GLOBEC SYMPOSIUM

Climate Variability and Sub-Arctic Marine Ecosystems

Victoria, B.C., Canada
16-20 May 2005

BOOK OF ABSTRACTS

This Book of Abstracts provides the essential guide to the program of the symposium. It contains background information, the timetable for the symposium and abstracts of the oral and poster presentations.

Cover images courtesy of George Hunt, Jim Lovvorn, Tony Pym and NASA SeaWiFS Project.

Introduction to the Symposium

On behalf of the Scientific Steering Committee, the local Organizing Committee, and our sponsors, we would like to welcome you to Victoria and this GLOBEC Symposium on **Climate Variability and Sub-Arctic Marine Ecosystems**. This represents the "kick off" activity of the new GLOBEC program entitled Ecosystem Studies of Sub-Arctic Seas (ESSAS). This symposium offers the opportunity to influence the implementation plans of both ESSAS and the new Bering Ecosystem STudy (BEST) through 1 day workshops at the beginning (BEST) and end (ESSAS) of the symposium.

Why Sub-Arctic Seas? These Seas support extraordinarily rich marine resources, which provide food and wealth to local communities. They include the Okhotsk Sea, Oyashio shelf region, Bering Sea, Hudson Bay, Newfoundland/Labrador shelves, Gulf of St Lawrence, Greenland shelves, Iceland regions, the Nordic seas and the Barents Sea, and share several features in common: seasonal ice cover, freshwater from ice-melt and runoff, dramatic seasonality, reduced sunlight and low biodiversity. Recently changes in species abundance or distribution have been observed within several Sub-Arctic marine ecosystems. A symposium on climate effects on the Sub-Arctic marine ecosystems is timely because these recent changes appear to correlate with fluctuations in the physical environment and because of the growing concern about anthropogenically-induced climate change. Also, in addition to ESSAS, several new national programs in Sub-Arctic seas have recently been initiated, e.g. Bering Ecosystems Study (BEST), the Norwegian component of ESSAS (NESSAS) and the Oyashio-Pollock project in Japan.

We were delighted with the quality of the invited speakers who accepted our invitations and the submissions we received. We are sure you will find the scientific presentations, both oral and posters, interesting and thought provoking. Added to this, the numerous discussions and debates held between sessions and after hours, and the meeting of old friends and new colleagues, should make this a great meeting. For those of you who live outside of Victoria, we hope that you will be able to take time to see some of this beautiful city and its surroundings before you leave. For all attending the Symposium, we hope that your stay will be enjoyable and scientifically rewarding.

George Hunt and Ken Drinkwater, Co-Convenors

Symposium Sponsors

Alaska Fisheries Science Centre (AFSC)
Fisheries and Oceans Canada
Global Ocean Ecosystem Dynamics (GLOBEC)
National Oceanic and Atmospheric Administration (NOAA)
National Science Foundation (NSF)
North Pacific Marine Science Organisation (PICES)
North Pacific Research Board (NPRB)
Norwegian Research Council

Scientific Steering Committee

Olafur S Asttorsson	- Iceland	Michael Kingsley	- West Greenland
Manuel Barange	- GLOBEC	Michio J. Kishi	- Japan
Ken Drinkwater	- Norway	Harald Loeng	- Norway
Mickle Flint	- Russia	Bernard Megrey	- USA
Jackie Grebmeier	- USA	Ian Perry	- Canada
Erica Head	- Canada	Sei-ichi Saitoh	- Japan
Hans-Jürgen Hirche	- Germany	Kurt Tande	- Norway
Anne Hollowed	- USA	Terry Whitledge	- USA
George Hunt	- USA		

Notes for Guidance

Oral presentations

To make the symposium run smoothly all speakers are asked to adhere strictly to their allocated times for their presentations. Those chairing sessions will be strict about enforcing time limits of talks! All speakers should see the audio-visual technicians when registering and provide them with a copy of their computer presentation at this time. If this is not possible, the presentations must be made available well in advance of the talk. Those using overheads or any other audio visual aids should also notify the technicians of their intentions early. Speakers need to contact the session chair prior to the start of their session to confirm the schedule.

Posters

The poster sessions will be on the evening of the 17th and 18th of May. Presenters are asked to attend their displays during these times. However, all posters should be displayed throughout the meeting for further viewing and discussion. Further instructions on the location of posters will be available on arrival at the Symposium.

Receptions

Mon 16 May 19:00 Official reception at Royal British Columbia Museum, for Workshop and Symposium attendees

Tue 17 May 18:00 Poster Reception at Victoria Conference Centre

Meeting Rooms

During the Symposium, the presentations will take place on Level One of the Conference Centre, further details will be given on arrival at the Symposium. Presentations given at the BEST and ESSAS Workshops will be given in the Saanich, Oak Bay and Victoria Rooms, all on Level One of the Conference Centre – again, further details will be given on arrival.

Meeting Information

Refreshments will be available during the morning and afternoon breaks in the Foyer. Lunches and dinners can be purchased at nearby restaurants. Internet connections will be available on a limited number of computers in the foyer. Contact the Symposium Secretariat, located in the foyer outside the conference room, for any additional information or special requests.

Manuscripts

We wish to remind both oral and poster presenters that a special issue of Progress in Oceanography will be devoted to the symposium. Those wishing to submit manuscripts for this symposium volume must send them electronically in MS Word to K. Drinkwater (k.drinkwater@imr.no) no later than September 15th 2005. No papers will be accepted after this date. They should adhere to the Progress in Oceanography format, the guidelines of which can be found at http://authors.elsevier.com/GuideForAuthors.html?PubId=422&dc=GFA.

All papers will go through the standard peer review process. Approximately 40-50 papers from the symposium can be accommodated in the Symposium volume. If we receive many more papers than this, the guest editors (G. Hunt, S. McKinnell, D. Mackas and K. Drinkwater) will prescreen the submissions. This prescreening will be based upon the paper's contribution to the themes of the Symposium and its scientific quality. In addition, a balance in the number and topics of the papers for the different themes will be considered.

Timetable of Events

Bering Ecosystem Study (BEST) Workshop

Mon 16 May	08:00-09:30	Registration for BEST Workshop and Symposium
	09:00-10:15	Introduction and discussion of the Draft Implementation Plan
	11:15-14:15	Contributed talks
	14:15-16:15	Break-out groups for planning sections or areas of interest
	15:00-18:30	Registration for Symposium
	19:00	Official reception at Royal British Columbia Museum

Climate Variability and Sub-Arctic Marine Ecosystems Symposium

Tue 17 May	08:00-17:30	Registration for the symposium			
	09:00-10:30	Opening			
	11:00-12:30	Session 1: Regional focus			
	14:00-18:00	Session 1: continued			
	18:00-20:00	Poster Reception			
Wed 18 May	08:30-10:20	Session 2: Physical forcing and biological response in the water column			
	10:50-12:30	Session 3: Climate warming impacts on trophic coupling			
	14:00-15:40	4a: Physics and Chemistry	4b:Primary production	4c:Secondary Production	4d: Fish, shellfish, marine birds and mammals
	16:10-18:00	4a continued	4b continued	4c continued	4d continued
	18:00-20:00	Poster Session			
Thur 19 May	08:30-10:20	Session 5: Climate change and structure of ecosystems: the potential for trophic cascades			
	10:50-12:30	Session 6: Recent changes in ecosystem structure or function			
	14:00-15-40	Session 7: Implications of climate-forced changed for management and social institutions			
	16:10-17:30	Reports from the chairs of disciplinary sessions and panel led discussion			
	17:30	Summary and closing			
	18:00-19:00	Registration for ESSAS Workshop			

Ecosystem Studies of Sub-Arctic Seas (ESSAS) Workshop

Fri 20 May	08:30-09:00	Registration for ESSAS workshop
	09:00-09:30	Introduction of Draft Implementation Plan
	09:30-10:15	Contributed talks by leaders of National Programs that may contribute to ESSAS
	11:15-11:45	Contributed talks
	11:45- 12:45	Open discussion of ESSAS Implementation Plans
	14:15-16:15	Break-out groups for planning sections or areas of interest
	16:30-18:00	Plenary discussion of Plan modifications

Oral Presentations

Opening

Tue 17 May	09:00	George Hunt (convenor); Laura Richards, DFO; Cisco Werner, GLOBEC

Keynote speaker

Tue 17 May	09:30	How will ocean warming in the next 50 years affect sub-Arctic marine ecosystems? *R.T. Barber*
	10:30	Break

Session 1: Regional focus

Chair: Bern Megrey

Tue 17 May	11:00	Climate variability and the ecosystems of the Barents and Norwegian Seas *H. Loeng*
	11:30	Climate variation and the Icelandic marine ecosystem *O.S. Astthorsson, A. Gislason and S. Jonsson*
	12:00	Physical and biological dynamics of the Northwest Atlantic *B. deYoung*
	12:30	Lunch
	14:00	Climate variability and the ecosystems of the eastern and western Bering Seas *K.Y. Aydin*
	14:30	Climate variability and the Okhotsk Sea ecosystem *V.V. Lapko*
	15:00	An overview of the Oyashio ecosystem *Y. Sakurai*
	15:30	The Southern Ocean Global Ocean Ecosystems Dynamics program *E.E. Hofmann*
	16:00	Break
	16:30	Panel-led discussion on regional comparisons. *Panel Members: Egil Sakshaug (discussion leader), Eileen Hofmann, Dave Mackas and Sei-ichi Saitoh*
	18-20:00	Poster reception

Session 2: Physical forcing and biological response in the water column
Chair: Mishio J. Kishi

Wed 18 May	08:30	Physical forcing in sub-Arctic marine ecosystems *S. Sundby*
	09:00	Eddy-induced cross-slope exchange along the Bering Sea shelf break using a 3D ocean general circulation model and satellite multi-sensor remote sensing *K. Mizobata, J. Wang and S.-I. Saitoh*
	09:20	Climatic effects on the biological production of the Faroe Shelf *B. Hansen, E. Gaard, K.M.H. Larsen, P. Steingrund, H. Drange and A.B. Sandø*
	09:40	Environmental disturbance and resource partitioning as a source of population regulation of Northeast Pacific groundfish *A.B. Hollowed*
	10:00	Climatic impact on fish stocks in the sub-Arctic North Atlantic and Northwest Pacific *A.S. Krovnin and G. Moury*
	10:20	Break

Session 3: Climate warming impacts on trophic coupling
Chair: Eileen Hofmann

Wed 18 May	10:50	Effects on zooplankton of a warming ocean: recent evidence from the North Pacific *D.L. Mackas and S. Batten*
	11:10	Effects of the 1988/89 climatic regime shift on the structure and function of the southwestern Japan/East Sea ecosystem *C.I. Zhang, S.C. Yoon and J.B. Lee*
	11:30	Reproductive responses of planktivorous and piscivorous birds to climate variability in the northern Sea of Okhotsk *A. Kitaysky and E. Golubova*
	11:50	Recruitment of northern shrimp (*Pandalus borealis*) at West Greenland in relation to spawning stock size and environmental variation *K. Wieland*
	12:10	Multi-year variations of zoobenthos along the Kola Transect (southwestern Barents Sea) as a reflection on climate fluctuations *N.V. Denisenko, S.G. Denisenko, E. Rachor and S.V. Vasilenko*
	12:30	Lunch

Session 4a: Physics and chemistry
Chair: Jim Overland

Wed 18 May	14:00	The alpha/beta ocean distinction: freshwater fluxes and ventilation *E. Carmack*
	14:20	Comparison of atmospheric forcing in the four sub-Arctic seas *M. Wang, N.A. Bond and J.E. Overland*
	14:40	The Aleutian Low, stormtracks, and environmental variability in the Bering Sea *S. Rodionov, J.E. Overland and N.A. Bond*
	15:00	Warming of the Kamchatka current and a circulation anomaly in the western sub-Arctic Pacific *K. Rogachev, E. Carmack, and N. Shlyk*
	15:20	Coupled sea-ice/ocean numerical simulations of the Bering Sea for the period 1996-2003 *E. Curchitser, A. Hermann, K. Hedstrom and P. Budgell*
	15:40	Break
	16:10	The Bering Strait throughflow - an ambassador of the Bering Sea *R.A. Woodgate, K. Aagaard and T. Weingartner*
	16:30	Carbon cycling in the Bering Sea and their impacts to marine ecosystems in the sub-Arctic waters and the Western Arctic Ocean *L. Chen, Z. Gao, L. Zhan and S. Xu*
	16:50	Interannual variability in parameters of thermal frontal zones in the Barents Sea *O.V. Titov, V.K. Ozhigin and S.A. Ivanov*
	17:10	Variability of the flow of water masses on the North Icelandic Shelf *S. Jonsson and H. Valdimarsson*
	17:30	Break

Session 4b: Primary production
Chair: Terry Whitledge

Wed 18 May	14:00	Comparative study of primary production between the Okhotsk Sea and the Bering Sea using satellite and *in situ* data sets *S.-I. Saitoh, T. Iida, T. E. Whitledge, T.-K. Rho, A. Shiomoto and K. Sasaoka*
	14:20	Interdecadal variation of the lower trophic ecosystem in the sub-Arctic Northern Pacific between 1948 and 2002, using a 3D-NEMURO coupled model *M.N. Aita, K. Tadokoro, Y. Yamanaka and M.J. Kishi*
	14:40	An ecosystem modeling study of phytoplankton distribution in the Okhotsk Sea. *T. Okunishi, M.J. Kishi and T. Yamashita*
	15:00	The springtime plankton dynamics in the Bering Sea shelf and its effects on wind forcing and solar radiation *T. Iida, S.-I. Saitoh, J. Wang and M. Jin*
	15:20	Does sea ice contribute to the biogeochemical cycles of the Bering Sea? *R. Gradinger, B, Bluhm and H. Eicken*
	15:40	Break

Session 4b: continued

Wed 18 May	16:10	Coccolithophorid blooms and their chemical-controlling features in the Eastern Bering Sea *J. Zhang, H. Nishitani, H. Narita and R.W. Jordan*
	16:30	Climate variability, primary productivity and export fluxes in the Beaufort Sea: a modelling study *D. Lavoie, K. Denman and R. Macdonald*
	16:50	The return of the diatom *Neodenticula seminae* in the NW Atlantic after an absence of 0.8 million years: a consequence of recent changes in the Bering Sea? *M. Starr, M. Poulin, D. Johns, L. Bérard-Therriault, M. Edwards, P.C. Reid and S. Roy*
	17:10	Are satellite data useful for the prediction of phytoplankton species succession in the Irminger Basin? *C. Holeton, S. Henson and M. Lucas*
	17:30	Break

Session 4c: Secondary production
Chair: Hans-Jurgen Hirsche

Wed 18 May	14:00	Zooplankton production - Where are we and how to make advances? *K.S. Tande, A. Edvardsen, S. Basedow and M. Fossheim*
	14:20	Climate and food web effects on formation of jellyfish blooms *J.E. Purcell and M.B. Decker*
	14:40	Basin-scale population dynamics of the copepod *Calanus finmarchicus* in the sub-Arctic North Atlantic *P.H. Wiebe, A. Bucklin, D.J. McGillicuddy and E. Ünal*
	15:00	Temporal and spatial changes in *Oithona* spp. biomass and productivity in the sub-Arctic North Atlantic *C. Castellani, X. Irigoien and R.P. Harris*
	15:20	Interdecadal variability in zooplankton and phytoplankton abundance on the Newfoundland and Scotian shelves *E. Head and D. Sameoto*
	15:40	Break
	16:10	Distribution and reproduction of the dominant copepods *Calanus finmarchicus* and *C. glacialis* in the northern North Atlantic and the Arctic Ocean: implications under global change *H.J. Hirche and K. Kosobokova*
	16:30	Overwintering dynamics of *Calanus finmarchicus* in the eastern Norwegian Sea: model simulations *D. Slagstad and K.S. Tande*
	16:50	Who or what is regulating zooplankton production in the southeastern Bering Sea? *J.M. Napp, G.L. Hunt, Jr., S. Moore and C.T. Baier*
	17:10	Interannual variations in seasonal abundance of *Eucalanus bungii* in Oyashio waters *T. Kobari, K. Tadokoro and H. Sugisaki*
	17:30	Break

Session 4d: Fish, shellfish seabirds and mammals
Chair: Sue Moore

Wed 18 May	14:00	Top predators: indicators of climate change in marine ecosystems *S. Wanless*
	14:20	Effects of climate changes on the biological environments in the East Sea *C.I. Lee, J.-Y. Lee, D.S. Kim and K.D. Cho*
	14:40	Understanding of processes driving temporal variation in recruits per spawner of Bering Sea salmon (*Oncorhynchus*) populations based on analyses of spatial scales of correlation among stocks *R.M. Peterman, B.J. Pyper, F.J. Mueter, B. Dorner and S.L. Haeseker*
	15:00	Variability in growth of chum salmon (*Oncorhynchus keta*) in sub-Arctic Pacific related to 1988/89 climate change *H. Seo, K. Seong, S. Kim and S. Kang*
	15:20	Feeding migration and diet of Norwegian spring spawning herring in relation to the seasonal cycle of *Calanus finmarchicus* in the Norwegian Sea *C.B.T. Årnes and W. Melle*
	15:40	Break
	16:10	Systems ecology of marine ecosystems: a comparison of ecosystem level properties of the Bering and Barents Sea *B.A. Megrey and K.Y. Aydin*
	16:30	Ocean climate variability and recruitment success of northern shrimp *Pandalus borealis* and snow crab *Chionoecetes opilio* on the Northwest Atlantic continental shelf *D. Gilbert ,Y. Lambert, P. Ouellet, B. Sainte-Marie, L. Savard and M. Starr*
	16:50	Impact of climate change on zooplankton communities, seabird populations and Arctic terrestrial ecosystem - a scenario *L. Stempniewicz*
	17:10	Climate change and murres: a circumpolar seesaw *D.B. Irons, T. Anker-Nilssen, A.J. Gaston, G.V. Byrd, K. Falk, G. Gilchrist, M. Hario, M. Hjernquist, Y.V. Krasnov, A. Mosbech, G. Robertson, B. Olsen, A. Petersen, H. Strom and K.D. Wohl*
	17:30	Break
	18-20:00	Poster Session

Session 5: Climate change and the structure of ecosystems: the potential for trophic cascades
Chair: Erica Head

Thur 19 May	08:30	Spatial and temporal operation of ecosystems: the response of Southern Ocean food-webs to variability and change. *E.J. Murphy*
	09:00	The structural forcing of climate; a tale of two food webs *S. Gaichas and K.Y. Aydin*
	09:20	Does climate-driven variability in the oceanographic structure of the Gulf of Alaska Shelf affect fish community composition by modulating the degree of interspecific competition between juvenile pollock and capelin? *E.A. Logerwell, A.B. Hollowed, C. Wilson and P. Stabeno*
	09:40	Modeling approaches to marine ecosystem research and management *E. Svendsen, M. Skogen, P. Budgell, G. Huse and B. Ådlandsvik*
	10:00	Effects of climate variability and change on the ecosystems of the sub-Arctic inland seas of Canada: The Gulf of St. Lawrence and Hudson Bay *F.J. Saucier*
	10:20	Break

Session 6: Recent changes in ecosystem structure or function
Chair: Ian Perry

Thur 19 May	10:50	Effects of climate change on fish distribution and dynamics in the northern North Atlantic *K. Brander*
	11:10	Interdecadal variability in *Neocalanus* copepods biomass in the Oyashio waters from 1970 to 2002 *K. Tadokoro, H. Sugisaki and H. Saito*
	11:30	The changing southeastern Bering Sea shelf *P. Stabeno, J.M. Napp and T.E.Whitledge*
	11:50	The Bering Strait region: an arctic ecosystem in change *J.M. Grebmeier, L.W. Cooper and J.R. Lovvorn*
	12:10	Ocean climate variability and its effects on marine resources on the Newfoundland and Labrador Shelf *E.B. Colbourne, D.G. Parsons and E.G. Dawe*
	12:30	Lunch

Session 7: Implications of climate-forced change for management and social institutions

Chair: Rosemary Ommer

Thur 19 May	14:00	Fisheries–climate interactions: observations from the North Atlantic Arc *L. Hamilton*
	14:20	Impacts of climate change on Arctic communities *L. Merculieff*
	14:40	On ice, walruses, and men: a story of three storytellers *I. Krupnik and G.C. Ray*
	15:00	Climate change, marine resources and community health *H. Dolan*
	15:20	Linking the past to the present and planning for the future: human and ecosystem health in the Gulf of Alaska *M.S. Murray, L.K. Duffy, S.C. Gerlach, C. Hirons and J. Schaaf*
	15:40	Break
	16:10	Reports from Chairs of disciplinary sessions
	16:30	Panel Led Discussion: On what should we focus if we are to understand and predict the effects of climate change on Sub-Arctic marine ecosystems? *Panel members: Dick Beamish (Chair), Egil Sakshaug, Anne Hollowed, Michael Flint*
	17:30	Symposium summary *Victor Smetacek*
	18:00	Closing of Symposium *George Hunt and Ken Drinkwater*

Abstracts: Oral Presentations

Keynote speaker

TUE 9:45 (KEYNOTE SPEAKER)

How will ocean warming in the next 50 years affect sub-Arctic marine ecosystems?

R.T. Barber, V. Lance, J. Sarmiento, R. Slater and M. Hiscock

Duke University, Nicholas School of the Environment and Earth Sciences, Marine Laboratory, 135 Duke Marine Lab Road Beaufort, NC 28516, USA

A recent model study investigated the response of oceanic ecosystems to ocean warming using six coupled climate ocean model simulations; the six independent models were forced with identical carbon dioxide increase scenarios. Major oceanic domains were defined on the basis of vertical velocity, maximum mixed layer depth and seasonal sea ice cover. Modeled conditions in 2050 were compared with control conditions (at the beginning of the industrial revolution, 1850). Satellite ocean color was used to develop an empirical model to predict chlorophyll from physical conditions. Using three primary production (PP) algorithms, we estimated the PP based on estimated chlorophyll concentrations. Analysis of the change in global PP in 2050 showed <1% change from 1850. This surprising result was caused by the offsetting of small PP decreases in the large tropical and temperate ocean by large PP increases in the small polar and subpolar regions. This presentation analyzes results of this model study for sub-Arctic regions, showing predicted changes in sea ice, depth of winter mixing and length of the growing season, and their biological consequences. The analysis includes comparison of the different predictions by various models as well as the mean prediction of all six models. To the degree possible, the 2050 model predictions are compared with the remarkable changes observed recently. The goal of this analysis is to set the stage for detailed discussions of biological consequences presented by other meeting participants, and to show the utility of this kind of model experiment for understanding ocean warming consequences.

Session 1: Regional focus

TUE 11:00 (SESSION 1)

Climate Variability and the Ecosystems of the Barents and Norwegian Seas

H. Loeng

Institute of Marine Research, P.O.Box 1870 Nordnes, 5817 Bergen, Norway

Physical factors that make arctic marine ecosystems unique are a very high proportion of shallow continental shelves, dramatic seasonal change, generally low insolation, low temperature, extensive permanent and seasonal ice-cover, and a large supply of freshwater from rivers and melting ice. Because of these conditions, many of which are challenging for marine biota, arctic marine ecosystems have a large number of specialists, many of which are not found elsewhere. These organisms have through time been able to adapt to the environment, they are still challenged by extreme inter-annual variations. The possible pathways by which climate variability may affect ecological processes are many and vary across a broad range of temporal and spatial scales. Climate variability affects fish both directly through physiology, including metabolic and reproductive processes, as well as through affecting their biological environment (predators, prey, species

interactions) and abiotic environment (habitat type and structure). Furthermore, ecological responses to climatic variation may be immediate or lagged, linear or nonlinear, and may result from interactions between climate and other sources of variability. The Barents and the Norwegian seas are two of the most productive seas adjacent to the Arctic Ocean. The presentation will focus on physical and biological characteristics of the two seas, and how the two ecosystems interact. It will also give some suggestions for how these two ecosystems might look like in the future and finally point out several gaps of knowledge in how climate influences these ecosystems.

TUE 11:30 (SESSION 1)

Climate variation and the Icelandic marine ecosystem

O.S. Astthorsson, A. Gislason and S. Jonsson
Marine Research Institute, Skulagata 4, Reykjavik, Iceland

The physical oceanographic character and faunal composition in the southern and western parts of the Icelandic marine ecosystem are different from that in the northern and eastern areas. The former areas are more or less continuously bathed by warm and saline Atlantic water while the latter are influenced by Atlantic, arctic and even polar water masses. In the Atlantic water, hydrographic conditions are relatively stable, while large interannual variations in water mass distribution (and temperature and salinity) characterize the mixed waters. Mean annual primary production is higher in the Atlantic water than in the mixed waters and also it is generally higher closer to land than farther offshore. Similarly, zooplankton production is generally higher in the Atlantic water than in the mixed waters. *Calanus finmarchicus* is usually the numerically dominant zooplankton species, *ca*. 60-90% in the south and *ca*. 60% in the north. About 40 species of fish and invertebrates are expoited commercially in Icelandic waters. The main spawning grounds of most of these stocks are in Atlantic waters while the feeding and nursing grounds are in mixed waters. In recent years the total catch has been in the range of 1.6-2.4 million tonnes. Capelin (*Mallotus villosus*) is by far the most important pelagic stock (annual catch ca. 0.7-1.5 million tonnes) and between year variations in the total catch are mainly due to variations in the capelin catch. Cod (*Gadus morhua*) is by far the most important demersal fish stock (catch in recent years *ca*. 200 thousand tonnes). Deep-water shrimp (*Pandalus borealis*) is the largest benthic invertebrate stock exploited (catch in recent years *ca*. 40 thousand tonnes). Whales are an important component of the Icelandic marine ecosystem. Long finned pilot whale (*Globicephala melaena*) and minke whale (*Balaenoptera acutorostrata*) are the most abundant cetacean species (*ca*. 60 thousand individuals). Icelandic waters are further an important habitat for some of the largest seabird populations in the Northeast Atlantic with an estimated 7.7 million breeding pairs of about 20 species breeding on the island. Atlantic puffin (*Fratercula arctica*) is by far the largest seabird population with 2.8 million breeding pairs. In the mixed waters to the north and east, available information suggests that a simple bottom up controlled food chain form phytoplankton through *Calanus*, capelin and to cod is a very dominating factor in the ecosystem. Less is know about the structure of the more complex southern part of the ecosystem. The Icelandic marine ecosystem is highly sensitive to climate variations as demonstrated by abundance and distribution changes of many species during the warm period in the 1930s, the cold period in the late 1960s and warming observed during recent years. Some of these are highlighted in the paper.

TUE 12:00 (SESSION 1)

Physical and biological dynamics of the Northwest Atlantic

Brad deYoung

Dept. of Physics and Physical Oceanography, Memorial University, St. John's, Canada NF A1B 3X7

The Northwest Atlantic is one of the most dynamic oceanic regions on the planet. Sea-ice and deep water form there in the winter, majestic icebergs sail by in summer. A strongly coupled advective regime, water masses can be traced along from Northern Labrador to the mid-Atlantic Bight. Nutrient and freshwater fluxes from Hudson Strait influence productivity all along the shelf to the south including the Newfoundland and Labrador shelves, the Gulf of St. Lawrence and the Scotian Shelf. The relative importance of along-shelf fluxes versus cross-shelf transport with the open ocean remains uncertain. While the seasonal signal still dominates in this region, we have seen dramatic interannual and decadal variability in conditions over the past fifty years for which we have good observations. Fifty years of overfishing has left its mark on the ecosystems of the Northwest Atlantic although it is clear the extremes of the physical environment have also influenced the distribution and productivity of fish of the Northwest Atlantic. New approaches to sampling the ocean and the shelf, and progress in numerical modeling, offer hope that some of our persistent questions may yet be answered.

TUE 14:00 (SESSION 1)

Climate variability and the ecosystems of the eastern and western Bering Seas

K.Y. Aydin

Alaska Fisheries Science Center, US NOAA Fisheries, REFM Division, 7600 Sand Point Way, NE Seattle, WA 98115, USA

The Bering Sea shelf and slope ecosystems have shown dramatic shifts in species composition and population productivity of groundfish, crabs, and other species over the past 40 years. The regions have also been the source of some of the world's most valuable fisheries, and extensive data on population trends, species growth, and diets are available for analysis. In this talk, I review some of the biological changes that have been observed in the recent past, present current hypotheses linking climate and animal populations, and discuss aspects of community structure and climate that may have led to the observed variation within the region. Given the broad extent of data available for these regions, it is important to pose a fundamental question: even with substantial research resources available, what is our prognosis for understanding variability in sub-Arctic large marine food webs?

TUE 14:30 (SESSION 1)

Climate variability and the Okhotsk Sea ecosystem

V.V. Lapko

Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO), 196, Komsomolskaya Str. Yuzhno-Sakhalinsk, 693023 Russia

The last years of the 20th century can be defined as a relatively cold period over the Far East. Cyclic changes in atmospheric processes and ice conditions in the Sea of Okhotsk indicate recurrence of a cold synoptic type atmospheric pattern development of heavy ice conditions and decreasing water temperature. Time series data on zooplankton abundance indicate cyclic fluctuations of biomass with insignificant interannual variations during the last two decades. The high levels of plankton

abundance were recorded in relatively warm climatic periods while the lowest biomass was observed in cold ones. In pelagic fish communities such species as pollock and sardine predominated from the late 1970s to the mid 1990s. Starting from the 1990s, the biomass of both species drastically decreased and the abundance of such fishes as herring, capelin, Japanese anchovy, salmon, arabesque greenling, etc. increased. However, up to now pollock remains the most abundant epipelagic fish in the Sea of Okhotsk in spite of a general decline of fish biomass. A significant decrease of biomass for demersal fishes of all major species and groups (cod, large and small flatfishes, skates) excepting sculpins occurred in the Sea of Okhotsk. Total stock of demersal fishes was halved since 1997 to 2000. The biomass of demersal invertebrates also decreased to one third in total, mainly due to crabs, shrimps and gastropods, while such groups as sea urchins and squids slightly increased in abundance.

TUE 15:00 (SESSION 1)

An overview of the Oyashio ecosystem

Y. Sakurai

Division of Marine Environment and Resources, Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato-cho, Hakodate, Hokkaido, 041-8611 Japan

The western sub-Arctic Pacific, including the Oyashio shelf region, is one of the high productivity zones in the world and supports a wide range of commercially important marine species. These include not only gadids such as the walleye pollock, but also sub-Arctic migrating pelagic fish such as salmon and herring. The western sub-Arctic Pacific is also an important summer feeding ground for subtropical migrants like the Japanese sardine, Japanese saury, whales and sea birds. The general biological oceanography questions for the Oyashio region consist of the following:

- How the Oyashio affects the ecology during the early development stages which may lead to changes in the stock of walleye pollock, a key species in the Oyashio shelf region.
- How to clarify the influence of the oceanic environment, phytoplankton and zooplankton to the stock variation of pelagic and demersal fish species through process studies and ecosystem modeling.
- How changes in ocean climate will alter the productivity of keystone species, including walleye pollock, salmon and pelagic migratory fishes and squids.
- How changes in physical and anthropogenic forcing mechanisms influence the relative importance of top down vs. bottom up control of energy flow in the Oyashio ecosystem.
- What are the mechanisms that link physical forcing to biological processes and their spatial and temporal scales of interaction?
- To what extent do biological processes regulate the structure, energy flow, and dynamics of the food webs in the Oyashio ecosystem.
- What are the societal and economic impacts of climate variability on the Oyashio marine ecosystems and the feedbacks from changes in ecosystem use on these impacts?

In this review, we will present summaries of recent research activities in Oyashio region related to Japan-GLOBEC projects.

TUE 15:30 (SESSION 1)

The Southern Ocean Global Ocean Ecosystems Dynamics program

E.E. Hofmann

Old Dominion University, Center for Coastal Physical Oceanography, 768 W 52nd Street, Norfolk, VA 23529, USA

The focus of the Southern Ocean Global Ocean Ecosystem Dynamics (SO GLOBEC) program is on understanding the physical and biological factors that contribute to enhanced Antarctic krill (*Euphausia superba*) growth, reproduction, recruitment, and survivorship throughout the year. This focus also includes the predators and competitors of Antarctic krill, such as penguins, seals, cetaceans, fish, and other zooplankton. The SO GLOBEC program includes an extensive field effort, with participation by several nations, which has provided coverage in different regions of the Antarctic, such as the west Antarctic Peninsula, the Scotia Sea, the Lazarev Sea and the area around 70ºE. The SO GLOBEC field studies are multidisciplinary and include components to measure circulation, hydrography, water column and sea-ice primary production, krill distribution and abundance, krill physiology, fish ecology, penguin, seal and cetacean distribution and abundance, and krill predator diets. Similar sampling in the national field programs provides a basis for making comparisons between environments that differ in sea-ice cover, hydrographic structure and biological characteristics. The SO GLOBEC field programs provided some of the first comprehensive austral winter measurements, which provide a basis for understanding the effect of climate variability in the Antarctic. This presentation will highlight results from the SO GLOBEC program and suggest areas where comparisons can be made with studies that will be done as part of the Ecosystem Studies of Sub-Arctic Seas program.

Session 2: Physical forcing and biological response in the water column

WED 8:30 (SESSION 2)

Physical forcing in sub-Arctic marine ecosystems

S. Sundby

Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

Changes in the large-scale atmospheric pressure systems display the most prominent examples of how marine ecosystems are influenced by physical forcing. The effects seem to become particularly clear and measurable because of the large spatial and temporal integration of the states and the processes involved. The mechanistic links between such large-scale features and the marine ecosystems are explained in a large diversity of ways depending on the region and the trophic level considered. In sub-Arctic marine ecosystems sea temperature is a dominating factor influencing marine populations both directly and indirectly through trophic transfer. However, the temperature is also strongly interlinked with other climate parameters such as advection of water masses, turbulence, light conditions and nutrient concentrations. Examples are given how marine populations respond differently to climate parameters in the various marine ecosystems. The concept of regime shifts in geophysics and marine ecosystems is discussed.

WED 9:00 (SESSION 2)

Eddy-induced cross-slope exchange along the Bering Sea shelf break using a 3D ocean general circulation model and satellite multi-sensor remote sensing

K. Mizobata, J. Wang and S.-I. Saitoh

Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato, Hakodate, Hokkaido, Japan, 041-8611

This study investigated the Bering Slope Current (BSC) eddy field, the primary production and the shelf-slope exchange during 1998-2002, using a 3D ocean general circulation model and satellite multi-sensor remote sensing. The eddy simulation revealed, 1) the fluctuation of the eddy field results from BSC-bathymetry interaction and baroclinic instability, and 2) high eddy activity induces an increase in cross-shelf fluxes at the shelf break. While the eddy activity is high during summer, the influence of the wind field on the eddy activity is small because of low wind speeds (about 2~3 ms^{-1}). In 1999, a La Niña year (indicating weak Aleutian Low in winter), the altimeter analysis shows the stable eddy field and low primary production over the Bering Sea basin and in the Gulf of Alaska. In 2002, an El Niño year (indicating strong Aleutian Low in winter), high eddy activity field was observed and primary production emerged around the Aleutian Passes, and over the Bering Sea Basin. The eddy kinetic energy variability over the Bering Sea Basin is affected by the inflow of North Pacific water through Aleutian Passes. These results indicate that the eddy field and the primary production over the Bering Sea basin tend to be changed by the climatic forcing through the inflow from Aleutian Passes.

WED 9:20 (SESSION 2)

Climatic effects on the biological production of the Faroe Shelf

B. Hansen, E. Gaard, K.M.H. Larsen, P. Steingrund, H. Drange and A.B. Sandø

Faroese Fisheries Laboratory, Box 3051, FO-110 Torshavn, Faroe Islands

The Faroe Shelf has a highly variable primary production. The accumulated new production during spring and early summer varies by at least a factor of three from one year to another and this seems to affect even top predators like the local cod and haddock stocks, which exhibit inter-annual variations in both recruitment and growth in phase with the primary production. Previous studies have indicated a causal link between these variations and winter air temperature. In cold winters, the on-shelf water becomes considerably more dense than the off-shelf water. This density difference is hypothesized to reduce the horizontal exchange between on-shelf and off-shelf waters and numerical models indicate that this can allow a strong spring bloom, whereas a weak density difference from a warm winter is suggested to enhance horizontal exchange and inhibit the spring bloom. This hypothesis is well supported by detailed investigations carried out since 1990, but it will only work, if off-shelf waters change slowly. Here, we expand the hypothesis by using the output from a numerical ocean model (MICOM) to simulate off-shelf conditions. From these and air temperature, we calculate accumulated new production during the spring bloom for all years since 1948 and compare these values to measured new production since 1990 and to cod and haddock recruitment and growth since 1960. In future climate change, differences between summer and winter temperatures and between air and sea temperatures may well change. This could affect biological production on the Faroe Shelf and other similar sub-Arctic areas profoundly.

WED 9:40 (SESSION 2)

Environmental disturbance and resource partitioning as a source of population regulation of Northeast Pacific groundfish

A.B. Hollowed

Alaska Fisheries Science Center, 7600 Sand Point Way NE Seattle, WA 98115, USA

This analysis provides two case studies for groundfish stocks with different levels of complexity in factors influencing early life history characteristics. In ocean systems, environmental disturbance influences the spatial distribution of habitat creating spatially and temporally dynamic patterns of resource availability and species interaction. The study provides evidence for ecological disturbance and its role in mediating competition and predation using information collected for two case studies of groundfish. Case 1 addresses factors influencing survival of rock sole, Alaska plaice and flathead sole in the Bering Sea. This analysis reveals that cross-shelf transport to nursery grounds may be a dominant factor controlling recruitment. Recruitment patterns are highly correlated with atmospheric forcing. Oceanographic influences on winter spawning flatfish shows that resource limitation has the highest probability of occurring when cross-shelf advection transports reproductive products into favorable nursery grounds. Case 2 addresses factors influencing survival of walleye pollock. Our analysis reveals that successful recruitment is linked to a complex sequence of events leading to intermittent recruitment events. Extreme year classes support the population through moderate longevity of the fish. The magnitude of extreme year classes is a function of predator abundance regulated by the production of juvenile fish necessary to satiate key predators. Predator controls are regulated by spatial temporal overlap of predator, abundance of alternative prey and the abundance of juvenile pollock. An alternative functional form for modeling spawners and recruitment is introduced that addresses temporal sequences of environmental disturbance.

WED 10:00 (SESSION 2)

Climatic impact on fish stocks in the sub-Arctic North Atlantic and Northwest Pacific

A.S. Krovnin and G. Moury

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17, Verkhnyaya Krasnoselskaya, Russia

Both the combined and separate principal component (PC) analysis was applied to 75 physical and biological time series from the sub-Arctic North Atlantic, Northwest Pacific and adjacent sub-Arcitc between 1970 and 2001. The results show a similarity between the first three biological and climatic PCs and PC scores for the full data set. However, while the biological PCs reveal a clear year-to-year persistence, the climatic PCs reveal a rather strong interannual variability superimposed on decadal regimes. Similar results were obtained by Hare and Mantua (2000) for the Northeast Pacific. At the same time, the correlations between global or regional atmospheric and oceanic indices and survival indices ranged between these three groups: unfavourable, moderate and favourable survival conditions these are weak in most cases, especially for moderate conditions. As for extreme cases of survival conditions, sometimes it is possible to distinguish the leading climatic factors possibly affecting the year-class formation. However, even in this situation the sign of the relationship may be opposite to that on the decadal time scale. The mechanisms involved will be discussed. In particular, there is a marked out-of-phase relationship between variations of sea surface temperature anomalies in the Northwest Pacific and Northwest Atlantic (r=-0.69) which can be explained by the teleconnection patterns in the middle troposphere. This relationship may be responsible for association in fish stock fluctuations in the above regions.

Session 3: Climate warming impacts on trophic coupling

WED 10:50 (SESSION 3)

Effects on zooplankton of a warming ocean: recent evidence from the North Pacific

D.L. Mackas and S. Batten

Fisheries and Oceans Canada, Institute of Ocean Sciences, PO Box 6000, Sidney, BC, Canada V8L 4B2

During the past three decades, there have been at least three mechanisms by which variability of sea surface temperature has been associated with large changes in zooplankton productivity patterns in the mid- and high-latitude North Pacific:

1. biological changes in zooplankton phenology (the timing of seasonal life history events). Warmer water is associated with an earlier peak of the biomass of large interzonal-migrant copepods (*Neocalanus* spp.) and an earlier onset of seasonal dormancy.
2. physical changes in vertical density stratification, and resulting bottom-up changes in nutrient supply and microplankton production. Warmer water is associated with lower total nutrient supply, and an earlier and narrower peak of microplankton production and biomass
3. indirect covariance due to changes in horizontal circulation, and shifts in zoogeographic boundaries. Warmer water is associated with stronger poleward/weaker equatorward transport, and with shifts in community composition toward species with smaller body size, lower lipid content, shorter life cycle, and semi-continuous reproduction.

In this paper, we review and update the evidence in each of these three responses, and speculate briefly about possible consequences of further warming.

WED 11:10 (SESSION 3)

Effects of the 1988/89 climatic regime shift on the structure and function of the southwestern Japan/East Sea ecosystem

C.I. Zhang, S.C. Yoon** and J.B. Lee

Pukyong National University, DaeYeon-3-dong, Nam-gu, Korea

*** Presenting author*

The late 1980s climatic regime shift (CRS) in the strength of North Pacific high pressure and the Kuroshio Current influenced the structure and function of the southwestern Japan/East Sea ecosystem. The seawater temperature anomaly at the 50m depth layer shifted from negative to positive after 1988. Composition of major zooplankton assemblages changed and zooplankton biomass started to increase in the late 1980s. The distributional area of subtropical zooplankton such as salps overlapped with that of small pelagics. An increase in recruitment and biomass of small pelagics, especially chub mackerel was attributed to the increase in the availability of their prey organisms in the ecosystem. The 1988/89 CRS event also changed the structure of the ecosystem, and the biomass and production of fisheries resources in the southwestern Japan/East Sea. The mean trophic level (TL) increased from 3.05 in the pre-1988 CRS period to 3.23 in the post-CRS period. Catch per unit area of 3 groups increased while those of 11 groups decreased. Total catch decreased by 9% due to the decrease in the catch of walleye pollock. These results indicated that

there were substantial changes in the function of major species in the southwestern Japan/East Sea ecosystem. The relative contribution of walleye pollock at the TL III to the total flow of energy drastically decreased from 36.4% in the pre-CRS period to 4.3% in the post-CRS period, while the relative contribution of common squid at the same TL doubled from 36.8% to 71.7% during the periods.

WED 11:30 (SESSION 3)

Reproductive responses of planktivorous and piscivorous birds to climate variability in the northern Sea of Okhotsk

A. Kitaysky [1] and E. Golubova [2]

[1]*Institute of Arctic Biology, Department of Biology and Wildlife, University of Alaska Fairbanks, 311 Irving 1, Fairbanks, AK, 99775, USA.*

[2]*Institute of Biological Problems of the North, Laboratory of Ornithology, Portovaya-18, Magadan, 685000, Russia*

We used long-term (1987-2004) series of observations on seabird reproductive success and oceanographic change in Tauyskaya Bay (Okhotsk Sea, northwestern Pacific) to evaluate the hypothesis that changes in marine climate may favour the productivity of one group of upper trophic level predators over another through fluctuations in the availability of their prey. We found that in the continental shelf ecosystems in the northwestern Pacific (Talan I., northern Okhotsk Sea), birds foraging on macro-zooplankton and birds foraging on forage fish show opposite reproductive trends. This pattern was strongly correlated with interannual climate variability in the North Pacific. A positive North Pacific index of atmospheric pressure anomaly, early dates of ice disappearance, and warm local sea-surface temperature were positively correlated with productivity of piscivorous and negatively correlated with productivity of planktivorous seabirds. A “warm” regime was associated with high abundance of mesozooplankton, which may in turn affect forage fish abundance. Macrozooplankton organisms, which are the main prey of planktivorous seabirds, were more abundant during a “cold” regime. During a “warm” regime, when inflow of oceanic waters into shelf areas was weak, proportions of oceanic copepods in seabird diets were lower compared to those during a “cold” regime when in-flow of oceanic waters was relatively strong. Thus, climate-driven alternations in a composition and timing of peak of zooplankton communities and abundance of forage fish probably represent causal mechanisms responsible for opposite trends in reproductive performance of piscivorous and planktivorous seabirds.

WED 11:50 (SESSION 3)

Recruitment of northern shrimp (*Pandalus borealis*) at West Greenland in relation to spawning stock size and environmental variation

K. Wieland

Greenland Insitute of Natural Resources, PO Box 570, DK 3900 Nuuk, Greenland

Survey estimates of biomass of northern shrimp in West Greenland waters increased from about 290,000 t in 1998 to about 650,000 t in 2003 and 2004. This increase was preceded by an increase of water temperature and several years in which recruitment was substantially above average. In the most recent years, however, recruitment decreased and was below what could have been expected from record high levels of spawning stock biomass. Standard and modified Ricker stock-recruitment

functions incorporating environmental variables were used in order to examine the effect of spawning stock size, mean female length, predator biomass (Atlantic cod and Greenland halibut) as well as surface and bottom temperature on the recruitment of northern shrimp at West Greenland. The standard Ricker model explained about 10% of the observed recruitment at age 2. A much higher proportion of the variability was explained with environmental variables incorporated in the stock-recruitment relationship. Here, significant variables were mean female size, bottom temperature in the year the larvae settled and biomass of Greenland halibut as a proxy for predation on the 1-group in addition to parental stock size. This indicates that recruitment of northern shrimp at West Greenland is not independent from spawning stock size (and hence from effects of the fishery) but the environment substantially modifies it.

WED 12:10 (SESSION 3)

Multi-year variations of zoobenthos along the Kola Transect (the southwestern Barents Sea) as a reflection on climate fluctuations

N.V. Denisenko, S.G. Denisenko, E. Rachor and S.V. Vasilenko

Zoological Institute of the Russian Academy of Sciences, Universitetskaya nab., 1199034, St. Petersburg, Russia

The Barents Sea is strongly influenced by the warm Atlantic waters and the frontier biogeographic zone is located in the western part of it, where the heating content of the sea water depends on climate fluctuations. Phases of warming and cooling in the sea are accompanied by variations in species composition and in biogeographic structure of marine zoobenthos. Studies carried out in the 1990s gave additional data for the better understanding of the role of climate fluctuations on zoobenthos distribution. The 5-year monitoring along 11 oceanographic standard stations at the Kola transect (S-N on 33º30'E) has shown variations not only in the species composition and its biogeographic structure with the temperature variability in the Barents Sea, but also in abundance, biomass, community structure and in predomination of different trophic groups in faunal associations. The monitoring data were supported by results from quantitative archive data collected along the section since the beginning of the 20th century. In the warming periods the shares of the boreal and Atlantic boreal-arctic forms of the bottom fauna, as well as its total abundance and biomass, increased. On the community level the role of the boreal species are not so important, while the Boreal-Arctic species are more numerous in abundance and biomass, and therefore dominant. In the warming periods among the dominant species, the surface deposit feeders were more importatnt than the subsurface deposit feeders.

Session 4a: Physics and chemistry

WED 14:00 (SESSION 4A)

The alpha/beta ocean distinction: freshwater fluxes and ventilation

E. Carmack

Department of Fisheries and Oceans, Institute of Ocean Sciences, 9860 West Saanich Road, Sidney, BC V8L 4B2 Canada

Two simple aspects of the ocean's climate system appear to have a surprisingly important role in transforming waters that feed the global thermohaline circulation, dominating patterns of biogeochemical flux and establishing macroecological domains. First, because of meridional distillation, the North Pacific is fresher than the North Atlantic; second, because of zonal distillation, the upper layers of subtropical seas are stratified by temperature (NT2 = gdT/dp > 0; here called alpha oceans), while the upper layers of high-latitude seas are stratified by salinity (NS2 = gdS/dp > 0; here called beta oceans). The physical basis for the boundary separating alpha and beta oceans is unclear, but may lie in the thermodynamical conservation equations published in 1961 by N. P. Fofonoff while working at the Pacific Biological Station in Nanaimo. It is clear that the resulting thermohaline distributions establish a 'downhill journey' from the North Pacific to the Arctic and then into the North Atlantic. The Arctic Ocean itself acts a double estuary, whereby waters entering from the North Atlantic become either denser through cooling (negative estuary) or lighter by freshening (positive estuary) as they circulate within the basin. It is argued that this simple distinction (alpha versus beta oceans) provides a broad framework for simple interpretation of key oceanic processes and rates, including the impacts of climate variability.

WED 14:20(SESSION 4A)

Comparison of atmospheric forcing in the four sub-Arctic seas

M. Wang, N.A. Bond and J.E. Overland

JISAO, University of Washington, JISAO/PMEL, box 753941, University of Washington, Seattle, WA 98195, USA

The present study builds upon previous work on the role of climate variability in controlling marine populations of various species in the sub-Arctic seas. Our objective is to carry out a comparative analysis of the variability of the atmospheric forcing of four sub-Arctic seas, the Bering Sea, Barents Sea, Sea of Okhotsk and Labrador Sea. We consider mechanisms influencing air-sea interaction on sub-seasonal to decadal time scales with a focus on parameters related to ice cover, ocean currents, mixing and stratification, based on data from the NCEP/NCAR reanalysis. The results are used to document the climatology and variability of elements of the atmospheric forcing important to the marine ecosystem, emphasizing the changes and trends that have occurred in the last few decades, and to identify and contrast the key forcing factors for each region. Our analysis is designed to provide information for pan-regional synthesis of the linkages between climate and the marine ecosystem.

WED 14:40 (SESSION 4A)

The Aleutian Low, stormtracks, and environmental variability in the Bering Sea

S. Rodionov, J.E. Overland and N.A. Bond
University of Washington/JISAO, PMEL, 7600 Sand Point Way, Seattle, WA 98115, USA

The Aleutian Low represents a primary element of the atmospheric forcing of the Bering Sea. Our analysis shows how variations in the Aleutian Low, and its associated storm tracks, are related to air-sea interactions in the Bering Sea during winter. The Bering Sea tends to be warmer (colder) than normal when the Aleutian Low is stronger (weaker), but the geographical position of this center of action is shown to be more important than its central pressure. The major atmospheric circulation pattern associated with mild winters in the Bering Sea is characterized by a shift of the Aleutian Low to the northwest of its normal position and an invigorated storm track along the Siberian coast. Another warm pattern, which became more frequent after the 1977 regime shift, is characterized by a strong Aleutian Low, when the storm track is shifted south over the central North Pacific and then curves to the northeast into the Gulf of Alaska and southeastern Bering Sea. In this situation, the low-level flow over the shelf tends to be of maritime origin and relatively mild, even when the winds are from the north. Anomalously cold winter weather in the Bering Sea generally occurs when the Aleutian Low is split into two centers, and when storm tracks are eastward staying south of the Aleutian Islands. This results in the relative preponderance of air masses of continental or Arctic origin over the shelf. Through their effects on wintertime atmospheric conditions, storm tracks have a profound effect on ice cover and hence the ecosystem of the Bering Sea. We show how these effects have been manifested on intra-seasonal to interannual time scales since the middle of the 20th century.

WED 15:00 (SESSION 4A)

Warming of the Kamchatka current and a circulation anomaly in the western sub-Arctic Pacific

K. Rogachev, E. Carmack and N. Shlyk
Pacific Oceanological Institute, 43 Baltiyskay Street, Vladivostok, 690041, Russia

A major challenge is to understand the mechanisms that determine variability within the Pacific western sub-Arctic boundary currents: the Kamchatka Current with its continuation, the Oyashio. Long-term oceanographic observations have revealed an increase in the temperature and salinity of the warm intermediate layer in the western sub-Arctic. In 1990, the Alaskan Current did not enter the Bering Sea through the Near Strait. At the end of 1991, however, this water started to enter the Bering Sea and the outflow of the Kamchatka Current increased. This increase of transport was accompanied by the rise of sea level in the Kamchatka Current. This current exhibits large seasonal and interannual variations of sea level (of order ~12 cm), superimposed on a pronounced decadal trend. Sea level in the Kamchatka Current had minimum values in 1990-1991, rose through to 1997 and then dropped until 2000. We show that such multi-year anomalies of sea level are associated with variations of the depth of halocline - dynamic height - and that they reflect the outflow of low salinity water from the Bering Sea.

WED 15:20 (SESSION 4A)

Coupled sea-ice/ocean numerical simulations of the Bering Sea for the period 1996-2003

E. Curchitser , A. Hermann , K. Hedstrom and P. Budgell
Lamont-Doherty Earth Observatory of Columbia U., 61 Route 9W, Pallisades, NY 10964, USA

A coupled, regional sea-ice/ocean model has been developed to examine the interannual variability of circulation, sea-ice extent, thickness and concentration within the Bering Sea for the period 1996-2003. In particular, we examine the variability induced by the 1997/1998 El Niño, and the post-1999 cool phase in the Northeast Pacific. Our coupled model is based on the Regional Ocean Modeling System (ROMS), implemented at 10 km resolution for a Northeast Pacific domain, which includes the Gulf of Alaska and the Bering Sea. The regional model is embedded in a lower resolution basin-scale model, which is used to generate the large-scale signals and provides both boundary and initial conditions for the Bering Sea via one-way nesting. Ice dynamics are based on the efficient elastic-viscous-plastic rheology of Hunke and Dukowicz (1997); ice thermodynamics are based upon Mellor and Kantha (1989) and include a three level ice layer, a snow layer, and a molecular sub-layer at the ice/ocean interface. Atmospheric forcing is derived from NCEP reanalysis fluxes, corrected for model sea surface temperature and sea-ice concentration. Regional model results are compared with satellite derived products based upon Pathfinder SSM/I and sea surface temperature. We further compare interannual patterns of the Bering with those of the Barents/Norwegian Seas, derived from ongoing, ROMS-based, sea-ice/ocean modelling of that region.

WED 16:10 (SESSION 4A)

The Bering Strait throughflow - an ambassador of the Bering Sea

R.A. Woodgate, K. Aagaard and T. Weingartner
University of Washington, Applied Physics Laboratory, 1013 NE 40th Street, Seattle, WA 98105, USA

At the northern end of the Bering Sea, the ~85 km wide, ~50 m deep Bering Strait offers the only ocean pathway for Bering Sea and Pacific waters into the Chukchi Sea and Arctic Ocean. The flow through the strait dominates the Chukchi Sea, and influences the Arctic Ocean and probably even global thermohaline circulation. The properties of the Bering Strait throughflow are determined by processes in the Bering Sea to the south. The throughflow is an integrator of Bering Sea change and, as such, acts as an ambassador of the Bering Sea to the world oceans. Since 1990, moored near-bottom measurements in the Bering Sea region have quantified seasonal and interannual variability in transport and watermass properties. The flow is highly variable. Weekly transports vary between ca - 2 Sv and + 3 Sv, and seasonal cycles are ca. 0.3 to 1.3 Sv, -1.7 to 8ºC; 31 to 34.5 psu. Interannual variability in water properties is substantial, with a clear warming from 1991 to 1997 followed by cooling until 2001. There are indications of increasing freshwater transport since 2002. As yet, there is not significant change in net volume transport. Recent summer/autumn CTD surveys and profiling moorings also indicate the substantial role of the coastally-trapped, buoyant Alaskan Coastal Current in the Bering Strait and Chukchi Sea regions and revise the Bering Strait freshwater flux estimate to ~ 2500 km^3/yr (with errors ~300 km^3/yr).

WED 16:30 (SESSION 4A)

Carbon cycling in the Bering Sea and their impacts to marine ecosystems in the sub-Arctic waters and the Western Arctic Ocean

L. Chen, Z. Gao, L. Zhan and S. Xu

Key Laboratory of Global Change and Marine-Atmospheric Chemistry, SOA, 1 Fuxingmenwai Av., Beijing 100860, PR China

The 1st and 2nd Chinese National Arctic Research Expedition were carried out respectively in the summers of 1999 and 2003 to survey the Bering Sea and the western Arctic Ocean. The partial pressure of CO_2 in surface water (pCO_2) was continually measured using a Li-Cor 6262 CO_2/H_2O infrared analyzer on board the icebreaker *Xuelong*. Distributions of pCO_2 show an obvious difference with geographic difference with lower values on the continental shelf, increasing in slope region and highest in abyssal plains such as the Canadian Basin. Major driving forces were analyzed and attributed to biological or physical processes. The Chukchi Sea appears to be a region of absorption of atmospheric CO_2 through rapid sea-ice melting, high primary production on the continental shelf and in the marginal ice zone (MIZ), and transformed water from the Bering Sea, etc. Concentrations of pCO_2 exhibit large fluctuations in the Chukchi continental shelf, which can be traced to inflows from the Bering Abyssal Plain and the Alaska coast current, which bring higher pCO_2 water to the shelf. In the Bering Strait adjacent area (66-69ºN), pCO_2 in mid-August is much lower than that in the end of July due to blooming of alga in this season. Between 68.5-69ºN along 169ºW, the pCO_2 and SST in August is much higher than in July, which is attributed to a water mass transport from the Alaska Coastal Current (ACC). In August in the MIZ, temperature and pCO_2 increased slightly with SST playing a major role in the melting of the sea ice, and the receding of the pack ice. In order to understand air-sea interaction of greenhouse gasses in the role of global climate change and contribute to IPY (International Polar Year) 2007/08, CHINARE will conduct the third and fourth Chinese National Arctic Research Expeditions, respectively in 2006 and 2008, especially focusing on the air-sea flux of greenhouse gases such as carbon dioxide relative to climate variability and impacts to sub-Arctic marine ecosystems in the Bering Sea and the western Arctic Ocean.

WED 16:50 (SESSION 4A)

Interannual variability in parameters of thermal frontal zones in the Barents Sea

O.V. Titov, V.K. Ozhigin and S.A. Ivanov

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, Murmansk, 183763, Russia

The location of the Barents Sea between the Arctic and boreal oceanic systems determines the lengthy frontal zones. The Barents Sea ecosystem supports high biological productivity and is endowed with diverse commercial species. To some extent, this is also encouraged by processes in the frontal zones. There are a number of papers dealing with the frontal zones in the Barents Sea; however, the issue on year-to-year variations in their parameters such as position and gradient values under the effect of climate fluctuations is still little known. Earlier it was hypothesized that changes in climate could have an effect on sharpening of the frontal zones in the Barents Sea. In this investigation we attempted to understand how climatic changes could affect biological and fish productivity in the Barents Sea. The objective of the paper is to estimate how sharp the thermal frontal zones in the Barents Sea were in years of different temperatures and ice coverage as well as to suggest indexes describing the main features of the long-term variability of the frontal zone parameters. To achieve this objective, a method to estimate interannual variability in parameters of the thermal frontal zones dependent on climate fluctuations is proposed; estimations of horizontal

temperature gradients were made and interannual variability in parameters of the thermal frontal zones was estimated. It was found that maximum temperature gradients were formed in years characterized by relatively high ice coverage in the Barents Sea and concurrent increase in temperature of Atlantic waters inflowing to its southern part. It is assumed that in such years a specific intermediate state of the Barents Sea ecosystem is formed, which is essential for its biological productivity.

WED 17:10 (SESSION 4A)

Variability of the flow of water masses on the North Icelandic Shelf

S. Jonsson and H. Valdimarsson

Marine Research Institute and University of Akureyri, Borgir v/Nordurslod, 600 Akureyri, Iceland

The North Icelandic shelf is an area that shows highly variable hydrographic properties. In the Denmark Strait, between Greenland and Iceland, the warm saline Atlantic Water of the Irminger Current meets the cold and relatively fresh Polar Water of the East Greenland Current. A mixture of these two water masses then flows along the shelf north of Iceland and it can vary from being pure Atlantic Water to consisting entirely of Polar Water. The relative amount of the water masses to a large extent determines the productivity and the living conditions on the shelf north of Iceland. It has been shown to affect the primary production and also the condition of the capelin stock in the area. To determine the flow along the shelf the Marine Research Institute in Iceland has been monitoring using Aanderaa current meters on a section north of Iceland. Since 1994 current meter measurements have been made on a single mooring but in 1999 the measurements were extended to three moorings. Additionally, measurements with a vessel mounted ADCP have been done annually in November since 2001. Together with the current measurements, CTD measurements have been made on standard sections in the area. All these measurements are used to study the structure of the flow and its variability. Also the amount of both Atlantic and Polar water masses carried by the flow are calculated. In the period 1994-1999 the flow consisted on the average of 66% of Atlantic Water.

Session 4b: Primary production

WED 14:00 (SESSION 4B)

Comparative study of primary production between the Okhotsk Sea and the Bering Sea using satellite and *in situ* data sets

S.-I. Saitoh, T. Iida, T. E. Whitledge, T. Rho, A. Shiomoto and K. Sasaoka

Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1, Minato-cho, Hakodate, Hokkaido, 041-8611, Japan

Interannual and seasonal variability of surface chlorophyll-a concentrations (Chl-a) and primary production (PP) are examined both in the Bering Sea and the Okhotsk Sea by using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Ocean Color Temperature Scanner (OCTS) datasets with sea surface temperature of AVHRR datasets in the period of 1997-2003. On the other hand, we validated the accuracy of satellite PP estimation model in comparison with *in-situ* PP measurement data on board of ships in both marginal seas. The results of EOF analysis on normalized monthly fields in spring shows that the east - west seesaw pattern Chl-*a* in the spring bloom period (April -

June) in the Bering Sea. This strong east - west signal is linked by ocean surface winds. The wind speed anomaly derived from Special Sensor Microwave Imager (SSM/I) shows similar features, the east - west pattern related to the position of the Aleutian Low. The Aleutian Low shifted from westward to eastward, weak wind stress facilitated the development of stratification, resulting in a strong spring bloom off Kamchatka. We found an increasing pattern of PP in both marginal seas after 2000 and there is a trend of increasing sea surface temperature. The PP minimum occurred in 1999 and corresponded to a decrease in the number of meso-scale eddies in the shelf edge region of the Bering Sea. Spring PP contributes strongly to yearly PP in the Okhotsk Sea whereas summer PP contributes most to yearly PP in the Bering Sea.

WEDS 14:20 (SESSION 4B)

Interdecadal variation of the lower trophic ecosystem in the sub-Arctic northern Pacific between 1948 and 2002, using a 3D-NEMURO coupled model

M.N. Aita, K. Tadokoro, Y. Yamanaka and M.J. Kishi

Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, 3173-25, Showa-machi, Kanazawa-ku, Yokohama-city, Kanagawa, 236-0001, Japan

Regime shifts, consisting of decadal-scale oscillations in atmosphere-ocean systems, have recently been the focus of many marine ecosystem studies. These 'regime shifts' effect the sea surface temperature and mixed layer depth (MLD), changing the environment for marine ecosystems. We simulated changes in the marine ecosystem caused by interdecadal climate variability, using data from 1948 to 2002 to drive a global three-dimensional physical-biological coupled model, '3D-NEMURO'. Comparing mean values before and after the late 1976/77 climatic regime shift, primary production decreased in the Oyashio region and the Bering Sea. The observational data show zooplankton biomass also decreased in the mid-1970s in the both regions. The results accompanied the shift in the Pacific Decadal Oscillation (PDO), an index of interdecadal climate variability in Pacific Ocean.

WEDS 14:40 (SESSION 4B)

An ecosystem modeling study of phytoplankton distribution in the Okhotsk Sea

T. Okunishi, M.J. Kishi and T. Yamashita

Graduate School of Engineering, Hokkaido University, Kita 13, Nishi 8, Kita-ku, Sapporo, 060-8628, Japan

A three dimensional ecosystem - physical coupled model is applied to the Okhotsk Sea. Factors that determine the spatial distribution of phytoplankton in the Okhotsk Sea in autumn and spring are analyzed, and the effects of sea ice on the spring bloom are also discussed. One of the most important factors determining the spatial distribution of phytoplankton in autumn is regional variation in mixed-layer depth. The model can explain the spatio-temporal variation of chlorophyll-a concentrations in the Okhotsk Sea during the spring blooms in 1997 and 2001. The start of the spring boom in the Okhotsk Sea depends on the light environment. By controlling the light intensity in sea surface water, sea ice controls the timing of the spring bloom.

WED 15:00 (SESSION 4B)

The springtime plankton dynamics in the Bering Sea shelf and the effects of wind forcing and solar radiation

T. Iida, S.-I. Saitoh, J. Wang and M. Jin

Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate Hokkaido, Japan

The interannual and seasonal variability of surface phytoplankton is examined in the Bering Sea by using Empirical Orthogonal Function (EOF) analysis of Sea-viewing Wide Field-of-view Sensor (SeaWiFS) datasets from 1998 to 2002. The results of the EOF analysis on normalized monthly fields in the spring (April – June), after removal of the temporal and spatial monthly means showed an east – west seesaw variability of phytoplankton concentrations in the springtime. This strong east - west signal is linked by ocean surface wind and solar radiation to the Aleutian Low position. The plankton dynamics were simulated with a vertical one-dimensional NPZD ecosystem model. The phytoplankton bloom period varied from early May to late May in relation to wind-driven convection in the eastern and western Bering Sea. The mixed layer depth was shallow with weak winds and strong solar radiance, resulting from large phytoplankton blooms. Therefore the timing and distribution of the phytoplankton bloom changed with the Aleutian Low system. In addition, the late spring bloom affected the zooplankton growth due to higher water temperatures and the concentrations of zooplankton were higher in the eastern or western regions. The zooplankton concentration maintained to early summer time, which would be affected by juvenile growth rate.

WED 15:20 (SESSION 4B)

Does sea ice contribute to the biogeochemical cycles of the Bering Sea?

R. Gradinger, B. Bluhm and H. Eicken

University of Alaska, Fairbanks School of Fisheries and Ocean Sciences, PO Box 757220 Fairbanks, AK 99709, USA

Sea ice is a major structuring component of polar waters. In sub-Arctic seas, research over the last three decades focused mainly on water column processes in marginal ice zones. More recently, the role of sea ice as a platform for marine mammals and birds received more attention, mainly due to the recent decrease in the Arctic sea ice cover. Surprisingly, the biota within the sea ice and their contribution to biomass and production within theses regions have received little scientific attention.

We present results from sea ice biological studies conducted in the seasonal ice zones of the nearshore and offshore Chukchi and Beaufort Seas in 2002, 2003 and 2004. Our studies showed clear regional trends, with ice algal biomass decreasing by two orders of magnitude progressing from the nutrient-rich shallow shelf across the shelf break to the nutrient-poor surface waters of the deeper basins in the Chukchi and Beaufort Seas. Similar comprehensive data on the contribution of sea-ice communities to primary production and food-web structure in the Bering Sea are lacking to date. Here, we will discuss the potential importance of ice biota by examining the Bering Sea ice sea-ice and oceanographic regime and extrapolating from our findings for the Chukchi and Beaufort shelves.

WED 16:10 (SESSION 4B)

Coccolithophorid blooms and their chemical-controlling features in the eastern Bering Sea

J. Zhang, H. Nishitani, H Narita and R.W. Jordan

Faculty of Science, Toyama University, 3190 Gofuku, Toyama, 930-8555, Japan

After 1997, coccolithophorid blooms were frequently observed by research vessels and satellites in the Eastern Bering Sea shelf, where diatoms have had the most dominate distribution. Here, we present biogeochemical data collected during cruises of the T/S Oshoro-Maru and R/V Mirai from 2000 to 2002. Our goal is to refine the controlling features of coccolithophorid blooms by each species' composition of phytoplankton and water characteristics. The scale of bloom and the abundance of coccolithophorids were different in each year. The most dominant phytoplankton group was coccolithophorids in 2000, which agrees with the large bloom observed by satellite. In 2001, diatoms dominated at 70% and coccolithophorids accounted for 30% at 58 - 58.5ºN. In 2002, diatoms dominated at nearly 100% at all stations. Coccolithophorid abundance was nearly halted at the pycnocline, since coccolithophorids existed in the middle shelf domain, which is known to be an area of cold-water pool distribution. The difference in density between the surface mixed layer and the cold-water pool gradually increased from 1980 to 2002, that is, seawater stratification in the middle shelf domain was strengthened as the result of the increased surface temperature and decreased salinity that have occurred recently. Then as a result, the stratification in the middle shelf domain greatly influences the species composition of phytoplankton and give occasion to coccolithophorid blooms, which are controlled by the rare storms and/or low river discharges in summer.

WED 16:30 (SESSION 4B)

Climate variability, primary productivity and export fluxes in the Beaufort Sea: a modelling study

D. Lavoie, K. Denman and R. Macdonald

University of Victoria, School of Earth and Ocean Sciences, PO Box 3055 STN CSC, Victoria, BC, V8W 3P6, Canada

The Beaufort Sea, like sub-Arctic seas, is characterized by seasonal ice cover, the influence of freshwater from ice-melt and runoff, reduced sunlight and low biodiversity. Climate warming is predicted to be more rapid and important in the Arctic than in other regions of the globe, and seasonally ice-covered regions of the Arctic are thus a good "laboratory" to predict how sub-Arctic ecosystems will be affected by climate variability. Changes have already been observed in the Arctic, the most important being the reduction in ice cover extent and thickness, and a longer ice-free season. The lengthening of the ice-free season may lead to an increase in primary production by phytoplankton, while the ice algae production could decrease due to earlier melting of the snow and ice cover. Although ice algae usually represent 5-15% of the total primary production on Arctic shelves, they can account for a high proportion of the organic carbon that makes its way to the benthos. A coupled 1D model (snow, ice, ocean, ice algae, phytoplankton, zooplankton, detritus) is used to explore the response of primary productivity and biogenic particle export to different climate change scenarios.

WED 16:50 (SESSION 4B)

The return of the diatom *Neodenticula seminae* in the NW Atlantic after an absence of 0.8 million years: a consequence of recent changes in the Bering Sea?

M. Starr, M. Poulin, D. Johns, L. Bérard-Therriault , M. Edwards, P.C. Reid and S. Roy

Maurice Lamontagne Institute, Fisheries and Oceans Canada, C.P. 1000, Mont-Joli, Québec, Canada, G5H 3Z4

Neodenticula seminae is an important member of the modern diatom assemblage in the Bering Sea and North Pacific. In the North Atlantic Ocean this species has only been recorded in Quaternary sediments that were dated between 0.8 and 1.2 million years ago. Here, we report for the first time since its total extinction in the NW Atlantic, the reappearance of *N. seminae* in this part of the globe. The rebirth of this Pacific species in the NW Atlantic is consistent with recent field and modelling observations indicating a greater influx of North Pacific water into the NW Atlantic, a reduction of summer ice extent and thickness in the Bering Sea, and a freshening and cooling of NW Atlantic waters. This finding provides the first evidence of a recent change in the marine ecosystem of the NW Atlantic Ocean that is without precedent at a human scale and that seems to be climatically forced. This supports the general perception that the present climatic conditions in the Bering Sea and the North Atlantic Ocean are truly exceptional and not just influenced by climatic variations at decadal or centennial time scales. In particular, the suggested spreading of upper layer fresh and cool waters from the North Pacific into the NW Atlantic could have important consequences on all trophic levels and fisheries.

WED 17:10 (SESSION 4B)

Are satellite data useful for the prediction of phytoplankton species succession in the Irminger Basin?

C. Holeton, S. Henson and M. Lucas

George Deacon Division, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK

The northern North Atlantic is a highly productive region and an important contributor to the global biological pump. Satellite data may help to increase our awareness of regional changes in the biological pump by spatially and temporally expanding our understanding of some of the factors controlling phytoplankton ecology. In this study we investigate the use of satellite data to estimate nutrient availability in the Irminger Basin. A series of four cruises was made to the Irminger Basin between December 2001 and December 2002 as part of the UK Marine Productivity programme. *In situ* inorganic nutrient measurements made between May and August 2002 are extended spatially and temporally by multiple regression with satellite sea surface temperature and chlorophyll-*a*, allowing nutrient availability to be estimated throughout the year. The data reveal that silica concentrations in the near surface waters are close to undetectable over much of the basin during June, but that nitrate and phosphate concentrations are unlikely to limit phytoplankton growth at any time. Based on these satellite estimates of nutrient availability, we hypothesise that silica limitation of diatom growth leads to a seasonal succession of phytoplankton species in the Irminger Basin. Our hypothesis will be examined in the context of available *in situ* measurements, including taxonomic and physiological (Fast Repetition Rate Fluorometer) data.

Session 4c: Secondary production

WED 14:00 (SESSION 4C)

Zooplankton production - Where are we and how to make advances?

K.S. Tande, A. Edvardsen, S. Basedow and M. Fossheim
Norwegian College of Fishery Science, University of Tromso, Breivika, 9037 Tromso, Norway

Quantifying production among planktonic crustaceans is still a difficult task despite several available approaches. This contribution reviews the various methods used, zooming in on the most promising new approaches. We estimate how errors in assessing mortality and growth on production may change during the recruitment period. Examples of the relation between the size of the overwintering population and the recruitment generation of ecologically important copepod species are given, mainly from northern latitudes, and demonstrate a high interannual variability. Our knowledge of causal relationships is still weak, and the talk focuses on discussing some of the most likely mechanisms involved. Finally, the talk advocates the most appropriate sampling approaches and technology platforms in order to bridge our gap in understanding the variability in production of marine planktonic copepods.

WED 14:20 (SESSION 4C)

Climate and food web effects on formation of jellyfish blooms

J.E. Purcell and M.B. Decker
Western Washington University, Shannon Point Marine Center, 1900 Shannon Point Rd, Anacortes, WA 98221, USA

Increasing interference of jellyfish with human enterprise has stimulated interest in understanding the conditions in which jellyfish populations thrive. Jellyfish are generally detrimental to fish populations because they are important predators of both zooplankton and ichthyoplankton. They directly interfere with fishing and power plant operations by clogging nets and intake screens. Long-term records of jellyfish abundances show that the population sizes of several species increase with certain environmental conditions, specifically, warm temperatures, low rainfall and high light levels. Climate indices, such as the North Atlantic and North Pacific Oscillation indices, also correlate with long-term records of jellyfish numbers. Experimental data show that temperature, salinity, light and prey availability significantly affect asexual production of medusae from the benthic polyps and hence could determine population size. Empirically-derived habitat models successfully predict the occurrence and density of jellyfish in Chesapeake Bay. We suggest that combined field, experimental and modeling studies will enable us to predict how changes in climate and plankton may affect future jellyfish populations in the Bering Sea and aid in understanding how these top predators affect energy flow through the ecosystem.

WED 14:40 (SESSION 4C)

Basin-scale population dynamics of the copepod *Calanus finmarchicus* in the sub-Arctic North Atlantic

P.H. Wiebe, A. Bucklin, D.J. McGillicuddy and E. Ünal

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, MS 02543, USA

The copepod *Calanus finmarchicus* is a pivotal species in the ecology and trophic dynamics of the North Atlantic zooplankton assemblage. The species shows significant geographic variation in timing of reproduction, seasonal patterns of abundance and vertical distribution, numbers of generations per year, and other life history traits. Questions remain regarding the degree and time/space scales of population structuring of the species across its distributional range in the North Atlantic Ocean basins. Current views include the "three gyre hypothesis" that partitions populations among the Nordic Seas, central North Atlantic, and Northwest Atlantic. This hypothesis will be revisited by examining the species' ocean basin scale distribution, abundance, and genetic diversity for evidence of significant divergence among geographic populations. Biological-physical models will be used to infer source and sink terms for the gyre populations and to estimate the extent of mixing (i.e. advective transport) among these gyres, focusing first on exchange with the Northwest Atlantic gyre. Despite enormous population sizes and trans-ocean basin distribution, *C. finmarchicus* appears to show significant geographic variation in time/space patterns of distribution, abundance, and genetic diversity. Large-scale physical structure in the North Atlantic (e.g. gyre circulation patterns) may be sufficient to partially isolate geographic populations and allow genetic divergence and adaptive evolution of critical life history traits.

WED 15:00 (SESSION 4C)

Temporal and spatial changes in *Oithona* spp. biomass and productivity in the sub-Arctic North Atlantic

C. Castellani, X. Irigoien and R.P. Harris

Proudman Oceanographic Laboratory, British Oceanographic Data Centre, Joseph Proudman Building, 6 Brownlow Street , Liverpool, L3 5DA, UK

Spatial and temporal changes in the biomass and production of *Oithona* spp. were investigated during four cruises in the Irminger and the Labrador Sea. Due to its high abundance, small size, selective feeding on microzooplankton, and coprophagus behaviour, *Oithona* spp. has been recognised as a key player in food-webs and carbon flux dynamics of the Southern Ocean and the North Sea, whereas its importance in sub-Arctic ecosystems remains still poorly documented. Although the highest biomass and production were measured in summer, *Oithona* was still abundant and actively reproducing in winter when other copepod species went into diapause. Nevertheless, the high egg production rates (EPR) and lower percentage of nauplii (< 50%) in summer as compared to winter-spring (up to 80%) suggests that recruitment was poor at this time of the year. EPR were highest in summer-spring on the Greenland and Iceland shelves and positively related to microzooplankton biomass, female body carbon and the percentage of reproducing females rather than to phytoplankton and temperature. A progressive decrease in *Oithona* biomass from the shelf edge to the inner Greenland and Iceland shelves where EPR and food supply were highest was associated with a decline in the percentage of nauplii suggesting that the trend observed was probably due to predation. On the other hand, offshore changes in copepod biomass were associated with fronts and eddies indicating that physical processes also affected copepod abundance. The study suggests that the variability in *Oithona* biomass and production results from both physical and biological factors and that *Oithona* could represent a source of food for predators

such as *Calanus*, euphausids and fish larvae particularly at times when other food sources become scarce. Results are discussed in relation to the potential links between climate variability and the role of *Oithona* in the sub-Arctic ecosystem of the North Atlantic.

WED 15:20 (SESSION 4C)

Interdecadal variability in zooplankton and phytoplankton abundance on the Newfoundland and Scotian shelves

E. Head and D. Sameoto

Department of Fisheries and Oceans, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS B2Y 4A2, Canada

A section that crosses the Newfoundland and Scotian shelves has been sampled by the Continuous Plankton Recorder (CPR) since 1960. These areas are not themselves seasonally ice-covered, but are downstream from areas (Labrador Shelf; Gulf of St. Lawrence) that are. The CPR data shows that abundances of several zooplankton species and three indices of phytoplankton abundance changed markedly in both regions between the 1960s, when the NAO was mainly in a negative phase, and the 1990s, when the NAO was mainly in a positive phase. Phytoplankton "colour" and numbers of diatoms and dinoflagellates were higher in both regions in the 1990s than in the 1960s, as were abundances of *Calanus hyperboreus, Calanus glacialis*, *Oithona* spp., *Centropages* spp. and *Metridia* spp. By contrast, abundances of *Calanus finmarchicus* and euphausiids were lower in the 1990s than in the 1960s. One outstanding feature in the data was a strong spatial and temporal co-incidence between patterns of abundance of *Oithona* spp. and dinoflagellates, with pronounced peaks in abundance appearing in the 1990s near the eastern or southern coast of Newfoundland in spring and fall. Other notable findings that arise from our additional sampling of the entire water column in the 1990s are (a) that the Arctic species *C. hyperboreus* and *C. glacialis* are significantly less efficiently sampled by the CPR than *C. finmarchicus*, and (b) that in spring and summer the total *Calanus* spp. biomass was probably higher in the 1990s than in the 1960s. Possible explanations for these observations will be discussed.

WED 16:10 (SESSION 4C)

Distribution and reproduction of the dominant copepods *Calanus finmarchicus* and *C. glacialis* in the northern North Atlantic and the Arctic Ocean - implications under global change

H.J. Hirche and K. Kosobokova

Alfred Wegener Institute for Polar and Marine Research, Columbusstrasse 1, D-27568 Bremerhaven, Germany

Based on field observations and laboratory experiments the distribution and reproductive biology of the two congener copepods *Calanus finmarchicus* and *Calanus glacialis* are described for the northern North Atlantic and the Arctic Ocean. They occupy two different hydrographic domains: *C. finmarchicus* dominates the Atlantic water masses, while *C. glacialis* is a key species and main prey for higher trophic levels in Arctic shelf seas. Due to the current regime expatriated *C. finmarchicus* is abundant in the polar and arctic waters of the central Greenland Sea, the northern Barents Sea, the East Greenland Shelf and the Arctic Ocean. *In situ* egg production experiments always demonstrate its reproductive failure in these regions, although the causes are as yet unknown. Climate change as forecasted by recent global change scenarios for the northern North Atlantic and the Arctic Ocean

may in the future permit the establishment of local populations where now this species is expatriated. In turn, recent studies have shown that in the arctic species *C. glacialis* a reproductive dormancy is induced in females at higher temperatures. In consequence, the habitat of this species may be in vain when sea temperatures rise. Both the occupation of new regions by *C. finmarchicus* and the inhibition of the productivity of *C. glacialis* should have strong consequences for the respective ecosystems.

WED 16:30 (SESSION 4C)

Overwintering dynamics of *Calanus finmarchicus* in the eastern Norwegian Sea: model simulations

D. Slagstad and K.S. Tande
SINTEF Fisheries and Aquaculture, N-7465 Trondheim, Norway

Very high concentrations of overwintering *Calanus finmarchicus* were found in the eastern Lofoten basin close to the shelf break from 1998 to 2000. A coupled hydrodynamic and ecological model has been used to study the formation of the overwintering distribution and its stability during the winter months when *C. finmarchicus* stay at the overwintering depth. The ecological model contains a stage-structured model of *C. finmarchicus*. The model was initiated with an overwintering stock, evenly distributed in the oceanic regions of the Norwegian Sea, i.e. depth >600 m. Spawning and development of the new generation took place in a dynamic relationship with vertical mixing and phytoplankton development. In late summer a high concentration of overwintering animals were found at the overwintering depth (700 – 1000 m) near the shelf break north of the North Sea, in the northeastern part of the Vøring Plateau and in the eastern part of the Lofoten Basin just outside slope of the Barents Sea Shelf. Particle tracking experiments reveal that most of the particles are drained out from the shelf in late summer. At the overwintering depth there is a southward current which is not continuous along the shelf break, but interrupted at topographic structures forming anticyclonic gyres. The average residence time is 3 to 4 months, but as much as 30 to 60% of animals entering the gyre in late summer may still be kept inside the eddy after 7 months. The physical basis for the dynamics of the anticyclonic gyres as well as the potential seeding effect of *Calanus* spawning stock to the western Barents Sea are being addressed in the paper.

WED 16:50 (SESSION 4C)

Who or what is regulating zooplankton production in the southeastern Bering Sea?

J.M. Napp, G.L. Hunt, Jr., S. Moore and C.T. Baier
NOAA Fisheries, Alaska Fisheries Science Center, 7600 Sand Point Way, NE, Seattle, WA 98115-0070, USA

Who or what controls biological production has been a common question for generations of marine scientists. The marine zooplankton community, which contains secondary, tertiary, and quaternary producers, is often cited as pivotal in the transfer of energy from primary production to higher trophic levels. In the Bering Sea, as in other high-latitude systems, high production by the zooplankton community is often cited as one reason for high standing stocks of living and protected marine resources. Climate-driven atmospheric forcing, principally in the form of the presence or absence of sea ice (and cold water temperatures) is hypothesized to strongly influence mesozooplankton production in the southeastern Bering Sea (Oscillating Control Hypothesis). Global, temperature-dependent copepod production models and historical temperature records from the region provide a way to estimate the magnitude of past fluctuations in copepod production. On the other side of the

equation, losses due to predation (by other zooplankton, fish, seabirds, and baleen whales) are potentially very high. We estimate that >100% of the zooplankton standing stock and 82 - 116% of the zooplankton production could easily be removed by the guild of planktivorous predators. We use historical records of predator biomass to examine past fluctuations in the balance between production and consumption of zooplankton. Last we will remark on the similarities and differences in zooplankton production and consumption between the southeastern Bering Sea and other sub-Arctic seas.

WED 17:10 (SESSION 4C)

Interannual variations in seasonal abundance of *Eucalanus bungii* in Oyashio waters

T. Kobari, K. Tadokoro and H. Sugisaki
Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan

Large grazing copepods are predominant among the zooplankton biomass in the sub-Arctic seas and important food resources for fishes, seabirds and whales. Thus, they are important components and major pathways of energy flow in the sub-Arctic marine ecosystems. Recently, there has been accumulating evidence that phyto- and zooplankton community responds to climate impacts in the different regions of the sub-Arctic seas. However, we have no information on long-term changes of *Eucalanus bungii* which might be sensitive to climate impacts because their life cycles is dependent on primary production. In the present study, interannual variations in seasonal abundance of *E. bungii* were investigated from zooplankton samples (the Odate Collections) collected from Oyashio waters during 1960 through 2002. Mean Population Stage (MPS) estimated from stage composition traced the standardised life cycle pattern, with dormant specimens maturing from March to April and recruited neonates from April to May, which develop during May through September. Seasonal abundance of *E. bungii* showed an oscillation pattern and the abundance peaks were delayed 30 days during the 1970s and 1990s compared with the 1980s. Similar patterns were observed for seasonal abundance of C1-C2 and C3-C5, while C6 occurrence was limited in April to May. These results suggest that emerged specimens from dormant mature by April but reproductive and early development season was delayed during 1970s and 1990s. Possible mechanisms of the delayed life cycle timing will be discussed.

Session 4d: Fish, shellfish, seabirds and mammals

WED 14:00 (SESSION 4D)

Top predators: indicators of climate change in marine ecosystems

S. Wanless
NERC Centre for Ecology and Hydrology, UK, CEH Banchory, Hill of Brathens, Banchory, Aberdeenshire AB31 4BW, UK

To understand the impacts of climate warming on upper trophic levels in marine ecosystems requires an interdisciplinary approach, particularly where fishery effects are also involved. In this presentation I will use recent research from the North Sea to illustrate this approach. The North Sea is a highly productive coastal shelf sea. It is one of the most intensively fished areas of the world and until recently fishery effects were regarded as the main driver of ecosystem change. The sandlance *Ammodytes marinus* forms the main trophic link between secondary producers and many mammalian, avian and fish top predators. Because of this key position, increasing landings of sandlance by an industrial fishery have intensified concerns about possible effects on the North Sea

ecosystem. Recently the situation has been exacerbated by apparent changes to the plankton community due to climate warming. This talk will use long term data on the demography, phenology and diet of top predators to review the impacts of climatic and fisheries drivers. It will also highlight how emerging technologies are enabling us to understand better the mechanisms underpinning the key functional relationships between predators, their prey and the marine environment. This knowledge is needed to improve our ability to forecast the outcomes of likely climatic scenarios and fisheries management options on predator populations.

WED 14:20 (SESSION 4D)

Effects of climate changes on the biological environments in the East Sea

C.I.Lee, J.-Y. Lee, D.S. Kim and K.D Cho

Research Center for Ocean Industrial and Development, Pukyong National University, 599-1 DaeYeon 3-dong, Namgu, Pusan 608-737, Republic of Korea

The effects of El Niño events on biological environments in the East Sea were investigated using the relationships between Southern Oscillation Index (SOI) for El Niño events and seawater temperature, zooplankton biomass and squid catchments using wavelet analysis methods. SOI data from 1900 to 2000 were collected from NOAA, and the seawater temperatures from 1961 to 2000 and zooplankton and squid catchments from 1980 to 2000 were from Korea Oceanographic Data Center and Japan Meteorological Agency. Dominant variations of temperature were found for periods from 4 to 8 years and in decadal oscillations. These periodic variations were highly correlated with El Niño events, both in the period 4 to 5 years and in decadal oscillations. However, it was found that the time lags between temperature variations from El Niño events were 1.3 and 4.5 years for the period of 4 to 5 years and decadal oscillations, respectively. In particular, decadal oscillations found both in El Niño events and temperature variations were highly correlated with variations of zooplankton biomass and squid catchments. In the late 1980s, a regime shift in the climate occurred and the variations of temperature, zooplankton biomass and squid catchments seem to reflect this phenomenon. It was also found that climate changes occurred at longer than decal periods, which also contributed to the temporal distributions of both lower-trophic and higher-trophic organisms.

WED 14:40 (SESSION 4D)

Understanding of processes driving temporal variation in recruits per spawner of Bering Sea salmon (*Oncorhynchus*) populations based on analyses of spatial scales of correlation among stocks

R.M. Peterman, B.J. Pyper, F.J. Mueter, B. Dorner and S.L. Haeseker

Simon Fraser University, School of Resource and Environmental Management, 8888 University Drive, Burnaby, British Columbia, Canada V5A 1S6

Important clues about mechanisms causing variation in productivity of fish stocks in the Bering Sea can be derived from estimates of spatial scale across which multiple fish stocks show positive correlation in their time series of productivities. This approach helps to eliminate hypotheses that are inconsistent with the observed variation in fish productivity, i.e., hypotheses that operate at spatial scales that are either too large or too small. The hypotheses that remain are less likely to result in random spurious relations than would otherwise be the case. We illustrate this approach through

analyses of over 100 stocks of pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), and sockeye (*O. nerka*) salmon in the Northeastern Pacific, including 20 stocks that enter the Bering Sea as juveniles. We used both within and between-species comparisons among stocks. We found that regional-scale environmental processes (those that are coherent across less than about 700 km) are more important drivers of temporal variation in recruits per spawner for salmon populations than the more-frequently-cited large, ocean-basin-scale indices of processes (e.g. PDO). For example, our results from applying a Kalman filter (to better estimate the temporal "signal" amid the "noise") showed that productivity of most chum salmon stocks in the Arctic-Yukon-Kuskokwim region of Alaska began a general decreasing trend during the late 1970s brood years, with a more severe decline in the early 1990s. The coherent decreasing trends in productivity of chum salmon within that region suggest that certain regional-scale physical and/or biological processes caused these changes.

WED 15:00 (SESSION 4D)

Variability in growth of chum salmon (*Oncorhynchus keta*) in sub-Arctic Pacific related to 1988/89 climate change

H. Seo, K. Seong, S. Kim and S. Kang

Pukyong National University, 599-1, Daeyeon 3-dong, Nam-gu, Korea

Decadal-scale climate change in 1976/77 and 1988/89 has been reported in the North Pacific, and a relationship between chum salmon growth and environmental conditions in the sub-Arctic Pacific Ocean was investigated assuming the proportionality between widths of scale rings and fish length at a certain age. Chum salmon have a wide distribution in the sub-Arctic North Pacific. Fry chum salmon released in Korean waters move to the Okhotsk Sea, and stay there as a juvenile stage during summer through late autumn. They overwinter in the western North Pacific Ocean, and then have a seasonal migration between the Bering Sea (summer) and the North Pacific (winter) several years until homing. Returning adult salmon to the eastern coast of Korea during 1984-1998 were collected, and scales were obtained. Scale analysis indicated that the growth of young salmon was better in the 1990s than in the 1980s in Korean waters. Concurrently, the seawater temperature and zooplankton abundance in Korean waters increased from the late 1980s, which might cause a favorable growth condition for young salmon. The Growth Index for the Okhotsk Sea was stable interannually, and neither SST nor zooplankton biomass fluctuated significantly during the study period. On the other hand, in the Bering Sea, salmon growth from age-2 to age-4 was better in the 1980s than in the early 1990s. Actually, zooplankton biomass in the eastern Bering Sea was generally higher in the 1980s than in the 1990s. Also, interannual fluctuation of zooplankton biomass and SST in the Bering Sea correlated with growth of chum salmon

---

WED 15:20 (SESSION 4D)

Feeding migration and diet of Norwegian spring spawning herring in relation to the seasonal cycle of *Calanus finmarchicus* in the Norwegian Sea

C.B.T. Årnes and W. Melle

Institute of Marine Research, Institute of Marine Research, FG5, Nordnesgt. 50, N-5024 Bergen, Norway

The aim of this study is two-fold: 1) to examine *Calanus finmarchicus* in the diet of herring (*Clupea harengus*) throughout their feeding migration in the Norwegian Sea, and 2) to study the timing of the herring migration in relation to the life cycle of *Calanus finmarchicus*. The feeding ecology and

distribution of herring were studied during cruises in 1994, 1995 and 1996 from the start of the feeding migration at the spawning grounds off the coast of Norway, to the main feeding area in the Atlantic and Arctic waters of the central and western Norwegian Sea. The feeding and migration have been related to differences in the seasonal cycle of production of *Calanus finmarchicus* in the different water masses obtained from zooplankton samples collected during the cruises. The herring feeds selectively on adults and older copepodite stages of *Calanus finmarchicus*. In the beginning of the season, the herring mainly feed on the overwintering population (G0), which concentrates towards the surface to feed and spawn during the phytoplankton spring bloom. The timing of the development of the *Calanus* population varies between water masses and the herring also inhabit different water masses during their feeding season, which seems to be related to the occurrence of older developmental stages of *C. finmarchicus*. The seasonal cycle of *Calanus finmarchicus* probably governs the feeding migration of herring. Thus, changes in the timing of the seasonal cycle related to climate variability may have strong influence on the feeding and migration of herring.

WED 16:10 (SESSION 4D)

Systems ecology of marine ecosystems: a comparison of ecosystem level properties of the Bering and Barents Sea

B.A. Megrey and K.Y. Aydin

NOAA/NMFS/Atlantic Fisheries Science Centre, 7600 Sand Point Way NE, Seattle, WA 98115, USA

The Bering and Barents Seas are both high latitude sub-Arctic ecosystems that share many similar biophysical and trophic characteristics and support valuable commercial fisheries. The objective of this paper is to compare system level characteristics that make the Bering and Barents Sea ecosystems unique. We use Ecopath models and systems ecology macrodescriptor metrics applied to the two marine ecosystems to identify key areas of differences and similarities. We also compare the variability in one system over time to the variability between systems. Metrics calculated include number of species, number of interactions or trophic links, connectivity of the system, number of interactions per species, a measure of directed connectance, and an assessment of overall web interaction strength. In addition, number of basal species, number of top predators, total number of intermediate species, number of cannibals, number of cycles, number of omnivores, number of predators for a prey item, number of prey items for a predator, predator to prey ratio, and other indices were enumerated. Calculated food web metrics for the Bering and Barents Seas are compared between systems as well as with other similar metrics from published sources. We attempt to relate these observations to the questions of the uniqueness of marine food webs, implications for system stability, how climate impacts the physical environment, how the physical environment effects the structure of fish communities in each sea, and how changes in the physical environment affect the production of fish and the ability of the Bering and Barents Seas to support stable fisheries and productive ecosystems.

WED 16:30 (SESSION 4D)

Ocean climate variability and recruitment success of northern shrimp *Pandalus borealis* and snow crab *Chionoecetes opilio* on the Northwest Atlantic continental shelf

D. Gilbert ,Y. Lambert., P. Ouellet*, B. Sainte-Marie, L. Savard and M. Starr

Department of Fisheries and Oceans Canada, Maurice Lamontagne Institute, 850 route de la mer, Mont-Joli (Quebec) Canada, G5H 3Z4

** Presenting Author*

Northern shrimp (*Pandalus borealis*) and snow crab (*Chionoecetes opilio*) are found in the Northwest Atlantic from Davis Strait to the Gulf of Maine and Eastern Scotian Shelf, respectively, in areas where temperature ranges from about -1ºC to 9ºC. Along this latitudinal gradient, populations of both species differ in several life history traits. Juvenile/adult distributions, molting frequency, growth rates, size-at-maturity and population productivity all vary from north to south. These observations are important in the context of climate change as latitudinal variations in the life history characteristics of both species suggest that modifications in the environmental conditions will significantly affect the dynamics of local stocks/populations. In both species, embryos are carried in a mass by females during their development. Following hatching, early larval stages are found in the upper layer of the water column, where they develop as members of the mesoplankton for a period of 2 to 4 months before settling as juveniles on the bottom. Results from recent field and laboratory studies demonstrated the influence of temperature fluctuations on egg incubation time, egg and larval number and quality, timing of larval emergence and synchronism with the spring bloom and, ultimately, larval survival rates. Recruitment rates in both species could be significantly influenced by ocean climate variability. Multidisciplinary, comparative studies of factors affecting snow crab and shrimp recruitment processes along this latitudinal gradient would allow us to model and predict the response of local populations to expected changes in climate.

WED 16:50 (SESSION 4D)

Impact of climate change on zooplankton communities, seabird populations and Arctic terrestrial ecosystem - a scenario

L. Stempniewicz

Department of Vertebrate Ecology and Zoology, University of Gdansk, Legionów 9, 80-441 Gdansk, Poland

Arctic ecosystems function in the contact zone of sea and land. The land part is not self-sufficient, due to constant shortage of nutrients. At the same time, production is very high in the sea. The homoeothermic animals play a crucial role, as their biochemical and physiological processes (e.g. food assimilation) take place in optimal temperature of their body. The most important group is seabirds that forage on sea and breed on land. Transporting from the sea large amounts of organic matter, they sustain the land part of the ecosystem and initiate the emergence of local tundra communities increasing primary and secondary production and species diversity. Climate changes, both cyclic (e.g. related with the North-Atlantic Oscillation) and long-term, lead to changes in the sea currents system and hydrologic regime, and consequently, to a rebuilding of zooplankton communities, with a dominance of large species in the cold Arctic waters and small ones in warmer waters of boreal origin. Domination of large forms favours plankton-eating seabirds, such as Little Auk, *Alle alle*, while the dominance of small forms redirects food chain to plankton-eating fish, and only then to fish-eating birds (e.g. guillemots *Uria* sp.). Thus, the

plankton-eating birds should dominate the avifauna in cold periods and recess in warmer periods, when fish-eaters prevail. The climate warming will result in serious consequences for the structure and functioning of terrestrial part of ecosystem, among others due to probable changes in the Arctic avifauna. Large colonies of plankton-eating Little Auks are located on mild mountain slopes, usually a few kilometres off the shore, whereas colonies of fish-eating guillemots are situated on rocky cliffs near by the coast. Their range of impacts is then much smaller because of the rapid washing-out of the biogenic salts (guano) deposited on the land back to the sea. This dramatically limits the range of occurrence of ornithogenic soils with the accompanying flora and fauna. Due to different diet, plankton-eating and fish-eating seabirds produce guano differing in chemical composition and favouring development of different bacterial, plant and animal communities.

WED 17:10 (SESSION 4D)

Climate change and murres: a circumpolar seesaw

D.B. Irons, T. Anker-Nilssen, A.J. Gaston, G.V. Byrd, K. Falk, G. Gilchrist, M. Hario, M. Hjernquist, Y.V. Krasnov, A. Mosbech, G. Robertson, B. Olsen, A. Petersen, H. Strom and K.D. Wohl
US Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska, 99503, USA

Data on murre population trends from 52 colonies involving more than 490 colonies/years from around the world were brought together for a circumpolar perspective of the effects of climate change on seabird populations. Circumpolar changes in common and thick-billed murre populations over the past 25 years were associated with decadal shifts of northern hemisphere atmospheric oscillations, the Pacific Decadal Oscillation and the North Atlantic Oscillation. These oscillations are correlated to decadal changes in the oceans temperatures. The long-term sea surface temperature (SST) trends in the northeast Atlantic and the northeast Pacific mirrored each other resulting in a seesaw effect. When the northeast Atlantic cooled, the northeast Pacific warmed, and visa versa. Murre population responses to climate shifts were dependent on the magnitude, not the direction of the shift. When SST shifted slightly (<~0.5°C), either positive or negative, murre populations increased, but when the shift was large (>~0.5°C) murre populations declined. The two species reacted somewhat differently to SST shifts. Thick-billed murre, the Arctic adapted species, did better when the SST increased slightly and the more temperate common murre did better when SST decreased slightly.

Session 5: Climate change and the structure of ecosystems: the potential for trophic cascades

THUR 8:30 (SESSION 5)

Spatial and temporal operation of ecosystems: the response of Southern Ocean food-webs to variability and change

E.J. Murphy

British Antarctic Survey, High Cross, Madingley Road, Cambridge, UK, CB3 0ET

Southern Ocean ecosystems show marked spatial and temporal variability at a range of scales, which is crucial in generating the observed food-web structure and in determining the ecosystem dynamics. In this paper I review the operation of Southern Ocean ecosystems considering how processes at a range of scales, from short-term (days-weeks) and local (km - 10's km) to long-term (decadal to century) and circumpolar, affect the dynamics of key species, their interactions and the structure of food-webs. I examine what is known about the ecological responses to both physical variability and harvesting and highlight some of the long-term changes that have occurred in Southern Ocean food-webs. I consider the legacy of these changes and the potential ecological impacts of projected future environmental change. Potential impacts include direct effects such as changes in rates of growth and survival, or rapid changes in distribution of key species such as Antarctic krill and indirect effects through interactions in food-webs generating trophic shifts and cascade effects. The review highlights the importance of understanding circumpolar climate and ecosystem processes in order to determine the responses of Southern Ocean ecosystems to climate variability and change.

THUR 09:00 (SESSION 5)

The structural forcing of climate; a tale of two food webs

S. Gaichas and K.Y. Aydin

NMFS Alaska Fisheries Science Center and University of Washington School of Fisheries and Aquatic Sciences, NOAA NMFS Alaska Fisheries Science Center, 7600 Sand Point Way NE, Building 4, Seattle, WA 98115, USA

Recent changes in the Eastern Bering Sea (EBS) and Gulf of Alaska (GOA) continental shelf ecosystems are manifested in some similar and some distinctive patterns of variation in groundfish biomass between areas. Given that similar species occupy these regions and fisheries management is also comparable, similarities might be expected, but to what can we attribute the differences? Climate is presumed to play a role, but mechanisms producing both the similar and the distinctive patterns observed in EBS and GOA groundfish biomass have yet to be identified. In this paper, we examine the transfer of energy and biomass through similarly structured model food webs of each ecosystem, and the reaction of each system to standardized frequencies of simulated "climate" variation. We find that some of the distinctive patterns of variation in biomass can emerge from identical "climate" frequencies propagating through food webs with different structural properties. We attempt to characterize the distinctive structural properties of each food web that result in different apparent "climate" effects. It is possible that identifying structural properties of food webs within fished ecosystems may hold as much promise for fisheries management as attempting to predict climate effects in these ecosystems individually.

THUR 09:20 (SESSION 5)

Does climate-driven variability in the oceanographic structure of the Gulf of Alaska Shelf affect fish community composition by modulating the degree of interspecific competition between juvenile pollock and capelin?

E.A. Logerwell, A.B. Hollowed, C. Wilson and P. Stabeno

Alaska Fisheries Science Center, F/AKC2, PO Box 15700, Seattle, WA 98115, USA

The results of AFSC and PMEL research during 2000-2002 off Kodiak Island in the Gulf of Alaska indicate that ocean conditions affect the cross-shelf distribution of juvenile walleye pollock and capelin. Pollock were found in warmer waters inshore of a mid-shelf hydrographic front, whereas capelin were found offshore in cool waters advected from the slope. Although this pattern was consistent among years, there was intra-annual variability in the location of the front. A weakening of the front over the course of approximately 10 days in 2002 resulted in an expansion of warm nearshore water towards the outer shelf. Juvenile pollock distribution similarly extended towards the outer shelf. Coincident with the change in pollock distribution, the abundance of capelin declined in the outer shelf region. These changes in fish distribution are consistent with competitive exclusion of capelin by juvenile pollock. We hypothesize that the intra-annual dynamics in water mass properties and fish distributions are a model of the larger-scale processes that resulted in the apparent community re-organization on the Gulf of Alaska shelf following the late 1970s regime shift. Patterns in the oceanography and fish distributions during the 2004 survey off Kodiak Island will be examined in light of this hypothesis. There are several mechanisms by which climate variability could influence physical structure off Kodiak Island. We will discuss the linkages between large-scale climate and local physical structure on the Gulf of Alaska shelf as well as the need for further understanding of the potential for competition between pollock and capelin.

THUR 09:40 (SESSION 5)

Modeling approaches to marine ecosystem research and management

E. Svendsen, M. Skogen, P. Budgell, G. Huse and B. Ådlandsvik

Institute of Marine Research, PO Box 1870 Nordnes, N-5817 Bergen, Norway

A major issue is how food webs are controlled or regulated by their environment and human interference. This obviously has important implications for the management of marine resources, whether the agenda is the harvesting of marine resources or the protection of species. Globally, second and third-level carnivorous fish such as cod are over-fished, forcing fisheries in many parts of world to harvest at lower trophic levels. Moreover, the extreme variation in physical factors in northern waters, especially light, temperature, and ice cover, that occur over seasonal, inter-annual and longer time-scales, cause major fluctuations at all trophic levels of the food web. Knowledge of the ecosystem dynamics is required to make proper evaluation and prediction of the impact of fishing on a marine food web, and a fundamental challenge in this context is distinguishing the impact of man from large natural variations. Due to the complexity of this challenge, it can only be solved by an extensive use of mathematical models in combination with assimilation of observations. The Norwegian modelling community has recently made significant progress in ice-ocean physical-chemical-biological numerical modelling. The modelling system includes physics from the ROMS model, three macro-nutrients (N, P, Si), primary production of diatoms and flagellates, and secondary production of *Calanus finmarchicus*, being the main zooplankton in the Northeast Atlantic ecosystem. One of the main goals is to use these modeling activities for an ecosystem approach to marine research and management, and examples will be given on how quantified knowledge of the physics and lower trophic levels impact and make predictions possible with respect to fisheries recruitment and migration.

THUR 10:00 (SESSION 5)

Effects of climate variability and change on the ecosystems of the sub-Arctic inland seas of Canada: The Gulf of St. Lawrence and Hudson Bay

F.J. Saucier

Institut des Sciences de la Mer, Université du Québec à Rimouski, 310 Allée des Ursulines, Rimouski (Qc) G5L 3A1, Canada

We review recent progress and future plans for understanding, detecting and predicting the effects of climate variability and changes on the ecosystems of the inland seas of Canada. The Gulf of St. Lawrence and the Hudson Bay marine systems are semi-enclosed seas that drain some 2200 km^3 of freshwater per year to the North Atlantic. They are characterized by the presence of a nearly complete winter sea ice cover, great variability from synoptic to interdecadal time scales, and large scale changes associated with climate warming and the hydrological cycle. We currently have in place continuous ecosystem-climate observing programs (the Atlantic Zone Monitoring Program in the Gulf of St. Lawrence and MERICA in Hudson Bay), a hierarchy of fully prognostic regional coupled atmosphere-ice-ocean-ecosystem models valid from synoptic to decadal scales, and inverse models to describe ecosystem structures and trophic interactions among groups over sub-decadal periods. Examples will be provided of the regional climate simulations, the inclusion of lower trophic dynamics linking nutrients to zooplankton via primary production (including ice algae and benthos), specific crustaceans and fish species, and the results of inverse ecosystem modelling. The next generation of climate-ecosystem models will bridge the different components of the ecosystem together toward comprehensive climatic, trophodynamic, and biogeochemical models. Efforts will be directed toward the assimilation of data and the further reduction of errors, the production of scenario estimates for climate warming and changes in the hydrological cycles, and the design of monitoring programs based on simulations that capture the extent of the variability.

Session 6: Recent changes in ecosystem structure or function

THUR 10:50 (SESSION 6)

Effects of climate change on fish distribution and dynamics in the northern North Atlantic

K. Brander

ICES, H C Andersens Blv. 44-46, DK 1553 Copenhagen V, Denmark

Some of the best observational studies of the effects of climate change on fish and other marine life date back to the 1930s, when the North Atlantic, particularly around Greenland and Iceland, went through a warm period which lasted for several decades. This period therefore provides a well-documented analogue from which to project likely biological impacts of the warming which has taken place over the last two decades. However the warm period from 1920 to the 1940s (and later in some areas) was a regional rather than a global phenomenon of finite length, whereas the recent warming is thought to be the beginning of a continuing trend whose end probably depends on human behaviour. Many changes have been recorded in plankton and fish distribution in the North Atlantic since the 1960s and these are consistent with the effects of rising sea temperatures. Marine biota reacts to temperature changes much more rapidly than terrestrial biota – the water masses which transport heat northwards also carry plankton and fish. What about changes other than gross distribution of cold and warm-water fish species? In particular can changes in reproduction and

growth, which govern the productivity of fisheries, be attributed confidently to changing climate? Some very recent evidence of climate effects on cod stocks in European waters will be presented and the implications of this will be discussed. What kinds of climate prediction do we need and how can these be applied in order to improve our management of fisheries?

THUR 11:10 (SESSION 6)

Interdecadal variability in *Neocalanus* copepods biomass in the Oyashio waters from 1970 to 2002

K. Tadokoro, H. Sugisaki and H. Saito

Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technogly, 3173-25 Showa-machi, Kanazawaku, Yokohama, Kanagawa 236-0001, Japan

Interdecadal variability in mesozooplankton and *Neocalanus* biomass were examined in the Oyashio waters from 1970 to 2002. The mesozooplankton biomass decreased in the late 1970s-early 1980s and increased in the early 1990s from summer to autumn, and the accompanied negative and positive phase shifts were observed in 1976/77-1981/82 and 1991/92-1992/93. The timing of the decrease in mesozooplankton biomass roughly corresponded with the 1976/77 climatic regime shift. On the other hand, the timing of the increase in biomass in 1993 was 4-5 years later from the climatic regime shift that occurred in 1988/89. The pattern of the interannual variations in mesozooplankton biomass corresponded with that of *N. plumchrus* throughout observation and that of *N. cristatus* after the 1980s. In a previous study, we reported that predation pressure on *N. plumchrus* by Japanese sardine was likely to affect interannual variation in *N. plumchrus* biomass during the summer in the 1980s. In this study, we observed that significant decrease in surface phosphate concentration in the early 1980s-early 1990s in July. This suggested that the primary production during summertime decreased in the period. Therefore, a decrease in phosphate concentration might negatively affect the food availability of the *N. plumchrus* We also observed similar patterns of the interannual variation in phosphate concentration at a 26.8 σ_t isopycnal which is the center of North Pacific Intermediate Water (NPIW). This suggested that the phosphate concentration not only decreased at the surface but also in the subsurface waters in the early 1980s-early 1990s.

THUR 11:30 (SESSION 6)

The changing southeastern Bering Sea shelf

P. Stabeno, J M. Napp and T.E. Whitledge

Pacific Marine Environmental Laboratory/NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, USA

For the last decade a series of biophysical moorings has been maintained at Site 2 (56.9°N, 164°W) on the Bering Sea shelf. A second series of biophysical moorings has been deployed at Site 4 (57.9ºN, 168.9ºW) since 1995 (continuous since 2000) providing almost six years of more sporadic data. Both moorings sites are in the middle domain at ~72m water depth. These data are used to quantify the marked changes that have occurred over the southeastern shelf in the last decade and to examine the mechanisms that control these changes. These shifts include: a reduction in the southern extent of sea ice; a significant warming of the water column; a reduction in the size of the "cold pool"; and a shift in the timing of the spring bloom at Site 2. These changes impact the ecosystem, from phytoplankton to upper trophic levels. To relate changes in the timing of the spring bloom to the ecosystem, we use maps of weekly ice concentration (1972-present) and numerical models to create weekly maps of the timing of the spring bloom over the central and southeastern

shelf. We relate these, together with time series obtained at the mooring sites, to climatic indices (e.g. Pacific Decadal Oscilaltion, the Arctic Oscillation and ENSO) and time series of year-class strength of pollock (*Theragra chalcogramma*) and other fish species. These long-term observations provide the critical component to understand the impact of climate shifts on the Bering Sea ecosystem.

THUR 11:50 (SESSION 6)

The Bering Strait region: an Arctic ecosystem in change

J.M. Grebmeier, L.W. Cooper and J.R. Lovvorn

University of Tennessee, Marine Biogeochemistry and Ecology Group, 10515 Research, Suite 100, Knoxville, Tennessee, 37932, USA

The detection of biological change in the Arctic marine environment coincides with recent observations of high-latitude environmental change, including a seasonal reduction in the extent and duration of sea ice, increased seawater temperature, and changing hydrographic conditions. Recent studies indicate that the northern Bering Sea is shifting towards an earlier spring transition between ice-covered and ice-free conditions, with changes in overlying primary production, pelagic-benthic coupling, and benthic production and community structure. These apparent changes could lead to dramatic impacts for higher-trophic level fauna, such as benthic-feeding walrus, bearded seals, gray whales and diving sea-ducks that are of cultural and subsistence significance to Arctic Native people. Recent indicators of contemporary Arctic change in the northern Bering Sea include seawater warming and reduction in ice extent. Our time-series studies indicate associated declines in bottom-dwelling clam populations in the shallow northern Bering shelf in the 1990s. In addition, declines in benthic amphipod populations north of St. Lawrence Island likely influenced the movement of migrating gray whales to feeding areas north of Bering Strait in the Chukchi Sea during this same time period. Finally, a potential consequence of a seawater warming and reduced ice extent in the northern Bering Sea could be the northward movement of bottom feeding fish currently in the southern Bering Sea that prey on benthic fauna, thus increasing the feeding pressure on the benthic prey base and enhance competition for this food source for benthic-feeding marine mammals and seabirds. This presentation will outline recent biological changes observed in the Bering Strait region through presentation of a >20 year environmental time series data set.

THUR 12:10 (SESSION 6)

Ocean climate variability and its effects on marine resources on the Newfoundland and Labrador Shelf

E.B. Colbourne, D.G. Parsons and E.G. Dawe

Department of Fisheries and Oceans, P. O. Box 5667, St. John's NL, A1C 5X1, Canada

The ocean climate in the Northwest Atlantic has undergone dramatic changes throughout the latter half of the 20th century. The 1950s and 1960s, the warmest decades in the instrumented record were followed by a 30-year period dominated by extreme variability. Ocean temperature experienced near-decadal oscillations and a declining trend to cold-fresh conditions. In addition, climate conditions within each of the past 3 decades fluctuated considerably, with the decade of the 1990s featuring the most extreme variations. Coincident with the observed changes in ocean

climate, many commercially exploited marine species have shown significant changes in abundance and distribution, particularly since the late 1980s. For example, populations of Atlantic cod off Newfoundland and Labrador decreased from all-time highs in the 1960s to historical low levels by the early 1990s. The decline in abundance of cod, as well as other fish species, contrasted the substantial increases in abundance of northern shrimp and snow crab. We investigate the effects of variations in ocean climate on recruitment in snow crab, northern shrimp and Atlantic cod. The results showed that cold-fresh conditions in Newfoundland and Labrador waters were related to poor recruitment in cod, while the reverse was true for the two crustacean species. We conclude that climate-induced changes in the productivity of groundfish and crustacean species were responsible, in part, for the regime shift evidenced in the fisheries of the Northwest Atlantic. However, the relative importance of climatic variation versus other contributing factors, including high fishing mortality on cod and release of predation on crab and shrimp, remains unknown.

Session 7: Implications of climate-forced change for management and social institutions

THUR 14:00 (SESSION 7)

Fisheries–climate interactions: observations from the North Atlantic Arc

L. Hamilton

University of New Hampshire, Sociology Department, Durham, NH 03824, USA

The North Atlantic Arc (NAArc) project examines human-environment interactions through a series of case studies. To date, such case studies have been completed in fisheries-dependent regions of Newfoundland, Greenland, Iceland and the Faroe Islands. Although each case study made unique discoveries, they also found strong patterns in common. The commonalities support three broad conclusions:

1. Socially important environmental changes result not simply from climatic change, but from interactions between climate, ecosystem and resource usage. For example, intensively exploited ecosystems have less resilience in the face of adverse climatic events.
2. Resource-dependent communities exhibit characteristic demographic and other social changes, including migration driven by interactions between resources and other socioeconomic forces.
3. Resource change creates winners and losers. How benefits and costs are distributed depends not simply on environmental advantages, but also on other variables of interest to social scientists, including institutional response, investments, human capital (education and skills) and social capital (networks and patterns of cooperation).

More generally, the NAArc findings argue against a simple view that climatic change deterministically drives societal outcomes. In all cases studied, the story proves to be more complex.

THUR 14:20 (SESSION 7)

Impacts of Climate Change on Arctic Communities

L. Merculieff

Alaska Native Science Commission, 429 L Street, Anchorage

Key findings from the Arctic Climate Impact Assessment report include UV-B impacts; sea level rise; sea ice reductions; permafrost disappearance; climate regime shifts; movement of treeline; significant reductions in the number and distribution of seals, walrus and polar bears; impacts on caribou population and health; and the introduction of new diseases and parasites. The ACIA also reports on the impact of climate change on the region's inhabitants, particularly its indigenous peoples who depend on hunting of polar bear, walrus, seals, caribou, as well as fishing and gathering as their primary food sources. These activities are the basis for cultural and social identity. Changes in species' ranges and availability, access to species, reduction in weather predictability and travel safety in chancing ice and weather conditions present serious challenges to human health and food security, and possibly even the survival of some cultures. Coastal flooding threatens many Alaska Native communities. It is vital to strengthen the voice of the region's inhabitants in key policy debates – as collectively, Arctic indigenous peoples are disproportionately burdened by these developments, yet under-represented at national and international forums where decisions are made. The purpose of this session is to present these impacts from an Alaska Native community perspective and to begin a dialogue to structure a collaborative effort among indigenous peoples of the Arctic to proactively address the issues of climate change.

THUR 14:40 (SESSION 7)

On ice, walruses, and men: a story of three storytellers

I. Krupnik[1] and G.C. Ray[2]

[1]*Arctic Studies Center, Department of Anthropology, National Museum of Natural History, Smithsonian Institution, 10th and Constitution Ave., NW, Washington, DC , 20013, USA*

[2]*Department of Environmental Sciences University of Virginia 271 Clarke Hall, USA*

Growing evidence indicates that recent changes in climate, ocean and atmospheric circulation, sea-ice distribution, and other physical parameters may soon trigger dramatic restructuring of Beringian ecosystems (i.e. the shelf areas of the Bering and Chukchi seas). Concerns have been expressed about prospective negative impacts of these changes on biological resources and native communities of Beringia. The Pacific walrus, one of the key species of Beringia, due to its very high biomass consumption and the effects of its feeding on benthic communities, could be an excellent indicator of ecosystem changes because of its close association with sea ice. The walrus is also crucial to human subsistence, due to extensive use by local hunters of two dozen indigenous communities in Alaska and the Russian Chukchi Peninsula. This paper evaluates three perspectives of changing walrus-ice-human relationships - from marine biology, indigenous knowledge, and cultural anthropology. All three types of knowledge have remarkable similarities, as well as significant gaps and important distinctions, suggesting the possibility of bridging, or 'integrating', these types of knowledge. Such an approach argues that differences could be rectified through more active knowledge sharing, enhanced documentation of indigenous records, and new scientific and methodological approaches. We conclude that interdisciplinary scientific partnership is vital to advance understanding of the relationships mentioned above, as no single vision could grasp the complexity of the processes and the positions of the key disciplines involved.

THUR 15:00 (SESSION 7)

Climate change, marine resources and community health

H. Dolan

Department of Geography, University of Victoria, University of Victoria, P.O. Box 3050, Stn CSC, Victoria, BC, V8W 3P5, Canada

Climate-related changes, both short-term variability and long-term climate change, have serious consequences for the health of northern coastal communities that owe much of their prosperity to rich marine resources. Climate change will likely have direct and indirect impacts on population and community health, via increased exposures to environmental risks and changes in marine resource quality and quantity, including reduced availability and access. The relationship between marine ecosystem changes and their manifestation in the health of local communities is not straightforward. As evidenced in research conducted by the Coasts Under Stress program, environmental changes interact with social institutions to affect the health of people and communities in unforeseen ways. Furthermore, communities themselves are not mere passive recipients of environmental change, but respond, autonomously and strategically, to uncertain changes in natural and social environments. These interactions have consequences for the health of local communities and their residents. We suggest that to better understand how changes to marine resources might affect the health of northern coastal communities a socio-ecological lens that recognizes these bi-directional relationships should be considered. This talk presents evidence from an interdisciplinary research project to illustrate the utility of a comprehensive framework to study human-environment relationships in the context of environmental change.

THUR 15:20 (SESSION 7)

Linking the past to the present and planning for the future: human and ecosystem health in the Gulf of Alaska

M.S. Murray, L.K. Duffy, S.C. Gerlach, A.C. Hirons and J. Schaaf

University of Alaska Fairbanks, Dept. of Anthropology, PO 757720, University of Alaska Fairbanks, Fairbanks, AK, 99775-7720, USA

Risk assessments, and assessments of individual and community health in the contemporary setting are often undertaken with, at best, an obligatory nod to the importance of the historical dimension. In this case study we present new data on marine mammals that bears upon subsistence choices and health at the community level in the face of changes in the marine food web and mercury bioaccumulation in the Gulf of Alaska (GOA). We derive a long-term frame of reference from research in archaeology, ecotoxicology and stable isotope chemistry. We also discuss why this framework is essential, in combination with future social impact and risk assessment analysis, for understanding and evaluating current conditions in Alaskan communities for whom consumption of marine resources is still important, both nutritionally and culturally. This research places present day changes in the marine ecosystem and in contaminant uptake in the context of past natural variability, (mid-Holocene to present), including possible changes in the length of the marine food web and climate change episodes. It is the first step towards predicting and modeling future scenarios, and especially human responses to real and perceived health hazards resulting from the consumption of marine species. The research also opens frontiers for understanding and managing the marine environment as an example of the integration of archaeological, biological, and physical approaches to human and marine system science.

Abstracts: Posters

Poster group: Ecosystem

POSTER E1

Impact of changes in hydrological and hydrochemical parameters on bioproductivity in the western Bering Sea

K.V. Batrak and O.S. Ivanova

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17, V. Krasnoselskaya, Moscow, 107140, Russia

The main objective of the present work is to consider and discuss the changes in the western Bering Sea ecosystem state during 1990-1995. For this purpose, data on the distribution of hydrological (T, S) and hydrochemical (O_2, PO_4, Si, NO_2, NO_3, NH_4, N_{org}) characteristics are used. Also, for the first time the analysis of data on the organic matter (N_{org},) collected by VNIRO scientists in the research cruises in the western Bering Sea for 1990s is presented. The relationships between interannual changes in, and their impact on, the bioproductivity of the region are studied.

POSTER E2

Current status and historical trend indicators of climate and fishing effects on the Bering Sea ecosystem

J. Boldt, P. Livingston and A.B. Hollowed

NOAA Fisheries, University of Washington, Joint Institute for the Study of Atmosphere and Ocean, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Bldg. 4, Seattle WA 98115-0070, USA

Both climate and fishing are agents of change that can affect the production and distribution of marine organisms in the North Pacific. It is well known that a major climate shift occurred in the North Pacific around 1976/77, a minor climate shift was observed in 1989, and another climate shift occurred in 1998/99. These climate shifts are reflected in ocean conditions, such as sea surface temperature, ice cover, and wind-driven transport. The relative importance of each of these climate shifts to physical conditions in the Bering Sea varies, as does their impact on the production and distribution of marine organisms. Fisheries can impact fish and ecosystems directly by selectivity, magnitude, timing, location, and methods of fish removal. There are other effects of fishing such as vessel disturbance, nutrient cycling, the introduction of exotic species, pollution, unobserved mortality, and habitat alteration. Both ocean conditions and fishing activity may affect the marine communities of the Bering Sea. The Ecosystem Considerations section of the Stock Assessment and Fishery Evaluation of the North Pacific Fisheries Management Council provides a current and historical perspective on status and trends of ecosystem components and ecosystem-level attributes using an indicator approach. Past and present indicators of climate and fishing effects on the Bering Sea ecosystem are summarized.

POSTER E3

Model simulations of the Gulf of St. Lawrence summer circulation and early life stages drift, growth and survival from 1955 to 2004

J. Chasse

Bedford Institute of Oceanography, Fisheries and Oceans Canada, PO Box 1006, Dartmouth, N.S. Canada, B2Y 4A2

We present the results of a three-dimensional bio-physical modeling system used to simulate the summer oceanic conditions as well as the drift, growth and survival of the early life stages of lobster, snow crab and cod in the Southern Gulf of St. Lawrence. Individual-Based Models (IBM) of the Early Life Stages (ELS) are incorporated into a full 3D hydrodynamic model of the ocean. The main biological input to the model is the parameterization of the distribution and abundance of the early stages of the life cycle and their growth and mortality rates. The model is driven with the NCEP atmospheric forcing, tides, precipitation and freshwater runoff. Simulations have been carried out for years 1955 to 2004 and a climatology (1971-2000) has been established from which anomalies are calculated. The results of the numerical system are discussed and compared with oceanographic observations and recruitment time series.

POSTER E4

Climate – ecosystem link in the western sub-Arctic North Pacific based on the 40 year time series of copepod community structure

S. Chiba, K. Tadokoro, H. Sugisaki and T. Saino

Frontier Research Center for Global Change/JAMSTEC, 3173-25 Showa-machi, Kanazawa-ku, Yokohama-shi, 236-0001 Japan

Based on the historically collected zooplankton samples from the 1950s to present in the western North Pacific, the Odate Collection, we started the project in 2003 to understand the link among climate, upper water environment and lower trophic level of the ecosystem. Coverage of the Odate Collection is the Oyashio, Kuroshio and Transition zone, and the total number of samples was over 20,000. We first picked up about 2000 samples for microscopic analysis from the Oyashio region, which is known for extensive spring blooms and as an efficient biological carbon pump. Species composition of copepods was analyzed for 1960–2001. Both quantitative and phenological variations were detected in copepod community structure, which roughly coincided with climatic regime shifts of 1976/1977 and 1988/1989. After the 1976/1977 regime shift, the productive season started later and terminated earlier than in previous years. In the 1990s, production of spring-type community was unsuccessful while that of the summer-type community was enhanced. Our results suggested that climatic forcing, which affected yearly lower trophic level production, might differ between wintertime and summertime. Possible hydrographic/chemical factors that affect copepod community structure and driven by climate variation will be discussed in the presentation.

POSTER E5

Benthic infaunal community on the southeastern Bering Sea shelf: the potential impact of global climate change

K. Coyle, R.C. Highsmith and B. Konar

Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99775-7220, USA

In the late 1950s and early 1960s, Soviet researchers collected benthic infaunal samples from the southeastern Bering Sea Shelf. Approximately 15 years later, in 1975 and 1976, researchers at University of Alaska Fairbanks (UAF) also sampled the region to assess infaunal biomass and abundance. We examined the two data sets to document any consistent differences in infaunal biomass between the two time periods. Of the 64 families identified from both data sets, 21 showed statistically significant differences in mean biomass. Of the 21 families showing significant differences, 19 (91%) of the families had higher mean biomass in the UAF data set. The above differences suggest a trend toward higher overall infaunal biomass during the interval between the late 1950s and the mid-1970s. Temperature measurements and literature data indicate that the mid-1970s was an unusually cold period relative to the period before and after. The above observations suggest the potential for periodic changes in infuanal biomass are due to temperature changes. A review of the available information on food web relationships and ecosystem dynamics in the southeastern Bering Sea indicated that during cold periods, infaunal biomass will be elevated relative to warm periods due to elevated carbon flux to the benthos and exclusion of benthic infaunal predators by the cold bottom water on the shelf. As long-term observations of temperature and sea-ice coverage indicate a secular warming trend on the Bering Sea shelf, the potential changes in food-web relationships could markedly alter energy flow to apex consumers.

POSTER E6

Distribution, seasonal changes in *Calanus glacialis* population structure and the role of this species in capelin feeding in the Barents Sea

A.V. Dolgov, E.L. Orlova, V.D. Boitsov, V.N. Nesterova, G.B. Rudneva, V.V. Sklyar, E.S. Tereschenko and L.L. Konstantinova

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, Murmansk 183763 Russia

This study is based on the multiage data (1982-1985, 1987, 1989, 1992, 2002-2003 – years differ by hydrological conditions) collected in summer-autumn period in the north part of the Barents Sea using a Jedy net. The role of Atlantic and Arctic water masses in *C. glacialis* distribution and population structure was observed. We document the time of *Calanus glacialis* spawning in the central and north-east part of the Barents Sea in some years. Data of daily vertical distribution of different age individuals is also presented. The zooplankton biomass and the importance of *C. glacialis* in various regions of the Barents Sea are found. Consumption of *C. glacialis* by capelin are examined for several years (1985, 2001-2003). The importance of this species in capelin feeding and fish fatness dynamics (the fatness was determined by biochemical method according to the fat content in muscles) in the drifting ice zone is shown.

POSTER E7

Spatial variations in water mass properties, phytoplankton, nutrients and forage fish during fall in the eastern Bering Sea

L. Eisner, K. Cieciel, E. Farley and J. Helle

Auke Bay Laboratory, NOAA, Auke Bay Laboratory, 11305 Glacier Hwy, Juneau, AK 99801, USA

Oceanographic and fisheries surveys were conducted during fall 2000-2004 on the eastern Bering Sea shelf, as part of a multiyear international research program, Bering-Aleutian Salmon International Survey (BASIS). Stations were located between 54ºN and 68ºN, and generally spaced 15-30 km apart, although spatial coverage varied by region and by year. Forage fish were captured with a surface net trawl and oceanographic data were obtained from vertical conductivity-temperature-depth (CTD) profiles and laboratory analyses of discrete water samples at select depths. Oceanographic variables include temperature, salinity, nutrients, chlorophyll a, and phytoplankton taxonomic characteristics (based on phytoplankton species identification and chlorophyll a size fractionation). We describe how spatial and temporal variations in water mass characteristics relate to phytoplankton biomass and taxonomic variations, nutrient concentrations and forage fish distributions. A long-term goal of our research is to provide information for understanding ecosystem interactions among climate, oceanography, and lower and higher trophic levels in the eastern Bering Sea.

POSTER E8

Arctic Ocean Diversity (ArcOD), a Census of Marine Life project

R. Gradinger, B. Bluhm and R.R. Hopcroft

University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, PO Box 757220, Fairbanks AK 99775-7220, USA

The Arctic climate is changing at a tremendous rate, which make efforts to identify the diversity of life in the major three realms (sea ice, water column and sea floor) of the Arctic and sub-Arctic seas an urgent issue. Current knowledge indicates that the Arctic seas hold a multitude of unique life forms adapted to the extremes of that environment. The Arctic Ocean Diversity (ArcOD) project is part of the Census of Marine Life (CoML) program. It aims at documenting the existing biodiversity of the Arctic using an international pan-Arctic approach. This program will consolidate what is known and strives to fill remaining gaps in our knowledge. A major effort is directed at implementing a coordinated effort using the unique opportunities arising during the International Polar Year 2007/2008. This poster presents the concept and structure of the ArcOD project.

POSTER E9

Physical forcing of phytoplankton community structure in continental shelf waters of the West Antarctic Peninsula

E.E. Hofmann, B.B. Prezelin, J.M. Klinck and M. Moline

Old Dominion University, Center for Coastal Physical Oceanography 768 W 52nd Street, Norfolk, VA 23529, USA

A previous study of the western Antarctic Peninsula (WAP) continental shelf that was based upon a multidisciplinary data set collected during austral summer of January 1993 identified a mechanism previously unrecognized that sets up a physical and chemical structure that supports enhanced

biological production. This biological production occurs when the southern boundary of the Antarctic Circumpolar Current (ACC) flows along the shelf edge and produces onshelf intrusions of nutrient-rich Upper Circumpolar Deep Water (UCDW), thereby allowing site-specific diatom-dominated phytoplankton communities to develop. The enhanced biological production potentially affects all components of the marine food web in this region. In this analysis, we extend the area and seasons studied through similar analyses of multidisciplinary data sets collected on four additional cruises that cover all seasons. We find that this newly recognized forcing is active in other regions of the WAP shelf where similar conditions are found, is episodic, and is forced by non-seasonal physical processes. The meander frequency of the ACC has consequences for the timing and location of UCDW intrusions. When multiple intrusions are observed, each event may be in a different stage. Further, the occurrence of an event in one area does not necessarily imply that similar events are ongoing in other areas along the WAP shelf. These observations show clearly that the phytoplankton community structure on the WAP shelf is determined by physical forcing. Moreover, variability in this physical forcing, such as may occur via climate change, can potentially affect the overall biological production of the WAP continental shelf system

---

POSTER E10

Oceanic subsidies in coastal waters enhance salmon survival, evidencing an ecological role of cross-shelf exchange

T. Kline

Prince William Sound Science Center, PO Box 1949, Cordova, AK 99574, USA

Differences in the relative amount of oceanic and coastal carbon assimilated by early marine pink salmon rearing in Prince William Sound (PWS) and on the inner Gulf of Alaska (GOA) shelf each year from 1998 to 2003 were determined using stable isotope analysis (SIA). The exceptionally large pink salmon (*Oncorhynchus gorbuscha*) runs that returned to PWS in 2003 were released from hatcheries or emerged from the gravel during the spring of 2002, the year when juveniles were the most dependent on oceanic carbon. Conversely, the highest dependency on coastal carbon by juveniles occurred in 2001; these returned in very low numbers in 2002. Oceanic subsidies in the form of zooplankton, which were more abundant in 2002 compared to 2001, are hypothesized to have enhanced survival in two ways. First, oceanic plankton from the Gulf augmented that available in the Sound and accelerated salmon growth reducing the time when they were most vulnerable to predation. Second, oceanic plankton from the Gulf augmented that available in the Sound such that concentrations were above threshold levels enabling potential salmon predators to switch to zooplankton. SIA data show that oceanic carbon drove salmon production in 2002. A high correlation between euphausiid numbers and salmon run size supports prey switching by salmon predators because euphausiids were not important for salmon early marine diets, but can be important for salmon predators. That low ^{13}C content carbon was associated with higher salmon returns to PWS contradicts a hypothesis that high ^{13}C reflects higher system capacity.

POSTER E11

Recruitment variation of eastern Bering Sea crabs: climate-forcing or top-down effects?

G.H. Kruse and J. Zheng

University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau Center, 11120 Glacier Highway, Juneau, AK 99801, USA

During the last three decades, population abundances of Eastern Bering Sea (EBS) crab stocks fluctuated greatly, driven by highly variable recruitment. During recent years, abundances of these stocks have been very low compared to historical high levels. This study aims to understand recruitment variation of six stocks of red king (*Paralithodes camtschaticus*), blue king (*P. platypus*), Tanner (*Chionoecetes bairdi*), and snow (*C. opilio*) crabs in the EBS. Most crab recruitment time series are not significantly correlated with each other. Spatial distributions of three broadly distributed crab stocks (EBS snow and Tanner crabs and Bristol Bay red king crab) have changed considerably over time, perhaps related in part to the regime shift in climate and physical oceanography in 1976-1977. Three climate forcing hypotheses on larval survival were proposed to explain crab recruitment variation of Bristol Bay red king crab and EBS Tanner and snow crabs. Some empirical evidence supports speculation that groundfish predation may play an important role in crab recruitment success in the EBS. However, spatial dynamics in the geographic distributions of groundfish and crabs over time make it difficult to relate crab recruitment strength to the groundfish biomass. Comprehensive field and spatially explicit modeling studies are needed to test the hypotheses and better understand the relative importance and compound effects of bottom-up and top-down controls on crab recruitment.

POSTER E12

Identifying spatio-temporal variations in the East/Japan Sea ecosystem using a neural network pattern recognition approach

J.B. Lee[1], C.I. Zhang[2], D.W. Lee[1], J.H. Choi[1], S. Kang[3] and Y.S. Kim[1]

[1]*National Fisheries Research and Development Institute, 408-1, Shirang-ri, Gijang-eup/gun, Busan 619-902, Korea*

[2]*Pukyong National University, Busan 608-737 Korea*

[3]*Salmon Research Team, East Seas Fisheries Research Institute, NFRDI, Yangyang 215 821 Korea*

A neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes. We examined the role of spatio-temporal oceanographic variability on the distribution patterns of small pelagics in the East/Japan Sea ecosystem. A self-organizing map (SOM), one of the neural network pattern recognition techniques, was applied in this study to seek clusters in the data using this unsupervised learning methodology over a twenty-year time series of physical and biological environmental data such as temperature, salinity and zooplankton, and CPUE distribution data of major small pelagics for the Korean large purse seine fishery in the ecosystem. A series of processing steps in training SOM was used, that is, first crude initial patterns were formed, following by a refinement, constructing monthly and annual frequency maps. Frequency maps have the dimensions of the SOM output array and show the frequency of occurrence of each pattern in the data set. We categorized physical and biological ocean environments using seawater temperature, salinity, density (σ_t) and zooplankton distribution, and defined marine ecosystem with thirty six stations grouped into the East/Japan Sea using this

unsupervised learning methodology. Based on the divided ecosystem, wavelet spectra exhibited strong decadal frequencies of 8-16 years within 95% confidence levels. We discuss shifts in the habitats of small pelagic fishes triggered by climatic events, such as ENSO and climatic regime shifts (CRS) in the East/Japan Sea ecosystem.

POSTER E13

Lower trophic food web dynamics on the SE Bering Sea shelf: a tale of two summers

E.J. Lessard, M.S. Foy and M. Bernhardt
University of Washington, School of Oceanography, Box 357490, Seattle WA 98195, USA

Research on lower trophic levels on the SE Bering Sea shelf has focused on the role of the spring diatom bloom as the main annual production event. However, substantial production must occur outside of the short spring bloom to fuel developing stages of juvenile fishes and their copepod prey. Examining community structure and lower trophic food web dynamics during summer is therefore critical for understanding the drivers of high fish production and ecosystem responses to climatic change. As part of a North Pacific marine research project, two cruises were made to the middle shelf domain in July 2000 and August 2001. Both summer periods were characterized by strong stratification and nutrient deplete surface waters; however, surface water was significantly warmer and mixed layer deeper in 2001. There was great spatial heterogeneity in plankton composition and biomass. Chlorophyll and microzooplankton biomass was nearly twice as high in 2001 than in 2000. Phytoplankton was typically dominated by small cells (<10 µm), however species composition was quite different between the two years. Diatoms were more prevalent in 2001, and several stations were dominated by the large diatom *Proboscia alata*. The microzooplankton community was also different; ciliates were more dominant in 2001. Phytoplankton growth rates were somewhat higher in 2001, but despite the community differences, microzooplankton grazing was typically 70% or more of growth, indicating a tight coupling of production and consumption during summer. Possible reasons for the differences and their implications for changes in the trophic structure on the shelf will be discussed.

POSTER E14

Organic matter pathways to zooplankton and benthos under pack ice in late winter and open water in late summer in the north-central Bering Sea

J.R. Lovvorn, L.W. Cooper, M.L. Brooks, C.C. De Ruyck, J.K. Bump and J.M. Grebmeier
University of Wyoming, Department of Zoology, Laramie, WY 82071, USA

On sub-Arctic continental shelves, much of the production from ice-edge spring blooms may sink to the bottom with little grazing by zooplankton, thereby supporting benthic communities. The importance of this settled phytoplankton to macrobenthos throughout the year may partly determine effects of long-term changes in ice cover. We studied organic matter (OM) pathways to macrobenthos and macrozooplankton under ice cover in late winter (March-April) and open water in late summer (September) in the north-central Bering Sea. In late winter, only a small fraction of OM in the water column was particulate. C:N ratios, ^{13}C, and ^{15}N in suspended particulate organic matter (SPOM) and sediments indicated little recent input of fresh ice algae or phytoplankton in ice-covered areas. For the three main deposit-feeding bivalves, ^{13}C and ^{15}N indicated similar diets among species, with minimal change in food quality between late summer and late winter, and between late winters

with very different ice cover. There were large increases in ^{13}C from SPOM to bulk sediments (+3.2‰) and from sediments to deposit-feeders (+1.6 to +3.0‰), but small differences in ^{15}N from SPOM to sediments (+1.2‰) and from sediments to deposit-feeders (-0.3 to +1.6‰). These values suggest that the diet of deposit-feeders during these non-bloom periods included substantial amounts of the cells or products of bacteria that had assimilated well-reworked carbon and isotopically light, dissolved inorganic nitrogen. By late summer and through winter, 4 to 11 months after the spring bloom, products of bacterial activity appeared to be an important route of OM into the benthic food web.

POSTER E15

Modeling the energy balance of spectacled eiders during long-term benthic change in the Bering Sea

J.R. Lovvorn, J.M. Grebmeier, L.W. Cooper, S.K. Richman, J.K. Bump and B.I. Sirenko
University of Wyoming, Department of Zoology, Laramie, WY 82071, USA

The world population of threatened spectacled eiders winters in the Bering Sea, where they dive 40-70 m among leads in the pack ice to feed on macrobenthos. Foraging costs relative to food intake rates are key to the eiders' overwinter survival and prebreeding condition. Based on field, laboratory, and remote sensing studies, we modeled effects on the eiders' energy balance of changes in benthos revealed by periodic sampling from 1950 to present. Biomechanical studies indicated that swim speed is critical to dive costs, and similar species with time-depth recorders closely regulated their speed throughout dives. Respirometry suggested that use of "waste" heat from exercising muscles greatly reduces thermoregulation costs. In dive tanks, the eiders' intake rates of infaunal bivalves varied with shell length and burial depth, as well as numbers/m^2. In the field, SPEI ate mostly a narrow length class of a single bivalve species. Although leads frequently open and close, the dynamics of shifting ice under different weather conditions had little effect on estimates of daily flight costs, except when south winds forced widespread closing of leads. Based on transect samples during winter 1999 and 2001, kriging was used to interpolate continuous grids for different species and sizes of bivalves. Long-term sampling at a subset of stations indicated ranges of prey densities and size structures for modeling extremes in those variables over time. Estimates of dive costs and intake rates for varying prey availability and weather will indicate the potential effects of long-term changes on the overwinter survival and breeding potential of spectacled eiders.

POSTER E16

The RIVSUM - zooplankton biomass - Atlantic mackerel story: does it hold with a second decade of data?

S. Plourde, M. Castonguay, B.A. Zakardjian and F. Maps
Department of Fisheries and Oceans Canada, Ocean Sciences Branch, Maurice Lamontagne Institute, 850 route de la Mer, C.P. 1000, Mont-Joli, Qc., G5H 3Z4, Canada

Previous studies identified a relationship linking variations in the physical environment to zooplankton biomass and Atlantic mackerel recruitment in southern Gulf of St. Lawrence (GSL) between 1982 and 1991. An exceptional mackerel year-class occurred in 1982, a year of low freshwater discharge (RIVSUM) during the winter-spring period and high zooplankton biomass in early summer. *Calanus finmarchicus* females, a species that overwinters in the deep area of the

GSL and has to recolonize this shallow region each year, were more abundant and widely distributed in the southern GSL in early summer of 1982, a year characterised by mackerel larvae having heavier and fuller stomachs. A greater incidence of *C. finmarchicus* nauplii in the diet of larvae mainly drove this interannual variability in the feeding success. A second exceptional mackerel year-class was observed in 1999, another year characterised by a low winter-spring RIVSUM and high zooplankton biomass. These observations suggest: (1) a connectivity between oceanographic conditions in the GSL and the potential for the advection and maintenance of high abundance of *C. finmarchicus* in the southern GSL in spring-summer, and (2) a causal link between production of copepod nauplii, feeding of mackerel larvae, and recruitment success. Hypothesis about the potential sources and mechanisms linking environmental conditions and *C. finmarchicus* in the southern GSL will be tested using data collected during the oceanographic-zooplankton-mackerel survey conducted in the southern GSL in June and a 3-dimensional coupled biological-physical model of the population dynamics of *C. finmarchicus* in the entire GSL in 1999 and 2000.

POSTER E17

The decline of *Themisto* amphipods, and other observations from seabird diet data on St. Lawrence island, Alaska

I.C. Rose[1], D.D. Roby[1], A.E. Gall[1], L. Sheffield[1] and D.B. Irons[2]

[1]*US Geological Survey - Oregon Cooperative Fish and Wildlife Research Unit at Oregon State University, Corvallis OR 97331, USA*

[2]*Migratory Bird Management Office, US Fish and Wildlife Service, Anchorage AK 99702, USA*

Seabirds are dependent on the marine environment for food, but must come to land to breed, making them ideal indicator species for detecting changes in the marine environment. For five summers, a joint project of the USGS-Oregon Cooperative Wildlife Research Unit at Oregon State University and the US Fish and Wildlife Service has monitored the productivity, diet and population dynamics of five species of seabirds nesting on St. Lawrence Island, AK. One significant change over the study period has been the decrease in the gammariid amphipod Themisto libellula as a dietary component of both Least Auklets (*Aethia pusilla*) and Crested Auklets (*A. cristatella*). *T. libellula* is a pelagic amphipod which is usually associated with Arctic water masses, but which was once found as far south as the Gulf of Alaska and the Southeastern Bering Sea (SEBS). It has now virtually disappeared from both seabird diets and plankton tows in the SEBS region, a phenomenon believed to be related to an overall warming trend since the 1970s. At St. Lawrence Island in the northern Bering Sea, *T. libellula* has decreased from a significant portion of both auklet species' nestling diets in 2000 (>20% by mass) to near absence in 2003 and 2004. We postulate that this is due to a continued range contraction of this amphipod species out of the subarctic part of its Pacific range, again due to ocean warming in Alaskan waters. Other observations of seabird diets from the five-year data set are presented and discussed as well.

POSTER E18

Linkages between climate, growth, competition at sea, and sockeye salmon abundance in Bristol Bay, Alaska, 1955-2000

G.T. Ruggerone and J.L. Nielsen

Natural Resources Consultants, Inc./US Geological Survey, 1900 West Nickerson Street, Suite 207, Seattle, WA 98119, USA

Salmon abundance in Bristol Bay, Alaska, and other northern regions more than doubled after the 1976/77 marine climate shift, yet biological mechanisms influencing salmon survival at sea are poorly understood. We tested several hypotheses linking climate to salmon growth, interspecific competition, and salmon production by measuring seasonal and annual marine scale growth of Bristol Bay sockeye salmon from 1955 to 2000. Increased sockeye salmon abundance after the mid-1970s was associated with greater salmon growth during the first and second years at sea, whereas growth during the third year tended to be below average. These differences in growth were more pronounced during specific seasons, depending on salmon age, and presumably reflected seasonal shifts in prey availability between the two periods. Additional research indicated significantly lower growth and lower survival of sockeye salmon during odd-numbered years when Asian pink salmon were abundant. Reduced growth in odd-numbered years began after peak growth in spring then continued through summer and fall even though pink salmon had left the high seas by late July. The alternating-year pattern of sockeye salmon growth was consistent before and after the mid-1970s climate shift, indicating competition transcended the climate shift. We hypothesize that high prey consumption rates by pink salmon during spring through mid-July of odd-numbered years, coupled with declining zooplankton biomass during summer and potentially cyclic abundances of squid and other prey, contributed to reduced prey availability and reduced growth of Bristol Bay sockeye salmon during late spring through fall of odd-numbered years.

POSTER E19

The influence of ocean conditions on interannual variation in diet composition and productivity of planktivorous seabirds on St. Lawrence Island in the Northern Bering Sea

L.M. Sheffield[1], A.E. Gall[1], D.D. Roby[1], I.C. Rose[1] and D.B. Irons[2].

[1]*USGS-Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, 104 Nash, Corvallis, OR 97331, USA*

[2]*US Fish and Wildlife Service - Migratory Bird Management, Anchorage, AK, 104 Nash Hall, Oregon State University, Corvallis, OR 97331, USA.*

Seabirds are sensitive indicators of change in marine ecosystems, and variation in seabird reproductive success has been closely linked with food availability (i.e. primary and secondary productivity) during the breeding season. Least (*Aethia pusilla*) and crested auklets *(A. cristatella*) are the most abundant planktivorous seabirds breeding in the North Pacific and Bering Sea and display annual variation in productivity related to changes in availability of their zooplankton prey. We examined the relationships between the composition of nestling diets and the productivity of least and crested auklets at two colonies on St. Lawrence Island, Alaska during five breeding seasons (2000–2004). Both auklet species displayed a trend toward earlier nest initiation during our study. Nesting success of least auklets was highest when high-lipid, oceanic copepods (*Neocalanus* spp.) were relatively abundant in the diet and lowest when the neritic, low-lipid copepod *Calanus marshallae* was more prevalent in the diet. Crested auklet nesting success was highest in years when large euphausiids (*Thysanoessa raschii*) and large copepods (*N. cristatus*) were prevalent in

the diet and lowest when amphipods (*Parathemisto libellula*) and the small copepod *N. flemingeri* were more prevalent in the diet. Advection of oceanic *Neocalanus* copepods far onto the shelf of the northern Bering Sea by the Anadyr Current appears to be a key determinant of auklet nesting success on St. Lawrence Island. Variation in seabird diets and productivity may provide a useful gauge of changes in marine food webs in the northern Bering Sea related to the strength of the Anadyr Current.

POSTER E20

Trophic structures and energy transfers in the lower pelagic and sympagic (ice associated) Arctic marine food webs

J.E. Søreide, S. Falk-Petersen, H. Hop, E.N. Hegseth and M. Carroll
Akvaplan-niva AS, Polar Environmental Centre, N-9296 Tromso, Norway

Changing ice conditions associated with different climatic regimes drive primary production on the northern Svalbard shelf and the Barents Sea through different carbon sources (ice algae vs. phytoplankton). By means of fatty acid biomarkers and stable isotope ratios (^{13}C and ^{15}N) we investigated the major energetic pathways and trophic structure in the lower pelagic and sympagic food chain in Svalbard waters and the Barents Sea. During seasonal (May, August and December) field campaigns in 2003-2004, samples from different ice conditions, algal bloom situations and algal communities were collected together with zooplankton and ice fauna from the respective conditions. Preliminary results indicate that ice algae is the major energy source for sympagic organisms, although increased input of energy from the pelagic system occur as the sympagic individuals grow larger. In the pelagic system, the herbivores mainly utilize pelagic algae, but depending upon the species, some grazing on ice algae is detectable. Zooplankton with enriched ^{13}C values combined with low ^{15}N is commonly found, indicating that there is an important sympagic-pelagic coupling in the marginal ice zone. A species trophic position in the lower Arctic marine food chain is dynamic and shifts with size and between seasons.

POSTER E21

Interannual differences in lower trophic level processes in the southeastern Bering Sea

S. Strom, K. Fredrickson and M.B. Olson
Shannon Point Marine Center, Western Washington University, 1900 Shannon Point Rd., Anacortes WA 98221, USA

We studied the regulation of phytoplankton production by nutrient availability and microzooplankton grazing during summer in the southeastern Bering Sea. Major differences between 1999, a cold year with a substantial coccolithophorid bloom, and 2004, a warm year, were seen for both production and grazing processes. Intrinsic growth rates of phytoplankton were moderate to high during 1999, and were lower and more strongly nutrient-limited during 2004. Microzooplankton grazing on coccolithophorids was reduced inside the 1999 bloom, probably contributing to bloom formation and persistence. Shelf-wide, however, a large fraction of primary production was consumed by microzooplankton (median = 92%). In contrast, grazing rates were very low during 2004, even relative to that year's lower phytoplankton growth, so that microzooplankton consumed a much smaller fraction of summer primary production (median = 36%). Hypotheses for these differences include changes in predation on microzooplankton and use of alternative food sources by

microzooplankton. These large interannual differences in lower trophic level processes will strongly influence the transfer of primary production to higher trophic levels in the rich southeastern Bering Sea ecosystem.

POSTER E22

Intra-specific variation of life history strategies across taxa in response to environmental forcing in sub-Arctic Seas

R.M. Suryan

Oregon State University, Hatfield Marine Science Center, 2030 S.E. Marine Science Dr., Newport, Oregon, 97365, USA

Variation in life history traits (e.g. age at maturity, fecundity, survival) of organisms is thought to reflect adaptations to environmental forcing occurring from both bottom-up and top-down processes. Such variation occurs not only among, but also within species, indicating demographic plasticity in response to differing environmental conditions. For example, in comparing species that inhabit the North Atlantic and North Pacific Oceans, intra-specific variation in life history traits has been observed at trophic levels ranging from zooplankton to sharks and seabirds. In all these cases, species in the Pacific exhibited lower annual fecundity but greater annual survival (K-selected tendency) than con-specifics in the Atlantic (r-selected tendency). Captive studies of fishes have shown that differences in growth and age of reproduction can indeed be a function of environmental control rather than genetic variation. Similar parallel occurrences also have been observed in adjacent seas, for example with zooplankton and seabird species in the North Atlantic and North Sea - tending toward more K-selected traits in cooler North Sea waters. These examples show system-wide adaptations in life history strategies resulting from environmental forcing and provide a framework for comparisons of ecosystem function among oceanic regions (or regimes) and may prove valuable in modeling ecosystem response to environmental change.

POSTER E23

Bering Sea ecosystems at the brink of the 20th and 21st centuries: contemporary status and long-term dynamics based on Russian biological research data

V.V. Sviridov and V.P. Shuntov

Pacific Scientific Research Fisheries Center (TINRO-Center), Laboratory of Applied Biocenology, 4, Schevtchenko Alley, Vladivostok, 690950 Russia

Starting from the previous decade, the studies and conclusions of many researchers on changes in ecosystems' biota and individual species abundance were interpreted as the result of global warming induced by the greenhouse effect. We do not support the viewpoint that the greenhouse effect plays a dominant role in the contemporary climate state. On the other hand, if we consider cyclicity at the scale of several centuries, it is evident that the middle of the 19th century is characterized by a new natural period, which is similar to the warm Viking Age. Under such conditions, this process is gradual. In addition, short-term cycles may function within long-term cycles (the examples are given for the Bering Sea during several latter decades). Interpretations of changes in specific regions biota as a result of global climate changes often appear to be unsuccessful due not only to the poor understanding of mechanisms that link biota with climate-oceanological and biocenological conditions. First of all this is due to the stronger influence of regional factors, in other words, spatially determined variability. It seems that the northeastern part of Asia and the adjacent waters are

always somewhat "out of sink" with global change. This is true for the Bering Sea in the eastern part (stronger influence of oceanic waters) and the western part (influence of run-off waters). Examples are given for plankton and nekton status during latter decades. The results of Russian research on the Bering Sea biological resources testify that latter decade changes in biota result mostly from well-known natural long-term dynamics,although some examples of overfishing serve as exceptions. The examples of interannual and long-term dynamics of the Bering Sea plankton, benthos, nekton and nektobenthos are provided.

Poster group: Fish, birds and marine mammals

POSTER FBM1

Comparative analysis of structure and dynamics of ichthyochenoses in the Barents Sea and other sub-Arctic Seas

A.V. Dolgov

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, Murmansk 183763, Russia

Composition and distribution of bottom ichthyocenoses in the Barents Sea are examined based on data from Russian surveys. Changes in the structure of ichthyocenoses and their dependence on water temperature, as well as their year-to-year variability are discussed. Composition and structure of the ichthyocenoses in the Barents Sea are compared with those in other sub-Arctic Seas.

POSTER FBM2

Some features of biology, population structure, distribution and consumption of Hyperiidae by fish in the Barents Sea

A.V. Dolgov, E.L. Orlova, V.N. Nesterova, G.B. Rudneva and D.I. Alexandrov

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street Murmansk 183763 Russia

The present study is based on samples collected in summer-autumn and autumn-winter periods using a Jedy net attached to a trawl net. The distribution and some features of the size and age population structure of Arctic species *Themisto libellula* (Hyperiidae) were observed. Presence of three size-groups and small (2-5 mm) individuals in the population all year round show a 3-year life cycle and prolonged spawning period in Arctic waters. The seasonal and interannual dynamics of consumption of *T. libellula* by pelagic and demersal fish (capelin, cod, arctic cod, and haddock) and data on the caloricity of this species were also observed.

POSTER FBM3

Exploring links between ichthyoplankton dynamics and the pelagic environment in the northwest Gulf of Alaska

M. Doyle, S. Picquelle, M. Spillane and K. Mier

Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA 98195, USA

Time series of the numerically dominant ichthyoplankton species in the vicinity of Shelikof Strait in the Gulf of Alaska exhibit strong interannual variability in abundance. The data, drawn from spring surveys between 1981 and 2003, are compared with time series of climate and ocean data representative of the local and basin-scale physical environment. While species-specific periodicity and amplitude of variation in abundance dominate, some inter-species correlations are apparent. Notable is a decadal trend of elevated levels of larval abundance during the 1990s, relative to the 1980s, for northern lampfish, Pacific cod, arrowtooth flounder and Pacific halibut. Statistically insignificant correlations between average larval size and abundance over the time period suggest that interannual variation in timing of egg and larval production among species may not be important. Rather, variations in the observed abundance of species may reflect interannual variation in the quantity of local egg and larval production, egg mortality, larval survival and growth, and the transport of eggs and larvae into and out of the study area. It is hypothesized that these early life history dynamics of fish populations in the northwest Gulf of Alaska are species-specifically linked to three key environmental variables, ocean temperatures, current patterns and larval food availability. To explore these links a variety of multivariate analytical techniques were applied to the data to detect patterns in the ichthyoplankton species time-series and identify potential explanatory, environmental variables.

POSTER FBM4

Cetacean distribution and abundance in relation to oceanographic domains on the Eastern Bering Sea shelf

N.A. Friday, J.M. Waite and S. Moore

National Marine Mammal Laboratory, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115-6349, USA

Vessel surveys for cetaceans have been conducted in association with a groundfish stock assessment survey in the Eastern Bering Sea. The central-eastern Bering Sea shelf was surveyed in 1999, the southeastern shelf in 2000 and 2004, and both areas in 2002. In all years, the surveys were conducted from the NOAA ship Miller Freeman using line-transect methodology with 25x binoculars. This analysis supplements previous data analyzed by Moore *et al*. (2002) and estimates abundance for three hydrographic domains (coastal, middle shelf, and outer shelf) which correspond to oceanographic and productivity patterns in the Bering Sea. Interannual variability in abundance and distribution are presented. Results are also compared to Tynan (2004) who estimated 1997 and 1999 cetacean abundance by hydrographic domain on the southeastern Bering Sea shelf, dominated by the middle shelf domain. The most common mysticete and odontocete were the fin whale and the Dall's porpoise for all years except 2004. In 2004, humpback whales were the most common mysticete, Pacific white-sided dolphins were the most common odontocete in terms of the number of individuals, but Dall's porpoise were more common in terms of sightings. Fin whales, found throughout the Bering Sea shelf, were clustered between the 100-200m isobaths. Humpback whales concentrated along the 50 m isobath north of the Alaska Peninsula. Minke whales were found throughout the middle and outer shelf domains. Dall's porpoise and harbor porpoise were primarily distributed on opposite sides of the 100 m isobath (with Dall's in deeper water).

POSTER FBM5

High gray whale densities at an oceanographic front in the south-central Chukchi Sea, Arctic, in 2003 versus low densities in the traditional feeding site, the Chirikov Basin

B. Bluhm, R.C. Highsmith, K. Coyle and B. Konar

University of Alaska Fairbanks, School of Fisheries and Ocean Sciences P O Box 757220, Fairbanks AK 99775-7220, USA

The eastern gray whale population migrates from the wintering grounds in Baja California north to the Bering and Chukchi Seas to exploit the rich benthic biomass, predominantly ampeliscid amphipods. Gray whale distribution and relative abundance were derived from sightings made during point sampling surveys conducted in the Chirikov Basin in the northern Bering Sea, and the south-central Chukchi Sea in June and September of 2003. The physical oceanographic conditions and chlorophyll concentrations of the regions suggest that gray whale densities were particularly high at an oceanographic front in the south-central Chukchi Sea. Sightings were few in the Chirikov Basin, a traditionally heavily used gray whale feeding site. This poster describes the observed whale densities and presents the physical and biological environmental conditions.

POSTER FBM6

Monitoring marine bird distributions across the sub-Arctic North Pacific using platform of opportunity vessels (2002 - 2004)

D. Hyrenbach, M. Henry, K. Morgan, C. Rintoul and W. Sydeman

Duke University Marine Lab., PRBO Conservation Science, Duke University Marine Laboratory, 135 Duke Marine Lab. Road, Beaufort, NC 28516, USA

In 2002, we initiated a multi-year monitoring program to survey marine bird communities from British Columbia (Canada) to Hokkaido (Japan), using the bulk-cargo carrier 'Skaubryn' as a platform of opportunity. This project seeks to document spatial gradients in upper-trophic predator assemblages, as well as temporal fluctuations in community structure across the subarctic North Pacific Ocean and the southern Bering Sea. We first developed standardized survey techniques using pilot data collected during the summer and fall of 2002. Using these standardized protocols, we have completed six more surveys since the summer of 2002. Herein, we provide a synthetic atlas of the seasonal (spring, summer, fall) and interannual (2002 – 2004) distribution of the numerically dominant seabird species along a 7,500 km transect. Our replicate surveys have documented clear spatial gradients in faunal distributions, with a particularly striking east to west segregation of three shearwater species: Sooty Shearwaters dominate off BC and in the Gulf of Alaska, Short-tailed Shearwaters are numerically dominant in the Southern Bering Sea, and Streaked Shearwaters are most numerous in the Kuroshio – Oyashio current. We have also documented seasonal changes associated with the latitudinal shifts of subtropical and subarctic species, and year-to-year fluctuations in seabird abundance, which have coincided with changing environmental conditions. This novel synoptic perspective of seabird distributions across the North Pacific underscores the value of cargo vessels as platforms of opportunity. In particular, large-scale standardized surveys are essential to facilitate regional comparisons of the structure and response of large marine ecosystems to environmental variability.

POSTER FBM7

Exploration of ecosystem indicators for use in management of a new fishery for capelin off West Greenland

A. Jarre, K. Wieland, R.P. Frandsen, B. Lyberth and M. Storr-Paulsen
Danish Institute for Fisheries Research, North Sea Centre, DK-9850 Hirtshals, Denmark

The marine ecosystem off West Greenland is an arcto-boreal system similar in structure to the Barents Sea, the Newfoundland Shelf and the Bering Sea. The West Greenland fishery is presently dominated by northern shrimp *Pandalus borealis*, Greenland halibut *Reinhardtius hippoglossus* and snow crab *Chionoecetes opilio*, with the contribution of Atlantic cod *Gadus morhua* slightly increasing from a historic low. Capelin *Mallotus villosus* and polar cod *Boreogadus saida* are important species of forage fishes both for predatory fishes, seabirds and marine mammals, and seasonal key dependence of some predators on this prey cannot be excluded. Forage fishes have not yet been fished commercially to any major extent off West Greenland, and knowledge on the biology and dynamics on the forage fishes off West Greenland is sparse. A new offshore fishery for capelin has for some time been in the planning phase. This contribution addresses the usefulness of several ecosystem indicators for the management of this new fishery in the West Greenland ecosystem. Additionally, trophic models are used to explore several fishing scenarios derived from assumptions on stock structure and spatial distribution, as well as hypothetical management objectives

---

POSTER FBM8

Interpretation of otolith chemistry of chum salmon in relation to climate and habitat changes

S. Kang, S. Kim, K. Telmer, D. Welch and Y.-H. Lee
National Fisheries Research and Development Institute, 408-1, Shirnag-ri, Gijang-eup, Gijang-gun, Busan 619-902, Korea

Contents of stable isotopes and trace elements in otolith of chum salmon (*Oncorhynchus keta*) have been used to investigate the life-history behavior and environmental changes in the North Pacific Ocean. Chum salmon otoliths were obtained from four hatcheries in the eastern (Canada and USA) and the western (Japan and Korea) North Pacific during 1997 and 1999 spawning seasons. Oxygen stable isotope (^{18}O) of Japanese salmon showed the highest values, and Canadian salmon the lowest, with mean differences of ca. 0.8‰ in three consecutive years. Assuming ^{18}O values are indicative of ocean temperatures, Asian salmon seem to reside in lower temperature than North American stocks. Over that period the mean ^{13}C values of each country did not show a coincident trend, whereas the mean ^{18}O values shifted around 1998. The lower ^{18}O in 1998 would represent a significant change in oceanic environment such as the strong El Niño of 1997/1998. Sr/Ca ratios, known as an indicator of salinity, were low at the primordial area of the otolith, increased suddenly and oscillated periodically to the margin, corresponding to the year-ring. Estuarine type of Sr/Ca profiles were found in the North American stock when they were young and near coastal areas. The zinc profiles oscillated and corresponded to the year-ring. However, the profiles of Sr and Zn oscillated out of phase after salmon migrated to the saline water. By examining stable isotopes ^{18}O and^{13}C values and Sr/Ca and Zn/Ca ratios in otolith, it would be possible to determine the timing of seaward migration and marine environmental changes related to climate.

POSTER FBM9

Retrospective analysis of density-dependent and density-independent growth of walleye pollock *Theragra chalcogramma* in the Bering Sea

S. Katakura, H. Ikeda, A. Nishimura, T. Nishiyama and Y. Sakurai

Graduate School of Fisheries Sciences, Hokkaido University, Minato-cho 3-1-1, Hakodate, Hokkaido 041-8611, Japan

This study analyzed the aspects of density-dependent and density-independent growth in walleye pollock *Theragra chalcogramma* in the eastern Bering Sea. The growth analyses of pollock at young ages derived from the back-calculation of processed otolith section, with our proposed "Lifetime Allometry Equations." Back-calculated length increased between 1965 and 1996 year-classes for the age 2 to age 5, but not for age 1 individuals. The length of age 7 individuals was related with their growth patterns that occurred during ages 1-2, particularly during the summer of age 1. During this summer, an increase of the Eastern Bering Sea adult pollock biomass caused the year-class strength to decrease, but individual body size increased. As a result, adult basin pollock body size increased. Density-dependent growth is supposed to occur during the summer of age 1 life history by cannibalism impacts. Growth during ages 0-1 were not affected by to the summer of age 1 growth, but were influenced by water temperature, indicating these individuals underwent density-independent growth. Relative merits of life for a moment determine or affect lifetime merits. We conclude this result with the "Carrier turning point hypothesis." Changes in growth increment during ages 0-1 coincided with those of time series of water temperature index in 1965-1996. Anomalies of growth increment during ages 0-1 increased abruptly during the 1977/78 regime shift.

POSTER FBM10

Predictive modelling of foraging strategies of marine indicator species (seabirds) with Geographic Information Systems (GIS), GPS data loggers and progressive habitat analyses along a sub-Arctic Pacific gradient

J. Kotzerka, S. Garthe and F. Huettmann

Institute of Polar Ecology, University of Kiel, 24148, Kiel, Germany

It is known that distributions of seabirds at sea are driven by several distinct predictors (e.g. food organisms, oceanographic parameters, fishery activities). Therefore, they can act as indicators of the marine environment. The climate and the seasonal ice cover in the sub-Arctic seas also seem to influence seabirds in most aspects of their breeding biology, their distribution at sea and in their foraging strategies. Changing climatic conditions will therefore cause different activity patterns of marine birds. Seabirds nowadays can be equipped with devices that determine animal movements and habitats together with environmental variables (e.g. miniature GPS- and compass-loggers with integrated temperature and pressure sensors). In this way marine birds can measure and monitor, in concert with GIS, the physical properties of the ocean in which they live and forage. Based on earlier work, we plan to carry out a comparison of St. Lawrence Island, Bering Sea, and the Kurile Islands, Sea of Okhotsk. We propose to study the foraging behaviour of seabirds at sea at geographically different colonies along a latitudinal gradient. For these regions, their dependence on typical oceanographic, and climatic parameters, as well as fishing activities will be studied and modelled with the help of data-loggers, GIS, and habitat data as well as "Resource Selection Functions" (RSF) and Discrete Choice Models. These results should allow us to relate seabirds to changing environmental and climatic conditions. The last objective is to obtain with spatial predictions relevant large-scale information for the environmental gradient of seabirds breeding in this Arctic region.

POSTER FBM11

Climate change, glacial recession and population declines in two sub-Arctic murrelets

K. Kuletz and J.F. Piatt
U.S. Fish and Wildlife Service, 1011 E. Tudor Rd., Anchorage, Alaska 99503, USA

The Kittlitz's Murrelet (*Brachyramphus brevirostris*) diverged from the Marbled Murrelet (*B. marmoratus*) at the onset of the ice ages during the late Pliocene. Today, the Marbled Murrelet occurs from Alaska to California and is the more abundant species. The Kittlitz's occurs in Alaska and Russia, in association with tidewater glaciers or areas with extensive ice sheets and remnant glaciers. In Alaska, Kittlitz's populations have declined by >80-90% during the past 15 years, corresponding to the recession of glaciers and ice fields, a result of global warming. Declines of Kittlitz's are most evident in fjords with retreating glaciers; such fjords generally have higher sediment loads and possibly lower primary productivity than those with stable or advancing glaciers, and thus population trends of Kittlitz's may be one signal of changes in associated waters. The Marbled Murrelet is more of a generalist in use of marine habitats, but it also has been declining at monitored areas in Alaska, by 75%-85% during the past 30 years. Both murrelets depend on similar fish species, which suggests that changes in prey have precipitated their respective declines. Kittlitz's consume a higher proportion of macro-zooplankton, however, and may thus be more directly affected by changes at lower trophic levels. Compared to Marbled Murrelets, the restricted range and more rapid decline of Kittlitz's reflect its greater reliance on glacially-influenced marine systems.

POSTER FBM12

Listening for endangered whales offshore Alaska, 1999-2004

S. Moore, K. Stafford, L. Munger, D. Mellinger and J. Hildebrand
NOAA/Alaska Fisheries Science Center, APL-UW, 1013 NE 40th Street, Seattle, WA 98105-6698, USA

In 1999, a multi-year project to advance the use of passive acoustics for detection and assessment of endangered whales offshore Alaska was initiated by the NOAA's Pacific Marine Environmental Laboratory (PMEL) and National Marine Mammal Laboratory (NMML). The NMML collaborated with researchers at Scripps Institution of Oceanography (SIO) and Oregon State University (OSU) to leverage expertise in underwater acoustics to cetacean research. Since 1999, multiple year-long deployments of autonomous recorders in the Gulf of Alaska (GOA), southeast Bering Sea, and the northwest Beaufort Sea have yielded unprecedented information on seasonal occurrence and calling behavior of endangered blue, fin, humpback, sperm, North Pacific right and bowhead whales. For example, two blue whale call types were discovered, and sperm whale clicks were detected year-round, on recorders deployed in the GOA. Calls from critically endangered North Pacific right whales were detected in the Bering Sea from May through November, and in regions of the western GOA where they have not been seen since the end of commercial whaling. Fin and humpback whale calls were ubiquitous on nearly all instruments suggesting these species may contribute significant top-down grazing pressure in some habitats. Since 2003, recorders have been deployed in tandem with PMEL oceanographic moorings in the Bering Sea, thereby enhancing the capability to model effects of environmental variables on cetacean call detection and seasonal occurrence. Due to robust sampling capability and integration with oceanographic moorings, passive acoustics is a primary tool to enable incorporation of cetacean detection to upcoming Ocean Observing Systems and ecosystem modeling.

POSTER FBM13

Passive acoustic research on endangered North Pacific right whales and fin whales in Alaskan waters

L. Munger, J. Hildebrand, S. Wiggins and S. Moore

Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, mail code 0205, La Jolla, CA, 92093-0205, USA

We used two types of passive, underwater acoustic instrumentation to provide information on endangered North Pacific right whales (*Eubalaena japonica*) and fin whales (*Balaenoptera physalus*) in the Bering Sea and western Gulf of Alaska. In the Bering Sea, we deployed DIrectional Fixing And Ranging (DIFAR) sonobuoys during vessel-based cetacean surveys in summers of 2002 and 2004 to detect and localize calling whales. Real-time acoustic localization guided the vessel to several sightings of rare right whales from distances of 20-100 km, enabling researchers to obtain photographs, biopsy samples, and to attach satellite tags. We also deployed autonomous, moored Acoustic Recording Packages (ARPs) in three study areas: the southeast Bering Sea middle-shelf domain (in years 2000-2002 and 2004-2005), the Bering Sea shelf break (2004-2005), and offshore Kodiak Island (2003). The ARPs recorded continuously over year-long periods at an effective bandwidth up to 250 Hz (2000-2002) or 500 Hz (2003 and later), encompassing that of fin whale calls and most North Pacific right whale calls. These recorders provided long-term data on calling whales over spatial scales ranging from 10 to 100s of km. We report preliminary findings on the seasonal occurrence of right and fin whale calls, and acoustic behavior on temporal scales of hours to days. Our research is conducted with collaboration and/or support from NOAA Alaska Fisheries Science Center, National Marine Mammal Laboratory, Southwest Fisheries Science Center, and Pacific Marine Environmental Laboratory; North Pacific Marine Research Institute and North Pacific Research Board, National Fish and Wildlife Foundation, and others.

POSTER FBM14

Feeding of predatory groundfish in the Shelikhov Bay in September 2004

V.V. Napazakov

Pacific Fisheries Research Centre (TINRO), Russia 4, Shevchenko Alley, Vladivostok 690950, Russia

In our study, food samples three species predatory fish were collected from bottom trawls at 41-195 m depth range in the Shelikhov Bay in September, 2004. Pacific cod (*Gadus macrocephalus*), great sculpin (*Myoxocephalus polyacanthocephalus*) and Okhotsk sculpin (*M. ochotensis*) were the subjects of our research. The general biomass of these species has formed about half of the total biomass of the groundfish community of the area. A total of 136 Pacific cod, 112 great sculpin and 62 Okhotsk sculpin stomachs were analyzed. The studies of groundfish feeding in the Shelikhov Bay were not carried out earlier, and the data on Okhotsk sculpin feeding is completely new. The Pacific cod and great sculpin diets consisted mainly of fish, shrimps, crabs and octopuses. The Okhotsk sculpin diet consisted mainly of shrimp, crab and fish. In the Shelikhov Bay the diets of these predators are similar with their prey consisting mainly of three systematic groups: decapods, fish and mollusks. The diet of Pacific cod, Okhotsk and great sculpins varies depending upon the size of the fish. As spatial niches of the two species of sculpins and of cod in the Shelikhov Bay overlap, they are potential competitors.

POSTER FBM15

Ecological characteristics of juvenile walleye pollock in the Pacific coast of Hokkaido and possible wasp waist control in their nursery ground

A. Nishimura, T. Yanagimoto, T. Hamatsu, T. Yasui and Y. Sakurai

Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsura-koi, Kushiro, Hokkaido, 085-0802, Japan

The Pacific coast of eastern Hokkaido (Doto area) is an important nursery area for juvenile walleye pollock, *Theragra chalcogramma*. The major spawning area is located in the southwestern part of Hokkaido (Funka Bay). The migration pattern of juveniles from the spawning area to nursery area has been deduced. In the nursery area, juvenile distribution was observed by an echo sounder and echo signs of juveniles were sampled with a trawl net in summer, 2000-2004. Juvenile abundance fluctuated year by year. In 2000, when there was a strong year class, juveniles were distributed below the thermocline (>30m) to the bottom, extensively on the shallower shelf (<150 m bottom), and schooling behavior was remarkable. Interannual variability in distribution, hatch-date, and early growth was elucidated in relation to the oceanographic condition. Their diets were dominated by small zooplankton, mainly copepods and euphausiids, and stomach fullness was variable by year and station. In 2000 and 2001, copepods were the important food organisms for the juvenile fish, euphausiids replaced to copepods after that. On the other hand, age-0 pollock were the primary prey of Pacific cod, adult walleye pollock, squid, flatfishes, etc. Predation by those species depended upon the density and spatial distribution of juveniles and potential predators. They are planktivorous and are an important source of food for predators. Once a strong year class is established, they constitute mid-trophic level “wasp-waist’’ populations in this season and area, and they play an important role to control the ecosystem.

POSTER FBM16

Predictable foraging hotspots for endangered short-tailed albatross in Alaska

J.F. Piatt, J. Wetzel and G. Balogh

USGS Alaska Science Center, 1011 E Tudor Rd, Anchorage AK 99503, USA

The three North Pacific albatrosses - Laysan, Black-footed and Short-tailed - forage widely over the North Pacific basin but are segregated in marine waters of Alaska during summer. Laysan (LAAL) and Black-footed (BFAL) albatrosses occur mostly in pelagic habitats south of the Aleutians and in the Gulf of Alaska (GOA), and they are segregated spatially from east (BFAL) to west (LAAL). Populations of Short-tailed Albatross (STAL) were driven to near extinction during the 1900s and observations at sea have been very limited until recent years. Because the STAL was historically hunted and eaten by coast-dwelling Aleuts and sometimes found far inshore on continental shelves, it was considered a “coastal” albatross. However, re-analysis of more than 1100 sight records of about 1800 birds suggests to us that the STAL concentrates its foraging effort in areas of upwelling along the outer continental shelf-edge in the northern GOA, along the length of the Bering Sea shelf-edge, and along shelf-edges and deep passes in the Aleutian islands. The species is only “coastal” where coastlines are close to strong upwelling zones. Because of its association with topographically defined upwelling systems, it appears that some hotspots for STAL are predictable.

POSTER FBM17

Annual fluctuations in recruitment of walleye pollock in Oyashio region related to environmental change

O. Shida, T. Hamatsu, A. Nishimura, A. Suzaki, K. Miyashita and Y. Sakurai

Muroran Branch, Hokkaido Hakodate Fisheries Experimental Station, Funami-cho, Muroran, Hokkaido 051-0013, Japan

The Pacific stock of walleye pollock, *Theragra chalcogramma*, in Japan is the largest walleye pollock stock around Japan and a key element of the Oyashio ecosystem. In southern Hokkaido, Japan, walleye pollock spawns mainly in January and February near the mouth of Funka Bay (FB). Most eggs and larvae are transported into the bay, and after early summer, juvenile pollock migrate along the southern coast of Hokkaido to a nursery ground on the continental shelf off eastern Hokkaido (EH). However, some eggs and larvae are transported southward to off the Tohoku region (TR). Transport depends largely on the Oyashio, which flows generally southward along the eastern coasts of Hokkaido and the TR. In the 1980s, when the Oyashio flowed strongly southward, recruitment estimated from VPA was kept a medium level over the decade. In the 1990s, when the Oyashio weakened, strong year classes occurred in 1991, 1994 and 1995, but not in the later half of the 1990s. Juvenile catches as indices of recruitment level from the TR were high in the 1980s and decreased in the 1990s. Although recruitment patterns differed between the 1980s and the 1990s, there was no significant difference in the average number of recruits between these decades. We discuss the possible relationships between environmental change and annual fluctuations in recruitment.

POSTER FBM18

Pre-spawning Pacific herring migration pattern and environmental variability in southeastern Bering Sea

N. Tojo, G.H. Kruse and F.C. Funk

University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau Center, 11120 Glacier Highway, Juneau, AK 99801, USA

Pacific herring (*Clupea pallasi*) in the southeastern Bering Sea undergo large-scale migrations. General locations of wintering grounds and pre-spawning migration pathways were known since foreign herring fisheries in the 1960s and 1970s. Herring overwinter near the Pribilof Islands, migrate east to the coast for spawning in spring, and thereafter migrate southwest along the Alaska Peninsula to the outer shelf where they move northwest, following bathymetry back to the Pribilof Islands in fall. Despite this general understanding, variability in herring seasonal migrations has not been investigated. We conducted a retrospective analysis of herring bycatch data collected by NMFS observers aboard groundfish vessels since the 1990s to examine spatio-temporal dynamics of annual migrations. Observed changes were compared with variability in climate and oceanographic conditions in ArcGIS. Recent herring bycatch confirms the general clockwise migration pattern observed in the 1960s and 1970s, but annual shifts in migration pathways were identified. Pre-spawning herring were concentrated in distinctly different areas, depending on whether spawning was early or late that year. Variability in sea ice appears responsible. In particular, thermal structure and dynamics around the ice edge affects 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. Shifts in herring migrations affect their availability as prey for marine mammals and seabirds, some of which have declined sharply in recent years.

POSTER FBM19

Thermocline shapes diving behavior of thick-billed murres

A. Takahashi, K. Matsumoto, G.L. Hunt, Jr., M.T. Shultz, A. Kitaysky, K. Sato and Y. Watanuki
Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato-cho, Hakodate 041-8611, Japan

Linking diving and foraging behavior of small seabirds with fine-scale characteristics of water masses has been challenging largely due to technological constraints. We examined the diving behavior of 12 chick-rearing thick-billed murres at St. George Island, Eastern Bering Sea, in relation to sea surface temperature (SST) and thermocline depth that were recorded by ventrally-attached depth-temperature-acceleration data loggers (16 g). Our initial results from summer 2004 showed that murres utilized various water masses, ranging from well-mixed water (SST 7-9°C, near the island) to well-stratified water (SST 9-12°C, relatively far from the island). Murres dived deeper (modal depth: 70-80 m) in the mixed water mass, whereas dives were shallower (modal depth: 20-30 m) and to just below the thermocline depth in the stratified water mass. In the stratified water mass, murres dived deeper, to below the thermocline, during the last dive bout in a foraging trip, when they were presumably foraging for a chick meal rather than foraging for themselves. We suggest that the thermocline is important in shaping depth utilization of thick-billed murres, possibly through its effect on the vertical distribution of both zooplankton and fish prey.

POSTER FBM20

Bowhead whales feed on plankton concentrated by tidal currents in Academy Bay, Sea of Okhotsk

K. Rogachev, E. Carmack and M. Foreman
Pacific Oceanological Institute, 43 Baltiyskay Street, Vladivostok, 690041, Russia

Academy Bay, Sea of Okhotsk, is the major summertime feeding ground for pelagic-feeding Bowhead whales (*Balaena mysticetus*) in the western sub-Arctic North Pacific. The present work combines satellite observations with physical (CTD, currents, tides) and biological measurements (zooplankton sampling). Sampling obtained aboard the RV Lugovoe during two seasons in August-September 2003 and July- August 2004 shows that tidal currents (with amplitude of ~0.8 m/s) act to aggregate zooplankton within this critically important ecosystem. Specifically, dense populations of dominant species of zooplankton (such as copepods *Calanus* sp., pteropods *Limacina helicina*, and chaetognaths *Sagitta* sp.) are concentrated within the Bay by physical mechanisms. We show that horizontal patchiness is controlled by the horizontal gradient of currents. The concentration of such organisms as molluscs *Limacina helicina* in the accumulation zone is due to physical processes: swimming in the ambient flow and convergence of the residual currents. In general, the horizontal patchiness is controlled by the horizontal gradient of currents. The hypothesis that tidal mechanisms aggregate plankton is supported by direct observations, showing the importance of the centrifugal upwelling off Cape Ukurunru and tidal-residual eddy formation within the Bay. At the same time some organisms migrate preferentially to the near-bottom boundary layer, either as part of their daily migration, or in order to avoid high turbulence. This combination of the centrifugal upwelling, tidal residual eddy and swimming behaviour together acts to concentrate zooplankton near the cape and provides the necessary densities of planktonic food supply for Bowhead whales.

POSTER FBM21

Species composition of ichthyofauna and its distribution on a shelf of western part of Bering Sea in October-November 2004

A.B. Savin and V.A. Shelekhov

Pacific Research Fisheries Centre (ÒINRÎ-centre), Shevchenko Alley, 4, 690950, Vladivostok, Russia

Bottom trawls were made by the FRV "KamtchatNIRO-1" on the shelf and continental slope of the Navarin area between 171° and 178°30'E in October-November 2004. Depth of catch ranged from 12 to 284 m. Sixty-four trawls were made with a horizontal opening 16 m and a vertical opening of 5 m. We analyzed bathymetric and longitudinal variability of benthic ichthyofauna in the surveyed area. Data were analyzed using multidimensional scaling and cluster analysis. A total of 91 species of fishes and lamprey belonged to 23 families. Cottidae (18 species), Pleuronectidae (12 species), Agonidae (8 species) were the most numerous in the fish community during the period of our research. Two species of the family Cottidae, *Gymnacanthus galeatus* and *Myoxocephalus polyacanthocephalus*, and also *Gadus macrocephalus* were most numerous, and occurred in more than 90% of catches. *Theragra chalcogramma, Eleginus gracilis*, sculpins of the genus Hemilepidotus*, Lepidopsetta polyxystra* and *Pleuronectes quadrituberculatus* occurred in more than 70% of catches. The biomass of fishes averaged 30.2 tons/km^2. *Gadidae* species made up 71.23% of the total biomass, Cottidae - 18.58% and Pleuronectidae - 7.23%. Walleye pollock was the most abundant species and comprised 45.4% of the total biomass, Saffron cod - 13.8%, Pacific cod - 12.1% and Yellow Irish Lord - 6.9%. Longitudinal changes in species composition besides bathymetric variability have been revealed. We distinguished 8 areas based on the species composition, number and occurrence of fishes. These were associated with features of the bottom topography on the shelf.

POSTER FBM22

Growth, condition, and reproductive capacity in Newfoundland cod under changing feeding and oceanic regimes

G. Sherwood, R. Rideout, S. Fudge and G. Rose

Memorial University, Marine Institute, 155 Ridge Rd. St. John's, NL Canada A1C 5R3

Cod populations in Newfoundland waters have shown differing growth, condition and recruitment since near universal declines in these properties during the cold period of the late 1980s and early 1990s. We compare cod responses in populations off Labrador (ca. 52-54ºN) and the northeast (ca. 48-49ºN) and south coasts (45-48ºN) of Newfoundland. Growth in length did not differ among areas. Many properties were highest in the southern group and lowest in the northern group, including somatic condition, age at maturity, fecundity, and modeled egg production. Northeast coast fish had higher rates of egg resorption and termination of spawning. These differences could not be explained by sea temperatures or salinities measured during surveys. All differences could be related to diet, as measured by stomach contents and isotope signatures. The cod diet off Labrador consisted almost entirely of shrimp. Northeast coast cod had a more varied diet that included other gadoids and some capelin, and had a benthic isotope signature. South coast cod exhibited the most varied diet, including capelin, sand lance, zooplankton and herring, stomach fullness indices twice that of the other groups, and a pelagic isotope signature. Measures that have historical counterparts (e.g. condition, fecundity) suggest major changes in the underlying ecosystem support for cod production through the food web.

POSTER FBM23

Variations in age-0 pollock distribution among eastern Bering Sea nursery areas: a comparative study through acoustic indices

A. Winter, G. Swartzman and K. Coyle
University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195-5020, USA

Cohort abundance of walleye pollock (*Theragra chalcogramma*) is subject to strong interannual variation in the eastern Bering Sea and this variation is largely determined in the age-0 juvenile stage. We estimated the distribution and abundance of age-0 pollock at five nursery areas around the eastern Bering shelf in three successive years (1997–1999) from echo-integration survey data. Concurrently, we calculated estimates of the distributions of euphausiids, a prey of juvenile pollock, from a frequency differencing algorithm, and estimates of the spatial overlap of groundfish predators with the age-0 pollock, from a single-target ratio algorithm. The analyses showed that all nurseries had low abundance of age-0 pollock in 1997, the year which ultimately produced the weakest adult year-class, and all nurseries had medium to high age-0 abundance in 1999, which produced the strongest of the three year-classes. In the intermediate year of 1998, only one nursery had high age-0 pollock abundance. Euphausiid aggregations had a consistently positive spatial correlation with age-0 pollock. Predator density ratios were positively correlated with age-0 pollock when predators were sparse and age-0 pollock were displaced relatively northward. Our results indicate that the abundance of age-0 pollock, and hence of adult cohorts, may be predictable from a concise set of acoustic indicators measuring the spatial distributions and biotic interactions of the age-0 pollock in selected nursery areas. The three years 1997 – 1999 had significant differences of climate and water temperature in the eastern Bering Sea, and represent an advantageous framework for testing these hypotheses.

Poster group: Physical and chemical

POSTER PC1

Bering Sea fronts: seasonal, interannual, and decadal variability

I. Belkin, P. Cornillon and D. Ullman
University of Rhode Island, 215 South Ferry Road, Narragansett, RI 02882, USA

The Bering Sea fronts were studied as part of a global survey of ocean fronts from Pathfinder SST data augmented by color/chlorophyll data from SeaWiFS and MODIS. Twice-daily satellite imagery with 9 km, 4 km and 1 km resolution was used to derive the fronts. Thermal fronts were detected from each image with the Cayula-Cornillon edge detection and declouding algorithms.

Several major questions will be addressed in our presentation:

1. What is the large-scale pattern of fronts in the Bering Sea?
2. How does this frontal pattern change with season?
3. How large is the seasonal, interannual, and decadal variability of fronts in terms of their location and thermohaline parameters?
4. How do surface fronts correlate with bathymetric steps (narrow zones of enhanced bottom slope) over the Bering Sea shelf? Are particular fronts associated with certain depths or topographic features (e.g. Coachman, 1986)?
5. Did the fronts, or some of them, experience decadal-scale regime shifts in the late 1970s, late 1980s and late 1990s? Were these "regime shifts" limited by certain parameters of some fronts? Did they change the entire frontal pattern?

POSTER PC2

Fronts of the sub-Arctic seas from satellite data

I. Belkin, P. Cornillon and D. Ullman

Graduate School of Oceanography, University of Rhode Island, 215 South Ferry Road, Narragansett, RI 02882, USA

We will present a review of satellite observations of ocean fronts in the sub-Arctic Seas, both in the northern North Atlantic and North Pacific, based largely on a unique archive of frontal data assembled at the University of Rhode Island. Thermal fronts were studied from the Pathfinder SST fields obtained from the AVHRR twice-daily images. The SST fronts were detected from each individual image using the Cayula-Cornillon front detection and declouding algorithms. Long-term frontal frequencies were computed and mapped for the entire sub-Arctic. Analysis of synoptic frontal SST maps together with frontal frequency maps allowed us to distinguish a number of new fronts and elucidate important features of some previously known fronts, especially with regard to their spatial structure and its seasonal and interannual variability.

Thermal fronts were compared with fronts derived from color/chlorophyll data supplied by SeaWiFS and MODIS. This comparison revealed a number of close spatial associations between thermal and chlorophyll fronts. In some cases, chlorophyll fronts were better defined than their thermal counterparts, thus serving as reliable indicators of the latter.

POSTER PC3

Interannual variability of cold and warm seasons and their duration

M.A. Bogdanov and Y.N. Tananaeva

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17, V. Krasnoselskaya, Moscow, 107140, Russia

The analysis of weekly SST maps for the Okhotsk, Barents, Bering and Norwegian seas reveals some essential interannual differences in the character of winter cooling and summer warming. We found that the interannual variability of the beginning dates of the seasons is opposite in sign to the variability of their duration. Thus, the earlier a season begins, the longer its duration (and vice versa). This regularity allows a rather early prediction of the ending of the current season. The beginning of a season was determined fromthe crossing of a chosen latitude or longitude by a chosen isotherm. The duration of the season was calculated by of the time of retreat of this isotherm. The variability of ice conditions in some sub-Arctic seas follows the same regularity and this information can also be used to predict the time of ice edge retreat for such regions as the West Kamchatka and South Kuril islands (Sea of Okhotsk), St. Mathew island and 62ºN (Bering Sea). For the Norwegian, Barents and Bering seas a trend towards shorter cold seasons was detected. Also, for the Bering Sea a trend was discovered indicating a more rapid summer warming and winter cooling.

POSTER PC4

What's cooking: are the currents important to the heat content on the Bering Sea shelf?

N.A. Bond, P. Stabeno and M.E. Sullivan
University of Washington/JISAO, Nicholas Bond, Box 357941, Seattle, WA 98195-7941, USA

Integrated heat contents on the southeast Bering Sea shelf have increased markedly over the last 10 years. It is an open question whether this is due merely to anomalous heating by the atmosphere leading to reduced ice cover, or whether a significant contribution to this trend can be attributed to flow anomalies over the shelf. As a means of addressing this issue, data on air-sea fluxes, temperature and currents over the shelf are used to evaluate momentum and heat budgets. This data consists of point measurements from moorings (surface meteorological parameters, currents and temperatures), and areal coverage of water temperatures and surface fluxes from trawl surveys and the NCEP Reanalysis, respectively. Special attention is devoted to the variability in the horizontal advection of heat on seasonal time scales. This aspect of the analysis shows the extent to which current anomalies over the shelf can be deduced from the atmospheric forcing. Our results provide quantitative measures of the degree to which physical oceanographic conditions on the Bering Sea shelf can be estimated in association with climate change.

POSTER PC5

Ocean circulation, property exchange, and sea ice variability in the Bering Sea – opportunities and challenges for ecosystem modeling

J. Clement, W. Maslowski, J. Dixon and W. Walczowski
Naval Postgraduate School, Dept of Oceanography, 833 Dyer Rd, Monterey, CA 93943, USA

Recent observations suggest a northward shift in species distribution in some highly productive sub-Arctic marine ecosystems. Many changes have been linked to the accelerated warming trend during the last decade, and to the associated retreat of the sea-ice cover in the Arctic. In particular, the Bering Sea has experienced periods of warming, variability in the sea-ice distribution, and subsequent changes in the marine ecosystem. However, quantification of ocean circulation in the Bering Sea and water mass and property exchanges across the Aleutian Island passes and with the Chukchi Sea presents multiple challenges. Some are of environmental nature (extreme weather, sea ice cover, shallow shelf and narrow straits) and some are due to the geopolitical reality (i.e. access to the west of the Date Line). To address some of these issues, we have developed a coupled ice-ocean model of the pan-Arctic region to allow for realistic representation of the ocean dynamics and exchanges between the Bering Sea and adjacent basins. Model results utilizing realistic atmospheric forcing (1979-2003) are presented. Modelled sea ice shows a decrease in recent years, which is corroborated by satellite observations. This decrease may have significant impacts on the ecosystems of the Bering and Chukchi seas. The existing model results provide a useful integrative frame of reference for observations in the Bering Sea, which are short-term and/or cover a small geographic region. Planned model improvements, extended multi-decadal integrations and future coupling with biological models are expected to significantly advance comprehensive understanding of the Bering Sea ecosystem.

POSTER PC6

Recent salinity changes in the northwest continental shelf waters – a Pacific connection?

K. Drinkwater
Institute of Marine Research, Box 1870, Nordnes, N-5817 Bergen, Norway

During the 1990s near-surface low salinity waters were observed over the continental shelves of Labrador to the Middle Atlantic Bight reaching record or near record lows in the past 50 years throughout the region. These low salinities lead to record high stratification in many of the regions. Similar low salinity waters were not observed off West Greenland suggesting that the cause is not due to advection associated with subpolar gyre. Recent studies show that approximately 50-60% of the water on the Labrador/Newfoundland Shelves is of Pacific origin that came through the Canadian Archipelago. In the 1990s, shifts in the ocean circulation associated with changes in the large-scale atmospheric patterns suggest more of the low salinity Arctic water of Pacific origin being exported through the Archipelago. Consistent with this hypothesis, a major bloom of a Pacific phytoplankton species was reported in the Gulf of St. Lawrence in 2001. Increased outflow from the Arctic through the Canadian Archipelago in the 1990s appears to be the most likely hypothesis to explain the low salinity observations off Labrador and farther south.

POSTER PC7

Snow-ice interactions and the mass balance and ecology of sea ice in the Pacific sub-Arctic seas

H. Eicken, R. Gradinger, T.C. Grenfell, C. Krembs, D.K. Perovich and K. Shirasawa
Geophysical Institute, University of Alaska Fairbanks, PO Box 757320, USA

Retreat of perennial Arctic sea ice since the late 1980s has resulted in an increase in the extent of the Pacific Seasonal Ice Zone (PACSIZ). The PACSIZ exhibits a broad latitudinal range from <45ºN (Okhotsk Sea) to >75ºN (Chukchi Sea). Sea ice plays an important role in the ecology of the Okhotsk, Bering and Chukchi Seas and fosters high biological productivity early in the season. Currently, we are lacking detailed data on the physical-biological characteristics of sea ice in the PACSIZ, in particular its response to and potential modulation of climate variability. Here, we report on measurements of the mass balance and properties of sea ice in the Okhotsk and Chukchi Seas. Apart from coastal measurements at Barrow, Alaska, Sakhalin, Russia and Mombetsu, Japan, data were from icebreaker cruises. The data highlight the importance of the snow cover for the sea-ice mass balance and its role in sub-Arctic marine ecosystems. Snow accumulation is shown to vary by up to an order of magnitude between the Okhotsk and Chukchi Seas. In the low-accumulation northern areas, ice growth occurs through accretion at the ice bottom, with a dominance of bottom ice-algal communities. In the southern high-accumulation areas surface flooding and snow-ice formation play an important role in the mass budget and ecology of the ice cover. Snow cover variations also strongly impact summer ice albedo and surface ablation. The potential impact of latitudinal shifts in precipitation patterns as well as the need for an integrated observation system for the PACSIZ is discussed.

POSTER PC8

Characteristics of pCO_2 in surface water of the Bering Basin and their effects on carbon cycle in the western Arctic Ocean

Z. Gao, S. Xu and L. Chen

Key Laboratory of Global Change and Marine Atmospheric Chemistry, Xiamen University, State Oceanic Administration, 178 Daxue Road, Xiamen 361005, PR China

Characteristics of the pCO_2 distribution in surface water of the Bering Basin and their relationships with the ambient hydrological conditions were discussed using variations of the partial pressure of CO_2 in surface water of the Bering Basin and the Chukchi Sea. Data in this study are from a field investigation during the First Chinese National Arctic Research Expedition in 1999. Compared to the high productivity in the Bering Continental Shelf, much lower levels of chlorophyll a were observed in the Bering Basin. The effect of hydrological factors on the pCO2 distribution in surface seawater of the Basin in summer has become a major driving force and dominated over biological factors. The Basin also presents a High Nutrient Low Chlorophyll (HNLC). In addition, the pCO_2 distribution in the Bering Basin was also found to be influenced from the Bering Slope Current which would transform to the Anadyr Current when it inflows northwestward over the Basin. The Anadyr Current would bring a water with high nutrients to the western Arctic Ocean where local nutrients are almost depleted in the surface water during the summer time. Resupplying nutrients would stimulate the growth of phytoplankton and enhance capacity of absorbing atmospheric CO_2 in the surface water. Otherwise, in the Bering Sea the dissolved inorganic carbon brought from freshwater are not deposited down to the deep sea water but most of them would be transported into the western Arctic Ocean by the Alaska Coastal Current to form a carbon sink. Therefore, the two carbon sinks in the western Arctic Ocean, one carried by the Anadyr Current and another by the Alaska Costal Current, will implicate the western Arctic Ocean in global change.

POSTER PC9

Influence of Aleutian Low on ice cover in the Okhotsk and Bering Seas

S.Y. Glebova

Pacific Fisheries Research Centre (TINRO), Russia 4, Shevchenko Alley, Vladivostok 690950, Russia

Year-to-year changes in ice cover in the Okhotsk and Bering seas exhibit an interesting feature: in certain periods the coverage in the two areas vary in phase, but in other periods they are out of phase. This is believed to be related to changes in the atmospheric regime. To investigate, the years were divided into four groups: those with 1) reduced ice coverage in both seas; 2) high ice coverage in both seas; 3) reduced ice in the Sea of Okhotsk and high ice coverage in the Bering Sea; and 4) high ice coverage in the Sea of Okhotsk and reduced ice in the Bering Sea. Then the charts of the mean sea surface atmospheric pressure, averaged for January–February, were constructed for each of these groups of years. The location of the Aleutian Low was determined and the general direction of the wind was estimated. In the case of the first group of years, the Aleutian Low was displaced northwestward from its mean position (51°N, 180°W) and located near East Kamchatka, so easterly winds prevailed over both seas. In the second case, the Aleutian Low was in the eastern Bering Sea, and the winds over both seas were mainly northerly. In the third case, the Aleutian Low had a southeastern position in the Gulf of Alaska, and northerly winds prevailed over the Bering Sea and easterly winds over the Sea of Okhotsk. Finally, in the fourth case, the Aleutian Low is displaced toward the southwest and was located on the oceanic side of Commander Islands. In this case, easterly winds blew over the Bering Sea and northerly winds over the Sea of Okhotsk.

POSTER PC10

Climate modulated changes in the ecosystem of the sub-Arctic Pacific Ocean: the role of El-Niño events

J.I. Goes, H.R. Gomes, A. Limsakul, K. Sasaoka, S.-I. Saitoh and T. Saino

Bigelow Laboratory for Ocean Sciences, 180 McKown Point Road, PO Box 475, West Boothbay Harbor, Maine 04575, USA

The sub-Arctic Pacific Ocean experiences strong climate-modulated seasonal, interannual to decadal variations in meteorological and physical oceanographic conditions, which can have a profound influence on biological processes in the region. A satellite database beginning from 1997 provided us with evidence of strong interannual variations in the supply of inorganic nitrate and new production in the sub-Arctic Pacific in association with the El Niño event of 1997. Although these data allowed us to view and describe large changes in new production along the entire breadth of the sub-Arctic Pacific basin, our accessibility to a 25-year database of shipboard measurements enabled us to better focus on the western sub-Arctic Pacific. Thus, in addition to the primary motive of corroborating our results from satellites, this exercise allowed us to obtain a clearer picture of the mechanistic connections between the atmosphere and the oceans, and the biological response to these changes. The results from this study make a compelling case that the primary driver for interannual variations in biological production in the western sub-Arctic Pacific is the strength of the wintertime monsoonal winds. These winds can be particularly strong during El Niño years, when the Aleutian Low intensifies and moves southeastwards. During this period, oceanographic conditions undergo several changes as is evident in the satellite and shipboard data. These changes in tandem, contribute to an increase in the supply of nutrients as well as an increase in the overall area of the North Pacific coming under the influence of high nutrients. Unusually calm springs that follow these windy winters provide water column stability required for phytoplankton to benefit from the availability of nutrients. Both the satellite and shipboard showed how these conditions were reversed following the transition to La Niña conditions.

POSTER PC11

Does sea ice contribute to the biogeochemical cycles of the Bering Sea?

R. Gradinger, B. Bluhm and H. Eicken

University of Alaska Fairbanks, School of Fisheries and Ocean, Sciences, PO Box 757220, Fairbanks, AK 99709, USA

Sea ice is a major structuring component of polar waters. In sub-Arctic seas, research over the last three decades focused mainly on water column processes in marginal ice zones. More recently, the role of sea ice as a platform for marine mammals and birds received more attention, mainly due to the recent decrease in the Arctic sea-ice cover. Surprisingly, the biota within the sea ice and their contribution to biomass and production within theses regions have received little scientific attention. We present results from sea-ice biological studies conducted in the seasonal ice zones of the nearshore and offshore Chukchi and Beaufort Seas in 2002, 2003 and 2004. Our studies showed clear regional trends, with ice algal biomass decreasing by two orders of magnitude progressing from the nutrient-rich shallow shelf across the shelf break to the nutrient-poor surface waters of the deeper basins in the Chukchi and Beaufort Seas. Similar comprehensive data on the contribution of sea-ice communities to primary production and food-web structure in the Bering Sea are lacking to date. Here, we will discuss the potential importance of ice biota by examining the Bering Sea ice and oceanographic regime and extrapolating from our findings for the Chukchi and Beaufort shelves.

POSTER PC12

Abnormal cooling of the Korean Eastern Sea water prior to the 1982/83 and the 1997/98 ENSO events in the East (Japan) Sea

C.-H. Hong and S.-E Park

Pukyong National University, 599-1 DaeYeon 3-dong, Namgu, Pusan, 608-736 Korea

Abnormal cooling of the Korean Eastern Sea Water (KESW) in the East (Japan) Sea prior to the 1982/83 and the 1997/98 ENSO events is examined using bimonthly routine observation data by National Fisheries Research and Development Institute in Korea during 1965-2002. The KESW, which roughly occupies a region in the west of 131ºE, showed extreme cold state in summer (August) of years (1981 and 1996) prior to the two ENSO events, which have been the greatest in the last-half century. In August of 1981 and 1996, interannual bimonthly mean anomalies at 100 m in the whole KESW region were -3.10º and -3.41ºC (SD=1.4ºC), respectively. The interannual mean temperature anomalies (IMTA) in 1981 and 1996 were also -1.75º and -1.57ºC; (SD=1.07ºC), respectively. Abnormal cooling evolutions during the two years were more outstanding at depth (100 m) rather than those at the surface (0 m). It should be noted that these cold states in the KESW consecutively lasted for 3-4 years even after the ending of each ENSO event, ranging from -0.34º to -1.42ºC in IMTA for the 1982/83 and -0.61º to -2.90ºC for the 1997/98 ENSO events, respectively, whereas warm states of the KESW appeared in 1982 (+0.32ºC) and 1998 (+0.28ºC) in the middle of the two ENSO events. Consequently, these results suggest that the extreme cooling in the KESW may occur prior to the greatest ENSO events.

POSTER PC13

Changes in climate and ocean conditions in the Northern Gulf of Alaska over the last 6,000 years as revealed through stable isotope analysis of archeological midden materials: initial results

G.V. Irvine, S.J. Carpenter, J. Schaaf and D.H. Mann

U.S. Geological Survey, Alaska Science Center, 1011 E. Tudor Rd. Anchorage, AK 99503, USA

Geochemical examination of bivalve midden material from Mink Island (XMK-030), located in the Shelikof Strait of the Gulf of Alaska, provides insight into how climate and biological productivity of the Alaska Coastal Current (ACC) have changed over the last ~6,000 years. Analysis of delta^{13}C and delta^{18}O isotope ratios from shell carbonates sampled at high resolution across individual shells of the butter clam, *Saxidomus giganteus*, and mussel, *Mytilus trossulus*, produces sub-monthly data spanning multiple years. Analyses of ancient bivalve midden material, representing well-documented climatic episodes, were contrasted with analyses of modern material from the same site. Preliminary data from ancient shells indicate that climate change has had a profound impact on freshwater influx to the ACC and that productivity has varied markedly over the last 6,000 years. Especially striking are contrasts in the seasonal patterns and strengths of productivity and temperature/salinity indicated by Little Ice Age (~ 540 years before present [BP]) and Mid-Holocene Thermal Optimum (~5750 BP) shell material. Data from the Medieval Warm Period (~850 BP) material show different and somewhat more mixed patterns than samples from other periods. The data from these different climate periods may help predict how ACC dynamics and ocean productivity will respond to future changes in climate, including global warming. Additionally, the use of stable isotope analyses of modern bivalve materials provides a tool for long-term monitoring of coastal marine environments, and is especially applicable to sampling of specific sites and/or remote environments.

POSTER PC14

Comparisons between *in situ* observational velocity and transport of Oyashio and TOPEX/POSEIDON altimetry data.

S.-I. Ito, K. Uehara, T Miyao, H. Miyake, I. Yasuda, T. Watanabe and Y. Shimizu

Tohoku Natl. Fish. Res. Inst., Fisheries Research Agency, 3-27-5, Shinhama-cho, Shiogama, Miyagi 985-0001, Japan

An observation line (OICE: Oyashio Intensive observation line off-Cape Erimo) along the TOPEX/POSEIDON (T/P) ground track 060 was set to estimate the Oyashio transport. Along this line repeated hydrographic observations had been conducted and mooring systems were deployed. T/P derived sea surface height anomaly (SSHA) was compared with velocity and transport on OICE. Although the decorrelation scale of SSHA was estimated at about 80-110 km in the Oyashio region, the SSHA also contains horizontal, small-scale noise, which was eliminated using a Gaussian filter. In the comparison between the SSHA difference across two selected points and the subsurface velocity measured by a moored Acoustic Doppler Current Profiler (ADCP), the highest correlation (0.92) appeared when the smoothing scale was set at 30 km with the two points as near as possible. For the transport in the Oyashio region, the geostrophic transport between 39º30´N and 42ºN was compared with the SSHA difference across the same two points. In this case the highest correlations (0.79, 0.88 and 0.93) occurred when the smoothing scale was set at 38, 6 and 9 km for reference levels of 1000, 2000 and 3000 db, respectively. The Oyashio transport time series was derived from the T/P SSHA data using these relationship. The annual mean transport was estimated as 9.46 Sv in the 3000 db reference case.

POSTER PC15

Interannual variability of Oyashio transport estimated from hydrographic observation and satellite altimetry.

S.-I. Ito, K. Uehara, T. Miyao, H. Miyake, I. Yasuda, T. Watanabe and Y. Shimizu

Tohoku Natl. Fish. Res. Inst., Fisheries Research Agency, 3-27-5, Shinhama-cho, Shiogama, Miyagi 985-0001, Japan

An observation line (OICE: Oyashio Intensive observation line off-Cape Erimo) along the TOPEX/POSEIDON (T/P) ground track 060 was set from the Hokkaido coast to estimate the Oyashio transport. The geostrophic transport of Oyashio between 39º30´N and 42ºN was compared with the SSHA difference across the same two points and a proper linear relationship was built up between them. Using this relationship, the annual mean transport was estimated as 9.46 Sv in the 3000 db reference case. The T/P derived Oyashio transport shows the maximum in winter and the minimum in autumn. Though it is consistent with the barotropic transport estimated from Sverdrup balance, the amplitude is much larger in the later one. The Oyashio transport time series shows a smaller value than that estimated from the Sverdrup balance in 1994-1996 and a larger value than that in 1997-2000. This difference is consistent with baroclinic response to wind stress field. As a result, it is noted that the baroclinic response is important as the barotropic one, especially for interannual variability of Oyashio transport.

POSTER PC16

The mechanism of AOU spatial differences in the North Pacific

S. Kakehi, K. Uehara, S.-I. Ito and K. Komatsu

Tohoku National Fisheries Research Institute, 3-27-5, Shinhama-cho, Shiogama,Mityagi, 985-0001, Japan

The spatial differences of AOU (Apparent Oxygen Utilization) in the North Pacific and AOU change ratios by water mixing, biological activities and air-sea exchange in the mixed water regions were investigated using hydrographic data on 155º, 160º, 167.5º and 175ºE lines from 35º to 45ºN obtained during May to June, 2004. An AOU change by water mixing was defined as the isopycnal mixing ratio between pure Oyashio and Kuroshio waters. An AOU change by biological activities was estimated by the Redfield ratio and nutrient concentrations. The influence of air-sea exchange on AOU changes was assumed to be the residuals from the observed AOU minus the AOU changes attributed to mixing and biological activities. The water mixing is the dominant mechanism of AOU spatial change throughout the whole water column. It causes AOU increases and decreases in the upper and lower layers, respectively, with the critical depth being at 26.7 σ_θ. The AOU change ratios by water mixing, biological activities and air-sea exchange are estimated as 50-80, 20-50 and less than 10 percent, respectively. The effect of air-sea exchange process is speculated to reach to the depth of the 26.7 σ_θ layer.

POSTER PC17

The geochemistry of heavy metal enrichment in surface sediments of Derugin Basin (Okhotsk Sea)

V.V. Kobylyansky, M.M. Domanov and A.I. Svininnikov

Federal Research Centre MCB "Electron", A-190 box 51, Moscow, 125190, Russia

Diagenetic processes of redistribution and concentrating of manganese, strontium, arsenic, molybdenum, and uranium on a chemical barrier: siliceous bottom deposits - seawater in a layer oxidated metalliferous sediments in Derugin Basin of the Okhotsk Sea were studied. The thickness of a stratum was 5-9 cm, but sometimes 20 cm and more. The material was taken during cruises on the R/V Professor Khromov in the summers of 2003 and 2004 in the Derugin Basin, and on the shelf and slope of Sakhalin Island. Cores from the upper 15-20 cm of sediment were sectioned into 1 cm intervals. Chemical analysis of samples was performed by atomic emission and mass spectrometry with inductive connected plasma. Coefficients of correlation, clusters and discriminant functions for 27 elements were determined. The surface oxidated layers of the sediments were enriched in contrast to the underlying sediments - manganese approximately 20 times, molybdenum 10 times, strontium and arsenic approximately 3 times, and uranium 2 times - but depleted in magnesium (1.6 times), rubidium and zinc (1.2 times), and iron, cerium and neodymium (1.1 times). It is shown that in early diagenetic redistribution of Mn, Sr, As, Mo and U, the dissolution, migration in a zone of the reduction sediments and deposition in a surface oxidated layer on contact with dissolved oxygen of seawater are the main processes (at the expense of high permeability of siliceous ooze and availability of organic matter). The modulus value of a hydrothermal material in sediments - Al/(Al+Mn+Fe) has magnitude in an oxidated layer: 0.29-0.41, and in the reduced ones: 0.50-0.57. Measurements of the sediments radioactivity are made *in situ* with the help of underwater gamma-spectrometer and also in the same samples in laboratory conditions. These experimental data on the amount of natural and artificial radionuclides in the sediments are used for specification of the some features of the diagenetic processes.

POSTER PC18

Calculations of electro-magnetic field parameters of ultra low frequency (ULF) in the zone of atmospheric phenomena

V.I. Korochentsev, V.V. Korochentsev, V.A. Kochetova and S.A. Shevkun

Far Eastern State Technical University, 3a, Axakovsky Street, Vladivostok, 690950, Russia

Many atmospheric disastrous phenomena are accompanied by great gradients of pressure, velocity of transfer of air and water layers, their temperature as well as electric discharges in the atmosphere. The above-listed events influence each other according to physical laws that are not yet explored properly. Often due to many reasons (obstacles on the way to approach or investigate the researched area, safety terms) in the research of electrical atmospheric discharges (different types of lightning) the remote distance method of physical parameters measurements should be used. Using remote sensing and applying instrumentation at remote distances, it is possible to measure successfully such phenomena as number of discharges in a unit of volume, their coordinates, power of electric discharge, frequency range of electromagnetic waves that are irradiated by lightning, discharges, etc. The present report suggests corrective mathematical algorithms that provided estimation of electric discharges power and their coordinates. Initial data for suggested mathematical algorithms are voltage of electric and magnetic fields measured in some area of space. This electromagnetic wave is beamed by every lightning and this variable may be measured at a great distance (safety distance) from the lightning, for example, using satellites. The field dimensions and a few frequencies could be processed applying the mathematical algorithms, which in real time (1:3 seconds) would assess electrical conditions of the field (lightning and other electric discharges) inside the explored atmospheric phenomenon. The work under consideration represents the theoretical computation results which could be compared with the experimental dimensions acquired from Intercosmos satellites by researchers of IZAMIRAN (Troitsk, Moscow region).

POSTER PC19

Physical oceanography of frontal zones in the sub-Arctic Seas

A.G. Kostianoy, J.C.J. Nihoul and V.B. Rodionov

P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, 36 Nakhimovsky Pr., Moscow, 117997, Russia

The Arctic Ocean and sub-Arctic seas are important components of the global climate system and are the most sensitive regions to climate change. Physical processes occurring in these regions influence regional and global circulation, heat and mass transfer through water exchange with the Atlantic and Pacific Oceans. One of the overall objectives of Arctic and sub-Arctic oceanographic research is to gain a better understanding of the mesoscale physical and biological processes in the seas. The presentation is based on the book “Physical Oceanography of Frontal Zones in the sub-Arctic Seas” by A.G. Kostianoy, J.C.J. Nihoul and V.B. Rodionov published in Elsevier in October 2004. This book presents the systematization and description of accumulated knowledge on oceanic fronts of the Norwegian, Greenland, Barents, and Bering Seas. The work is based on numerous observational data, collected by the authors during special sea experiments directed to the investigation of physical processes and phenomena in areas of the North Polar Frontal Zone (NPFZ) and in the northern part of the Bering Sea, on archive data of the USSR Hydrometeocenter and other research institutions, as well as on Russian and Western literature. The book contains general information on the oceanic fronts of the sub-Arctic Seas, a brief history of their investigation, the state of the current knowledge, as well as a detailed description of the thermohaline structure of all frontal zones in the Norwegian, Greenland, Barents, and Bering Seas and of neighboring fronts of Arctic and coastal origins.

POSTER PC20

Stratification and mixing on the southeast Bering Sea Shelf

C. Ladd, F.J. Mueter, P. Stabeno and G.L. Hunt, Jr.

University of Washington, 7600 Sand Point Way, Building 3, Seattle, WA 98115-6349, USA

On the southeast Bering Sea shelf, initiation of the spring phytoplankton bloom is related to the onset of stratification. In summer, after the spring bloom has depleted the surface water of nutrients, vertical mixing entrains nutrients into the surface layer resulting in further production. Using the results from a series of one-dimensional mixed layer model runs, variability in spring/summer stratification and mixing was explored. The model runs were validated by comparison with data from two moorings on the southeast Bering Sea shelf deployed by the Fisheries Oceanography Coordinated Investigations (FOCI) (M2: 56.9ºN, 164.1ºW and M4: 57.9ºN, 168.9ºW). The model reproduced well the observed temperature, mixed layer depth, and timing of mixing events from the mooring data during the summers of 1995 – 2004. Model runs from 1951 to 2004 provide time series of the timing of spring stratification, average mixed layer depths, average stratification and entrainment during the summer over the southeast Bering Sea. The timing of initial spring stratification appears to influence walleye pollock survival. Spawner-to-recruit survival rates were significantly higher when spring stratification during the larval and juvenile stages occurred earlier. Variability of these indices on interannual and longer timescales will be discussed.

POSTER PC21

A study on the decadal variations of physical and biogeochemical elements in the East/Japan Sea

J.-Y. Lee, C.I. Lee and K.-R. Kim

School of Earth and Environmental Sciences, Seoul National University, Seoul 151-742, Korea

Concerning the effect of climate changes on oceanographic environments, temporal variations of both physical and biogeochemical elements were investigated with extracted data from the World Ocean Database (WOD01) and the Southern Oscillation Index (SOI). Standard depth data of sea water temperature, nutrients (nitrate, phosphate and silica) and dissolved oxygen from 1971 to 2000 were used in the analysis. From wavelet power spectrum analysis, it was found that a period of 4 to 8 years was dominant in the temperature variations. However, even though temperature variations in the East/Japan Sea are highly correlated with El Niño events with a typical period of from 4 to 8 years, these variations, especially in the surface layers down to 200 m, are also affected by decadal variations of the Tsushima Warm Current which originate from the open sea. The effects of climate changes caused the East/Japan Sea to experience temporal variations not only in the physical elementsbut also in the biology, especially in the magnitude of spring phytoplankton blooms. While these results indicate that biological environments respond to climate-induced physical changes, it was found that temporal changes of nutrient concentrations in the surface layer could be more closely related to nutrient supply from the sub-surface layers rather than long term effects of climate changes.

POSTER PC22

Interannual variations of sea level in the Bering Sea revealed by satellite altimetry

P.B. Lobanova and V.R. Foux

Department of Oceanology, St. Petersburg State University, 33/35 10th Line, St. Petersburg, 199178 Russia

A trend of sea-level rise caused by global warming has not a clear manifestation and even an opposite response at some locations in the world oceans. The Bering Sea is one such area. In this paper we study sea level changes in the Bering Sea using altimetry data of the Topex/Poseidon satellite for the period 1993-2001 provided by AVISO. Tidal corrected along-track data on sea-level anomalies for every ascending and descending satellite track crossing the Bering Sea from the Aleutian Islands to Asia and North America with 10-day intervals were analyzed using statistical methods. We show that the typical pattern observed all over the basin is of increasing sea level from 1993 by 1997 but decreasing in the following period. Some local peculiarities are found in different parts of the Sea which are not significant in comparison with the general trend. The maximum mean annual sea level anomalies observed in 1997 were around 10 cm. A continuous decrease of sea level over 1998-2001 caused negative anomalies up to -14 cm and resulted in a negative trend of sea level variations in the Bering Sea over the study period. This tendency contradicts the global warming trend but is in agreement with the regional climate variations over the North Pacific and the Arctic reported recently. The El Niño event of 1997-98 and variations in the AO and PDO are reflected in the observed character of the sea level changes of the Bering Sea.

POSTER PC23

Climate change and its effects on the sub-Arctic Sea - model perspective

W. Maslowski, J. Clement, J. Dixon, W. Walczowski, J. Walsh and C. Williams

Naval Postgraduate School, Department of Oceanography, 833 Dyer Road, Monterey, CA 93943, USA

Growing observational evidence suggests that the Arctic Ocean has experienced an accelerated warming trend since the 1990s. Based on passive microwave satellite data, the Arctic sea-ice extent set an all-time record minimum in summer 2002, which was closely followed in summer 2003 and 2004. The continuous reductions of ice cover and warming and freshening of the upper ocean will lead to significant changes in the sub-Arctic marine ecosystems, including their large scale forcing, overall dynamics, bio-physical structure and variability. Understanding those physical regimes and their long-term variability is crucial to studies of ecosystem response ranging from local biogeochemistry to fisheries, birds and marine mammals. To study the pan-Arctic ocean response to climate change we use a regional ice-ocean model forced with realistic atmospheric data. The model domain configured at 9 km and 45 levels extends from the North Pacific, across the Arctic Ocean and the Nordic Seas, into the North Atlantic. This approach allows studies of all the northern latitude ice-covered sub-Arctic seas. Large-scale and long-term model results allow integration and synthesis of local observations and intercomparisons between sub-Arctic seas. Results will be presented to demonstrate model skill in simulating the recent warming trend and its effects on the physical oceanography of the sub-Arctic seas. The feasibility of coupling physical and biogeochemical models will be demonstrated based on an ongoing study in the Chukchi and Beaufort seas. Our analyses suggests that this warming trend, if continued, may significantly affect global climate and also change the socio-economic importance of the pan-Arctic region.

POSTER PC24

Regional patterns of change: Bering Sea ice in spring 1972-2004

S.L. McNutt, P. Stabeno, J.E. Overland, S. Salo, M. Spillane and C. Picco

Geophysical Institute, University of Alaska, C/O NOAA/PMEL, 7600 Sand Point Way, Seattle, WA 98115, USA

The location, extent, residence time, and condition of spring sea ice in the Bering Sea play an important role in primary productivity and health of the ecosystem on the shelf, and show dramatic changes in recent years. Regional patterns and the timing of spring sea-ice retreat impact the upper ocean and its biota, and can provide a basis for investigating observed biogeographical changes in the ecosystem as a whole. One of the key changes that affects the Bering Sea and Alaska is a transition toward warmer temperatures in spring since the regime shift of 1976-1977. These temperature changes have resulted in ice melting in the Bering Sea one week earlier in the 1990s relative to the 1980s, especially noticeable in the month of May. Analysis of monthly sea-ice records for May 1972-2004 show distinct differences in regional meltback patterns, consistent with reorganization of a complex system after an abrupt climate shift. Since the 1980s, there has not been a return to sea-ice conditions as experienced before the regime shift of 1976. However, observations in recent years suggest that the system may be settling into a pattern similar to that of the period before 1976, but with a shorter residence time for ice cover on the shelf, a change in the timing of ice retreat, decreased sea-ice thickness, and migration of the ice edge-associated productivity northward across the shelf. These patterns provide biogeographical evidence of the lingering effects of changing sea-ice conditions on the ecosystem.

POSTER PC25

Impact of hemispheric climate on variability of sub-Arctic Seas

J.E. Overland, N.A. Bond and M. Wang

Pacific Marine Environmental Laboratory/NOAA, 7600 Sand Point Way NE Seattle, WA 98115-6349, USA

Based on present understanding of atmospheric climate, two patterns of wintertime hemispheric variability have major impact on sub-Arctic Seas. These are the Arctic Oscillation (AO) and a mode resembling the Pacific-North American (PNA) pattern. The AO modulates the strength of westerly winds, particularly in the North Atlantic, and the PNA-like pattern largely involves the intensity of the Aleutian low. The patterns together account for half of the variance of sea level pressure (SLP) north of 20ºN on interannual and longer timescales, and most of the hemispheric SLP trends over the previous 40 years. These patterns are important to the ocean through their influence on regional winds, and hence currents, especially in the Barents and Labrador Seas, and through their impact on air-sea heat exchange, and hence seasonal sea ice, especially in the Bering and Okhotsk Seas. They account for well-known behavior such as the tendency for temperature anomalies in the Barents and Labrador Seas to be out of phase, and for the regime shift that occurred in the Bering Sea in the 1970s. While primary centers of the AO and PNA-like patterns are in the Atlantic and Pacific, respectively, they each have significant projections in the other ocean, which induce different types of regional variability. These projections also imply some degree of association between sub-Arctic seas. There are important limitations in the ability of these two patterns to characterize the variability in air-sea interactions. For example, neither accounts for much of the variability in the Sea of Okhotsk.

POSTER PC26

Sea level changes associated with the warming and freshening of the coastal northern North Pacific

T.C. Royer and C.E. Grosch

Old Dominion University, Center for Coastal Physical Oceanography, 768 W. 52nd St., Norfolk, VA 23508-2055, USA

Sea levels at Seward, Alaska are compared with the secular changes in the steric heights determined for the hydrographic structure at a long time series station nearby. The 33-year time series of temperature and salinity versus depth to 250 m at the mouth of Resurrection Bay, Alaska (60ºN, 149ºW) (GAK 1) contain low frequency trends of increasing temperature throughout the water column and salinity trends that decrease in the upper layer (0-100 m) and increase in the lower layer (100-250 m). These changes are consistent with an acceleration of the Alaska Coastal Current, which is suggested by a conceptual feedback model for this region. The water temperatures increased by about 0.03ºC $year^{-1}$ while the salinities in the upper layer decreased by about 0.003 $year^{-1}$ as the salinities in the lower layer increased at a similar rate. From October 1997 to 2004 both salinity rates increased by an order of magnitude. The sea level anomalies (corrected for inverse barometer effects) are compared with the steric contributions to sea level at Seward and other long term sea level stations nearby to evaluate the relative importance of contributions of the temperature and salinity to the sea level. Since the sea level record length exceeds that of the hydrographic time series, implications of earlier changes in the coastal conditions might be able to be inferred from those data. Probable steric contributions of the historical (since 1931) coastal freshwater discharges will be examined.

POSTER PC27

Spatial and temporal considerations in temperature over the changing Bering Sea Shelf

M.E. Sullivan, P. Stabeno, N.A. Bond and A.B. Hollowed

JISAO, Univ. of Washington, 7600 Sand Point Way NE, Bldg 3, Seattle, WA 98115, USA

Oceanographic, climatic, and fisheries data are imperative to delineate and explore the impact of climate change on ecosystems. We use both shipboard collection (spatial) and moorings (temporal) to examine changes on the Bering Sea shelf. Hydrographic data have been collected in June-July over the eastern Bering Sea shelf as part of an annual trawl survey conducted by the Alaska Fisheries Science Center (NOAA/AFSC). A 20x20 nautical mile uniform grid was established when the surveys began in 1971 over the area ranging from 54ºN to 63ºN. Data have been collected annually since 1979, and have a consistently dense coverage since 1995. These data provide a spatial depiction of temperature gradients on the eastern Bering Sea shelf. Cross-shelf, along-shelf and horizontal sections have been prepared showing temperature contours, and allow us to define cold pool extent and mixed-layer depths across these areas. The longevity of the surveys will allow us to look at patterns and changes over time. Two biophysical oceanographic mooring sites will be used to compare temporal trends within the same region. Mooring M2 has a 10-year record (56.9ºN, 164ºW). Mooring M4 has a 6-year record (57.9ºN, 168.9ºW). The Bering Sea appears to be warming. These data sets are crucial to examining the mechanisms of change.

POSTER PC28

Changes of sea-ice thickness in the Chukchi Sea

K. Tateyama, H. Enomoto and K. Shirasawa
Kitami Institute of Technology, 165 Koen-cho, Kitami, Hokkaido 090-8507, Japan

In order to estimate the influence of the global warming in the Arctic Ocean, changes in sea-ice thickness were investigated in the Chuckchi Sea. We used the *in situ* sea-ice thickness measured by the acoustic sonar mounted on a submarine during 1986-1998, which were received from NSIDC. For 2003-2004, we used the sea-ice thickness measured by the ship-borne electromagnetic inductive device acquired by CHINARE-2003 and SBI-04. We also used the sea ice thickness index derived from the satellite microwave radiometer SSM/I and AMSR-E for 1992-2004. The histogram of sea-ice thickness in the 1990s showed that the ice was thinner in comparison with the 1980s. The data for the 2000s showed almost the same peak of frequency in the ice thickness compared with the 1990s but the ratio to thin ice thickness has increased significantly.

POSTER PC29

Large-scale fluctuations of thermal regime in the Okhotsk and Bering Seas and their interconnection with atmospheric forcing

E.I. Ustinova and Y.D. Sorokin
Pacific Fisheries Research Center (TINRO), 4, Shevchenko Alley, Vladivostok 690950, Russia

Large-scale variability of the thermal regime in the Okhotsk and Bering Seas is analyzed to reveal the links between the processes in the atmosphere and the hydrosphere. For this purpose, long time series data on ice coverage, water and air temperature, and several atmospheric and climatic indices (e.g. repeatability of the types of atmospheric circulation, intensity of the Far-Eastern centers of atmosphere action, winter monsoon index, global and Northern Hemisphere average surface air temperatures, PDO index, etc.) are considered. The variability in temperature is opposite between the Okhotsk and Bering Seas, but at high-frequencies only. Low-frequency oscillations are mainly synchronic at the time scale > 4 years. Both relatively short (2-3 years) and long (10 years and more) cycles gradually change their period and amplitude over the course of analyzed data, for all series. Low-frequency variability is found to be different for water and air temperatures. Quasi-decadal fluctuations are more evident in the cold season. The linkages between the atmosphere and ocean processes in these seas are different for different temporal and spatial scales. For example, the changes of ice cover in the Okhotsk Sea have the closest connection with the variations of global and Northern Hemisphere average surface air temperatures for the time scale > 7 years, but for the short-term scale, the large ice cover anomalies appear as the fast response (with 10-20 days delay) to strong winter atmospheric anomalies over the Far-Eastern region.

POSTER PC30

Interrelation of water circulation with atmospheric circulation in the Bering Sea

G.A. Vlasova and V.I. Rostov

Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, 43 Baltiyaskya Street, Vladivostok, 690041, Russia

The marginal Bering Sea is a unique area with complex hydrophysical and meteorological processes. A 2nd order hydrodynamic model based on the principles of self-similarity is used to estimate the water circulation and calculate the integral functions of the flow from the surface to the bottom for the Bering Sea, taking into account the influence of various types of atmospheric circulation. The model allows us to consider the atmospheric influences, spatial distribution of the water density, variable coefficients of the vertical and horizontal turbulent exchange effect, bottom topography and the coastal outline. Various synoptic atmospheric situations were considered: the "north-western", "Okhotsk-Aleutian" and "latitudinal-Aleutian" and is based on the location of the main trajectories of cyclones. It is shown that the seasonal and interannual changes in the seawater hydrodynamic structure depends mostly on the atmospheric processes. The Bering Sea is characterized by strong cyclonic activity. During the "north-western" type of atmospheric circulation the anticyclonic structures are disposed to the west of the Aleutian Basin along the 500-m isobath. Under "Okhotsk-Aleutian" conditions, single anticyclonic vortices penetrate from the Pacific Ocean into the Aleutian Basin. In "latitudinal-Aleutian" conditions, anticyclonic structures are located in the latitudinal direction along the Aleutian Islands.

POSTER PC31

Modeling environmental hydrodynamic fields of the bering sea: toward a Coupled Ice-Ocean-Biogeochemical Model (CIOBM)

J. Wang and H. Hu

International Arctic Research Center, University of Alaska Fairbanks, 930 Koyukuk Drive, Fairbanks, Alaska, PO Box 757340930, USA

Pacific herring (*Clupea pallasi*) in the southeastern Bering Sea undergo large-scale migrations. General locations of wintering grounds and pre-spawning migration pathways were known since foreign herring fisheries in the 1960s and 1970s. Herring overwinter near the Pribilof Islands, migrate east to the coast for spawning in spring, and thereafter migrate southwest along the Alaska Peninsula to the outer shelf where they move northwest, following bathymetry back to the Pribilof Islands in fall. Despite this general understanding, variability in herring seasonal migrations has not been investigated. We conducted a retrospective analysis of herring bycatch data collected by NMFS observers aboard groundfish vessels since the 1990s to examine spatio-temporal dynamics of annual migrations. Observed changes were compared with variability in climate and oceanographic conditions in ArcGIS. Recent herring bycatch confirms the general clockwise migration pattern observed in the 1960s and 1970s, but annual shifts in migration pathways were identified. Pre-spawning herring were concentrated in distinctly different areas, depending on whether spawning was early or late that year. Variability in sea ice appears to be responsible. In particular, thermal structure and dynamics around the ice edge affects herring migration timing and route, as well as spawning timing. Given the 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. Shifts in herring migrations affect their availability as prey for marine mammals and seabirds, some of which have declined sharply in recent years. To study the marine ecosystem of the Bering Sea with a 3D Coupled Ice-Ocean-Biogeochemical Model (CIOBM), the environmental hydrodynamics should be simulated correctly. We simulated the tides and

tidal current with the Princeton Ocean Model (POM). The simulated M2 and K1 co-tidal charts are consistent with previous studies. When comparing the vertical current structure of the M2 and K1, it shows that the M2 tidal current has stronger vertical shear structures than the K1 tide. The reason seems to be the horizontal current velocity difference. The calculated Eulerian tidal residual current, Stokes drift current, and the combined tidal residual current of the M2 tide has a weak anticyclonic circulation along the deep Bering Sea, while in the shallow shelf, the tidal residual current of 0.02-0.03 m/s is northward or northwestward, which has a long-term effect on material (such as nutrients) transport. By contrast with the tidal modeling, we simulated the ocean circulation step by step:

1) The simulated diagnostic barotropic circulation shows a main Alaskan Stream (AS); nevertheless, the Bering Sea shelf current is very weak and there is no the Bering Slope Current (BSC) and Kamchatka Current (KC).
2) The simulated diagnostic baroclinic circulation shows that the AS flows into the Bering Sea mainly from Unimak Strait and the neighboring passages/straits; the western boundary KC flows along the western side of the basin; the eastward BSC flows along the northern Aleutian Islands; the BSC is evident northwestward along the 1000 m isobath; and the Bering Sea shelf current is northward. All these features from simulations are consistent with available observations. When the monthly wind field is applied, although the AS and BSC change little, the KC and the shelf current become much stronger. It indicates that the wind field is very important to the western boundary KC and shelf circulation in the Bering Sea.
3) The simulated prognostic baroclinic circulation with wind forcing is much the same as the diagnostic baroclinic circulations with wind forcing.

We are simulating the combined tidal, wind-driven and density-driven circulation simultaneously, which like the real ocean, will drive the ecosystem dynamics in the Bering Sea.

POSTER PC32

Circulation in the St. Lawrence Island polynya region

T. Weingartner, K. Aagaard, S. Danielson, S. Martin, D. Quadfasel and J. Meincke
Institute of Marine Science, University of Alaska, Fairbanks, AK 99775, USA

Year-long records of current, temperature, and salinity from 15 moorings, satellite-tracked drifters, and shipboard measurements from the shelf south of St. Lawrence Island, including the polynya, are used to describe the regional oceanography of the northern Bering Sea shelf. The mean flow is eastward at ~0.05 ms^{-1} within a 70 km wide band south of the island but, further south, the flow is northward at ~0.02 ms^{-1}. Drifter trajectories indicate the transport of low-salinity water from the Alaskan coast westward across the shelf and thence northward into the region surrounding the polynya. Flow variations are wind-driven with the regional salinity field changing due to competition between: a) the eastward flow of nutrient-rich, saline waters from the Gulf of Anadyr and b) saline waters produced within the polynya in winter. Our circulation scenario suggests that this region maintains the properties of the Bering Shelf Water (BSW). BSW encompasses much of the central Bering Shelf and is a mixture of saline, isotopically heavy dO^{18} waters with isotopically light freshwater from the Alaskan coast. Cold, saline waters produced within the St. Lawrence Island polynya during winter are advected northward through Shpanberg Strait by the mean circulation field rather than fluxed southward by eddies as predicted from theory. Polynya waters do not contribute to the cold pool of the central Bering Sea shelf south and southwest of St. Lawrence Island through summer. Thus, the cold pool is probably formed by local winter heat loss.

POSTER PC33

Circulation features in northern Bering Sea inferred from drifters, moored current meters, and numerical modeling

P. Winsor[1], D. Chapman*, S. Danielson[2], T. Weingartner[2], K. Aagaard[3] and L. King[4]

[1]*Physical Oceanography Department, Woods Hole Oceanographic Institution, Woods Hole, Clark 306A MA. 02543, USA*

[2]*Institute of Marine Science, University of Alaska, Fairbanks, AK, USA*

[3]*Applied Physics Laboratory, University of Washington, Seattle, WA.*

[4]*Mekoryuk, Nunivak Island, AK, USA*

**Deceased*

We use a small set of drifters deployed in the northern Bering Sea during autumn of 2002 together with moored current meters and simple numerical modeling to investigate circulation features in the northern Bering Sea. The drift track of one of these drifters suggests that the drifter encountered three stages, each dominated by different flow dynamics. Stage 1 shows how winds can drive nearshore, relatively fresh coastal waters far (~150 km) offshore within a short time period (~6 days). Stage 2 suggests that coastal water advected offshore may produce a baroclinic northwesterly flow from west of Nunivak Island towards St. Lawrence Island (SLI). The third stage shows evidence that water south of SLI is advected eastward, flows around the Northeast Cape, and is then rapidly drawn northward by the flow through Bering Strait. Using simple dynamical arguments and numerical modeling we show that the alongshore, mean eastward flow south of SLI is largely controlled by the Bering Strait throughflow. This control is caused by broadening of the western boundary current north of SLI due to topographic effects, and is dominant forcing for flow everywhere north of SLI. We discuss the different flow regimes and their importance for water mass properties in the northern Bering Sea.

POSTER PC34

Absolute transport estimates in the East Greenland Current and Nordic Seas during Arctic Ocean 2002

P. Winsor and D.J. Torres

Woods Hole Oceanographic Institution, Clark 306A, Woods Hole Massachusetts, MA, 02543, USA

In spring 2002, the Swedish icebreaker Oden and RV Knorr of Woods Hole conducted an extensive oceanographic survey of the East Greenland Current (EGC) from north of Fram Strait to south of Denmark Strait as a part of the Arctic Ocean 2002 program to study the Nordic Seas. The Oden survey concentrated on water mass formation in ice covered waters and the interactions between the waters of the Arctic Ocean and the Nordic Seas. Here we present estimates of transports of properties through hydrographic sections from north of Fram Strait to south of Denmark Strait using hydrographic and lowered ADCP data. The observations show, among other things, that much of the freshwater transport during winter-to-spring like conditions is concentrated under the sea ice, with the core of the EGC located close to the Greenland coast.

POSTER PC35

The impact of bio-optical processes on the properties of the upper ocean: a sensitivity study using a 3D circulation model of the Labrador Sea

Y. Wu, P. Trevor, C. Tang and S. Sathyendranath

Bedford Institute of Oceanography, Ocean Sciences Division, Box 1006, Dartmouth, Nova Scotia B2Y 4A2, Canada

In the open water, phytoplankton dominates the absorption property of the visible light (400-700nm). Phytoplankton regulates sea surface temperature (SST) and mixed-layer depth (MLD), which in turn affects air-sea fluxes. To improve our understanding of the biological impact on the upper ocean, we investigated the effects of seasonal change of light attenuation associated with phytoplankton on SST and MLD in a sub-Arctic region, the Labrador Sea, using a 3D circulation model. The attenuation coefficient for solar radiation in the water was obtained from a bio-optical model applied to the SeaWiFS dataset. The ocean model is the Princeton Ocean Model implemented on a generalized vertical coordinate system to improve the vertical resolution. The model domain is from Davis Strait to the Gulf Stream and from the coast to 42ºW. The model was run from 1999 to 2003 with forcing fields calculated from 6-hourly meteorological data from NCEP. The results were compared with model runs using a time invariant light attenuation coefficients. Our results show that the SST difference (bio-optical model minus invariant light attenuation model) in most areas of the model domain exceeds 1ºC in summer and fall (July–September) but negligible in winter and spring. In the central Labrador Sea and the Grand Banks, the temperature increase is up to 3ºC. The MLD in summer decreases by 10-20%. Below the mixed-layer, the temperature decreases by about 0.3ºC due to reduced solar radiation in the bio-optical model. The effects of advection on the shelf and the implications of the model results on climate modeling will be discussed.

POSTER PC36

Climate forcing on a coastal sea ecosystem: conceptual model and some evidences in Peter the Great Bay (Japan Sea)

Y.I. Zuenko

Pacific Fisheries Research Institute, 4, Shevchenko Alley, Vladivostok 690950, Russia

Frequent observations on the physical and chemical variables of seawater, and of plankton structure and abundance in the coastal area, in the summer seasons of 1980-1981 and 1993-1999 allow us to understand the links between climate patterns and the state of the pelagic ecosystem. Three main mechanisms of climate forcing were revealed:

1. Vertical stability of the water column regulates nutrient supply and primary production;
2. Cross-shelf water exchange, provided mostly by wind-induced currents, causes a direct transport of salt, nutrients, and plankton organisms toward/outward the coastal zone; an additional effect of this wind-driven surge is the thickening of the upper mixed layer that may cause cessation of photosynthesis because of photolimitation;
3. Terrestrial freshwater discharge causes salinity and transparency lowering and nutrients enrichment in estuarine and pre-estuarine areas where primary production and species composition of plankton depend on the river run-off.

All of these mechanisms are determined by meteorological variables such as wind, cloudiness and precipitation, which are controlled by large-scale atmospheric circulation. Strong summer monsoon causes cloudy and windy weather in Peter the Great Bay and strengthens the shoreward water transport. As a result, water stratification is weakened, sea surface salinity is high, the upper mixed

layer is thick, nutrient concentrations in the upper layer are heightened, phytoplankton abundance is unstable, sometimes high, copepods are abundant with domination of deep-water (*Oithona* spp., *Pseudocalanus newmani*) and warm-water (*Paracalanus parvus*, *Calanus pacificus*) species, and planktonic carnivores (*Sagittas*) are numerous. This situation was observed in Peter the Great Bay in the middle of the 1990s. Under opposite conditions of weak monsoons observed in the early 1980s and again in the late 1990s, the stratification is sharp, salinity is lowered, primary production in summer period is low because of lack of nutrients, and zooplankton is at relatively low abundance levels, with a predominance of *Cladocera* species and neritic copepods *Acartia hudsonica*.

Poster group: Nutrients, phytoplankton and primary production

POSTER PP1

Inter-annual variability of the St. Lawrence productivity: a modelling study

M. Chifflet, M. Starr, V. Le Fouest, F.J. Saucier and B.A. Zakardjian

Maurice Lamontagne Institute (Fisheries and Oceans Canada) and ISMER, PO Box 1000, Mont-Joli, Québec, Canada G5H 3Z4

The productivity of the St. Lawrence is strongly dependent on circulation and freshwater input. How natural climate variability or climate changes may affect the dynamics of this sub-Arctic ecosystem need to be evaluated in order to provide sound policy strategies. Here, we present results of a coupled 3D physical–ecosystem model of the estuary and Gulf of St Lawrence that was developed to study the complex interactions between climate forcing and the productivity of biological resources at the base of the food chain. The physical model is a high-resolution 3D baroclinic circulation model (5 km in the horizontal and 5 m in the vertical) that is presently operational for the St. Lawrence basin. It includes a level 2.5 turbulent kinetic energy scheme and an ice module. The ecosystem model includes eight compartments: nitrate and ammonium, two classes of phytoplankton (diatoms and flagellates), two classes of zooplankton (microzooplankton and mesozooplankton), and two sizes of detritus. This ecosystem model is driven by the physical model using realistic tidal, atmospheric and hydrologic forcing for three years: 1997 as a typical year with high ice cover and high runoff, 1999 as a warm and productive year with low runoff and low ice cover and 1998, an intermediate year with low ice cover and high runoff. The simulated results of the seasonal and inter-annual variability in ocean climate and primary production are compared to field observations from the Atlantic Zonal Monitoring Program. Particular attention is directed towards the influence of climatic and hydrodynamic factors that exert a control on the nutrient distribution, seasonal plankton biomass, timing and magnitude of the spring bloom. Our results highlight the strong influence of winter hydrodynamic processes on the inter-annual variability in the St. Lawrence productivity.

POSTER PP2

The spring bloom along the Primorye coast of the East /Japan Sea

J. Chun-Ok and K. Kyung-Ryul

Seoul National University, School of Earth and Environmental Sciences, Seoul 151-747, Korea

A survey of the East/Japan Sea was carried out on a research vessel (*R/V Roger Revelle*) from February 28 to March 15, 2000. We analyzed temperature, salinity, nutrients (nitrate, phosphate, silicate) and sea surface chlorophyll *a* of SeaWiFS 8-day Standard Mapped Image (SMI) during this

period. Sea surface chlorophyll *a* concentration was higher than 0.8 mg/m^3 (two times the mean concentration during summer and winter in the East/Japan Sea) off the Primorye coast. The halocline was formed off the Primorye coast by melting of sea ice in the Tartarskiy Strait and nutrients concentrations were at least five times higher than typical half-saturation constants. Therefore, these results indicate that the spring bloom along the Primorye coast is affected by the formation of halocline due to sea-ice melting in the Tartarskiy Strait, and it seems that interannual variability of sea-ice melting can affect the spring bloom of the Primorye coast. The relationship of interannual variability between sea ice and sea surface chlorophyll *a* will be discussed.

POSTER PP3

Temporal and spatial variability in summer phytoplankton composition, numbers and biomass over the middle shelf of the eastern Bering Sea

M.V. Flint, I.N. Sukhanova, T.E. Whitledge and D.A. Stockwell

P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences, 36 Nakhimovski prospekt, Moscow 117997, Russia

The middle shelf domain is one of the most productive areas of the eastern Bering Sea shelf, the biotope that supports profound populations of planktivorous fish, sea birds and marine mammals in summer time. Due to the low influence of advection, the middle shelf ecosystem depends on local phytoplankton productivity to support consumers. But the composition, quantitative distribution and temporal variability of phytoplankton over the middle shelf are some of the major biological features of the ecosystem which are poorly known. In order to estimate these parameters phytoplankton was sampled and concurrent CTD and nutrient data were collected over the middle shelf between 56°16´N and 59°19´N in July 2000 and August 2001. Both years were relatively warm and showed little difference in spring conditions, the date when vertical stratification was established, or the physical and hydrochemical conditions in summer time. In July 2000, phytoplankton was mainly dominated by flagellates and dinoflagellates in numbers and by diatoms and dinoflagellates in biomass. Total cell numbers in the upper part of water column including the mixed layer and pycnocline varied in a range of 0.04-1.6x10^6 cells/l while total biomass varied in a range of 2.2 - 48.2 mgC/m^3. In August 2001, diatoms and coccolithophorids dominated the community by both numbers and biomass. In 2001 total phytoplankton numbers were close to that in 2000 but biomass was significantly higher and high spatial variability in the parameters was observed. In August 2001 phytoplankton numbers varied in the range of 0.09-1.7x10^6 cells/l and biomass covered a range of 7.7-418.6 mgC/m^3. Two paradoxes can be seen in the distribution pattern of phytoplankton over the Bering Sea middle shelf in summer time. First, a high level of spatial variability in composition and numbers/biomass is present against a background of uniform distribution of physical and hydrochemical parameters. Second, large numbers and biomass (comparable with those typical for the spring bloom) occur in some areas in late summer at the sharp pycnocline that lies beneath a euphotic zone with extremely low nutrients. These differences in phytoplankton parameters between 2000 and 2001 were accompanied by a well pronounced difference in biomass of herbivorous zooplankton. Biomass of the predominant grazer *Calanus marshallae* in August 2001 was more than an order of magnitude lower than in July 2000.

POSTER PP4

Changes in fatty acid composition of POM during an Arctic spring bloom

E. Leu, S. Falk-Petersen, S. Kwasniewski, A. Wulff, K. Edvardsen and D.O. Hessen
University of Oslo, Biological Institute, PO Box 1066, Blindern, N-0316 Oslo, Norway

Arctic marine ecosystems typically show a pronounced seasonality with a very distinct peak of primary production during the spring bloom in April-May. Essential polyunsaturated fatty acids (PUFAs) are among the key metabolites that are synthesized by phytoplankton in this period playing a fundamental role for the Arctic food-web. The spring bloom in an Arctic fjord is characterized by high water transparency, midnight sun and low temperatures together with a lack of stratification of the water masses. Spring depletion of stratospheric ozone may increase underwater UV radiation intensities, which are further enhanced by the high albedo due to snow-covered surroundings. We followed the changes in fatty acid composition of POM during a spring bloom in Kongsfjorden, Svalbard, in 2003 and 2004 to test for an eventual oxidation of PUFAs in phytoplankton. Several abiotic parameters were analyzed, with focus on underwater UV light, as well as photosynthetic pigments and the taxonomic composition of the phytoplankton community. The aim of the study was to identify factors affecting the nutritional quality of phytoplankton in terms of their fatty acid profiles, notably PUFAs. Changes in taxonomy following the natural succession were superimposed on abiotic parameters, and proved to be the main determinant of the fatty acid dynamics in POM. Stratospheric ozone values were very high during both sampling seasons, but also judging from under-ice sampling and depth profiles, UV radiation did not play a significant, direct role for fatty acid profiles in POM.

POSTER PP5

Satellite observations of the Bering Sea Green Belt

S.R. Okkonen and G.M. Schmidt
Institute of Marine Science, University of Alaska Fairbanks, Box 1025, Kasilof, Alaska 99610, USA

TOPEX altimeter measurements of sea surface topography and SeaWiFS imagery of chlorophyll a concentration are used to describe the surface structure of the Bering Sea 'Green Belt' and its relationship to the Bering Slope Current eddy field during the 2000, 2001, and 2002 spring blooms. During spring 2000, high surface chlorophyll a concentrations (>10 mg m^{-3}) were associated with an anticyclonic eddy group that propagated along isobaths above the continental slope and entrained chlorophyll from the shelf-slope front. During spring 2001, anticyclonic eddies in the northwest Bering Sea had propagated off-slope prior to the onset of the spring bloom and were too far from the shelf-slope front to entrain frontal chlorophyll during the bloom. A second chlorophyll front associated with the leading edge of the off-slope eddies was observed. Between these two fronts was a region of relatively low chlorophyll *a* concentration (~1 mg m^{-3}). The eddy field during the 2002 spring bloom was observed to propagate northwestward adjacent to the shelf-break and entrain chlorophyll from the shelf-slope region in a manner similar to what was observed during the 2000 spring bloom. These observations suggest that eddies are important, if not the principal, agents that cause variability in the distribution of Green Belt chlorophyll during the spring bloom in the central Bering Sea.

POSTER PP6

Bering Sea productivity and the influence of ammonia on total productivity in the Bering Sea

T. Rho, T.E. Whitledge and D.A. Stockwell

Institute of Marine Science, School of Fisheries and Ocean Science, University of Alaska Fairbanks, PO Box 757220, Fairbanks, AK 99775-7220, USA

Interaction between ammonium and nitrate, especially ammonium inhibition of nitrate uptake rates, was investigated using shipboard nutrient addition experiments over the middle domain of the southeastern Bering Sea shelf during early summer of 2000. Ambient nitrate concentrations in the ammonium treatment were not utilized until ambient ammonium concentration reached less than 7 M. Absolute nitrate uptake rates showed the same trend as ambient nitrate concentrations. Carbon uptake rates were similar in short incubations (4 hours) regardless of any nitrogen treatments (control, nitrate, ammonium, and nitrate and ammonium treatments), but showed a large increase with nitrogen additions during long periods incubations. This study suggests that the additional input of ammonium in early spring may delay the utilization of nitrate observed in the spring of 1998 and 1999 and results in an increase of total primary production over the southeastern Bering Sea shelf. Thus, during summer, the supply of ammonium from remineralization on the boundary between the water column and sediment or within the sediment may have resulted in the higher primary production over the inner shelf during 1997-2001 than earlier estimates. This study also suggests that we must be careful to choose a critical ammonium concentration for nitrate inhibition in ecosystem models.

POSTER PP7

Seasonal and spatial variability of chlorophyll-a distribution in the La Perouse Strait from satellite SeaWiFS and ship surveying data

G. Shevchenko, Z. Tshay and L. Gavrina

Sakhalin Research Institute of Fishery and Oceanography, 196 Komsomolskaya Street, Yuzhno-Sakhalinsk, Russia 693023

The oceanological and hydrobiological processes in the La Perouse Strait are very interesting because this area of sub-Arctic Okhotsk Sea is under the influence of the Japan Sea subtropic waters of the Soya Warm Current. To investigate these processes, satellite SST and chlorophyll-a concentration data were analyzed. OC2 algorithm of atmosphere correction was applied to correct SeaWIFS data and the EOF method was used to determine spatial and seasonal variability of chlorophyll-*a* concentration on the basis of 10-day averaged maps. The first EOF mode of chlorophyll-*a* (48% of total variance) has maximal values in the southeastern part of the Strait and in the northern part of Aniva Bay. The amplitude of the first mode has a great maximum in spring (the second half of April or first half of May). This maximum is connected with sea-ice thawing (time of diatomaceous algae blooming). It varies significantly from year to year, the largest bloom being in May 2004. The chlorophyll amplitude has a minimum in the summer and a second maximum in the fall. The latter is weaker and more stable compared to spring. We obtained close results with two maxima of chlorophyll-*a* concentration in spring and autumn from ship measurements. A total of 10 expeditions were carried out in Aiva Bay in different seasons of 2001-2002 using the vessel *Dmitry Peskov*. Having determined vertical variations of chlorophyll-*a* from ship surveying and its spatial distribution from SeaWIFS, we could estimate its total mass in the La Perouse Strait. It reached 4000 tons in the May 2004.

POSTER PP8

Primary productivity estimates over the middle shelf of the eastern Bering Sea and a comparison of two techniques

D.A. Stockwell, T.K. Rho, T.E. Whitledge, I.N. Sukhanova and M.V. Flint

University of Alaska Fairbanks, Institute of Marine Science, 245 O'Neill Building, PO Box 757220, Fairbanks, Alaska 99775-7220, USA

In August 2001, estimates of primary productivity were made over the middle shelf of the eastern Bering Sea, using C-14 and C-13 techniques. Diatoms and coccolithophorids typically dominated these communities in both number and biomass. Variability in the Bering Sea exists over a range of time scales and distances, resulting from multiple mechanisms. Size-fractionation of both chlorophyll and primary productivity estimates demonstrated high spatial variability throughout the study area. Distributions of phytoplankton biomass and productivity rates are examined with respect to the physical and hydrographic conditions of summertime Bering Sea. Direct comparisons of C-14 and C-13 techniques are examined with respect to the changing phytoplankton communities. The dominance of different phytoplankton populations over the shelf will be discussed with respect to associated changes in phytoplankton biomass and productivity rates.

POSTER PP9

Long term mooring observations of nutrients, fluorescence and temperature/salinity at mooring sites M2 and M4 in the middle shelf of the SE Bering Sea

T.E. Whitledge, J.M. Napp and P. Stabeno

School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, PO Box 757220, Fairbanks, AK 99775-7220, USA

Ten years of records from the moorings at M2 and 6 years for M4 reveal seasonal cycles in temperature, fluoresence and nutrients at these sites at the 70 m isobath in the middle shelf of the SE Bering Sea. A phytoplankton bloom associated with the arrival and melting of sea ice, occurred in March/April during 1995, 1997 and 1999. In each year, the bloom began even though the water column was not yet stratified. In 1996, 1998 and 2000-2003, when ice was present early in the year (before March), the bloom was delayed until May after the water column became stratified. Measurements of nitrate concentrations at Site 2 over a four year period reveal a seasonal cycle that varies significantly among years depending on physical conditions and resulting in surface depletion occurring after the blooms. The entire water column is replenished with nutrients in late fall after the breakdown of the shelf frontal systems. High nutrient concentrations continue during the winter months. Nitrate drawdown commences during March/April and becomes depleted (<2 M) during the summer months. There are periods of marked variability driven by physical mixing processes during all months of the year. The use of a moored nitrate meter, together with the other data on moorings, provides critical information on when and by what process this replacement occurs as well as any secular trends associated with warming. It also provides information on the frequency of mixing events that increase nutrients in the euphotic zone. This information can then be related to the phytoplankton blooms through examination of the fluorescence.

POSTER PP10

Nutrient and primary production trends over the past two decades for SE Bering Sea shelf regions

T.E. Whitledge, T. Rho, D.A. Stockwell, I.N. Sukhanova and M.V. Flint

University of Alaska Fairbanks, Institute of Marine Science, School of Fisheries and Ocean Sciences, PO Box 757220, Fairbanks, AK, 99775-7220, USA

To better understand the seasonal and spatial distributions of primary production over the southeastern Bering Sea Shelf, we analyzed ^{14}C productivity data from the Processes and Resources of the Bering Sea Shelf (PROBES) and ^{13}C productivity data from the recent studies such as the Southeast Bering Sea Carrying Capacity (SEBSCC), the Inner Front (IF), and Plankton Processes studies. Spring production contributes 41-55% to total annual production over the shelf. The annual production in the inner shelf (133.0 $gCm^{-2}y^{-1}$) is similar to that in the middle shelf (143.8 $gCm^{-2}y^{-1}$) and the outer shelf (138.3 $gCm^{-2}y^{-1}$). These results are similar to past estimates for the middle shelf and the outer shelf, but results from the inner shelf are larger due to better seasonal sampling of the high summer and fall production rates. The annual production at the shelf break region (143.5 $gCm^{-2}y^{-1}$) is also similar to the other shelf regions although the maximal productivity is in the range 3.3 to 4.8 $gCm^{-2}y^{-1}$, which may result from the seasonal cycle of production. The seasonal cycle and spatial distribution of primary production show large variations due to the physical conditions such as the advance and retreat of sea ice, winds, the strength of upwelling, and the slope of front at shelf break that control onshore transport of slope water in the surface and bottom layers of the outer shelf.

Poster Group: Zooplankton

POSTER Z1

Regional differences in the overwintering depth of *Calanus finmarchicus* in the sub-Arctic North Atlantic: the role of predation?

C.I.H. Anderson, M. Heath, S. Fielding and A.S. Brierley

University of St Andrews, Gatty Marine Laboratory, East Sands, St Andrews, KY16 8LB, UK

Investigations of predator-prey interactions in the open ocean need to consider the vertical distribution of organisms as well as their horizontal distribution, as animals must be coincident in all three dimensions for predation to take place. The copepod *Calanus finmarchicus* has a lifecycle characterised by an overwintering diapause phase in deep water. The average depth of diapause varies regionally, and several reasons for this have been put forward including the avoidance of mesopelagic predators, whose depth and abundance are also thought to vary between regions. The relative depth and abundance of predators, and their importance to the overwintering depth of *Calanus*, was tested using data on the vertical distribution of *Calanus* from coupled Optical Plankton Counter-net studies and on that of predators from concurrent surveys using a scientific echosounder in the Irminger, Norwegian and other seas of the northern North Atlantic. Predators of *Calanus*, such as euphausiids and myctophid fish, are major components of acoustic deep scattering layers (DSLs) observed throughout the North Atlantic. Differences were found in the abundance and distribution of likely predators between regions, and this was correlated to the depth distribution of overwintering *Calanus.* Results from further studies in the Irminger Sea region, that additionally used ADCP backscatter data, showed that while the majority of the overwintering

population of *Calanus* in the region may find a depth refuge from the predation pressure present in the DSLs, at the smaller scale the DSLs appear to respond to the depth of the *Calanus* to maximise overlap between them.

POSTER Z2

Pelagic and sympagic amphipods – trophic links in Arctic and sub-Arctic seas

H. Auel and I. Werner
Marine Zoology (FB 2), University of Bremen, PO Box 330 440, D-28334, Bremen, Germany

Carnivorous amphipods such as the dominant hyperiids, *Themisto libellula* and *T. abyssorum*, represent important links from herbivorous zooplankton to higher trophic levels including fishes, seabirds and seals. According to Norwegian acoustic surveys, the biomass of *Themisto* in the Norwegian and Greenland Seas exceeds 100 Million tons. In addition, masses of ice-associated amphipods, i.e. *Gammarus wilkitzkii, Apherusa glacialis, Onisimus glacialis* and *O. nanseni,* are exported from the Arctic Ocean together with their drift ice habitat into sub-Arctic seas. In areas where the sea ice eventually melts, e.g. the Greenland Sea, these sympagic amphipods contribute to the food supply for pelagic and benthic species. During six cruises covering most of the seasonal cycle, the distribution, trophodynamics, metabolic and respiration rates of pelagic and sympagic amphipods were studied in the Greenland Sea. Both pelagic and sympagic species, show distinct metabolic adaptations to their respective habitats. *G. wilkitzkii* can consume large quantities of food, eight times more than its momentary metabolic demand, in order to compensate for its semi-attached life-style with a higher risk of starvation periods. Lipid biomarker analyses were performed to assess the diet composition. Besides ice algae and sympagic fauna, under-ice amphipods also prey on planktic copepods, while pelagic *T. libellula* show a strong link to ice algal primary production. Biomarkers indicate a multiple exchange and dynamic re-cycling of organic matter between the sea-ice community and the pelagic realm. Thus, cryo-pelagic coupling processes are essential for our understanding of trophic interactions and carbon fluxes in Arctic and sub-Arctic seas.

POSTER Z3

Cannibalism of female *Calanus finmarchicus* on their nauplii

S. Basedow and K.S. Tande
Norwegian College of Fishery Science, Universtiy of Tromsø, Breivika, 9037 Tromsø, Norway

Interannual variability in population size of the biomass dominating copepod *Calanus finmarchicus* in the North Atlantic is high, but the cause of the observed variance is still poorly understood. Recruitment of nauplii is a key factor in the population dynamics of *C. finmarchicus* and determines the fate of larvae of many commercially important fish species. Recruitment of nauplii to copepodites may not only depend on ambient algal composition but also on cannibalism. The cannibalistic impact of adult *Calanus* spp. is assumed to be strongest during the pre-bloom with low abundance of algae. We hypothesize that *C. finmarchicus* females cannibalize on their nauplii until there is enough algae to meet their energy demands and tested this by exposing adult females to different concentrations of algae (*Thalassiosira weissflogii*) and nauplii. Preliminary results revealed high clearance rates on nauplii, however independent on algae concentration (0-5 mg chlorophyll m^{-3}). Experiments on possible cannibalism at higher chlorophyll concentrations will be conducted in spring 2005.

POSTER Z4

Seasonal changes in zooplankton trophic structure from spring to autumn in the Fram Strait

K. Blachowiak-Samolyk, S. Kwasniewski, H. Hop and S. Falk-Petersen
Institute of Oceanology of Polish Academy of Sciences, 55 Powst, Warszawy St. 81-712 Sopot, Poland

Horizontal and vertical distribution of mesozooplankton were investigated in May and August 2003 on shelf and deep-sea stations in the Fram Strait, northeast of Spitsbergen. The abundance and proportion of trophic functional groups of zooplankton changed from the beginning to the end of the primary production period as well as between shelf and deep-water locations. Few numerically important omnivorous zooplankters (*Fritillaria borealis, Oikopleura and Echinodermata* larvae) were more abundant in spring, whereas some of the herbivorous components, *Calanus finmarchicus* and *Pseudocalanus*, together with predators, mainly *Chaetognatha* and *Pareuchaeta*, reached higher abundances at the end of the summer. However, the vertical distributions of carnivores and their potential prey were remarkingly similar between seasons. The observed variability in proportion of various trophic groups of zooplankton is mainly related to seasonal changes in the physical characteristics of the water column as well as the prevailing plankton bloom situation. Possible implications of the biological dynamics for zooplankton and the carbon flux in the pelagic realm are also postulated.

POSTER Z5

The rise and fall of jellyfish in the Bering Sea: Is there a climate link?

R.D. Brodeur, J.E. Purcell, P. Stabeno, N.A. Bond, M.B. Decker, L. Ciannelli, G.L. Hunt Jr., and E. Acuna
Northwest Fisheries Science Center, NOAA Fisheries, Hatfield Marine Science Center, 2030 S. Marine Science Drive, Newport, OR 97365, USA

We have documented a dramatic increase in jellyfish biomass over the Eastern Bering Sea Shelf throughout the 1990s based on summer bottom trawl surveys conducted consistently since 1979. The biomass trend reached its zenith in the summer of 2000 and has since undergone a precipitous decline and stabilized at 1980s levels during the last four years. The 2000 peak was strongly influenced by several large catches at the shallower stations in the Inner Shelf Domain. Since that time, the majority of the biomass has been confined to the Middle Shelf Domain as was typical in the 1990s. Species composition data from recent years suggests that the bulk of the biomass is made up of one species, *Chrysaora melanaster*. The timing of the onset of the outburst and decline coincided with transitions between climatic regimes. In particular, 1989 appears to have marked the beginning of a period of moderate temperatures in the Bering Sea, after the very warm conditions of the late 1970s through the 1980s. Relative warmth returned to the Bering after 2000, as expressed in terms of surface temperatures and ice cover in winter (2002 was an exception), and total heat content in summer. We investigated changes in temperature, ice cover, atmospheric indices and current patterns to determine which factors were correlated with changes in jellyfish biomass. We propose that fluctuating environmental conditions may effect the jellyfish populations directly through increasing ephyra production or indirectly via changes in availability of food to young jellyfish during their development.

POSTER Z6

Genetic diversity of the sub-Arctic copepod, *Calanus finmarchicus:* interannual variation of populations in the Gulf of Maine, Northwest Atlantic

A. Bucklin, E. Ünal, J.G. Beaudet and P.H. Wiebe

University of New Hampshire, Ocean Process Analysis Laboratory, 142 Morse Hall, 39 College Road, Durham, NH 03824 USA

Physical oceanographic conditions in the Gulf of Maine, NW Atlantic show significant interannual variation driven in part by the North Atlantic Oscillation (NAO). A precipitous drop in the NAO index during 1996 resulted in the presence of cold fresh Labrador Sea water in the Gulf of Maine throughout much of 1998. This coincided with low abundances of diapausing *C. finmarchicus* during fall 1998, which is thought to have caused low abundances during the following winter. Such year-to-year variation in abundance may be reflected in the species population genetic diversity and may result in significant shifts in population genetic make-up. Whether any year-to-year changes in genetic diversity are driven by differential mortality and natural selection is an open question. DNA sequences of nuclear genes encoding metabolic enzymes were determined for *C. finmarchicus* samples collected from the Gulf of Maine during 1997, 1998, and 1999. Synonymous and non-synonymous substitutions in enzyme-coding gene regions were discriminated. Time/space patterns of genetic diversity were examined for evidence of natural selection driving interannual variation of *C. finmarchicus* populations.

POSTER Z7

Winter distribution of zooplankton biomass in the northern Norwegian Sea

A. Edvardsen[1], D. Slagstad[2], J.-C. Gascard[3], K.S. Tande[1] and E. Halvorsen[1]

[1]*Norwegian College of Fishery Sciences, University of Tromso, 9037 Tromso, Norway*

[2]*SINTEF Fisheries and Aquaculture, Arkitekt Ebbellsvei 10, Trondheim N-7465, Norway*

[3]*Universite Pierre et Marie Curie, 4 Place Jussieu, Paris Cedex 05 75252, France*

Surveys in off-shelf areas in the NE Norwegian Sea since the year 2000, have indicated a semi-consistent spatial pattern of high zooplankton concentrations. This paper reports results from the winter cruise in 2003, which was largely designed to substantiate the findings from the three previous years. Over-wintering zooplankton were generally found in the depth range 600-1200 m and in the temperature range -1 to 3°C. The highest concentrations of zooplankton were found along the shelf slope north of 70°N. High biomass concentrations were found at the same location as in previous winters. Based on the spatial distribution of zooplankton, simulated current fields and available drifter data, it is proposed that areas of high zooplankton biomass are formed by an interaction between zooplankton vertical behaviour and large-scale topographically-steered eddy/gyre activity in the area. We discuss how a shift in the positioning of over-wintering habitats might effect the advection and recruitment of zooplankton during their growth season.

POSTER Z8

Biochemical determination of population age structure in euphausiids

H.R. Harvey, S.-J. Ju, W.T. Peterson, L. Feinberg and T. Shaw

Chesapeake Biological Laboratory, Univ. Maryland Center for Environmental Science, PO Box 38, Solomons, MD 20688, USA

Euphausiids play a key role in the marine ecosystem as a link between primary producers and top predators. Understanding their precise demographic structure is needed to assess growth and recruitment as well as determine how changes in environmental conditions alter their condition and distribution. Since age determination of crustaceans cannot be accomplished using traditional approaches, we evaluated the potential of age pigments (collectively termed lipofuscin) to determine the age structure of *Euphausia pacifica* in field collections. The rate of lipofuscin accumulation was determined using krill of known age reared from larvae in the laboratory for over 1 year. Lipofuscin was extracted from neural tissues (eye and eye-stalk), quantified, and normalized to protein content to allow comparisons across animal sizes. Multiple fluorescent components from krill were observed, with the major product having a maximum fluorescence at excitation of 355 nm and emission of 510 nm. While the growth rate from known-age krill was log-linear (regression coefficient=0.85), the lipofuscin accumulation rate of the same individuals was linear (regression coefficient=0.76). Field collections as part of the NEP GLOBEC program were sorted immediately after tows into representative size classes for evaluation. Populations of krill contained variable levels of lipofuscin dependant on size and age. Most of field-collected sub-adults and adults were found to be older than 100 days and younger than 1 yr based on lipofuscin age estimation. Based on biochemical measures of age, the lifespan of *E. pacifica* in the northeast Pacific is no longer than 2 years. Our results suggest that biochemical indices allow a practical approach to estimate population age structure and together with other measures can provide estimates of vital rates (i.e. longevity, mortality, growth) for krill populations in dynamic environments.

POSTER Z9

Amphipod prey of gray whales in the northern Bering Sea: changes in abundance and distribution

R.C. Highsmith, K. Coyle, B. Bluhm and B. Konar

University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Fairbanks AK 99775-7220, USA

Gray whales (*Eschrichtius robustus*) migrate from Baja California to the northern Bering Sea and Chukchi Sea, where they are reported to feed primarily on infaunal ampeliscid amphipods, especially the large species Ampelisca macrocephala. Typically, a few thousand whales feed from May to October in an area of approximately 40,000 km2 of the Chirikov Basin in the northern Bering Sea. The Chirikov ampeliscid community was previously studied from 1986 to 1988. Because of the reported significant decline in the gray whale population during 1999-2001, we repeated our 1980s studies in 2002 and 2003. The study area is bounded by 64 -65ºN and 168-170ºW. We reoccupied 20 established stations and utilized the same methodology as in the previous study so direct comparisons of species' population abundances and geographic distribution could be made. The results for 2002 indicate that major ampleliscid species' abundances remained similar at some stations and declined significantly at others. In the 1980s, the highest ampeliscid densities were at stations near the center of the study site. In 2002, densities were much lower at these stations and highest densities were in the northwest corner of the site, where gray whales were observed feeding. In contrast to the 1980s, few whales were observed in the central study area.

POSTER Z10

Egg production rates of the larger copepods in the Gulf of Alaska: *Calanus marshallae*, *Calanus pacificus*, *Eucalanus bungii* and *Neocalanus flemingeri*

R.R. Hopcroft and C. Clarke,
University of Alaska, Institute of Marine Science, Fairbanks, AK 99775, USA

Egg production rates and strategies of four common larger-bodied copepods in the Gulf of Alaska are presented and contrasted. Both *Calanus* species display the highest rates of specific egg production (SEP), although *Calanus marshallae* showed greater variability than *Calanus pacificus*. Neither appeared closely coupled to ambient chlorophyll concentration. *Neocalanus flemingeri* produced the largest clutch sizes, but egg production was fuelled entirely by lipid accumulation from the previous year, yielding an average SEP over the active spawning period of only a few percent. *Eucalanus bungii* produced clutches intermediate in size between the other species, but despite the potential for large clutches, egg production was extremely variable between individuals, and SEP was even lower than that of *Neocalanus*. The significance of these reproductive strategies relative to their life-history strategies is considered.

POSTER Z11

Rates of production by larvaceans in the northern Bering Sea

R.R. Hopcroft and C. Clarke
University of Alaska, Institute of Marine Science Fairbanks, AK 99775, USA

The larvacean community north of St. Lawrence Island through Bering Strait was surveyed during early July 2002. The community was composed of *Oikopleura vanhoeffeni*, *O. labradoriensis*, and *Fritillaria borealis*. Populations were reproductively mature: fecundity by *O. vanhoeffeni* ranged from 1200-4900 eggs per female, with egg hatching time of <2 days. House production averaged 2.4 houses per day. Preliminary growth rates for recently hatched individuals were determined by the artificial cohort method for *Oikopleura* spp. and F. borealis: they ranged from 18-41% increases in body weight per day. Larvacean biomass was typically ~10% that of the copepod community. These numbers suggest they have the ability to both outgrow and out-reproduce copepod populations, explaining their ability to bloom under favourable conditions in this region.

POSTER Z12

Lipid ecology of euphausiids in the North East Pacific and Polar Oceans

S.-J. Ju and H.R. Harvey
Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, PO Box 38, Solomons, MD 20688, USA

Four species of euphausiids were collected from the Northeast Pacific (sub-Arctic species) and Southern Ocean (Antarctic species) to investigate the ecology (i.e. feeding, reproduction) of euphausiids in the diverse environments using lipid biomarkers. In the Northeast Pacific, the dominant krill include *Euphausia pacifica* and *Thysanoessa spinifera* collected from January to August 2000 and 2002 as part of the NEP GLOBEC program. Two major species of Antarctic krill, *Euphausia superba* and *E. crystallorophias*, were collected in austral winter (July-August 2001 and 2002) and fall (April 2002) as part fo the Southern Ocean GLOBEC program. For each collection,

total lipid, lipid classes, and lipid biomarkers were measured in adults, juveniles and larvae. Antarctic krill were found to have much higher lipid content than their sub-Arctic relatives (10-50% and 5-20% of dry mass, respectively) with significant seasonal variations. While phospholipids were the dominant lipid class in sub-Arctic krill, the storage lipids (wax esters and triacylglycerols for *E. crystallorophias* and *E. superba*, respectively) were the dominant lipid class in Antarctic krill, accounting for more than 40% of the total lipid content. In all krill species the fatty acids 16:0, 18:1 (n-9), 20:5 (n-3) were major components with minor differences between species and seasons. 22:6 (n-3) was absent from Antarctic krill, but present in sub-Arctic species. Sterol profiles showed that cholesterol was the most abundant sterol in all krill, with significant amounts of cholesta-5,24-dien-3-ol (desmosterol) found in Antarctic krill and abundant in sea-ice algae. Larval stage of krill contained higher amounts of polyunsaturated fatty acids and algal derived sterols than either juveniles or adults. Lipid profiles suggest krill alter their diets dependent upon life stage and season. For Antarctic krill, larvae actively feed on sea-ice associated organisms while juveniles and adults feed on seston and copepods in the water column during austral winter. Analyses of lipid content and compositions indicate that lipid dynamics in krill are closely linked to their life cycle (i.e. overwintering, reproduction) and environmental conditions (i.e. food availability).

POSTER Z13

Retention areas of zooplankton and ichthyoplankton in Varanger Fjord in north Norway during the late spring period in 2002

C. Li, M. Fossheim and K.S. Tande

Norwegian College of Fishery Sciences, University of Tromso, 9037 Tromso, Norway

The strategic programme BASECOEX (capelin and herring in the Barents Sea coexistence or exclusion) is a multidisciplinary research concept where the major aim is to establish new knowledge regarding capelin-herring interactions in the Barents Sea. The project undertook in 2002 field surveys to resolve the 3-dimensional advection, migration and *in situ* population dynamic rates of zooplankton and capelin larvae in a mesoscale physical setting in the spawning area close to Varanger fjord in Finnmark. The study site was near to a seabed spawning site in a very energetic environment. High-resolution data from the Scanfish package (including OPC and Seabird CTDF) are being analyzed to understand the variations in zooplankton and ichthyoplankton. These vertical and horizontal gradients in zooplankton and ichthyoplankton are used to further understand the consequences of the physical transportation mechanisms for the biological components traced by the OPC.

POSTER Z14

Zooplankton and ichthyoplankton in Varanger Fjord, north Norway in spring 2002

C. Li, M. Fossheim and K.S. Tande

Norwegian College of Fishery Sciences, University of Tromsø, N-9037 Tromsø, Norway

The strategic programme BASECOEX (capelin and herring in the Barents Sea Coexistence or Exclusion) is a multidisciplinary research concept where the major aim is to establish new knowledge regarding capelin-herring interactions in the Barents Sea. In May 2002 the project undertook field surveys to resolve the 3-dimentional advection, migration and in situ population dynamic rates of zooplankton and capelin larvae in a mesoscale physical setting in the spawning area close to Varanger fjord, North Norway. The study site was close to a seabed spawning site of capelin,

located in the transition between the fjord and more exposed shelf bank areas in a very dynamic environment. High-resolution data from the Scanfish package (including OPC and Seabird CTDF) are being analyzed to understand how variations of mesoscale physical fields and bottom topography affect 3D variations in zooplankton and ichthyoplankton. Vertical and horizontal gradients in zooplankton and ichthyoplankton are explored to shed light on the consequences of physical transportation mechanisms.

POSTER Z15

Seasonal and diel changes in quantitative distribution patterns of zooplankton off the Pacific coast of eastern Hokkaido, Japan, estimated by an acoustic dual-frequency algorithm

K. Miyashita and K. Sasaki

Laboratory of Marine Ecosystem Change Analysis, Field Science Center for the Northern Biosphere, Hokkaido University, 3-1-1, Minato-cho, Hakodate, Hokkaido 041-8611 Japan

In the sub-Arctic ocean, zooplankton are an important prey for nekton, seabirds and marine mammals, and play a vital role in the ecosystem, so accurate estimates of zooplankton abundance are needed by ecosystem-based fisheries stock managers. In this study, we examined seasonal and diel changes in the quantitative distribution patterns of zooplankton off the Pacific coast of eastern Hokkaido, Japan, using an acoustic dual-frequency algorithm. The acoustic, net sampling and CTD data were collected during the 4 cruises of the R/V Kaiyo-maru No.3 (January 2000, June 2000, January 2001 and June 2001) carried out by the Fisheries Research Agency of Japan. A total of 19 transects were sampled each cruise, and a day and a night survey was conducted along each transect lines within a 24-hour period. After each survey, we were able to accurately discriminate between zooplankton (mainly krill and copepods) and fish (mainly walleye pollock) using an acoustic dual-frequency algorithm that took net-sampling data into consideration. The identified echograms of zooplankton were overlaid with CTD data (temperature and salinity) using GIS. In the June surveys, dense zooplankton layers occurred above the continental shelf over the entire survey area, and remarkable diel changes in vertical distribution patterns of zooplankton were observed. In contrast, in the January surveys, coastal Oyashio water (temperatures <2.5°C, salinities <32.6) occurred above the continental shelf, and no dense zooplankton layers or diel changes were observed.

POSTER Z16

Variations in climate and their impacts on the egg production and recruitment of *Calanus finmarchicus* in the lower St. Lawrence estuary, Canada

S. Plourde, P. Joly, M. Starr and L. St-Amand

Department of Fisheries and Oceans Canada, Ocean Sciences Branch, Maurice Lamontagne Institute, 850 route de la Mer, C.P. 1000, Mont-Joli, Qc., G5H 3Z4, Canada

During the period 1991-1997, the reproduction in the marine copepod *Calanus finmarchicus* in the lower St. Lawrence estuary (LSLE) typically starts in June in response to the late onset of the phytoplankton bloom, while elevated phytoplankton biomass in summer sustains high egg production rates (EPR) until mid September. This seasonal pattern in reproduction resulted in a peak of population recruitment centred in July and early August. Changes in the freshwater regime in the LSLE during the late 1990s and early 2000s appeared to have profound impacts on the dynamics of *C. finmarchicus*. In 1998 and 1999, the spring maximum in freshwater discharge and the onset of

the phytoplankton bloom occurred in April and May respectively, one month earlier than during the period of 1991 to 1997. Accordingly, *C. finmarchicus* initiated reproduction at least one month earlier than during the 1991-1997 period with EPR up to 25-35 eggs female^{-1} d^{-1} in mid-May to early June, attained maximum EPR in mid-July and showed 'lower than normal' reproductive activity from late July to late September. During a year of sustained freshwater runoff in late spring and early summer (2004), the main period of EPR occurred 6-8 weeks later (late August) and was 4-5 weeks shorter than during the period of 1991 to 1997. EPR in *C. finmarchicus* appeared food-limited during most of the summer in 2004. Such changes in the timing of reproduction might have important implications for the population dynamics of *C. finmarchicus* in the LSLE.

POSTER Z17

Characteristics of vertical migration of zooplankton in coastal Newfoundland

N. Record and B. De Young

Physical Oceanography, Memorial University of Newfoundland, St. John's, NL A1B-3X7, Canada

Zooplankton populations in three regions of coastal Newfoundland (Trinity Bay, Placentia Bay, and Funk Island Bank) were observed using Acoustic Doppler Current Profilers (ADCPs) from 1999 to 2004. The acoustic backscatter data show a consistent diel vertical migration of zooplankton toward the surface during evening twilight hours, and away from the surface during morning twilight hours. In fact, the water is so dense with zooplankton that ADCP vertical velocity data (designed to record velocities of water currents) can be used to measure the vertical velocity of migrating zooplankton in the water column by correlating appropriate backscatter levels with velocities. This approach is applied to the 1999-2004 ADCP data from multiple coastal locations, examining day-to-day variations in migration patterns, timing, and character, and correlating these variations with changes in physical conditions of the water column and light intensity. The findings are then viewed in the larger context of the recent changes in these ecosystems.

POSTER Z18

Northwest Atlantic plankton trends 1959 to 2003

D. Sameoto

Department of Fisheries and Oceans, Bedford Institute of Oceanography, PO Box 1006 , Dartmouth, N.S., Canada B2Y 4A2

Continuous Plankton Recorder Survey data collected for the years 1959 to 2003 between Iceland and New England showed that significant changes occurred in the abundance and seasonal timing of the blooms of both phytoplankton and zooplankton taxa, phytoplankton increased and some zooplankton species decreased. Changes occurred after 1991 in the region west of longitude 45ºW rather than east of 45ºW where these changes were not observed. There is evidence that the zooplankton community is now returning to a state similar to that seen in the 1960s. It is suggested that the plankton changes were related to changes in the Labrador Current system.

POSTER Z19

Seasonal accumulation of allochthonous Calanus spp. in a northern Norwegian fjord

S. Skreslet, K. Olsen and K.S. Tande

Faculty of Fisheries and Natural Sciences, Bodø University College, N-8049 Bodø, Norway

At a station in the Saltford in northern Norway, vertical tows by a 200 µm WP-2 net from bottom to surface were made for one year to study the demography of *Calanus* spp. *C. finmarchicus* and *C. hyperboreus*, which dominated in numbers, and *C. glacialis* that was present in low numbers, reproduced during spring. Their progeny were resident until June-July when the new generations were lost, probably by advection to shelf waters. In the following period, *C. finmarchicus* demography was dominated by CIV-Vs, but periodic recruitment from different source regions was indicated by conspicuous shifts in prosome length, fatty acid ratios and interspecific ratios with other *Calanus* spp. The first immigrants of *C. finmarchicus* and *C. hyperboreus* that occurred in September were accompanied by *C. helgolandicus* and *C. glacialis* but they quickly disappeared only to reappear after some months. *C. finmarchicus* and *C. hyperboreus* were much more abundant than the other two species but their sample size decreased towards the reproduction period in March-April, probably due to local predation. However, incidents of their increased abundance occurred together with the appearance of one of the two other *Calanus* spp., indicate an inflow of communities from Arctic and boreal source regions, as revealed by *C. glacialis* and *C. helgolandicus*, respectively. Thus, the Calanus spp. that emerge in northern Norwegian fjords during autumn and winter and recruit to local reproducing stocks in spring, may originate from different and distant parts of the Nordic Seas.

POSTER Z20

Influence of climatic variables on the advection and exchange of krill between a large estuary and the inner shelf: a modelling approach applied in the St. Lawrence system

M. Sourisseau, B.A. Zakardjian, Y. Simard and F.J. Saucier

Institut des sciences de la mer de Rimouski (ISMER), Université du québec à Rimouski, 310, allée des Ursulines, C.P. 3300, Rimouski (Québec) Canada G5L 3A1

The current structure near the mouth of the St. Lawrence estuary is strongly dynamic under the effects of winds, tides, river runoff, seasonal circulation and non-local meteorological forcing from the Gulf of St. Lawrence. The seasonal variability of the circulation is still not well understood. Using a 3D physical model and a physical/biological coupling, we have tested several assumptions and attempted to estimate the impact of climatic forcing on krill exchanges between the Gulf and the lower estuary of St. Lawrence. Various krill behaviours, including a diel vertical migration, were tested. The results highlight two states in the current patterns near the mouth and the importance of the transverse front position at the mouth. Instabilities of the frontal position create transition periods associated with a water inflow from the Gulf and along on the north coast. These events appear essential for the krill dynamics in the estuary because the krill concentration in this region of the Gulf was high under the effects of aggregation processes. According to the fact that krill larvae stay in the surface water and are therefore flushed out of the lower estuary, krill recruitment in the estuary is sensitive to periodic events which result from runoff variations of the estuary rivers, tides, unstable waves and wind forcing.

POSTER Z21

Egg production of *Calanus finmarchicus* in the Norwegian Sea

E.K. Stenevik, C.B.T. Åarnes, W. Melle and B. Ellertsen

Institute of Marine Research, PO Box 1870 Nordnes, 5817 Bergen, Norway

The egg production of *Calanus finmarchicus* was studied during basin scale surveys in May 2003 and 2004 in the Norwegian Sea. During the surveys, about 20 live females collected from each of 46 vertical tows were incubated in chambers containing a false bottom with 180 µm plankton net and kept at their *in situ* temperature. The females were inserted into the upper part of the chamber, while the negatively buoyant eggs sunk through the plankton net and thereby reduced the possibility of cannibalism. After 24 hours the eggs were counted, the size of the female recorded and the mean daily female-specific egg production rate was calculated for each station. The population fecundity was estimated as the product of the individual egg production rate and the number of female *C. finmarchicus* in net hauls on each station. Individual egg production rate and population fecundity were related to environmental conditions such as sea temperature, water column chlorophyll content, time of the day, oceanographic frontal systems, predator abundance and also demography and gonad development within the population of *C. finmarchicus*.

POSTER Z22

Different features in zooplankton communities between the Okhotsk Sea and neighboring Oyashio region

A. Yamaguchi, Y. Ueno, J. Seki and T. Ikeda

Hokkaido University, Marine Biodiversity Laboratory, Graduate School of Fisheries, Hokkaido University, 3-1-1 Minato-cho, Japan

Based on the zooplankton samples collected in the southern Okhotsk Sea and neighboring Oyashio region during the autumns (September-December) of 1996 to 1998, regional differences in vertical distribution patterns, biomass and structure of the entire zooplankton community, as well as the body size of dominant copepods, were analyzed. While zooplankton in the Okhotsk Sea was similar to that in the Oyashio region in terms of fauna, its biomass, community structure and vertical distribution patterns were quite different between these two regions. Zooplankton biomass in the surface layer (0 m-thermocline) in the Okhotsk Sea was less than that of the Oyashio region. This is partly due to the fact that large copepods are distributed in the mesopelagic zone in the Okhotsk Sea while this was the epipelagic zone in the Oyashio region. Within the same copepods, specimens from the Okhotsk Sea were larger than those from the Oyashio region, suggesting their development in cooler mesopelagic zones in the former. Standing stocks of most zooplankton taxa were less in the Okhotsk Sea than in the Oyashio region, with a notable exception for the copepod *Metridia okhotensis*. The abundance of *M. okhotensis* in the Okhotsk Sea was 30 times greater than that in Oyashio region, and indeed they were the most dominant component (60%) of the total copepod number in the Okhotsk Sea. The development of strong pycnocline in Okhotsk Sea may be a key feature causing these regional differences in the features of zooplankton communities between the Okhotsk Sea and Oyashio region.

Poster group: Human dimensions

POSTER HD1

Local community involvement in 'ocean observing systems': Whose ocean is it and who really observes it?

T.A. Okey, A. Butler, M.Y. Brubaker and A.K. Salomon

CSIRO Marine Research, PO Box 120, Cleveland, Queensland 4163, Australia

Ocean observing systems are being planned worldwide, but local communities are rarely included in the development of overall goals, operations, data collection, or interpretation. This oversight is foolish since coastal communities who are culturally, traditionally, or economically tied to the sea observe ocean systems constantly and already posses a valuable time series of system change. Local communities have knowledge of observable megafauna, macroflora, and ecosystem dynamics that ocean observing systems do not detect and track, but which are invaluable complements to the oceanographic information that these systems will monitor. Indigenous communities, in particular, will be extremely valuable partners in detecting ocean change and assessing the drivers of change. This is illustrated by the demonstrated value of 'traditional ecological knowledge' and the keen observational skills of indigenous people, and also by a growing capacity for the support and performance of western-based science. However, local communities often lack the expertise or inclination to approach the planners of ocean observing systems with such a vision of scientific complementarity. Rather than attempting to minimize the impacts of science programs on local communities, we propose general guidelines that scientists and agencies can follow to maximize the generation of useful knowledge from ocean observing systems by integrating knowledge systems through local community inclusion.

Addresses of registered participants
(as at 8th April 2005)

Mrs Cecilie Broms Årnes
Institute of Marine Research
FG5 PO Box 1870
Bergen 5817
NORWAY
Tel: +47 9260 1879
Email: cecilie.broms.aarnes@imr.no

Ms Maki Noguchi Aita
Frontier Research Centre for Global Change
JAMSTEC
3173-25 Showa-machi, Kanazawa-ku
Yokohama Kanagawa 236-0001
JAPAN
Tel: +81 4577 85576
Email: macky@jamstec.go.jp

Dr Vera Alexander
School of Fisheries and Ocean Sciences
University of Alaska
245 O'Neill Building
Fairbanks AK 99775-7220
USA
Tel: +1 907 474 5071
Email: vera@sfos.uaf.edu

Dr Cairistiona Anderson
University of St Andrews
Gatty Marine Lab
East Sands
St Andrews Fife KY16 8LB
UK
Tel: +44 1334 473485
Email: ciha@st-and.ac.uk

Dawn Ashby
GLOBEC IPO
Plymouth Marine Laboratory
Prospect Place
PL1 3DH
Tel: +44 1752 633401
Email: d.ashby@pml.ac.uk

Dr Carin Ashjian
Woods Hole Oceanographic Institution
MS #33 WHOI
Woods Hole
MA 02540
USA
Tel: +1 508 289 3457
Email: cashjian@whoi.edu

Dr Olafur S. Astthorsson
Marine Institute of Iceland
Skulagotu 4
Reykjavik
ICELAND
Tel: +354 552 0240
Email: osa@hafro.is

Dr Holger Auel
Marine Zoology
University of Bremen
PO Box 330 440
D-28334 Bremen
GERMANY
Tel: +49 421 2189 566
Email:hauel@uni-bremen.de

Dr Kerim Aydin
Alaska Fisheries Science Center
REFM Division
7600 Sand Point Way NE
Seattle WA 98115
USA
Tel: +1 206 526 4225
Email: Kerim.Aydin@noaa.gov

Ms Ksenia Batrak
VNIRO
17 v. Krasnoselskaya
Moscow 107140
RUSSIA
Tel: +7 095 264 9187
Email: ksusha@vniro.ru

Dr Manuel Barange
GLOBEC IPO
Plymouth Marine Laboratory
Prospect Place
Plymouth PL1 3DH
UK
Tel: +44 1752 633160
Email: m.barange@pml.ac.uk

Prof Richard T. Barber
Division of Coastal Systems Science and Policy
School of the Environment and Earth Sciences
Duke University, 135 Duke Marine Lab Road
Beaufort
NC 28516-9721
USA
Tel: +1 252 504 7578
Email: rbarber@duke.edu

Sunnje Basedow
Norwegian College of Fishery Science
Universtiy of Breivika
9037 Tromsø
NORWAY
Tel: +47 77 64 61 29
Email: sunnjeb@nfh.uit.no

Dr Dick Beamish
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo BC V9R 5K6
CANADA
Tel: +1 250 756 7029
Email: beamishr@pac.dfo-mpo.gc.ca

Dr Igor Belkin
215 South Ferry Rd
Rhode Island
Narragansett 02882
USA
Tel: +1 401 874-6533
Email: ibelkin@gso.uri.edu

Dr Katarzyna Blachowiak-Samolyk
Institute of Oceanology
Polish Academy of Sciences
55 Powst. Warszawy St.
SOPOT 81-712
POLAND
Tel: +48 58551 7283
Email: kasiab@iopan.gda.pl

Dr Bodil Bluhm
University of Alaska Fairbanks
245 O'Neil Building
School of Fisheries and Ocean Sciences
Fairbanks, 99775
Alaska
USA
Phone +1 907 474 6332
Email : bluhm@ims.uaf.edu

Dr Jennifer Boldt
JISAO, NOAA Fisheries
7600 Sand Point Way NE, Bldg 4
Seattle
WA 98115-0070
USA
Tel: +1 206 526 4693
Email: jennifer.boldt@noaa.gov

Dr Nicholas Bond
University of Washington/JISAO
Box 354235
University of Washington
Seattle WA 98195-4235
USA
Tel: +1 206 526 6459
Email: nicholas.bond@noaa.gov

Dr Keith Brander
International Council for the Exploration of the Sea
Palaegade 2-4
Copenhagen 1261
DENMARK
Tel: +45 3338 6728
Email: keith@ices.dk

Dr Lawson W. Brigham
US Arctic Research Commission
420 L Street, Suite 315
Anchorage
Alaska 99501
USA
Tel: +1 907 271 4577
Email: usarc@acsalaska.net

Dr Richard Brodeur
NOAA/NWFSC
HMSC 2030
Marine Institute Drive
OR, 97365
USA
Tel: +1 541 867 0336
Email: Rick.Brodeur@noaa.gov

Dr Ann Bucklin
University of New Hampshire
OPAL, 142 Morse Hall
39 College Road
NH 03824
USA
Tel: +1 603 863 0122
Email: ann.bucklin@unh.edu

Dr Eddy Carmack
Institute of Ocean Sciences
PO Box 6000
Sidney
BC V8L 4B2
CANADA
Tel: +1 250 363 6585
Email: carmacke@dfo-mpo.gc.ca

Dr Claudia Castellani
BODC
Joseph Proudman Building
6 Brownlow Street
Liverpool
L3 5DA
UK
Tel: +44 1517 954 882
Email: cxc@bodc.ac.uk

Prof. Liqi Chen
Key Laboratory of Global Change and Marine-Atmospheric Chemistry
1 Fuxingmenwai Av.
Beijing 100860
PR CHINA
Tel: +86 106 801 7625
Email: lqchen@soa.gov.cn

Dr Sanae Chiba
Frontier Research Center for Global Change
JAMSTEC
3173-25 Showa-machi
Yokoyama Kanagawa 236-0001
JAPAN
Tel: +81 45 778 5604
Email: chibas@jamstec.go.jp

Dr Marina Chifflet
Fisheries and Oceans Canada
Institut Maurice-Lamontagne
850 route de la Mer
Mont-Joli
Québec G5H 3Z4
CANADA
Tel: +1 418 775 0676
Email: chiffletm@dfo-mpo.gc.ca

Sang Chul Yoon
Pukyong National University
Daeyeon-3 dong
Nam-gu
Busan 608737
REPUBLIC OF KOREA
Tel: +82 516 206 124
Email: adam75@mail1.pknu.ac.kr

Ms Jo Chun-Ok
Seoul National University
24-305E School of Earth and Environmental Sciences
Seoul 151-742
KOREA
Tel: +82 2 877 6741
Email: cojoo100@snu.ac.kr

Ms Jaclyn Clement
Naval Postgraduate School
Dept. of Oceanography
833 Dyer Road
Monterey CA 93943
USA
Tel: +1 831 656 3226
Email: jlclemen@nps.edu

Dr Eugene B. Colbourne
Department of Fisheries and Oceans
PO Box 5667
St. John's NL A1C 5X1
CANADA
Tel: +1 709 772 6106
Email: colbourn@dfo-mpo.gc.ca

Dr Kenneth O. Coyle
Institute of Marine Science
University of Alaska
Fairbanks AK 99775-7220
USA
Tel: +1 907 474 7705
Email: coyle@ims.uaf.edu

Dr Enrique Curchitser
Lamont Doherty Earth Observatory
Columbia University
201-c 61 Route 9w
Palisades 10964
USA
Tel: +1 84 536 586 91
Email: enrique@ldeo.columbia.edu

Dr Mary Beth Decker
Yale University
Department of Ecology & Evolutionary Biology
165 Prospect St.
New Haven, CT 06520-8106
USA
Tel: +1 203 432 6293
Email: marybeth.decker@yale.edu

Dr. Nina V. Denisenko
Zoological Institute of the Russian Academy of Sciences
Universitetskaya nab.1, 199034, St.-Petersburg
RUSSIA
Tel: +7 812 328 1311
Email: denist@rol.ru

Dr Holly Dolan
Department of Geography
University of Victoria
P.O. Box 3050, Stn CSC
Victoria, BC, V8W 3P5
CANADA
Tel: +1 250 721 7342
Email: hdolan@uvic.ca

Dr Andrey Dolgov
PINRO
6 Knipovich Street
Murmansk
183763
RUSSIA
Tel: +7 8152 472 532
Email: dolgov@pinro.ru

Ms. Miriam Doyle
JISAO
7600 Sand Point Way NE
Seattle WA 98115
USA
Tel: +1 206 526 4318
Email: Miriam.Doyle@noaa.gov

Dr Don Dragoo
Alaska Maritime NWR-USFWS
95 Sterling Hwy
Suite 1
Homer, Alaska 99603-7473
USA
Tel: +1 907 226 4626
Email: don_dragoo@fws.gov

Dr Ken Drinkwater
Institute of Marine Research
PO Box 1870 Nordnes
N-5817
Bergen N-5817
NORWAY
Tel: +47 5523 6990
Email: kendrink@ims.no

Dr Hajo Eicken
Geophysical Institute
University of Alaska Fairbanks
PO Box 757320
Fairbanks AK 99775-7320
USA
Tel: +1 907474 7280
Email: hajo.eicken@gi.alaska.edu

Dr Lisa B. Eisner
Auke Bay Laboratory/NOAA
11305 Glacier Hwy.
Juneau
Alaska AK 99801
USA
Tel: +1 907 789 6602
Email: lisa.eisner@noaa.gov

Dr Ben Fitzhugh
University of Washington
M32 Denny Hall
Box 353100
Seattle 98195-3100
USA
Tel: +1 206 543-9604
Email: fitzhugh@u.washington.edu

Dr Mikhail Vladimirovich Flint
P.P. Shirshov Institute of Oceanology
Russian Academy of Sciences
Nakhimovskiy prospekt 36
Moscow 117997
RUSSIA
Tel: +7 951 248 515
Email: m_flint@orc.ru

Ms Sarah Gaichas
NMFS Alaska Fisheries Science Center
University of Washington
7116 Greenwood Ave N, Unit 406
Seattle WA 98103
USA
Tel: +1 206 783 1092
Email: sarah.gaichas@noaa.gov

Dr Joaquim I. Goes
Bigelow Laboratory for Ocean Sciences
West Boothbay Harbor
Maine
04571
USA
Tel: +1 207 633 9600
Email: jgoes@bigelow.org

Mr Rolf Gradinger
University of Alaska Fairbanks
245 O'Neil Building
School of Fisheries and Ocean Sciences
Fairbanks, 99775
Alaska
USA
Tel: +1 907 474 4704
Email:rgradinger@ims.uaf.edu

Dr Jacqueline M. Grebmeier
University of Tennessee
1015 Research Dr, Bldg A.
Suite 100
Knoxville TS 37932
USA
Tel: +1 865 974 2592
Email: jgrebmei@utk.edu

Prof. Chester E. Grosch
Center for Coastal Physical Oceanography
Old Dominion University
Norfolk
Virginia 23529
USA
Tel: +1 757 683 4931
Email: enright@ccpo.odu.edu

Prof. Lawrence C. Hamilton
Dept. of Sociology, HSSC
University of New Hampshire
Durham NH 03824-3509
USA
Tel: +1 603 862 1859
Email: Lawrence.Hamilton@unh.edu

Prof. Kimio Hanawa
Department of Geophysics
Graduate School of Science
Tohoku University
Aoba-ku Sendai 980-8578
JAPAN
Tel: +81 2221 76526
Email: hanawa@pol.geophys.tohoku.ac.jp

Dr Bogi Hansen
Faroese Fisheries Laboratory
PO Box 3051
Torshavn FO-110
FAROES
Tel: +29 835 3900
Email: bogihan@frs.fo

Prof. H. Rodger Harvey
University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory
PO Box 38
Solomons MD 20688
USA
Tel: +1 410 326 7206
Email: harvey@cbl.umces.edu

Dr Erica Head
Dept. of Fisheries and Oceans
Ocean Sciences Division, Bedford Institute of Oceanography
PO Box 1006
Dartmouth NS B2Y 4A2
CANADA
Tel: +1 902 426 2317
Email: HeadE@mar.dfo-mpo.gc.ca

Dr Ray Highsmith
University of Alaska Fairbanks
School of Fisheries and Ocean Sciences
Fairbanks AK 99775-7220
USA
Tel: +1 907 474 7836
Email: highsmith@guru.uaf.edu

Dr Hans-Jurgen Hirche
AWI
Columbstrasse
Building D-2300
Bremerhaven D-27568
GERMANY
Tel: +49 471 4831 1336
Email: hhirche@awi-bremerhaven.de

Dr Eileen Hofmann
Old Dominion University
768 W. 52nd Street
Norfolk VA 23529
USA
Tel: +1 757 683 5334
Email: hofmann@ccpo.odu.edu

Claire Holeton
Southampton Oceanography Centre
George Deacon Division
European Way
Southampton SO14 3ZH
UK
Tel: +44 7944 425048
Email: clh302@soc.soton.ac.uk

Dr Anne Hollowed
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way NE.
Seattle WA 98115
USA
Tel: +1 206 526 4223
Email: anne.hollowed@noaa.gov

Dr Chul-Hoon Hong
Pukyong National University
599-1Daeyeon 3-dong
Namgu
Pusan 608-736
KOREA
Tel: +81 516 206 891
Email: hongch@pknu.ac.kr

Dr Russ Hopcroft
University of Alaska
Institute of Marine Science
University of Alaska
Fairbanks AK 99775
USA
Tel: +1 907 474 7842
Email: hopcroft@ims.uaf.edu

Dr George L. Hunt Jr.
321 Steinhaus Hall
University of California Irvine
Irvine, CA 92697-2525
USA
Tel: +1 949 497 1914
Email: glhunt@ucl.edu

Dr Karl David Hyrenbach
University of Washington
135 Duke Marine Laboratory
Beaufort
NC 28516
USA
Tel: +1 252 504 7576
Email: khyrenba@duke.edu

Mr Takahiro Iida
Graduate School of Fisheries Sciences
Hokkaido University
3-1-1 Minato-cho
Hakodate Hokkaido 041-8611
JAPAN
Tel: +81 138 40 5618
Email: tiida@salmon.fish.hokudai.ac.jp

Dr David Irons
US Fish & Wildlife Service
1011 East Tudor Road
Anchorage AK 99516
USA
Tel: +1 907 786 3376
Email: david_irons@fws.gov

Dr Gail V. Irvine
U.S. Geological Survey
Alaska Science Centre
1011 E Tudor Rd
Anchorage 99503
USA
Tel: +1 907 786 3653
Email: gail_irvine@usgs.gov

Dr Shin-ichi Ito
Tohoku Nationall. Fisheries. Research. Institute.
3-27-5, Shinhama-cho
Shiogama
Miyagi 985-0001
JAPAN
Tel: +81-22-365-9928
Email: goito@affrc.go.jp

Prof Steingrimur Jonsson
University of Akureyri and Marine Research Institute
Borgir v/Nordurslod
Akureyri
600
ICELAND
Tel: +354 463 0948
Email: steing@unak.is

Dr Se-Jong Ju
Chesapeake Biological Laboratory
University of Maryland
Center for Environmental Science
PO Box 38, 1 Williams Street, Solomons MD 20688
USA
Tel: +1 410 326 7307
Email: ju@cbl.umces.edu

Shigeho Kakehi
Tohoku National Fisheries Research Institute
3-27-5, Shinhama-cho
Shiogama
Mityagi 985-0001
JAPAN
Tel: +81-22-365-9928
Email: kakehi@affrc.go.jp

Dr Sukyung Kang
National Fisheries Research and Development Institute
408-1, Shirang-Ri, Gijang-Eup, Gijang-Gun
Busan 619-902
REPUBLIC OF KOREA
Tel: +82 51 720 2293
Email: kangsk@momaf.go.kr

Seiji Katakura
Graduate School of Fisheries Sciences
Hokkaido University
Minato-cho 3-1-1
Hakodate Hokkaido 041-8611
JAPAN
Tel: +81 138 405 591
Email: katakura@fish.hokudai.ac.jp

Prof Suam Kim
Pukyong National University
599-1, Daeyeon 3-dong
Namgu
Busan 608-737
KOREA
Tel: +82 516 206 268
Email: suamkim@pknu.ac.kr

Michael C.S. Kingsley
Greenland Institute of Natural Resources
PO Box 570
DK-3900 Nuuk
GREENLAND
Tel: +299 36 1200
Email: mcsk@natur.gl

Prof. Michio J. Kishi
Graduate School of Fisheries Sciences
Hokkaido University/FRSGC
3-1-1 Minato-cho
Hakodate, Hokkaido 041-8611
JAPAN
Tel: +81 138 408 873
Email: mjkishi@nifty.com

Prof. Alexander Kitaysky
Institute of Arctic Biology
Department of Biology and Wildlife
University of Alaska Fairbanks,
311 Irving 1, Fairbanks,
AK, 99775
USA
Tel: +1 907 474 5179
Email: ffask@uaf.edu

Dr Thomas Kline
Prince William Sound Science Center
PO Box 705
300 Breakwater Ave
Cordova AK 74
USA
Tel: +1 907 424 5800, ext 233
Email: tkline@pwssc.gen.ac.us

Dr Toru Kobari
Faculty of Fisheries
Kagoshima University
4-50-20 Shimoarata
Kagoshima 890-0056
JAPAN
Tel: +81 99 286 4140
Email: kobari@fish.kagoshima-u.ac.jp

Mr Vladimir V. Kobylyansky
Federal Research Centre
A-190 Box 51
Moscow 125190
RUSSIA
Tel: +7 0953 307 122
Email: koba@org.citnet.ru

Ms Jana Kotzerka
Institute of Polar Ecology
Wischhof str.
1-3 Gebunde 12
Kiel 24148
GERMANY
Tel: +49 431 600 1270
Email: mkotzerka@ipoe.uni-kiel.de

Dr. Andrei Krovnin
Russian Federal Research Institute
of Fisheries and Oceanography (VNIRO)
17 Verkhnyaya Krasnoselskaya
Moscow
RUSSIA
Tel: +7 0952 648 401
Email: akrovnin@vniro.ru

Dr Igor Krupnik
Arctic Studies Center
National Museum of Natural History
10th and Constitution Ave. NW
Washington DC 20560-0112
USA
Tel: +1 202 633 1901
Email: krupnik.igor@nmnh.si.edu

Dr Gordon H. Kruse
University of Alaska
School of Fisheries and Ocean Sciences
Juneau Center 11120 Glacier Highway
Juneau
Alaska 99801
USA
Tel: +1 907 465 8458
Email: Gordon.Kruse@uaf.edu

Ms Kathy Kuletz
US Fish and Wildlife Service
1011 E. Tudor Road
Anchorage
Alaska AK 99503
USA
Tel: +1 907 786 3453
Email: kathy_kuletz@fws.gov

Dr Carol A. Ladd
University of Washington
7600 Sand Point Way
Seattle WA 98115-6349
USA
Tel: +1 206 526 6024
Email: carol.ladd@noaa.gov

Dr Viktor V. Lapko
Sakhalin Research Institute of Fisheries and Oceanography
196, Komsomol St.
Yuzhno-Sakhalinsk 693023
RUSSIA
Tel: +7 4242 456 741
Email: lapko@sakhniro.ru

Diane Lavoie
University of Victoria
SEOS, PO Box 3055
STN CSC
Victoria V8W 3P6
CANADA
Tel: +1 250 363 9266
Email: lavoied@uvic.ca

Dr Chung Il Lee
Research Center for Ocean Industrial and Development
Pukyong National University
599-1 Daeyeon 3dong, Namgu
Busan 608-737
REPUBLIC OF KOREA
Tel: +82 516 206 211
Email: leeci@mail1.pknu.ac.kr

Jae Bong Lee
National Fisheries Research and Development Institute
408-1, Shirang-ri
Gijang-eup/gun
Busan 619-902
REPUBLIC OF KOREA
Tel: +82 517 202 296
Email: leejb@nfrdi.re.kr

Evelyn J. Lessard
School of Oceanography
University of Washington
Box 357940
Seattle 98195
USA
Tel: +1 206 543 8795
Email: elessard@u.washington.edu

Ms Eva Leu
University of Oslo
Biological Institute
PO Box 1066, Blindern
Oslo 0316
NORWAY
Tel: +47 22 85 42 98
Email: eva.leu@bio.uio.no

Chaolun Li
Norwegian College of Fishery Sciences
University of Tromso
Tromso 9037
NORWAY
Tel: +47 77 64 60 79
Email: lcl@ms.qdio.ac.cn

Polina Vyacheslavovna Lobanova
Department of Oceanology
St. Petersburg State University
33/35 10th Line
St Petersburg 199178
RUSSIA
Tel: +7 812 328 97 09
Email: pl19@mail.ru

Dr Harald Loeng
Institute of Marine Research
Po Box 1870
Nordnes
Bergen 5817
NORWAY
Tel: +47 5523 8466
Email: harald.loeng@imr.no

Dr Elizabeth A. Logerwell
Alaska Fisheries Science Center
F/AKC2
PO Box 15700
Seattle WA 98115
USA
Tel: +1 206 526 4231
Email: libby.logerwell@noaa.gov

Dr James Lovvorn
University of Wyoming
Department of Zoology
Laramie WY 82071
USA
Tel: +1 307 766 6100
Email: lovvorn@uwyo.edu

Dr David L. Mackas
Fisheries and Oceans
Institute of Ocean Sciences
PO Box 6000
Sidney BC V8L 4B2
CANADA
Tel: +1 250 363 6442
Email: mackasd@dfo-mpo.gc.ca

Dr Wieslaw Maslowski
Oceanography Department
833 Dyer Road
Monterey
93943
USA
Tel: +1 831 656 3162
Email: maslowsk@nps.edu

Prof S. Lyn McNutt
NOAA/PMEL
7600 Sand Point Way
Seattle
WA 98115
USA
Tel: +1 360 7944 109
Email: Lyn.McNutt@noaa.gov

Dr Bernard Megrey
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way NE
Seattle WA 98115-634
USA
Tel: +1 206 526 4147
Email: bern.megrey@noaa.gov

Dr Webjørn Melle
Institute of Marine Research
PO Box 1870
Nordnes
Bergen N-5817
NORWAY
Tel: +47 55 23 84 77
Email: webjorn@imr.no

Dr Larry Merculieff
Alaska Native Science Commission
429 L Street
Anchorage
AK 99501
USA
Tel: +1 907 258 2672
Email: lmerculieff@aknsc.org

Dr Arthur J. Miller
Scripps Institution of Oceanography
Climate Research Division
0224 SIO-UCSD
La Jolla
CA 92093-0224
USA
Tel: +1 858 534 8033
Email: ajmiller@ucsd.edu

Dr Kazushi Miyashita
Laboratory of Marine Ecosystem Change Analysis
Field Science Center for the Northern Biosphere
3-1-1 Minato-cho
Hakodate Hokkaido 041-8611
JAPAN
Tel: +81 138 40 8856
Email: miyashi@fish.hokudai.ac.jp

Kohei Mizobata
Graduate School of Fisheries Sciences
Hokkaido University
3-1-1, Minato
Hakodate Hokkaido 041-8611
JAPAN
Tel: +81 138 40 5618
Email: mizobata@salmon.fish.hokudai.ac.jp

Dr Sue Moore
National Marine Mammal Laboratory
NOAA/NMFS/Alaska Fisheries
7600 Sand Point Way, NE
Seattle WA 98115
USA
Tel: +1 206 685 2124
Email: sue.moore@noaa.gov

Mr Christopher-John Mundy
Centre for Earth Observation Science
Faculty of Earth, Environment and Resources
University of Manitoba
Winnipeg Manitoba R3T 2N2
CANADA
Tel: +1 204 453 0513
Email: ummundy0@cc.umanitoba.ca

Ms Lisa M. Munger
Scripps Institution of Oceanography
University of California
9500 Gilman Drive
La Jolla CA 92093-0205
USA
Tel: +1 858 534 5755
Email: lmunger@ucse.edu

Dr Eugene Murphy
British Antarctic Survey
High Cross
Madingley Road
Cambridge CB3 0ET
UK
Tel: +44 1223 221614
Email: e.murphy@bas.ac.uk

Prof Maribeth Murray
HARC
University of Alaska Fairbanks
PO Box 757720
Fairbanks 99775-7720
USA
Tel: +1 907-474-6751
Email: ffmsm@uaf.edu

Dr Vladimir V. Napazakov
Pacific Research Fisheries Centre
Bld. 90, apt.313
Okeanskiy St.
Vladivostok 690002
RUSSIA
Tel: +8 9147 123 026
Email: napazakov@tinro.ru

Dr Jeffrey M. Napp
NOAA Fisheries
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle WA 98115 0070
USA
Tel: +1 206 526 4148
Email: jeff.napp@noaa.gov

Dr Jennifer L. Nielsen
USGS Alaska Science Center
1011 East Tudor Road
Anchorage
Alaska 99503
USA
Tel: +1 907 786 3670
Email: jennifer_nielsen@usgs.gov

Dr Akira Nishimura
Hokkaido National Fisheries Research Institute
116 Katsura-koi
Kushiro
Hokkaido 085-0802
JAPAN
Tel: +81 154 92 1716
Email: anishimu@fra.affrc.go.jp

Dr Thomas A. Okey
CSIRO Marine Research
PO Box 120
Cleveland
QLD 4163
AUSTRALIA
Tel: +61 738 267 236
Email: tom.okey@csiro.au

Dr Stephen Okkonen
Institute of Marine Science
University of Alaska Fairbanks
Box 1025
Kasilof AK 99610
USA
Tel: +1 907 283 3234
Email: okkonen@alaska.net

Dr Takeshi Okunishi
Graduate School of Engineering
Hokkaido University
Kita 13, Nishi 8, Kita-ku
Sapporo Hokkaido 060-8628
JAPAN
Tel: +81 11 706 6184
Email: okunishi@eng.hokudai.ac.jp

Dr Rosemary Ommer
Centre for Studies in Religion and Society
Sedgewick Building B112
PO Box 1700 STN CSC
Victoria BC V8W 2Y2
CANADA
Tel: +1 250 472 4544
Email: coast@uvic.ca

Dr Patrick Ouellet
Fisheries and Oceans Canada
Maurice Lamontage Institute
850 route de la mer
Mont-Joli Quebec G5H 3Z4
CANADA
Tel: +1 418 775 0675
Email: ouelletp@dfo-mpo.gc.ca

Dr James E. Overland
PMEL/NOAA
7600 Sand Point Way NE
Seattle WA 98115-6349
USA
Tel: +1 206 526 6795
Email: James.E.Overland@noaa.gov

Dr Clarence Pautzke
North Pacific Research Board
1007 West 3rd Ave
Suite 100
Anchorage 99501
USA
Tel: +1 907 644 6700
Email: cpautzke@nprb.org

Dr Ian Perry
Fisheries & Oceans Canada
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo BC V9T 6N7
CANADA
Tel: +1 250 756 7137
Email: perryi@pac.dfo-mpo.gc.ca

Dr Randall M. Peterman
School of Resource and Environmental Management
8888 University Drive Simon Fraser University
BC, Burnaby V5A 1S6
CANADA
Tel: +1 604 291 4683
Email: peterman@sfu.ca

John F Piatt
Alaska Science Center USGS
1011 E. Tudor Road
Anchorage
AK 99503
USA
Phone : +1 360 774 0516
Email : john_piatt@usgs.gov

Dr Stephane Plourde
Department of Fisheries and Oceans Canada
Ocean Sciences Branch Institut Maurice-Lamontagne
850 route de la Mer C.P. 1000
Mont-Joli Quebec G5H 3Z4
CANADA
Tel: +1 418 775 0676
Email: plourdes@dfo-mpo.gc.ca

Dr Jennifer E. Purcell
Western Washington University
Shannon Point Marine Center
1900 Shannon Point Road, Anacrotes
Washington 98221
USA
Tel: +1 360 650 7400
Email: purcelj@cc.wwu.edu

Mr Nicholas Record
Memorial University of Newfoundland
Box 55, Department of Physics and Physical Oceanography
St John's
NL A1B-3X7
CANADA
Tel: +1 709 737 6136
Email: nrecord@physics.mun.ca

Dr TaeKeun Rho
Institute of Marine Science
University of Alaska, Fairbanks
PO Box 757220
Alaska AK 99775-7220
USA
Tel: +1 907 474 7797
Email: tkrho@ims.uaf.edu

Ms Marie Robert
Fisheries and Oceans Canada
Institute of Ocean Sciences
OSAP, PO Box 6000
986 West Saanich Road,
Sidney BC V8L 4B2
CANADA
Tel: +1 250 363 6612
Email: robertm@pac.dfo-mpo.gc.ca

Dr Dan Roby
Oregon State University
Fisheries & Wildlife
104 Nash
Corvallis OR 97331
USA
Tel: +1 541 737 1955
Email: daniel.roby@oregonstate.edu

Dr Sergei Rodionov
University of Washington/JISAO
PMEL, 7600 Sand Point Way
Seattle, WA 98115
USA
Tel: +1 206 526-6211
Email: sergei@u.washington.edu

Dr Konstantin Rogachev
Pacific Oceanological Institute
43 Baltiyskay Street
Russian Academy of Sciences
Vladivostok 690041
RUSSIA
Tel: +7 4232 312 158
Email: rogachev@poi.dvo.ru

Dr George Rose
Marine Institute, 155 Ridge Rd
PO Box 4920, St Johns
A1C 5R3
CANADA
Tel: +1 709 778 0482
Email: grose@mi.mun.ca

Mr Ian Rose
Oregon State University
Fisheries & Wildlife
104 Nash
Corvallis OR 97331
USA
Tel: +1 541 737 1955
Email: daniel.roby@oregonstate.edu

Prof. Thomas C. Royer
Old Dominion University
Center for Coastal Physical Oceanography
768 W, 52nd Street
Norfolk Virginia 23508-2055
USA
Tel: +1 757 683 5547
Email: royer@ccpo.odu.edu

Dr Greg Ruggerone
Natural resources Consultants, Inc
1900 West Nickerson Street
Suite 207
Seattle WA 98119
USA
Tel: +1 206 285 3480
Email: gruggerone@nrccorp.com

Dr Sei-Ichi Saitoh
Graduate School of Fisheries
Hokkaido University
3-1-1, Minato-cho
Hakodate 041-8611
JAPAN
Tel: +81 138 408 843
Email: ssaitoh@salmon.fish.hokudai

Prof Egil Sakshaug
Biological Station
Norwegian University of Science and Technology
Trondheim N-7491
NORWAY
Tel: +47 735 915 83
Email: egil.sakshaug@bio.ntnu.no

Prof. Yasunori Sakurai
Department of Marine Biological Sciences
Faculty of Fisheries, Hokkaido Unviersity
3-1-1, Minato-cho
Hakodate
Hokkaido 041-8611
JAPAN
Tel: +81 138 40 8861
Email: sakurai@fish.hokudai.ac.jp

Doug Sameoto
Dept. of Fisheries and Oceans
Bedford Institute of Oceanography
P.O. box 1006
Dartmouth, N.S., B2Y 4A2
CANADA
Tel: +1 902 469 0960
Email: sameotod@mar.dfo-mpo.gc.ca

François Saucier
Institute of Ocean Science
University of Quebec
310 Ursulines Street
Rimouski G5L 3A1
CANADA
Tel: +1 418 723 1986
Email: francois_saucier@uqar.qc.ca

Dr Andrey Savin
Pacific Scientific Research Fisheries Center
Shevchenko 4
Vladivostok 690950
RUSSIA
Tel: +8 4232 40 08 81
Email: savin@tinro.ru

Hyunju Seo
Department of Marine Biology
Pukyong National University
599-1, Daeyeon3-dong
Nam-gu, Busan 608-737
KOREA
Tel: +82 51 207 692
Email: uagiri@hanamail

Ms Lisa Sheffield
Oregon State University
Fisheries & Wildlife
104 Nash
Corvallis OR 97331
USA
Tel: +1 541 737 4531
Email: sheffiel@onid.orst.edu

Dr Graham Sherwood
Marine Institute of Memorial University
PO Box 4920
St John's
A1C 5R3
CANADA
Tel: +1 709 778 0482
Email: grose@mi.mun.ca

Dr Georgy Shevchenko
Laboratory of Biological Oceanography
SAKHNIRO
196 Komsonolskaya St
Yuzhno-Sakhalinsk 693023
RUSSIA
Tel: +7 4242 456 770
Email: shevchenko@sakhniro.us

Mr Serger Shevkun
Far Eastern State Technical University
690950 Axakovsky pereulok 3a
Vladivostok 690950
RUSSIA
Tel: +7 4232 450 982
Email: shevk2004@mail.ru

Mr Osamu Shida
Mororan Branch
Hakodate Fisheries Experimental Station
Funami-cho 1-133-31
Mororan Hokkaido 051-0013
JAPAN
Tel: +81 143 222 327
Email: shidao@fishexp.pref.hokkaido.jp

Dr Dag Slagstad
SINTEF Fisheries and Aquaculture
Arkitekt Ebbellsvei 10
Trondheim N-7465
NORWAY
Tel: +47 7359 2407
Email: dag.slagstad@sintef.no

Dr Victor Smetacek
Alfred-Wegener-Institut fur Polar und Meeresforschung
Am Handelshafen 12
Bremerhaven D-27570
GERMANY
Tel: +49 471 4831 1440
Email: vsmetacek@awi-bremerhaven.de

Ms Janne Søreide
Akvaplan-niva
Polar Environmental Centre
Tromso N-9296
NORWAY
Tel: +47 7775 0305
Email: janne@akvaplan.niva.no

Dr Phyllis Stabeno
PMEL/NOAA
7600 Sand Point Way NE
Seattle WA 98115
USA
Tel: +1 206 526 6453
Email: phyllis.stabeno@noaa.gov

Dr Michel Starr
Fisheries and Oceans Canada
Institut Maurice-Lamontagne
Mont-Joli
Québec G5H 3Z4
CANADA
Tel: +1 418 775 0611
Email: starrm@dfo-mpo.gc.ca

Prof Lech Stempniewicz
University of Gdansk
Dept. of Verterbrate Ecology & Zoology
Legionow 9
Gdansk 80-441
POLAND
Tel: +48 585 201 690
Email: biols@univ.gda.pl

Dr Erling Stenevik
Instiitute of Marine Research
PO Box 1870
Nordnes 5817
Bergen
NORWAY
Tel: +47 5523 8486
Email: erling.stenevik@imr.no

Dr Dean A. Stockwell
University of Alaska
Institute of Marine Science,245 O'Neill Building
OP Box 757220
Fairbanks AK 99775-7220
USA
Tel: +1 907 474 5556
Email: dean@ims.uaf.edu

Ms Suzanne Strom
Western Washington University
Shannon Point Marine Center
1900 Shannon Point Road
Anacortes WA 98221
USA
Tel: +1 360 293 2188
Email: stroms@cc.wwu.edu

Ms Margaret E. Sullivan
JISAO
University of Washington
7600 Sand Point Way NE, Bldg 3
Seattle WA 98115
USA
Tel: +1 206 526 6185
Email: peggy.sullivan@noaa.gov

Dr Svein Sundby
Institute of Marine Research
Postboks 1870
Nordnes
Bergen 5817
NORWAY
Tel: +47 5523 8468
Email: svein.sundby@imr.no

Mr Robert M. Suryan
Oregon State University
Hatfield Marine Science Center
2030 SE Marine Science Drive
Newport OR 97365
USA
Tel: +1 541 867 0223
Email: rob.suryan@oregonstate.edu

Dr Einar Svendsen
Institute of Marine Research
PO Box 1870 Nordnes
Bergen N-5817
NORWAY
Tel: +47 5523 8458
Email: einar@imr.no

Dr Vladimir V. Sviridov
Laboratory of Applied Biocenology
Pacific Scientific Research Fisheries Center
Shevchenko 4
Vladivostok 690950
RUSSIA
Tel: +7 4232 401 504
Email: sv@tinro.ru

Dr Kazuaki Tadokoro
Frontier Research Center for Global Change
3173-25 Showamachi Kanazawa-ku
Yokohama
Kanagawa 143-0015
JAPAN
Tel: +81 45 778 5602
Email: denden@jamstec.go.jp

Dr Akinori Takahashi
Graduate School of Fisheries Sciences, Hokkaido
3-1-1 Minato-cho
Hakodate 041-8611
JAPAN
Tel: +81-138-40-8889
Email: atak@fish.hokudai.ac.jp

Prof Kurt Tande
Norwegian College of Fishery Science
University of Tromso
Tromso 9037
NORWAY
Tel: +47 7764 4524
Email: kurtt@nfh.uit.no

Dr Charles Tang
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth
Nova Scotia B2Y 4A2
CANADA
Tel: +1 902 426 2960
Email: tangc@mar.dfo-mpo.gc.ca

Dr Kazutaka Tateyama
Kitami Institute of Technology
165 Koen-cho
Kitami
Hokkaido 090 8507
JAPAN
Tel: +81 157 269 466
Email: tateyaka@mail.kitami-it.ac.jp

Dr. Oleg Titov
Polar Research Institute of Marine Fisheries
and Oceanography (PINRO)
6 Knipovich Street
Murmansk
183763
RUSSIA
Tel: +7 8152 472 532
Email: inter@pinro.ru

Mr Naoki Tojo
Juneau Center, SFOS, UAF
11120 Glacier Hwy.
Juneau
AK 99801
USA
Tel: +1 907 465 8453
Email: n.tojo@uaf.edu

Ms Ebru Unal
Ocean Process Analysis Laboratory
University of New Hampshire
142 Morse Hall, 39 College Road
Durham, NH 03824
USA
Tel: +1 603 862 4974
Email: euy@unh.edu

Dr Elena I. Ustinova
15, ap. 200
Admiral Spiridonov Street
Vladivostok 690013
RUSSIA
Tel: +7 4232 296 118
Email: ustinova@tinro.ru

Prof Leonid S. Vilenchik
Federal Research Centre
A-190 Box 51
Moscow 125190
RUSSIA
Tel: +7 0953 307 122
Email: koba@org.citnet.ru

Jia Wang
International Arctic Research Center,
University of Alaska Fairbanks
930 Koyukuk Dr.
Fairbanks
USA
Tel: +1 9074 742 685
Email: jiaqinwang@yahoo.com

Dr Muyin Wang
JISAO/University of Washington
Box 3579741
Seattle
WA 98115
USA
Tel: +1 206 526 4532
Email: muyin.wang@noaa.gov

Dr Sarah Wanless
NERC Centre for Ecology and Hydrobiology
Hill of Brathens
Banchory
Aberdeenshire AB31 4BY
UK
Tel: +44 1330 826343
Email: swanl@ceh.ac.uk

Dr Thomas Weingartner
Institute of Marine Science
University of Alaska Fairbanks
245 O'Neil Building
Fairbanks, 99775
Alaska
USA
Tel: +1 907 474 7993
Email: weingart@ims.uaf.edu

Dr Cisco Werner
Department of Marine Sciences
University of North Carolina
12-7 Venable Hall, CB3300
Chapel Hill NC 27599-3300
USA
Tel: +1 9199 620 269
Email: cisco@email.unc.edu

Prof Terry Whitledge
Institute of Marine Science
234 Irving II, PO Box 757220
University of Alaska Fairbanks
Fairbanks AK 99775-7220
USA
Tel: +1 907 474 7229
Email: terr@ims.uaf.edu

Dr Peter H. Wiebe
Woods Hole Oceanographic Institution
MS#33
Woods Hole
MA 02543
USA
Tel: +1 508 289 2313
Email: pwiebe@whoi.edu

Dr Kai Wieland
Greenland Institute of Natural Resources
PO Box 570
DK 3900
Nuuk 3990
GREENLAND
Tel: +299 361 200
Email: wieland@natur.gl

Dr Peter Winsor
Woods Hole Oceanographic Institution
Clark 306A, MS#21
Woods Hole
MA 02543
USA
Tel: +1 508 289 2533
Email: pwinsor@whoi.edu

Mr Andreas Winter
University of Washington
School of Aquatic and Fishery Sciences
Box 355020
Seattle WA 98195-5020
USA
Tel: +1 206 221 5471
Email: awinter@u.washington.edu

Dr Rebecca Woodgate
University of Washington
Applied Physics Laboratory
1013 NE 40th Street
Seattle WA 98105
USA
Tel: +1 206 221 3268
Email: woodgate@apl.washington.edu

Mr Ian Wrohan
University of Victoria
1306 Bay Street
Victoria BC V8R 2A4
CANADA
Tel: +1 250 370 5487
Email: iwrohan@hotmail.com

Dr Yong Sheng Wu
Bedford Institute of Oceanography
Coastal Ocean Science
PO Box 1006
Dartmouth NS B2Y 4A2
CANADA
Tel: +1 902 463 1838
Email: wuy@mar.dfo-mpo

Dr Atsushi Yamaguchi
Graduate School of Fisheries
Hokkaido University
3-1-1 Minato -cho
Hokkaido 041-8611
JAPAN
Tel: +81 138 40 5543
Email: a-yama@fish.hokudai.ac.jp

Dr Alison York
Arctic Research Consortium of the USD
3535 College Road Suite 101
Fairbanks
AK 99079
USA
Tel: +1 9074 741 600
Email: york@arcus.org

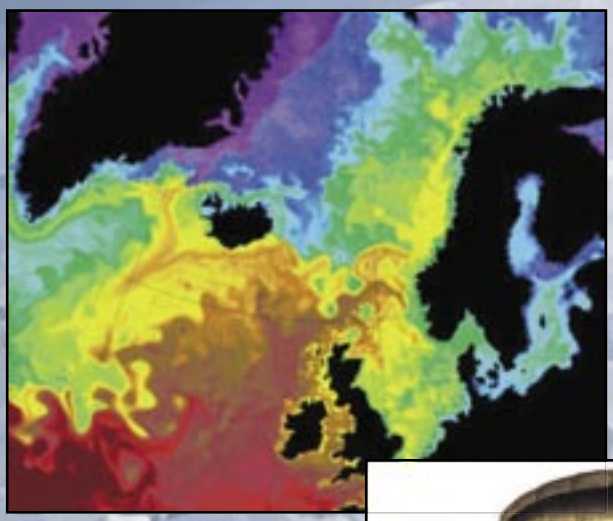
Dr Brad de Young
Dept. of Physics and Physical Oceanography
Memorial University
St. John's NF A1B 3X7
CANADA
Tel: +1 709 737 8839
Email: bdeyoung@physics.mun.ca

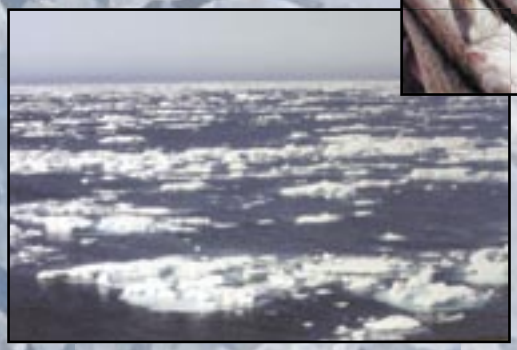
Prof Bruno Zakardjian
Institut des Sciences de la Mer de Rimouski
Université du Québec à Rimouski
310 allée des ursulines
CANADA
Tel: +1 418 723 1986 1570
Email: Bruno_Zakardjian@uqar.qc.ca

Prof. J Zhang
Faculty of Science
Toyama University
3190 Gofuku
Toyama 930-8555
JAPAN
Tel: +81 76 445 6665
Email: jzhang@sci.toyama-u.ac.jp

Dr Yury I. Zuenko
Pacific Fisheries Research Centre
4, Shevchenko Alley
Vladivostok 690950
RUSSIA
Tel: +7 4232 400 934
Email: zuenko@tinro.ru

Index





The Research Council of Norway

Alaska Fisheries Science Center

NSF

PICES
North Pacific Marine Science Organization

NOAA

Fisheries and Oceans Canada

NPRB
NORTH PACIFIC RESEARCH BOARD