30 ***Lunch***

13:30-13:55 **Albert J. Hermann, Thomas M. Powell, Elizabeth L. Dobbins, Sarah Hinckley, Enrique N. Curchitser, Dale B. Haidvogel and Kenneth Coyle**
A comparison of different NPZ models for the Northeast Pacific (W1-3230)

13:55-14:20 **Naoki Yoshie, Katsunari Sato, Yasuhiro Yamanaka and Jun Nishioka**
Incorporating iron cycle into a lower trophic level marine ecosystem model, NEMURO (W1-2827)

14:20-15:30 **Discussion**

15:30-16:00 ***Tea/Coffee Break***

16:00-18:00 **IFEP-AP Meeting**
Co-Chairmen: Shigenobu Takeda (Japan) and C.S. Wong (Canada)

Poster

Debby Ianson, Christoph Voelker Kenneth L. Denman, Eric Kunze and Nadja Steiner
The importance of iron in a biogeochemical patch model of the NE Pacific iron manipulation experiment, SERIES (W1-3063)

PICES XV W1-3036 Invited
The organic complexation in modeling the iron geochemistry and bioavailability

Marie **Boye**[1], Olivier Aumont[2], Constant M.G. van den Berg[3] and Hein J.W. de Baar[4]

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There is now compelling evidence that dissolved iron is principally complexed by organic ligands in oceanic waters. This organic complexation is a central factor in oceanic iron cycling and playing a key role in iron solubility and geochemistry, as well as in selective iron bioavailability. Despite this role of the physical-chemical speciation, cycling of the organic chelators in the ocean is still poorly understood. The chemistry of iron, especially its organic complexation, is also poorly represented in the most of current biogeochemical models. An overview of the distribution and speciation of the organic iron-chelators in the global ocean will be presented to examine the vertical and horizontal gradients of the organic iron in relation to dissolved iron, dominant planktonic assemblages, and circulation patterns. *In situ* data of the organic iron speciation will hence be used to run the PISCES biogeochemical model to evaluate its impact on iron geochemistry and bioavailability in the global ocean.

PICES XV W1-3186 Oral
Modeling responses of iron enrichment in the equatorial Pacific Ocean

Fei **Chai**[1], Lei Shi[1], M-S Jiang[2], Yi Chao[3], Francisco Chavez[4] and Richard Barber[5]

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Using a three-dimensional physical-biogeochemical model we have investigated the modeled responses of diatom productivity and biogenic silica export to iron enrichment in the equatorial Pacific, and compared the model simulation with in situ (IronEx II) iron fertilization results. In the eastern equatorial Pacific, an area of 500,000 km^2 was enhanced with iron by changing the photosynthetic efficiency and silicate and nitrogen uptake kinetics of phytoplankton in the model for a period of 20 days. The vertically integrated Chl-*a* and primary production increased by about 3-fold five days after the start of the experiment, similar to that observed in the IronEx II experiment. Diatoms contribute to the initial increase of the total phytoplankton biomass, but decrease sharply after10 days because of mesozooplankton grazing. The modeled surface nutrients (silicate and nitrate) and TCO_2 anomaly fields, obtained from the difference between the "iron addition" and "ambient" (without iron) concentrations, also agreed well with the IronEx II observations. The enriched patch is tracked with an inert tracer similar to the SF6 used in the IronEx II. The modeled depth-time distribution of sinking biogenic silica (BSi) indicates that it would take more than 30 days after iron injection to detect any significant BSi export out of the euphotic zone. The numerical experiments demonstrate the value of ecosystem modeling for evaluating the detailed interaction between silicon cycle and iron fertilization in the equatorial Pacific.

PICES XV W1-2934 Oral
Influences of initial plankton conditions and mixed layer depth on the outcome of iron-fertilization experiments

Masahiko **Fujii**[1,2] and Fei Chai[1]

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Several *in situ* iron-enrichment experiments have been conducted, but the response of the phytoplankton community was different. We use a marine ecosystem model to investigate the effect of iron on phytoplankton in response to different initial plankton conditions and mixed layer depth. Sensitivity analysis of the model results to the mixed layer depth reveals that the modeled response to the same treatment of iron enhancement

differed dramatically corresponding to different mixed layer depth. Magnitude of the iron-induced biogeochemical responses in the surface water, such as maximum chlorophyll, is inversely correlated with the mixed layer depth, similar to the observations. The significant decrease in maximum surface chlorophyll with mixed layer depth results from the difference in diatom concentration in the mixed layer, which is determined by vertical mixing. Sensitivity of the model to initial mesozooplankton (as grazers on diatoms) biomass shows that the column-integrated net community production and export production are more strongly controlled by the initial mesozooplankton biomass than by the mixed layer depth. Higher initial mesozooplankton biomass yields high grazing pressure on diatoms, which results in no accumulation of diatom biomass. The initial diatom biomass is also important to the outcome of iron enrichment but is not as crucial as the mixed layer depth and the initial mesozooplankton biomass. This modeling study suggests not only mixed layer depth but also initial biomass of diatoms and its principle grazers are crucial factors for the response of the phytoplankton community to the iron enrichments, and should be considered in designing future iron-enrichment experiments.

PICES XV W1-3230 Oral
A comparison of different NPZ models for the Northeast Pacific

Albert J. **Hermann**[1], Thomas M. Powell[2], Elizabeth L. Dobbins[1], Sarah Hinckley[3], Enrique N. Curchitser[4], Dale B. Haidvogel[5] and Kenneth Coyle[6]

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As part of the synthesis phase of the Northeast Pacific US-GLOBEC program, we have begun simulating lower trophic level (NPZ) dynamics of the Northeast Pacific between Baja California and the Bering Strait, out to ~1500 km offshore. As a first step, a "generic" NPZ model, presumed relevant to both the California Current and the Gulf of Alaska under a single set of internal parameters for mesoplankton, was implemented on a 10-km resolution grid (the Northeast Pacific grid; NEP) and simulated over a span of years which includes multiple El Niños (and the 1997-1998 event in particular). The NEP model is embedded in a larger-scale circulation model of the North Pacific. While some features of the area (*e.g.* upwelling-driven production off California) were reproduced by the simple NPZ model, others features (*e.g.* higher production on the Gulf of Alaska shelf relative to the basin, as evidenced by SeaWiFS data) were not well captured. These discrepancies underscore the need for multiple size classes of phytoplankton and zooplankton, and/or the inclusion of iron as a limiting micronutrient. To address these needs, we compare results from more complex NPZ models on the NEP grid, including a multiple size class model initially developed for the Coastal Gulf of Alaska (CGOA-NPZ), both with and without iron limitation. Through EOFs and other spatial analysis, we explore what is gained (and lost) by the use of these more complex models of the Northeast Pacific, relative to the simpler NPZ model.

PICES XV W1-3063 Poster
The importance of iron in a biogeochemical patch model of the NE Pacific iron manipulation experiment, SERIES

Debby **Ianson**[1], Christoph Voelker[2], Kenneth L. Denman[3], Eric Kunze[4] and Nadja Steiner[3]

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We have developed a simple physical model, which is forced by using sulphurhexaflouride and CTD observations, to emulate dilution as a function of time in the Subarctic Ecological Response to Iron Enrichment Study (SERIES) iron manipulation experiment. Within this model we have embedded the 7-component ecosystem model of Denman *et al*. (in press) that includes two size classes of phytoplankton and state variables nitrogen, carbon and silica. Ecological parameters have been optimized using a genetic algorithm to best reproduce observed chlorophyll observations (two size classes). The optimum parameter set varies little relative to the one used with the same ecological model embedded in a 1-D physical model and that is able to simulate

seasonal cycles at Station Papa. Our model results reproduce SERIES observations reasonably well, however the diatom bloom is much more gradual in the model than it was in the natural system. We have experimented with iron quota models and show that it is necessary to model luxury uptake of iron by diatoms to achieve both the peak and abrupt crash of the diatom bloom.

PICES XV W1-3146 Oral
Determination of iron solubility of Asian dust in the surface seawater

Atsushi **Ooki**[1], Jun Nishioka[2] and Tsuneo Ono[1]

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Iron is an important trace nutrient for phytoplankton in the ocean. Recent studies have focused on the relationship between iron budget and marine ecosystem response. In the open ocean, the main source of iron in the surface layer is due to atmospheric deposition of mineral dust and/or supply from the deeper water. In the North Pacific, the Asian Dust is the dominant source of mineral dust to the surface ocean. To determine the amount of Asian Dust deposition and its related iron solubility in the seawater, it is essential to quantify the iron supply from the atmosphere to the North Pacific. Wide range of iron solubility of mineral dust, from < 0.1% to several percents reported by several recent studies, has caused large uncertainty of iron budget. The following factors contribute to this uncertainty: 1) the experimental method has not been fully established because of the difficulty measuring adsorption loss of iron; 2) atmospheric reaction would change the iron solubility of mineral dust during the transport from the dust source region to the ocean; 3) anthropogenic iron, a main source of iron in the urban air, may elevate the iron solubility of the dust like aerosol. We developed the extraction method to resolve the adsorption loss problem. The iron solubility of Asian Dust particles collected in the loess plateau (which is used as reference material) and the aerosol particle collected in the northern part of the Japanese islands during the Asian Dust season were 1.6% and 1.4 - 2.4%, respectively. Atmospheric reaction of Asian Dust particles does not change the iron solubility.

PICES XV W1-3208 Oral
Phosphate and iron concentrations in an ocean carbon cycle model

Daisuke **Tsumune**[1], Keith Lindsay[2], Gokhan Danabasoglu[2], Scott Doney[3], Jun Nishioka[4], Takeshi Yoshimura[1], Frank Bryan[2] and Nakashiki Norikazu[1]

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An ocean carbon cycle model is presented in the framework of the Community Climate System Model version 3 (CCSM3). This model is based on the Ocean Carbon Model Intercomparison Project (OCMIP-2) biotic carbon model, modified by the addition of a prognostic equation for productivity and the inclusion of iron as a co-limiting nutrient. Aeolian deposition is the sole source of iron, and scavenging of iron is parameterized based on previous studies. The ocean general circulation model is based on CCSM3 POP with a resolution of 3.6 degree in longitude and 0.8 to 1.8 degree in latitude with 25 vertical levels. Previous studies with this model found a number of biases in the distribution of nutrients relative to observations. In this study we investigated the sensitivity of the simulation to the specification of the uptake ratio of phosphate and iron during production, and to the parameterization of eddy mixing. An uptake ratio that is an increasing function of iron concentration gave more realistic distribution than a uniform uptake ratio. A modification to the standard Gent-McWilliams eddy mixing parameterization that more accurately treats near surface fluxes also resulted in improvements in the carbon cycle simulation.

PICES XV W1-2827 Oral

Incorporating iron cycle into a lower trophic level marine ecosystem model, NEMURO

Naoki **Yoshie**[1], Katsunari Sato[2], Yasuhiro Yamanaka[2,3] and Jun Nishioka[4]

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Iron is an important micronutrient for marine phytoplankton and controls primary productivity and trophic structure of planktonic communities in HNLC regions. However iron cycle has not been explicitly included in the lower trophic level marine ecosystem model, NEMURO (North Pacific Ecosystem Model Used for Regional Oceanography) developed by CCCC/MODEL task team of PICES. In this study, we have explicitly introduced iron cycle into NEMURO, to understand roles of iron in marine ecosystem and biogeochemical dynamics. NEMURO with iron cycle includes with the following five iron compartments: (1) dissolved inorganic free iron (Fe_f); (2) dissolved iron complexed with organic ligands (FeL); (3) particulate iron (Fe_p); (4) particulate iron attached on aeolian dust (FeD); and (5) iron included in biota (FeB). The model was applied to station A7 (41°30'N, 145°30'E) in the western subarctic North Pacific, where diatom blooms regularly in spring. The model simulations showed seasonal variations of each iron compartment and successfully simulated the temporal variations of dissolved iron observed from winter to early summer. The model results suggested the concentration of dissolved iron in the surface water was mostly controlled by the supply of particulate iron from the deep water associated with the winter deep mixing.

W2 FIS Workshop
Linking climate to trends in productivity of key commercial species in the subarctic Pacific

Co-Convenors: Richard J. Beamish (Canada), Anne B. Hollowed (U.S.A.), Masahide Kaeriyama (Japan), Suam Kim (Korea) and Vladimir I. Radchenko (Russia)

Purpose:
PICES Working Group 16 has completed its report on the impacts of climate and climate change on the key commercial species in subarctic Pacific. An important conclusion was that climate is a major factor affecting the productivity of virtually all key species. The mode of climate variability varied among species, but it was clear that climate-related trends in production were common. It was also apparent that a relatively small number of species make up a large percentage of all commercial landings. Assessing the impacts of climate and climate change on commercial fisheries was one of the main reasons that PICES was established. An objective of this workshop is to achieve consensus on a list of 12 - 15 of the most important commercial species that will help to identify the specific linkages between climate and trends in production. After this agreement is achieved and there is further clarification of the effects of climate variability, the key species would then become an index of climate-related impacts. With time, this could become an important forecasting tool for industry and governments. Linking annual trends in key species production with climate and ocean indices would also introduce a dimension to the PICES ecosystem status report that will attract a more general audience, including the popular press.

Strategy:
Prior to the workshop participants will identify key species for climate forecasts. Participants will accumulate catch and biomass time series and if available associated production information (recruitment time series, size at age, maturity at age). Participants will identify climate indices that are likely factors influencing catch and production time trends. Participants will identify techniques for incorporating ecosystem indicators into forecasts. Recommendations for a common forecasting technique will be advanced.

Day 1, Friday, October 13, 2006 09:00-17:00

09:00-09:10 **Introduction by Convenors**

Theme 1: Evidence for climate change impacts

09:10-09:30 **Richard J. Beamish**
The impact of future climate trends on the key species and their fisheries off the Pacific coast of Canada (W2-3197)

09:30-09:50 **Vladimir I. Radchenko**
Trends in Russian fisheries in the North Pacific in relation to basic stock conditions and their variability under the climate change (W2-3204)

09:50-10:10 **Yeong Gong, Hee-Dong Jeong, Jong-Hwa Park, Ki-Tack Seong, Sang-Woo Kim and In-Seong Han**
Fluctuations of fish populations in the waters off Korea and its adjacent regions (W2-3192)

10:10-10:30 **Masahide Kaeriyama**
Long-term fluctuations of chum salmon and Pacific herring populations in Hokkaido during 1883-2000 (W2-3234)

10:30-11:00 ***Tea/Coffee Break***

11:00-11:20 **Anne B. Hollowed and Jennifer Boldt**
An overview of evidence for climate impacts on Northeast Pacific marine fishes and recommendations for a framework for forecasting annual marine production (W2-3231)

11:20-15:30 **Discussion Theme 1** (with a Lunch Break at 12:00-14:00)

- What are our standards for cause and effect? Should we have a standard?
- What climate indices should be considered? Regional or Basin Scale?
- What response variables should be considered?
- Are lags apparent?
- Are regional partitions apparent?
- Final selection of candidate species for PICES forecast

15:30-16:00 ***Tea/Coffee Break***

Theme 2: Management implications

16:00-16:20 **Z.T. A'mar, A.E. Punt and M.W. Dorn**
The Management Strategy Evaluation approach and the Gulf of Alaska walleye pollock fishery (W2-3260)

16:20-16:40 **Michael J. Schirripa**
The potential effects of including/excluding environmental factors into stock assessments (W2-3122)

16:40-17:00 **Jae Bong Lee, Suam Kim, Chang-Ik Zhang, Jin-Yeong Kim and Sukyung Kang**
Evidences of climate-induced impacts on key commercial species around Korean waters (W2-3232)

Day 2, Saturday, October 14, 2006 09:00-17:00

09:00-10:30 **Discussion Theme 2**

- Should managers shift biological reference points when production regimes are shifting? – Student presentation
- Detection probabilities – Contrast physical and biological time series
- Communication of impacts to managers
- Time lines for forecasts

10:30-11:00 ***Tea/Coffee Break***

Theme 3: Techniques for comparing production trends of selected species across regions

11:00-11:20 **Andrea Belgrano**
Linking multi-species fisheries to climate variability: A phenomenological approach (W2-2878)

11:20-12:00 **Discussion Theme 3**

- Condition factors
- Should aggregate indices be considered?
- Is there a difference in detection accuracy in heavily fished and lightly fished systems?
- Is there a difference in detection accuracy in systems dominated by pelagic species?
- Should we consider broader ecosystem impacts? Shifting predation mortality, shifting spatial distribution?

12:00-14:00 ***Lunch***

14:00-15:30 **Advice to PICES regarding formation of forecasts**

- Is there a need for a community forecasting tool?
- Standardizing techniques for incorporating ecosystem indicators
- Standardizing techniques for presentation of results

15:30-16:00 ***Tea/Coffee Break***

16:00-17:00 **Continue if necessary**

PICES XV W2-3260 Oral

The Management Strategy Evaluation approach and the Gulf of Alaska walleye pollock fishery

Z.T. **A'mar**, A.E. Punt and M.W. Dorn

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Management strategy evaluation (MSE) is the process of using simulation testing to examine the robustness of proposed management strategies to error and uncertainty. MSE involves using a model (the "operating model") to represent the true underlying dynamics of the resource and to generate future data, an estimation model to assess the state of the stock relative to agreed target and limit reference points at each time step based on the simulated data, and a catch control rule to determine management actions (*e.g.*, the Total Allowable Catch, TAC) given the results of the stock assessment. The latter two steps constitute the management strategy. The parameters of the management strategy can be selected to achieve desired (but conflicting) management goals and objectives. The results of an MSE are performance measures that quantify the effectiveness of the estimating model and the management strategy. An MSE is performed based on the Gulf of Alaska walleye pollock fishery.

PICES XV W2-3197 Oral

The impact of future climate trends on the key species and their fisheries off the Pacific coast of Canada

Richard J. **Beamish**

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In Working Group 16, Canada identified approximately 11 species that were key to the economy of the Pacific Coast fishery. There were five species of Pacific salmon, sablefish, Pacific herring, Pacific hake, Pacific halibut, Pacific Ocean perch and Pacific cod. Dungeness crab and spot prawns are two more important commercial species that could be affected by future trends in climate. The management of hatchery produced salmon as well as the commercial production of farmed salmon are also key activities that are associated with west coast sea food production. Production data for these species and activities will be presented at the workshop. The impact of climate and climate trends on production will be reviewed through the use of simple models and informed speculation. After discussions with representatives from other countries, a representative number of these species and activities will be selected to be used in basin-scale comparative studies of past and future climate impacts on production.

PICES XV W2-2878 Oral

Linking multi-species fisheries to climate variability: A phenomenological approach

Andrea **Belgrano**

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Emergent empirical patterns in complex systems, such as those involved in multi-species fisheries, can be generated by processes related to invariant-variant factors such as class-size, body mass, species abundance, composition and interactions across different spatial and temporal scales. Such empirical patterns can be used to account for ecosystem dynamics, structure and species associations or interactions over broad biogeographical areas. Different climatological conditions can affect such interactions to result in patterns that show consistency in relation to environmental conditions. A phenomenological framework linking climate variability to inter-annual dynamics in species production for the Eastern Bering Sea (EBS) will be presented.

PICES XV W2-3231 Oral

An overview of evidence for climate impacts on Northeast Pacific marine fishes and recommendations for a framework for forecasting annual marine production

Anne B. **Hollowed**[1] and Jennifer Boldt[2]

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A metric of scientific understanding is the ability to predict future outcomes based on knowledge of key environmental forcing factors. Numerous publications provide evidence for climate impacts on marine fish. This paper attempts to standardize this information by identifying a common suite of local, regional and basin level ecosystem indicators for use in a comparative study. Production time series (*e.g.*, growth and recruitment) are compared to the ecosystem indicators in a systematic manner to identify the statistical significance of hypothesized functional relationships. Numerical modeling, non-linear and linear techniques are used to evaluate the relationships. Multivariate statistical analyses are used to identify commonalities between species and regions. A common suite of years are held back from the analysis and used to evaluate the predictive power of statistical relationships. Data sets are evaluated for evidence of responses to large scale climate shifts as well as long term climate change. The analysis provides a framework for a PICES annual forecast of marine production.

PICES XV W2-3192 Oral

Fluctuations of fish populations in the waters off Korea and its adjacent regions

Yeong Gong[1], Hee-Dong **Jeong**[2], Jong-Hwa Park[2], Ki-Tack Seong[2], Sang-Woo Kim[2] and In-Seong Han[2]

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Long-term fluctuations of pelagic fish and squid populations in the Tsushima Warm Current (TWC) and Kuroshio-Oyashio Current (KOC) regions are examined based on the catch records updated for the period of 1900-2003. Over the past 100 years the abundance of herring, sardine, anchovy, chub mackerel, saury and common squid show synchronous patterns of variability in the two regions, which suggest that they are influenced by common climate shifts. An orderly alternation of dominant (exhibiting a peak in abundance) species has been observed in the two regions.

The different fishing activities and limited fishing grounds in the TWC region were responsible for the different amplitude in the abundance trends between the two regions during the peak of cool-sardine period (1980s). The phase difference of biological response of some species between the two regions to the climate shifts was attributed to the heavy fishing and to the shifting of early stages of the species by the currents in the ecosystems. Each of the species returning to the common source area (spawning grounds) after feeding in the two different current systems could be exploited as a shared population and conserved as a single large population during the abundant period.

PICES XV W2-3234 Oral

Long-term fluctuations of chum salmon and Pacific herring populations in Hokkaido during 1883-2000

Masahide **Kaeriyama**

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PICES Working Group 16 presents the impacts of climate and climate change on the key commercial species in subarctic Pacific. Long-term population dynamics of chum salmon (*Oncorhynchus keta*) and Pacific herring (*Clupea pallasii*) in Hokkaido were compared in relation to impact of climate trends, inter-specific interaction, fisheries, and hatchery program. For the sustainable fisheries management of both species, a management framework should be proposed that addresses four elements: inter- and intra-specific interaction, ecosystem-based approach, climatic indicator, and coordinated action plan for fisheries and hatchery programs.

PICES XV W2-3232 Oral
Evidences of climate-induced impacts on key commercial species around Korean waters

Jae Bong **Lee**[1], Suam Kim[2], Chang-Ik Zhang[2], Jin-Yeong Kim[1] and Sukyung Kang[1]

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This paper presents the evidence of climate-induced impacts on productivity of key commercial species and their fisheries around Korean waters, based on decadal scale and ENSO scale variability. The warming trend after the 1976 and 1988 climatic regime shifts (CRS) was associated with a decline in cold-water species (*e.g.,* walleye pollock) and an increase in warm-water species (*e.g.,* common squid, jellyfish, mackerels). After the 1988 CRS, shared region in distribution between Jack mackerel and common mackerel decreased. These shifts in the habitats of common squid and Jack mackerel resulted in changes in habitat areas of Pacific sardine and mackerel. Also, a recent cooling phenomenon after 1998 was associated with an increase in cold-water species (*e.g.,* Pacific cod, herring) in Korean waters. We discuss plausible management plans around Korean waters assuming climate change effected on the productivity and distribution of such species.

PICES XV W2-3204 Oral
Trends in Russian fisheries in the North Pacific in relation to basic stock conditions and their variability under the climate change

Vladimir I. **Radchenko**

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Fishing expeditions in the Russian far-eastern seas have traditionally used trawls tocatch fish. Trawl fisheries accounted for the largest proportion of the Russian catch in the North Pacific and the following species dominated the trawl catch: walleye pollock, herring, Pacific cod, Commander squid. Most of the the groundfishes were captured over the shelf and continental slope. In the last five years, fish species accounted for 91.8% to 94.7% of the Russian catch. The species composition of pelagic fish catch (walleye pollock - 51.8%, herring - 11.7%, pink salmon – 8.2%, Pacific saury – 3.1% of total fishery harvest) appears to be sensitive to climate change impacts. It is possible to predict future abundance of fish conditioned on periodically fluctuating large-scale climatic factors and factors manifesting lasting trends, possibly, because of the lower variation frequency. Future trends in species composition were predicted under assumptions regarding the recurring regime shifts. These forecasts indicate that walleye pollock and Japanese sardine stocks will increase in the third decade of the present century. The Pacific cod stock dynamics (3.2% of total) is similar to pollock. Trends in pink salmon catch and abundance are expected to increase in response to an increase in the heat budget of the upper layer of ocean. The catches of other salmon species (sockeye - 1.3%, chum - 1.6% of total) are expected to remain stable. Crab stocks (red king crab – 0.4%, Snow crab – 0.7%) were strongly exhausted by fishery, but they are expected to continue to play important role because of the high market cost.

PICES XV W2-3122 Oral
The potential effects of including/excluding environmental factors into stock assessments

Michael J. **Schirripa**[1] and J.J. Colbert[2]

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The PICES Working Group 16 report on the impacts of climate and climate change concluded that climate is a major factor affecting the productivity of virtually all key commercial species. However, almost none of the stock assessments conducted on these species explicitly include climate effects in the assessment model. The objective of this investigation is to evaluate the potential effects that the absence of climate variability in an assessment has on the estimation of stock status and the conservation benchmarks used to manage a stock.

Using biological and environmental parameters based on 2005 assessment of U.S. west coast sablefish, we use a data simulator (FSIM) to produce data sets where recruitment of age-0 fish is explicitly driven by a known environmental effect. We then analyzed these simulated data sets with the stock assessment software currently in use on most of the west coast groundfish stocks (Stock Synthesis II) in ways that both omit and explicitly include an environmental effect on recruitment. The resulting estimates of simulated parameter values, conservation benchmarks, and stock status were then compared to the true underlying values used in creating the simulated data sets. This comparison highlights the consequences, if any, of omitting climate variability from model specification when, in fact, a relationship between climate and stock productivity exists.

W3 MEQ/FIS Workshop
Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area

Co-Convenors: Glen Jamieson (Canada), Patricia Livingston (U.S.A.) and Chang Ik Zhang (Korea)

The management of human activities that impact ocean ecosystems requires planning and engagement of stakeholders to meet the objectives of ecosystem-based management, which in turn requires identification of areas to determine which stakeholders need to be involved in each specific process. Area boundaries are typically based upon science (*i.e.* eco-regions), human community (*i.e.* coastal community composition), administrative (*i.e.* historical resource management areas) and international considerations (*i.e.* transboundary issues). This workshop will consider the science requirements for eco-region identification in the PICES area, and we solicit presentations that: 1) highlight national or regional experiences or frameworks in place for delineating marine sub-regions or eco-regions; 2) demonstrate the use of a variety of physical and/or biological criteria for region identification; or 3) explain the specific management purposes behind various sub-regional identification schemes. Workshop discussion will involve participants in reviewing the existing Large Marine Ecosystem boundaries of the PICES area and developing recommendations for criteria to be used in sub-regional identification in the North Pacific.

Sunday, October 15, 2006 09:00-18:00

09:00-09:10 **Introduction by Convenors**

09:10-09:50 **Elizabeth Fulton, Vincent Lyne and Donna Hayes** (Invited)
Bioregionalisation and ecosystem-based management in Australia (W3-2908)

09:50-10:15 **Glen S. Jamieson**
Canada's ecoregion determination approach (W3-2898)

10:15-10:40 **Jae Bong Lee, Chang Ik Zhang, Dong Woo Lee, Jong Hwa Park and Jong Hee Lee**
Marine sub-regions determined with physical and biological criteria in Korean waters (W3-3019)

10:40-11:00 ***Tea/Coffee Break***

11:00-11:25 **Chris J. Harvey, Isaac C. Kaplan and Phillip S. Levin**
Selecting model domains and boundaries in ecosystem modeling of the U.S. West Coast: Process determines scale (W3-3184)

11:25-11:50 **David L. Fluharty**
Aligning institutions with ecosystems for marine science (W3-3195)

11:50-12:15 **Patricia A. Livingston and John F. Piatt**
Progress in U.S. ecoregion definitions for ocean ecosystems and an Alaskan example (W3-3196)

12:15-14:00 ***Lunch***

14:00-14:40 **R. Ian Perry** (Invited)
Ecosystem typologies in the North Pacific – A useful concept for ecosystem-based management? (W3-3062)

14:40-15:05 **Michael P. Seki and Jarad Makaiau**
Archipelagic fishery ecosystem plans for the U.S. central and western Pacific islands (W3-3209)

15:05-15:30 **William J. Sydeman, Sonia D. Batten, Michael Henry, Chris Rintoul, David W. Welch, Ken H. Morgan and K. David Hyrenbach**
Meso-marine ecosystems of the North Pacific: Application to ecosystem-based management (W3-3220)

15:30-16:00 ***Tea/Coffee Break***

16:00-16:25 **Vadim A. Shtrik**
Use of the classification and structure of coastal zone macro-vegetation for global and local eco-regional identification of coastal areas in the North Pacific (W3-3221)

16:25-16:50 **Tatsu Kishida**
Physical and biological criteria for region identification around Japan (W3-3258)

16:50-18:00 **Discussion and Summary**

PICES XV W3-3195 Oral
Aligning institutions with ecosystems for marine science

David L. **Fluharty**

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As criteria are being developed to define the extent of ecosystems and interactions at various ecosystem scales, it is critical that consideration is given to the match with institutional scales for provision of scientific advice and administration of ecosystem research. Recent efforts to define ecosystems for the United States are examined in light of assessment of institutional core capacities for providing scientific advice and research in three regions, *i.e.*, U.S. West Coast, Alaska and the Hawaiian Islands. Current institutional alignments appear to be workable at large scale but more difficult to provide at scales relevant to nearshore resource processes and where ecosystems are transboundary.

PICES XV W3-2908 Invited
Bioregionalisation and ecosystem-based management in Australia

Elizabeth **Fulton**, Vincent Lyne and Donna Hayes

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A critical factor in the successful implementation of ecosystem-based management is to be dealing (as far as possible) with appropriate spatial regions. While managing at the level of an eco-region is not a guarantee in itself for successful management outcomes, it has been shown repeatedly that trying to manage across regions with very different conditions (physical and ecological) makes the task much more difficult, if not impossible. As part of Australia's move to ecosystem-based management, Australian researchers have been grappling with the issue of eco-region (or bioregion) definition for a decade now. The resulting hierarchical classification scheme has been successfully applied across multiple scales and in many system types; and its output is becoming an accepted component of management support packages – both as maps for use in defining coherent management areas, but also as part of ecosystem-level modeling tools. This discussion will outline the basic bioregionalisation scheme, the data and criteria that it uses (physical, chemical and biological) and the implications for management on different scales.

PICES XV W3-3184 Oral
Selecting model domains and boundaries in ecosystem modeling of the U.S. West Coast: Process determines scale

Chris J. **Harvey**, Isaac C. Kaplan and Phillip S. Levin

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Major marine ecosystems along the West Coast of the United States are defined in space by both fixed and dynamic physical boundaries. The dominant feature, the California Current ecosystem, is the eastern limb of the North Pacific subtropical gyre and flows over the narrow continental shelf and slope. The other major ecosystems are three large estuaries (Puget Sound, the Columbia River estuary, San Francisco Bay). Each system can be divided into smaller basins, regions or districts based on physical characteristics, ecological differences, and artificial boundaries established for governance, management, and conservation. For example, in our ecosystem model of the northern portion of the California Current, we have delineated 62 polygons based on oceanography and ecology (depth; upwelling zones; proximity to major coastal features and zoogeographic boundaries), fisheries management, and data availability. The large model domain is consistent with the scale of the processes we are examining, namely the influence of climate variability, species interactions, fisheries effects, and economics, and how different fisheries management strategies will perform given the dynamics of these processes. Including finer-scale processes, such as localized circulation patterns, habitat patchiness, eutrophication, species introductions, or establishment of marine reserves, will require model domains on the scale of one of the smaller ecosystems, such as Puget Sound, or on subregions of the California Current. Both modeling scales allow us to examine the effects of artificial boundaries, such as political borders or management

zones, which can induce steep mortality gradients on species whose natural ranges or migration patterns cross them.

PICES XV W3-2898 Oral
Canada's ecoregion determination approach

Glen **Jamieson**

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An important first step in achieving ecosystem-based management (EBM) is the definition within a country of broad geographical areas, *i.e.*, ecoregions that have a common ecological basis. Each ecoregion would be managed under a common set of operational objectives to achieve integrated management, with some objectives at least probably differing among defined ecoregions. In 2004, Fisheries and Oceans evaluated Canada's marine waters against three broad categories of criteria: geological, physical oceanographic and biological properties. The approach adopted was non-hierarchical and was based on overlaying criteria and looking for common patterns. This process resulted in the identification of 17 ecoregions in Canada: four in the Pacific, six in the Arctic and seven in the Atlantic. It was also recognized that ecoregions did not terminate at Canada's jurisdictional boundaries, and on the Pacific for example, three of the ecoregions were considered to extend into adjacent American waters. Optimal operational management of trans-boundary species thus requires collaboration between different management regimes and the sharing of scientific data. Informal collaborative approaches such as the proposed Big Eddy initiative are presented as a mechanism to help develop appropriate joint resource management.

PICES XV W3-3258 Oral
Physical and biological criteria for region identification around Japan

Tatsu **Kishida**

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I compiled eco-regions around Japan based on both physical oceanography and biological features such as species composition of fishery resources. According to the compilation, marginal seas located around Japan, *i.e.*, the East China Sea, the Sea of Japan and the Sea of Okhotsk are highly independent eco-regions. The northwest Pacific Ocean was divided into two eco-regions, which are the Kuroshio Current (warm current) system and Oyashio Current (cold current) system, although many fishes and other animals in Kuroshio Current system migrate seasonally into the transitional region between Kuroshio and Oyashio or Oyashio region for utilizing the higher productivity of these regions. Each current system is also divided into pelagic and demersal ecosystems in coastal areas along the Japanese Archipelago.

Fisheries resources are assessed by each stock corresponding to the eco-regions described above, though restricted to the Japanese EEZ. In Japan TACs are classified by species and allocated to each fishery and prefecture by political decision to regulate the bias of seasonal or geographical distribution of the fisheries resources. To avoid competitions among fisheries, for example, between coastal and offshore, fishing ground restrictions are strictly established.

PICES XV W3-3019 Oral
Marine sub-regions determined with physical and biological criteria in Korean waters

Jae Bong **Lee**[1], Chang Ik Zhang[2], Dong Woo Lee[1], Jong Hwa Park[1] and Jong Hee Lee[2]

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We defined marine sub-regions to plan and engage science-based policies, such as ecosystem-based fisheries management in Korea. We categorized physical and biological ocean environments using data on seawater temperature, salinity and density at surface and 50m depth layers, and zooplankton biomass in Korean waters. These data were taken from 157 stations and stored at the Korea Ocean Data Center (KODC) over 40 years (1965-2004) and divided water-masses around Korean waters using self-organization mapping (SOM), which is one of many potential neural network pattern recognition techniques that seek clusters in data using unsupervised learning methodology. We discussed usage of other criteria to identify the management regions, such as existing resource management areas and coastal community locations.

PICES XV W3-3196 Oral
Progress in U.S. ecoregion definitions for ocean ecosystems and an Alaskan example

Patricia A. **Livingston**[1] and John F. Piatt[2]

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U.S. marine fisheries research and management outside state waters is primarily conducted by the National Oceanic and Atmospheric Administration (NOAA). NOAA has been advancing an ecosystem approach to ocean management for a number of years. Recent efforts have led to the designation of Large Marine Ecosystems (LMEs) for organizing research and management efforts. NOAA Fisheries recently held a workshop to further advance these efforts by discussing how to move forward in the definition of ecoregions within U.S. LMEs. We outline here the progress from this workshop and show an example of ecoregion definition for Alaska and relate it to the U.S. efforts.

PICES XV W3-3062 Invited
Ecosystem typologies in the North Pacific – A useful concept for ecosystem-based management?

R. Ian **Perry**

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Landscapes and ecosystems are relatively easy to identify for terrestrial environments, and have become easier to identify for marine environments with the development of space-based remote sensors for sea temperature, winds, and ocean colour. The biogeochemistry community has made great advances in delineating marine biomes and biogeochemical provinces, and several excellent studies and books have been published. The marine fisheries community (through FAO) has been collecting fisheries statistics for >50 years within large ocean areas loosely defined on physical oceanographic characteristics. More recently the concept of Large Marine Ecosystems has been elaborated, and several have been defined at smaller scales than the FAO regions. Relatively little work has been done, however, to reconcile and overlap these biogeochemical and fisheries-based ecosystem typologies, with the Sea Around Us project being a notable exception. Integrating these typologies raises issues of the match of temporal and spatial scales from physics to plankton to fish, seasonality, and the sensitivities of these typologies to climate variability and global change. In addition to these ecosystem typologies, the North Pacific (and other oceans) are overlain with a mesh of fisheries management and reporting areas which may, or may not, relate to marine ecosystem typologies. As a contribution to the report of PICES Working Group 19 on "Ecosystem-based management science and its application to the North Pacific", this presentation explores the reasons/needs to identify 'ecosystems' in the North Pacific for ecosystem-based management. It reviews the existing ecosystem typologies proposed for the North Pacific, and the network of

national fisheries reporting areas, at regional (coastal) to basin scales. It concludes with a discussion of the dangers of defining ecosystem-based management areas that are mismatched (larger or smaller) against its component ecosystem(s). Throughout, the reality of political boundaries must also be recognized.

PICES XV W3-3209 Oral
Archipelagic fishery ecosystem plans for the U.S. central and western Pacific islands

Michael P. **Seki**[1] and Jarad Makaiau[2]

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Efforts to advance an ecosystem approach to fishery management for offshore fisheries in the U.S. central and western Pacific islands have focused on moving from species-based fishery management plans (FMPs) to place-based fishery ecosystem plans (FEPs). Existing FMPs for insular resources (bottomfish, crustaceans, precious corals, and coral reef resouces) are being restructured as archipelagic fishery ecosystem plans (FEPs). These include: a Mariana Archipelago FEP (for Guam and the Northern Marianas Islands), a Hawaii Archipelago FEP, an American Samoa Archipelago, and a Pacific Islands Remote Island Areas FEP (for islands and atolls of Baker, Howland, Jarvis, Johnston, Palmyra, Wake and Kingman Reef). An existing FMP for pelagic resources will become a Pacific pelagic FEP. The structural changes will facilitate the incorporation of ecosystem-based principles into the management of fisheries in the jurisdictional waters surrounding the U.S. Pacific islands.

Criteria relevant to determination of FEP objectives, boundaries, management unit species, advisory group structure, regional/international coordination and community participation approaches have been vetted through a series of meetings and workshops. An overview of the process and outcomes are presented here.

PICES XV W3-3221 Oral
Use of the classification and structure of coastal zone macro-vegetation for global and local eco-regional identification of coastal areas in the North Pacific

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The sub-regional identification scheme of coastal zone for boreal seas of Russia is described. The scheme is based on detailed analysis of macro algae vegetation of Far East Seas of Russia. The presentation deals with the problem of classification and correct determination of coastal eco-systems as key-point regions for bio-cycles of many dominant species of open sea ecosystems. The follow aspects will be discussed in the presentation.

- Structure and classification of macro-vegetation of coastal zone as criteria for eco-region identification for North Pacific Seas (Russian sector).
- Some examples of local sub-regional identification by method of macro-algae indication (Japanese Sea, Bering Sea, and Sea of Okhotsk).
- Using the bathymetry analyses of alga flora and zone division of phytocoenoses as indicator of ecosystem conditions.
- Using the global and local eco-regional identification schemes for monitoring purposes of coastal ecosystems and for ecosystem-based management of human activities.

PICES XV W3-3220 Oral

Meso-marine ecosystems of the North Pacific: Application to ecosystem-based management

William J. **Sydeman**[1], S.D. Batten[2], M. Henry[1], C. Rintoul[1], D.W. Welch[3], K.H. Morgan[4] and K.D. Hyrenbach[1]

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We studied physical and biological variability across the sub-arctic North Pacific Ocean (along a 7,500 km transect from British Columbia, Canada, to Hokkaido, Japan) to test the hypothesis that "eco-regions" of the North Pacific are persistent between seasons and years. Plankton samples were collected with a Continuous Plankton Recorder (CPR) while observers recorded marine birds and mammals. Physical oceanographic properties were measured using data loggers and XBTs. Temperature and Chlorophyll-*a* concentrations were obtained from satellite imagery. Using multi-dimensional clustering of physics, plankton and top predator data for data collected in 2002, we identified 10 distinct North Pacific biological communities (eco-regions) which we term "meso-marine ecosystems" (MMEs). MMEs have clear bathymetric and boundary current associations (Batten *et al.*, 2006, DSR II). Using data from all years (2002-2005), we now investigate the temporal persistence of MMEs over 4 years and 3 seasons (winter, summer, fall). Eco-regional boundaries were persistent through time, but varied, to a certain extent, by season. Regular monitoring of MMEs, including dynamic changes in plankton and predator communities, will enhance our ability to detect the ecosystem fluctuations that affect fish and other species, thereby promoting an ecosystem-approach to ocean resource management.

W4 MEQ Workshop
Review of selected harmful algae in the PICES region: II. *Dinophysis* and *Cochlodinium*
and HAB-S Meeting

Co-Convenors: Charles G. Trick (Canada) and Yasunori Watanabe (Japan)

This workshop is the second of an annual series in which Harmful Algal Bloom (HAB) species that impact all or most countries in the North Pacific are discussed in detail. In 2006, we will focus on two genera, *Dinophysis* and *Cochlodinium*. *Dinophysis*, including DSP (Diarrhetic Shellfish Poisoning) producing species such as *D. acuminata*, *D. acuta*, *D. caudata* and *D. fortii*, is distributed in the PICES region. The integration of the information from each country will advance our understanding of this genus. *Cochlodinium polykrikoides* causes serious damage to finfish aquaculture in Korea and Japan. It also has potential to spread to other countries. Topics will include detection methods, ecosystem comparisons, and new advancements in physiology and ecology from each of the member countries. In particular, we would like to stress those factors which need additional study in order to develop a predictive capacity for these HABs. This workshop will be preceded by a half-day laboratory demonstration on detection techniques for algal toxins.

MEQ Workshop
Laboratory demonstration on detection techniques for algal toxins
Friday, October 13, 2006 13:00-18:00

Reiji Sekiguchi, Natsuki Takahashi, Toshiyuki Suzuki
Protein phosphatase 2A inhibition assay for okadaic acid and its analogs in shellfish

Satoshi Nagai, Yukihiko Matsuyama and Shigeru Itakura
Simple, rapid, specific and cost effective method for identifying *Alexandrium tamarense* and *A. catenella* using "LAMP" method.

MEQ Workshop
Scientific Session, Saturday, October 14, 2006 09:00-18:00

09:00-09:10 **Introduction by Convenors**

Cochlodinium

09:10-09:55 **Kazumi Matsuoka** (Invited)
Recent progress of the study on a harmful dinoflagellate - *Cochlodinium polykrikoides* (W4-2836)

09:55-10:15 **Hak-Gyoon Kim, Chang-Kyu Lee, Kyong-Ho An, Wol-Ae Lim, Sook-Yang Kim and Young-Tae Park**
The known and unknown on the initiation of *Cochlodinium polykrikoides* blooms in Korean waters (W4-2860)

10:15-10:35 **Kazutaka Miyahara, Ryosuke Uji and Mineo Yamaguchi**
Harmful blooms of *Cochlodinium polykrikoides* in the southwestern Sea of Japan (San-in coastal waters) (W4-3013)

10:35-11:00 ***Tea/Coffee Break***

11:00-11:20 **Changkyu Lee, Youngtae Park, Kyeongho An and Yoon Lee**
Impact of yellow clay on respiration and phytoplankton uptake of benthic shellfish (W4-3149)

11:20-11:40 **Takafumi Yoshida and Takashi Ogawa**
Activity of CEARAC about Harmful Algal Blooms in the NOWPAP region (W4-2823)

Cochlodinium and Dinophysis

11:40-12:10 **Tatiana Yu. Orlova, Marina S. Selina and Galina V. Konovalova**
Species of the genera *Cochlodinium* and *Dinophysis* from the east coast of Russia (W4-2861)

12:10-12:40 **Vera L. Trainer and Charles G. Trick**
Cochlodinium and *Dinophysis* in western U.S. and Canada (W4-3233)

12:40-14:00 ***Lunch***

Dinophysis

14:00-14:45 **Patrick Gentien** (Invited)
The rare marine protist *Dinophysis acuminata* (W4-3109)

14:45-15:30 **Beatriz Reguera, L. Escalera, S. Gonzalez-Gil, G. Pizarro, L. Velo and J.M. Franco** (Invited)
What we know and what we do not know about *Dinophysis* (W4-3237)

15:30-16:00 ***Tea/Coffee Break***

16:00-16:20 **Ichiro Imai and Goh Nishitani**
Are *Dinophysis* spp. always responsible for DSP toxicity of bivalves? (W4-3033)

16:20-16:40 **Toshiyuki Suzuki, Akira Miyazono, Yutaka Okumura and Takashi Kamiyama**
LC-MS/MS analysis of lipophilic toxins in Japanese *Dinophysis* species (W4-3031)

16:40-17:00 **Jinhui Wang, Yutao Qin, Caicai Liu, Xiangshen Chen and Ren Xu**
Dinophysis spp.: The abundance, distribution and the toxicity of DSP in the East China Sea (W4-2888)

17:00-18:00 **Discussion and Summary**

HAB-S Meeting
Sunday, October 15, 2006 09:00-18:00

09:00-09:30 **Vera Trainer and Hak-Gyoon Kim**
Welcome, goals of HAB Section meeting

09:30-10:00 **Hao Guo**
The Monitoring System on HABs in China (W4_HAB-3259)

10:00-10:30 **Vera L. Trainer, Barbara M. Hickey and Michael G. Foreman**
A regional U.S. west coast observing system for toxigenic *Pseudo-nitzschia* (W4_HAB-3169)

10:30-11:00 ***Tea/Coffee Break***

11:00-11:30 **Henrik Oksfeldt Enevoldsen and Monica Lion**
Progress in the development of an international collaborative harmful algal event data base: The joint IOC-ICES-PICES HAE-DAT (W4_HAB-3235)

11:30-12:30 Discussion and assistance in entering year 2002 data into HAE-DAT

12:30-14:00 ***Lunch***

Country Reports/HAE-DAT (year 2002) reports

14:00-14:20 **Japan** (Yasunori Watanabe)

14:20-14:40 **China** (Jinhui Wang)

14:40-15:00 **Korea** (Hak-Gyoon Kim)

15:00-15:30 **Russia** (Tatyana Yu. Orlova)

15:30-16:00 ***Tea/Coffee Break***

16:00-16:20 **Canada** (Charles G. Trick)

16:20-16:40 **U.S.A.** (Vera L. Trainer)

16:40-18:00 **Discussion and Summary**

W4 Workshop Abstracts

PICES XV W4-3109 Invited
The rare marine protist *Dinophysis acuminata*

Patrick **Gentien**[1], Elisabeth Nézan[1], Pascal Lazure[1] and Hongqin Xie[2]

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Marine species, like a vast majority of species, face the challenge of sexual recombination. In the ocean, sex is a battle against dispersal. At low densities, species must overcome the Allee effect in decreasing the separation distance between potential gametes. Although rare, *Dinophysis acuminata* is the major harmful planktonic species in marine European waters. As such, its intensive monitoring provides a unique opportunity to study a rare marine species. We describe here the strategy whereby it takes advantage of temporary hydrodynamic structures. This feature of *D. acuminata* population dynamics is essential to the understanding and therefore, to the prediction of harmful events at the coast. Building up on the limited knowledge we have of this species and using general concepts enabled us to establish a prediction scheme of *D. acuminata* harmful events at the coast. This scheme has been validated on a 12 year time series and will be further improved when the nutritive source for this dinoflagellate is discovered.

PICES XV W4-3033 Oral
Are *Dinophysis* spp. always responsible for DSP toxicity of bivalves?

Ichiro **Imai**[1] and Goh Nishitani[2]

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Toxins of diarrhetic shellfish poisoning (DSP) are thought to originate from toxic *Dinophysis* species. However, in Tohoku districts such as Mutsu Bay in northern Japan, there have been some cases in which the scallop toxicity increased in the absence of *Dinophysis*, or in which the scallop toxicity did not increase during blooms of *D. acuminata* and *D. fortii*. Additionally in the Seto Inland Sea, western Japan, DSP incidents have never detected despite having often blooms of *D. fortii* with cell densities higher than 3000 cells L^{-1}. According to the mixotrophy and the attachment of picophytoplankton cells to *D. acuminata* and *D. fortii*, we hypothesize that *Dinophysis* spp. may be originally nontoxic and may become toxic secondarily through the ingestion of toxic small-sized phytoplankton. From the results of monitorings conducted in Mutsu Bay in 2000, DSP toxins were detected twice in the mid-gut gland of scallops on 26 June and on 3 July. Relatively high cell densities of *D. fortii* were observed on June 26 and September 11, and may only contribute to the bivalve toxicity during late June to early July. *D. acuminata* was not responsible for the toxicity of scallops in Mutsu Bay in 2000. ELISA-monitorings of small-sized (0.7–5 μm) plankton fraction in seawater could detect DSP toxins from two weeks before the detection of the toxin in scallops.

Fluctuations of *Dinophysis* spp. and small phytoplankton (cryptophytes, other nano-phytoplankton, cyanobacteria and eukaryotic pico-phytoplankton) were investigated in Hiroshima Bay, Mutsu Bay and Ise Bay, Japan. Small-sized cryptophytes (< 5 μm) showed a close relationship with *D. acuminata* in Hiroshima Bay and Mutsu Bay. In Ise Bay, peaks of the occurrences of middle- (5–10 μm) and small-sized cryptophytes were observed 2–3 weeks before the peak of *D. acuminata*. These cryptophytes decreased rapidly with increases in *D. acuminata.* These results suggest a possibility that small-sized cryptophytes may be food organisms for mixotrophic *Dinophysis*.

As a new aspect, we have newly found toxicities of attached material on the surface of scallops in Mutsu Bay in August of 2005. Identification and isolation of toxic organisms from the surface of scallops appear to be urgent tasks for making clear the mechanisms of DSP occurrences in Mutsu Bay.

PICES XV W4-2860 Oral

The known and unknown on the initiation of *Cochlodinium polykrikoides* blooms in Korean waters

Hak-Gyoon **Kim**[1], Chang-Kyu Lee[2], Kyong-Ho An[2], Wol-Ae Lim[2], Sook-Yang Kim[2] and Young-Tae Park[2]

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Fish-killing dinoflagellate, *Cochlodinium polykrikoides*, blooms have been recurred and become widespread in Korean waters since 1995. The first bloom has been observed in the central part of the South Sea for the last decade. It was a mixing zone of slightly eutrophic and warm waters triggered by nutrients from eutrophic coastal water and heat energy from Kuroshio warm current. Then the subsequent blooms make enlarge their plume to neighboring waters by winds and tidal currents, and become dense enough to kill fish by merge of transported and concurring bloom therein. They move to the eastward to the same direction of Kuroshio Current. Our recent known is that the most important driving forces for the initiation of *C. polykrikoides* bloom are the heat supply from Kuroshio Current and the other is the nutrient load from the coastal waters.

Besides, the unknown is that where *C. polykrikoides* come from. Are they come from benthic resting cysts or from the transported swimming cells by way of Kuroshiwo current? To clarify the initiation, bio-geographical distribution of *C. polykrikoides* with oceanographic properties have to be studied simultaneously in the Western Pacific, East and South China Sea, and coastal waters bordering China, Japan and Korea. That is why regional collaborative *C. polykrikoides* monitoring network should be established to encompass all those interested areas to clarify the unknown which is the essential for early prediction and collaborative management and mitigation of harmful algal blooms (HABs) among PICES member countries.

PICES XV W4-3149 Oral

Impact of yellow clay on respiration and phytoplankton uptake of benthic shellfish

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Yellow clay dispersion has been applied to mitigate red tides in Korea since 1995. The effects of clay dispersion include the coagulation, sedimentation, and destruction of phytoplankton. The present study documents the impact on the shellfish physiology with three marine shellfishes by examinations of yellow clay uptake, respiration, and clearance rate (CR) of animals after the treatment of yellow clay. Mussel took much clay in early and kept it longer. Abalone was a slow clay-taker relatively. The amount of clay in gills and inside cavities of shellfishes was increased in a temporal manner and the inside of the shellfishes was turned to be a full of clay by 2 h. The ejection of the accumulated clay was evident from as early as 30 minutes rescued from clay pools. The whole clay in shellfishes was discharged by 6 h passed after their removal. The amount of oxygen consumed was decreased by the level of clay, and however there was no statistical significant between treatments. After a peak in 30 min, CRs declined rapidly and the CRs became restored to the level of the untreated control groups within 2 h. The treated amount of clay did not directly contribute to the alternation of the CRs and the eating habit of shellfishes was returned to normal after 30 min with clay particles still within their organs.

PICES XV W4-2836 Invited

Recent progress of the study on a harmful dinoflagellate - *Cochlodinium polykrikoides*

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An unarmored chain-forming dinoflagellate *Cochlodinium polykrikoides* was described from Puerto Rico by Marglaef in 1961. This species was first recognized in the Yatsushiro Sound of West Japan in 1975 and then caused a serious economic damage to yellow-tail aquaculture industries in the same area in 1978. Thereafter, it has been known to be harmful for fish aquaculture in western Japan and southern Korea for the last two decades. Another chain-forming species, *Cochlodinium heterolobatum* was described from New Jersey, U.S.A. by Silva in 1967. Under such circumstances, several taxonomic studies on these species with other related taxa have been conducted. Recent taxonomic progress on these species is that *C. polykrikoides* and *C. heterolobatum* has been synonymized. However, another taxonomic issue with *Cochlodinium catenatum* described by Okamura from the coast of Tokyo Bay, Central Japan in 1916 revealed.

Regarding the geographical expansion of *C. polykrikoides* in the relation to the intraspecific variety, SSU rDNA sequences of *C. polykrikoides* strains collected from Japan, Korea, Philippines and Malaysia were analysed. Sequence divergences between all Korean and most of Japanese strains were completely identical, while other strains had several substitutions to them. According to this data, the origin of this species seems to be in and around tropical to subtropical coastal areas such as the Philippines and Saba, Malaysia.

However, its biological nature such as optimum environmental conditions for reproduction, life history including resting cysts and ichtyotoxicity are not fully understood for the moment. Noxious effects on aquaculture, expanding mechanisms and taxonomic histories of motile cells and cysts was summarized and discussed in the present study for clarification of various problems concerning with *C. polykrikoides*.

PICES XV W4-3013 Oral

Harmful blooms of *Cochlodinium polykrikoides* in the southwestern Sea of Japan (San-in coastal waters)

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Since 2002, blooms of *Cochlodinium polykrikoides* have often been observed in early autumn in the southwestern Sea of Japan (San-in coastal waters in Tottori and Hyogo prefectures, Japan) and caused a great deal of damages to local coastal fisheries. This study reports on the bloom of 2003, focusing on the distribution and its association with oceanographic conditions. The bloom was first found in the western Hyogo on September 15 and in the eastern Tottori on September 16, and then spread over all around Tottori and to the eastern Hyogo on September 17-18. Detritus-like dark brown masses composed of inactive or decayed cells of *C. polykrikoides* were accumulated on the seafloor in the middle and end of the bloom. Water temperature, salinity and dissolved oxygen during the bloom ranged 24.9-28.4^{o}C, 26.80-32.11 and 2.3-9.3 m*l*/*l*, respectively. The maximum cell density of *C. polykrikoides* was 12,400 cells/m*l* and various kinds of prevalent aquatic animals such as not only finfishes, but also molluscs and echinoids, were crucially damaged, killed, stranded and observed to behave abnormally. Flow pattern of the Tsushima Current and images of SST and chlorophyll-*a* from satellite observations suggested that the bloom was presumably related to the Tsushima Current; it flowed specifically alongside the coastal area, where water temperature was about 1^{o}C higher than that of 2002. The bloom occurred in so wide-spread areas of Tottori and Hyogo that careful monitoring and observation are needed to prevent recurrent damages to the fisheries in the areas.

PICES XV W4-2861 Oral
Species of the genera *Cochlodinium* and *Dinophysis* from the east coast of Russia

Tatiana **Orlova**, Marina Selina and Galina Konovalova

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Species composition, distribution and occurrence of *Cochlodinium* spp. and *Dinophysis* spp. from the east coast of Russia are discussed. Nine species of *Cochlodinium* are known from the Russian Pacific coast. *Cochlodinium* is an infrequent component of phytoplankton that is usually observed in August-October at low density (100-200 cells/l). One short duration outbreak of *Cochlodinium* sp. cf. *polykrikoides* (up 2 000 000 cell/l) was registered in hypereutrophic area of Amurskii Bay in July, 2003.

Twenty eight species of *Dinophysis* are known for the Far Eastern Seas of Russia. Four species, *D. acuminata*, *D. acuta*, *D. fortii* and *D. rotundata*, were common and abundant. *D. acuminata* is the most widespread and abundant species in Russian waters. Highest concentrations of this species were observed on Kamchatka in October (450 000 cells/l) and in the coastal waters of Primorye in August (11 000 cells/l). *D. acuta* is the most common species near Sakhalin Isl. (2 000 cells/l). The maximum concentration of *D. fortii* (3 000 cells/l) was observed in Peter-the-Great Bay in Primorye. Seasonal fluctuations of *Dinophysis* indicate higher abundance in summer and autumn. The toxin composition of *Dinophysis* from Russian waters remains to be determined.

PICES XV W4-3237 Invited
What we know and what we do not know about *Dinophysis*

Beatriz **Reguera**, L. Escalera, S. Gonzalez-Gil, G. Pizarro, L. Velo and J.M. Franco

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Dinoflagellates of the genus *Dinophysis* Ehrenberg may constitute the main threat for shellfish growers in many coastal regions of Europe, New Zealand, Chile and Japan. Despite their moderate presence (<40 cell L^{-1}) most of the year, some species, such as *Dinophysis acuminata* and *D. acuta*, can reach high numbers (10^3-10^5 cell L^{-1}), develop very persistent blooms, and lead to prolonged closures of shellfish harvesting. Their scarcity and patchy distribution requires sampling strategies different from conventional phytoplankton sampling. Up to date, nobody has succeeded to obtain permanent cultures of any species of *Dinophysis*; the sexual cycle has been described but some stages have not been reproduced in the laboratory; studies on physiology and behaviour, toxin profile and toxin content per cell and genetics have been based on field populations and/or isolation of cells by microcapillarity. Here we revise existing information on the biology, ecology and toxinology of *Dinophysis* spp., their shared attributes and their species-specific features, and identify the main issues that require focused attention to solve important gaps in knowledge on the main species of *Dinophysis* from the point of view of their world-wide economic impact.

PICES XV W4-3031 Oral
LC-MS/MS analysis of lipophilic toxins in Japanese *Dinophysis* species

Toshiyuki **Suzuki**[1], Akira Miyazono[2], Yutaka Okumura[1] and Takashi Kamiyama[1]

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Quantification of lipophilic toxins associated with diarrhetic shellfish poisoning (DSP) in the toxic dinoflagelate *Dinophysis fortii, D. acuminata, D. mitra, D. norvegica, D. tripos, D. infundibulus* and *D. rotundata* collected in coastal waters Hokkaido, Japan in 2005 was carried out by liquid chromatography-tandem mass spectrometry (LC-MS/MS). Okadaic acid (OA), OA diol-esters, dinophysistoxin-1 (DTX1), 7-*O*-palmitoyldinophysistoxin-1 (DTX3), pectenotoxin-1 (PTX1), pectenotoxin-2 (PTX2), pectenotoxin-6 (PTX6), pectenotoxin-11 (PTX11), pectenotoxin-2 seco-acid (PTX2sa), yessotoxin (YTX) and 45-hydroxyyessotoxin (45-OHYTX) in the *Dinophysis* species were quantified by LC-MS/MS. PTX2 was the dominant toxin in *D. acuminata, D. norvegica* and *D. infundibulus* whereas both DTX1 and PTX2 were the principal toxins in *D. fortii. D. mitra* and *D. tripos* did not produced any toxins. In our previous study, several OA diol-esters and a novel pectenotoxin, PTX11, were discovered in *D. acuta* collected in New Zealand. These toxins were not detected in any *Dinophysis* strains in Japan.

PICES XV W4-3233 Oral
Cochlodinium and *Dinophysis* in western U.S. and Canada

Vera L. Trainer[1] and Charles G. **Trick**[2]

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At least 4-5 *Dinophysis* species, including *D. fortii, D. tripos, D. parva, D. acuminata,* and *D. acuta,* some of which are known to be toxic elsewhere in the world are found in western U.S. and Canadian waters. Beginning in 2003, total dinophysistoxins (DTX, pectenotoxins, and okadaic acid) were measured at levels above 1g/g in manila clam, Pacific oyster, littleneck clam, and geoduck clam harvested from British Columbia in western Canada. European Union (EU) countries require testing for these toxins in shellfish that are shipped into Europe from Canada, but there is no requirement to test for these toxins in shellfish distributed within the U.S. The first recorded *Cochlodinium* bloom that caused mortality of aquacultured salmon on the west coast of Canada from August through October 1999 resulted in economic losses of approximately $2 million. Fish stopped feeding when cell counts exceeded 400 cells/ml in the net pens, and mortality was observed when cells numbered above 2000 cells/ml. This genus has been observed in samples on the U.S. west coast, but to date, no finfish mortalities due to this organism have been observed. Western Pacific nations suffer many more problems due to *Cochlodinium* and *Dinophysis* than the U.S. and Canada.

PICES XV W4-2888 Oral
Dinophysis spp.: The abundance, distribution and the toxicity of DSP in the East China Sea

Jinhui **Wang**, Yutao Qin , Caicai Liu , Xiangshen Chen and Ren Xu

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There are 4 potential DSP causing algae in East China Sea, including *Dinophysis caudata*, *D. fortii*, *D. acuminata*, and *D. rotundata.* Two species, *D. caudate* and *D. fortii*, are abundant and can be found throughout the year, with a maximum density of *Dinophysis caudata* up to 30,000 cell/L, and an occurrence frequency ranging from 2%~38%. The density of *Dinophysis* spp. has a positive correlation with temperature and pH but a negative correlation with suspended particles and nutrient concentrations. DSP was detected in 21 of 44 shellfish species. The detection rate of 10 species of shellfish ranged from 8 to 33%, including Comb pen shell, scallop, heptic moon shell, mussel, Venus clam, Oyster, Periwinkle and Blood clam. The levels of toxicity ranged from undetectable to 10 Mu/100g. One half of the samples presented okadaic acid levels ranging from 0.007 to 1.255μg/100g; the toxin levels of 11 natural grown shellfish was higher than cultured species, and the toxicity of these species ranged from 5 to 15 Mu/100g with the concentration of okadaic acid ranged from 0.36 4.94μg/100g; it is suggested that mussel (*Mytilus edulis, Perna viridis*), heptic moon shell (*Polynices didyma*), Oyster (*Ostrea rivularis*), Blood clam (*Scapharca subcrenata*) and *Gomphina veneriform* may serve as early warning indicator species for DSP detection and risk management activities.

PICES XV W4-2823 Oral
Activity of CEARAC about Harmful Algal Blooms in the NOWPAP region

Takafumi **Yoshida** and Takeshi Ogawa

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CEARAC (Special Monitoring and Coastal Environmental Assessment Regional Activity Centre) has carried out regional activities in the NOWPAP (Northwest Pacific Action Plan) region. In these activities, CEARAC is implementing activities related to Harmful Algal Blooms in Working Group 3. CEARAC/WG3 has compiled a National Report on HAB of each member country (China, Japan, Korea and Russia) and integrated Report of the NOWPAP region and established HAB Reference Database.

In red tide species, *Cochlodinium* is one of the species of concern in the NOWPAP region for damage to coastal fisheries. Therefore, WG3 has organized the corresponding group on *Cochlodinium* (CCG) so as to make a set of information on *Cochlodinium*. In CCG activities, a website has been constructed which introduces *Cochlodinium* briefly to scientists and the public concerning environmental problems. The website includes pictures of *Cochlodinium*, explanation of the species, and information of its damage to the fishery, and so on. We also made a brochure of *Cochlodinium* to share information in the NOWPAP region.

In 2006-2007 biennium, CEARAC/WG3 suggested an activity for "Promotion of Mitigation" of red tides as a main activity and a booklet will be made on countermeasures against red tide which includes *Cochlodinium*. This booklet aims to share information on countermeasures against red tides among the NOWPAP members, to contribute to establishing policies and measures against red tides with stakeholders and related agencies. CEARAC and NOWPAP would like to share the information with PICES and work together.

HAB Meeting Abstracts

PICES XV W4_HAB-3235 Oral
Progress in the development of an international collaborative harmful algal event data base: The joint IOC-ICES-PICES HAE-DAT

Henrik Oksfeldt **Enevoldsen**[1] and Monica Lion[2]

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The IOC, ICES and PICES are jointly operating the Harmful Algal Event Data base HAE-DAT with the view to expand the partnership and thereby build a global harmful algal event database. HAE-DAT provides a comprehensive format for reporting all types of algal events which are perceived by society as harmful. For the PICES region will additionally be recorded algal blooms which did not cause any harm. During 2005-2006 HAE-DAT had its software platform upgraded and improved and during 2006 the associated mapping function is being developed. The test version of the mapping function will be presented for trial, comments and discussion. Progress in submission of 2000-onward records from the PICES areas will be assessed and assistance will be provided as required.

PICES XV W4_HAB-3259 Oral
The Monitoring System on HABs in China

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The first red tide in China was recorded in 1933, from then on more than 800 red tide events have been documented. The research on red tides has gained importance since 1978, but recent work has focused on the survey of morphologic/physiological/ecological parameters. The comprehensive and solid national monitoring system on HABs started formally in 2002, when 10 red tide monitoring zones were established. There are 33 red tide monitoring zones in Chinese coastal areas that have enhanced our knowledge of red tides. Research on HABs has placed recent emphasis on early warning and forecasting. This emergency response system has play an important role in mitigating and preventing the impacts of red tides in recent years.

PICES XV W4_HAB-3169 Oral
A regional U.S. west coast observing system for toxigenic *Pseudo-nitzschia*

Vera L. **Trainer**[1], Barbara M. Hickey[2], and Michael G. Foreman[3]

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The presence of domoic acid, the toxin produced periodically by diatoms of the genus *Pseudo-nitzschia*, appears to be associated with topographically retentive regions off the North American west coast. The biological and physical processes of *Pseudo-nitzschia* bloom development, toxicity, and transport are currently being characterized in detail for one such feature, the Juan de Fuca eddy. We have learned that transport of cells from this eddy to the coast is strongly associated with downwelling-favorable wind events. Because circulation in retentive regions is generally more robust than in open coastal regions, these areas may better lend themselves to modeling of transport pathways. Numerical circulation models, forced with winds predicted several days into the future, such as with the MM5 atmospheric model, together with drifters deployed during key harmful algal bloom (HAB) development periods will be used to predict regional scale movement of toxigenic cells. Sensing platforms, placed in offshore areas that include likely initiation sites for HABs, will be used to collect both real-time and time series data needed to initialize, calibrate, and validate physical and biological models and associated forecasts. With the system fully in place, managers will be able to use the models and real-time data

from drifters and moored arrays to forecast landfall of an identified bloom event with some accuracy. This will give them enough warning to minimize the impact on human health while at the same time allowing harvest of coastal resources, including razor clams and Dungeness crabs.

W5 POC Workshop
Evaluation of climate change projections

Co-Convenors: Michael G. Foreman (Canada) and Yasuhiro Yamanaka (Japan)

The most recent set of global climate model projections have been submitted to, and are being analyzed by, the Intergovernmental Panel on Climate Change (IPCC) for the publication of their Fourth Assessment Report in 2007. PICES Working Group 20 was created to perform an evaluation of these projections for the North Pacific and its marginal seas, and to compute products, such as ensemble averages, that would assist PICES groups like the Climate Forcing and Marine Ecosystem Response Task Team (CFAME), in their analysis of climate effects on marine ecosystems, and ecosystem feedbacks to climate. In this workshop, presentations and discussions will focus on ongoing research that addresses the terms of reference of the new working group, and on strategies for future work that is needed to fill the gaps. Presentations related to the direct analysis of global climate projections and the calculation of ensemble averages; to results from higher-resolution regional ocean and coupled atmosphere-ocean models that are forced by, and take their boundary conditions from the IPCC models; and to the development of local and regional data sets (*e.g.*, SST, river flow, sea ice cover) based on either model projections or historical observations, will all be welcome. The development of work/action plans, liaisons with other PICES groups and outside organizations (*e.g.*, CLIVAR), and future activities will also be discussed.

Saturday, October 14, 2006 09:00-18:00

09:00-09:15 **Introduction by Convenors**

09:15-09:45 **Curtis Covey** (Invited)
Managing, using and expanding the IPCC database of climate model output (W5-2774)

09:45-10:00 **Hiroyasu Hasumi and Takashi T. Sakamoto**
Overview of the present state and future projection of North Pacific climate simulated by CCSR/NIES/FRCGC global coupled models (W5-3190)

10:00-10:15 **Muyin Wang, James E. Overland and Nicholas A. Bond**
What will the North Pacific look like in the next 40 years? (W5-3047)

10:15-10:30 **Michael G. Foreman**
Highlights from recent publications describing climate projections for the North Pacific (W5-3179)

10:30-10:45 **Rong-Shuo Cai, Ji-Long Chen and Rong-Hui Huang**
The response of marine environment in the offshore area of China and its adjacent ocean to recent global climate change (W5-3249)

10:45-11:00 ***Tea/Coffee Break***

11:00-11:30 **Michio Kawamiya, Chisato Yoshikawa, Tomomichi Kato and Taroh Matsuno** (Invited)
Significance of ocean's response to climate warming in the global carbon cycle (W5-3011)

11:30-12:00 **Keith B. Rodgers, Christophe Menkes, Thomas Gorgues, Laurent Bopp and Olivier Aumont** (Invited)
A modeling study of interannual to decadal variability in Equatorial Pacific biogeochemistry and ecosystems (W5-2906)

12:00-12:15 **Sang-Wook Yeh, Cheol-Ho Kim, Young-Gyu Park and HongSik Min**
Characteristics of Pacific sea surface temperature variability associated with global warming during the 20th century (W5-3003)

12:15-12:30 **Zhenya Song and Fangli Qiao**
The establishment of the atmosphere-surface wave-ocean circulation coupled numerical model and its applications (W5-3216)

12:30-12:45 **Elena I. Ustinova**
Evaluation of climatic variability in the Far-Eastern Seas using regional data sets (W5-2874)

12:45-14:00 ***Lunch***

14:00-14:15 **William Crawford, Jake Galbraith and Nick Bolingbroke**
Temperature and salinity along Line-P: Fifty years of observations (W5-3202)

14:15-14:30 **Hee-Dong Jeong, In-Seong Han, Ig-Chan Pang, Ki-Tack Seong, Woo-Jin Go, Sang-Woo Kim, Won-Deuk Yoon, Yong-Kyu Choi and Jun-Yong Yang**
Seasonal long-term variation of temperature in Korean waters (W5-3191)

14:30-14:45 **Masao Ishii, Takayuki Tokieda, Shu Saito, Takashi Midorikawa, Shinji Masuda and Akira Nakadate**
Decadal trend of dissolved oxygen in the North Pacific along 165ºE – A preview (W5-3006)

14:45-15:00 **Dong-Young Lee and K.C. Jun**
Estimation of design wave height through long-term simulation of sea states for the North East Asia regional seas (W5-3064)

15:00-18:00 **Discussion** (with a Tea/Coffee Break at 15:30-15:50)

- what CFAME would like from WG20
- overall WG plans: who will do what, collaborations, *etc.*
- future workshops (inter-sessional, with CFAME?)
- funding possibilities

PICES XV W5-3249 Oral

The response of marine environment in the offshore area of China and its adjacent ocean to recent global climate change

Rong-Shuo **Cai**[1], Ji-Long Chen[2] and Rong-Hui Huang[2]

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Due to the severity of impact of global climate warming on marine environment and ecosystem and sustainable development of economy and society, the impacts of global climate change for recent 50 years on winter and summer wind field near sea surface, sea surface zonal and meridional wind stresses and sea surface temperature (SST) in the offshore area of China, including the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea, and its adjacent ocean, mainly including the tropical and subtropical western Pacific, are analyzed by using the wind data from ERA-40 reanalysis data, the high-resolution reanalysis data of ocean climate such as HadISST and SODA (Simple Ocean Data Assimilation) and so on. The analyzed results show that due to the impact of global climate warming, the winter and summer monsoon flows became weak over the offshore area of China and its adjacent Ocean after 1976, which caused the weakening of winter and summer sea surface wind stresses, especially the meridional sea surface wind stresses, and obvious increase of SST in the area. Moreover, the results also show that the weakening of winter and summer sea surface wind stresses and the increase of SST are particularly significant in the East China Sea. The weakening of winter and summer sea surface wind stresses and the warming of SST in the offshore area of China these can provide a favorable marine environment for the frequent occurrence of red tide in the offshore area of China. Besides, from variation of the distributions of circulation divergences over the offshore area of China, it can be clearly seen that after 1976, the circulation divergences over this area intensified, which were not helpful to the formation of upwelling flow in the offshore area of China. It will have an influence on the transportation of nutrients in the coastal water. In order to promote the research on the response and adaptation of marine environment and ecosystem in the offshore area of China to global climate change, some scientific problems on this aspect, which urgently need to study, are also proposed in this paper.

PICES XV W5-2774 Invited

Managing, using and expanding the IPCC database of climate model output

Curtis **Covey**

Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, LLNL Mail Code L-103, 7000 East Avenue, Livermore, CA, 94550, U.S.A. E-mail: covey1@llnl.gov

Our program at Livermore has accepted a request from the Intergovernmental Panel on Climate Change to assemble and manage a database of output from coupled ocean-atmosphere general circulation models. The output includes both retrospective simulations of 20th century climate evolution and predictions of 21st century climate change under a variety of emissions scenarios. Although it was originally created to help prepare the IPCC's 2007 assessment report, the database has a variety of other uses and is open to any interested scientist. It contains 27 Terabytes of data comprising output from 22 different models. To date we have over 600 registered users, who have produced over 150 scientific publications involving the data. I will talk about my experience helping to manage the database and using its contents, as well as plans for adding interactive land and ocean biogeochemistry to the climate models contributing to a new database.

PICES XV W5-3202 Oral
Temperature and salinity along Line-P: Fifty years of observations

William **Crawford**[1], Jake Galbraith[2] and Nick Bolingbroke[1]

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Accurate profiles of ocean temperature and salinity have been collected along Line-P since the 1950s, forming the Line-P series that extends from coastal waters out 1420 kilometres into the Gulf of Alaska. Data along these stations were sampled from 1950s to 1981 by Canadian Department of Transport weatherships on their way from Victoria, Canada, to Ocean Station Papa at 50°N, 145°W. Canadian Fisheries and Oceans research vessels took over sampling in 1981 when the weatherships program ended. Throughout these years the ocean measurements have been managed by scientists of the Pacific Biological Station in Nanaimo, BC, and then by scientists of Fisheries and Oceans Canada at the Institute of Ocean Sciences in Sidney, BC. We used archived measurements of temperature and salinity to compute climatology of the seasonal cycle of these properties, as well as seawater density, at standard depths along Line-P. From these we computed time series anomalies of temperature and salinity averaged over several depth layers along Line-P. Results are presented graphically as Hovmøller plots, extending in time from 1950 to 2005 and in distance from Station P1 to P26 (OSP). Major climate events such as the sudden warming in 1976/77 and cooling in 1997/98 are clearly present in these plots. Density differences between near-surface waters and the 100-m layer have increased over the past 50 years. Interestingly, the top 150 metres of the ocean along Line-P in 1999 to 2002 were as cold as ever observed previously, despite the general warming since 1950. Since 2001 the top 100 metres have been significantly fresher than the 50-year average. These observations will continue to be collected, and will form a significant contribution to ocean climate programs.

PICES XV W5-3179 Oral
Highlights from recent publications describing climate projections for the North Pacific

Michael G. **Foreman**

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The submission of climate model projections for the upcoming IPCC 4th assessment report has provided a unique opportunity for intercomparison and the calculation of ensemble averages. Publications are beginning to appear describing some of these results and more are expected soon. In this presentation, we will highlight some specific findings for the North Pacific and describe their applicability to the objectives of PICES Working Group 20.

PICES XV W5-3190 Oral
Overview of the present state and future projection of North Pacific climate simulated by CCSR/NIES/FRCGC global coupled models

Hiroyasu **Hasumi**[1] and Takashi T. Sakamoto[2]

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The research consortium of the Center for Climate System Research (CCSR), the National Institute for Environmental Studies (NIES), and the Frontier Research Center for Global Change (FRCGC) submitted two sets of climate projection results to IPCC AR4, using global coupled models with two different resolutions. The higher resolution model is made up of T106 (~1°) atmosphere and eddy-permitting ocean, while the lower resolution version incorporates T42 (~3°) atmosphere and coarse-resolution (~1°) ocean. The two models exhibit different responses to global warming in some respects. In order to answer the question of where and how resolution matters, we also conducted present climate simulations using two more models: one with a higher resolution atmosphere and lower resolution ocean, and the other with a lower resolution atmosphere and

higher resolution ocean. Here we discuss resolution dependence of the present state and future projections of the CCSR/NIES/FRCGC global coupled models, with a focus on the North Pacific region.

PICES XV W5-3006 Oral
Decadal trend of dissolved oxygen in the North Pacific along 165ºE – A preview

Masao **Ishii**[1], Takayuki Tokieda[1], Shu Saito[1], Takashi Midorikawa[1], Shinji Masuda[2], and Akira Nakadate[2]

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An increase of total inorganic carbon (TCO_2) during the last decade has been observed in the upper layer of the western North Pacific along 137ºE and 165ºE, and in the thermocline of the western equatorial Pacific. It is primarily ascribed to the invasion of the anthropogenic CO_2 into the ocean interior, but the concurrent change in the dissolved oxygen (DO) suggests that changes in ocean circulation and/or biogeochemistry is also playing an important role in changing the TCO_2 inventory. The Japan Meteorological Agency has been conducting routine observations of a hydrographic section in the top 2000m of water along 165ºE between 50ºN and 28ºN, and between 28ºN and 3ºS once or twice a year since 1997. The observed parameters include chemical components such as DO. Routine high-quality TCO_2 measurements were also started in 2003 at several stations along 165ºE. We will present some preliminary results showing trends in DO and TCO_2 in these regions.

PICES XV W5-3191 Oral
Seasonal long-term variation of temperature in Korean waters

Hee-Dong **Jeong**, In-Seong Han, Ig-Chan Pang, Ki-Tack Seong, Woo-Jin Go, Sang-Woo Kim, Won-Deuk Yoon, Yong-Kyu Choi and Jun-Yong Yang

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Serial oceanographic investigations in Korean waters have been carried out by NFRDI (National Fisheries Research and Development Institute) over 37 years from 1968 to 2004. In this study, we examine seasonal and annual long-term variations of temperature and the long-term trend of annual temperature. The data show that the annual mean sea surface temperature (SST) has clearly increased by about 0.9°. The increase of SST was about 0.7° in August and was about 1.35° in February. This indicates that the annual amplitude of SST variation would be decreased by the strong increasing trend in winter temperatures. Korean waters can be geographically divided into three seas; East Sea, South Sea and Yellow Sea. The trends of SST increase for the three seas in August and February were found to be 0.47° and 1.47° in the East Sea; 0.81° and 0.70° in the South Sea; and 0.71° and 1.45° in the Yellow Sea, respectively. The annual amplitude of SST decreased by about 0.63° and 0.07° in the East Sea and Yellow Sea respectively, but it slightly increased about 0.11° in the South Sea during last 37 years.

PICES XV W5-3011 Invited
Significance of ocean's response to climate warming in the global carbon cycle

Michio **Kawamiya**, Chisato Yoshikawa, Tomomichi Kato and Taroh Matsuno

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It has been recognized through modeling efforts that climate – carbon cycle interactions may form a positive feedback loop for the global warming. The actual extent of the feedback is, however, strongly model dependent. This situation necessitates an organized activity to compare results from various models and discuss what causes such differences between models. An international project C4MIP (Coupled Carbon-Cycle Climate Model Inter-comparison Project) has been established in order to facilitate such comparative studies (Friedlingstein *et al.*, in press) and discussions made under C4MIP are likely to be reflected in the 4th assessment report of IPCC (Intergovernmental Panel on Climate Change). All the eleven models participating in C4MIP show an agreement in that CO_2 uptake by both the land and the ocean is reduced due to future warming, although the

increase of atmospheric CO_2 concentration varies among models between 20ppm and 200ppm by the end of the 21st century. Eight models attribute most of the changes to the land, while three attribute it comparably to both the land and the ocean; the role of the ocean does not appear to be dominant in the climate – carbon cycle feedback. However, there are some inconsistencies between results from ocean carbon cycle models and those from observation-based studies. For example, air-sea CO_2 fluxes obtained by inversion techniques and carbon isotope analysis yield much larger interannual variations than those by computed by forward numerical models. Such problems may indicate that the oceanic feedback in the climate – carbon cycle system is currently underestimated.

PICES XV W5-3064 Oral
Estimation of design wave height through long-term simulation of sea states for the North East Asia regional seas

Dong-Young **Lee**, K.C. Jun

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Two types of long term wave climate information are desired for many marine and coastal applications especially for the design of coastal structures: the design waves and operational waves. In conventional methods of design criteria estimation, it is assumed that the climate is stationary and the statistics and extreme analysis of long-term measured or hindcasted data can be used in statistical predictions for the future. However, such a steady state assumption is questionable due to global climate change.

Since the availability of field wave data for the waters around Korean peninsula is limited in its ability to cover a significant period of time so as to provide reliable wave statistics, the wave climate information needs to be generated by means of long-term wave hindcasting using available meteorological data. Design wave heights for the return periods of 30, 50 and 100 years for 16 directions at each grid point of a grid with 18 km resolution for the waters around Korean peninsula have been estimated by means of extreme wave analysis using the detailed wave simulation data for major typhoons that affected Korea since 1951 and continuous hindcasted wave data since 1979.

Methods of extreme statistical analysis that consider recent extreme events like typhoon Maemi in 2003 were evaluated for more stable results of design wave height estimation for the return periods of 30-50 years, which is commonly applied in designing coastal structures like breakwaters. The impact of global climate change in the estimation of design wave height for the return periods of 30 and 50 years was analyzed and will be discussed

PICES XV W5-2906 Invited
A modeling study of interannual to decadal variability in Equatorial Pacific biogeochemistry and ecosystems

Keith B. **Rodgers**[1], Christophe Menkes[2], Thomas Gorgues[2], Laurent Bopp[3] and Olivier Aumont[2,4]

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A three dimensional ocean circulation model (the ORCA2 configuration of OPA), which has a foodweb/biogeochemistry model (PISCES) embedded in it, and which has been forced with NCEP reanalysis fluxes, has been used to study variability in the supply of nutrients to the euphotic zone/upwelling regions of the eastern Equatorial Pacific. Our main finding is that the model exhibits a significant decrease in Fe, Chl, and NO_3 concentrations after 1976 for the upwelling regions of the Eastern Equatorial Pacific. For Fe and Chl, this shift in the mean state is shown to reflect a large change in the amplitude of the seasonal cycle, with seasonally maximum values having been larger for the earlier period. For NO_3, there is more of a change in the mean state. These changes can be understood as being due to the interplay of two mechanisms. First, the s0=25.0 potential density surface corresponding to the core of the Equatorial Undercurrent (EUC) was deeper in the western Equatorial Pacific during the earlier period, resulting in an enhanced eastward transport of Fe. Second, as a result of stronger tradewinds, the upwelling was deeper and stronger during the upwelling-favorable season

during the early period, increasing the vertical transport of Fe to the surface. The implications of this nonlinear response in ocean biogeochemistry for climate change are discussed.

PICES XV W5-3216 Oral

The establishment of the atmosphere-surface wave-ocean circulation coupled numerical model and its applications

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A common problem of coupled ocean-atmosphere general circulation models (CGCMs) without flux correction is that the simulated equatorial cold tongue generally tends to be too strong, narrow, and extends too far westward. This bias in SST simulation is attributed to two causes: coupling flux errors and inaccurate parameterizations, and numerical inaccuracies. One important reason may be the inaccurate reconstructed mixed layer and thermocline depth arising from an imperfect vertical mixing scheme.

Based on wave-circulation coupled theory, the MASNUM atmosphere-wave-circulation coupled model was established. It incorporates the MASNUM wave number spectral model and the coupled ocean-atmosphere general circulation model, FGCM-0. This model is applied to study climate research. The results compared with FGCM-0 simulations are summarized as follows:

(1) Compared with the results from the original CGCM (FGCM-0), the modeled SST increases more than 0.8° with the maximum of 1.2° in the eastern Pacific (160-180ºE, 0-3ºN), while the western boundary of the 26.0° isotherm moves from 165ºE to 180ºE. The overly-westward extension of the simulated equatorial cold tongue is suppressed by incorporating wave-induced mixing in the model. The simulated SST is generally improved and the maximum improvement is more than 1.0°. The simulated SST improvement in the north tropical Pacific is much better than that in the southern tropical Pacific.

(2) Compared with Levitus data, the error in globally averaged SST decreases to 0.09° from 1.03°. The error in the tropical region (0-360E, 25N-25S) averaged SST decreases to 0.10° from 1.19°, while the error decreases from 1.28° to 0.37° in the Indian Ocean, to 0.01° from 1.15° in the tropical Pacific, and to 0.62° from 1.81° in the tropical Atlantic.

(3) An analysis of the Nino3 Index indicates that the atmosphere-wave-circulation coupled model can better simulate the main character of ENSO events. The cycle simulated by the established coupled model is 2.5-years, which is close to the observed value of 2.8-years, while it is 5-years for the original coupled model. The difference of the amplitude decreases from 2.412° to 1.035°, and the improvement reaches 27%.

(4) An analysis of the western equatorial Pacific and Indian Ocean sea surface wind shows that the atmosphere-wave-circulation coupled model can better simulate the warm pool and the Indian Ocean. It also suppresses the too strong eastern wind by reducing the cold bias of SST.

(5) A process analysis indicates that wave-induced mixing drops the SST in the OGCM because strengthened vertical mixing can bring more cold water upward, and in the coupled model the non-uniformity of the SST decreases can generate the horizontal gradient of the SLAP. This leads to the ocean surface circulation anomaly which can restrain the overly-westward extension of the cold tongue in the tropical Pacific. But most importantly is that the vertical circulation anomaly induced by the horizontal circulation is the key factor in suppressing the overly-westward extension of the cold tongue. A net heat flux has a bad effect on the over-westward cold tongue extension.

The MASNUM atmosphere-wave-circulation coupled model established in this paper successfully solves a common problem, namely that the simulated equatorial cold tongue is generally too strong, narrow, and extends too far westward. The model can also simulate ENSO and climate better. It is important for climate research and the development of the climate system coupled model.

PICES XV W5-2874 Oral
Evaluation of climatic variability in the Far-Eastern Seas using regional data sets

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The purpose of the study is to evaluate the low-frequency variability of some climatically significant parameters in the Far-Eastern Seas using regional data sets based on historical observations. Multi-year data on ice cover, air and water temperature from the meteorological stations located along the coast of the Far-Eastern Seas are the longest time series of relatively regular and homogeneous hydrometeorological information for the Seas, although still the total observation number is small. Ice cover data are based mainly on regular aircraft observations carried out by Russian Hydrometeorological Service before 1992 and on satellite information after that. The longest time series of ice cover was the data on the maximum annual ice cover from 1929 to 2006 for the Okhotsk Sea. It is noted, that since 1996 extreme ice cover in the Okhotsk Sea has been observed more often. Large-scale changes in the ice cover of the Sea are connected to variations of globally-averaged surface air temperature anomalies for time scales longer than 7 years. The main difference in the spectra of air temperature at the meteorological stations and ice cover is that the air temperature variance is mainly comprised of quasi-biennial oscillations, while the major part of the ice cover variance is comprised of low-frequency oscillations with periods about a decade and more. There are seasonal distinctions in the low-frequency variability of water and air temperature.

PICES XV W5-3047 Oral
What will the North Pacific look like in the next 40 years?

Muyin **Wang**[1], James E. Overland[2] and Nicholas A. Bond[1]

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Projections for the North Pacific from 16 coupled ocean-atmospheric models obtained as part of the 4th IPCC Assessment show a future climate with a basin-wide warming signal that will surpass the amplitude of the Pacific Decadal Oscillation (PDO) - the leading mode of natural climate variability - in a few decades, even for the modest CO_2 increase scenarios (SA1B and B1). The models were first evaluated against observed variations in the late 20th century. All models reproduce the PDO as the dominant mode in the Pacific in 20th century, with 11 models producing a spatial correlation with the observed pattern greater than 0.6. There will be substantial changes on not just the basin-scale, but also regional processes such as sea-ice concentration in the Bering Sea, shifts in ocean fronts, ocean circulation in the NW Pacific and coastal upwelling off of the US west coast. Of particular importance is that the spatial pattern of the model-projected temperature trends is more uniform than the east-west dipole pattern of the PDO. Prior relationships between climate and ecosystems, especially those associated with the PDO, may not be robust long into the 21st century.

PICES XV W5-3003 Oral
Characteristics of Pacific sea surface temperature variability associated with global warming during the 20th century

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Observations of the Earth's near-surface temperature since 1900 show that a global-mean temperature increase occurs from 1910 to 1940 and from 1970 to the present (Tett *et al.*, 1999, Nature), and these increases correspond with the variability of global sea surface temperature (SST). Previous studies have suggested that though the primary cause of global warming during the first half of the 20th may be due to variations in the sun's irradiance, during the late 20th it is mainly due to human induced anthropogenic forcing. In this paper we analyze the characteristics of Pacific SST variability during these two epochs. In particular, we focus on the differences of North Pacific SST variability in terms of its amplitude, period and connections with the tropics. Our result indicates that there are striking differences in linear trends in the North Pacific, supporting the hypothesis that the causes of SST increase during the two epochs are quite different.

W6 MONITOR/TCODE Workshop
Data management, delivery and visualization of high-volume data products

Co-Convenors: David L. Mackas (Canada), Thomas C. Royer (U.S.A.) and Sei-Ichi Saitoh (Japan)

Long-term monitoring of multidisciplinary data in boundary currents is a high priority for PICES nations. Boundary currents are locations where many monitoring activities now take place. They are very important economically and also highly variable in both space and time. Dense near real-time data from many disciplines are vital to describe the systems and for the timely management of the coastal resources. Rapid analysis of the data is essential, however, increased data rates and their diversity are challenging the users. Cabled arrays and satellite altimeter, color and scatterometer (wind) measurements are examples of these new dense data sets. This workshop will discuss the availability of such data and how we can effectively use them, focusing especially on availability, uses, GIS applications and other methods of display and analysis tools. A re-population of the North Pacific Metadata Base will be emphasized. Demonstrations of data archiving, displays and real-time availability are welcome.

Sunday, October 15, 2006 09:00-18:00

09:00-09:10 **Introduction by Convenors**

09:10-09:50 **Lynn M. deWitt** (Invited)
Simplifying data integration and interoperability through standardized data access and transport protocols (W6-2854)

09:50-10:05 **Takashi Yoshida**
NEAR-GOOS and Japanese operational oceanographic observations (W6-3244)

10:05-10:20 **Gongke Tan, D.Y. Lee, X. Hu and M. Li**
Design and operation of offshore observing platform in the Yellow Sea (W6-3252)

10:20-10:35 **Molly McCammon, G. Carl Schoch and Mark Johnson**
AOOS: Implementing an Ocean Observing System in Alaska (Observer_Poster-3194)

10:35-11:00 ***Tea/Coffee Break***

11:00-11:15 **John A. Barth, Jan A. Newton and NANOOS Colleagues**
Northwest Association of Networked Ocean Observing Systems (NANOOS) (Observer_Poster-3095)

11:15-11:30 **M. Elizabeth Clarke, Bob Gref, Frank Schwing, Chris Goldfinger, Chris Romsos and Jonathan T. Phinney**
A pilot data system for the Pacific Coast Ocean Observing System (PaCOOS) (W6-3255)

11:30-11:45 **Vera L. Trainer, Barbara M. Hickey and Michael G. Foreman**
A regional U.S. west coast observing system for toxigenic *Pseudo-nitzschia* (W4_HAB-3169)

11:45-12:00 **Nobuyuki Shikama**
Japanese Argo Program (W6-3187)

12:00-12:15 **S. Allen Macklin, Bernard A. Megrey, Kimberly Bahl and Toru Suzuki**
A federation of PICES member country metadatabases (W6-3143)

12:15-12:30 **Clarence Pautzke and Molly McCammon**
The Alaska Marine Information System – A collective database for Alaska's large marine ecosystems (W6-3240)

12:30-14:00 ***Lunch***

14:00-14:15 **Takashi Setou, Kosei Komatsu and Yasumasa Miyazawa**
Modification of the OI parameters for effective introduction *in situ* data obtained by Japanese local fisheries research institutions into the JCOPE Ocean forecast system (W6-3137)

14:15-16:00 **E-Poster and Poster presentations** (up to 10 min. each, with 25-min. Tea/Coffee Break)

16:00-16:15 **Katsuya Saitoh, Hitoshi Iizumi, Osamu Kato, Tatsuro Watanabe, Kosei Komatsu, Shi-ichi Ito, Kaoru Nakata and Kouji Aoyagi**
Giant jellyfish monitoring system in Japan (W6-3261)

16:15-16:30 **Sei-Ichi Saitoh, Fumihiro Takahashi, Daichi Tachikawa, Motoki Hiraki, Masami Yoshida, Teruaki Hiura and Hidetada Kiyofuji**
Research and development of ubiquitous information services for sustainable fisheries operation and management in the offshore around Japan (W6-3206)

16:30-16:45 **Young Jae Ro and Kwang Young Jung**
Real-time monitoring experiences in the coastal waters in Korea: Implementation and scientific application (W6-2799)

16:45-18:00 **Discussion**

Posters and E-Posters

Stepan G. Antushev, Vitaly K. Fischenko and Andrey V. Golik
Implementation of distributed oceanographic data management and data processing technologies in FEBRAS (W6-3024, E-poster)

Hernan E. Garcia, Tim P. Boyer, Sydney Levitus, Ricardo A. Locarnini, John I. Antonov, Daphne Johnson, Igor Smolyar, Olga Baranova and Alexey Mishonov
The World Ocean Database and Atlas 2005 (W6-2877, Poster)

Andrey V. Golik, Stepan G. Antushev and Vitaly K. Fischenko
About scope of OpenGIS technology in oceanographic data management and visualization (W6-3018, E-poster)

Alex Kozyr and Misha Krassovski
Web-Accessible Visualization and Extraction System (WAVES) for oceanographic data (W6-3141, E-poster)

Dmitry D. Kaplunenko, Vyacheslav B. Lobanov, Olga O. Trusenkova and Svetlana Y. Ladychenko
Web-based system to study mesoscale water dynamics and structure by merging satellite and *in situ* data (W6-3144, E-poster)

Jee-Eun Min, Joo-Hyung Ryu, Yu-Hwan Ahn and Kyu-Sung Lee
Optical properties of marine particles around the Southwest Sea of the Korean peninsula (W6-3026, Poster)

A. Gavrev, A. Pan, V. Plotnikov, V. Rostov and I. Rostov
Web-based sea ice data bases application (W6-2903, Poster)

Joon-Yong Yang, Hee-dong Jeong, Kyu Kui Jung and Ki-Tack Seong
Real-time oceanographic information for pelagic fishery based on Argo data (W6-3217, E-poster)

PICES XV W6-3024 E-poster

Implementation of distributed oceanographic data management and data processing technologies in FEBRAS

Stepan G. **Antushev**, Vitaly K. Fischenko and Andrey V. Golik

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Substantial amounts of oceanographic data have been collected in Far Eastern Branch of Russian Academy of Sciences (FEBRAS) scientific institutes. It is necessary to provide easy and up-to-date access to these distributed data for all interested scientists. It is also necessary to provide them with the most effective program tools for analytical processing of corresponding data types. Many of such programs are computation-intensive and it is reasonable to utilize the distributed computational resources of FEBRAS. Such problems are being solved in FEBRAS corporate oceanographic research and information system (ORIS) which is being developed in Pacific Oceanological Institute (POI) using distributed data management and distributed computation technologies. Universal services were developed that translate users requests into corresponding requests to data servers located in POI, other FEBRAS institutes and marine experimental stations. To operate with distributed data more comfortably and effectively, we use data caching and replication. To perform the particular user's request ORIS uses the "nearest" data server with required data. There are also data processing tools in ORIS and some of them are computation-intensive. These techniques utilize institute's distributed computational resources or shared FEBRAS supercomputer resources. To implement user access to distributed data and computational resources we use software compliant with OGSA (Open Grid Services Architecture) wherever possible. It allows us to transform ORIS into FEBRAS regional oceanographic Grid project. These informational, computational and analytical resources are potentially available to users of other PICES oceanographic grid-systems.

PICES XV W6-3255 Oral

A pilot data system for the Pacific Coast Ocean Observing System (PaCOOS)

M. Elizabeth **Clarke**[1], Bob Gref[1], Frank Schwing[2], Chris Goldfinger[3], Chris Romsos[3] and Jonathan T. Phinney[4]

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PaCOOS is a developing national ocean observing system for the California Current with participants from federal and state government agencies, academic institutions, NGO's and Integrated Ocean Observation System (IOOS) Regional Associations. Its role is as an integrator of the ocean observing system along the entire California LME with its initial focus on ecosystem information collected by NOAA. To date, data access and management as well as pilot ecosystem models and assessments are under development. Two pilot projects were carried out to develop the methods for accessing and transporting two distributed data sets of differing types and formats, and to demonstrate how integration and interoperability of distributed data sets can be accomplished. These pilot projects were designed to incorporate physical, geological and biological data from a variety of sources and formats into a single data system. One pilot is GIS based, and uses seafloor bathymetry, sample data, sidescan sonar, and surficial geology, combined with fish and invertebrate data to develop a relational database that can be spatially queried to identify relationships between geologic and biologic datasets. The other pilot focused on implementing an OPeNDAP server for physical and biological data from California Cooperative Fisheries Investigations (CalCOFI). Important features of the PaCOOS data system are that it integrates a variety of datasets and allows them the transparency and interoperability to be integrated within a larger context of the national IOOS data system.

PICES XV W6-2854 Invited
Simplifying data integration and interoperability through standardized data access and transport protocols

Lynn M. **deWitt**

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Elaborate visualization tools have become an important aspect of scientific analysis, providing interesting ways to view data, but often making it more difficult to retrieve data for purposes other than those configured into a particular tool. The sophistication of these tools often causes data providers to lose sight of one of the primary goals of serving scientific data: to provide a means for scientists and other end users to easily browse, subset, and download data for integration into their own research. Application of current data transport and storage technologies can enable data managers to serve data without expending a major effort in web page development. By taking advantage of standard data formats and rapidly developing transport technologies such as OPeNDAP and THREDDS, as well as emerging OGC standards, data can quickly be made available over the Internet for scientists to import directly into their favorite desktop applications such as Matlab, or can easily be served by open-source packages such as the Live Access Server and DChart. Standardization and compatibility of data formats and transport mechanisms is especially essential for projects such as studies of large marine ecosystems, where there is need for integration of disparate data collected from a variety of platforms. This presentation will highlight some of the current data format, transport, and serving technologies that ERD has found to be most useful, discuss their implementation, and demonstrate how these technologies have been used to meet the needs of a variety of projects.

PICES XV W6-2877 Poster
The World Ocean Database and Atlas 2005

Hernan E. **Garcia**, Tim P. Boyer, Sydney Levitus, Ricardo A. Locarnini, John I. Antonov, Daphne Johnson, Igor Smolyar, Olga Baranova and Alexey Mishonov

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We present the newly released World Ocean Database 2005 (WOD05) and World Ocean Atlas 2005 (WOA05) products as tools for ocean climate studies. WOD05 is a collection of scientifically quality-controlled ocean profile and plankton data that includes temperature, salinity, oxygen, phosphate, nitrate, silicate, chlorophyll, alkalinity, pH, pCO_2, TCO_2, Tritium, $\Delta^{13}C$, $\Delta^{14}C$, $\Delta^{18}O$, Freons, Helium, $\Delta^{3}He$, Neon, and plankton measurements. WOD05 includes additional data and variables not available in previous releases. WOA05 is an analysis of all quality-controlled historical profile data for temperature, salinity, dissolved oxygen, apparent oxygen utilization, percent oxygen saturation, and nutrients (phosphate, nitrate, silicate) available from the National Oceanographic Data Center (NODC) and World Data Center (WDC) for Oceanography, Silver Spring, Maryland, U.S.A. The data have been analyzed in a consistent, objective manner on a one degree latitude longitude grid at standard oceanographic levels between the surface and ocean bottom to a maximum depth of 5500 m. Annual, seasonal, and monthly analyses have been computed. Data distribution maps and seasonal and monthly difference (from the annual mean) fields are also presented at selected standard depth levels. We acknowledge the scientists, technicians, and programmers who have collected or submitted data to national and regional data centers as well as the managers and staff at data centers. WOD05 allows for the storage of metadata including information about principal investigators and institutions to recognize their efforts. WOD05 and WOA05 data are available from http://www.nodc.noaa.gov.

PICES XV W6-3018 E-poster

About scope of OpenGIS technology in oceanographic data management and visualization

Andrey V. **Golik**, Stepan G. Antushev and Vitaly K. Fischenko

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GIS-technologies provide efficient tools for management, visualization and analysis of spatial data. Consequently they are very applicable in oceanography where almost all data are spatial. GIS based on web-technologies are especially effective. Such systems allow a large number of specialists to work with the same data storage archives using a shared and unified web-interface, reducing the need for installation and upgrade of special software. Such web-based oceanographic data systems are becoming widespread in different oceanographic organizations, and have already contributed to general progress in oceanography. A useful next step would be access to and integration of the wide range of oceanographic GIS-resources that are being developed by participants of large international projects. Such GIS resources integration would be exceptionally useful, and PICES is well placed to provide international coordination.

The international GIS-community has developed a set of OpenGIS-standards which specify main GIS-services. Systems which meet these standards can easily interact by internet–exchange of data, visual images of data, *etc.* An especially useful feature is the capability to provide broadly available representations of proprietary GIS resources through user interfaces of professional OpenGIS-compliant systems like NASA World Wind (http://worldwind.arc.nasa.gov/) and Google Earth (http://earth.google.com/). Such systems allow users to combine their own data layers with a huge number of third-party data layers, offer global coverage, and provide very effective tools for 3D visualization.

A corporate oceanographic GIS-system has been under development by POI FEBRAS since 2001. It covers the northwestern part of the Pacific Ocean. Currently we are working on implementation of OpenGIS specifications, which will provide interaction with NASA World Wind, Google Earth and other standard-compliant GIS.

PICES XV W6-3137 Oral

Modification of the OI parameters for effective introduction *in situ* data obtained by Japanese local fisheries research institutions into the JCOPE Ocean forecast system

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Japanese local fisheries research institutions constitute a horizontally close-arranged monitoring system around the coastal region off Japan in the western North Pacific. Most of these *in situ* data (hereafter FRDATA), however, have not been distributed to the global network; consequently they were not used for current operational ocean predictions. Fisheries Research Agency (FRA) and Frontier Research Center for Global Change (FRCGC) cooperatively incorporate FRDATA into the JCOPE (Japan Coastal Ocean predictability experiment) ocean forecast system developed by FRCGC, composed of an OGCM assimilated with satellite SSH/SST and hydrographic data of Global Temperature-Salinity Profile Program (GTSPP) designed by NOAA. The present system focuses on reproducing the Kuroshio, which succeeded in prediction of the Kuroshio large meander event 2004-2005. In this study, in order to introduce FRDATA efficiently into the JCOPE, the parameters (*i.e.* decorrelation scales) of optimum interpolation (OI) in the first process of the data assimilation were modified. Consequently, the decorrelation scales were properly reduced, and hydrographic structures were represented more precisely. For example, the position, temperature gradients and temperature values of warm water eddies and the First Oyashio Intrusion east of Japan was properly reproduced. The FRDATA incorporation and the OI parameter modification improved initial values of ocean forecasts, and then hindcast experiments indicated remarkable increase of the prediction accuracy especially in the region east of Japan.

PICES XV W6-3141 E-poster
Web-Accessible Visualization and Extraction System (WAVES) for oceanographic data

Alexander **Kozyr** and Misha Krassovski

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WAVES V1.0, a web-based, database driven tool for oceanographic data (discrete measurements only at this time) extraction, allows users to choose data types and formats. The interface has one front page and all on-screen results are shown in a new window. The main page is divided in sections that help to navigate and keep different types of parameters grouped. In the Query Parameters section, users can set up search criteria and limits. Single parameters, for example temperature from/to: 25ºC, can be used as well as a range of parameters, *e.g.* temperature from: 20ºC to: 25ºC. Data location coordinates can be entered manually or dragging a box on the map. The map is fitted to Geographical Region, Section, and Cruise ID as drop-down-menus and all changes are reflected on the map. The output parameters section lists all the variables that can be extracted from the database. The data format is set up in the Output Form section. Users have options to obtain an on-screen table, a downloadable file (CSV, TSV, NetCDF formats) or on-screen property-property plots. The interactive map is designed to provide the metadata information displayed in the clickable Metadata section by using an Information mode. Users can receive metadata information by clicking on a cruise line, or dragging a box in the research area of the map. The map also has a Navigation mode. In the Navigation mode users can move map around, zoom in and out and see the entire map extent. WAVES is available at http://cdiac.ornl.gov/oceans/search.html

PICES XV W6-3144 E-poster
Web-based system to study mesoscale water dynamics and structure by merging satellite and *in situ* data

Dmitry D. Kaplunenko, Vyacheslav B. **Lobanov**, Olga O. Trusenkova and Svetlana Y. Ladychenko

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Mesoscale features are important components of circulation in the Japan Sea and adjacent areas. Sustained monitoring of mesoscale eddies and meanders would require detailed and repeated surveys which are not feasible for major part of the world ocean. However for the area of the Japan Sea an existing flow of hydrographic data available through Internet might be enough to resolve mentioned structures. Our work describes the principles of web-based system of data merging and assimilation for study mentioned problems. The system is based on virtual merging of CTD data obtained in POI cruises of 1999-2004 with the data available through the NEAR-GOOS databases and data of Argo profiling floats. These *in situ* CTD data are combined with satellite information obtained from TOPEX/POSEIDON and ERS-2 satellites (altimetry, sea surface height), NOAA AVHRR satellites (sea surface temperature, SST) and merged SST based on infrared and microwave satellite data (New Generation SST project). An organizing and linking of some parts of specific data and archives was made using the Virtual Data Base (VDB) technology by the technique of forming integrated database from the sources of data distributed at different locations. The obtained results allow analyzing kinematics, dynamic and a water mass characteristic of mesoscale eddies in the Japan Sea and in the area of Kuroshio-Oyashio confluence zone. In this way more detailed quantitative analysis of these peculiarities is the subject of future development this system.

PICES XV W6-3143 Oral
A federation of PICES member country metadatabases

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Shared ecosystems (*e.g.*, the Sea of Japan/East Sea ecosystem is shared by China, Russia, Japan and Korea) are often a source of conflict due to the national interests of the countries attempting to manage them and extract their resources. To manage marine ecosystems effectively, access to data about them must occur across human-imposed political boundaries. We seek to create a "metadata federation" of member countries (Canada, Peoples Republic of China, Japan, Republic of Korea, Russian Federation, and U.S.A.) of the North Pacific Marine Science Organization (PICES). Through English-language coding of metadata using the Federal Geographic Data Committee standard; acquisition, installation and configuration of Z39.50 communications software on a public-access server and registration with a clearinghouse, it is possible for any metadata-serving agency to become part of the PICES Metadata Federation. The federation enables an Internet user to search the collected metadata holdings of any or all members, thus providing access to information across national holdings in a single search. To date, metadata collections from the Russian Federation, Republic of Korea and U.S.A. are federated. Japan is in the process of joining. This activity supports PICES' goals: (1) to promote and co-ordinate marine scientific research in the northern North Pacific and adjacent marginal seas, particularly northward from 30 degrees north; (2) to advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impact of human activities on them; and (3) to promote the collection and rapid exchange of scientific information on these issues.

PICES XV W6-3026 Poster
Optical properties of marine particles around the Southwest Sea of the Korean peninsula

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Studying the upwelling light field is important in Ocean Color Remote Sensing (OCRS) because it brings immense information concerning the ocean environmental properties. This quantity emerges from the sea-surface after incidence light energy has been absorbed and scattered by sea water constituents. In this process, the amount of scattering is a lot smaller than that of absorption relatively. So the understanding of Inherent Optical Properties (IOP), especially absorption, is very important in OCRS. Many studies have been accomplished in various seas around the world. In optically more complex waters around Korea, we have found only a few investigations on the IOP. Thus, in this study we analyze the absorption coefficient of sea water constituents such as phytoplankton, Suspended Sediment (SS) and Dissolved Organic Matter (DOM). For this study 107 water samples were collected in the Southwest Sea of Korea during 2001 to 2005. Phytoplankton exhibited pronounced absorption features at 440nm, 465nm and 675nm. Some cases had the absorption features at 550 nm. Absorption coefficient values of phytoplankton at 443nm are appeared ranged of 0.02 to 0.11 m^{-1}. That result is little lower than other sea waters comparatively. The absorption spectral shape of SS and DOM showed exponentially decreasing pattern. Each graph's slope includes information of absorption characteristics. Our result shows that slope of SS is 0.065nm^{-1} and that of DOM is 0.013nm^{-1}. The results were also compared with those from other sea waters. Our future study will concentrate on application of these results to inverse-forward ocean optical models.

PICES XV W6-3240 Oral

The Alaska Marine Information System – A collective database for Alaska's large marine ecosystems

Clarence **Pautzke** and Molly McCammon

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The North Pacific Research Board (NPRB) is supporting the development of the Alaska Marine Information System (AMIS) which is a web-accessible information system covering the North Pacific with emphasis on data collected in three large marine ecosystems – Arctic Ocean (Beaufort and Chukchi Seas), Bering Sea and Aleutian Islands, and the Gulf of Alaska. AMIS was commissioned by NPRB in 2004 and its original purpose was to be a long-term archive of marine data easily retrievable by the science community and public alike. In the past year, the conceptual scope of AMIS has evolved through leadership provided by the Alaska Ocean Observing System (AOOS), the Arctic Region Supercomputing Center (ARSC) at the University of Alaska (UAF), and NPRB. Data derived from NPRB projects still will be available via a project browser on the NPRB web page at www.nprb.org. The project browser allows searches for projects, data, publications, contacts, and investigators.

The enhanced AMIS will go beyond NPRB data and provide a coordinated database based on a collaboration of NPRB, AOOS, ARSC-UAF and NOAA. The database will be housed at ARSC-UAF and the current vision is to make historical, real-time, and forecast data available via an easy-to-use web-based interface to provide the best information to Alaskan and national stakeholders. Data collected by major research organizations off Alaska including NPRB, NOAA, AOOS, Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, and U.S. Geological Survey, will be made available in a timely manner. Software programs will be available to map the data and to relate databases. AOOS will provide data and information products from observation platforms including weather stations, oceanographic surveys and mooring, satellites, and surface current radars. Other data on fish, birds, and marine mammals, along with environmental effects of human activities, will be available also. It is hoped that the new AMIS eventually will become a single site with sponsorship from many agencies providing data that will meet national data standards and be highly useful to both the science and stakeholder communities.

PICES XV W6-2799 Oral

Real-time monitoring experiences in the coastal waters in Korea: Implementation and scientific application

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This study describes the history of the realtime monitoring experiences in the Kangjin Bay, South Sea, Korea in terms of the system components and its implementation and maintenance, data quality control and analysis and oceanographic applications.

The system consists of three major parts: a data logger with an array of sensors for water quality, current and meteorological conditions; a wireless data communication device equipped with cdma module; and a local power source (solar panel and battery).

The system has been operating continuously starting from early 2001 and the data array is published on the web page (http://oceaninfo.co.kr) on a realtime basis. The data quality is controlled and checked both in realtime and delayed mode to ensure the best possible quality.

Time series of numerous oceanographic parameters are being produced and analyzed for scientific and practical applications including the generation of realtime warning messages. From short term to intra-annual periods, variability of oceanic conditions such as water temperature, salinity, dissolved oxygen, current, and many others are analyzed in term of spectra and multiple correlation. These data are also utilized for numerical model initialization and validation. Ultimately the data array will be a basis for comprehensive understanding of the local ecosystem dynamics. One important application now being emphasized is the generation mechanism of the anoxia in the Kangjin Bay in summer season.

PICES XV W6-2903 Poster
Web-based sea ice data bases application

A. Gavrev, A. Pan, V. Plotnikov, V. Rostov and Igor **Rostov**

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Initial version of the data bases on sea ice of the Far Eastern Seas was developed as static-type information-analytical system. The system provides quick access to raw data, gridded data, analytical means and attributive information. Basing on the system different ice condition characteristics were calculated and described. There is no any dynamic with data output in this static-type system. So it makes process of the systems extremely inefficient on data search and sorting. Possible solution of this problem is to make Internet oriented fully dynamic output, with quite new level of interaction with user. Modern web technology allows successful transfer of all GIS advantages to web applications.

Creation of dynamic web-systems means development information products, which have complicated structure and make multistage data processing. The dynamic web-system of data displaying demands use various web-technologies, means of processing vector and raster graphics, languages web-programming, DB-management systems and others special tools. System development is conducted by principle of "modules" which allows improving a product while in service. System "Ice conditions of the Far Eastern seas. The Bering and Okhotsk Seas" has been developed in 2005-2006. Thay contains following original decade and processed sea ice data for the period 1963-2004: closeness, age/thickness, prevailing form, hummocking, snow-cover. The developed system allows building dynamic images of maps on the basis of characteristics specified by the user and dates.

PICES XV W6-3261 Oral
Giant jellyfish monitoring system in Japan

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In 2005, giant jellyfish (*Nemopilema nomurai*) became abundant in Japanese waters, causing damage to the fisheries of Japan. This damage was especialley severe in coastal areas of the Sea of Japan. In 2006, Japan Fisheries Agency started to a new program for assessment and monitoring of giant jellyfish damage. Giant jellyfish monitoring system was constructed with National Federation of Fisheries Co-operative Associations, Japan Fisheries Information Center and Fisheries Research Agency. This system consists of six sub-systems, including ocean monitoring, market monitoring, remote sensing, biological monitoring (migration and decomposition), a forecast system, and a network of buoys. The ocean monitoring system is divided into two networks (an offshore monitoring network and the coast monitoring network). The collected data is used for a current state diagnostic analysis, and for a forecast analysis. The analyzed data is promptly delivered to fisherman and their fisheries association by the Internet, fax, and cellular phone. Web-GIS (geographical information system) is an important feature of the Internet information service.

PICES XV W6-3206 Oral

Research and development of ubiquitous information services for sustainable fisheries operation and management in the offshore around Japan

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This paper presents an overview of a newly-developed, broad-coverage fisheries information system that combines satellite remote sensing with geographical information system (RS/GIS). The system was developed to provide high value-added fisheries oceanographic information for anytime and at any ocean location. This system is designed for wide use by fishermen and managers in fisheries cooperation or fisheries experimental stations, as well as by scientists. The system consists of four subsystems; MODIS (Moderate Resolution Imaging Spectroradiometer) receiving subsystem, database subsystem, analysis subsystem, and GIS subsystem (WebGIS and onboard-GIS). MODIS provides sea surface temperature, chlorophyll-*a* concentration and sea ice distribution. The database manages the all products under Oracle software. The analysis subsystem produces level 1 to level 5 products, including fishing ground forecasting for Japanese common squid, Pacific saury and Albacore tune. All procedures run automatically, so that the fishermen could receive information in near real time through communications satellites (maritime satellite internet services). The GIS subsystem contains two parts, one is WebGIS (ArcGIS) on land, and the other is GIS on offshore using GEOBASE. Users can generate dynamically products such as graphic overlays, and measuring distances to nearest port or between fishing grounds. This system can help to support effective fishing activities by optimizing time and cost of travel to fishing ground destinations or to nearest landing port, and will promote sustainable fisheries operation and management in the offshore around Japan.

PICES XV W6-3187 Oral

Japanese Argo Program

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Japanese Argo Program is being implemented successfully through tight collaboration of several ministries, agencies, and universities supervised by the Japan Argo Promotion Committee. The functions of national Argo data center are shared between Japan Meteorological Agency for real time data and JAMSTEC for delayed mode data, and fulfilled efficiently. JAMSTEC is the principal organization of Japanese Argo Program and has been making a great contribution to the international Argo Program In the following aspects;

1) JAMSTEC has been deploying about 100 Argo floats every year in the Pacific, Indian and Southern Oceans totaling up to 471 since 2001.

2) JAMSTEC improved delayed-mode quality control methods, edited and released new climatological databases for the Pacific and Indian Oceans to make quality control level much higher. JAMSTEC manages the Pacific Argo Regional Center (PARC) in cooperation with CSIRO and IPRC. The function of PARC is monitoring delayed-mode quality control level of all Argo data obtained in the North and South Pacific and inform the principal investigators when the quality control level has some doubts.

3) JAMSTEC is developing a new float with a gear pump which enables to make float size much smaller than conventional ones and to make float working at a depth deeper than 2000 m. JAMSTEC has developed a profiling system for the Arctic Ocean (an Arctic Argo float) which was deployed near the North Pole in April 2006 and sending data to GTS and the Argo Global Data Center.

PICES XV W6-3252 Oral
Design and operation of offshore observing platform in the Yellow Sea

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Establishment of an Operational Oceanographic System is needed for the prevention of natural disaster, development of coastal regions, development and management of ocean resources, preservation of ocean environments, and ocean service for the sea-based industry. The integrated and systematic ocean observing system is a base and a first important step to construct an operational oceanographic system, since it will produce real-time information on the ocean environmental parameters for various applications. Recently, China and Republic of Korea governments signed an agreement to construct a real-time offshore observing system in the Yellow Sea.

China and Korea both Governments already agreed to integrate their offshore observing platforms in the Yellow Sea to set up a regional real-time observing system of the Yellow Sea. The system constitutes of three platforms, one is No. 15 Buoy that belongs to China, the second is Ieodo Ocean Station of the Republic of Korea, and both governments will invest to construct a new buoy to fill the gap between Chinese No. 15 Buoy and Korean Ieodo Ocean Station. The data will BE collected in real through satellite communication and all THE data collected from three platforms will BE shared fully. The observing platforms are also a part for Global Ocean Observing System (GOOS). The paper will present the technical design of the new buoy and study on the operation of real-time observing system through cooperation between SOA, China and KORDI, Republic of Korea.

PICES XV W6-3217 E-poster
Real-time oceanographic information for pelagic fishery based on Argo data

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Oceanographic information from the open ocean is useful in searching for new fishing grounds of pelagic fisheries. Although the data obtained by satellite, fixed buoy and research vessel are available for pelagic fisheries, their spatial coverages have been restricted to few locations or within narrow depth limits. Pelagic fishery operations have an additional need for real-time global and continuous subsurface information from sub-surface layers of the open ocean. Fortunately, Argo floats now deliver temperature and salinity profiles for the upper 2000m of the ocean plus velocity at depth. Argo is an international program with purposes of examining the global scale ocean circulation program and air-sea interaction. The Argo array should approach 3000 floats by the end of 2006. All Argo data are relayed and made publicly available within hours after collection.

As the number of profiles obtained by Argo floats in the open ocean increases, temperature information becomes more useful for pelagic fisheries. In order to aid pelagic fisheries KODC has distributed the real-time oceanographic information for pelagic fisheries based on Argo data through the KODC website (http://kodc.nfrdi.re.kr). The system displays vertical profiles, horizontal distribution maps, and vertical sections of temperature with various methods of visualization.

PICES XV W6-3244 Oral

NEAR-GOOS and Japanese operational oceanographic observations

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NEAR-GOOS, a regional pilot version of GOOS in the North East Asian Region, were initiated in 1996. NEAR-GOOS efforts have been focused on the enhancement of oceanographic observational data exchange for daily mapping of oceanographic condition, in its initial stage. The data exchange system was successfully established and is now operational, and many users have recognized it as a source of various oceanographic data and products. The amount of observational data has been increasing with cooperation among various Japanese ocean-related organizations/institutes. One of the keys of success of NEAR-GOOS was a good coordination of institutes and agencies which carry out operational oceanographic observations. The variety of oceanographic products provided by the NEAR-GOOS partners has also increased.

W7 CCCC/CFAME Workshop
Climate forcing and marine ecosystems

Co-Convenors: Kerim Y. Aydin (U.S.A.), Jacquelynne R. King (Canada) and Akihiko Yatsu (Japan)

The CFAME (Climate Forcing and Marine Ecosystems) Task Team is developing new theoretical and mathematical frameworks to extend the traditional single species concept of carrying capacity into the multi-species and ecosystem domains. Three major ecosystems of the North Pacific were selected for this approach: Sea of Okhotsk, California Current System and East China/Yellow Sea. For each ecosystem the Task Team will review the physical processes that define an ecosystem, build an overview of dominant species across trophic levels, and describe how the population dynamics of these species have changed over time. The conceptual linkages between the physical processes and food-web structures will allow a comparison of varying responses of the different North Pacific marine ecosystems to basin-wide climate forcing events. This workshop is a continuation of work that was initiated at a CFAME workshop in January 2006 (Tokyo, Japan). It will focus on key species data for the East China/Yellow Sea and Sea of Okhotsk regions, to facilitate inter-comparisons among the three target ecosystems.

Friday, October 13, 2006 09:00-18:00

09:00-09:30 **Introduction by Convenors**

- Introductions
- Review CFAME Workplan
  - life history strategists' response to climate forcing (January workshop)
  - mechanisms of climate forcing on ecosystems (this workshop)
  - climate scenarios and potential impacts (potential future work with POC)
- Ecosystem Workshop Objectives
  - overview of selected ecosystems
  - discussion of other potential ecosystems of interest
  - conceptual mechanisms of climate forcing on selected ecosystems
  - methods of comparing ecosystems
  - recommended future workplan for CFAME
  - potential CFAME-POC future collaboration

09:30-10:00 **Vera Agostini, G.A. McFarlane and J.R. King** (Invited)
An overview of the California Current ecosystem (W7-3256)

10:00-10:30 **Victor Lapko** (Invited)
An overview of the Okhotsk Sea ecosystem (W7-3108)

10:30-10:50 ***Tea/Coffee Break***

10:50-11:20 **Young Shil Kang, Seung Heo, Jae-Kyoung Shon and Gyung Soo Park** (Invited)
Variations of zooplankton and oceanographic conditions in response to climatic changes in the East China/Yellow Sea (W7-3185)

11:20-11:40 **Xiuren Ning, Chuanlan Lin, Jilan Su, Chenggang Liu and Junxian Shi**
Environmental changes and the responses of the ecosystems in the Bohai Sea during 1960-1996 (W7-2840)

11:40-12:30 **Discussion**

- other potential ecosystems of interest
- conceptual mechanisms of climate forcing for selected ecosystems

12:30-14:00 ***Lunch***

14:00-14:20 **Sarah K. Gaichas, Kerim Y. Aydin and Vera N. Agostini**
Quantitative methods for comparative ecosystem analysis: Relationships and thresholds in the Gulf of Alaska and the California Current (W7-2901)

14:20-15:30 **Discussion**

- methods of classifying ecosystems
- approaches to comparing ecosystem responses

15:30-16:00 ***Tea/Coffee Break***

16:00-18:00 **Discussion**

- recommended future ecosystem comparison work for CFAME
    - overall theme and focus
    - topics for inter-sessional meetings
- CFAME-POC collaboration
    - suggested climate variables required from POC modeling work
    - workshop report and assignment of tasks

PICES XV W7-3256 Invited
An overview of the California Current ecosystem

Vera **Agostini**[1], G.A. McFarlane[2] and J.R. King[2]

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The California Current system extends southward from the west coast of Vancouver Island to Baja California. In winter, southerly winds dominate causing onshore transport combined with downwelling and poleward transport of surface waters. Northwesterly winds dominate in summer, causing surface waters to flow southerly and coastal upwelling results. The annual transition between winter and summer current patterns occurs in the spring (March-April) and again in the fall (September-October). During the upwelling season, surface waters are driven offshore and replaced by intermediate depth, nutrient rich water. Relative intensity of Aleutian Lows in winter has been linked to the winter circulation, with subsequent impacts on mixed layer depth, phytoplankton production and coastward retention of zooplankton and larval fish in spring. At the northern extent of the California Current system, winter storms are frequent and strong and freshwater input is significant. In this region, primary productivity and zooplankton biomass have a strong seasonal component. Along the coasts of southern Washington and Oregon, the winds are mostly upwelling favorable, freshwater input is minor and primary productivity is stongly seasonal and zooplankton biomass has a seasonal pattern. In the southern extent of the California Current system, there are few storms and weaker winds. In this region stratification is stable and weak local upwelling occurs. Primary productivity and zooplankton biomass exhibit a damped seasonality. In the northern California Current region, the zooplankton community is comprised of the euphausiids *Euphasia pacifica* and *Thysanoessa spinifera* and coldwater boreal and subarctic copepods, such as *Pseudocalanus minimus* and *Neocalanus plumchrus*. In the southern California Current region, the diversity of euphausiids is higher, and only warm water copepods (*Calanus pacificus* and *Metridia pacifica*) are present. Several species of pelagic tunicates comprise a large portion of the zooplankton biomass in this region. Throughout the California Current system, the zooplankton community composition and biomass exhibit decadal-scale patterns of variability. Two migratory pelagic fish species dominate the California Current system: Pacific sardine (*Sardinops sagax*) and Pacific hake (*Merluccius productus*). Both species spawn off of California in winter, and migrate northwards in summer to feed throughouth the system. There have been decadal-scale patterns of variability in spawning biomass, northward extent of summer migration and migratory behaviour observed for both fish species.

PICES XV W7-2901 Oral
Quantitative methods for comparative ecosystem analysis: Relationships and thresholds in the Gulf of Alaska and the California Current

Sarah **Gaichas**[1], K. Aydin[1], and V. Agostini[2]

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Improved understanding of ecosystem structure and function is essential to developing ecosystem based fishery management strategies. In this presentation, we use new analytical methods to identify structurally important species and explore how life history characteristics of these key species may affect ecosystem dynamics under different climate and fishing scenarios. To identify structurally important species, we used “complex systems” approaches which have been applied in many biological, social, and physical systems. We present example results from each of these methods for the Gulf of Alaska, with preliminary comparisons to the California Current. We use the complex systems approaches to identify both static and dynamic sources of robustness in the ecosystem, and also potential ecosystem thresholds where the state of the ecosystem is prone to rapid change. Some potential thresholds relate to the network properties of food web structure, while other thresholds relate to fishing intensity interacting with dynamic predator prey functional responses in the ecosystem. Combining these methods with management appropriate to the life history of the key species and a realistic accounting of uncertainty can support fishery sustainability in the ecosystem context, allowing managers to consider relationships and to operate within both single species and ecosystem-level thresholds. Finally, we suggest a concept of “ecosystem sustainability” where the goal is to sustain relationships between species

(including humans), and which views ecosystems as complex adaptive systems which are simultaneously robust to random disturbance and yet prone to rapid, irreversible state changes under certain conditions.

PICES XV W7-3185 Invited
Variations of zooplankton and oceanographic condition in response to climatic changes in the East China/Yellow Sea

Young-Shil **Kang**, Seung Heo, Jae-Kyoung Shon and Gyung Soo Park

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Long-term changes of zooplankton and oceanographic condition were studied to figure out the climate forcing, in particular regime shifts, on marine ecosystem in the East China/Yellow Sea.

Data of zooplankton biomass, abundance of four taxa (copepods, chaetognaths, amphipods and euphausiids), temperature and salinity were analyzed with PCA (Principal component analysis) and Duncan test. The data were divided into four time periods based on the two regime shifts, 1977~88(PI) and 1989~97(PII), and one possible regime shift, 1998~2005(PIII).

Principal component analysis (PCA) not revealed a clear long-term changes in responded to regime shifts but showed the stepwise change around 1997/98. Zooplankton biomass decreased to the mid-1980 and then increased continuously to 2005 with annual variations. The increasing trends were gradual in the PII and sharp during the PIII. By contrast with the increasing trends in the PII and PIII, the 1997 and 2003 showed low biomasses, in particular, in June and August. Of four major taxa, copepods gradually decreased from the PI, II to PIII, and amphipods, euphausiids and chaetognaths showed sharp increase during the PIII. Seasonal peak was shifted from autumn in the PII to April in the PIII.

Sea surface temperature (SST) slowly decreased to the mid-1980, in particular, in February and April and then gradually increased to 2005 with the interannual fluctuations. Compared with the SST, the temperature at 50 m depth showed the cycle of *ca.* 15years. In particular, the temperature at 50 m depth steeply decreased after the end of PII. On the other hand, the bottom cold water mass continuously increased after the early-1980 in annual mean but showed the cycle of *ca*. 15years in August.

Salinity at surface and 50 m sharply increased during the early PII and then kept a steady state during PI to PII. The salinity in PIII steeply decreased.

Those results suggest that zooplankton not strongly responded to PI, PII and PIII but showed stepwise changes in the 1978-1980, 1997 and an El Niño event in 2002/03. In addition, the increasing gradients between PII and PIII were very different, and chaetognaths and amphipods abundance changed rapidly after PII. Oceanographic condition also showed the striking changes in salinity and temperature around PII and PIII. In the PIII, sea surface temperature sharply increased in April and sea surface salinity dramatically decreased in October. Additionally, zooplankton biomass increased in April and October in the PIII.

PICES XV W7-3108 Invited
An overview of the Okhotsk Sea ecosystem

Viktor **Lapko**

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The basic data required for comparative analysis of Okhotsk Sea ecosystem along with other major ecosystem domains of the North Pacific is presented for consideration at CFAME Task Team workshop. The most pronounced climate-oceanologic processes influencing on ecosystem status are described. State of plankton communities, biomass, productivity and trophic interaction of such key fishes as pollock, herring, salmon, *etc.* composing a major portion of food-web structure are reviewed. It's made an attempt to estimate how such parameters changed under effect of physical factors including through population dynamics of the most abundant species of fishes thus forming an integral ecosystem response to major climate events occurred over North Pacific.

PICES XV W7-2840 Oral

Environmental changes and the responses of the ecosystems in the Bohai Sea during 1960-1996

Xiuren **Ning**[1,2,3], Chuanlan Lin[3], Jilan Su[1,3], Chenggang Liu[1,2,3] and Junxian Shi[3]

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Through analyzing physical and chemical data obtained from seasonal monitoring along the transect B maintained by State Oceanic Administration (SOA), and from the marine ecosystem surveys conducted by the Yellow Sea Fisheries Research Institute (YSFRI) in the Bohai Sea during 1960-1996, studies on environmental changes and the responses of the ecosystems in this period were carried out. It was found that, in the Bohai Sea T, S, DIN and N:P ratios appeared positive fluctuation trends, while DO, P, Si and Si:N ratios exhibited negative trends during the monitored period. The annual change rates of T, S, DIN and N:P were 0.005 to 0.013°C $year^{-1}$, 0.04 to 0.14 psu $year^{-1}$, 0.25 to 0.52 μmol L^{-1} $year^{-1}$ and 1.23 to 2.37 $year^{-1}$, respectively. While ranges of the annual change rates of DO, P, Si and Si:N were -1.59 to -2.30μmol L^{-1} $year^{-1}$, -0.007 to -0.011μmol L^{-1} $year^{-1}$, -0.385 to -0.602μmol L^{-1} $year^{-1}$ and -0.064 to -0.494 $year^{-1}$, respectively. The most environmental variations were probably related to freshwater deficit, causing increase in salinity and decrease in concentrations of P and Si in the Bohai Sea. Since 1980's the freshwater deficit has reached up to about 1 m y^{-1} in the Sea. Since 1985, the concentrations of P and Si dropped to near to the ecological threshold for diatom growth, some time near to zero for a long time and in large areas of the Bohai Sea, and the N:P ratios were below the Redfield ratio, while the Si:N ratios were below the suitable value for diatom growth. The ecosystems have experienced limitation of the key nutrients, *i.e.* P and Si. Ecological investigation shows that there were some pronounced responses of ecosystems to the environmental changes in the Sea, such as decreases in standing stock and production of phytoplankton, economical living resources, the indices of the recruitment for prawn (*Penaeus orientalis*), and the changes in fish community structure and species diversity, resulted from the impacts of the key nutrient limitation, particularly phosphorus.

W8

BIO/POC Workshop
Responses of marine mammals and seabirds to large-scale and long-term climate change: Mechanisms of environmental forcing

Co-sponsored by Hokkaido University Center of Excellence
Co-Convenors: Yutaka Watanuki and Shoshiro Minobe (Japan), Rolf Ream and William J. Sydeman (U.S.A.)

Distribution and abundance, diets, and breeding performance of marine mammals and seabirds reflect local marine environments. A number of studies from the western and eastern North Pacific indicate interannual to interdecadal changes in these environment. In particular, low-frequency climate changes sometimes result in profound effects on marine ecosystems, yet the influence of these factors on seabirds and mammals has not been adequately quantified. In the North Atlantic, their breeding performance and population dynamics has been related to changes in the NAO. Papers that examine synchrony in responses by these taxa to interannual to interdecadal climate variability in the North Pacific are solicited. Studies describing and testing mechanisms of environmental forcing from physics to prey, on seabirds and marine mammals are of particular interest. With sufficient interest by the participants, an appropriate primary journal will be approached to publish the papers presented at the workshop.

Thursday, October 12, 2006 13:00-17:00

13:00-13:05 **Introduction by Convenors**

13:05-13:30 **Shin-ichi Ito, Kenneth A. Rose, Bernard A. Megrey, Francisco Werner, Douglas Hay, Maki Noguchi Aita, Yasuhiro Yamanaka, Michio J. Kishi, Jake Schweigert, Matthew Birch Foster, Dan Ware, David Eslinger, Robert Klumb and S. Lan Smith** (Invited)
Responses of fish growth to large-scale and long-term climate change: A comparison of herring and saury in the North Pacific using NEMURO.FISH, a coupled fish bioenergetics and lower trophic level ecosystem model (W8-3080)

13:30-13:55 **Sei-Ichi Saitoh, Takahiro Iida, Suguru Okamoto, TaeKeun Rho and Toru Hirawake** (Invited)
Temporal and spatial variability of primary production in the sub-arctic North Pacific using satellite multi-sensor remote sensing (W8-3205)

13:55-14:20 **Arthur J. Miller** (Invited)
The climate-ocean regime shift hypothesis of the Steller sea lion decline in Alaska (W8-3056)

14:20-14:40 **Andrew W. Trites, Pamela M. Lestenkof and Erin Ashe**
Responses of northern fur seals to large-scale and long-term climate change (W8-3168)

14:40-15:00 ***Tea/Coffee Break***

15:00-15:25 **Julie A. Thayer, Scott A. Hatch, Mark Hipfner, Leslie Slater, Yutaka Watanuki and William J. Sydeman** (Invited)
Forage fish prey of a piscivorous seabird in the North Pacific: Synchrony and relationships with ocean climate (W8-3092)

15:25-15:45 **Shoshrio Minobe, William J. Sydeman, Yutaka Watanuki and Vernon Byrd**
Climate influences on seabirds in the Japan and Bering Seas and California Current (W8-3153)

15:45-16:10 **Sarah Wanless and Morten Frederiksen** (Invited)
Climate responses of avian predators in a heavily exploited shallow sea ecosystem: Effects on trophic interactions and consequences for ecosystem control in the North Sea (W8-2814)

16:10-16:30 **Hyun Woo Kim, David W. Weller, Amanda L. Bradford and Zang Geun Kim**
Body condition of western gray whales in relation to environmental change in the North Pacific (W8-2913)

16:30-17:00 **Discussion**

Posters

Keiko Kato, Takeomi Isono, Kaoru Hattori, Orio Yamamura and Yasunori Sakurai
Winter movement of Steller sea lions (*Eumetopias jubatus*) to the northern coast of Japan related to sea-ice conditions in the Sea of Okhotsk during 1989-2004 (W8-3082)

Motohiro Ito, Hiroshi Minami and Yutaka Watanuki
Quick prey switching in a seabird: Seasonal changes of diet for adults and chicks of Rhinoceros Auklets (W8-2815)

Shiroh Yonezaki, Masashi Kiyota, Hiroshi Okamura and Norihisa Baba
Possibility of diet selection of northern fur seals in the Northwestern Pacific (W8-2962)

PICES XV W8-3080 Invited

Responses of fish growth to large-scale and long-term climate change: A comparison of herring and saury in the North Pacific using NEMURO.FISH, a coupled fish bioenergetics and lower trophic level ecosystem model

Shin-ichi **Ito**[1], Kenneth A. Rose[2], Bernard A. Megrey[3], Francisco Werner[4], Douglas Hay[5], Maki Noguchi Aita[6], Yasuhiro Yamanaka[7], Michio J. Kishi[8], Jake Schweigert[9], Matthew Birch Foster[10], Dan Ware[11], David Eslinger[12], Robert Klumb[13] and S. Lan Smith[14]

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NEMURO.FISH consists of a fish bioenergetics model coupled to the NEMURO lower trophic model, and there are two types of coupling: one-way and two-way. In the two-way coupling, the amount of predated zooplankton is removed from the zooplankton abundance and the excretion and egestion are converted to the nutrient pool. However, this effect is only important in the case that the predation pressure from fish is fairly large. In the one-way coupling, only the zooplankton is used to fish growth and there are no feedback to the zooplankton density. We used the one-way coupling NEMURO.FISH to investigate the responses of fish growth to large-scale and long-term climate change. The NEMURO.FISH was driven by the zooplankton density and sea water temperature time series which is derived from the global three dimensional NEMURO model coupled with physical ocean general circulation model forced by realistic climate forcing. We focused on the herring and saury growth in the North Pacific and compared the two species growth. Also we compared the growth of those two species in the Eastern and Western North Pacific. The result of the integration showed the responses to the regime shifts like 1977-78, 1988-89, *etc*. However, the response is complicated and there were time lags from the regime shifts to the fish responses. Also the fish responses strongly depended on not only species and but also the location. This result suggests the importance of the understandings of the local characteristics of the fish life history and climate change.

PICES XV W8-3082 Poster

Winter movement of Steller sea lions (*Eumetopias jubatus*) to the northern coast of Japan related to sea-ice conditions in the Sea of Okhotsk during 1989-2004

Keiko **Kato**[1], Takeomi Isono[2], Kaoru Hattori[3], Orio Yamamura[3] and Yasunori Sakurai[1]

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Steller sea lions that have rookeries in the Sea of Okhotsk and Kuril Islands are known to move to the northern coast of Japan in winter to avoid heavy sea ice around the rookeries. In Japan, sea lions are a threatened species, but the damage they cause to fishing gear such as bottom gill nets has gradually increased along the Sea of Japan coast of Hokkaido Island since the late-1980s and reached more than $10 million in the early-2000s. To reduce this damage and improve the conservation of Steller sea lions, we need to clarify why they migrate from the Sea of Okhotsk to the Sea of Japan coast of Hokkaido during winter and spring. The increase of fishing-gear damage and sightings by fishermen along the Sea of Japan coast of Hokkaido coincided with the establishment of a rookery on Tyuleny Island off southern Sakhalin. In this study, we examined if the population increase that occurred in northern Japan after the late-1980s is related to the occurrence of sea ice around Tyuleny Island. The increase in numbers of females and pups showed a negative relationship with the date when the sea ice around the island melted in spring. We estimate that the winter movement of Steller sea lions to the northern

coast of Japan is related to the increase of the sea lion population at Tyuleny Island caused by changes in sea-ice conditions after the late-1980s.

PICES XV W8-2913 Oral
Body condition of western gray whales in relation to environmental change in the North Pacific

Hyun Woo **Kim**[1,4], David W. Weller[2], Amanda L. Bradford [3] and Zang Geun Kim[4]

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The population size of western gray whales (*Eschrichtius robustus*) in the western Pacific is estimated to be approximately 120 individuals and they are listed by the IUCN as critically endangered. Most individuals of the western population are observed off Piltun Lagoon on the northeastern coast of Sakhalin Island, Russia, during the summer feeding season. Since 1995, a collaborative Russia-U.S. research program has been conducting individual monitoring of western gray whales summering off Piltun Lagoon by use of photo-identification methods. Body condition of individual whales was determined using a photo-based method that specifically examined the relative amount of subcutaneous fat in three distinct body regions that included areas surrounding the head, shoulders and flanks. Loss of fat in these regions suggests some degree of abnormal nutritional stress. Since the body condition of western gray whales varied interannually, as apparent by the total number of individuals observed to be "skinny" in any given year, we hypothesized that this variability was likely to be linked with changes in the oceanic environment and climate of the North Pacific. To address this question, counts of skinny whales in their summer feeding area between 1999 and 2005 were compared to the Pacific Decadal Oscillation Index (PDO) and maximum ice cover area in the Okhotsk Sea. Preliminary results show that when the summer PDO was in a positive phase the number of skinny whales observed was lower than in years when the index was in a negative phase during which time higher numbers of skinny whales were observed.

PICES XV W8-3056 Invited
The climate-ocean regime shift hypothesis of the Steller sea lion decline in Alaska

Arthur J. **Miller**

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Declines of Steller sea lion populations in the Aleutian Islands and Gulf of Alaska could be a consequence of physical oceanographic changes associated with the 1976-77 climate regime shift. Changes in ocean climate are hypothesized to have affected the quantity, quality and accessibility of prey, which in turn may have affected the rates of birth and death of sea lions. Recent studies of the spatial and temporal variations in the ocean climate system of the North Pacific support this hypothesis. Ocean climate changes appear to have created adaptive opportunities for various species that are preyed upon by Steller sea lions at mid-trophic levels. The east-west asymmetry of the oceanic response to climate forcing after 1976-77 is consistent with both the temporal aspect (populations decreased after the late 1970's) and the spatial aspect of the decline (western, but not eastern, sea lion populations decreased). Shifts in ocean climate are the most parsimonious underlying explanation for the broad suite of ecosystem changes that have been observed in the North Pacific Ocean in recent decades.

PICES XV W8-3153 Oral
Climate influences on seabirds in the Japan and Bering Seas and California Current

Shoshiro **Minobe**[1], William J. Sydeman[2], Yutaka Watanuki[3] and Vernon Byrd[4]

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We investigated the relationships between reproduction success (annual productivity) of 8 species of seabird and atmospheric and oceanographic conditions. The seabird data include two kittiwake (black- and red-legged) and two murre (common and thick-billed) species at St. Paul and St. George islands, which belong to Pribilof Islands in the Bering Sea, and five species (common murre, cassin's auklet, brandt's cormorant, pelagic cormorant, pigeon guillemot) at Southeast Farallon Island off northern California. Climate parameters examined were sea surface temperature (SST), surface air-pressure, and sea-ice concentration in the Bering Sea taken from NCEP reanalysis and HadISST datasets.

For kittiwakes at the Pribilof Islands, wintertime conditions were related to productivity. Colder SST and greater sea-ice concentrations was associated with greater reproductive success, especially over the past decade (1995-2005). The corresponding negative pressure anomalies are observed broadly over North America continent. For murres at the Pribilofs, colder SST anomalies in summer over the northern North Pacific with some penetration to the southern Bering Sea contributed to higher breeding success. At the same time, pressure anomalies indicate a surface pressure dipole with the positive center in western Alaska and negative center in western northern North Pacific. For species at southeast Farallon Island, a strong influence from the tropics (El Niño signal) was observed. The corresponding SST and atmospheric pressure patterns suggest that strong coastal upwelling associated with El Niño contributed higher reproductive success. Climate influence on rhinoceros auklet in Teuri Island in the Japan Sea will also be presented at the meeting.

PICES XV W8-3205 Invited
Temporal and spatial variability of primary production in the sub-arctic North Pacific using satellite multi-sensor remote sensing

Sei-Ichi **Saitoh**, Takahiro Iida, Suguru Okamoto, TaeKeun Rho and Toru Hirawake

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The sub-arctic North Pacific represents one of the world's most biologically productive regions. The quantitative assessment of phytoplankton production in this region is very important to estimate global primary production. Recent development of ocean color sensors such as SeaWiFS, MODIS and GLI has been accompanied by an increased effort to establish algorithms for determining ocean optical properties, phytoplankton pigments, and primary production from ocean color imagery. In this study, we investigated the distribution of phytoplankton biomass and primary production in sub-arctic North Pacific and their marginal seas during 1998-2004, using satellite multi-sensor remote sensing. We employed Ocean color (Chlorophyll-*a* (Chl-*a*), SeaWiFS), photosynthesis active solar radiation (PAR, SeaWiFS), sea surface temperature (SST, AVHRR), and sea surface height anomaly (SSHA, AVISO) datasets. Primary production was calculated using the vertically generalized production model (VGPM). Understanding the mechanism of difference factors controlling phytoplankton production between eastern and western sub-arctic North Pacific is very important to clarify the geochemical carbon cycles and global climate change effect to marine ecosystem. We will discuss on the comparison of the East-West variability of Chl-*a* and primary production in the sub-arctic North Pacific using multi-sensor remote sensing.

PICES XV W8-3092 Invited

Forage fish prey of a piscivorous seabird in the North Pacific: Synchrony and relationships with ocean climate

Julie **Thayer**[1,2,3], D.F. Bertram[4], S.A. Hatch[5], M. Hipfner[6], L. Slater[7], Y. Watanuki[8] and W.J. Sydeman[2]

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Synchronous changes in ocean climate variability and coastal pelagic fisheries have been identified in different marine ecosystems around the globe. Such synchrony may also be conveyed to upper-trophic levels and influence predator dynamics. We used a seabird predator, rhinoceros auklet (*Cerorhinca monocerata*), to sample forage fish communities at six locations around the coastal North Pacific. Forage species included anchovy (*Engraulis*), sandlance (*Ammodytes*), capelin (*Mallotus*) and juvenile rockfish (*Sebastes*), among others. We investigated whether forage fish community dynamics, as indicated by seabird diet composition, were related to local marine conditions and whether dietary changes between sites covaried through time. We compared local marine conditions as indexed by SST between regions and found concordance across the eastern Pacific but a predominately inverse pattern between eastern sites and the western site in the Japan Sea/Tsushima Current. Temporal patterns in forage fish communities included inter-annual and possibly longer-term variations. Forage fish dynamics were most strongly related to changes in SST in the California Current and Eastern Transition Zone. We found regional synchrony among the main forage species at several sites in the eastern Pacific. Unlike patterns in SST, however, changes in juvenile salmon varied inversely between California Current and Gulf of Alaska sites. We also observed weak co-variation between primary forage species in the west and the Eastern Transition Zone. Long-term and large-scale marine bird diet sampling may thus be a useful indicator of bio-physical changes in North Pacific marine ecosystems, and reveal processes by which upper-trophic predators are affected by climate variation.

PICES XV W8-3168 Oral

Responses of northern fur seals to large-scale and long-term climate change

Andrew W. **Trites**, Pamela M. Lestenkof and Erin Ashe

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Northern fur seals from the Pribilof Islands, Alaska, are the longest studied species of marine mammals in the world. Estimates of numbers of pups born and measures of body size span 100 years. More recent time series of population data collected since the 1950s include pregnancy rates, survival rates of pups and juveniles, and annual changes in body size (as measured from teeth annuli). Some of the changes noted in fur seal dynamics over the past century appear to be density dependent responses to the effects of over-hunting of immature males and mature females. However, other changes in fur seal dynamics correlate with the timing and intensity of ocean climate conditions (as measured by the Pacific Decadal Oscillation). This suggests that breeding performance and population dynamics of northern fur seals is related to some extent by climate-mediated changes in the marine ecosystem. Large scale changes in ocean climate may affect fur seals by altering the relative abundances and nutritional quality of the prey that are available to them. Such a driving mechanism might explain the concurrent declines of northern fur seals, Steller sea lions and harbor seals that occurred in the Bering Sea, Gulf of Alaska and Aleutian Islands in the 1970s and 1980s.

PICES XV W8-2814 Invited

Climate responses of avian predators in a heavily exploited shallow sea ecosystem: Effects on trophic interactions and consequences for ecosystem control in the North Sea

Sarah **Wanless** and Morten Frederiksen

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The North Sea is one of the most heavily fished regions in the world and fisheries have undoubtedly had major impacts on its ecosystem structure and function. However, in recent years climate change effects have also started to become apparent across all trophic levels including top predators. Throughout most of the North Sea lesser sandeels, *Ammodytes marinus*, are the dominant mid-trophic pelagic fish. Thus understanding differences in spatial, temporal and species responses to climate requires information about ecosystem regulation and also detailed knowledge of trophic interactions, particularly relationships between seabird breeding success and sandeel availability and quality. We give examples to show how long-term, large-scale seabird monitoring of population size, breeding success and diet can be used in conjunction with time series data from our intensive population studies on the Isle of May, to address these issues and thereby help elucidate the relative importance of climatic and fisheries drivers.

PICES XV W8-2815 Poster

Quick prey switching in a seabird: Seasonal changes of diet for adults and chicks of Rhinoceros Auklets

Motohiro Ito[1], Hiroshi Minami[2] and Yutaka **Watanuki**[1]

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Prey availability is known to affect production of chicks and body condition of adults in seabirds. We found positive correlation between Tsushima current flow in spring and chick production of Rhinoceros Auklet at Teuri Island, and assumed that the timing of northward expansion of anchovy is a key factor. We investigated seasonal changes in the diet for chicks and adults using stomach contents and bill-loads for chicks in 2004 and 2005. Based on stomach contents collected by water off-loading technique, adults mainly fed on krill during egg-laying and incubation. During early chick-rearing period stomach contents of adults and bill-loads for chicks were mainly comprised of 0+ sandlance and juvenile Atka mackerel. In mid chick-rearing period, diet for both adults and chicks switched to anchovy within a week. We conclude that diet types of adults shifted seasonally but did not differ from that for chicks during chick-rearing period. These dietary shifts presumably due to the seasonal northward expansion of the distribution of anchovy. In addition, the quick prey change indicates some behavioral mechanism of prey switching in this species that have a long (>100 km) potential foraging range.

PICES XV W8-2962 Poster

Possibility of diet selection of northern fur seals in the Northwestern Pacific

Shiroh **Yonezaki**[1], Masashi Kiyota[1], Hiroshi Okamura[1] and Norihisa Baba[2]

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Northern fur seals (*Callorhinus ursinus*) have been considered as opportunistic feeders that prey on those species that are most available in their pelagic habitat. However, analysis of our long-term stomach contents data revealed that some prey species (*e.g.*, Japanese anchovy (*Engraulis japonicus*)) were preyed infrequently in spite of their abundance in the Northwestern Pacific. The purpose of this study is to examine the possibility of prey preference of fur seals in the Northwestern Pacific. Diet composition in digestive tract contents of fur seals collected at sea was compared with composition of prey species in trawl net samples collected in the same area period. The trawl samples were taken at nighttime from the depths ranged of 0 to 60 m in consideration of the feeding depth of fur seals. The dominant diet species were lanternfishes (Myctophidae) and sparkling enope squid (*Watasenia scintillans*), while the main prey species in trawl samples were Japanese anchovy,

lanternfishes, and sparkling enope squids. Statistical analysis on resource selection demonstrated significant negative selection of Japanese anchovy by northern fur seals. These results indicate a possibility that fur seals choose their diet from available prey species in their marine habitat. In the Northwestern Pacific, it was reported that the diet composition of fur seals changed according to the change in the long-term shifts in the food environment (*e.g.*, Quasi-decadal alternations in dominant small pelagic fishes). Northern fur seals may be selecting the prey items that can be utilized most efficiently in a given food environment.

W9 MIE-AP Workshop and Advisory Panel Meeting Micronekton sampling gear inter-calibration experiment

Co-Convenors: Evgeny A. Pakhomov (Canada) and Orio Yamamura (Japan)

The PICES Advisory Panel on *Micronekton inter-calibration experiment* (MIE-AP) was established to evaluate the efficacy of sampling gears and the procedures employed by different investigators to sample micronekton in the North Pacific and other parts of the world's oceans. An initial field effort, conducted just prior to PICES XIII, involved an 8-day (October 6-13, 2004) research cruise aboard the NOAA ship *Oscar Elton Sette* in Central North Pacific waters off the west side of Oahu Island (MIE-1). The second cruise (MIE-2) took place from September 27 to October 3, 2005, on board R/V *Hokko Maru* in Oyashio waters. The workshop will review data and findings from both cruises and discuss further data processing, other sampling gears to be tested and plans for MIE-3 experiment.

See related presentations at the BIO Topic Session (S5)

Wednesday, October 13, 2006 09:00-13:00

09:00-09:10 **Welcome and introductions**

09:10-09:40 **Evgeny A. Pakhomov, M.P. Seki, A.V. Suntsov, R.D. Brodeur and K.R. Owen**
Comparison of three sampling gears during the first Micronekton Intercalibration Experiment (MIE-1): Size composition of selected taxonomic groups and total macroplankton and micronekton (W9-2781)

09:40-10:00 **Andrey V. Suntsov, Michael P. Seki, Evgeny A. Pakhomov and Richard D. Brodeur**
Diversity and abundance of Hawaiian ichthyoplankton: Comparison of three types of midwater nets (W9-3125)

10:00-10:30 **Discussion on MIE-1 results and data processing**

10:30-10:50 ***Tea/Coffee break***

10:50-11:20 **Orio Yamamura, Hiroya Sugizaki, Shin-suke Abe, Kazuhiro Sadayasu, Ryu-ichi Matsukura, Kazushi Miyashita, Akihiro Hino and Tadashi Tokai**
Inter-calibration of micronekton sampling gear during the 2005 MIE-2 cruise (W9-3193)

11:20-11:40 **Hiroki Yasuma, Kazushi Miyashita and Orio Yamamura**
Acoustic identification and density estimate of a lanternfish, *Diaphus theta*, off Hokkaido, Japan (W9-2821)

11:40-12:10 **Discussion on MIE-2 results and data processing**

12:10-13:00 **Discussion on future MIE-AP activities**

- further data analysis
- other sampling gears to be tested
- possibility of MIE-3 experiment
- proposal of workshop/session at PICES XVI

PICES XV W9-2781 Oral

Comparison of three sampling gears during the first Micronekton Intercalibration Experiment (MIE-1): Size composition of selected taxonomic groups and total macroplankton and micronekton

Evgeny A. **Pakhomov**[1,2], M.P. Seki[3], A.V. Suntsov[4], R.D. Brodeur[5] and K.R. Owen[6]

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Results from the first Micronekton Intercalibration Experiment (MIE-1) conducted during October 6-12, 2004 on the leeward side of Oahu Island, Hawaii are presented. Three sampling gears, including a 140 m^2 pelagic Cobb trawl (CT), a 4 m^2 Hokkaido University rectangular frame trawl (HT) and a 2-m Isaacs-Kidd Midwater Trawl (IKMT) were deployed in a random sequence either in the upper 150m during the darkness or at 550m during the daytime from the NOAA research vessel *Oscar Elton Sette*. Deployment of the three types of gear resulted in a collection of more than 100 species of macroplankton and micronekton. Midwater fish, family Myctophidae in particular, predominated among identified species. Based on our preliminary taxonomic treatment, basic community indices to estimate diversity, *e.g.* evenness and species richness, were very similar for the HT and IKMT gears. This was particularly evident for the number of species and for daytime diversity and evenness indices. Both day and night deployment of the CT clearly procured more species per trawl, which was also reflected in higher diversity and evenness indices. Overall, it was evident that, although the taxonomic composition of catches was similar, the individual gears sampled different size groups of macroplankton and micronekton. In the sampled size range, the most intercomparable data were obtained within the 30 to 50 mm size spectrum. A closer scrutiny of gear types and mesh sizes prior to similar experiments as well as an adoption of the "standard" sampling gear is recommended.

PICES XV W9-3125 Oral

Diversity and abundance of Hawaiian ichthyoplankton: Comparison of three types of midwater nets

Andrey V. **Suntsov**[1], Michael P. Seki[2], Evgeny A. Pakhomov[3] and Richard D. Brodeur[4]

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During a recent Micronekton Intercalibration Experiment (PICES initiative, October 2004), an intensive sampling of oceanic micronekton was carried out off the leeward side of Oahu, Hawaii using three types of sampling gear – a 140 m^2 pelagic Cobb Trawl, a 4 m^2 Hokkaido University Rectangular Frame Trawl and a standard 2 m Isaaks-Kidd Midwater Trawl. Fish larvae, opportunistically collected in these tropical oligotrophic waters, showed high diversity, with a total of 61 families and 115-120 species recorded during the entire sampling period. Family Myctophidae was the most diverse, represented by 18 species, followed by Muraenidae (6-8 species) and Paralepididae, Gonostomatidae, Serranidae - (4 species). The majority of fish families (84%) were represented by 1-2 species. Larvae of deep-sea pelagic fishes dominated (26 families) followed by coastal families (21), epipelagic (9) and demersal groups (5). In terms of occurrence, lanternfish larvae were most frequently collected (present in 73% of samples), followed by larval bothids (67%), gempylids (60%) and engraulids (52%). The most common and abundant fish larvae (forming over 3% of total abundance) were *Encrasicholina punctifer* (Engraulidae), *Ceratoscopelus warmingi* (Myctophidae), *Gempylus serpens* (Gempylidae), *Engyprosopon* sp. (Bothidae) and *Cubiceps pauciradiatus* (Nomeidae). Samples collected with the Hokkaido University Rectangular Frame Trawl showed the highest ichthyoplankton diversity and abundance as indicatedby the number of families, species and total individuals collected. This trend was universal for both day and night sampling. Cobb Trawl samples showed the lowest diversity and abundance, and Isaaks-Kidd Trawl samples were intermediate.

PICES XV W9-3193 Oral
Inter-calibration of micronekton sampling gear during the 2005 MIE-2 cruise

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Catchability of sampling gears for micronekton was compared during the MIE-2 cruise aboard the *Hokko-Maru* (904t) in the coastal area off southeastern Hokkaido Island during Sep 23-Oct 3, 2005. The gears compared were: MOCNESS-10 (MOC), MOHT (Oozeki et al, 2004), Hokkaido Univ. Frame Trawl (HUFT: Itaya *et al.* 2001) and a stern midwater trawling net (MT) equipped with a Multi-Sampler (an opening-closing multiple codend system). Every net was towed at 4 stations at the outer shelf (bottom depth: 380-480m) during daytime and nighttime, with an exception of MT, which was towed at 2 stations only during daytime. Every net was towed obliquely from a depth of 300 m to the sea surface (MOHT & HUFT), or specimens from the 300-0 m layer were used (MOC and MT). In total, the myctophid *Diaphus theta* was the dominant micronekton caught (> 80% in number, > 70% in wet wt). The catch efficiency of different gears was determined using catch number and weight of *D. theta* per volume of water filtered. *D. theta* was divided into two distinct size classes (20-30 mm and 40-84 mm) and the catch efficiency (E_c) for each size class was compared. Overall, MOHT showed the highest E_c for large-sized fish (approximate ratio of E_c ; MOC: HUFT: MOHT: MT = 1: 1: 10: 1.5), and the HUFT showed equally high E_c for small-sized fish (≤ 30 mm; 1:10: 10: 0). This result perhaps reflects the high towing speed (3-5 kt) and stable towing angle (8°) of MOHT, which was attained by the newly designed depressor. Based on the present results, we strongly recommend employing MOHT for the quantitative sampling of micronekton.

PICES XV W9-2821 Oral
Acoustic identification and density estimate of a lanternfish, *Diaphus theta*, off Hokkaido, Japan

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Diaphus theta is the most abundant mesopelagic fish in the northwestern Pacific. Field acoustic data and biological samples were obtained both day and night off of eastern Hokkaido, Japan in September 2006 to estimate fish density and to estimate diel changes in vertical distribution. The difference in acoustical target strength (TS) between 38 kHz and 120 kHz was applied to identify *D. theta* using field echo data. Theoretical estimation using swimbladder acoustic scattering models showed that the TS difference ($\Delta TS = TS_{120}kHz - TS_{38}kHz$) of larger fishes (> 60 mm) was between –4 and 1 dB whereas for smaller fishes (< 60 mm) it was less than –4 dB. These values differed from those of other major component species of the deep-scattering layer, such as krill and pollock, suggesting that the echo from *D. theta* is acoustically unique. Diel vertical distributions of *D. theta* were estimated after acoustic identification. Relatively dense schools were observed at around 400 m during daytime, although the schools were scattered widely above 100-m during nighttime. These results correlated well with biological sampling data obtained by MOCNESS or IKMT nets. In the surface layer (< 100 m), estimated fish densities were about ten-fold higher at nighttime than in daytime.

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Acronyms

AP	Advisory Panel
BASIS	Bering-Aleutian Salmon International Survey, NPAFC
BIO	Biological Oceanography Committee
CCCC	Climate Change and Carrying Capacity Program
CFAME	Climate Forcing and Marine Ecosystem Response Task Team, CCCC
CLIVAR	Climate Variability and Predictability Program
COE	Center of Execellence, Hokkaido University
CPR-AP	Advisory Panel on the Continuous Plankton Recorder Survey in the North Pacific
CC-S	Carbon and Climate Section
CREAMS-AP	Advisory Panel on the Circulation Research of the East Asian Marginal Seas Program
DEEP	Deep-Sea Ecosystems and Exploitation Programm, Japan Fisheries Research Agency
DSP	Diarrhetic Shellfish Poisoning
EBM	Ecosystem-Based Management
ENSO	El Niño-Southern Oscillation
F&A	Finance and Administration Commitee
FIS	Fishery Science Committee
FISP	Future Integrative Science Program, PICES
GC	Governing Council
GLOBEC	Global Ocean Ecosystem Dynamics Programme
GOOS	Global Ocean Observing System
HAB-S	Harmful Algal Blooms Section
IFEP-AP	Advisory Panel on Iron Fertilization Experiment in the Subarctic Pacific Ocean
IMBER	Integrated Marine Biogeochemistry and Ecosystems Research
MBM-AP	Advisory Panel on Marine Birds and Mammals
MEQ	Marine Environmental Quality Committee
MIE-AP	Advisory Panel on Micronekton Inter-calibration Experiment
MODEL	Conceptual / Theoretical and Modelling Task Team, CCCC
MONITOR	Technical Committee on Monitoring
NAO	North Atlantic Oscillation
NPAFC	North Pacific Anadromus Fish Commission
POC	Physical Oceanography and Climate Committee
S1	Session 1 Science Board Symposium on *Boundary current ecosystems*
S2	Session 2 BIO/FIS Topic Session on *The human dimension of jellyfish blooms*
S3	Session 3 BIO Topic Session on *Interactions between biogeochemical cycles and marine food webs in the North Pacific* (co-sponsored by IMBER)
S4	Session 4 BIO Topic Session on *Synthesis of* in situ *iron enrichment experiments in the eastern and westrn subarctic Pacific*
S5	Session 5 BIO Topic Session on *Advances in epi- and meso-pelagic ecosystem research*
S6	Session 6 CCCC/MODEL Topic Session on *Modeling and historical data analysis of pelagic fish, with special focus on sardine and anchovy*
S7	Session 7 FIS/CCCC Topic Session on *Key recruitment processes and life history strategies: Bridging the temporal and spatial gap between models and data*
S8	Session 8 FIS/MEQ Topic Session on *Aquaculture and sustainable management of the marine ecosystem*
S9	Session 9 MEQ Topic Session on *Harmful algal blooms in the PICES region: New trends and potential links with anthropogenic influences*

S10	Session 10 POC/MONITOR/CCCC Topic Session on *Synchronous and asynchronous responses of North Pacific boundary current systems to climate variability*
SB	Science Board
SEEDS	Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study
SERIES	Subarctic Ecosystem Response to Iron Enrichment Study
SG	Study Group
SOLAS	Surface Ocean Low Atmosphere Study
TCODE	Technical Committee on Data Exchange
W1	IFEP/MODEL Workshop on *Modeling iron biogeochemistry and ocean ecosystems* (co-sponsored by SOLAS)
W2	FIS Workshop on *Linking climate to trends in productivity of key commercial species in the subarctic Pacific*
W3	MEQ/FIS Workshop on *Criteria relevant to the determination of unit eco-regions for ecosystem-based management in the PICES area*
W4	MEQ Workshop & Laboratory demonstration *on Review of selected harmful algae in the PICES region: II.* Dinophysis *and* Cochlodinium
W5	POC Workshop on *Evaluation of climate change projections*
W6	MONITOR/TCODE Workshop on *Data management, delivery and visualization of high-volume data products*
W7	CCCC/CFAME Workshop on *Climate forcing and marine ecosystems*
W8	BIO/POC Workshop on *Responses of marine mammals and seabirds to large-scale and long-term climate change: Mechanisms of environmental forcing* (co-sponsored by COE)
W9	MIE-AP Workshop on *Micronekton sampling gear inter-calibration experiment*
WG	Working Group