2nd ESSAS Open Science Meeting

Comparative Studies of Climate Effects on Polar and Sub-Polar Ecosystems: Progress in Observation and Prediction

May 22-26, 2011
Seattle, WA, USA

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Welcome

On behalf of the symposium conveners, organizers, and scientific steering committee, we welcome you to beautiful Seattle, a city of many cultural opportunities and natural wonders. Here along the shores of Puget Sound and close to the foot of Mount Rainier, we join together close to 200 scientists from 13 countries to share our knowledge of and excitement in the study of sub-polar marine ecosystems and the people who depend upon them. The theme of this symposium "*Comparative Studies of Climate Effects on Polar and Sub-Polar Ecosystems: Progress in Observation and Prediction*" encompasses a wide diversity of studies, from climate and physical oceanography to fish, seabirds and marine mammals, and with a session on socio-economic implications of climate change to remind us that people are a part of the marine ecosystems that we study. Eight sessions and five workshops will address the state of our knowledge on how climate change will impact the sub-polar seas and their diverse ecosystems. We will examine the connections within food webs from phytoplankton to zooplankton and fish, and we will learn about nutrient and carbon cycling, and much more. We look forward to the many excellent presentations that are planned, and encourage all participants to take advantage of this unique opportunity to exchange experiences and ideas with fellow marine ecologists from around the world. We would like to thank PICES, ICES, and the numerous people who have worked over the past three years to bring this symposium together. The symposium was made possible only through the hard work of the local and international organizers, professionals at the PICES Secretariat, your participation, and the generous financial support from our sponsors. Without those efforts and funds, it would have been impossible to convene a symposium of such broad scope. The hard work will continue after the symposium to assemble some of the best papers presented here in a special issue of the ICES *Journal of Marine Science*, as well as some other special volumes focused on a sub-set of the sessions.

Seattle is a cultural center of the Pacific Northwest; the Seattle Art Museum, the Olympic Sculpture Park, and the Seattle Science Center are all within easy walking distance of the venue. Downtown Seattle is well known for a multitude of interesting shopping opportunities, among which is the famous Pike Place Market, just a short walk up the hill from your hotel. As well, Seattle is the jumping off spot for visiting a number of spectacular national parks, such as Mt. Rainier National Park, the Olympic National Park with its spectacular temperate rain forests, and the North Cascades National Park. We hope that you will use the occasion of this Open Science Meeting as an opportunity to explore Seattle and the region with your family, friends, and colleagues, and hope that you will have a productive, stimulating, and enjoyable meeting, the memories of which will be warm and lasting.

George L. Hunt, Jr.
Symposium Convenor and Chair of the Local Organizing Committee

Michio J. Kishi and Olafur S. Astthorsson
Symposium Convenors

Organizers and Sponsors

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University of Tromsø, Norway

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PICES Secretariat

George L. Hunt, Jr.
University of Washington, USA

International Sponsors

ESSAS
Ecosystem Studies of Sub-Arctic Seas

GOOS
Global Ocean Observing System

IMBER
Integrated Marine Biogeochemical Ecosystem Research

ICES
International Council for the Exploration of the Sea

PICES
North Pacific Marine Science Organization

National Sponsors

ADFG
Alaska Department of Fish and Game

NOAA
Alaska Fisheries Science Center

Arctic Section of NOAA

NSF
National Science Foundation, Arctic Natural Sciences

NPFMC
North Pacific Fisheries Management Council

NPRB
North Pacific Research Board

SAFS
School of Aquatic and Fishery Sciences, U. Washington

Meeting Timetable

Sunday, May 22				
09:00 12:30	**Workshop 1**	**Workshop 2**	**Workshop 3**	**Workshop 4**
13:30 17:30				**Workshop 5**
Monday, May 23				
08:30 09:00	**OPENING SESSION**			
09:00 12:30	**Plenary**			
14:00 18:15	**Session 2 (Day 1)**	**Session 4 & 9**	**Session 5**	
Tuesday, May 24				
08:30 12:30	**Plenary**			
14:00 18:15	**Session 1 (Day 1)**	**Session 6**	**Session 8**	
Wednesday, May 25				
08:30 12:30	**Plenary**			
14:00 15:55	**Session 1 (Day 2)**	**Session 3**	**Session 7**	
16:05 18:00	**Session 2 (Day 2)**			
18:00 21:00	**Poster Session**			
Thursday, May 26				
	CLOSING SESSION			
08:30 12:00	**Overview and awards**			
13:30 15:00	**Plenary talks**			
15:00 15:30	**Concluding Remarks**			

List of Sessions and Workshops

S1	Comparative studies of polar and sub-polar ecosystems
S2	New observations and understanding of eastern and western Bering Sea ecosystems
S3	Modeling marine ecosystem dynamics in high latitude regions
S4/S9	Nutrients, biogeochemistry and acidification in a changing climate
S5	New insights from the International Polar Year (IPY) studies
S6	National ESSAS programs: Recent advances and contribution
S7	Anticipating socio-economic and policy consequences of global changes in sub-polar and polar marine ecosystems
S8	Interactions between gadoids and crustaceans: The roles of climate, predation, and fisheries
W1	Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas
W2	Arctic-Sub-Arctic interactions
W3	Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects
W4	Comparative analyses of gadid and crustacean dynamics across subarctic ecosystems
W5	Comparative analyses of marine bird and mammal responses to climate change

Notes for Guidance

Presentations

In order to allow the sessions to run smoothly, and in fairness to other speakers, all presentations are expected to adhere strictly to the time allocated. All authors should designate at least 3 minutes for questions.

Authors can download their presentations straight to the computers where the session/workshop will be held.

Important: Please rename your files: time-name.ppt (*e.g.* 0900-Smith.ppt, 1530-Kim.ppt).

If complications occur due to incompatibilities between PCs and Macs, Macintosh owners may use their own computers to make presentations.

Posters

Posters will be on display from 12:00 on May 23. An evening poster session (with appetizers and drinks) will be held from 18:00-21:00 on May 25, when poster presenters are expected to be available to answer questions. Posters must be removed at the end of the poster session at 21:00 of May 25.

Internet access

Free Internet access via wireless LAN will be available at the Marriott Waterfront Hotel lobby.

Social activities (for all participants and registered guests)

The ***Welcome Reception*** will be held on May 23, 2011, at the Seattle Aquarium. The reception will run from 6:30 PM to 10:30 PM and will include appetizers, two drink tickets and a cash bar for those who are thirsty. The Aquarium is located on Pier 59, 1483 Alaskan Way in Seattle, a short walk from the meeting venue at the Marriott Waterfront Hotel. Registered Guests of OSM participants are also welcome. Children older than 12 are welcome as Registered Guests; children 12 and under may attend without charge and do not need to be registered.

There will be a ***Poster Reception*** on the evening of Wednesday, May 25, at the OSM venue in the Marriott Waterfront Hotel from 6:00 PM to 9:00 PM. Appetizers will be served and two drink tickets will be issued to each registered participant and registered guest. A cash bar will be available throughout the reception. It is requested that poster authors be at their posters for at least one hour during the reception to answer questions. It would be appreciated if authors would post the times that they will be at their posters to facilitate planning of visits to posters by attendees.

Instructions for those planning to submit a paper for consideration for the special volume of the ICES Journal of Marine Science

In addition to the several specialized volumes that will build on individual sessions (*e.g.* gadids and crustaceans, the modeling volume, the Bering Sea volume), there will be a volume of the ICES Journal of Marine Science dedicated to the overall symposium. The instructions below refer to submissions to that volume.

Manuscripts for the special symposium issue of the ICES Journal of Marine Science need to be submitted online through the IJMS ScholarOne Manuscripts website (http://mc.manuscriptcentral.com/icesjms) or by clicking "Submit electronically" at the Oxford Journals website (http://icesjms.oxfordjournals.org). The deadline for receipt of manuscripts is 1 September 2011 (which is based strictly on the publication schedule of the Journal), but a few extra days may be allowed to very few authors if they negotiate in advance a receipt date with the guest editors (George Hunt, geohunt2@u.washington.edu or Ken Drinkwater, ken.drinkwater@imr.no).

Read the Instructions to Authors and follow the Online Submission Instructions, noting particularly the need to classify the manuscript as a symposium paper (select Climate effects on Polar/Subpolar systems from the drop-down menu); then press Submit Now! Questions on technical issues related to submission may be directed to Margaret Searle (icesjms.editorialoffice@oup.com). Please note, however, that the symposium has been granted a finite page budget of 300 pp, so to accommodate as many papers as possible, authors are asked to limit their manuscript size to the following maxima (note, these are higher limits and not targets): abstract, 200 words; core text (from Introduction to Acknowledgements), 5500 words; core references, 50; tables and artwork together, 8 of modest size, fewer if they are large. Motivation to exceed these limits may be provided, but will need to be very strong to succeed.

Appendices in the Journal are supplanted by Supplementary material as the preferred means of publishing material not suitable for the core text. During the online submission process, you will be asked to supply the following information.

(1) In a cover letter, you must provide a written justification as to why you believe the content of the paper is relevant to the special symposium issue of the Journal, highlighting the paper's research significance and particularly its innovative message, along with its primary scientific contribution.

(2) Include names and current contact addresses (including e-mail addresses) of three appropriate referees who have not been associated with the research being published, or closely affiliated with any of the authors in the past five years.

(3) Confirm that the material is original, is not submitted elsewhere, and has the full written approval of all co-authors to submit.

(4) Confirm that the author has adhered to general guidelines for the ethical use of animals in research, the legal requirements of the country in which the work was carried out, and any institutional guidelines (if national certificates are available, append those). If ethical considerations arose in the course of the study, the author should describe in the manuscript how those considerations were addressed. In exceptional cases, where unresolved ethical questions remain, the manuscript may be sent to appropriate experts in the ethical use of animals in research for additional refereeing. In such cases, the decision as to whether the manuscript is accepted for publication remains with the guest editor or, in the final instance, the Journal's Editor-in-Chief.

Failure to adhere to these four requirements and the size criteria in the first paragraph will result in the rejection of your submission, without assignment to associate guest editor or review. Remember that it will be competitive (based on available publishing space as much as on quality) to get your manuscript accepted in the issue, so adherence to guidelines will have to be the first criterion for selection.

Ideally, text and figures should be in separate files, and manuscript texts should be submitted preferably in MS Word format; other formats may be accepted on prior agreement, but do not send manuscript texts in PDF format.

Schedules
Oral Presentations

May 22 - W1

Workshop 1 (W1)

Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas

Co-Convenors:
Anne Hollowed (USA)
Harold Loeng (Norway)

Invited Speakers:
Trond Kristiansen (Norway)
Hyunju Seo (Korea)

This workshop will review life history information and habitat associations to assess the risk of immigration and settlement of new biological populations in the Arctic and surrounding shelf seas in response to the retreat of sea ice. Criteria necessary to establish new species in the Arctic Ocean and surrounding areas will be developed and compared to expected conditions based on climate scenarios. Ways for cooperation in information sharing between groups charged with managing the Arctic will be explored and the results of the workshop will be reported to both PICES and ICES scientists working on these issues.

9:00	***Introduction by Convenors***
9:10	**Trond Kristiansen (Invited)** Analyzing warm and cold climate phases to understand differences in survival of larval fish: Possible implications of climate variability (W1-7552)
9:30	**Hyunju Seo, Hideaki Kudo and Masahide Kaeriyama (Invited)** The effect of global warming and density-dependence on Hokkaido chum salmon from the 1940s to the early-2000s (W1-7502)
9:50	**Nicholas A. Bond, Paul D. Spencer and Anne B. Hollowed** Impacts of climate change on the habitat of Bering Sea arrowtooth flounder (W1-7493)
10:05	**Anne B. Hollowed, Steven Barbeaux, Edward Farley, Edward D. Cokelet, Stan Kotwicki, Patrick Ressler, Cliff Spital and Christopher Wilson** Forecasting climate change impacts on forage fish distributions in the Bering Sea (W1-7500)
10:20	***Coffee/Tea Break***
10:40	**Michael Klages, Eduard Bauerfeind, Antje Boetius, Melanie Bergmann, Christiane Hasemann, Eva-Maria Nöthig, Ingo Schewe and Thomas Soltwedel** Rapid shifts of the marine ecosystem at HAUSGARTEN deep-sea observatory (Fram Strait; 79°N, 04°E) observed over the past decade (W1-7513)
10:55	**Daria Martynova and Nikolay Usov** A life with and without ice in the White Sea: Who will stay tuned? (W1-7401)
11:10	**Group Discussion** Review information on the life history and habitat associations to assess the risk of immigration and settlement of new biological populations in the Arctic and surrounding shelf seas in response to the retreat of sea ice. Establish the habitat requirements necessary for viable range extensions of major fish stocks. Develop criteria necessary to establish residency of new species in the Arctic Ocean and surrounding shelf seas.
12:30	***Lunch***

14:00	**Discussion** Consider climate scenarios for arctic and surrounding shelf seas to evaluate the likelihood of range extensions of selected fish stocks using the criteria.
15:00	***Coffee/Tea Break***
15:20	**Discussion** Continue
16:40	**Discussion** Review and report on ongoing relevant activities in the area and suggest ways for cooperation
17:00	Summary and recommendations
17:30	Workshop ends

May 22 - W2

Workshop 2 (W2)

Arctic-Sub-Arctic interactions

Convenors:
Kenneth F. Drinkwater (Norway)
Thomas Haine (USA)

This workshop will build on the work of the Arctic-Subarctic Ocean Fluxes (ASOF) community that has focused on quantifying the fluxes around the Arctic and the successful IPY session on *Arctic-Subarctic connections: Ecosystems and biodiversity* at the Oslo IPY Conference in June of 2010. It will bring together several disperse groups that are studying these fluxes and their biophysical effects, including: ESSAS that has concentrated on the Subarctic and the effects on the marine biota, especially fish; those working on the benthic-pelagic coupling and the biogeochemistry in the Barents and the Greenland shelves; those looking at the interaction between the Chukchi Sea and the western Bering Sea; scientists who during the IPY studied the effects of the Bering Sea on the Western Arctic; and other interested scientists. The object is to identify the gaps in our knowledge and to highlight what research can be carried out over the next few years to fill some of these gaps in our understanding of the effects of the interactions between the Arctic and Sub-Arctic and to coordinate the research on these issues. Areas of interest include physical, biogeochemical, and food web studies.

9:00	***Introduction by Convenors***
9:15	**T. Haine** ASOF Views on Interactions
9:35	**E. Carmack** Views on Arctic-Subarctic Interactions
9:55	**Charles H. Greene, Bruce C. Monger, Louise P. McGarry, Matthew D. Connelly, Neesha R. Schnepf, Andrew J. Pershing, Igor M. Belkin, Paula S. Fratantoni, David G. Mountain, Robert S. Pickart, Andrey Proshutinsky, Rubao Ji, James J. Bisagni, Changsheng Chen, Sirpa M.A. Hakkinen, Dale B. Haidvogel, Jia Wang, Charles Hannah, Erica Head, Peter Smith, P. Chris Reid and Alessandra Conversi** Remote climate forcing of regime shifts in northwest Atlantic shelf ecosystems (W2-7372)
10:15	***Coffee/Tea Break***
10:35	**K. Drinkwater / J. Grebmeir** Discussion: What are the important issues?
12:30	***Lunch***
14:00	**R. Woodgate** Fluxes through the Bering Strait
14:20	**J. Grebmeier** Biological effects of exchange in Bering Strait
14:40	**Peter Rhines, Eleanor Frajka-Williams and Hjálmar Hátun** Dynamics of upper ocean low-salinity waters in controlling winter convection, water-mass transformation and spring blooms (W2-7481)
15:00	**M. Reigstad** The role of Arctic Outflow on the East Greenland Shelves

15:20	**M. St. John** The BASIN Project
15:40	***Coffee/Tea Break***
16:00	**P. Rhines /M. Reigstad** Discussion: How to address the important questions
16:30	**K. Drinkwater /T. Haine** Summary of workshop and follow-up work
17:30	Workshop ends

May 22 - W3

Workshop 3 (W3)

Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects

Co-Convenors:
Erica Head (Canada)
Andrew Leising (USA)
William Peterson (USA)
Jaimie Pierson (USA)

This workshop will bring together researchers interested in understanding how climate and life history patterns of zooplankton interact to produce the observed distributions and abundances of key species found throughout the boreal Sub-Arctic and Arctic seas. The Workshop will build on work funded through the GLOBEC Pan-Regional Synthesis project, which is exploring how species pairs of copepods in the genus *Calanus* co-exist in the Atlantic and Pacific basins. That work is a combination of modeling efforts and data analysis, and combines both abundance and distribution data with vital rate data on reproduction, feeding, and development. This workshop will facilitate expansion of that work beyond a single genus. We seek enhanced collaboration within the community to further the understanding of how zooplankton life histories are affected by climate change. Of special interest will be the influence of ice cover and the prediction of the effects of reduced ice cover under global warming. Participation of researchers studying climate affects on zooplankton prey and predators is also encouraged.

9:00	***Introduction by Convenors***
9:20	**Andrew Leising and James Pierson** Is *Calanus pacificus* just a warmer-adapted *Calanus finmarchicus*? (W3-7397)
9:40	**William T. Peterson, Cheryl Morgan and Jay Peterson** *Calanus marshallae*: Life history, seasonal cycle of abundance and egg production rates in the shelf waters off Newport, Oregon (W3-7515)
10:00	**C. Tracy Shaw, Leah R. Feinberg and William T. Peterson** Life histories of the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* in the upwelling region off Newport, OR, USA (W3-7400)
10:20	***Coffee/Tea Break***
10:40	**James Pierson, Jeffrey Runge, Erica Head, Stéphane Plourde, Catherine Johnson, Andrew Leising, Frédéric Maps, David Kimmel and Andrew J. Pershing** Predicting copepod dormancy timing in response to climate change (W3-7398)
11:00	**Discussion**
12:30	***Lunch***
14:00	**Stéphane Plourde, Jeffrey Runge, James Pierson, Erica Head, Pierre Pepin, Catherine Johnson, Astthor Gislason, Xabier Irigoien, David Kimmel, Andrew Leising, Andrew J. Pershing, Frédéric Maps and Webjørn Melle** ***Presenter: James Pierson on behalf of Stéphane Plourde*** A pan-regional comparison of the seasonal climatology in mortality and population dynamics of *Calanus finmarchicus* across the North Atlantic (W3-7443)

14:20 **Erica Head, Wendy Gentleman, Leslie Harris and Marc Ringuette**
Reality and the estimation of mortality for copepod eggs (W3-7399)

14:40 **Nicholas R. Record, Andrew J. Pershing and Frédéric Maps**
Modeling copepod biodiversity using evolutionary computing (W3-7492)

15:00 **Atsushi Tsuda, Shinji Shimode and Kazutaka Takahashi**
Neocalanus vs. Calanus oceans. Comparative study on the life histories of *Neocalanus* and *Calanus* copepods, and their global distribution (W3-7468)

15:20 ***Coffee/Tea Break***

15:40 **Discussion**

16:00 Breakout Groups

17:00 Group reports

18:00 Workshop ends

May 22 - W4

Workshop 4 (W4)

Comparative analyses of gadid and crustacean dynamics across subarctic ecosystems

Co-Convenors:
Earl Dawe (Canada)
Franz J. Mueter (USA)

This half-day workshop aims to summarize and synthesize the main findings to date of comparative analyses regarding the effects of climate and predator-prey interactions on gadid and crustacean stocks across subarctic ecosystems. The focus will be on studies conducted under the auspices of ESSAS Working Group 4, but the workshop is open to anyone conducting comparative analyses on fish and crustacean stocks in subarctic seas. As a secondary goal, we will discuss future directions for comparative studies of fish and crustacean resources across subarctic systems and the future of Working Group 4.

9:00	***Introduction by Convenors***
9:10	**Stephanie Boudreau** The role of large benthic decapods in marine ecosystems
9:30	**Franz Mueter / Earl Dawe** Gadid-crustacean interactions in subarctic marine ecosystems: What have we learned?
9:50	Discussion of main findings from working group to date
10:20	Brief overview of papers planned for special MEPS volume
10:40	***Coffee/Tea Break***
11:00	Break-out groups to discuss and coordinate collaborative contributions
12:00	Future directions and future of Working Group 4
12:30	Workshop ends

May 22 - W5

Workshop 5 (W5)

Comparative analyses of Marine bird and mammal responses to climate change

Co-Convenors:
Rolf Ream (USA)
William J. Sydeman (USA)
Yutaka Watanuki (Japan)

This workshop will focus on how to best integrate ongoing and new research on marine birds and mammals into long-term PICES and ESSAS programs and objectives; the overarching goal is to produce a strategic vision and plan for activities of the PICES MBMAP over the next 5 years. Specific workshop objectives include (1) producing an outline of potential new goals reflecting climate change impacts on marine birds and mammals in the northern hemisphere, (2) design and implementation of sub-groups to work on specific areas of interest including (i) models of climate impact (e.g., NEMURO.BIRD), (ii) conservation of threatened and endangered species, and (iii) communication, and (3) initial writing of strategic plan documents. The workshop will include some oral presentations, but the emphasis will be on discussions leading to planning documents.

13:30	***Introduction by Convenors***
13:40	**Martin Renner, John F. Piatt, Kathy Kuletz and George L. Hunt, Jr.** Changes in the distribution of hotspots of pelagic seabird species diversity and abundance in the Bering Sea and North Pacific over four decades (W5-7550)
14:10	**William Sydeman** Presentation on ecological indicators
14:40	Discussion on presentations
15:10	***Coffee/Tea Break***
15:30	**Discussion** Future of the PICES Advisory Panel on Marine Birds and Mammals
16:30	Workshop ends

May 23 - Opening Plenary

Opening Day Plenary Session

8:30	**George L. Hunt, Jr.** Welcome and opening remarks
8:40	**Danielle Merculief, Steven Isaac, Caitlin Bourdukofsky, Anthony Lekanof, Cara Mandregan, Joshua Prokopiof, Ashley Merculief, Carmen Philemonof, Brandi Merculief, Michael Dirks, Dallas Roberts, David Merculief, Chelsea Lekanof, Andronika Emanoff, Barbara Chapman, William Lekanof and Mich Ridgway** Aleut ecological studies in Pribilof Domain – Maritime heritage and recent work presented by student researchers from the Pribilof Islands, "The Galapagos of the North"
9:00	**Eddy C. Carmack (Invited)** Climate connectivities: Roles of the Arctic and subarctic oceans in global change (S5-7467)
9:30	**Anthony Gaston, Jennifer Provencher, Paul Smith, Kyle Elliott, Mark Mallory and Grant Gilchrist (Invited)** Seabirds and changing ice conditions in the Canadian Arctic (S5-7487)
10:00	**Michiyo Yamamoto-Kawai, Fiona A. McLaughlin and Eddy C. Carmack (Invited)** Effects of ocean acidification, warming and melting of sea ice on aragonite saturation of Canada Basin surface water (S4-7411)
10:30	***Coffee/Tea Break***
11:00	**Lou A. Codispoti (Invited)** Nutrient and productivity variations in Arctic and sub-Arctic seas (S4-7352)
11:30	**Gennady V. Khen and Eugeny O. Basyuk (Invited)** Hydrography and biological resources in the western Bering Sea (S2-7346)
12:00	**Phyllis Stabeno, Sue E. Moore, Calvin Mordy, Jeffrey M. Napp and Michael Sigler (Invited)** A comparison of the physics, chemistry, and biology of warm and cold years on the eastern Bering Sea shelf (S2-7546)
12:30	Session ends

May 23 - S2 (day 1)

Session 2 (S2)

New observations and understanding of eastern and western Bering Sea ecosystems

Co-Convenors:
Rodger Harvey (USA)
Oleg N. Katugin (Russia)
Sang Heon Lee (Korea)
Mike Sigler (USA)

Invited Speakers:
Gennady Khen (Russia) - presents on May 23, Plenary Session
Franz J. Mueter (USA)
Phyllis Stabeno (USA) - presents on May 23, Plenary Session

This session is meant to showcase the recent major efforts in the Bering Sea Ecosystem Study (BEST) and the Bering Sea Integrated Ecosystem Research Program (BSIERP), as well as the compendium of new information provided in the most recent PICES North Pacific Ecosystem Status Report and studies that have been carried out in the Bering Sea by Russia, Korea, Japan and China. These papers will provide an opportunity to gain an overall perspective of the relative importance of various forcing mechanisms in driving marine ecosystem dynamics.

14:00 ***Introduction by Convenors***

14:05 **Franz J. Mueter, Mikhail A. Stepanenko, Anatoly V. Smirnov and Orio Yamamura (Invited)**
Comparing walleye pollock dynamics across the Bering Sea and adjacent areas (S2-7532)

14:35 **Jessica Cross and Jeremy Mathis**
Controls on in carbonate mineral saturation states and ocean acidification on the southeastern Bering Sea shelf (S2-7366)

14:55 **Rolf Gradinger, Katrin Iken and Bodil A. Bluhm**
Sedimentation processes under the seasonal sea ice of the Bering Sea (S2-7456)

15:15 **Raymond Sambrotto, Jinlun Zhang, Didier Burdloff, Ana Maria Aguilar-Islas and Kali McKee**
Sea-ice dispersal and source influence productivity patterns in the northern Bering Sea (S2-7458)

15:35 **David H. Shull, Allan H. Devol and Margaret S. Esch**
Bioturbation and organic carbon mineralization pathways in Bering Shelf sediments (S2-7482)

15:55 ***Coffee/Tea Break***

16:25 **Jeffrey M. Napp, Lisa Eisner, Edward Farley, Kathy Mier, Alexei Pinchuk and Phyllis Stabeno**
North-south variation in eastern Bering Sea shelf spring and late summer zooplankton assemblages (S2-7522)

16:45 **Evelyn J. Lessard, Megan Schatz, C. Tracy Shaw and Michael Foy**
Seasonal and interannual patterns in euphausiid diets and feeding rates in the eastern Bering Sea: Three years of BEST observations (S2-7384)

17:05 **Sandra Parker-Stetter, John K. Horne, Edward Farley and Lisa Eisner**
Evaluating linkages between forage fish distributions and physical oceanography in the eastern Bering Sea (S2-7459)

17:25 **Kanako Toge, Rei Yamashita, Kentaro Kazama, Masaaki Fukuwaka, Orio Yamamura and Yutaka Watanuki**
Biennial change of the pink salmon biomass and its effects on the body condition of two species of seabirds in the central Bering Sea (S2-7386)

17:45 **Duane E. Stevenson and Robert R. Lauth**
Latitudinal trends and temporal shifts in the seafloor ecosystem of the eastern Bering Sea shelf and southeastern Chukchi Sea (S2-7450)

18:05 Discussion

18:15 Session ends

May 23 - S4 & S9

Session 4 and Session 9 merged (S4 & S9)

Nutrients, biogeochemistry and acidification in a changing climate

S4 Co-Convenors:
Knut Yngve Børsheim (Norway)
Al Devol (USA)
Michiyo Yamamoto-Kawai (Japan)
Humio Mitsudera (Japan)
Jean-Eric Tremblay (Canada)

S9 Co-Convenors:
Kenneth Denman (Canada)
Christoph Heinze (Norway)
Yukihira Nojiri (Japan)
Jim Overland (USA)
Hans Pörtner (Germany)

S4 Invited Speakers:
Lou Codispoti (USA) - presents on May 23, Plenary Session
Eva Falck (Norway)
Shigeto Nishino (Japan) - presents on May 25, Plenary Session

S9 Invited Speakers:
Jim Christian (Canada) - presents on May 24, Plenary Session
Mishiyo Yamamoto-Kawai (Japan) - presents on May 23, Plenary Session

This session will focus on the sources of macro- and micro-nutrients in the sub-Arctic seas. How does the importance of the various pathways to primary production vary with season, and how do they affect the fate of the production? How do these differ between the Atlantic and Pacific oceans? How are these processes influenced by the presence of sea ice? Additionally, this session will include papers that discuss the responses of high latitude regions to either future climate or increasing acidification, or their combined response. Of particular interest are physical, chemical or biological thresholds or tipping points that will lead to large-scale changes in an ecosystem.

14:00 ***Introduction by Convenors***

14:05 **Eva Falck, Frede Thingstad, Paul Wassmann and Knut Yngve Børsheim (Invited)**
Presenter: Knut Yngve Børsheim on behalf of Eva Falk
Tracing Pacific water entering the Polar Ocean through the Bering Strait using N/P ratio signatures (S4-7412)

14:35 **Humio Mitsudera, Keisuke Uchimoto and Tomohiro Nakamura**
Cold water belt formation off the Soya Warm Current along the northeastern coast of Hokkaido (S4-7410)

14:55 **Tore Johannessen**
The advantage of being eaten: Do zooplankton stimulate growth of their preferred algal prey? (S4-7488)

15:15 **Zhongyong Gao, Liqi Chen and Heng Sun**
Developments of Arctic carbon sink from 1999 to 2010 (S4-7416)

15:35 **Julie Granger, Maria Prokopenko, Daniel Sigman and Calvin Mordy**
The predominance of benthic processes for N cycling on the eastern Bering Sea shelf as evidenced by the N and O isotope ratios of water-column nitrate (S4-7444)

15:55 ***Coffee/Tea Break***

16:25 **Keisuke Uchimoto, Tomohiro Nakamura, Jun Nishioka, Humio Mitsudera, Kazuhiro Misumi and Daisuke Tsumune**
Toward a simulation of iron circulation from the Okhotsk Sea to the Pacific (S4-7423)

16:45 **Kenshi Kuma, Yuta Nakayama, Satoshi Fujita and Koji Shimada**
Iron and humic-type fluorescent dissolved organic matter in the western Arctic Ocean (S4-7462)

17:05 **Margaret S. Esch, David H. Shull, Allan H. Devol and Bradley Moran**
Iron and manganese oxide reduction in Bering Sea shelf sediments (S4-7514)

17:25 **John Crusius, Rob Campbell and Andrew Schroth**
Abundant, seasonally variable supply of glacier flour-derived iron drives high nitrate consumption in Copper River plume and adjacent Gulf of Alaska continental shelf (S4-7540)

17:45 Discussion

18:15 Session ends

May 23 - S5

Session 5 (S5)

New insights from the International Polar Year (IPY) studies

Co-Convenors:
Kenneth F. Drinkwater (Norway)
William A. Montevecchi (Canada)
Sei-ichi Saitoh (Japan)
Jinping Zhao (China)

Invited Speakers:
Eddy C. Carmack (Canada) - presents on May 23, Plenary Session
Anthony Gaston (Canada) - presents on May 23, Plenary Session
Naomi Harada (Japan)

This session provides the opportunity to present new and exciting results from the IPY field studies conducted during 2007-2008. This includes physical, chemical and biological investigations in both the north and south polar regions. Contributions are sought from the ESSAS sponsored IPY consortium, Ecosystem Studies of Sub-arctic and Arctic Regions (ESSAR), as well as from other IPY programs.

14:00 ***Introduction by Convenors***

14:05 **Naomi Harada, Miyako Sato, Kazumasa Oguri, Kyoko Hagino, Yusuke Okazaki, Kota Katsuki, Yoshinori Tsuji, Kyung-Hoon Shin, Osamu Tadai, Sei-ichi Saitoh, Hisashi Narita, Susumu Konno, Richard W. Jordan and Yoshihiro Shiraiwa (Invited)**
Biomarker records of coccolithophorid *Emiliania huxleyi* bloom in the Bering Sea over the past decades (S5-7348)

14:35 **Tao Li, Jinping Zhao and David Baber**
Distribution of in-water solar radiation in Marginal Ice Zone in Beaufort Sea (S5-7360)

14:55 **Kjell Arne Mork, Kenneth F. Drinkwater, Steingrímur Jónsson and Héðinn Valdimarsson**
Current observations at the Jan Mayen Ridge (S5-7387)

15:15 **Héðinn Valdimarsson and Steingrímur Jónsson**
Hydrographic conditions and circulation in the Iceland Sea during the Iceland Sea ecosystem study (S5-7424)

15:35 **Toru Hirawake, Amane Fujiwara, Shintaro Takao, Katsuhito Shinmyo and Sei-ichi Saitoh**
Optically derived primary production and size structure of phytoplankton in the polar oceans (S5-7509)

15:55 ***Coffee/Tea Break***

16:25 **Astthor Gislason and Teresa Silva**
Abundance, composition and development of zooplankton in the subarctic Iceland Sea in 2006, 2007 and 2008 (S5-7429)

16:45 **Michael L. Carroll, William G. Ambrose Jr., William L. Locke V, Stuart K. Ryan and Gregory A. Henkes**
Reading between the lines: Bivalve growth rate variations across the Barents Sea Polar Front (S5-7426)

17:05 **Hiroko Sasaki, Keiko Sekiguchi and Sei-ichi Saitoh**
Cetacean habitat distribution in the eastern Bering Sea and Chukchi Sea (S5-7496)

17:25 **Joel P. Heath, Grant Gilchrist and Lucassie Arragutainaq**
Winter ecology of Common Eiders in polynya and floe edge habitats in eastern Hudson Bay, Nunavut (S5-7483)

17:45 **William A. Montevecchi, Gail Davoren, April Hedd, Laura McFarlane-Tranquilla, Anthony Gaston, Chantelle Burke, Paul Regular, Grant Gilchrist, Greg Robertson, Paul Smith, Dave Fifield and Richard Phillips**
Seabirds respond to Arctic ecosystem change and identify risk (S5-7389)

18:05 Discussion

18:15 Session ends

May 24 - Plenary

Plenary Session

8:30 **James Christian (Invited)**
The boreal ocean in the enhanced greenhouse (S4-7541)

9:00 **J.M. (Lobo) Orensanz, Billy Ernst, Julian Burgos and David A. Armstrong (Invited)**
Fluctuations in recruitment of snow crab in the Eastern Bering Sea and the role of cod predation (S8-7526)

9:30 **Patrick Ouellet, Louise Savard, César Fuentes-Yaco, Peter Galbraith, Trevor Platt and Alain Fréchet (Invited)**
Oceanography and northern shrimp (*Pandalus borealis*, Krøyer 1838) recruitment variability in the Gulf of St. Lawrence and northwest Atlantic (S8-7344)

10:00 **Marit Reigstad, Paul Wassmann, Christian Wexels-Riser and Dag Slagstad (Invited)**
Pelagic-benthic coupling and important regulating mechanisms across the European Arctic and sub-Arctic regions (S1-7470)

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

11:00 **Jacqueline M. Grebmeier and Lee W. Cooper (Invited)**
The impact of changing sea ice and hydrographic conditions on biological communities in the northern Bering and Chukchi Seas (S1-7476)

11:30 **Orio Yamamura, Tetsuichiro Funamoto, Masayuki Chimura, Tomonori Azumaya, Tomonori Hamatsu, Osamu Shida, Yasunori Sakurai, Hiroshi Yoshinari, Koji Kooka and Hiroko Kuroda (Invited)**
Recruitment variability of Japan Pacific walleye pollock: A synthesis from DoCoFis Program (S6-7406)

12:00 **Sen Tok Kim (Invited)**
The Sea of Okhotsk: Some conceptions applying to climate-oceanography events and fish resources dynamics (S6-7343)

12:30 Session ends

May 24 - S1 (day 1)

Session 1 (S1)

Comparative studies of polar and sub-polar ecosystems

Co-Convenors:
Erica Head (Canada)
Kohei Mizobata (Japan)
Koji Shimada (Japan)
Hyung-Cheol Shin (Korea)
Nils Chr. Stenseth (Norway)
Paul Wassmann (Norway)

Invited Speakers:
Jackie Grebmeier (USA) - presents on May 24, Plenary Session
Suam Kim (Korea)
Marit Reigstad (Norway) - presents on May 24, Plenary Session

Comparative studies have been one of the leading aspects of the ESSAS program. In this session results from comparative studies of entire ecosystems or of significant ecosystem components (zooplankton, fish, seabirds) will be presented. All papers should compare aspects of two or more systems. These can be among different polar or sub-polar seas or between sub-polar seas and other types of ecosystems, e.g. temperate, tropical, etc. Methods papers, as well as results from comparative studies, will be considered. Papers are sought on the similarities and differences in ecosystem structure and function and the processes that lead to these differences.

14:00 ***Introduction by Convenors***

14:05 **Suam Kim, Chang-Ik Zhang, Sukyung Kang and Hyunju Seo (Invited)**
Comparison of ecological characteristics of fish communities and oceanographic features in coastal areas of the western and eastern North Pacific Ocean (S1-7408)

14:35 **Charles H. Greene, Bruce C. Monger, Louise P. McGarry, Matthew D. Connelly, Neesha R. Schnepf, Andrew J. Pershing, Igor M. Belkin, Paula S. Fratantoni, David G. Mountain, Robert S. Pickart, Andrey Proshutinsky, Rubao Ji, James J. Bisagni, Changsheng Chen, Sirpa M.A. Hakkinen, Dale B. Haidvogel, Jia Wang, Charles Hannah, Erica Head, Peter Smith, P. Chris Reid and Alessandra Conversi**
Remote climate forcing of regime shifts in Northwest Atlantic shelf ecosystems (S1-7475)

14:55 **Christian Möllmann, Lena Bergström, Thorsten Blenckner, Michele Casini, Juha Flinkman, Rabea Diekmann, Anna Gårdmark, Georgs Kornilovs, Martin Lindegren, Bärbel Müller-Karulis, Saskia Otto and Maris Plikshs**
Climate effects on Baltic Sea sub-ecosystems: A comparison using a meta-analytical approach (S1-7368)

15:15 **Makio C. Honda, Kazuhiko Matsumoto, Kosei Sasaoka, Tetsuichi Fujiki, Hajime Kawakami, Masahide Wakita, Minoru Kitamura, Shuichi Watanabe and Toshiro Saino**
Effect of climate change on marine ecosystems and material cycles: Time-series observations in the sub-arctic and sub-tropical gyres (S1-7355)

15:35 **Zhongyong Gao, Liqi Chenand Heng Sun**
Comparison of decadal changes in the carbon sink and potential responses to climate change in the western Arctic Ocean and the Southern Ocean (S1-7418)

15:55 ***Coffee/Tea Break***

16:25 **Andrei S. Krovnin, Boris Kotenev, Marat Bogdanov and Georgy Moury**
Comparison of decadal and interdecadal dynamics of mass pelagic fish stocks in the North Atlantic and North Pacific in relation to climate variations in the Northern Hemisphere (S1-7388)

16:45 **Jürgen Alheit, Kenneth F. Drinkwater, Thomas Pohlmann and Carola Wagner**
The impact of climate variability and change on the Barents Sea and the North Sea: A comparison (S1-7517)

17:05 **Sarah Gaichas, Jason S. Link, Thomas J. Miller, Tim Essington, Ian Perry, Alida Bundy, Jennifer Boldt, Kenneth F. Drinkwater and Erlend Moksness**
Using production models as tools to examine factors that influence productivity of marine systems: Contrasts across levels of aggregation, ecosystems and drivers (S1-7448)

17:25 **Eugene J. Murphy, Eileen E. Hofmann, Rachel D. Cavanagh, Tosca Ballerini, Andrea Pinones, Nadine M. Johnston and Simeon Hill**
Comparisons of Southern Ocean ecosystems (S1-7438)

17:45 **Jarrod A. Santora, William J. Sydeman, John C. Field and Christian S. Reiss**
Comparative spatial dynamics of krill and predators at mid and high latitudes: Implications for trophic transfer and conservation (S1-7361)

18:05 Discussion

18:15 Session ends

May 24 - S6

Session 6 (S6)

National ESSAS programs: Recent advances and contribution

Co-Convenors:
Olafur S. Astthorsson (Iceland)
Yasunori Sakurai (Japan)
Svein Sundby (Norway)
Kai Wieland (Denmark)

Invited Speakers:
Sen Tok Kim (Russia) - presents on May 24, Plenary Session
Orio Yamamura (Japan) - presents on May 24, Plenary Session

Several large national programs under ESSAS have been completed or are underway, including in Japan, the US, Iceland and Norway. In addition, several other countries are involved in ESSAS studies although having no formal nationally-funded project. This session provides the opportunity to present the results from all of the ESSAS programs. In particular, presentations that provide a synthesis of large or several smaller projects within a nation are especially encouraged.

14:00 ***Introduction by Convenors***

14:05 **Olafur K. Palsson, Astthor Gislason, Bjorn Gunnarsson, Hafsteinn Gudfinnsson, Hildur Petursdottir, Solveig Olafsdottir, Sveinn Sveinbjornsson, Konrad Thorisson and Héðinn Valdimarsson**
The ecosystem of the Iceland Sea 2006-2008: Main patterns in structure and function (S6-7436)

14:35 **Kenneth F. Drinkwater and the NESSAR Team**
Density-compensating fronts in the Norwegian and Barents Seas and their biological influence (S6-7362)

14:55 **Padmini Dalpadado, Randi Ingvaldsen, Leif Christian Stige and Bjarte Bogstad**
Climate effects on the Barents Sea ecosystem dynamics (S6-7351)

15:15 **Sünnje L. Basedow, Meng Zhou and Kurt S. Tande**
Comparison of spring bloom dynamics between the subpolar Norwegian Sea and the polar front in the Barents Sea (S6-7474)

15:35 **Jinping Zhao and Kenneth F. Drinkwater**
Interannual variability of the surface heat fluxes and potential air-sea coupling in the Nordic Seas and their links with the Arctic Oscillation (S6-7370)

15:55 ***Coffee/Tea Break***

16:25 **Olafur S. Astthorsson, Héðinn Valdimarsson and Asta Gudmundsdottir**
Climate related changes in abundance and distribution of mackerel (*Scomber scombrus*) in Icelandic waters (S6-7427)

16:45 **Thomas Juul-Pedersen and Søren Rysgaard**
Greenland Climate Research Centre - Studying climate change up close (S6-7377)

17:05 **Erica Head, Kumiko Azetsu-Scott, Glen Harrison, Ross Hendry, Bill Li, John Loder, Igor Yashayaev and Phil Yeats**
Changes in hydrography and ecosystem structure and function in shelf and deep water regions of the Labrador Sea (1990-2009) (S6-7433)

17:25 **George L. Hunt, Jr., Lisa Eisner, Kathy Kuletz, Bob Lauth, Elizabeth Logerwell, Martin Renner and Michael Sigler**
Fluxes, fishes and feathers: Relationships among the Bering, Chukchi and Beaufort Seas in a time of climate change (S6-7359)

17:45 **Konstantin Rogachev**
Hydrographic control of marine ecosystem in the shelf waters of the northern Sea of Okhotsk (S6-7341)

18:05 Discussion

18:15 Session ends

May 24 - S8

Session 8 (S8)

Interactions between gadoids and crustaceans: The roles of climate, predation, and fisheries

Co-Convenors:
AnneDorte Burmeister (Greenland)
Earl Dawe (Canada)
Franz J. Mueter (USA)
Olafur Palsson (Iceland)

Invited Speakers:
Patrick Ouellet (Canada) - presents on May 24, Plenary Session
José M. (Lobo) Orensanz (Argentina) - presents on May 24, Plenary Session

In this session we seek papers that document and investigate the processes that lead to shifts between demersal fish, especially gadoids such as cod and pollock, and crustaceans, such as shrimp and crabs. What role does gadoid predation play on the dynamics of shrimp and crabs? How does this compare to the influence of climate regimes or the effects of industrialized fishing? How does the spatial overlap between gadoids and crustaceans change seasonally and annually? Papers that address these questions either within a single ecosystem or compare different sub-Arctic regions are sought.

14:00 ***Introduction by Convenors***

14:05 **Gordon H. Kruse, Jie Zheng and William R. Bechtol**
Effects of climate and gadid predation on red king crab population dynamics in Alaska (S8-7345)

14:35 **Stephanie A. Boudreau and Boris Worm**
Exploring relationships between decapods, cod and temperature through time-series analysis: What we have learned in the northwest Atlantic (S8-7379)

14:55 **Laurinda Marcello, Franz J. Mueter, Olafur S. Astthorsson, Carsten Hvingel, Dave Orr, Patrick Ouellet and Louise Savard**
A comparison of northern shrimp population dynamics among multiple ecosystems: Influences of gadoid predation and temperature (S8-7403)

15:15 **Kai Wieland, Nikoline Ziemer, Kaj Sünksen and Helle Siegstad**
Environmental effects on recruitment of Northern shrimp (*Pandalus borealis*) in West Greenland waters: Impact of temperature and main predators (S8-7358)

15:35 **Ingibjörg G. Jónsdóttir and Höskuldur Björnsson**
Interaction between northern shrimp and cod in inshore and offshore areas around Iceland (S8-7432)

15:55 ***Coffee/Tea Break***

16:25 **Earl Dawe, Mariano Koen-Alonso, Don Stansbury, Darrell Mullowney and Denis Chabot**
Effects of predation on Canadian Atlantic crustacean resources: A comparison between the Newfoundland-Labrador Shelf and the Gulf of St. Lawrence (S8-7445)

16:45 **Matthew J.S. Windle, George A. Rose, Rodolphe Devillers and Marie-Josée Fortin**
Spatial-temporal variations in shifting ecosystems: A GWR analysis in the Northwest Atlantic (S8-7356)

17:05 **Dan Urban (Invited)**
Seasonal predation patterns of Pacific cod and walleye pollock in Marmot Bay, Alaska (S8-7480)

17:25 **AnnDorte Burmeister and Bernard Sainte-Marie**
Potential effects of climate change on size at terminal molt and fecundity in snow crab (*Chionoecetes opilio*) in West Greenland waters (S8-7479)

17:45 **Earl Dawe, Mikio Moriyasu, Darrell Mullowney, Elmer Wade and Flore Jacques**
Effect of bottom temperature on growth of snow crab: A comparison between the Newfoundland-Labrador Shelf and the southern Gulf of St. Lawrence (S8-7446)

18:05 Discussion

18:15 Session ends

May 25 - Plenary

Plenary Session

8:30 **Diane Lavoie, Joël Chassé and Michel Starr (Invited)**
Modelling the impacts of climate change and variability on productivity and health of high-latitude marine ecosystems: The Beaufort Sea and Gulf of St. Lawrence case studies (S3-7466)

9:00 **Dag Slagstad, Morten Alver and Ingrid Ellingsen (Invited)**
Changes in phytoplankton and zooplankton production in the Nordic Seas under a warmer climatic regime (S3-7521)

9:30 **Takeshi Okunishi (Invited)**
A modeling study of marine pelagic ecosystems in the western North Pacific (S3-7415)

10:00 **Shigeto Nishino, Takashi Kikuchi, Michiyo Yamamoto-Kawai, Yusuke Kawaguchi, Toru Hirawake and Motoyo Itoh (Invited)**
Changes in spreading of nutrient-rich shelf water into the Canada Basin due to sea ice melt (S4-7414)

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

11:00 **Mitsutaku Makino and Yasunori Sakurai (Invited)**
Climate effects on fisheries in the Shiretoko World Natural Heritage, Japan (S7-7354)

11:30 **James McGoodwin (Invited)**
Enhancing the resilience of small high-latitude fishing communities to climatic and marine-ecosystem change (S7-7381)

12:00 **Anthony Charles (Invited)**
Policy adaptation and dynamic governance of marine social-ecological systems: Coping with climate change and economic change (S7-7503)

12:30 Session ends

May 25 - S1 (day 2)

Session 1 (S1)

Comparative studies of polar and sub-polar ecosystems

Co-Convenors:
Erica Head (Canada)
Kohei Mizobata (Japan)
Koji Shimada (Japan)
Hyung-Cheol Shin (Korea)
Nils Chr. Stenseth (Norway)
Paul Wassmann (Norway)

Invited Speakers:
Jackie Grebmeier (USA) - presents on May 24, Plenary Session
Suam Kim (Korea)
Marit Reigstad (Norway) - presents on May 24, Plenary Session

Comparative studies have been one of the leading aspects of the ESSAS program. In this session results from comparative studies of entire ecosystems or of significant ecosystem components (zooplankton, fish, seabirds) will be presented. All papers should compare aspects of two or more systems. These can be among different polar or sub-polar seas or between sub-polar seas and other types of ecosystems, e.g. temperate, tropical, etc. Methods papers, as well as results from comparative studies, will be considered. Papers are sought on the similarities and differences in ecosystem structure and function and the processes that lead to these differences.

14:00	***Introduction by Convenors***
14:05	**Igor M. Belkin** Polar Fronts: Major ecosystem boundaries in the North Atlantic, North Pacific, and Southern Ocean (S1-7518)
14:25	**Atsushi Tsuda, Shinji Shimode and Kazutaka Takahashi** Comparative study of the life histories of *Eucalanidae* copepods in the subtropical and subarctic Pacific (S1-7469)
14:45	**Jaume Forcada, Eugene J. Murphy and Phillip N. Trathan** Multispecies data reveal how sub-Antarctic and Antarctic marine predators respond to variation and change in Southern Ocean ecosystems (S1-7491)
15:05	**William J. Sydeman, Sarah Ann Thompson, Jarrod A. Santora and Julie A. Thayer** A meta-analysis of seabird-climate relationships (S1-7498)
15:25	**Kristin L. Laidre and Mads Peter Heide-Jørgensen** Climate change and baleen whale trophic cascades in Greenland (S1-7516)
15:45	Discussion
15:55	Session ends

May 25 - S2 (day 2)

Session 2 (S2)

New observations and understanding of eastern and western Bering Sea ecosystems

Co-Convenors:
Rodger Harvey (USA)
Oleg N. Katugin (Russia)
Sang Heon Lee (Korea)
Mike Sigler (USA)

Invited Speakers:
Gennady Khen (Russia) - presents on May 23, Plenary Session
Franz J. Mueter (USA)
Phyllis Stabeno (USA) - presents on May 23, Plenary Session

This session is meant to showcase the recent major efforts in the Bering Sea Ecosystem Study (BEST) and the Bering Sea Integrated Ecosystem Research Program (BSIERP), as well as the compendium of new information provided in the most recent PICES North Pacific Ecosystem Status Report and studies that have been carried out in the Bering Sea by Russia, Korea, Japan and China. These papers will provide an opportunity to gain an overall perspective of the relative importance of various forcing mechanisms in driving marine ecosystem dynamics.

16:05	***Introduction by Convenors***
16:10	**Tracey I. Smart, Janet T. Duffy-Anderson and John K. Horne** Alternating climate states influence walleye pollock early life stages in the southeastern Bering Sea (S2-7365)
16:30	**Ron A. Heintz, Elizabeth C. Siddon and Edward Farley** Climate related changes in the nutritional condition of young-of-the-year pollock (*Theragra chalcogramma*) from the eastern Bering Sea (S2-7529)
16:50	**George Noongwook and Henry P. Huntington** Ecosystem influences on hunting success in Savoonga, Alaska (S2-7464)
17:10	**Rosana Paredes, Ann M.A. Harding, Daniel D. Roby, David B. Irons, Robert M. Suryan, Rachael A. Orben, Heather Renner, Alexander Kitaysky, Kelly Benoit-Bird and Scott Heppell** Links between at-sea foraging behavior and breeding performance of black-legged kittiwakes nesting at colonies in different Bering Sea domains (S2-7527)
17:30	**Peter Boveng, Josh London and Michael Cameron** Movements and dive behavior of ribbon and spotted seals: Evidence for resource partitioning in the Bering Sea (S2-7531)
17:50	Discussion
18:00	Session ends

May 25 - S3

Session 3 (S3)

Modeling marine ecosystem dynamics in high latitude regions

Co-Convenors:
Enrique Curchitser (USA)
Geir Huse (Norway)
Shin-ichi Ito (Japan)

Invited Speakers:
Diane Lavoie (Canada) - presents on May 25, Plenary Session
Takeshi Okunishi (Japan) - presents on May 25, Plenary Session
Dag Slagstad (Norway) - presents on May 25, Plenary Session

This session will highlight different approaches to modeling the impacts of climate variability on high latitude marine ecosystems and their ability to support sustainable ecosystem services. Papers on different types of models will be accepted including mass-balance (ECOPATH) models, size-based models, rule-of-thumb approaches, minimalist models, individual based models (IBMs) and end-to-end models. Special emphasis will be placed on models that examine trophic interactions as well as models that link biogeochemical processes with higher trophic level production. Papers on methods for estimating uncertainties in model predictions are also encouraged.

14:00 ***Introduction by Convenors***

14:05 **Seth Danielson, Enrique N. Curchitser, Kate Hedstrom and Tom Weingartner**
Evaluation of a numerical model and application of results to understanding modes of variability in the Bering Sea ice/ocean/ecosystem (S3-7497)

14:25 **Geir Huse, Webjørn Melle, Morten Skogen, Solfrid Hjøllo and Einar Svendsen**
A 3D super-individual model with emergent life history and behaviour for *Calanus finmarchicus* in the Norwegian Sea (S3-7363)

14:45 **Mary Beth Decker, Lorenzo Ciannelli, Robert R. Lauth, Richard D. Brodeur, Nicholas A. Bond, Carol Ladd, Jeffrey M. Napp, Atsushi Yamaguchi, Patrick H. Ressler, Kristin Cieciel and George L. Hunt, Jr.**
Insights into the eastern Bering Sea through a jellyfish lens: Recent trends and tests of predictive models (S3-7501)

15:05 **Trond Kristiansen, Charles Stock, Kenneth F. Drinkwater and Enrique N. Curchitser**
Effects of climate change on the survival of larval cod (S3-7422)

15:25 **Kate Hedstrom, Jerome Fiechter, Kenneth A. Rose, Enrique N. Curchitser, Miguel Bernal, Shin-ichi Ito, Salvador Lluch-Cota and Alan Haynie**
Development of a climate-to-fish-to-fishers model: Data structures and domain decomposition (S3-7547)

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

16:10 **Wolfgang Fennel and H. Radtke**
An Eulerian nutrient to fish model (S3-7396)

16:30 **Daniel Howell, Anatoly Filin, Bjarte Bogstad, Jan Erik Stiansen and Elena Eriksen**
Unquantifiable uncertainty in projecting stock response to climate change: Example from NEA cod (S3-7342)

16:50 **Frode B. Vikebø, Åse Husebø, Aril Slotte and Erling Kåre Stenevik**
Ocean variability and recruitment in Norwegian spring-spawning herring (S3-7507)

17:10 **Neil S. Banas**
Limits on predictability in a size-spectral plankton model: A strategy for ensemble forecasting of diverse ecosystems (S3-7523)

17:30 **Benjamin Planque and U. Lindstrøm**
A minimal Barents Sea ecosystem model from first principles (S3-7471)

17:50 Discussion

18:00 Session ends

May 25 - S7

Session 7 (S7)

Anticipating socio-economic and policy consequences of global changes in sub-polar and polar marine ecosystems

Co-Convenors:
Keith Criddle (USA)
David Fluharty (USA)
Mitsutaku Makino (Japan)
Ian Perry (Canada)

Invited Speakers:
Anthony Charles (Canada) - presents on May 25, Plenary Session
Mitsutaku Makino (Japan) - presents on May 25, Plenary Session
James McGoodwin (USA) - presents on May 25, Plenary Session

Polar and sub-polar marine systems are expected to be strongly impacted by anticipated climate change, and by anticipated economic development relating to fishing, tourism and, hydrocarbon exploration. Human socio-economic systems in these regions year-round or seasonally are finely tuned to their present environments, with few alternative livelihood opportunities, and are also expected to be severely affected by these changes. This session will explore the potential for anticipating socio-economic conditions in coupled polar and sub-polar marine social-ecological systems. It seeks to identify the key policy issues and what policies are needed as these regions experience climate-driven environmental changes and economic development, with the focus on marine-related issues. Policy needs will include requirements for monitoring and observing of the full coupled social-ecological systems. A comparative approach among the different communities and countries of these regions will enable separation of general from regional and local understanding and policy issues. Such an approach could include the roles of seasonal migrants into these regions for marine-related activities. The session specifically seeks papers that address anticipating marine socio-economic aspects of climate change and economic development, anticipated policy needs related to these issues, and the understanding and information needs (e.g. monitoring) required to forecast responses and to formulate policies. Comparative studies at a variety of spatial scales, as well as studies that examine interactions and feedback mechanisms between humans and the environment, are particularly welcome. Publication of a collection of these presentations in a relevant primary journal will be discussed.

14:00	***Introduction by Convenors***
14:05	**Dave Fluharty** Social and economic assessments of the future Arctic: Special cases local and distant (S7-7533)
14:25	**Alf Håkon Hoel** Fisheries management in the face of climate change: The case of the Arctic (S7-7534)
14:45	**Alan Haynie and Lisa Pfeiffer** Climate change and location choice in the Pacific cod longline fishery (S7-7485)
15:05	**Alan Haynie and Lisa Pfeiffer** Modeling the impacts of climate change on fleet behavior in the Bering Sea pollock fishery (S7-7461)
15:25	**Henry P. Huntington** Fisheries management in newly accessible seas (S7-7465)
15:45	***Coffee/Tea Break***

16:10 **James Strong and Keith R. Criddle**
Institutional structure and profit maximization in the Eastern Bering Sea fishery for Alaska pollock (S7-7535)

16:30 **Keith R. Criddle**
Cooperative and noncooperative strategies for management of Bering Sea pollock (S7-7380)

16:50 **Dave Fraser**
Rationalization, randomness and romance: A fisher's response to change in dynamic bio-physical, socio-political, and economic systems (S7-7504)

17:10 **Emilie Springer**
Exploring features of social-environmental history in eastern Prince William as a mode of anticipating human responses to future transitions within the Copper River and proximate marine ecosystem (S7-7511)

17:30 **Alida Bundy and Ian Perry**
Understanding the human dimensions of marine global change: The IMBER Working Group (S7-7449)

17:50 Discussion

18:00 Session ends

May 26 - Closing Plenary

Closing day Plenary Session

8:30	**Overview by Session / Workshop Leaders**
10:30	***Coffee/Tea Break***
11:00	**Music** Oded Ben-Horin (Norway)
11:30	Awards for best student papers and posters
12:00	***Lunch***
13:30	**Kevin R. Arrigo (Invited)** Impact of climate change on lower trophic levels in polar and sub-polar seas
14:00	**Steven A. Murawski (Invited)** Understanding ecosystem processes: A key to predicting climate effects
14:30	**Keith R. Criddle (Invited)** Adaptation and maladaptation to environmental change - Factors that influence the fragility or resilience of sub-Arctic fisheries and fishing dependent communities
15:00	Concluding Remarks

List of Poster Presentations

Poster Session: May 25, 18:00-21:00

Session 1 (S1) Posters

Comparative studies of polar and sub-polar ecosystems

S1-P1 **Maksim Ivanov and A.S. Astakhov**
Mercury distribution in air and bottom sediments of the Chukchi Sea

S1-P2 **Vladimir B. Darnitskiy and Maxim A. Ishchenko**
Topographical generated eddies in Antarctic and Subantarctic waters near Southern Ocean submarine ridges

S1-P6 **Eileen E. Hofmann, Michael S. Dinniman and John M. Klinck**
The influence of surface winds on Circumpolar Deep Water transport and ice shelf basal melt along the western Antarctic Peninsula

S1-P7 **Eugene J. Murphy, Rachel D. Cavanagh, Eileen E. Hofmann, Simeon Hill, Nadine M. Johnston, Phillip N. Trathan, Andrew Constable, Daniel P. Costa, Mathew Pinkerton, John M. Klinck, Dieter Wolf-Gladrow and Kendra L. Daly**
Developing integrated models of Southern Ocean food webs

S1-P8 **Eileen E. Hofmann, Sophie Beauvais and Lisa Maddison**
The IMBER Project

S1-P9 **Sarah Ann Thompson, William J. Sydeman, Elvira S. Poloczanska, Anthony J. Richardson and Christopher J. Brown**
Marine climate change ecology: A meta-database for assessing impacts

Session 2 (S2) Posters

New observations and understanding of eastern and western Bering Sea ecosystems

S2-P1 **Michael Sigler, Kathy Kuletz, Patrick Ressler, Nancy A. Friday, Christopher Wilson and Alex Zerbini**
Apex predators and hot spot persistence in the southeast Bering Sea

S2-P2 **Xuehua Cui, Jacqueline M. Grebmeier, Lee W. Cooper, James R. Lovvorn, Christopher A. North, William L. Seaver and Jason M. Kolts**
Spatial distribution of groundfish in the northern Bering Sea in relation to environmental variation and feeding habitat

S2-P3 **Jinlun Zhang, Rebecca Woodgate and Sarah Mangiameli**
Seasonal predictability of the properties of cold bottom waters on the Bering Sea shelf

S2-P4 **Chiko Tsukazaki, Ken-Ichiro Ishii, Rui Saito, Kohei Matsuno, Atsushi Yamaguchi and Ichiro Imai**
Distribution of diatom resting stages in bottom sediments of the eastern Bering Sea in the summer of 2009

S2-P5 **Rie Ohashi, Kohei Matsuno, Rui Saito, Atsushi Yamaguchi and Ichiro Imai**
Inter-annual changes in the zooplankton biomass during summers of 1994-2009 and zooplankton community structure in 2006 in the Bering Sea shelf

S2-P6 **Vladimir V. Kulik**
Correlation between mesopelagic fish abundance and PDO in the upper pelagic northwestern Pacific Ocean

S2-P7 **Jonaotaro Onodera, Takuya Yoshida and Kozo Takahashi**
Long-term monitoring of sinking diatom fluxes at Stations AB and SA in the Bering Sea and the central Subarctic Pacific, 1990-2006

S2-P8 **Takahiro Iida, Kohei Mizobata and Sei-ichi Saitoh**
Distribution and recent changes of coccolithophore (*Emiliania huxleyi*) blooms in the eastern Bering Sea shelf

S2-P9 **Stan Kotwicki and Robert R. Lauth**
Temperature and population density effects on the spatial distribution of groundfishes and crabs in the eastern Bering Sea shelf

S2-P10 **Beverly A. Agler and Greg Ruggerone**
Growth of Norton Sound and Kuskokwim River, Alaska chum salmon in relation to climatic factors and inter- and intra-specific competition

S2-P11 **Henry P. Huntington**
Local and traditional knowledge of the eastern Bering Sea ecosystem

S2-P12 **Elizabeth C. Siddon and Ron A. Heintz**
Conceptual model of energy allocation in walleye pollock (*Theragra chalcogramma*) from larvae to age-1

S2-P13 **Igor M. Belkin and S. Kalei Shotwell**
North Pacific Polar Front: Trans-ocean link/barrier/blender and its impact on the Gulf of Alaska, Aleutians, and Bering Sea ecosystems

S2-P14 **Kathy Kuletz, Martin Renner, Sandra Parker-Stetter, Patrick Ressler, Edward Farley, Robert M. Suryan and Elizabeth Labunski**
Seabirds and their prey during late summer and fall in the Bering Sea: Energetic bottleneck or cornucopia?

S2-P15 **Nancy A. Friday, Alexandre N. Zerbini, Janice M. Waite, Sue E. Moore and Phillip J. Clapham**
Cetacean distribution on the Eastern Bering Sea shelf in June and July of 2002, 2008, and 2010

S2-P16 **Lisa Eisner, Jeanette Gann and Kristin Cieciel**
Phytoplankton biomass and size structure during late summer/early fall in the eastern Being Sea

S2-P17 **Maria Prokopenko, Julie Granger, Matthew Long, Calvin Mordy, Peter DiFiore, Edward D. Cokelet, Nancy Kachel, Daniel Sigman and Bradley Moran**
Rates of net community and gross photosynthetic production on the Eastern Bering Sea shelf as estimated from O_2/Ar ratios and triple O isotopes under non-steady state conditions

S2-P18 **Olav A. Ormseth**
A nearshore survey of fishes and invertebrates in northern Bristol Bay, eastern Bering Sea, Alaska

S2-P19 **Robert G. Campbell, Carin Ashjian, Barry Sherr, Evelyn Sherr, Celia Gelfman, Philip Alatalo, Celia Ross and Donna VanKeuren**
Physiological ecology of *Calanus* in the Bering Sea during spring sea-ice conditions: Feeding, reproduction, and population genetics

S2-P20 **Orio Yamamura, Osamu Sakai, Masaaki Fukuwaka and Tomonori Azumaya**
Interactions among Pacific salmons *Oncorhynchus* spp. in the Bering Sea Basin: Evidence from diets and stable isotopes

S2-P21 **L. Michelle Ridgway, Nora R. Foster, David W. Scholland Peter Hickman**
Going off the deep end – Faunal diversity in Bering Sea marginal ice zone submarine canyons

S2-P22 **Thomas Wilderbuer and William Stockhausen**
Updated analysis of flatfish recruitment response to climate variability and ocean conditions in the Eastern Bering Sea

Session 3 (S3) Posters

Modeling marine ecosystem dynamics in high latitude regions

S3-P1 **Kjersti Eline Tønnessen Busch and Svein Sundby**
Why fish eggs are bigger towards high latitudes - Evolution within boundaries

S3-P2 **Shin-ichi Ito, Takeshi Okunishi, Michio J. Kishi and Muyin Wang**
Evaluation of uncertainty of Pacific saury (*Cololabis saira*) responses to future climate change

S3-P3 **Kerim Aydin, Ivonne Ortiz and Albert J. Hermann**
Forage-euphausiid abundance in space and time: Seasonal patterns

S3-P4 **Paul D. Spencer, Nicholas A. Bond and Anne B. Hollowed**
A simple model for estimating the rate of predation of arrowtooth flounder on walleye pollock on the Bering Sea shelf over the first half of the 21st Century

S3-P5 **Igor M. Belkin, Ayan Chaudhuri and Avijit Gangopadhyay**
Model realism and model validation: An oceanographer's view of the North Atlantic circulation through the eyes of the ROMS

S3-P6 **Albert J. Hermann, Georgina A. Gibson, Kerim Aydin, Nicholas A. Bond, Wei Cheng, Enrique N. Curchitser, Kate Hedstrom, Ivonne Ortiz, Muyin Wang, Phyllis Stabeno, Lisa Eisner and Markus Janout**
Modeled and observed modes of biophysical variability on the Bering Sea shelf

Session 4 and Session 9 merged (S4 & S9) Posters

Nutrients, biogeochemistry and acidification in a changing climate

S4-P1 **Colleen E. Harpold**
Interannual variability of *Neocalanus flemingeri* and *N. plumchrus* in Shelikof Strait, Alaska

S4-P2 **Towe Holmborn, Andreas Brutemark, Jonna Engström-Öst, Elena Gorokhova, Hedvig Hogfors and Anu Vehmaa**
Influence of elevated CO_2 concentrations on reproductive success and early nauplii development of the copepod *Acartia bifilosa* in the Baltic Sea

S4-P3 **Paul Loubere and Mathieu Richaud**
Organic carbon flux and seabed nutrient regeneration in fjord to abyssal settings of the sub-polar North Atlantic

S4-P4 **Bodil A. Bluhm, Katrin Iken, Boris I. Sirenko, Sarah M. Hardy, Brenda A. Holladay, Jared Weems and Kenneth Dunton**
Food web structure and epibenthic megafauna in the Chukchi Sea: A temporal comparison

S4-P5 **Allan H. Devol, David H. Shull, Heather Whitney and Calvin Mordy**
Denitrification in Bering Sea shelf sediments

Session 5 (S5) Posters

New insights from the International Polar Year (IPY) studies

S5-P1 **Kohei Matsuno, Atsushi Yamaguchi and Ichiro Imai**
Year-to-year changes of mesozooplankton biomass, community and size spectra in the Chukchi Sea during summers of 1991/92 and 2007/08

S5-P2 **Yinxin Zeng, Yang Zou, Jacqueline M. Grebmeier and Tianling Zheng**
Culture-independent and -dependent methods to investigate the diversity of planktonic bacteria in the northern Bering Sea

S5-P3 **Ling Lin, Jianfeng He, Fang Zhang, Minghong Cai, Jianfang Chen and Yunlong Zhao**
Environmental influences on the distribution of heterotrophic bacteria in the Bering Sea and Arctic Ocean during summer 2008

S5-P4 **Konrad Thorisson and Bjorn Gunnarsson**
Drift, age and origin of capelin larvae in Icelandic waters

S5-P6 **Steingrímur Jónsson and Héðinn Valdimarsson**
Circulation and hydrography over the Kolbeinsey Ridge

S5-P7 **Hildur Petursdottir and Astthor Gislason**
Trophic interactions of the pelagic ecosystem in the Iceland Sea as evaluated by fatty acid and stable isotopes analyses

S5-P8 **Astthor Gislason, Hildur Petursdottir and Teresa Silva**
Effect of the frontal area north of Iceland on small-scale plankton distribution

S5-P9 **Olafur K. Palsson, Sveinn Sveinbjornsson, Thorsteinn Sigurdsson and Héðinn Valdimarsson**
Capelin in the Iceland Sea: Long-term patterns in life history and physical processes

S5-P10 **Rachel D. Cavanagh, Eugene J. Murphy, Eileen E. Hofmann and Nadine M. Johnston**
Coordinating international research on Southern Ocean ecosystems: Implementation of the ICED programme

S5-P11 **Gail K. Davoren, Paulette Penton, Joseph Allen, Chantelle Burke and William A. Montevecchi**
Influence of the biology and behaviour of forage fish on top predators in northeastern Newfoundland

S5-P12 **Gennady V. Khen on behalf of Nikolay S. Vanin**
Opposite regimes of atmospheric circulation over the East Arctic and hydrological conditions of the west Chukchi Sea shelf in summer 2007 and 2003

Session 6 (S6) Posters

National ESSAS programs: Recent advances and contribution

S6-P1 **Kenneth F. Drinkwater**
Influence of climate variability and change on the ecosystems of the Barents Sea and adjacent waters: Review and synthesis of recent studies from the NESSAS project

S6-P2 **Benjamin Planque, E. Johannesen, K. Michalsen, R. Primicerio, M. Fossheim, Randi Ingvaldsen and M. Aschan**
Barents Sea Ecosystem Resilience under global environmental change

S6-P3 **HaeKyun Yoo, Jun Yamamoto and Yasunori Sakurai**
Laboratory studies on response to temperature change of Walleye Pollock larvae

Session 7 (S7) Poster

Anticipating socio-economic and policy consequences of global changes in sub-polar and polar marine ecosystems

S7-P2 **Danielle Merculief, Caitlin Bourdukofsky, Anthony Lekanof, Cara Mandregan, Joshua Prokopiof, Ashley Merculief, Carmen Philemonof, Brandi Merculief, Michael Dirks, Dallas Roberts, David Merculief, Chelsea Lekanof, Barbara Chapman, William Lekanof and L. Michelle Ridgway**

Pribilof Islands, Alaska community based King Crab Ecological and Economic Research Program

Session 8 (S8) Posters

Interactions between gadoids and crustaceans: The roles of climate, predation, and fisheries

S8-P1 **Laurinda Marcello, Franz J. Mueter, Earl Dawe and Mikio Moriyasu**
Effects of temperature and gadoid predation on snow crab recruitment: Comparisons between the Bering Sea and Atlantic Canada

S8-P2 **Orio Yamamura, Tetsuichiro Funamoto, Masayuki Chimura, Satoshi Honda and Tatsuki Oshima**
Decadal shift in the diets of walleye pollock in the Oyashio area

S8-P3 **Jonathan Richar and Gordon H. Kruse**
Recruitment mechanisms of eastern Bering Sea Tanner crab, *Chionoecetes bairdi*

Workshop 1 (W1) Poster

Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas

W1-P1 **H.K. Ha, Y.N. Kim, E.J. Yang and K.H. Chung**
Spatial variability of warm eddies in western boundary of Canada Basin: Biochemical implication

Workshop 2 (W2) Posters

Arctic-Sub-Arctic interactions

W2-P1 **Konstantin Rogachev**
Oceanography and large zooplankton within a bowhead whale feeding area in the Northwest Sea of Okhotsk

W2-P2 **Natalia Shlyk, Konstantin Rogachev and Pavel Saluk**
Magnitude and spatial variability of the phytoplankton bloom in the changing Sea of Okhotsk

Workshop 3 (W3) Poster

Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects

W3-P1 Cameron **Thompson** and Jeffrey Runge

Mortality estimation of the copepod *Calanus finmarchicus* in the Gulf of Maine using the VLT method and molting incubations to estimate development rates

Abstracts
Oral Presentations

W1 Oral Presentations

May 22, 9:10 (W1-7552)

Analyzing warm and cold climate phases to understand differences in survival of larval fish: Possible implications of climate variability

Trond **Kristiansen**

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Fisheries exploitation, habitat destruction, and climate are important drivers of variability in recruitment success. Understanding variability in recruitment can reveal mechanisms behind widespread declines in the abundance of key species in marine and terrestrial ecosystems. The timing, amplitude, and duration of spring blooms directly and indirectly affect the survival and recruitment of many marine species, particularly in temperate and boreal ecosystems. At higher latitudes, the onsets of spring blooms are largely determined by seasonal patterns of light, temperature, and nutrients in the water column. In years when the water column is colder than usual, the spring blooms generally occur later, while in years when the water is unusually warm, the spring blooms occur earlier.

Here, I discuss possible implications of cold and warm phases across the sub-arctic and how these phases may influence primary productivity and consequently the survival and recruitment of fish. I propose that a key factor for enhancing survival is the duration of the overlap between larval and prey abundance and not the actual timing of the peak abundance. During warm years, the duration of the overlap between larval fish and their prey is prolonged due to an early onset of the spring bloom. The elevated primary production observed during warm years is a result of earlier stratification, a prolonged growth season, and increased metabolic rates across functional groups and trophic levels. This prolonged season enhances cumulative growth and survival, leading to a greater number of large individuals with enhanced potential for survival to recruitment.

May 22, 9:30 (W1-7502)

The effect of global warming and density-dependence on Hokkaido chum salmon from the 1940s to the early-2000s

Hyunju **Seo**[1], Hideaki Kudo[2] and Masahide Kaeriyama[2]

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We used multiple regression and path analysis to examine the effects of regional and larger spatial scales of climatic/oceanic conditions on growth, survival, and population dynamics of chum salmon (*Oncorhynchus keta*). Variability in the growth of chum salmon at ages 1 to 4 was estimated from scale analysis and the back-calculation method using scales of 4-year-old adults returning to the Ishikari River in Hokkaido, Japan, 1943–2005. Growth at age-1 was less during the period from the 1940s to the mid-1970s compared to the period from the mid-1980s to the present. On the other hand, growth at ages 2 to 4 has declined since the 1980s. Path analysis indicated that the growth at age-1 in the Okhotsk Sea was directly impacted by warmer sea surface temperature (SST) associated with global warming. The increased growth at age-1 led directly to higher survival rates and indirectly to larger population sizes. Subsequently, in the Bering Sea, the larger population size was directly associated with decreased growth at age-3 and indirectly associated with shorter adult fork lengths despite the lack of relationships among SST, zooplankton biomass, and growth at ages. Therefore, the increased growth at age-1 relating to global warming positively, at least initially, affected the survival of juvenile salmon in the Okhotsk Sea during the period of critical mortality. The higher survival rates in turn appear to be causing a population density–dependent effect on growth at ages 2 to 4 and maturation due to limit of carrying capacity in the Bering Sea.

May 22, 9:50 (W1-7493)

Impacts of climate change on the habitat of Bering Sea arrowtooth flounder

Nicholas A. **Bond**, Paul D. Spencer and Anne B. Hollowed

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The population of arrowtooth flounder (*Atheresthes sp.)* in the Bering Sea has grown markedly over the past 20 years. Since this species is a major predator on the commercially-valuable stock of walleye pollock (*Theragra chalcogramma*), it is important to determine how its population is liable to evolve in association with climate change. Arrowtooth flounder tend to avoid the summer "cold pool", defined as water cooler than 2 deg. C in the middle shelf domain. The cold pool cannot be properly simulated by most IPCC-class global climate models due to their poor representation of the bathymetry of the shelf and vertical mixing. On the other hand, the historical record indicates that the area and southward extent of the cold pool corresponds closely with the maximum sea ice extent the winter before, and to a lesser extent, the sea level pressure in spring. These parameters can be projected, in principle, by global climate models. Projections of these variables, and an empirical relationship based on observations, are used to make estimates of future cold pool extents, and ultimately, potential arrowtooth flounder populations. This application represents an example for which a crucial environmental parameter cannot be forecast directly, but can be inferred using proxies.

May 22, 10:05 (W1-7500)

Forecasting climate change impacts on forage fish distributions in the Bering Sea

Anne B. **Hollowed**[1], Steven Barbeaux[1], Edward Farley[2], Edward D. Cokelet[3], Stan Kotwicki[1], Patrick Ressler[1], Cliff Spital and Christopher Wilson[1]

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This paper examines potential climate change impacts on the boundaries of suitable ocean habitat, and whether these changes will affect the spatial distribution and interactions between forage fishes in the Bering Sea. The study focuses on the summer distributions of forage fish age-0 and age-1 walleye pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*) that were collected during National Marine Fisheries Service acoustic trawl, surface trawl and bottom trawl surveys conducted in the Bering Sea between 2004 and 2009. We consider the current processes governing spatial distributions of forage fish and project how these processes will be influenced by climate change. Under current ocean conditions, forage fish exhibit evidence of resource partitioning. Interannual variability in the spatial extent of the cold pool is an important feature defining the ocean habitats used by forage fishes. Statistical analyses reveal that frontal boundaries partitioning these habitats and geostrophic flow features in the outer domain are important zones of aggregation for forage species. Global warming is likely to impact the strength of frontal boundaries and partitions of resources used by forage fishes. As stratification weakens in the middle domain and frontal boundaries between the inner and middle domain become more diffuse, it is likely that competitive interactions and predator prey interactions will increase, resulting in increased stress on forage fish in the Bering Sea.

May 22, 10:40 (W1-7513)

Rapid shifts of the marine ecosystem at HAUSGARTEN deep-sea observatory (Fram Strait; 79°N, 04°E) observed over the past decade

Michael **Klages**, Eduard Bauerfeind, Antje Boetius, Melanie Bergmann, Christiane Hasemann, Eva-Maria Nöthig, Ingo Schewe and Thomas Soltwedel

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Long time series of marine fauna and flora in the Arctic are rare. Here we report about the HAUSGARTEN long-term deep-sea observatory established in 1999 by the Alfred Wegener Institute for Polar and Marine Research (AWI) in the eastern Fram Strait. Multidisciplinary investigations covering all compartments of the deep-sea ecosystem including sea ice cover and the water column are carried out at 16 permanent stations located along a depth transect from the Vestnesa Ridge (~1200m) towards the Molloy Deep (~5500m), and along a latitudinal transect following the 2500m isobath between 78°30'N and 79°45'N. Since the start of the time series a sampling program in both water column and sediment, the deployment of moorings and dedicated free-falling systems (observation platforms) have been carried out. Towed photo and video systems allowed for studies of large-scale distribution patterns of macro- and megabenthic organisms. Particle collection traps deployed year round over the period from 2000 until today revealed shifts in species communities in the upper 300m of the water column that indicate a varying influence of Atlantic water masses during the period studied. Temperature measurements close to the seafloor at 2500m depth revealed a constant increase since the beginning of our studies. The decrease of sea-ice extent and thickness over the past decade is accompanied by decreasing food quality and microbial biomass over almost the entire depth transect. Various other observed effects on deep-sea communities will be presented.

May 22, 10:55 (W1-7401)

A life with and without ice in the White Sea: Who will stay tuned?

Daria **Martynova** and Nikolay Usov

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The White Sea (66°N), a semi-enclosed sea of the Russian sub-Arctic, is characterized by seasonal ice coverage and combines arctic, eurytherm and boreal copepod fauna. It appears to be one of the high-Arctic areas during both the hydrological winter (ice coverage season) and spring, but in summer the features of temperate seas are usual. These unique peculiarities and specific water exchange dynamics with the Arctic Ocean makes the White Sea to become an object for the studying the ecosystem end-to-end model. A multidisciplinary approach was applied, including the analysis of 50-year monitoring series (hydrology and zooplankton dynamics) and experiments on the species reproduction and physiology, with special emphasis on modelling different environmental scenarios. The population dynamics of the Arctic species are affected by macroclimatic fluctuations, which have local mediate impact. The reproduction success in the Arctic species is governed by the food sufficiency during the gonad maturation period. The phytoplankton and ice coverage dynamics may have significant effect on the Arctic copepod species, while the boreal ones depend on the food quality in autumn period and on the temperature conditions in early summer. The temperature has no effect in molting ratio comparing to the food insufficiency in boreal species. Ratio "arctic:boreal" species abundance decreases significantly during the period of monitoring (since 1964), *i.e.* the role of warm-water species rose up in this part of the White Sea as a result of considerable temperature increase in upper 25-m water layer in late spring (June), which means earlier beginning of summer.

W2 Oral Presentations

May 22, 9:55 (W2-7372)

Remote climate forcing of regime shifts in northwest Atlantic shelf ecosystems

Charles H. **Greene**[1], Bruce C. Monger[1], Louise P. McGarry[1], Matthew D. Connelly[1], Neesha R. Schnepf[1], Andrew J. Pershing[2], Igor M. Belkin[3], Paula S. Fratantoni[4], David G. Mountain[5], Robert S. Pickart[5], Andrey Proshutinsky[5], Rubao Ji[6], James J. Bisagni[7], Changsheng Chen[7], Sirpa M.A. Hakkinen[8], Dale B. Haidvogel[9], Jia Wang[10], Charles Hannah[11], Erica Head[11], Peter Smith[11], P. Chris Reid[12] and Alessandra Conversi[13]

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10 Great Lakes Environmental Research Laboratory, NOAA, Ann Arbor, MI, USA
11 Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS, B2Y 4A2, Canada
12 Sir Alister Hardy Foundation for Ocean Science, Plymouth, PL1 2PB, UK
13 Marine Sciences Institute, Italian National Research Council, La Spezia, IT 19032 and Marine Institute, University of Plymouth, Plymouth, PL4 8AA, UK

Regime shifts in Northwest Atlantic shelf ecosystems can be remotely forced by climate-associated atmosphere-ocean interactions in the North Atlantic and Arctic Ocean Basins. This remote climate forcing is mediated primarily by basin- and hemispheric-scale changes in ocean circulation. Here, we synthesize results from process-oriented field studies and retrospective analyses of time-series data to document the linkages between climate, ocean circulation, and ecosystem dynamics. Our results demonstrate that bottom-up forcing associated with climate plays a prominent role in the dynamics of these ecosystems, comparable in importance to that of top-down forcing associated with overfishing. We conclude that a broad perspective, one encompassing the impacts of basin- and hemispheric-scale climate processes on marine ecosystems, will be critical to the sustainable management of marine living resources.

May 22, 14:40 (W2-7481)

Dynamics of upper ocean low-salinity waters in controlling winter convection, water-mass transformation and spring blooms

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Low salinity waters from the Greenland boundary current system flow over the Labrador Sea, as eddies and background gyre circulation, providing stratification which helps to shape the regions of deep wintertime convection (from Seaglider and satellite observations, Lilly *et al.* 2003, Hátun *et al.* 2007). This advected low-salinity water also produces the dominant spring phytoplankton bloom of the western subpolar gyre (Wu *et al.* 2008, Frajka-Williams *et al.* 2009, 2010).

Model studies (Chanut *et al.* 2008) support the role of imported upper-ocean buoyancy in controlling deep convection, which also accounts for the rapid restratification of the water column in spring. Here we describe more widely the climatology of the integrated upper ocean buoyancy (or 'convection resistance') and its relationship with water-mass transformation and wintertime mixed-layer depths.

Circulation- and climate models need to explore their representation of advection of surface freshwater at the rim of the Arctic; in Nature it occurs in narrow filaments, yet affects basin-scale physical and biological structure.

W3 Oral Presentations

May 22, 9:20 (W3-7397)

Is *Calanus pacificus* just a warmer-adapted *Calanus finmarchicus*?

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Using the best available laboratory-collected data, the temperature-corrected stage-by-stage development rates of *Calanus pacificus* are actually extremely similar to those of *Calanus finmarchicus*, when also compared to those of *Calanus marshallae* and *Calanus helgolandicus*. This is surprising, given the closer assumed evolutionary affinity of *C. pacificus* to *C. marshallae*, and the closer ecological ties between *C. finmarchicus* and *C. marshallae* (cold-water species) versus *C. pacificus* and *C. helgolandicus* (warm-water species). *C. pacificus* growth rates as a function of temperature, however, are more similar to *C. marshallae* for some stages, more similar to *C. finmarchicus* for a few stages, and inbetween the two for the remaining stages (*C. helgolandicus* stage-by-stage growth rates as a function of temperature were not available for comparison). Here, we compare the effects of these variations in growth and development rates on the adult size vs temperature relationships, and projected outcomes due to projected ocean warming. Further, as closing the year-to-year population cycles of these species requires an inclusion of a dormant phase, we posit the question of whether the weight-specific, lipid-respiration rates of *C. finmarchicus* during dormancy, as a function of temperature (the only species for which such information is known) can be used for *C. pacificus*, through the use of an individual-based model. Lastly, we also examine the effects of ocean warming on the resulting population dynamics of *C. pacificus*, using these *C. finmarchicus* corrected parameters.

May 22, 9:40 (W3-7515)

Calanus marshallae: Life history, seasonal cycle of abundance and egg production rates in the shelf waters off Newport, Oregon

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We have been monitoring hydrography, nutrients, chlorophyll and species composition of zooplankton in coastal waters off Newport, Oregon (44.6°N) on a biweekly basis for the past 15 years (1996-present). We have found that copepod species composition closely tracks the Pacific Decadal Oscillation (PDO) with a "warm water community" present during positive phase of the PDO and a "cold water community" during negative phase. *Calanus marshallae*, a species common in coastal waters of the Bering Sea and Gulf of Alaska, is a dominant member of the "cold water community". It awakens from diapause in early-to-late-January and passes through perhaps 5-6 generations before C5s enter diapause in September or October. Females lay eggs throughout the nine month growth season at rates which average ~ 25 eggs female^{-1} day^{-1}. Egg production rates (EPRs) are correlated with the PDO - the more negative the PDO the greater the egg production; during such times, EPRs often average ~40-45 eggs female^{-1} day^{-1} with maximum rates of 70-80 eggs female^{-1} day^{-1}. The abundance and biomass of *C. marshallae* peaks in July-August, the same time as the maxima in upwelling. Losses to offshore waters during the upwelling season are minimized due to ontogenetic migrations; the degree to which losses occur to the south of our sampling site are not well established and we will discuss the suggestion that Capes Blanco and Mendocino (43°N and 41°N) are faunal boundaries for this and other boreal subarctic copepod species.

May 22, 10:00 (W3-7400)

Life histories of the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera* in the upwelling region off Newport, OR, USA

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Climate change scenarios suggest that global warming may lead to changes in the strength of coastal upwelling and changes in the magnitude and duration of natural climate cycles such as the PDO. Our biweekly zooplankton sampling (1996-present) encompasses variations in timing and intensity of upwelling and cool and warm phases of the PDO, which allows us to investigate some potential effects of climate change on the euphausiids *Euphausia pacifica* and *Thysanoessa spinifera*. *E. pacifica* spawning is strongly associated with the timing of the onset of upwelling but not with upwelling strength. Spawning peaks four months after the spring transition and juveniles appear two months later. In 2005 upwelling was delayed and krill spawning was similarly delayed. Survivorship of larvae produced that summer was considerably lower than during other years. *T. spinifera* spawn prior to and during upwelling and seem to be more strongly affected by water temperature. 2002 was an anomalously cold year and *T. spinifera,* usually a shelf species, was found far offshore. Their reproductive effort in 2002 was the highest seen during this study. *E. pacifica* were not strongly affected by the temperatures they experienced during this study and were always present. *T. spinifera* were rare or absent during warmer ocean conditions. Changes in timing of the spring transition are likely to affect *E. pacifica* spawning behavior. Consistently warmer ocean temperatures are likely to result in a decrease in *T. spinifera* abundance and spawning. Both scenarios will affect the availability of euphausiids to higher trophic level predators.

May 22, 10:40 (W3-7398)

Predicting copepod dormancy timing in response to climate change

James **Pierson**[1], Jeffrey Runge[2], Erica Head[3], Stéphane Plourde[4], Catherine Johnson[3], Andrew Leising[5], Frédéric Maps[2], David Kimmel[6] and Andrew J. Pershing[2]

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Dormancy is a life history trait common among many copepod genera in sub-polar and polar seas, but the timing of entry into and exit from the dormant state varies within a species throughout its range. This variation in timing is likely driven by various competing biological and environmental factors, both of which are subject to changing climatic conditions. Further, dormancy timing has implications for food web interactions in sub-polar and polar seas, because copepods are both grazers on primary producers and an important food sources for larval and forage fish. We are using numerical models and historical data analysis to compare both inter- and intra-specific variation in dormancy timing in copepods of the genus *Calanus*. Our goal is to better understand the ultimate factors controlling dormancy in *Calanus,* and to better predict how dormancy timing will respond to climate change. The time-series data will be analyzed to look at spatial and interannual differences in dormancy timing for particular species, and the individual-based models will be used to test how various scenarios may impact the observations of dormancy timing, as well as variations within individuals. The results will enhance our understanding of how dormancy controls vary within and between species, and provide a mechanism to predict how climate changes could impact the life-histories of these species throughout their range.

May 22, 14:00 (W3-7443)

A pan-regional comparison of the seasonal climatology in mortality and population dynamics of *Calanus finmarchicus* across the North Atlantic

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Mortality is a key population dynamics parameter that likely drives the evolution of several life history traits. Adequate quantitative knowledge on mortality and its relation with environmental parameters is a prerequisite for any prognostic modeling of zooplankton population dynamics. Here we used the Vertical Life Table approach to compare the monthly pattern in stage-specific mortality of the copepod *Calanus finmarchicus* in several regions across the Northwest and Northeast Atlantic encompassing a wide range of environmental conditions such as temperature, phytoplankton biomass, and *Calanus* population density. We adopted a climatological approach using multi-year data sets in order to obtain robust mortality estimates capturing long-term monthly environmental forcing for a quantitative comparison of these different ecosystems. Abundance data were corrected for the presence on overwintering stages (non- or slow-developing) in order to estimate mortality of the surface-dwelling 'active' component of the population. Both temperature and chlorophyll *a* biomass were used to estimate development time and to include region-specific food limitation potential in our analysis. Preliminary results based on a sub-set of regions suggested that temperature had a general scaling effect on mortality with some differences in monthly stage-specific mortality patterns among regions. In particular, mortality in stage pair egg-C1 (average mortality from egg to C1) showed region-specific relationships with temperature, food availability and abundance of adult stages. Our results will be synthesized as population survival trajectories that will be compared among regions during comparable seasons.

May 22, 14:20 (W3-7399)

Reality and the estimation of mortality for copepod eggs

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Copepod population dynamics are highly sensitive to mortality rates, and our ability to predict abundance and production relies on accurate mortality estimates, especially for the early life stages. Here, we used vertical life table (single time point) methods to estimate egg mortalities for *Calanus finmarchicus* in the Labrador Sea. Calculations used *in situ* measurements of female and egg abundance, chlorophyll concentration and temperature at 82 stations, and egg production and hatching rates based on experiments carried out at sub-sets of these stations. The estimation method most commonly used in the literature resulted in realistic mortality rates (*i.e.* between 0 and 1 d^{-1}) at less than half of the stations, with extreme outliers (*i.e.* < -1 or > 3 d^{-1}) at almost 20%. An alternative method that is less prone to outliers resulted in marginally better results, but restricting the analyses to those stations where egg production was actually measured or by averaging abundance data over groups of stations did not lead to further improvements. For sampling error to explain these results, there would have to have been significant (by a factor of 2-10) errors in the field measurements. Thus, the most parsimonious explanation is that field conditions at more than half of our stations violated the vertical method assumptions, such as steady-state abundances and constant environmental conditions. This puts into question our ability to accurately characterize mortality, and whether the correlations of seemingly realistic mortality rates with environmental variables are reliable. Implications for predicting copepod population dynamics are discussed.

May 22, 14:40 (W3-7492)

Modeling copepod biodiversity using evolutionary computing

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Much effort has gone into studying the effects of climate change on individual species, mostly through simple relationships with temperature. However, species range limits in both space and time, are determined by both direct physical effects and by interactions with predators, competitors, and prey. The effects of changing conditions on communities and assemblages are not as well understood and are difficult to simulate in standard coupled models. Drawing on techniques taken from evolutionary computing, we designed a copepod community model. Copepod species are represented by a digital chromosome of parameters, so that different sets of parameter values map to different species. Computational processes mimicking mutation and selection allow diverse communities to emerge. We begin by testing this paradigm on the Calanus species complex in the North Atlantic, and then broaden our scope to more general copepod communities. We explore how temperature, resource availability, and mortality regimes structure these modeled copepod communities.

May 22, 15:00 (W3-7468)

Neocalanus vs. Calanus oceans. Comparative study on the life histories of *Neocalanus* and *Calanus* copepods, and their global distribution

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Calanus and *Neocalanus* copepods are large-sized and abundant copepods. They are one of the most important copepods as preys for higher trophic animals and carbon cycling in the world oceans. Life cycles of *Calanus* and *Neocalanus* species in middle and high latitude have been studied well, which are characterized by seasonal occurrence to the surface layer with ontogenetic vertical migration. However, information of low latitude species is limited. First, we investigated life cycle of *Neocalanus gracilis* in the subtropical Pacific. *N. gracilis* showed a continuous reproduction in the epipelagic layer throughout a year. However, spawning in the subsurface layer and small-scale ontogenetic vertical migration were observed. Moreover, oil-sac was observed in late copepodite stages (C5 and C6 female) and C1, suggesting a reproduction depending on the accumulated materials and lecithotrophic nauplius stages. These life cycle strategies are considered as adaptation to oligotrophic environment (low-food availability) and high predation risk in the surface layer. These oligotrophic-adapted characteristics might facilitate the polar-ward immigration of this genus in the Pacific and the Southern Ocean where is characterized by HNLC (high nutrient low chlorophyll) environment. Global distribution of *Calanus* and *Neocalanus* was re-considered in relation to the differences of life-cycle strategy of these genus.

W5 Oral Presentation

May 22, 13:40 (W5-7550)

Changes in the distribution of hotspots of pelagic seabird species diversity and abundance in the Bering Sea and North Pacific over four decades

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Using ship-based pelagic surveys from the North Pacific Pelagic Seabird Database, we examine the distribution of hotspots of summer seabird species richness and diversity at several spatial scales. We correct for heterogeneous survey intensity and discuss several diversity measures. Focusing on the Bering Sea, we calculate the diversity anomaly for each of the four decades. After smoothing and interpolating these anomalies we show areas in which diversity increased and decreased. We find that, with the exception of the shelf south of the Pribilof Islands, seabird species diversity has increased over most of the Bering Sea. Independently of scale, rarefied species richness is positively related to sea surface temperature, but negatively to primary productivity. Our results have implications to forecasting the effects of climate change on the Bering Sea ecosystem and its seabird communities.

May 23 Opening Plenary Session

May 23, 8:40 (Open-7544)

Aleut ecological studies in Pribilof Domain – Maritime heritage and recent work presented by student researchers from the Pribilof Islands, "The Galapagos of the North"

Danielle **Merculief**[1], Steven **Isaac**[1], Caitlin **Bourdukofsky**[1], Anthony **Lekanof**[1], Cara Mandregan[1], Joshua Prokopiof[1], Ashley Merculief[1], Carmen Philemonof[1], Brandi Merculief[1], Michael **Dirks**[1], Dallas Roberts[1], David Merculief[1], Andronika **Emanoff**[1], Chelsea Lekanof[1], Barbara Chapman[1], William **Lekanof**[1] and L. Michelle Ridgway[2]

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Aleut maritime cultural heritage imbues modern life in Pribilof Domain with a unique perspective on human interdependence with the Bering Sea ecosystem. Alaska's Pribilof Islands lie at the extreme southern extent of the seasonal Arctic sea ice zone – an island archipelago situated on continental shelf edge, or Beringian margin. Enriched waters at this crossroads of oceanic provinces are responsible for high biological productivity and biodiversity, for which our region is called "The Galapagos of the North". Students in the Pribilof School District have drawn upon ancestral knowledge relayed through elders to focus their scientific research on elements of the Bering Sea which shape transportation, subsistence food harvesting practices and economies for their island communities. We will present highlights of results of four years of collaborative research conducted in nearshore waters around St. Paul Island and St. George Island during spring and summer seasons.

Our investigations confirm high species richness of nearshore flora and fauna. *Stongylocentrotus* sp. sea urchin population density, roe quality and roe percent of body weight continue to provide a rich, accessible resource for local consumption at St. George Island. Kelp species from the Class Phaeophyceae provide important canopy habitat around both islands and exhibit summer growth rates of approximately 11% per day. The rarest kelp on earth, *Aureophycus* sp. is distributed as far north as St. George Island in shallow subtidal patches, begins blade growth as early as March and appears to senesce in October. Zooplankton fueling the Pribilof Domain foodweb are typical of the middle and outer shelf assemblages. Fish, seal and sea lion stomach contents suggests a complex upper foodweb based on fish and crustaceans.*Paralithodes* sp. king crab adults and pelagic larvae are in very low abundance near the islands, but juvenile king crab observed in nearshore waters confirms that the Pribilof Domain still provides adequate juvenile "shellhash" habitat to support rebuilding of this economically important species.

May 23, 9:00 (S5-7467), Invited

Climate connectivities: Roles of the Arctic and subarctic oceans in global change

Eddy C. **Carmack**

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The Arctic Ocean is changing fast, and to fully understand why requires that we view its two-way interconnection with its neighboring subarctic domains. First, the Arctic and subarctic oceans surrounding northern North America and Eurasia are fully connected to one another and fulfill an absolutely critical role in global-scale hydrological and thermohaline cycles. Second, the changes in the physical system actually observed this past decade years have far out-paced the most pessimistic of model predictions used in the 4th IPCC report of 2007. Third, geochemical and biological systems are now responding to changes in the physical system. Finally, humans are inextricably linked to the changes we are observing today, both as drivers of change through our greenhouse gas emissions and as the very populations needing to prepare for the uncertainties that lie ahead. This talk will review results from the IPY – Canada's Three Oceans (C3O) project to demonstrate 1) the Arctic's place in the global climate system, 2) the essential connectivities among the Arctic and subarctic ocean and 3) explore what such changes – as components of a coupled system – will mean in terms of marine life and ecosystems, invasive species, ocean acidification and challenges to governance. The system is complex, the clock is ticking and we are dangerously slow out of the gate; original data across multiple scales is sorely needed now.

May 23, 9:30 (S5-7487), Invited

Seabirds and changing ice conditions in the Canadian Arctic

Anthony **Gaston**[1], Jennifer Provencher[2], Paul Smith[1], Kyle Elliott[3], Mark Mallory[4] and Grant Gilchrist[1]

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The timing of sea ice break-up and the duration of the open water period have shown striking changes over most of Canadian Arctic waters during the past three decades. These changes have not been linear, but in many areas involve a step transition that encompasses most of the observed change. We report on the impact of these changes on marine birds and their diets, with particular emphasis on Thick-billed Murres *Uria lomvia.* In Hudson Bay, the timing of ice break-up advanced by three weeks between 1983-2010, while the timing of egg-laying by the birds advanced by only 6 days. The resulting mis-match showed a close correlation with nestling growth rates, with chicks growing best when the gap between ice break-up and laying was least. An abrupt change in ice regime in the mid-1990s was contemporary with a switch in nestling diets from ice-associated Arctic cod *Boregadus saida* to other fish. Changes in ocean food webs created by changing ice conditions will likely led to deterioration in breeding conditions for murres and other marine birds.

May 23, 10:00 (S4-7411), Invited

Effects of ocean acidification, warming and melting of sea ice on aragonite saturation of Canada Basin surface water

Michiyo **Yamamoto-Kawai**[1], Fiona A. McLaughlin[2] and Eddy C. Carmack[2]

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In 2008, surface waters in the Canada Basin of the Arctic Ocean were found to be undersaturated with respect to aragonite. This undersaturation is associated with recent extensive melting of sea ice in this region, as well as elevated sea surface temperature and atmospheric CO_2 concentrations. We have estimated the relative contribution of each of these controlling factors to the calcium carbonate saturation state (Ω) from observations of dissolved inorganic carbon, total alkalinity and oxygen isotope ratio. Results indicate that the increase in atmospheric CO_2 has lowered surface Ω by ~0.3 in the Canada Basin since preindustrial times. Recent melting of sea ice has further lowered mean Ω by 0.4, and of this, half was due to dilution of surface water and half was due to the change in air-sea disequilibrium state. Surface water warming has generally counteracted the mean decrease in Ω by 0.1.

May 23, 11:00 (S4-7352), Invited

Nutrient and productivity variations in Arctic and sub-Arctic seas

Lou A. **Codispoti**

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Northern seas exhibit significant inter and intra-sea variability in their nutrient and productivity regimes. Net community production (NCP) can range from <20g C m^{-2} a^{-1} in Arctic Ocean interior and outflow seas to order of magnitude higher values in inflow seas. The positions of the Arctic's Atlantic and Pacific approaches with respect to the oceanic conveyer belt favor higher nutrients in the Pacific sector, but local topographic influences are also important. Ridges restrict northward penetration of deep/higher nutrient Atlantic waters. When combined with convection this leads to uniform and modest pre-bloom nutrient concentrations in inflowing Atlantic waters of ~11µM that support NCP of ~30-50g C m^{-2} a^{-1} in the Nordic and Barents seas. Topography also impacts nutrients in the Pacific Sector. The Bering Sea Shelf and its slope contribute to a year-round upwelling of nutrient rich Anadyr Water that flows onto the western shelf and into the Arctic Ocean. Within this upwelling, NCP values may exceed 200g C m^{-2} a^{-1}. The atmospheric circulation of water vapor and runoff enhances salt stratification in the Pacific sector thereby reducing the impact of convective mixing on the nutrient supply. During the vegetative season, the northeastern Bering Sea is dominated by low salinity, low nutrient waters resulting in low NCP. Strong salt stratification within the Arctic Ocean limits convection and enhances the importance of advective inputs of nutrients from the Atlantic and Pacific approaches. NCP tends to decrease with distance from these sources.

May 23, 11:30 (S2-7346), Invited

Hydrography and biological resources in the western Bering Sea

Gennady V. **Khen** and Eugeny O. Basyuk

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The western part of the Bering Sea is colder than its eastern part, has a narrow continental shelf (20-80 km), and deep water exchange with the Pacific Ocean occurs there. Last decade an intense warming occurred in the west and since 2007 the sea surface temperature became higher than in the east. In intermediate layers of the Commander Basin and Anadyr Bay in mid decade a temperature decrease occurred and continues to the present time. The water exchange with the Pacific Ocean in general has stayed weak since the early 1990s and the water transport of the Kamchatka Current is 2-3 times lower than in 1970-1980s. Biological resources in the western Bering Sea are significantly less than those in the east and large interannual fluctuations occur. Two periods of high fish biomass are distinguished: the first one (1958-1964) is due to herring and the second one (1975-1984) is due to walleye pollock (Naumenko, 1996). The herring population increased in the second half of the 1990s again but during the current decade the total biomass of commercial species of fish was at a low level. The causes of the fluctuations are not completely clear. Detailed studies of environmental conditions, predation and fisheries in relation to the population dynamics of the species are required.

May 23, 12:00 (S2-7546), Invited

A comparison of the physics, chemistry, and biology of warm and cold years on the eastern Bering Sea shelf

Phyllis **Stabeno**[1], Sue E. Moore[2], Calvin Mordy[3], Jeffrey M. Napp[4] and Michael Sigler[5]

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As a subarctic sea, the eastern Bering Sea is sensitive to shifts in climate, with many of the changes resulting from variations in sea ice. From 1972–2000, there was high interannual variability of areal extent of ice during spring. In 2000, this shifted to a 5-year period of low spring ice extent, transitioning in 2006 to a 4-year period of extensive sea ice. High (low) areal extent of sea ice in spring was associated with cold (warm) water column temperatures for the following 6 months. The ecosystem of southeastern shelf (including ocean currents, types and abundance of zooplankton, recruitment of walleye pollock and Pacific cod, and distribution and abundance of fin and humpback whales) differed markedly between warm and cold years. The ecosystem appears to respond differently to multi-year periods of warm or cold than to year-to-year variability. For instance, prolonged cold periods appear to allow increased concentrations of large crustacean zooplankton such as *Calanus* and *Thysanoessa* that are important prey for fish, seabirds, and cetaceans. In contrast to changes over the southern shelf, the northern Bering Sea (north of ~60°N) will continue to have extensive ice through April and, thus, even under climate warming scenarios, the bottom temperatures on the northern shelf will remain cold. Changes in the ecosystem over the northern shelf will likely be more subtle. For instance, some species of fish (*e.g.* sockeye and pink salmon) may expand their ranges northward, while other species (*e.g.* pollock and arrowtooth flounder) are unlikely to become common there.

S2 Oral Presentations

May 23, 14:05 (S2-7532), Invited

Comparing walleye pollock dynamics across the Bering Sea and adjacent areas

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Walleye pollock (*Theragra chalcogramma*) are a commercially and ecologically important species in the Bering Sea. Our understanding of walleye pollock recruitment dynamics on the eastern Bering Sea shelf has greatly advanced in recent years due to intensive field and modeling studies conducted during a period of contrasting environmental conditions. These studies have shown that, although warm, ice-free conditions on the shelf may benefit early larval growth and survival, they can result in poor feeding conditions for early juveniles in late summer and fall, thus reducing overwinter survival and subsequent year-class strength. In the past, strong year classes of the eastern Bering Sea pollock stock have been associated with high abundances of these year classes in adjacent areas such as along the Aleutian Island chain and, at least in some years, in the western Bering Sea. This suggests that pollock from the eastern Bering Sea stock contribute directly to adjacent areas through migration of juvenile or subadult stages or that synchronicity in recruitment may be induced by large-scale environmental drivers affecting different pollock stocks in similar ways. Here we review available data on the distribution of different life stages of walleye pollock across the Bering Sea and compare their trophic role and patterns of recruitment and abundance across the Bering Sea and adjacent ecosystems.

May 23, 14:35 (S2-7366)

Controls on in carbonate mineral saturation states and ocean acidification on the southeastern Bering Sea shelf

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Increasing CO_2 concentrations in the atmosphere and ocean have induced an anthropogenic acidification phenomenon, particularly in high latitude seas. These effects are expected to result in consistent undersaturations of carbonate minerals by mid-century, although seasonal undersaturations of some minerals have already been documented on the Alaskan continental shelf. In the Bering Sea coastal margin, high DIC river discharge and remineralization processes create a seasonal source of CO_2 to the atmosphere and precondition these waters to have low carbonate mineral saturation states. In contrast, the high productivity of the green belt increases carbonate mineral saturation states in surface waters and allows for atmospheric uptake of CO_2 in this region seasonally. The exported organic matter is remineralized in bottom waters, generating high concentrations of DIC and low carbonate saturation states and causing a biological amplification of ocean acidification in this region. In 2008 and 2009, the integrated annual production of carbon was very similar (2008: 97 Tg C yr^{-1}; 2009: 97.2 Tg C yr^{-1}), although rates of production differed between the two years and caused some variation the spatial distribution of carbonate mineral undersaturations. Significant interannual fluctuations in the volume of river discharge also contributed to these variations. Some keystone species of the Pacific-Arctic region could be susceptible to reduced calcification rates under increasing ocean acidity and carbonate mineral suppression. The reduced ability of some of these species produce shells or tests may have profound implications for Bering Sea benthic ecosystems, including the commercially valuable crab fishery.

May 23, 14:55 (S2-7456)

Sedimentation processes under the seasonal sea ice of the Bering Sea

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Algal concentrations in the sea ice and water column and sinking rates from sediment traps were measured during the 2008 and 2009 Bering Sea Ecosystem Study spring field campaigns in the ice-covered Bering Sea. Integrated ice algal pigment concentration (mean over both field seasons: 5.0mg chl-*a* m^{-2}) significantly exceeded water column pigment concentrations in the upper 5m (mean over both field seasons: 3.3mg chl-*a* m^{-2}). The ice algal concentrations are among the highest observed anywhere in the Arctic. Sediment traps deployed in 5m depth revealed mean sinking rates of 3.6mg chl-*a* m^{-2} d^{-1}. Sinking rates increased over time from <0.5 mg chl-*a* m^{-2} d^{-1} in early March to maximum values of up to 27.2mg chl-*a* m^{-2} d^{-1} by the end of April. These flux rates and their seasonality are similar to observations in other Arctic shelf seas. The significant concentrations of ice algae produced in the Bering Sea are released during periods of advanced melt and become available to pelagic and benthic consumers.

May 23, 15:15 (S2-7458)

Sea-ice dispersal and source influence productivity patterns in the northern Bering Sea

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The marginal ice zone (MIZ) environment often is associated with elevated phytoplankton productivity. This relationship is not absolute however, and the results of sampling in the northern Bering Sea over several years indicated that the MIZ in spring exhibited a range of productivity from meso-oligotrophic to extremely eutrophic. When these variations in productivity were examined together with sea ice dynamics as suggested by AMSER-E observations and a numerical model, it appeared that the source regions and paths traveled by sea-ice play critical roles in determining ice edge productivity. In particular, ice advected into warmer, offshore waters was associated with extensive productivity in the large, melt-water pools formed along its seaward edge. Winds that pushed the ice onshore resulted in diffuse, less intense blooms. The positive impact of advection was intensified for ice generated in coastal regions, an effect we attribute to the greater content of algal seed populations and biologically utilizable iron that was acquired by the ice in shallow waters. The intensity of ice edge blooms is not simply dependent on local conditions, but also on the regional forcing of the winter and spring ice field. The large impact of the ice-edge bloom on the benthic food web links the variations in ice dynamics and regional forcing to the dominant trophic transfer pathway on this and other high-latitude shelves. The impact of climatic variations on the source and dispersion of sea ice therefore, may be important predictors of climate impact on the ecology of these regions.

May 23, 15:35 (S2-7482)

Bioturbation and organic carbon mineralization pathways in Bering Shelf sediments

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Oxidation of organic carbon in Bering Shelf sediments drives important sediment geochemical processes such as oxidation and reduction of metals, nutrient cycling, and sediment-water exchange of solutes. These processes are modified by the activities of benthos that mix and redistribute organic matter and other particles and solutes. To better understand how the activities of benthic organisms influence these processes, we quantified rates of bioturbation and bioirrigation along with rates of aerobic and anaerobic organic carbon oxidation. Rates of aerobic carbon oxidation, denitrification, manganese and iron reduction, and sulfate reduction were strongly influenced by bioturbation and bioirrigation. Geographic patterns of OC oxidation were consistent with expected patterns of benthic-pelagic coupling; a greater proportion of OC was oxidized anaerobically in areas where we would expect a greater export of OC to the benthos. Among anaerobic processes, iron reduction and sulfate reduction were generally the dominant remineralization pathways.

May 23, 16:25 (S2-7522)

North-south variation in eastern Bering Sea shelf spring and late summer zooplankton assemblages

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The presence or absence of sea ice is a major structuring element of the eastern Bering Sea shelf. It affects water temperature, the presence or absence of a cold pool, the magnitude, duration, and timing of the spring phytoplankton bloom, and circulation on the shelf. We examined north-south patterns in zooplankton community structure to see if annual ice extent also affected the structure and distribution of zooplankton communities. Data were collected along a north-south transect on the 70m isobath (Middle Shelf Domain) in spring and late summer, and from a fixed grid during late summer (2006–2010). We used a two-way classification analysis forming clusters of stations and species assemblages based on the Bray-Curtis index of similarity and a flexible linkage clustering technique. Differences in the zooplankton taxa in each assemblage and along a north – south gradient among years were evident, with spring showing the largest differences. In the early part of the time series, when sea ice was less extensive, Outer Shelf Domain taxa (*Neocalanus* and *Metridia*) were present over the middle shelf, whereas they were largely absent during the years when ice penetration into the southeast was more extensive. This result implies that cross shelf transport varies with ice extent. It has implications for both the distribution and biomass of zooplankton as well as the feeding of planktivorous seabirds, marine mammals and fishes over the middle shelf should the presence and extent of sea ice decrease with general climate warming.

May 23, 16:45 (S2-7384)

Seasonal and interannual patterns in euphausiid diets and feeding rates in the eastern Bering Sea: Three years of BEST observations

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As part of the Bering Ecosystem Study (BEST) program, our goal is to investigate how changing sea-ice conditions may affect the ecology and population dynamics of euphausiid species in the eastern Bering Sea. We hypothesized that seasonal and interannual variation in the timing and extent of sea-ice and associated food resources would lead to differences in diet, nutrition and ultimately production and availability of euphausiids as prey for higher trophic levels. To test this, we measured feeding rates of six species of euphausiids, with a particular emphasis on the two dominant species (*Thysanoessa raschii* and *Thysanoessa inermis*). Shipboard incubation experiments were used to measure feeding rates on chlorophyll size-fractions, as well as phytoplankton and microzooplankton taxa, under varying conditions (north, south and cross-shelf, ice-covered, ice-edge and open water) in spring and summer in 2008-2010. In ice-covered and ice-edge water in spring, euphausiids exhibited very high feeding rates on ice algae, and ice algae were a key dietary resource for *T. raschii* in spring. Average phytoplankton ingestion rates of *T.raschii* and *T. inermis*, were ca. twice as high in the spring as summer in both years. Microzooplankton was ingested by both species in spring and summer, but was a much larger proportion of the diet in summer when large algae were less abundant. As the three study years were relatively cold and presented similar oceanic conditions, little interannual variation in these feeding patterns were seen.

May 23, 17:05 (S2-7459)

Evaluating linkages between forage fish distributions and physical oceanography in the eastern Bering Sea

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Late-summer distributions of forage fish (*e.g.* age-0 walleye pollock, age-0 Pacific cod, age-1+ capelin) were evaluated using combined acoustic, midwater trawling, surface trawling, and oceanographic surveys in the eastern Bering Sea from 2008 to 2010. Previous observations of these species had been based only on surface trawls (2003-2007). Surface trawl data suggested age-0 pollock were primarily found in the Middle Domain with high densities near the pycnocline. Acoustic and midwater trawl observations determined that in 2008 to 2010 age-0 pollock were also found in large (>50m high, several km long) aggregations in deep (>100m bottom depth) Outer Domain areas. In 2010, catch-per-unit-effort of age-0 Pacific cod in surface waters was higher than in any previous (2003-2009) year. Interestingly, the high Pacific cod catches in 2010 correspond to the lowest catches of age-0 pollock in the surface waters. Capelin distributions during the 2008-2010 combined surveys were patchy and fish were generally restricted to surface waters although larger schools were found throughout the water column in the Inner Domain and extending below the pycncline in the Middle Domain. We are now evaluating relationships between oceanographic characteristics (*e.g.* pycnocline strength and depth, surface and bottom temperatures) and biomass of forage fish species in surface and deep water. This research is a key component in understanding relationships between late-summer water column properties and forage fish distributions, with implications for prey availability for apex predators and overwinter survival of forage fish species.

May 23, 17:25 (S2-7386)

Biennial change of the pink salmon biomass and its effects on the body condition of two species of seabirds in the central Bering Sea

Kanako Toge[1], Rei Yamashita[2], Kentaro Kazama[1], Masaaki Fukuwaka[3], Orio Yamamura[3] and Yutaka **Watanuki**[1]

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Seabirds and large fishes are important top predators in marine ecosystems, but few studies have explored the potential for competition between these groups. This study investigated the relationship between an observed biennial change of pink salmon *Oncorhynchus gorbuscha* biomass in the central Bering Sea and the body condition of the short-tailed shearwater *Puffinus tenuirostris* and tufted puffin *Fratercula cirrhata*. Samples were collected with research gill nets over seven summers. Pink salmon and shearwaters feed on krill, small fishes and squids, while the puffins feed on fish and squids. The pink salmon biomass showed a negative relationship with the shearwater's body mass and liver mass but the effects on those of puffins were not obvious. We interpret these results as evidence that fishes can negatively affect mean prey intake of seabirds if they feed on a shared prey in the pelagic ecosystem.

May 23, 17:45 (S2-7450)

Latitudinal trends and temporal shifts in the seafloor ecosystem of the eastern Bering Sea shelf and southeastern Chukchi Sea

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Latitudinal species diversity gradients are well known in ecosystems throughout the world. However, trends in relative abundance and other shifts in community structure with latitude, which can be more sensitive to environmental shifts such as climate change, have received less attention. We investigated latitudinal trends in the seafloor community of the eastern Bering Sea and southeastern Chukchi Sea using catches of fishes and epibenthic macroinvertebrates in bottom trawl surveys conducted from 1976 through 2010. Our results indicate that the biomass of the epibenthic community declines with increasing latitude in the eastern Bering Sea, although the pattern is not clear in the southeastern Chukchi Sea. This latitudinal trend is driven by declining fish catches in the northern Bering Sea, which reflect changes in the structure of the fish community. The fish fauna in northern latitudes is increasingly dominated by gadids, though the species composition of the gadid fauna changes with latitude. Invertebrates make up a larger proportion of the catch in trawls conducted at higher latitudes, and macroinvertebrate biomass increases with latitude in the southeastern Chukchi Sea. Temperature data from bottom trawl surveys over the past decade show a distinct temperature shift in the eastern Bering Sea around 2005, as the warm period of 2001–2005 was followed by five cold years. This shift in the summer temperature regime of the Bering Sea corresponds with lower fish catches, particularly in the "cold pool" region (58–61°N), and a higher proportion of epibenthic invertebrates in the trawl catches of the past five years.

S4 Oral Presentations (merged with S9)

May 23, 14:05 (S4-7412), Invited

Tracing Pacific water entering the Polar Ocean through the Bering Strait using N/P ratio signatures

Eva **Falck**, Frede Thingstad, Paul Wassmann and Knut Yngve Børsheim
Presenter: Knut Yngve Børsheim on behalf of Eva Falk

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When Pacific water passes the shallow regions of the Bering Sea, denitrification decreases the concentration of combined nitrogen. Therefore the Pacific water entering the Arctic Ocean is characterized by low N/P ratio. Cold waters are not conducive to the requirements of nitrogen fixers such as cyanobacteria, consequently the low N/P signature is maintained in the Arctic Ocean and can be identified in Pacific water leaving through the Fram Strait. The identification, transport and fate of Pacific water entering the Arctic Ocean will be discussed.

May 23, 14:35 (S4-7410)

Cold water belt formation off the Soya Warm Current along the northeastern coast of Hokkaido

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The Soya Warm Current (SWC) flows along the northeastern coast of Hokkaido: it is intensified when it passes through a shallow strait between the Japan Sea and the Sea of Okhotsk. In summer, it has a jet-like structure downstream of the strait with a surface maximum speed exceeding 1 m/s at its axis. A cold water belt is formed offshore of SWC with a subsurface doming structure. It is well-known that there is abundant primary production along the cold water belt even during summer. In this presentation, mechanisms of the upwelling and cold water belt formation are discussed from the point of view of nonlinear resonance between a barotropic stratified flow and a shallow sill. An idealized model and a realistic model were both used to identify the mechanisms. When the barotropic current rides over the sill, the thermocline is displaced greatly due to resonance, and consequently the subsurface layer may outcrop, corresponding to upwelling along the southwestern coast of the Sakhalin Island. The thermocline is elevated due to the upwelling, which then propagates downstream along SWC. This thermocline shoaling supports abundant primary production along SWC even in summer.

May 23, 14:55 (S4-7488)

The advantage of being eaten: Do zooplankton stimulate growth of their preferred algal prey?

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Measurements in a temperate marine ecosystem reveal maximal primary productivity in summer when phytoplankton biomass is low and nutrients hardly detectable as measured at macro-scales. This implies high grazing rates, rapid cycling of ample nutrients at micro-scales and the dominance of edible phytoplankton over non-grazed species. It is suggested that grazed phytoplankton gain competitive advantages by the cost of grazing being outweighed by the benefits of receiving recycled nutrients according to the following conceptual model: Phytoplankton are spatially structured in terms of clonal copies at micro-scales due to asexual reproduction. Herbivores graze where the concentration of preferred algal prey is high and that of unedible algae is low. During grazing, clonal cells that are left receive recycled nutrients from the grazers and continue to grow, whereas cells in patches dominated by non-grazed algae experience nutrient limitation, poor growth and low abundance. Consequently, zooplankton exert a strong influence on the algal community. However, in contrast to the traditional concept of top-down control in ecosystems, both predator and prey enhance abundance by coexisting.

This idea has potentially far-reaching implications. For example, along the south coast of Norway repeated incidents of abrupt and persistent recruitment collapses in gadoids have been observed locally. These collapses have been linked to gradual cultural eutrophication which has resulted in abrupt changes in the planktonic community and deprivation of adequate pray for the 0-group gadoids. The proposed positive coexsistence of herbivore zooplankton and phytoplankton may provide a mechanistic explanation for ecosystem resilience and abrupt regime shifts as a result of gradual environmental changes.

May 23, 15:15 (S4-7416)

Developments of Arctic carbon sink from 1999 to 2010

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Polar oceans play an important role in the global carbon cycle. Measurements of atmospheric and surface sea water pCO_2 were conducted during the 1st, 2nd, 3rd and 4th Chinese National Arctic Research Expedition (CHINARE) cruises in July to September of 1999, 2003, 2008 and 2010 respectively. The Arctic carbon sinks increases during the past 11 years from 1999 to 2010 accompanying the receding of sea ice cover. Especially, our summer 2008 CO_2 data suggest that increased initial ice-melting will enhance air-sea CO_2 flux greatly in the western Arctic Ocean. Greater summertime ice melting is projected to occur in the following years with an increasing speed. The increased CO_2 uptake by the Arctic Ocean slopes and basins, thus, may provide a negative feedback mechanism to reduce atmospheric CO_2 and thus rate of warming. However, such CO_2 sink will be weakened gradually as our data also suggest that a complete ice-free condition in the slope and basin areas for a prolong period during the summer may result in an increase in surface pCO_2 and reduced CO_2 flux (though still higher than today). Furthermore, warming and ice-melt also will promote permafrost thawing in the Arctic continent and thus increases river inputs of dissolved inorganic carbon (DIC) and organic carbon that are expected to be recycled as CO_2, thus further reducing the capacity of the Arctic Ocean to absorb the atmospheric CO_2.

May 23, 15:35 (S4-7444)

The predominance of benthic processes for N cycling on the eastern Bering Sea shelf as evidenced by the N and O isotope ratios of water-column nitrate

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We surveyed the N and O isotope ratios of water column nitrate on the Eastern Bering Sea Shelf in early spring of 2007 and 2008 to identify the sources and sinks of fixed N to the shelf, and to determine the proportion of nitrate newly advected to the shelf in comparison that remineralized directly on the shelf. Both the N and O isotope ratios show evidence that a high proportion of nitrate in the ice-covered shelf waters is remineralized directly on the shelf from a previous season's growth, rather than advected directly from the shelf edge. At the inner shelf, the O isotope ratios reveal that nearly 100% of the ambient nitrate was remineralized at the inner shelf, and at least 40-80% of ambient nitrate was remineralized throughout the middle shelf. Correlations of the shelf fixed N-deficit with both the N and O isotope ratios of nitrate suggest that N remineralization and benthic denitrification are linked mechanistically, invoking nitrification-coupled denitrification in sediment as the dominant driver of fixed N loss on the shelf. The isotope ratios of nitrate thus reveal the importance of benthic processes to the shelf N cycling. These results are assessed in the context of the changing shelf hydrography and sea ice extent due to climate warming.

May 23, 16:25 (S4-7423)

Toward a simulation of iron circulation from the Okhotsk Sea to the Pacific

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Recent observations suggest that many materials are transported to the western subarctic gyre in the North Pacific from the Sea of Okhotsk. The main origin of the materials is the northwestern shelf in the Sea of Okhotsk, where they are incorporated into dense shelf water (DSW) and are transported in the intermediate layer. Among those materials, iron has recently been focused on because it is an essential micro-nutrient for the control of phytoplankton growth. We are aiming to simulate the flow of iron from the Sea of Okhotsk to the Pacific, and are developing a regional model that covers the northwestern North Pacific. The physical part of the model includes brine rejection during ice formation and tidal mixing effects along the Kuril Straits, both of which play leading roles in forming current fields and water masses in the intermediate layer in the Sea of Okhotsk. By conducting a tracer experiment and a simulation of chlorofluorocarbons, we have confirmed that the model is satisfactorily able to represent transportation of materials in the intermediate layer. For Iron we used one the simplest models, based on the Parekh's model. It considers phosphate, dissolved organic phosphorus and iron, with biological uptake and regeneration indexed to phosphorus. We hope that this model serves as a first step toward simulating iron circulation in the western subarctic gyre in the North Pacific.

May 23, 16:45 (S4-7462)

Iron and humic-type fluorescent dissolved organic matter in the western Arctic Ocean

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In the shelf, slope and basin regions (Chukchi Sea and Canada Basin) remarkably high dissolved Fe ([D-Fe]) and humic-type fluorescence (H-flu) intensity as humic-type fluorescent dissolved organic matter (humic-type FDOM) were found at depths between 25 and 200m with the subsurface maxima of [D-Fe] (1.0–3.2 nM) and H-flu intensity [4–5 quinine sulfate units (QSU)] in the upper halocline layer (Upper HL), associated with a prominent nutrient maximum. The high [D-Fe] and H-flu intensity within the Upper HL are probably due to the Fe(III) complexation with natural organic ligands, such as marine dissolved humic substances, resulting mainly from brine rejection during sea ice formation and interactions with sediments on the shelves. However, subsurface maxima of total Fe (10–50 nM) were found in the lower halocline layer (Lower HL), beneath the Upper HL, of all slope and basin regions and may be attributed to the balance between the supply of dissolved pore-water iron from shelf sediments to the overlying water, the oxidative precipitation of dissolved iron, Fe(III) complexation, and the resuspension of sedimentary particles. The finding of a subsurface dissolved iron maxima, in the Upper HL associated with humic-type FDOM, in all regions is the first confirmation for the lateral iron transport into the halocline layer from the shelves to the Arctic basin.

May 23, 17:05 (S4-7514)

Iron and manganese oxide reduction in Bering Sea shelf sediments

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Reduction rates of iron (Fe) and manganese (Mn) oxides were examined in the sediments of the southeastern Bering Sea, an area known for high levels of primary productivity, which is iron-limited in off-shore waters. Assessment of the relative importance of these remineralization pathways will help us further understand the dynamics of sedimentary respiration and the potential influence on overall productivity. At each sampling location, sediment oxygen consumption was directly measured using incubation cores. Iron and Mn oxide concentrations and their reduction rates were determined. Bioturbation rates were also quantified using profiles of excess ^{234}Th. Results varied across the Bering shelf. Average rates of bioturbation were highest in the northern region, and lowest in the off-shelf region. Rates if Fe oxide reduction followed the same trend with the highest rates in the northern and middle regions. Conversely, Mn oxide reduction was found to be of minor significance, with low rates found across the shelf. These results indicate that Fe oxide reduction is a significant pathway for the degradation of organic matter in the northern and middle-shelf regions, where organic matter supply and benthic biomass densities are high. A possible shift in energy flow from the benthic to the pelagic ecosystem due to current trends in climate change may have dramatic impacts on the productivity of this region.

May 23, 17:25 (S4-7540)

Abundant, seasonally variable supply of glacier flour-derived iron drives high nitrate consumption in Copper River plume and adjacent Gulf of Alaska continental shelf

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Recent work has suggested that high iron supply may contribute to a northward increase in phytoplankton biomass along the U.S. west coast, consistent with "bottom-up" control of these coastal ecosystems. We examine this hypothesis in waters of the Copper River plume and nearby continental shelf in the northern Gulf of Alaska. High concentrations (several hundred nM) of "total dissolvable" Fe (unfiltered, pH ~2) were present in surface-waters spanning the continental shelf in early April 2010, from resuspension of fine glacial flour. Concentrations decreased dramatically beyond the shelf break. This fine particulate matter represents a large source of "dissolved" Fe to these waters. Surface-water nitrate concentrations were fairly uniform (~15uM) across the entire shelf at this time, due to deep winter mixing. By late July this shelf particulate Fe source is greatly diminished, owing to strong stratification. Yet there is abundant "total dissolvable" Fe (several uM) at this time from the Copper River plume (largest single freshwater source to the GoA) and lower, significant concentrations in the AK coastal current (that reflect the cumulative impact of melting glaciers from further south). By late July this abundant supply of iron, together with strong stratification, lead to complete consumption of surface-water nitrate across the entire shelf (and extending tens of km beyond the shelf). These data are consistent with the idea that high primary productivity in this region is fueled by abundant wintertime surface-water nitrate, together with iron supply from fine, labile, glacier-derived particulate matter from seasonally variable sources.

S5 Oral Presentations

May 23, 14:05 (S5-7348), Invited

Biomarker records of coccolithophorid *Emiliania huxleyi* bloom in the Bering Sea over the past decades

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Temporally and spatially large-scale blooms of *Emiliania huxleyi* (*E. huxleyi*) have been distinguished annually in the eastern continental shelf of the Bering Sea since 1997, because ocean color imagery with data from the satellite-borne Sea-viewing Wide Field-of-view sensor was launched in this year. In 1997, a combination of atmospheric mechanisms produced summer weather anomalies such as calm winds, clear skies, and warm air temperature over the Bering Sea and the weather anomalies caused depletion of the subpycnocline nutrient reservoir. Their frequent occurrence, often sustained over several months, has resulted in trophic-level changes to the ecosystem, not only in the Bering Sea but also in the adjacent Arctic Ocean. We will present evidence from decades-long biomarker, alkenone, which is produced by *E. huxleyi*, records in continental shelf sediments which suggest that *E. huxleyi* blooms have been a significant feature in the Bering Sea since the late 1970s. In addition, we will also present that the close relationship between biomarker content, Aleutian Low activity and sea surface salinity trends over the past decades implies that the warming and freshening of Bering Sea waters are crucial for the promotion of *E. huxleyi* blooms.

May 23, 14:35 (S5-7360)

Distribution of in-water solar radiation in Marginal Ice Zone in Beaufort Sea

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The distribution of in-water solar radiation of Marginal Ice Zones (MIZ) was observed in periods of 18-27 July and 25-29 September, 2009, in the Beaufort Sea. The aim was to improve our knowledge of the influence of sea ice on the distribution of in-water solar energy within the MIZ and the optical properties of sea water in the Beaufort Sea in summer. The section observations of in-water radiative energy were also obtained with profiles at diverse sites, which were positioned at different distances from the floe ice. The results show that there was a notable influence of ice cover on the distribution of solar radiation at horizontal length scales within distances of 30 m of the ice edge but varying with depth. Moreover, the variations of upwelling radiance in sea water are more sensitive to ice cover than downwelling irradiance. The strongest radiant energy occurs at the band of 450-500nm particular at depth with the sharp reduction of energy at wavelengths of more than 600nm in sea water. The diffuse attenuation coefficient of downwelling irradiance ranged from 0.01 to 0.2m^{-1} for the waveband of 400-600nm then increased significantly to 0.7m^{-1} at wavelength of 700nm. The diffuse attenuation coefficient of upwelling radiance was around 0.1m^{-1} at wavebands of 400-550nm but no reliable records were obtained at more than 550nm due to the significant extinction of energy. There is slightly stronger attenuation under clear sky conditions than overcast, as well as near the ice edge compared to far away from ice.

May 23, 14:55 (S5-7387)

Current observations at the Jan Mayen Ridge

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The Jan Mayen Ridge, which runs southwards from the island of Jan Mayen, separates the warmer and saltier Atlantic water in the Norwegian Sea from the colder and fresher Arctic water in the Iceland Sea. Two cruises were carried out in this area, in 2007 and 2008, when a wide range of field observations were collected. Two moorings were additionally deployed, providing current measurements over two years, with the purpose to investigate the flow between the Norwegian and Iceland Sea. The current measurements from the shallowest mooring, at 800m depth on the Ridge, show a net weak unstable flow of Atlantic Water from the Norwegian Sea to the Iceland Sea. It had no significant seasonal variation, except near the bottom. At the second mooring, located in a 2000m deep canyon within the Ridge, the current in the whole water column varies seasonally. In the upper 600m the flow is directed from the Norwegian Sea to the Iceland Sea during winter and vice versa during summer. Near the bottom there is a net flow of deep water from the Norwegian Sea into the Iceland Sea during both seasons, and its seasonal variation is linked to seasonal changes in the internal gyre circulation within the Norwegian Sea. The weekly mean currents are in general weak, but wind stress changes over the area can create inertial oscillation in the upper layer with amplitude in the current of about 40 cm s^{-1}.

May 23, 15:15 (S5-7424)

Hydrographic conditions and circulation in the Iceland Sea during the Iceland Sea ecosystem study

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During the years 2006-2008 a national ESSSAS project on the Iceland Sea ecosystem was carried out. There were annual cruises in late summer covering the whole Iceland Sea and additionally on the quarterly standard cruises parts of the area were covered. Over the last 10-15 years the Iceland Sea has been influenced increasingly by waters of Atlantic origin via the inflow through the Denmark Strait to the area north of Iceland that has been measured with current meters since 1994. Also the inflow of Atlantic water south of Jan Mayen into the Iceland Sea has been warmer and saltier. During this time increasing temperatures and salinities have been observed in the return Atlantic water which enters the Iceland Sea from the north below the polar water in the East Greenland Current. Accordingly this period has been one with rather meager coverage of sea-ice in the area. These conditions are reflected in the observations done during the Iceland Sea Ecosystem project in the years 2006-2008. Studies of older data and time series support this. A moored profiler measuring conductivity, temperature and current was deployed for 14 months on the western flank of the Kolbeinsey Ridge at 68°N over the 1000m isobath. This gives high resolution data ideal for looking at seasonal and shorter scale variability. The data show that the ridge directs Atlantic water that enters the Iceland Sea through Denmark Strait into the deep part of the Iceland Sea.

May 23, 15:35 (S5-7509)

Optically derived primary production and size structure of phytoplankton in the polar oceans

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Ocean color remote sensing has been used to estimate primary production based on chlorophyll *a* concentration as an index of phytoplankton biomass. Recent progress in optical models to calculate inherent optical properties (IOP's) such as absorption and scattering coefficient from satellite reflectance data is extending the capability of ocean color data. Absorption and scattering coefficient of phytoplankton is important optical feature to express pigment composition, physiological state, size and quality of cell wall and so on. Therefore the IOP's are available to derive primary productivity and size structure from satellite data. To monitor spatio-temporal variability in ecological structure related to recent environmental change in the polar region, IOP's based algorithms to derive production and size structure of phytoplankton were developed.

Absorption coefficient in the Southern Ocean and Arctic Ocean was used to replace factors in the vertical generalized production model (VGPM) which is the most frequently used model and using sea surface temperature (SST). Although the model has a large error near sea ice edge, column integrated net primary production, PP_{eu}, was estimated with high accuracy and independently of the SST. Size discrimination model was developed using absorption coefficient ratio and spectral slope of scattering coefficients in the Arctic Ocean. The algorithm provides the ratio of large phytoplankton larger than 5μm and represented the dominance of smaller phytoplankton in summer of 2007. These bio-optical algorithms based on the IOP's will reveal more detailed aspects on a change in lower trophic levels in the polar oceans than using only chlorophyll *a*.

May 23, 16:25 (S5-7429)

Abundance, composition and development of zooplankton in the subarctic Iceland Sea in 2006, 2007 and 2008

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The abundance, composition and development of zooplankton in the subarctic Iceland Sea was studied in relation to hydrographic features and phytoplankton growth during three years (2006-2008), based on large scale sampling from surface waters and depth stratified sampling from the whole water column at selected sites. Zooplankton stayed deep during winter (~200-1000 m, ~0°C), had ascended to the surface layers by May (~0-100 m) and returned to deeper layers after August. Mesozooplankton diversity in late summer was highly variable but tended to be highest near the shelf edges and lowest in the central Iceland Sea. Redundancy analysis (RDA) showed that 29% of mesozooplankton variability was explained by five variables (salinity, year 2008, bottom depth, temperature and chlorophyll *a*). Three main zooplankton communities were identified; 1) Atlantic community in the eastern region with *Calanus finmarchicus*, *Pseudocalanus* spp. and Chaetognaths as most abundant, 2) Arctic community at relatively high latitudes and longitudes with realitvely high numbers of *C. hyperboreus, C.glacialis* and *Microcalanus* spp., and 3) a community with coastal affinities at lower latitudes with relatively high numbers of *e.g. Temora longicornis*, *Acartia* spp. and larvae of benthic animals. This community was particularly evident in 2008. The distribution pattern of macrozooplankton was found by the RDA analysis to be related to that of chlorophyll *a* and salinity. In general, results show that the region is a meeting place of Arctic and Atlantic species, with the copepods *C. finmarchicus* and *C. hyperboreus*, the amphipod *Themisto abyssorum* and the euphausiid *Thysanoessa longicaudata* as key players.

May 23, 16:45 (S5-7426)

Reading between the lines: Bivalve growth rate variations across the Barents Sea Polar Front

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Analysis of bivalve shell increments provides a means to reconstruct long-term patterns in growth histories and assess factors that regulate marine ecosystems. Through the IPY, we examined shell growth patterns and tissue stable isotopic composition ($\delta^{13}C$ and $\delta^{15}N$) of two Arctic bivalve species (*Clinocardium ciliatum* and *Hiatella arctica*) in the northwest Barents Sea to evaluate the influence of different water masses and the polar front on growth and to assess the influence of climatic variability on ecological processes over decadal scales. Overall shell growth rates were highest in Atlantic water compared to those from Arctic water and the Polar Front, despite the greater depth of the Atlantic water sites. Tissue stable isotope values progressively increased from Polar to Atlantic waters, with Polar waters enriched in $\delta^{13}C$ by 2.3‰ and in $\delta^{15}N$ by 1.8‰ compared to Atlantic waters. These results reveal differences in food sources, quantity, timing, and in pelagic-benthic coupling between water masses of the Barents Sea on relatively small spatial scales. Temporal patterns of ontogenetically-adjusted growth oscillated between periods of higher and lower growth coincident with variations of the North Atlantic Oscillation (NAO) and local environmental variables, with the former explaining up to 43% of interannual variation in growth. A declining trend in standardized shell growth over the 32-year chronology may be indicative of climate change in the region. These results demonstrate that sclerochronological analysis of benthic bivalves is a useful tool in assessing possible effects of climatically driven changes in water mass distributions in the Barents Sea.

May 23, 17:05 (S5-7496)

Cetacean habitat distribution in the eastern Bering Sea and Chukchi Sea

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Many Cetacean species are found in the eastern Bering Sea and Chukchi Sea, and they play the important role in the ecosystem; however, few studies have been conducted for cetaceans and knowledge of their habitat is very limited. The objectives of this study are to clarify the distribution and the oceanographic condition of cetaceans in the eastern Bering Sea and Chukchi Sea, and then to construct suitable habitat area using satellite remote sensing. Cetacean distribution data were taken from cetacean sighting surveys during the North Pacific cruises 2003, 2005-2008 conducted by T/S *Oshoro-Maru* that belongs to Hokkaido University. From these surveys, including IPY cruises (2007 and 2008), we chose 7 species (4 species of baleen whales and 3 species of toothed whale) for this study. To understand spatial and temporal oceanographic characteristics of the cetacean sighting positions, MODIS/AQUA sea surface temperature (SST) and chlorophyll *a* concentration (Chl-*a*), and bathymetry data were analyzed. First, we extracted oceanographic data from satellite data at cetacean sighted positions. Next we clustered and overlaid these data to clarify the cetacean distribution. To analysis and cluster the data, we used ArcGIS9.3. Each species characteristic habitat was examined by overlaying the environmental variables. Finally, we examined Generalized Linear Models (GLM) to further investigate their habitat (presence/absence). The results from GLM indicate that the different variables contribute to each species habitat.

May 23, 17:25 (S5-7483)

Winter ecology of Common Eiders in polynya and floe edge habitats in eastern Hudson Bay, Nunavut

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Polynyas and floe edges in east Hudson Bay provide important winter habitat for wildlife, particularly Common Eiders and their benthic invertebrate prey. Our research investigates how sea ice and oceanographic conditions influence the foraging and community ecology of eiders in these habitats. Eiders require open water to dive for food like mussels and sea urchins, and so their winter foraging range is constrained by sea ice extent. Strong currents can maintain open water, but influence diving and foraging costs. As currents increase in speed, profitability decreases non-linearly and eiders stop diving and rest on the ice edge in peak currents of the tidal cycle. Using foraging data of wild birds, we present a multi-scale approach which considers tradeoffs between short term diving energetics, medium term digestive bottlenecks, and longer term periodic changes in profitability over tidal, diel and lunar time scales. We demonstrate how the interactions among these rate processes can produce regime shifts in foraging dynamics and lead to adaptive strategies that are seemingly counter-intuitive. This quantitative individual based approach provides a mechanistic understanding of winter survival that can be linked to landscape and population dynamics. In conjunction with oceanographic deployments, we are now using time lapse imaging technologies to simultaneously monitor wildlife and sea ice dynamics in these habitats as part of a community based research and monitoring program. This will be particularly important for understanding the response of sea ice ecosystems in Hudson Bay to hydroelectric developments and climate related environmental change.

May 23, 17:45 (S5-7389)

Seabirds respond to Arctic ecosystem change and identify risk

William A. **Montevecchi**[1], Gail Davoren[3], April Hedd[1], Laura McFarlane-Tranquilla[1], Anthony Gaston[2], Chantelle Burke[1], Paul Regular[1], Grant Gilchrist[2], Greg Robertson[3], Paul Smith[2], Dave Fifield[1,2] and Richard Phillips[4]

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Vessel surveys of capelin (keystone forage fish) and oceanographic conditions concurrent with seabird diet collection in the Low Arctic indicate that warmer ocean temperatures result in murres delivering fewer gravid capelin (most energy rich, preferred prey) and gannets consuming less capelin at colonies. Tracking studies of murres from 7 colonies ranging from High to Low Arctic regions (Nunavut to Newfoundland) in eastern Canada revealed species, colony and individually-specific wintering areas and movement patterns with inter-annual consistency. High Arctic Thick-billed Murres migrated longer distances and wintered further north than Low Arctic Common Murres. Important wintering areas were identified, *e.g.* Grand Bank shelf-edge (particularly for Common Murres), Davis Strait, Labrador Sea, and SW Greenland (for Thick-billed Murres). Murre species overlapped considerably on the Grand Bank and along coastal Newfoundland. Different wintering areas carry different climatic and anthropogenic risks – inshore sea ice entrapment, hunting, by-catch in gillnets, ship-source pollution and offshore oil platforms. For example, changes in High Arctic ice conditions (2007, 2009) facilitated inshore spring "wrecks" of Thick-billed Murres in Newfoundland. We document previously unknown off-shelf pelagic movements of murres during spring, some near the Mid-Atlantic Ridge, revealing a high use oceanic area also exploited by murres from Arctic regions in the northeastern Atlantic and a diversity of other seabird species and top predators. This new information improves understanding of how fitness and population dynamics integrate with seasonal/annual cycles of habitat use and ocean climate. This helps mitigate anthropogenic influences that interact with climatic effects on Arctic animals and coastal communities.

May 24 Plenary Session

May 24, 8:30 (S4-7541), Invited

The boreal ocean in the enhanced greenhouse

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Climate change and ocean acidification will affect all aspects of ocean ecosystem function in the future and have likely already begun to do so. High-latitude ecosystems are among the most vulnerable due to the naturally shallow depth of the calcite and aragonite saturation horizons and, in the northern hemisphere, large inputs of fresh water. Impacts on some ecosystem components such as calcifying phytoplankton profoundly affect the rest of the ecosystem by altering water chemistry. Models of these processes remain rudimentary. The Canadian Earth System Model is a fully coupled climate/carbon-cycle model with prognostic ocean and terrestrial carbon cycle models; the model has been used to simulate the historical climate using known emissions, and future climates, using IPCC emission scenarios and Representative Concentration Pathways. Model projections for future climates include substantial change in ocean biogeochemistry in the mid-to-high-latitude northern hemisphere, including a shoaling of the aragonite saturation horizon and reduced primary and export production. Much of the flux of organic matter to the sediments occurs in boreal marginal seas, so future climate changes have the potential to impact benthic as well as pelagic ecosystems, even at depths of hundreds to thousands of meters.

May 24, 9:00 (S8-7526), Invited

Fluctuations in recruitment of snow crab in the Eastern Bering Sea and the role of cod predation

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Landings of snow crab from the eastern Bering Sea have declined from a maximum of nearly 150,000mt in 1991 to historical lows on the order of 12,000mt by 2000, as the geographic range of the snow crab spawning female stock contracted dramatically to the north. This phenomenon has been addressed by the Environmental Ratchet Hypothesis, claiming that the contraction resulted from a combination of circulation patterns, the spatial dynamics of benthic stages in relation to near-bottom temperature, and cod predation. Recruitment to the mature female pool cycled regularly with a period of approximately 7 years and declining amplitude; the period matches time between egg extrusion by a female and terminal molt of her female progeny. Correspondence suggests a dynamic linkage between the pulses, with each one in the sequence becoming the parental stock for the subsequent. The principal source of mortality of immature benthic stages of snow crabs is cod predation on Instars iii-vii, settled 1-4 years earlier. Geographic spread of immature females in cod stomachs during the summers contracted one year after pulse core years, and expanded abruptly one year later. As the geographic spread of immature crab found in cod stomachs expanded, there was an increase in the relative significance of Instar iv, which became overwhelmingly dominant three years after pulse core years. Cod predation tracks the cycle of recruitment in time and space and may contribute to the environmental ratchet effect, but does not appear to control the cyclic pattern of recruitment.

May 24, 9:30 (S8-7344), Invited

Oceanography and northern shrimp (*Pandalus borealis*, Krøyer 1838) recruitment variability in the Gulf of St. Lawrence and northwest Atlantic

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Northern shrimp (*Pandalus borealis*) is the most abundant shrimp species in the northern Gulf of St. Lawrence (GSL) while Atlantic cod (*Gadus morhua*, Linnaeus 1758) is the dominant large gadoid in the area. In the early 1980s, cod biomass was estimated at ~400,000 tons; biomass is now estimated at ~30,000 tons, following the population's collapse in the early 1990s. While the absence of survey data before 1990 precludes the study of interactions with cod during the period of high cod abundance, research surveys since 1990 indicate that positive trends in shrimp biomass were observed while the cod biomass was still decreasing in the early 1990s. However, since 2000 strong fluctuations have been observed in shrimp biomass even though cod biomass remains low. This seems to indicate that recruitment success is the most important factor explaining these fluctuations. Our recent investigations on shrimp in the GSL and the northwest Atlantic demonstrated the influence of spring oceanographic conditions on recruitment. Remotely sensed data were used to derive ocean surface characteristics (spring phytoplankton bloom and sea surface temperature [SST]) affecting shrimp productions at crucial moments in larval development. Throughout the northwest Atlantic, hatching is correlated with bloom timing and larval survival is positively associated with bloom duration and high SST warming rates following hatching. In the context of climate change, northern shrimp populations could be negatively affected by changes in the timing of hatching, timing of the bloom and water temperatures during larval growth and development.

May 24, 10:00 (S1-7470), Invited

Pelagic-benthic coupling and important regulating mechanisms across the European Arctic and sub-Arctic regions

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The European Arctic and sub-Arctic comprise several functionally different regions, exemplified as flowthrough shelves (Barents Sea), outflow shelves (East Greenland shelf), gateways (Fram Strait) and the Arctic Deep Ocean. The regions are characterised by differences in ice conditions, in Atlantic and Arctic water influence, and in the strength of stratification. These different physical characteristics have strong impacts on the ecosystems with differences in annual primary productivity, grazer community, and distribution of organic matter between pelagic and benthic systems, *i.e.* the pelagic-benthic coupling. Since the mid-90ties, short-exposure and high vertical resolution sediment trap studies (20-200m) have been combined with studies of the pelagic plankton community in all these regions to identify processes important for vertical carbon flux regulation. A compilation of these data has given rise to a conceptual scheme suggesting how the vertical carbon export may change in the different regions as a response to the predicted changes in sea-ice cover, stratification and productivity. The important role of grazers, including meso- and microzooplankton, for vertical flux regulation is also exemplified through their ability, when present, to consume a considerable fraction of the potential vertical export, preventing nutrients and energy from being lost from the pelagic food web. The possibility of short-circuiting this retention, both through mixing and grazing by specific zooplankton groups, is also of importance. The species and stage composition of zooplankton, their spatial- and vertical distribution, along with the physical water column structure will therefore play an important role for the pelagic-benthic coupling in future sub-Arctic and Arctic regions.

May 24, 11:00 (S1-7476), Invited

The impact of changing sea ice and hydrographic conditions on biological communities in the northern Bering and Chukchi Seas

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Observations indicate that changes in the timing of sea ice formation and retreat, along with increasing seawater temperatures, are driving shifts in marine species composition that likely signal large-scale marine ecosystem reorganization. In recent years, wide variability in seasonal sea ice retreat in the northern Bering Sea has been observed, but to the north in the neighboring Chukchi Sea ecosystem there has been consistent and large early season ice retreat and historically late sea ice formation in the fall months. The latitudinal gradient in sea ice persistence, chlorophyll concentrations, and carbon export to the sediments from the northern Bering Sea to the Chukchi Sea has a direct impact on ecosystem structure in this subarctic-arctic complex. Variations in seawater hydrography, light, primary production, pelagic-benthic coupling and benthic carbon cycling are all tied to sea ice and temperature changes. Potential biological impacts include shifts in species composition and abundance, trophic transfer efficiency, and northward range expansions. One consequence might be a transitional change from a benthic-dominated northern Bering and Chukchi shelf region to a more pelagic-dominated system, with a direct impact on higher trophic level productivity. Several programs undertaken during recent years, including the Bering Sea Research Program, Canada's Three Oceans, the Russian US Long-term Census of the Arctic Ocean, and the Western Arctic Shelf-Basin Interactions are providing insights into the key processes influencing ecosystem function and change in this region. Data sets from these programs will be discussed in the context of biological response to sea ice changes.

May 24, 11:30 (S6-7406), Invited

Recruitment variability of Japan Pacific walleye pollock: A synthesis from DoCoFis Program

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The recruitment of Japan Pacific population (JPP) of walleye pollock, one of the most important fishery stocks in Japan, has varied by an order of magnitude. To clarify the factors determining the year class (YC) strength of JPP, a joint research program, DoCoFis-pollock, was established in 2006. This project comprised studies on physical oceanography, satellite imaging, egg and larval distribution/abundance, juvenile ecology and modeling. It was based on the 'traffic light' concept model (Shida *et al.*, 2007); a strong YC occurs when all of the processes (traffic lights) are favorable for survival. In the course of the 5 years of studies, some processes were confirmed to be critically important while some others were less important. The factors crucially affecting the YC strength were: 1) flow field in the spawning ground (*i.e.* balance between Coastal Oyashio Current and northwesterly seasonal wind), 2) hatch date distribution of settled juveniles and 3) post-settlement mortality in the nursery ground. Based on the results, we pose a new hypothesis on the generation of a strong year class in the JPP pollock.

May 24, 12:00 (S6-7343), Invited

The Sea of Okhotsk: Some conceptions applying to climate-oceanography events and fish resources dynamics

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The Sea of Okhotsk is distinguished by its high biological productivity and significant impact on the surrounding waters of the ocean. The sea large-scale warming is defined by oscillation of the oceanic East Kamchatka and Soya Currents. East Kamchatka Current is the western part of Pacific Subartctic Gyre that allows seeking similarity in tendencies within the total Gyre area. The intensity of currents is often related to the predominant type of atmospheric circulation. Under the spring predominance of Okhotsk-Aleutian type of atmospheric circulation, there was observed a significant penetration of Soya Current into the Sea of Okhotsk and summer warming in the southern area. The periodic cooling and warming processes influence the Okhotsk Sea ecosystem and cause the long-term dynamics of biological communities. The 1970-1980s are characterized as a period of matching of warm climatic-oceanological shift and a very high level of fish stocks. In the Sea of Okhotsk the maximum total biomass was caused by the large stocks of gadoid fishes, primarily walleye pollock. The first half of the 1990s was noted as a transitional period when the marine ecosystem appeared to be restructured. There was an abrupt decrease in walleye pollock resources, but increase in herring biomass. Overall, the total biomass of fish of the Sea of Okhotsk in the mid-1990s has decreased by at least 10 million tons. In the early 2000s, the situation had reached a critical level, but at the end of the first decade signs appeared indicating some sea warming and renewal of the walleye pollock resources.

S1- day 1 Oral Presentations

May 24, 14:05 (S1-7408), Invited

Comparison of ecological characteristics of fish communities and oceanographic features in coastal areas of the western and eastern North Pacific Ocean

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Due to the differences in oceanographic features, ecosystem structures and fisheries have different characteristics in the western and eastern North Pacific (NP). Warm and cool currents merge at mid latitudes in the western NP, and flow eastward forming a meander and rings, while the current diverges toward the pole and equator near the coast in the eastern NP. There is a relatively broad continental shelf and some semi-closed regional seas in the western NP, while there is a narrow continental shelf, some sounds and an archipelago off the continent in the eastern NP. Changes in sea surface temperature have shown different spatial patterns between the two regions in recent years. The expectation is that the warming rate of the surface air temperature during this century will be about 1.5 times higher in the western NP than in the eastern NP. Long longevity and demersal behavior is common in fish populations of the eastern NP, while small pelagic fish (SPF) with short longevity dominates in the western NP. The tendency of increasing levels of invertebrates such as jellyfish and squids is common, but the intensity of invertebrate outbursts seems to be higher in the western NP. As common features in recent years, there has been a northward movement of fish populations, increases in salmon in surface layer, and decreases in groundfish at depth. Especially, pink salmon biomass in both regions has fluctuated in a similar way, following climatic regime shifts in the 20th century.

May 24, 14:35 (S1-7475)

Remote climate forcing of regime shifts in Northwest Atlantic shelf ecosystems

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Regime shifts in Northwest Atlantic shelf ecosystems can be remotely forced by climate-associated atmosphere-ocean interactions in the North Atlantic and Arctic Ocean Basins. This remote climate forcing is mediated primarily by basin- and hemispheric-scale changes in ocean circulation. Here, we synthesize results from process-oriented field studies and retrospective analyses of time-series data to document the linkages between climate, ocean circulation, and ecosystem dynamics. Our results demonstrate that bottom-up forcing associated with climate plays a prominent role in the dynamics of these ecosystems, comparable in importance to that of top-down forcing associated with overfishing. We conclude that a broad perspective, one encompassing the impacts of basin- and hemispheric-scale climate processes on marine ecosystems, will be critical to the sustainable management of marine living resources.

May 24, 14:55 (S1-7368)

Climate effects on Baltic Sea sub-ecosystems: A comparison using a meta-analytical approach

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6 Institute of Food Safety, Animal Health and Environment, Fish Resources Research Dept., 8 Daugavgrivas Str., LV-1048, Riga, Latvia
7 NationalInstitute of Aquatic Resources, Technical University of Denmark, Charlottenlund Castle, DK-2920, Charlottenlund, Denmark

The Baltic Sea, the largest brackish water system in the world ocean, can be described as a series of regional sub-ecosystems. These are situated along gradients of temperature, salinity, biodiversity and species composition. These gradients provide ideal preconditions for a comparative study of the impact of climate on ecosystems which vary from truly marine to almost limnic, and from temperate to sub-polar. Here we investigate changes in structure and function of six Baltic Sea sub-ecosystems. We use long-term time-series representing multiple trophic levels from phyto- and zooplankton to planktivorous and piscivorous fish. We test for the impact of hydro-climatic variables on single populations, on composite indicators of trophic levels and on holistic ecosystem indicators derived by multivariate statistical analyses. Subsequently, we conduct a Random-Effects Meta-Analysis using derived correlation coefficients as effect sizes. The meta-analytical approach allows us to evaluate the overall effect of climate across all sub-systems, and to test for differences in effect sizes between systems and trophic levels. Finally, we conduct an analysis of changes in trophic control as a potential mechanism mediating climatic to structural ecosystem changes. For every sub-ecosystem we perform moving correlation analyses and model the derived correlation coefficients as functions of hydro-climatic variables, fishing pressure and nutrient loads using Generalized Additive Modelling. By applying this combination of statistical techniques with a unique long-term, multi-site and multi-trophic level data set, we show the interplay between climate and other anthropogenic impacts in causing large-scale ecosystem changes.

May 24, 15:15 (S1-7355)

Effect of climate change on marine ecosystems and material cycles: Time-series observations in the sub-arctic and sub-tropical gyres

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Climate change has been causing changes in the ocean such as increased water temperatures and stratification and acidification. It is expected that these changes will affect marine ecosystems and material cycles (*e.g.* carbon cycle). In order to clarify the mechanisms of changes in marine ecosystems and the material cycle, and investigate how these changes feed back to the climate, we have initiated comparative time-series observations at sub-arctic and sub-tropical stations (K2: 47N/160E, S1: 30N/145E), which have different oceanography and external forcings. During cruises in winter (January-February) and autumn (October-November) 2010, the following biogeochemical characteristics were observed: 1) diatoms were predominant at K2 compared with S1, 2) the concentration of nutrients at S1 was very low even in winter, 3) K2 is source for CO_2 to the atmosphere in winter and sink in autumn, while S1 is sink all year round, 4) primary productivity at S1 was higher than that at K2 in winter and vice versa in autumn. In addition to these observations, the roles of zooplankton and bacteria in the carbon cycle were also investigated. As well as repeated hydrographic measurements, time-series observations for primary productivity and material fluxes were made using a fast repetition rate fluorometer (FRRF) profiler and moored sediment trap systems. Sediment trap observation revealed that the maximum total mass flux was in May at 200m, and that this peak also appeared at 500m and 4810m with time lags. Total mass fluxes and seasonal variability were less at S1 than at K2.

May 24, 15:35 (S1-7418)

Comparison of decadal changes in the carbon sink and potential responses to climate change in the western Arctic Ocean and the Southern Ocean

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Polar oceans play an important role in the global carbon cycle. Model results show that the Southern Ocean (SO) carbon sink has weakened with global climate change. Our results over 9 years of observation, however, show that this is only partly true. Using the icebreaker R/V Xuelong, underway pCO_2 observations in the air and surface water were made during the CHINARE (Chinese National Antarctic Research Expedition) cruises held in the austral summer of 1999/2000, 2004/05 and 2007/08 respectively. Overall, the pCO_2 in surface sea water increased faster than it increased in the air and there was ocean acidification. There were, however, seasonal differences, so that the above was the case in December, but not in January. The difference in pCO_2 between air and the surface sea water (ΔpCO_2) decreased dramatically from 1999 to 2007 in December, but not in January. Instead, calculations of carbon flux reveal that the SO carbon sink was stable in December and increased markedly in January. One reason for this change is the enhancement of the wind speed in the SO. However, the difference in the ΔpCO_2 change between December and January suggests that the biological pump in the SO might have been enhanced under climate change. This is a potential feedback of the SO to climate change.

Underway pCO_2 observations of the atmosphere and surface waters were also made during the 1st, 2nd, 3rd and 4th Chinese National Arctic Research Expedition cruises between July and September in 1999, 2003, 2008, and 2010. The Arctic carbon sink increased between 1999 and 2010, as sea ice cover decreased. Our summer 2008 CO_2 data especially suggest that increasingly early ice-melt will greatly increase the air-sea CO_2 flux in the western Arctic Ocean. Increased ice melt in summer is projected to occur in the future with increasing speed. The increased CO_2 uptake by the Arctic Ocean slopes and basins, thus, may provide a negative feedback mechanism to reduce atmospheric CO_2 and thus the rate of global warming. This CO_2 sink may gradually weaken, however, since our data also suggest that completely ice-free conditions in the slope and basin areas for prolonged periods during the summer may result in increased surface pCO_2 and reduced CO_2 flux (although it will remain higher than today). Furthermore, increased warming and ice-melt will also promote permafrost thawing in the Arctic landmass and thus increase river inputs of DIC and organic carbon, which will likely be recycled as CO_2, further reducing the capacity of the Arctic Ocean to absorb atmospheric CO_2.

May 24, 16:25 (S1-7388)

Comparison of decadal and interdecadal dynamics of mass pelagic fish stocks in the North Atlantic and North Pacific in relation to climate variations in the Northern Hemisphere

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A comparison of ecosystem functioning in the western and eastern subarctic (and arctic) regions of both the North Atlantic and North Pacific shows the essential differences in their response to decadal and interdecadal climate variations. This is most evident for the catch dynamics of important commercial fish species. However, a comparison of decadal and interdecadal changes in the Norwegian and Barents Sea ecosystems with those in the Far East marginal seas and in the western boundary currents of the Western Subarctic Gyre of the North Pacific demonstrates their synchronous response to climatic variations at the same time scales. This is seen most clearly in the interdecadal variability of the Norwegian spring-spawning herring and Far East pink salmon stocks. The analysis of physical and biological factors determining this synchronicity showed that the main reason appears to have been the simultaneous shift in the timing of the start of the spring bloom, the peak of spring and summer zooplankton development, and the duration of production season, which have occurred over multidecadal time scales of climatic regimes in the Northern Hemisphere. The earlier beginning of blooming and longer duration of the production season favor an increase in the stock abundance, and vice versa. The main physical predictors of the above changes are discussed. In particular, the reason for expectations for a strong year-class of herring in 2012 and high pink salmon catches in 2011-2015 will be discussed.

May 24, 16:45 (S1-7517)

The impact of climate variability and change on the Barents Sea and the North Sea: A comparison

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We compare a boreal ecosystem, the North Sea, and a sub-polar one, the Barents Sea, with the aim of analyzing the impacts of climate variability and change on the structure and function of both systems. Both systems share physical and biological commonalities, but also exhibit distinctive differences. They are both relatively shallow, partly enclosed shelf seas with strong tidal currents resulting in regions of well-mixed waters separated from deep stratified ones. They also support important commercial fish species such as cod and herring. Due to its more northern location, the Barents Sea has distinctly cooler temperatures and is characterised by seasonal ice coverage over its northern half. In contrast to the North Sea, the Barents Sea ecosystem is under a much stronger influence of advection of warmer Atlantic waters from the south bringing heat, salt, nutrients and plankton. The main differences in zooplankton and fish communities are the dominance of *Calanus finmarchicus* and capelin in the Barents Sea, the latter being an important prey for cod and herring. Both ecosystems are impacted by the same large-scale atmospheric and hydrographic forcing. For example, both reacted concurrently to the drastic increase of the NAO index in the late 1980s with step-wise changes in physical and biological variables indicating ecosystem regime shifts. However, whereas North Sea cod biomass decreased with increasing temperatures associated with the NAO strengthening, Barents Sea cod biomass increased. Both systems have shown strong reactions to the multi-decadal dynamics of the AMO over the last century, as indicated by the temperature-related pole-ward movements of fish and benthic organisms during warm periods.

May 24, 17:05 (S1-7448)

Using production models as tools to examine factors that influence productivity of marine systems: Contrasts across levels of aggregation, ecosystems and drivers

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The inherent complexity and large-scale of marine ecosystems suggest that progress toward understanding how they influence and regulate patterns of fisheries production requires a comparative approach. We present the results from the second year of an international workshop focused on applying various surplus production model configurations as a tool for ecosystem comparison with the goal to answer the question - how does ecosystem structure and function interact to support fisheries production, and what processes amplify, dampen or obstruct the production that ecosystems provide? Our workshop goals have been to understand how multiple drivers of productivity in fishery ecosystems simultaneously interact to determine overall production levels. The production modeling was applied to 10 northern hemisphere ecosystems and results compared across systems, levels of species aggregation, and drivers. We also estimate management-relevant metrics and ecosystem attributes, similarly comparing them. We also describe the utility of applying surplus production models in single-species, multi-species, and aggregate species group frameworks. We conclude by elucidating challenges of fitting such modeling approaches to similar species or functional guilds in contrasting arrangements (different species within ecosystems and similar species among ecosystems) to better delineate what controls ecosystem fisheries production. Preliminary results confirm that Systemic Yield is less than the sum of SS Yields, which has important ramifications. Further implications of our results for future work relevant to operational oceanography, population and community modeling, and ecosystem-based fisheries management are also discussed.

May 24, 17:25 (S1-7438)

Comparisons of Southern Ocean ecosystems

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The structure of oceanic ecosystems is maintained by biological and physical process interactions at multiple scales. Here we consider key processes that determine the structure and variability of Southern Ocean food webs at local and regional scales. We compare the general structure and dynamics of local ecosystems around South Georgia and West Antarctic Peninsula regions. We consider the process interactions in these ecosystems, where biological processes interact with sub-mesoscale and mesoscale physical processes associated with shelf and shelf-edges to generate spatial structure that underpins food web operation. At larger regional scales, across the Scotia Sea and along the Antarctic Peninsula, marked differences in seasonality and local patterns of circulation generate significant differences in dynamics. We also consider the processes generating interannual variability and change in these areas and examine the responses of key species and food webs to variability and how these regional systems operate as part of the wider circumpolar ecosystem. These analyses highlight the open and connected nature of regional ecosystems and the importance of quantifying the spatial and temporal operation and variability of such large scale ecosystems. The resulting complexity of the operation of these large scale ecosystems highlights the requirement to consider the inherent uncertainty in our analyses and models of ecosystem operation and structure. Such analyses should consider multi-scale analyses at local, regional and circumpolar scales and cross scale interactions encompassing multiple levels of biological organisation.

May 24, 17:45 (S1-7361)

Comparative spatial dynamics of krill and predators at mid and high latitudes: Implications for trophic transfer and conservation

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A framework for comparing marine ecosystems, explicit in scale and treatment, is needed to understand and forecast future responses of marine systems to climate and other anthropogenic pressures (*e.g.*, fishing). In concept, investigations of predator-prey dynamics between areas where predators and prey fill similar niches should provide the insight we seek. In the Southern Ocean and California Current Ecosystems (CCE), krill are integral to ecosystem organization and food web dynamics. Penguins and auks, shearwaters and petrels, and baleen whales, respectively, comprise key predator communities on which a comparative analysis of marine ecosystem functions can be based. In this study, we investigate the spatial organization of krill patches and its influence on predators in mid and high latitude marine ecosystems. We use data from 2 studies where foraging seabird, whale, and krill distributions were collected simultaneously between 2000 and 2010. Seabird density was mapped using visual surveys simultaneously with krill sampling via a combination of hydroacoustics and nets. We map krill hotspots and test the hypothesis that krill-predators forage in regions of high spatial persistence where patterning (i.e. size and connectivity) of krill patches is maintained by predictable physical oceanographic properties, such as fronts and shelf-break habitats. Key questions to be addressed are: 1) Where are the persistent krill-predator 'hotspots' in representative study regions? 2) Are krill-predators hotspots in the Antarctic the same size/shape as those in the CCE? 3) Do similar krill predators (*e.g.* auks and penguins) respond in similar ways to krill patchiness? We conclude by addressing how climate change may alter the stability and predictability of krill-krill predator dynamics in these disparate marine ecosystems.

S6 Oral Presentations

May 24, 14:05 (S6-7436)

The ecosystem of the Iceland Sea 2006-2008: Main patterns in structure and function

Olafur K. **Palsson**, Astthor Gislason, Bjorn Gunnarsson, Hafsteinn Gudfinnsson, Hildur Petursdottir, Solveig Olafsdottir, Sveinn Sveinbjornsson, Konrad Thorisson and Héðinn Valdimarsson

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The Iceland Sea Ecosystem Project was carried out during 2006-2008. The main objective of the program was to analyse principal patterns in the ecosystem, with particular attention to changes in distribution and behaviour of the capelin stock in the area since the mid 1990s. Large amount of data were collected in 10 surveys, covering mainly February – August. The main focus was on patterns and processes in hydrography (physical and chemical), primary production, phytoplankton biomass, and composition, zooplankton abundance and composition and trophic pathways, and capelin larval and adult life history. The main results of analyses of these data (presented in more detail in several, in-depth contributions at this meeting) are summarized in a comprehensive description of the structure and function of the Iceland Sea ecosystem, including the adjacent waters of north Iceland and east Greenland.

May 24, 14:35 (S6-7362)

Density-compensating fronts in the Norwegian and Barents Seas and their biological influence

Kenneth F. **Drinkwater**[1] and the NESSAR Team

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The IPY Project NESSAR (Norwegian Ecosystem Studies of Subarctic and Arctic Regions) examined the physical dynamics, as well as the structure and function of the marine ecosystems, in and around the Arctic Fronts separating Atlantic and Arctic waters in the Norwegian and Barents seas. Field studies during 2007 and 2008 were carried out on the Jan Mayen Front between the Norwegian and Iceland Seas and the Polar Front in the Barents Sea. These fronts exhibit strong horizontal gradients in temperature and salinity but weak density gradients owing to density compensation. There is intense interleaving of the two water masses in the vicinity of the fronts and although there is elevated turbulence levels there owing to both current shear and double diffusion, the levels are still relatively weak. There is no evidence of increased primary production or high phytoplankton biomass in the front. Small zooplankton appears to be more prominent at the front and large zooplankton away from the front in the Barents Sea. The fish distributions (herring in the Norwegian Sea and capelin in the Barents Sea) relative to front will also be discussed. Finally some preliminary comparisons between the two regions will be presented.

May 24, 14:55 (S6-7351)

Climate effects on the Barents Sea ecosystem dynamics

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The Barents Sea is a productive shelf ecosystem sustaining many ecologically and economically important fish species. Zooplankton (copepods, krill and amphipods) are major prey items for many pelagic plankton-feeding fish, which in the Barents Sea are young herring (*Clupea harengus*), capelin (*Mallotus villosus*) and polar cod (*Boreogadus saida*). Zooplankton also constitutes a large part of the diet of demersal fish such as cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), especially at younger ages. Even the trophic levels higher up in the food chain (mammals and sea birds), benefit through feeding directly on zooplankton or indirectly by consuming plankton feeding fishes. Climate effects such as increase in temperature and changes in currents are likely to affect the productivity and structure of polar ecosystems. It is already evident that large shifts in plankton communities are occurring especially in the North Sea, and in the southern Norwegian Sea, and these changes already have consequences on the fisheries in some of these regions. Modification in the plankton community in the Norwegian Sea may have implications on the productivity of the Barents Sea ecosystem as plankton is advected into the region through the inflowing warm North Atlantic Current (originating from the Gulf Stream). The sea ice dynamics in the polar ecosystems are also changing and will most likely lead to changes in primary and secondary production in the Arctic region. The current investigations focus on ecosystem studies, exploring structural and productivity changes in the Barents Sea plankton community due to climate variability. Main focus of this study will be: 1) role of advection and other climate driving forces on zooplankton dynamics, 2) predator - prey interactions and, 3) shifts in zooplankton communities in the subarctic and arctic as a response to climate change and its consequences on higher trophic levels.

May 24, 15:15 (S6-7474)

Comparison of spring bloom dynamics between the subpolar Norwegian Sea and the polar front in the Barents Sea

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Differences and similarities in the response of the mesozooplankton community to spatial and temporal patterns of phytoplankton distribution are analysed based on data collected during spring 2003 off the shelf break in the northern Norwegian Sea, and in spring 2008 at the polar front in the Barents Sea. High-resolution data were collected using an optical plankton counter, a CTD (Conductivity, Depth and Salinity) sensor, and a fluorometer mounted on a towed instrument package. Based on the observed data, relationships between hydrographic, chlorophyll and zooplankton fields in both systems were analysed. The slope of the biovolume spectra allows us to estimate population process rates and trophic interactions in these two different systems. Additionally, at the polar front growth rates estimated from grazing experiments were analysed with respect to the phytoplantkon and microzooplankton community.

May 24, 15:35 (S6-7370)

Interannual variability of the surface heat fluxes and potential air-sea coupling in the Nordic Seas and their links with the Arctic Oscillation

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The average sea level pressure in the Nordic Seas is significantly correlated with the Arctic Oscillation (AO) Index. To identify possible thermal dynamical links for this correlation, the air-sea heat fluxes provided by the NCEP-DOE Reanalysis 2 were analyzed. The variations of net short-wave and long-wave radiation in all four basins (Greenland and Iceland Seas, Norwegian and Lofoten Basins) are well correlated but show low contribution to the AO index variability. On the other hand, sensible and latent heat fluxes show stronger association with the AO index but important differences between basins. Sensible heat fluxes are highest, with the maximum anomaly in the Greenland Sea. Latent heat in the Greenland Sea is also larger compared with those in the other basins. The long-term variation of total heat flux over the entire Nordic Seas correlated well with AO index ($r=0.70$; $p<0.05$), suggesting the AO is strongly influenced by the heat flux. The correlation coefficients of the AO index from 1979-2008 are 0.49 with the downward long-wave radiation, 0.52 with the sensible heat flux, and 0.57 with the latent heat flux but are higher for 1979-2000 (0.57, 0.58, 0.72, respectively). The decrease in the correlations after 2000 might be because of Arctic warming. We also describe the regional contribution of heat fluxes to AO index variability to reveal the response of the heat fluxes to variations of the atmosphere and to the heat advection by the warm Atlantic inflow current.

May 24, 16:25 (S6-7427)

Climate related changes in abundance and distribution of mackerel (*Scomber scombrus*) in Icelandic waters

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The Icelandic marine ecosystem is a high productive boreal/sub-arctic system which sustains extensive demersal and pelagic fishery. Since the mid 1990s marked warming has been observed in the North East Atlantic Ocean and in the waters around Iceland along with more extended distribution of warm Atlantic water. Waters in upper layers south and west of Iceland have increased in temperature by about 1-2°C. The same signal but to a lesser degree has been observed along the northern and eastern shelves. Since at about the same time marked bio-geographical changes have been manifested at different tropic levels in the Icelandic marine ecosystem. The most striking in this context is probably an unprecedented increase in North East Atlantic mackerel almost all around Iceland in recent years.

Mackerel has until recently been considered a vagrant species in Icelandic waters and historical records indicate that occurrence is mainly related to warm periods in the North Atlantic Ocean and around Iceland. Systematic records of rare fishes in Icelandic waters demonstrate that recent occurrence of mackerel began to increase during the mid 1990s and since the early 2000s routine research surveys and information from the fishing fleet have caught gradually increasing numbers. During past four years this major distributional shift has then resulted in a direct fishery which within the Icelandic EEZ has increased from about 1700 tons in 2006 to about 120.000 tons in 2010.

We present information from various sources on the on occurrence of mackerel since it was first recorded (1895) with certainty in Icelandic waters while main emphasis is on changes that have taken place in abundance and distribution since mid 1990s. The findings are considered in the context of climatic variations, competition and overlapping distribution with other pelagic fish and carrying capacity of the marine ecosystem.

May 24, 16:45 (S6-7377)

Greenland Climate Research Centre - Studying climate change up close

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The Greenland Climate Research Centre (GCRC) was established in 2009, but has a solid foundation in previous years of research and monitoring efforts. GCRC's mission *"to gain, integrate and communicate knowledge on natural, technological and social sciences concerning climate change impacting Greenland"* incorporate work on expected impacts of climate change on Arctic marine, limnic and terrestrial environments and on Greenlandic society.

A network of projects was initiated to improve our knowledge of past and present conditions of Greenlandic marine ecosystems and to observe and predict future changes. A central aspect of these projects is the link to the Greenland Ice Sheet, changes to glaciers and freshwater runoff and changing sea ice conditions. The basis for this work is continuous monitoring of a sub-arctic (Godthåbsfjord, SW Greenland) and a high-arctic (Young Sound, NE Greenland) marine ecosystem, combined with field and experimental research.

A regional model (HIRHAM, B2 scenario) for Greenland predicts increased precipitation and higher air temperatures by the end of this century. In the high-Arctic Young Sound, the model predicts a doubling of the ice-free period. This will increase light availability for primary producers. In addition, the future increase in precipitation-evaporation will cause an increased meltwater discharge and double nutrient input to the fjord through an increased estuarine circulation. Increased light availability and nutrient input is expected to triple primary production over the next 50 yrs. The increased flux of organic matter to the seafloor may cause oxygen deficits in protected deeper basins as has been observed in temperate locations.

May 24, 17:05 (S6-7433)

Changes in hydrography and ecosystem structure and function in shelf and deep water regions of the Labrador Sea (1990-2009)

Erica **Head**, Kumiko Azetsu-Scott, Glen Harrison, Ross Hendry, Bill Li, John Loder, Igor Yashayaev and Phil Yeats

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The Labrador Sea is influenced by influxes of arctic water on and along its western and eastern shelves and of Atlantic water along the Greenland slope: the central region contains a mixture of Atlantic and arctic waters and is an area where there is exchange between the surface and deep waters, via deep convection in winter. Over the last 20 years there has been a general increase in air temperatures, which have led to increases in near surface seawater temperatures, modified by changes in the contribution of arctic water over the shelves, and by inter-annual differences in the depth of convection. These changes have led to changes in nutrient concentrations, which vary among regions. As well there has been a discernable decrease in pH, due to increasing levels of carbon dioxide in the air and water. These changes have been accompanied by changes in the abundance, composition and seasonal cycles of phytoplankton and bacteria, and in the species composition of zooplankton and the dynamics of the dominant zooplankton species, the copepod *Calanus finmarchicus*.

May 24, 17:25 (S6-7359)

Fluxes, fishes and feathers: Relationships among the Bering, Chukchi and Beaufort Seas in a time of climate change

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Ocean currents, seasonal sea ice formation, and bottom temperatures determine linkages among and barriers between the biota of the Bering, Chukchi and Beaufort seas. Two currents flow from the Bering Sea to the Chukchi and thence to the Beaufort; the Alaska Coastal Current is depleted of nutrients, whereas the Anadyr Current is replete with nutrients and copepods from the Bering shelf slope. These currents create faunal continuity from the southeastern Bering through the Chukchi. In contrast, the middle shelf of the eastern Bering is marked by a discontinuity at about 60 degrees north, with annual sea ice formation and a permanent layer of cold bottom water in the north; in the south, the bottom water (cold pool), formed by melting sea ice, varies annually in extent and average temperature. These differences have profound effects on the mid-shelf biota. In the north, much of the spring primary production is associated with ice algae and ice-edge blooms, and sinks to the bottom to support a rich benthos. In the south, there is often an open water spring bloom, and much of the primary production is captured by a pelagic food web. Climate warming will reduce the duration and extent of seasonal ice cover there, thereby warming the southern region, and allowing fish populations to shift northward within the southeastern Bering shelf, as is already being observed. However, seasonal ice cover in the north will persist, and the northern regions will remain dominated by benthic-pelagic coupling and cold bottom waters, both barriers to the northward migration of species typical of the southeastern Bering Sea.

May 24, 17:45 (S6-7341)

Hydrographic control of marine ecosystem in the shelf waters of the northern Sea of Okhotsk

Konstantin **Rogachev**

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Northern Sea of Okhotsk is an important summertime feeding ground for pelagic-feeding Bowhead whales (*Balaena mysticetus*) in the western subarctic North Pacific. The present work combines satellite observations with physical measurements (CTD, currents) and zooplankton sampling. Data show that dense populations of large zooplankton (such as the copepod *Calanus glacialis* and shelled pteropod *Limacina helicina*) are concentrated within this important ecosystem. A high density patch of *L. helicina* (>2 g /m^3) was observed in the upper layer. This pelagic mollusk plays a key role in the ecosystem as a food source for predators such as fishes, whales and birds. Satellite data and *in situ* observations revealed anticyclonic eddies in the bays and regional cyclonic circulation in the shelf waters of the north-western Okhotsk Sea. The bays have large discharge by rivers and are therefore considered as the regions of fresh water influence. Regional cyclonic circulation is established due to seasonal change in wind. Intensified cyclonic gyre allows low salinity water to flow northward andstrengthens stratification in the surface layer. This cyclonic circulation retains the *L. helicina* within this gyre. This circulation determines not only the oceanography of the region, but also the distribution of a key species of the ecosystem.

S8 Oral Presentations

May 24, 14:05 (S8-7345)

Effects of climate and gadid predation on red king crab population dynamics in Alaska

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We contrasted the population dynamics of red king crab stocks from three systems: Kodiak Island (Gulf of Alaska, GOA), Bristol Bay (southeastern Bering Sea, BS) and Norton Sound (northern BS). In the late 1970s a climate regime shift caused a benthic community reorganization involving a switch from invertebrates to groundfish, dominated by gadoids, in the GOA and southeastern BS. In the northern BS, this climate change resulted in a large biomass increase without major changes in benthic community composition. Unlike the ice-free GOA, generally warmer conditions since the late 1970s in the BS have been interrupted by occasional years of extensive winter sea ice, which periodically has returned the BS to pre-regime-shift temperature conditions. Crab abundance fluctuated most widely for Kodiak, followed by Bristol Bay, and then Norton Sound; the magnitude of fluctuations in crab abundance appears related to the magnitude of recruitment variability and fishing intensity. Processes regulating crab recruitment strength remain elusive, but appear to involve parental stock size, as well as bottom-up (climate-driven) and top-down (predation) mechanisms. We speculate about bottom-up mechanisms, which seem to be indexed by the Pacific Decadal Oscillation index. Predation is indicated by a negative association between crab recruitment and biomass of Pacific cod *(Gadus macrocephalus)* and other groundfish for both Kodiak and Bristol Bay, but not for Norton Sound. Understanding the role of predation is constrained by variable overlap between groundfish predators and crab prey, as well as absence of field observations on predation in nearshore juvenile crab nursery habitats.

May 24, 14:35 (S8-7379)

Exploring relationships between decapods, cod and temperature through time-series analysis: What we have learned in the northwest Atlantic

Stephanie A. **Boudreau** and Boris Worm

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Following the overexploitation and collapse of Atlantic cod (*Gadus morhua*) stocks in the northwest Atlantic, populations of northern shrimp (*Pandalus borealis*), snow crab (*Chionoecetes opilio*) and American lobster (*Homarus americanus*) have increased. Time-series of cod and the 3 decapod species were correlated, separately, to examine if population dynamics were consistent with ‘‘top-down’’ or ‘‘bottom-up’’ mechanisms. We present a summary of what we have learned to date:

(1) Cod and shrimp biomass were negatively correlated, however this interaction was temperature dependent, with stronger evidence of top-down control in colder temperatures. Cod biomass was positively correlated with ocean temperature;

(2) Snow crab abundance was negatively correlated with temperature at 7- to 10-year lags whereas cod and temperature were positively related at 1- to 7-year lags. Snow crab and cod abundance were negatively correlated, with cod leading snow crab by up to a 5-year lag. Negative correlations between cod and crab abundance were observed both at the warmer and colder portions of their ranges;

(3) Cod and lobster abundance indices in the Gulf of Maine revealed negative correlations at time lags ranging from 0- to 9-years. This was corroborated with results from a local ecological knowledge survey. Temperature did not emerge as a main driver in that survey;

Our results are broadly consistent with top-down view of ecosystem control indicating that decreases in predator populations can affect increases at lower trophic levels. In addition, changes in ocean temperature can affect both predator and prey, as well as the strength of their interactions.

May 24, 14:55 (S8-7403)

A comparison of northern shrimp population dynamics among multiple ecosystems: Influences of gadoid predation and temperature

Laurinda **Marcello**[1], Franz J. Mueter[1], Olafur S. Astthorsson[2], Carsten Hvingel[3], Dave Orr[4], Patrick Ouellet[5] and Louise Savard[5]

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Northern shrimp (*Pandalus borealis*) have a circumpolar distribution and are an economically important fishery resource through much of their range. In some areas, shrimp stock dynamics have been linked to cod predation through catch data series. In others, environmental effects such as temperature have been reported as an important driver. Here, we seek to improve our understanding of what causes variability in the biomass and recruitment of northern shrimp populations across ecosystems using survey data where available. We will use a regression approach to model the effects of gadoid fishes, water temperature, and, where possible, spawner abundance on northern shrimp recruitment and/or biomass in several North Atlantic ecosystems. We will compare results across ecosystems to determine if estimated effects of gadoid predation and temperature on northern shrimp populations are consistent across ecosystems or whether each ecosystem seems to be governed by independent factors.

May 24, 15:15 (S8-7358)

Environmental effects on recruitment of Northern shrimp (*Pandalus borealis*) in West Greenland waters: Impact of temperature and main predators

Kai **Wieland**[1], Nikoline Ziemer[2], Kaj Sünksen[2] and Helle Siegstad[2]

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Survey estimates of biomass of northern shrimp (*Pandalus borealis*) in West Greenland waters increased from about 178,000 tons in 1998 to about 598,000 tons in 2003. The increase in stock size was preceded by an increase in water temperature and several consecutive years in which recruitment was substantially above average. Recruitment has been poor since then despite record high levels of spawning stock biomass in the years 2003 to 2005, and survey biomass declined to 278,500 tons in 2009. Standard and modified Ricker stock-recruitment functions are compared with multiple regression models incorporating environmental variables in order to examine the effect of spawning stock size, predator biomass (Atlantic cod, *Gadus morhua*, and Greenland halibut, *Reinhardtius hippoglossoides*) as well as surface and bottom temperature on northern shrimp recruitment in West Greenland waters and to describe how the environment may modify an underlying stock-recruitment relationship. Bottom temperature and biomass of Greenland halibut were significant explanatory variables in an exploratory analysis but the results were not considered as conclusive due to the short time series (1993-2004) available at that time (Wieland unpubl.). Our study now spans 18 years (1993-2010) of recruitment estimates and extends previous work with the inclusion of top-down as well as bottom-up processes.

May 24, 15:35 (S8-7432)

Interaction between northern shrimp and cod in inshore and offshore areas around Iceland

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Northern shrimp (*Pandalus borealis*) is found in inshore and offshore areas around Iceland. Shrimp was one of the most important commercial species in Icelandic waters. However, in the past 15 years the size of the shrimp populations has decreased and most of the inshore shrimp populations have collapsed. The collapse followed rapid increase of cod and later haddock abundance in the shrimp grounds. Predation is an important factor in shrimp stock dynamics and various fish species prey on shrimp. Therefore it is likely that the increase in cod and haddock contributed to the collapse of the inshore shrimp populations. The shrimp population in the offshore area was not as severely depleted as in the inshore area but it still suffered major depletion after 1996 following a rapid increase in cod abundance in the area. Since then abundance of cod has been relatively high and the landings of shrimp an order of magnitude lower than before. To study the importance of cod on shrimp stock dynamics in different habitats, stomach contents of cod in inshore and offshore shrimp areas were studied. The data were available from shrimp surveys since 1999. Both annual and spatial comparisons were made. The analyses indicated that relatively few prey items were dominant in the stomachs and shrimp was one of the main species in the diet. Calculations of shrimp consumption from an evacuation rate model indicated that consumption by cod was of greater importance than fishing in some years. What seemed to affect shrimp consumption were abundance of shrimp in the area and abundance of other prey.

May 24, 16:25 (S8-7445)

Effects of predation on Canadian Atlantic crustacean resources: A comparison between the Newfoundland-Labrador Shelf and the Gulf of St. Lawrence

Earl **Dawe**[1], Mariano Koen-Alonso[1], Don Stansbury[1], Darrell Mullowney[1] and Denis Chabot[2]

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This study addresses the hypothesis that predation by groundfish species (Atlantic cod (*Gadus morhua*) and Greenland halibut (*Reinhardtius hippopglossoides*)) is important in regulating the abundance of snow crab (*Chionoecetes opilio*) and northern shrimp (*Pandalus borealis*) on the Newfoundland-Labrador (NL) shelf and in the Gulf of St. Lawrence (GSL). This was approached through direct examination of the importance of these crustacean prey species in the predator diets. A second approach was to consider the spatial interaction between each predator-prey pair. Annual trends in a Global Index of Co-location (GIC) were compared based on those size groups of prey that were most important to each predator and those size groups of predators that preyed most intensely on each prey species. Preliminary results from the NL shelf show that snow crab has not been an important component of the diet of either predator throughout the time series (*i.e.* since the late 1970's). However, the contribution of shrimp to the diet of both predators has increased since the early 1990's, concurrent with a decline in capelin abundance. All pairwise predator-prey comparisons indicated a high degree of spatial interaction, with the Greenland halibut and shrimp interaction being especially close. Overall, there is no evidence that predation is controlling snow crab abundance. In the case of shrimp, predation may be a factor, based on importance of shrimp in diets and close predator-prey interactions.

May 24, 16:45 (S8-7356)

Spatial-temporal variations in shifting ecosystems: A GWR analysis in the Northwest Atlantic

Matthew J.S. **Windle**[1], George A. Rose[1], Rodolphe Devillers[2] and Marie-Josée Fortin[3]

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Ecological relationships within large marine ecosystems often are determined by averaging population and environmental data over broad geographic areas. In such instances, important regional variability in the relationships between species and their environment (*i.e.* spatial non-stationarity of ecological processes) may be overlooked. We apply a local modelling technique, geographically weighted regression (GWR), to a time-series of autumn multispecies trawl survey data from the Newfoundland region (NAFO 2J3KLNO) to examine how spatial relationships among key ecosystem components have changed against a backdrop of severe fishing pressure, trophic regime shifts, and variability in ocean climate. For the period of 1985-1994 (pre-collapse of groundfish stocks), GWR predicted the distribution of Atlantic cod using a key prey species (capelin), species richness and diversity indices, and environmental variables (bottom temperature, salinity, depth, surficial sediments). A subsequent GWR analysis for the period 1995-2008 predicted cod distribution, with the previous predictive variables supplemented by additional co-located prey species (snow crab and northern shrimp). The GWR analyses generally outperformed global regression and generalized additive models (GAMs). Mapped outputs of GWR coefficients revealed that spatial relationships between cod, prey species and environmental variables differed significantly within years. The spatial variation of relationships remained relatively consistent during 1995-2008, perhaps as a result of decreasing population levels of cod and capelin and restricted distributions of invertebrate species. A *k*-means cluster analysis based on GWR t-values delineated distinct zones of temporally-dynamic species–environment relationships to illustrate the ecosystem changes that have occurred.

May 24, 17:05 (S8-7480), Invited

Seasonal predation patterns of Pacific cod and walleye pollock in Marmot Bay, Alaska

Dan **Urban**

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Pacific cod *Gadus macrocephalus* and walleye pollock *Theragra chalcogramma* stomach samples were collected during a seasonal study of Marmot Bay in the central Gulf of Alaska from June of 1998 to June of 1999. Crustaceans comprised the majority of the diet of both species but major differences were found between their food habits both spatially and temporally. While both cod and pollock consumed a wide variety of species, fish formed a large component by weight of cod diets, especially in older fish. Pollock fed largely on invertebrates, mainly euphausiids during all sampling periods. Seasonally, in outer Marmot Bay, euphausiids were also the main food of cod, but overall they were less than 1% by weight of the total cod diet. Northern shrimp *Pandalus eous* by weight was 11% of both cod and pollock diets, but again seasonal patterns reveal that pollock fed more consistently on *P. eous* during all sampling periods while cod targeted them only in several locations and periods during the year. Tanner crab *Chionoecetes bairdi* were the largest prey item of cod both by number and weight but were virtually non-existent in pollock diets. In general, diet overlap between cod and pollock varied widely by season revealing very different opportunistic foraging strategies in this sub-arctic bay.

May 24, 17:25 (S8-7479)

Potential effects of climate change on size at terminal molt and fecundity in snow crab (*Chionoecetes opilio*) in West Greenland waters

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Geographic variation in size and fecundity of snow crabs (*Chionoecetes opilio*) were investigated along the west coast of Greenland to test the hypothesis that size at terminal molt is temperature-dependent and increasing temperature influences potential reproductive outcome. Snow crabs were collected in small mesh traps in Disko Bay (68–69°N) and 6 sites near Sisimiut (66–67°N) in May and June from 2000 to 2010. Average bottom temperature over the study period ranged from -0.8 to 3.2°C across the sampling sites. The mean of annual values of adult median carapace width (CW) against overall mean temperature by site revealed a significant pattern of increasing size at terminal molt with increasing temperature in both sexes and the increase was proportional in the case of minimum size, but less than proportional in the case of maximum size. Temperature effects on body size of crabs may result from a change in the number of instars until terminal molt and/or in the size increment through successive molts. Mature (ovigerous) females ranged in size from 42 to 95mm CW. For mature females there was a positive correlation between CW and fecundity, and size-specific number of eggs increased with temperature. Our findings are important from an applied perspective in that they indicate that climate change will modify per capita reproductive output in both females and males, because individual fecundity scales exponentially to female body size, as well as to the proportion of adult males that achieve such large sizes as to become vulnerable to the fishery under a fixed minimum legal size limit. With rising temperature, potential reproductive output might increase substantially in females as they shift from a biennial to an annual reproductive mode. We discuss the implications of our findings for population reproductive potential and possible effect of climate change.

May 24, 17:45 (S8-7446)

Effect of bottom temperature on growth of snow crab: A comparison between the Newfoundland-Labrador Shelf and the southern Gulf of St. Lawrence

Earl **Dawe**[1], Mikio Moriyasu[2], Darrell Mullowney[1], Elmer Wade[2] and Flore Jacques[2]

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This study addresses the hypotheses that 1) The size at which snow crabs commit to their final molt is conditioned by the thermal regime experienced during their most recent inter-molt period and is related to temperature-dependent energy budgets; and, 2) The frequency of molting in snow crab is directly related to temperature, as in most other crustaceans. The effect of temperature on size-at-terminal molt was investigated by comparing the size-at-maturity and size-at-adulthood of recently terminally-molted female and male crabs, respectively, with bottom temperature based on survey sets where any recently molted crabs of that sex were caught. The effect of temperature on molting frequency was investigated by comparing the percentage of juvenile/adolescent (non-terminally-molted) males caught that had not recently molted ('skip-molters'), with bottom temperature based on those sets that caught any adolescent or new-shelled adult males. The preliminary results obtained from the Newfoundland-Labrador shelf (NL) and the southern Gulf of St. Lawrence (SGSL) corroborate the temperature effects on the growth pattern in snow crab. In both regions, the size at 50%-maturity significantly increased throughout the available temperature range. Males residing at unfavorably high temperatures delay their final molt and ultimately undergo their molt to adulthood at large size and with low energy balance. This effect was especially clear for NL females, likely reflecting sex and area differences in migration patterns and thermal regime, which likely influences the efficiency of thermal conditioning. The implications to natural mortality and recruitment to fisheries are discussed. Initial results of temperature effects on molting frequency were inconclusive.

May 25 Plenary Session

May 25, 8:30 (S3-7466), Invited

Modelling the impacts of climate change and variability on productivity and health of high-latitude marine ecosystems: The Beaufort Sea and Gulf of St. Lawrence case studies

Diane **Lavoie**[1], Joël Chassé[2] and Michel Starr[1]

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This talk will present different models and methods used to assess the impact of climate change and variability on different components of the marine ecosystem of the Beaufort Sea and Gulf of St. Lawrence. In the Beaufort Sea, changes in primary production resulting from the decrease in sea ice cover were estimated with a one-dimensional NPZD model and with a statistical downscaling method to provide forcing for the future projections. In the Gulf of St. Lawrence, different three-dimensional oceanic models (GSS4, G2, NEMO/OPA), coupled to a biogeochemical model (NPZD, oxygen, pH) are used to study the impact of anthropogenic forcing and climate variability on different component of the ecosystem. More specifically, the models are used to study (1) the development of an hypoxic and acid zone in the St. Lawrence Estuary, which has an impact on the health and distribution of some species, (2) the impact of changes in run-off on nutrient inputs and primary production in the St. Lawrence system, and (3), changes in the spatial distribution of krill aggregations linked to changes in transport and environmental conditions. A dynamical downscaling method will be used to provide model forcing for the future and study the impact of climate change on these different aspects of the Gulf of St. Lawrence ecosystem.

May 25, 9:00 (S3-7521), Invited

Changes in phytoplankton and zooplankton production in the Nordic Seas under a warmer climatic regime

Dag **Slagstad**, Morten Alver and Ingrid Ellingsen

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The production regime in the Nordic Seas is to a large degree dependant on different water masses. In Atlantic regions, deep winter mixing ensures that nutrients are brought towards the surface. Thermal stratification initiates the spring bloom, but does also limits the nutrient supply during the summer. In Arctic and Coastal regions, stratification is first initiated by melting ice or fresh water supply from land. These processes are likely to change with the predicted increase in air temperature, especially at high latitudes. One way to assess the effect of such changes on biological processes is to use numerical models. We present results from a coupled hydrodynamic, ice, chemical and biological models system (SINMOD) of the Arctic Ocean and the Nordic Seas using various atmospheric forcings. These include artificial increased air temperature at high latitudes that melts the summer sea ice in the Arctic and the IPCC A2 scenario for CO_2 in the atmosphere. Results indicate that there will be a shift in distribution of *Calanus finmarchicus* and *C. glacialis* in the Barents Sea around 2060 (A2 scenario). *C. finmarchicus* will still not be able to develop a population in Arctic Ocean even in a strong warming scenario. Primary production in the Norwegian and Southern Barents Sea appears to be more constrained by nutrient limitation when stratification increases as a result of reduced heat flux to the atmosphere.

May 25, 9:30 (S3-7415), Invited

A modeling study of marine pelagic ecosystems in the western North Pacific

Takeshi **Okunishi**

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A two-dimensional individual-based fish movement model coupled with fish bioenergetics was developed in order to simulate the observed migration and growth of Japanese sardine (*Sardinops melanostictus*) in the western North Pacific. In the model, which is derived from the observed ocean environmental data, fish behavior for migration was improved based on a kinesis model. The model successfully simulated the observed transport patterns during the egg and larval stages and the northward feeding migrations during the juvenile stage in 2005, 2006 and 2007. In autumn, the observed juvenile sardine were mainly distributed in the subarctic water region off the Kuril Islands, which is a high chlorophyll *a* (Chl-*a*) concentration region. The model reproduced the fish distribution having a high density in this region. The high Chl-*a* concentration area in autumn may contribute to increasing the survival rate of Japanese sardine by cascading up the food chain from the high primary production as an important habitat for recruitment success of Japanese sardine.

May 25, 10:00 (S4-7414), Invited

Changes in spreading of nutrient-rich shelf water into the Canada Basin due to sea ice melt

Shigeto **Nishino**[1], Takashi Kikuchi[1], Michiyo Yamamoto-Kawai[2], Yusuke Kawaguchi[1], Toru Hirawake[3] and Motoyo Itoh[1]

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In recent years, the Arctic has rapidly lost its summer sea ice cover. The melting of thick, solid multi-year ice has produced fragmented and mobile sea ice with which the wind can drive the ocean circulation more efficiently. The enhanced ocean circulation changes nutrient distributions, and therefore, could impact ecosystem characteristics and biogeochemical processes in the Arctic Ocean. In the previous studies focused on the Canada Basin, it is indicated that the accumulation and thickening of fresh and nutrient-poor surface waters can inhibit nutrient supply from deep layers and thus decrease phytoplankton production. Ocean circulation should also be considered to extend this vertical one-dimensional interpretation. For example, the accumulation of freshwater in the Canada Basin produces a density gradient between the Chukchi Sea shelf and the basin, resulting in the formation of strong westward flow over the shelf slope. This strong westward flow prevents the spread of nutrient-rich shelf water towards the central Canada Basin. This blocking of nutrient-rich water may inhibit phytoplankton growth and reduce export production in the Canada Basin. We will further discuss the spreading of shelf water in the Siberian side of the Arctic Ocean and its implications for an increase in export production due to sea-ice melt.

May 25, 11:00 (S7-7354), Invited

Climate effects on fisheries in the Shiretoko World Natural Heritage, Japan

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The Shiretoko peninsula and its adjacent coastal area were inscribed on the UNESCO World Natural Heritage List in 2005. The first part of this paper presents the ecosystem conservation framework in this heritage area. In the Heritage Management Plan, indicator species for the ecosystems were identified and monitoring systems for them were established. Under the plan, local coastal fishers also play core roles in the ecosystem conservation measures, especially in ecosystem monitoring. In order to facilitate cross-sector coordination (especially between the fisheries and tourism sectors), a system of new management organizations was established by the national government. This new system integrates wide-ranging policy measures and legal bases into ecosystem conservation. In recent years, many phenomena have been observed that imply changes in the Shiretoko ecosystem, *e.g.*, decreases in the amount of ice, changes in the location of fishing grounds, appearance of unconventional species, *etc*. The latter part of this paper introduces the anticipated effects from climate change to the Shiretoko ecosystems and the coastal fisheries. Finally, we discuss the policy and research needs related to these changes.

May 25, 11:30 (S7-7381), Invited

Enhancing the resilience of small high-latitude fishing communities to climatic and marine-ecosystem change

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Field research in two small high-latitude fishing communities in Southwest Alaska explored their capacities to adapt to the climatic and marine-ecosystem changes that are forecast in the 2001 and 2007 IPCC reports. These two communities, one an industrialized commercial fishery, the other an indigenous subsistence fishery, are in the Bristol Bay region where they exploit the largest sockeye salmon runs in the world. As high-latitude communities they are especially at risk to changes that will be prompted by climatic and environmental change, and as relatively small communities they are at even greater risk by virtue of having few alternative livelihood opportunities. The initial focus of the research was to assess each community's social and economic capacity for adapting to anticipated climatic and marine-environmental changes, including increased frequency and intensity of storms, sea level rise, saltwater intrusion, and changes in marine ecosystems. The adaptive capacities of their respective fisheries-management systems were also considered. Then as the research evolved consideration was also extended to their capacities for adapting to other anticipated phenomena, including seasonal variations in their human populations, impacts from recreational fishing, hunting, and tourism, and hydrocarbon and mining development. This presentation presents findings that emerged from the research and proposes local, regional, and international-level policies for enhancing these communities' adaptive capacities. It also offers a few policy suggestions for small high-latitude fishing communities in general.

May 25, 12:00 (S7-7503), Invited

Policy adaptation and dynamic governance of marine social-ecological systems: Coping with climate change and economic change

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The challenge of anticipating change includes elements of both prediction and adaptation. Within marine social-ecological systems, while predictive capabilities for the ecological aspects remain highly uncertain, such capabilities are even less developed for the human components of the systems. Yet efforts to predict the socio-economic, cultural and governance consequences of global change processes are very much needed in a marine context – at multiple scales, from coastal communities through to large-scale fishing industries and national governments. Alongside this task of predicting the consequences of global change lies the daunting parallel challenge of adaptation to such change, especially in a northern world where change, both climatic and economic, can take place at high rates. The need for such adaptation is related to the marine system's vulnerability, while success in this adaptation, within the context of climate change, is typically seen as related to the adaptive capacity of the system. A critical element of this, one not always fully examined, is the flexibility of governance, and specifically the capability for policy adaptation. The ingredients needed to make management and policy more 'robust' and adaptive must be better understood, to facilitate effective adaptation to change within northern marine systems, now and in the future.

S1 - day 2, Oral Presentations

May 25, 14:05 (S1-7518)

Polar Fronts: Major ecosystem boundaries in the North Atlantic, North Pacific, and Southern Ocean

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Polar Fronts are major oceanographic boundaries in boreal and austral oceans. They are marked by distinct subsurface temperature minima, remnants of winter convection. As such, the Polar Fronts are key climatic thresholds that play important roles as ecological boundaries. In terms of vertical structure (stratification), Polar Fronts appear remarkably similar in the North Atlantic, North Pacific, and Southern Ocean. In terms of circulation, these fronts also play similar roles in all oceans, acting as (1) advective links and conduits for physical, chemical, and biological anomalies; (2) barriers separating major ecosystems; (3) blenders between adjacent ecosystems. Yet, notwithstanding structural and functional similarities, Polar Fronts play different roles in each of these three oceans. In this presentation, I will first review structural and functional similarities between Polar Fronts in different oceans and between ecological manifestations of these fronts. Then, I will focus on fundamental differences between the North Atlantic and North Pacific on one hand, and between the boreal oceans and the Southern Ocean on the other. Finally, I will address the issue of climatic stability of Polar Fronts in the different oceans and the impact of climate change on ecosystems separated and connected by these fronts.

May 25, 14:25 (S1-7469)

Comparative study of the life histories of *Eucalanidae* copepods in the subtropical and subarctic Pacific

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Eucalanidae species are large sized copepods, which are dominant in both subarctic and subtropical oceans. Species diversity is high at low latitudes and there are a limited number of species with high biomass at high latitudes. The life cycles of high latitude species have been well studied (*Eucalanus bungii* and *Rhincalanus gigas*), but information on low latitude species is limited. We investigated the distribution and the life cycles of the Eucalanidae over the wide area of the western North Pacific from 15 to 49ºN. Four species in the tropical and subtropical region showed an epipelagic-type life cycle, characterized by continuous reproduction in the epipelagic layer. In contrast, eight species including subtropical species (*Eucalanus bungii, E. californicus, E. hyalinus/spinifer, Pareucalanus parki, Rhincalanus nastus, R.rostifrons, Subeucalanus crassus*) showed seasonal OVM (ontogenetic vertical migration). In these species, most of the population was below 200m in their late copepodite stages, and young copepodite stages were only observed from winter to spring at stations with relatively high chlorophyll *a* concentrations in the surface layer. These results suggest OVM evolved from the epipelagic-type life cycle as an adaptation to utilize the sporadic and unpredictable new production in the oligotrophic environment, and in similar way as an adaptation to the seasonally changing food availability in high latitude oceans.

May 25, 14:45 (S1-7491)

Multispecies data reveal how sub-Antarctic and Antarctic marine predators respond to variation and change in Southern Ocean ecosystems

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Recent, rapid, regional climate changes that are still ongoing in the Southern Ocean have important consequences for sub-Antarctic and Antarctic biodiversity. This is highlighted by the Scotia Sea regional food web which is centered around a single species: Antarctic krill. Previous analyses have highlighted that fluctuations in the dynamics of krill populations are related to climate, and that these can impact the structure and function of the food web across the Scotia Sea. Here we report on retrospective analyses of multispecies data from krill predators (with different resolution - individuals to populations), and provide insights into long-term changes in their diet, life histories and population dynamics across the Scotia Sea. Synchronous and contrasting responses of penguin species, breeding sympatrically at locations on South Georgia (sub-Antarctic) and the South Orkney Islands (Antarctic) suggest that recent years reflect a period of more variable food availability. Life history changes of Antarctic fur seals at South Georgia indicate an unprecedented loss of demographic buffering to a decreasing food supply, which is correlated with ocean warming. These results reveal that cryospheric and oceanographic changes are having ecosystem wide impacts in connected polar and sub-polar regions, and the impacts on mid-trophic levels affect predator-prey interactions. Differences in long-term diet plasticity among predator populations suggest that environmental change may potentially alter predator communities. Understanding the resilience of these populations to ecosystem change requires data on long-term variation in phenology, prey-switching ability and potential for alternative food web interactions.

May 25, 15:05 (S1-7498)

A meta-analysis of seabird-climate relationships

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Being globally distributed and arguably the most conspicuous marine organisms living at the interface of the atmosphere and the ocean, seabirds have been well-studied in many high latitude ecosystems. Moreover, it is hypothesized that owing to their trophic positioning as secondary or tertiary consumers and ease of study, seabirds serve as reliable indicators of change in marine ecosystems driven by climate and human activities (resource exploitation, coastal development, energy production, etc.). In this paper, we present a synthesis of results obtained from an initial analysis of a unique seabird-climate meta-database (see Thompson *et al.* for details). Based upon 91 studies encompassing 95 species from 24 ocean regions and integrating 2,599 records of seabird parameters and ocean climate variables such as SST, sea ice extent (SIE), climate indices, etc., we investigate whether climatic relationships with seabirds vary or are similar between ecosystems, habitats, or species, and whether unknown systematic variability (*e.g.*, positive correlations with SST on the western side of ocean basins and negative correlations in the east) can be established. We found inconsistent relationships with SST (both positive and negative) but relatively consistent relationships with SIE (positive, more is better), and that in most cases seabird-climate relationships were indirect, mediated through changes in prey fields and food availability. We suggest that most seabird-climate relationships are non-linear, but that only through synthesis of multiple population responses will non-linearities be revealed. We also identify "hotspots" of seabird-climate studies (*e.g.* NE Atlantic), and where there are deficiencies in research (*e.g.*, mechanistic understanding).

May 25, 15:25 (S1-7516)

Climate change and baleen whale trophic cascades in Greenland

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Fluxes of organisms across ecosystem boundaries have major consequences for community dynamics. Many large sub-Arctic baleen whale species move into the West Greenland ecosystem to feed in summer months. For a brief period, these whales overlap with high Arctic baleen whales before the latter make their northbound spring migration. We examined movements and foraging behavior of two co-occurring baleen whale species in West Greenland: the Arctic bowhead whale (*Balaena mysticetus*) and the sub-Arctic humpback whale (*Megaptera novaeangliae*). Data on area use, diving, and phenology were collected by satellite-linked transmitters and archival telemetry together with intensive and localized sampling of physical ocean conditions and zooplankton prey to understand foraging behavior. Between 2008 and 2010, 90 bowhead whales and 64 humpback whales were tagged with satellite transmitters in Disko Bay, West Greenland. Bowhead whales remained mainly in the northern half of Disko Bay in an area of about 30,000 km^2 until their spring migration, while humpback whales moved back and forth rapidly between several smaller feeding areas along the west coast, including the southern half of Disko Bay. The tracking data demonstrated an almost zero spatial overlap in May and early June when the two species were concurrently present. Sub-Arctic top predators are expected to expand their range northward with reduced sea ice and increasing temperatures. Thus, quantifying baseline trophic relationships, especially given the rapid changes in the West Greenland climate, allows for better insight into how climate change will be a driving force on interspecies interactions and competition.

S2 - day 2, Oral Presentations

May 25, 16:10 (S2-7365)

Alternating climate states influence walleye pollock early life stages in the southeastern Bering Sea

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We examined the influence of environmental conditions on walleye pollock (*Theragra chalcogramma*) in discrete, early life stanzas (eggs, larvae, juveniles) in the southeastern Bering Sea. Of the environmental conditions examined, temperature explained more variation in density of all early life stages than any other variable. Lower than average temperatures were associated with high densities of eggs and newly hatched yolksac larvae; average and higher than average temperatures were associated with high densities of developed larvae. We examined the hypotheses that densities of pollock early life stages were determined by temperature-dependent differences in spatial distributions, phenology, growth rates, and mortality rates. We quantified stage-specific changes in spatio-temporal distribution in cold and warm years using centers of distribution and generalized additive models. Analyses show that all pollock early life stages shift shoreward or east under warm conditions relative to cold, similar to spatial shifts seen in distributions of sub-adults and adults. Temporal distributions addressed the hypotheses that spawning, hatching, and larval development are delayed under cold conditions. We found evidence of delayed hatching and larval development through feeding and notochord flexion stages. Observed, reduced growth rates through the juvenile in cold years stage support the notion of delayed juvenile transition. Furthermore, calculated mortality rates indicate significant loss of pollock larvae and early juveniles in cold years relative to warm years. Our data indicate that future shifts in environmental conditions will have profound influences on the early life stages of an ecologically and economically dominant member of the Bering Sea community.

May 25, 16:30 (S2-7529)

Climate related changes in the nutritional condition of young-of-the-year pollock (*Theragra chalcogramma*) from the eastern Bering Sea

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In winter, fish at high latitudes rely on their endogenous energy supplies to satisfy their metabolic needs and survive until spring when foraging conditions improve. For young-of-the-year (YOY) this problem is particularly acute because provisioning for winter can only occur within a relatively small window of time; after metamorphosis is completed and prior to the onset of winter. This suggests that the quality of forage during the latter part of the growing season is likely to be an important determinant to recruitment success. In the Bering Sea climate-related oceanographic conditions are believed to influence the quality of forage available to young-of-the-year (YOY) walleye pollock. In warm years the available prey is predominately small copepods such as *Oithona sp*. and *Psuedocalanus sp*. while in cold years predominate prey include larger calanoids such as *Calanus marshallae* and euphausiids. Similarly, diets of YOY pollock vary between warm and cold conditions in the Bering Sea. The lipid content of small copepods, approximately 1.5%, is significantly lower than that of euphausiids and large copepods (5% to 6%, respectively). Consequently, we have observed improved nutritional condition of YOY pollock at the end of summer during cold years (4.8kJ/g wet weight) compared with warm years (3.7kJ/g). Moreover, this improved condition of YOY pollock in cold years has a direct relationship with recruitment the following summer (r^2=0.79). Our data suggest that warming conditions in the Bering Sea are likely to lead to reduced recruitment to age-1 for this ecologically and economically important species.

May 25, 16:50 (S2-7464)

Ecosystem influences on hunting success in Savoonga, Alaska

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Yupik whalers and hunters from Savoonga, on St. Lawrence Island in the northern Bering Sea, have identified several major ecosystem influences on hunting success. At present, the ecosystem as a whole appears productive and healthy from the hunters' point of view, but access for hunting is a challenge, especially as weather and sea ice patterns change. Earlier spring break-up of ice has led to an earlier migration of bowhead whales, but less stable weather has made whaling more difficult. In Savoonga, the later freeze-up of ice in fall has allowed the development of a fall/winter whale hunt in addition to the spring hunt. For walrus, hunting depends primarily on ice and wind conditions. Rapid break-up and melt of ice in spring results in a brief hunting season and thus limited success. Wind and ice conditions taken together show greater correlation with walrus hunting success than either variable alone. Other hunting patterns have shifted in response to changes in the local abundance and distribution of marine mammals and seabirds. At present, the hunters have been able to adapt to the climatic changes that have been seen to date at Savoonga, indicating a high degree of flexibility across a range of environmental conditions.

May 25, 17:10 (S2-7527)

Links between at-sea foraging behavior and breeding performance of black-legged kittiwakes nesting at colonies in different Bering Sea domains

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The southeastern Bering Sea shelf has experienced dramatic fluctuations in large-scale climate/ocean conditions, and population declines of several top predators. We investigated the foraging behavior of black-legged kittiwakes (*Rissa tridactyla*) nesting at colonies on three islands in the southeastern Bering Sea, and the effect of colony location on foraging ecology, diet, and reproductive performance. We compared kittiwakes from two colonies on the continental shelf (St. George and St. Paul islands in the Pribilofs) during 2008-2010; and one colony in the basin (Bogoslof Island) during 2009. Food availability was lower for kittiwakes nesting at the Pribilofs compared to Bogoslof in 2009, as indicated by less fish in the diet, lower chick feeding frequencies, lower chick survival, and higher stress levels in adults. GPS tracking revealed that Pribilof kittiwakes undertook longer distance foraging trips at night, whereas Bogoslof kittiwakes did not. Pribilof kittiwakes foraged on less profitable prey over the shelf during the day to meet chick requirements, and commuted record distances (up to 450km) overnight to feed either on lipid-rich lanternfishes (all three years) or age-1 pollock (2009). Bogoslof kittiwakes also fed largely on lanternfishes over the basin, but much closer to their colony. The greater foraging range of Pribilof kittiwakes was apparently in response to scarcity of predictable patches of juvenile pollock near the surface, within commuting distance, and over the shelf. Pribilof kittiwakes may be experiencing chronically low productivity due to shifting distribution and abundance of key forage species on the Bering Sea shelf.

May 25, 17:30 (S2-7531)

Movements and dive behavior of ribbon and spotted seals: Evidence for resource partitioning in the Bering Sea

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Since 2007, 139 satellite telemetry tags have been deployed on ribbon and spotted seals in the central Bering Sea. The movements and dive behaviors recorded by these tags show evidence of resource partitioning between these similar-sized phocid seals. Movements of tagged spotted seals were mostly confined to the continental shelf and the majority of recorded dives were less than 90m with virtually no dives exceeding 200m. Ribbon seals ranged beyond the continental shelf and their dives were distributed over a wider range of depths with some dives exceeding 600m. During the critical breeding and molting period both species are strongly associated with sea-ice, their distributions overlap within the marginal ice zone, and they are known to have similar diets. However, we found that most spotted seal dives were to depths less than 70m while a much greater fraction of ribbon seal dives were deeper than 70m, and some deeper dives evidently occurred beyond the shelf break. Resource partitioning between ribbon and spotted seals has been previously theorized based on blood chemistries and diet studies, but this represents the first empirical evidence showing segregation during the critical breeding and molting period. These data provide important information about the diving capabilities of ribbon and spotted seals and are valuable for assessing how a changing environment may differentially impact these species.

S3 Oral Presentations

May 25, 14:05 (S3-7497)

Evaluation of a numerical model and application of results to understanding modes of variability in the Bering Sea ice/ocean/ecosystem

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Bering Sea model evaluation efforts are hampered by the lack of historical data with which to evaluate model performance. We have carefully selected and handled a suite of diverse observations to evaluate a variety of model results, which allows us to quantitatively examine the performance of a 35-year (1970-2005) hindcast integration of the Bering Sea. Among other comparisons, we evaluate model performance against moored multi-year temperature, salinity and current fields, remotely sensed passive microwave sea ice concentrations, and hydrographic data.

Following Wilmott (1985) and Taylor (2001), the primary metrics were employed in model/data comparisons include mean, standard deviation, cross-correlation and root-mean-square error (RMSE) computations. Spectral analysis, least squares harmonic fits for tidal parameters and bulk temporal/spatial averaging are also used to help assess time series data. The model evaluations provide confidence in model results and subsequently guide application of the model to appropriate research questions.

Empirical Orthogonal Function (EOF) analyses of the near-surface (0-20m) and sub-surface (40-100m) depth levels provide insight to the spatial structure and temporal variability in the temperature and salinity fields. Cross-correlation of the associated principal component time series with a set of biological and physical indices yields statistically significant correlations that suggest causes, and potential impacts, of the resultant EOF patterns.

May 25, 14:25 (S3-7363)

A 3D super-individual model with emergent life history and behaviour for *Calanus finmarchicus* in the Norwegian Sea

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The copepod *Calanus finmarchicus* is the dominant species of the meso-zooplankton in the Norwegian Sea ecosystem. The species is largely herbivorous and constitutes an important link between the phytoplankton and the abundant fish resources in the Norwegian Sea, including Norwegian spring spawning herring, blue whiting and mackerel. Spatially explicit models are key tools for understanding the zooplankton dynamics of the heterogeneous Norwegian Sea which contains warm Atlantic water masses to the south and east and cold Arctic water masses to the North. Here, we present an individual based model with emergent life-history and behavior for C. *finmarchicus*. The objectives are to validate the approach, investigate the importance of the simulated adaptive process on retention and fitness of *Calanus* and the importance of inter annual variability on the distribution and production of C. *finmarchicus* in the Norwegian Sea. The results show that the simulated population is able to remain productive within the Norwegian Sea basin for hundreds of years. The evolved life history resembles that observed for C. *finmarchicus*. Long-term simulations show that there in considerable interannual variability in *Calanus* production, biomass and advection into the downstream Barents Sea.

May 25, 14:45 (S3-7501)

Insights into the eastern Bering Sea through a jellyfish lens: Recent trends and tests of predictive models

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A steep increase in jellyfish biomass, primarily *Chrysaora melanaster*, was documented over the eastern Bering Sea shelf throughout the 1990s. Their biomass peaked in summer 2000 and then declined precipitously, stabilizing at a moderate level during 2001-2008. Surveys in 2009 and 2010 indicate that jellyfish biomass has increased once again to late-1990s levels. The onsets of the biomass increase during the 1990s and decline in 2000 coincided with transitions between climatic regimes. Our previous investigations of a 27-year time series examined relationships between jellyfish biomass and temperature, ice cover, atmospheric variables, current patterns, zooplankton biomass, and associated fish biomass in two regions using Generalized Additive Models (GAM). These analyses indicated that jellyfish outbreaks during 1982-2004 were influenced regionally by interacting variables such as sea ice cover, sea surface temperature, currents, wind mixing and food availability. Using new environmental data from 2005-2009, we "hindcast" our models to determine if our previously developed models would accurate predict recent increases in Bering Sea jellyfish. GAMs predicting jellyfish biomass for the period 1982-2009 explained 85.4% and 89.5% of the variance for the southeast and northwest portions of the survey area, respectively. Peaks in zooplankton biomass during the time series precede increases in jellyfish biomass, suggesting that food availability is a key factor contributing to fluctuations in jellyfish populations. Jellyfish, which are both predators and competitors of fish, appear to be responding to physical conditions in concert with crustacean zooplankton, and may be providing keys to understanding ecosystem changes in the eastern Bering Sea.

May 25, 15:05 (S3-7422)

Effects of climate change on the survival of larval cod

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Understanding how climate change may impact important commercial fisheries is critical for developing sustainable fisheries management strategies. In this study, we used simulations from an Earth System Model (NOAA GFDL ESM2.1) coupled with an individual-based model (IBM) for larval fish to provide a first assessment of the potential importance of climate-change driven changes in primary productivity and temperature on cod recruitment in the North Atlantic to the year 2100. ESM model output was averaged over regions covering 5x5 latitude-longitude grid for four regions covering the geographic boundaries of the current cod range. The physical and environmental data were incorporated into a mechanistic IBM used to simulate the critical early phases in the life of larval fish (*e.g.* cod) in a changing environment. Large phytoplankton production was predicted to decrease in most regions, thereby lowering the number of meso-zooplankton in the water column. Meso-zooplankton is important prey items for larval cod and a reduction in their numbers has large impacts on larval cod survival. The combination of lowered prey abundance with increased energy requirement for growth and metabolism through increased temperature had a negative impact on cod recruitment in the southern regions of the North Atlantic, while in the northern regions the increase in temperature has a positive effect on recruitment. Together, these results suggest climate change could have significant and variable impacts on the survival of larval cod in the North Atlantic.

May 25, 15:25 (S3-7547)

Development of a climate-to-fish-to-fishers model: Data structures and domain decomposition

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Results from a coupled ecosystem model for physics-to-fish-to-fishers will be shown. In its present form, the model has been configured for examining the long-term population cycles of anchovy and sardine in the California Current system although its underlying algorithms can be implemented in other systems and for other fish such as sub-Arctic herring. This presentation will focus on the numerical methods and computing considerations for dynamically coupling the physics, lower trophic level, upper trophic level models and fishing fleets. The physics is represented by the Regional Ocean Modeling System (ROMS), which has been designed to run on parallel architectures using the Message Passing Interface (MPI) that is common on the current generation of supercomputers. The lower trophic level model is a version of the NEMURO nitrogen-phytoplankton-zooplankton model. The fish community is represented using a full life cycle, individual and bioenergetics-based approach. The agent-based fishing fleet is modeled after the sardine fishery in the Western US with fishing expeditions limited to 24 hours. When combining the models, which are a mix of Eulerian and Lagrangian approaches, care must be taken to ensure that the modeling system continues to function on tens of processors with many thousands of individuals without running into resource limitations – or worse, results that depend on the number of processors. We will describe several of the numerical algorithms we are using in our coupled model, including those for spatially-locating eggs from spawning and scaling the predator-prey interactions among the fish species represented in the model and between the fishers and the fish.

May 25, 16:10 (S3-7396)

An Eulerian nutrient to fish model

Wolfgang **Fennel** and H. Radtke

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A new generation of a model that integrates lower and upper parts of the marine food web in a three dimensional circulation model is presented for the example system of the Baltic Sea. The Baltic is an excellent test bed because the fish stocks are dominated by two prey species (sprat and herring) and one predator (cod). The NPZDF-model has an explicit two-way interaction between a biogeochemical model and size dependent Eulerian Fish model. The dynamics of the fish model is driven by size (mass-class) dependent predator-prey interactions while the interaction between the NPZD and fish models is established through feeding of prey fish on zooplankton and recycling of fish biomass to nutrients and detritus. The fish model component is embedded into the advanced three dimensional biogeochemical model ERGOM of the IOW. In order to grasp fish behavior, such as migration, we let the fish swim to follow the food and to go to their respective spawning areas during the reproduction season. The approach can be transferred also to other systems.

Among the various aspects that can be studied with the model system, we look at the role of fish regarding transport of matter. In particular, in the spawning areas of cod and sprat, it seems that fish contribute significantly the deposition of matter to these areas.

May 25, 16:30 (S3-7342)

Unquantifiable uncertainty in projecting stock response to climate change: Example from NEA cod

Daniel **Howell**[1], Anatoly Filin[2], Bjarte Bogstad[1], Jan Erik Stiansen[1] and Elena Eriksen[1]

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Data from the years 1946-1992 suggests a positive relationship between recruitment of cod in the Barents Sea and the sea temperature at the Kola section during the year of spawning. However analysis of subsequent data from 1993-2009 indicates that this relationship no longer holds. This change in the recruitment dynamics will clearly have an impact on our understanding of future stock dynamics and long term yield. It also highlights the impacts on our ability to predict biological responses to climate change arising from possible future changes in similar relationships in other species and ecosystems. This paper uses a multi-species "STOCOBAR" forward simulation model to evaluate the dynamics under a variety of climate scenarios and recruitment hypotheses, highlighting the differences between temperature-dependent and temperature-independent recruitment. The divergence between the modelled populations and yields under the different recruitment hypotheses indicates the impossibility of predicting the future evolution of a stock with any degree of certainty, or even with any quantifiable degree of uncertainty. These results highlight the importance of having a management regime that is robust to unpredicted and unpredictable changes in stock dynamics.

May 25, 16:50 (S3-7507)

Ocean variability and recruitment in Norwegian spring-spawning herring

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Early hatching has been shown to be associated with increased survival of Norwegian spring-spawning herring (Clupea harengus) larvae. Hatching date itself is negatively correlated with wintering temperature of adults and positively correlated with the percentage of recruit spawners. This suggests indirect effects on larval survival, whereby low percentages of recruit spawners and high temperatures during gonad development lead to early spawning. (Early hatching could be favorable for survival by allowing the larvae to drift passed areas where potential predators concentrate in spring, before predation pressure increases.) However, modeling exercises show that early hatching and shallow larval drift results in much quicker northbound transport than late hatched and deeper distributed larvae, though this varies between years. In fact, the effect of hatching date and vertical distribution in larvae is comparable to the inter-annual variation in northward transport towards the nursery ground in the first two months of pelagic free drift. Here we compare the relative importance of hatching date and current strength in the Norwegian Coastal current on spatiotemporal distribution of larvae for the years 1989 until 2008.

May 25, 17:10 (S3-7523)

Limits on predictability in a size-spectral plankton model: A strategy for ensemble forecasting of diverse ecosystems

Neil S. **Banas**

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This talk uses an idealized model of complex planktonic predator-prey interactions to suggest a strategy for ensemble forecasting, uncertainty estimation, and improved representation of biological diversity patterns in marine ecosystem models. Usually, ensemble forecasting in ecosystem models (if it is attempted at all) is discussed in terms of varying a number of uncertain free parameters that control the solution. Here I suggest an alternate strategy much closer to the way ensemble forecasting is done in physical modeling, where the model itself is complex enough to allow rich, realistically chaotic dynamics, parameters are chosen by broad empirical averages and not varied, and only initial conditions vary among ensemble members.

The model is NPZ (nutrient-phytoplankton-zooplankton) style, with 40 size classes of phytoplankton and zooplankton. General, empirical allometric relationships are used to parameterize not just vital rates but also—crucially—the optimal prey size and size selectivity for each grazer class. This inclusion of complex prey preferences yields a system with 1) emergent biomass-diversity patterns consistent with global observations, and 2) significant chaotic time evolution, in terms of both total biomass and community composition, on timescales from days to months. When a simple annual cycle in nutrient supply is repeated exactly for ten years, spring bloom magnitude varies by a factor of two among years. Simpler variants on the same model ecosystem also show this high level of intrinsic unpredictability. Thus it might be important to partition long-term model projections into central functional relationships and "ecosystem weather."

May 25, 17:30 (S3-7471)

A minimal Barents Sea ecosystem model from first principles

Benjamin **Planque** and U. Lindstrøm

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Developing marine ecosystem models is notoriously difficult because of the diversity and complexity of ecological processes to account for, the presence of non-linearities, the broad range of spatial and temporal scales to cover, and more generally the many unknowns on ecosystem fundamental processes. Here, we adopt a minimal approach to model the dynamics of the Barents Sea ecosystem. The stochastic model is constrained on the basis on first principles (mass-balance and life-history traits). We explore the ability of the model to reproduce a range of features of the observed Barents Sea ecosystem dynamics.

S7 Oral Presentations

May 25, 14:05 (S7-7533)

Social and economic assessments of the future Arctic: Special cases local and distant

Dave **Fluharty**

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The Arctic presents an interesting case for how to identify, incorporate and balance the interests of largely indigenous peoples and the national, regional and global interest in how its management regime is defined. The sudden prospect of a summertime ice-free Arctic has thrust these questions onto a global stage much more rapidly than expected. Current thinking can be characterized as representing a view of a very slowly changing Arctic whereas the observed events are more rapid. These "fast" and "slow" aspects of the emerging policy demands of the Arctic present significant challenges for analysis. It is necessary to first characterize current responses. Second, it is useful to examine other rapidly changing resource regimes – especially where there is a local indigenous population with direct interests and a regional or global set of private and public interests which might be orthogonal to the local peoples' views. Finally, what approaches are available to address this potential mismatch in interests of indigenous peoples, national and regional bodies and the global nature of Arctic issues.

May 25, 14:25 (S7-7534)

Fisheries management in the face of climate change: The case of the Arctic

Alf Håkon **Hoel**

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The Arctic Climate Impact Assessment (2005) addressed the potential implications of climate change on Arctic and Sub-Arctic fisheries. A key finding here was that "The total effect of a moderate warming of climate on fish stocks is likely to be of less importance than the effects of fisheries policies and their enforcement". Drawing on examples from Arctic commercial fisheries, this paper discusses the implications of this finding for fisheries policy. The institutional mechanisms for the management of such fisheries at various levels of governance in are accounted for, and their capacity to adapt to changing climatic circumstances addressed.

May 25, 14:45 (S7-7485)

Climate change and location choice in the Pacific cod longline fishery

Alan **Haynie** and Lisa Pfeiffer

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Pacific cod is an economically important groundfish that is targeted by trawl, pot, and longline gear in waters off Alaska. An important sector of the fishery is the "freezer longliner" segment of the Bering Sea which in 2008 accounted for $220 million of the Pacific cod first wholesale value of $435 million. These vessels are catcher/processors, meaning that fish caught are processed and frozen in a factory on board the ship.

In this preliminary work, we explore the change that has occurred in the fishery and the manner in which fishing location choice has changed after cooperatives were created beginning in 2004. Limited entry management creates race-to-fish incentives in which harvesters maximize the number of fish caught per fishing day. Cooperative management systems allow vessels to choose how fish to maximize the value per pound of fish. We explore differences in the location choice behavior of vessels after cooperatives were formed. We also expect to find differences in the way harvesters respond to climate variation. Warm years in the Bering Sea are characterized by earlier sea ice retreat, a smaller cold pool (water less than 2°C that persists into the summer), and warmer ocean temperatures. This may have impacts on where harvesters choose to fish. Understanding the relationship

between fishing location and climate variables is essential in predicting the effects of future warming on the pacific cod fishery. We draw on experiences with Pacific cod and pollock to discuss the importance of economics in integrated climate prediction models for fisheries.

May 25, 15:05 (S7-7461)

Modeling the impacts of climate change on fleet behavior in the Bering Sea pollock fishery

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Purely ecological studies have observed a northward shift in the distribution of subarctic marine species, and predict further shifts as the ocean warms. Utilizing a robust oceanographic and economic dataset, we find that when making predictions about capture fisheries (as opposed to fish stocks), it is crucial to consider the profit maximizing behavior of harvesters. Commercial fishermen choose where to fish based on observable and unobservable characteristics of the area and the fisher, including the expected revenue in an area, travel distances and costs, vessel characteristics, institutional factors, and environmental conditions. We develop a discrete choice model to investigate the behavior of the catcher-processor sector of the Bering Sea pollock fishery, which is the largest commercial fishery in the United States.

This research is one component of the BEST-BSIERP Bering Sea Project, an inter-disciplinary investigation of the effects of climate change on the Bering Sea. Key among these effects is the role of climate on fish location and abundance and the impact that weather plays in daily participation and location choices for vessels. The spatial economic model incorporates climate data (for example, ice cover and sea surface temperature) into the model, permitting us to determine the relative impact of observable contemporaneous environmental conditions on location choices. We include predictions of changing pollock abundance in the model, which directly affect the total allowable catch available to the fishery. This allows us to predict responses to scenarios developed by oceanographic and ecosystem modelers involved in Bering Sea project.

May 25, 15:25 (S7-7465)

Fisheries management in newly accessible seas

Henry P. **Huntington**

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The retreat of summer sea ice in the Arctic Ocean and surrounding seas has removed a major barrier to the expansion of commercial fisheries into these waters. Physical access, however, is just one factor. Whether there are commercially valuable fish stocks, whether such stocks might appear over time, and how new fisheries can be managed both in a rapidly changing environment and potentially in international waters, are all open questions. In the United States, the North Pacific Fishery Management Council, with support from the fishing industry, has set a zero-catch limit for U.S. waters in the Chukchi and Beaufort seas, recognizing the uncertainties in biology and economics of Arctic fisheries at this time. In the Canadian Beaufort Sea, the Canada-Inuvialuit Fisheries Joint Management Committee is considering a similar approach for offshore fisheries. And the U.S. is promoting the same idea for the international waters of the Central Arctic Basin, which could only be achieved through international action. In all three cases, the intent is not necessarily to close fisheries forever, but rather to allow time for a better understanding of the direction of environmental change and better information to support sound management of commercial fisheries if and when they begin.

May 25, 16:10 (S7-7535)

Institutional structure and profit maximization in the Eastern Bering Sea fishery for Alaska pollock

James **Strong** and Keith R. Criddle

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Walleye pollock (*Theragra chalcogramma*) is the largest whitefish fishery in the world and largest in U.S. by volume. The Alaska fishery has gross exvessel revenues of $300 million and a first wholesale value of over $1 billion. The market for U.S. pollock products has evolved significantly since the early 1990s, when U.S. pollock processors focused mainly on selling surimi and roe to Japan. The formation of harvesting cooperatives, resulting from the passage of the American Fisheries Act, has resulted in a complex suite of alternatives that includes increasing global markets and a diverse mix of product forms. Understanding how benefits of the fishery are distributed requires an understanding of international trade in pollock products. This paper reports on the development of an international market model for pollock products for 2000-2008, with a particular emphasis on surimi, fillets, and roe and their primary markets in the United States, Europe, and Japan. The simultaneous-equation equilibrium model included nine structural equations, with four allocation equations and five inverse demand equations. The model was fitted using an iterated 3 stage least-squares estimator. Results conformed with theoretically anticipated relationships with respect to price, income, and substitution effects. The model and its results will assist fishery managers in determining optimum yield for the fishery.

May 25, 16:30 (S7-7380)

Cooperative and noncooperative strategies for management of Bering Sea pollock

Keith R. **Criddle**

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Climate-induced shifts in the geographic distribution of an exploited fish population can expose that population to potentially discordant management regimes. For example, while there is general agreement that the eastern Bering Sea pollock (*Theragra chalcogramma*) fishery is well managed, the stock is not wholly contained within the U.S. EEZ and there are concerns about the role of historic and potential future catches from the Donut Hole and the Navarin Basin. The management of straddling stocks can be highly contentious and challenging, particularly when the stock is migratory or when the spatial distribution of abundance is variable. The absolute abundance of pollock and the spatial distribution of pollock abundance have varied considerably over the past three decades, with warmer conditions being associated with a shift of the center of abundance to the north and west, where a portion of the stock is subject to harvest by vessels licensed to operate in the Russian Federation EEZ. We use stochastic simulations to explore the attributes of cooperative and noncooperative harvest management strategies from the perspective of U.S. and Russian pollock fisheries under climate-induced changes in abundance and the distribution of abundance.

May 25, 16:50 (S7-7504)

Rationalization, randomness and romance: A fisher's response to change in dynamic bio-physical, socio-political, and economic systems

Dave **Fraser**

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Adapting to change is the constant challenge in the life of a fisher. Rationalized fisheries present both opportunities to adapt as well as barriers to adaptation. Economic models that attempt to predict how fishers will adapt to climate change based on rational economic behaviour may fail to capture significant elements of the decision making processes of fishers.

May 25, 17:10 (S7-7511)

Exploring features of social-environmental history in eastern Prince William as a mode of anticipating human responses to future transitions within the Copper River and proximate marine ecosystem

Emilie **Springer**

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This presentation will explore definitions of adaptation and consider the success of adaptation in the physical community of Cordova, Alaska and other cultural and social communities that are environmentally reliant to marine and freshwater systems in this region of Alaska. To consider possible future transitions and coping strategies, I will look into the major historic events that have already occurred within the region and the resulting human constructed frameworks that have facilitated adaptation. General thematics are likely to include: politics and policy, culture and identity, physical setting and conditions of the Copper River watershed, regional occupational preferences and other opportunities for financial transitions. This project will also consider the prospects and limitations for choices in the region and reflect on how localized choices are expressed via differing forms of public media and individual communication. Major points of transition in the region include: the development of the mining industry in the early 1900's, Alaska's transition to statehood and the role of state policy on salmon and salmon traps in Prince William Sound, the role of tourism in Cordova, the impacts and outcomes of the Exxon Valdez Oil Spill, community based research opportunities and the controversial "million dollar bridge." Academic and interpretive themes are based in anthropology and cultural geography.

May 25, 17:30 (S7-7449)

Understanding the human dimensions of marine global change: The IMBER Working Group

Alida Bundy[1] and Ian **Perry**[2]

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It is becoming widely recognized that human activities impact the ocean from bottom-up and top-down, and reciprocally, that human activities are impacted by ocean dynamics and marine global change. Such changes can result from the effects of ocean acidification, intensive fishing, habitat disruption, climate change, and their interactions. However, the pathways along which these interactions occur are often poorly understood, leading to surprises and unexpected outcomes. In addition, it is usually unclear as to what policies and management actions are needed to reduce vulnerabilities, and to mitigate and avoid, undesirable outcomes. The Integrated Marine Biogeochemistry and Ecosystem Research program (IMBER) has given impetus to these human aspects of marine global change with the formation of a Working Group on Human Dimensions, composed of natural and social scientists. The HD-WG will address Theme 4 of the IMBER Science Plan "Responses of Society", the goals of which are to promote understanding of the multiple feedbacks between human and ocean systems, and to clarify what human institutions can do either to mitigate human-caused perturbations in the ocean systems or to adapt to system changes. The WG will build on and extend the work of the GLOBEC Focus 4 WG, which focused attention on marine ecosystems as social-ecological systems. This presentation will describe the plans and activities for this WG, and the questions being considered. It will invite collaborations with natural and social scientists in ESSAS and other programs to build on these activities to improve understanding of human interactions with marine global change.

May 26 Closing Plenary Session

May 26, 13:30, Invited

Impact of climate change on lower trophic levels in polar and sub-polar seas

Kevin R. **Arrigo**

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Many polar and sub-polar waters are undergoing dramatic changes due to increased anthropogenic emissions of greenhouse gases. The most pronounced of these changes is an accelerating decrease in sea ice cover in the Arctic Ocean and in parts of Antarctica. As a consequence, sea ice cover in affected regions is thinner, melts earlier, and freezes later in the year that it did a few decades ago. Changes in the amount of ice cover and in its seasonal timing has both direct and indirect effects on populations of lower trophic level organisms, especially phytoplankton. Direct impacts include a longer phytoplankton growing season and an earlier phytoplankton bloom. If this bloom is also associated with warmer waters, increased losses to grazers and altered export efficiency can result. Indirect impacts of reduced sea ice cover include increased wind stress on open water and increased vertical mixing. More vigorous mixing can promote replenishment of depleted surface nutrients, increasing rates of primary production even more. As a result of these changes, many polar ecosystems may be undergoing a shift from ice algal dominance to pelagic phytoplankton dominance, which will likely have important biogeochemical and ecological implications for this unique environment.

May 26, 14:00, Invited

Understanding ecosystem processes: A key to predicting climate effects

Steven A. **Murawski**

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Since early in the 20th century, marine ecologists have demonstrated that ecosystem biodiversity and productivity are organized on environmental gradients. These gradients in temperature, depth, salinity and other parameters describe the envelope in which species exist and, much as with terrestrial ecosystems, determine gross patterns of productivity and complexity. Climate change and variability manifest their impacts in the productivity, phenology and distribution patterns of marine life. Using a reductionist paradigm, one can observe over time how particular species respond to variations within these long term environmental gradients, and are affected by other simultaneous effects such as fishing, pollution and other factors. However, while we can use past variations in distribution and recruitment success in relation to climate-related variables, they do not lead to predictions of how whole ecosystems will respond. In this paper I examine several hypotheses of climate control of underlying processes related to trophic dynamics, biodiversity and ecosystem structure. The goal is to provide a general understanding of how fundamental ecosystem processes interact with climate scenarios to produce new environmental gradients to which existing species respond. Comparative ecosystem studies provide the basis strong inferences for climate-related responses.

May 26, 14:30, Invited

Adaptation and maladaptation to environmental change - Factors that influence the fragility or resilience of sub-Arctic fisheries and fishing dependent communities

Keith R. **Criddle**

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The sustainability of fisheries and fishery dependent communities is primarily dependent on the intrinsic characteristics of social,economic, and legal systems that determinewho is allowed to fish and how fishing takes place. Some sub-Arctic fisheries and fishery dependent communities have proven resilient to changes in fish abundance, changes in exvessel prices, changes in the cost of factors of production, changes in macroeconomic conditions, changes living costs and employment opportunities within the community, and demographic changes. Factors that contribute to resilience or exacerbate fragilityare illustrated by reference to sub-Arctic fisheries that have weathered or recovered from the influence of adverse forcing and others that have not. Key factors are within the scope of fisheries policy include tradeoffs between economic efficiencies associated with specialized single species fisheries and heightened sensitivity to variations in the magnitude or unit value of that species. In contrast, generalist fleets trade reduced economic efficiency for reduced exposure to losses associated with variations in the abundance or value of any one species. Durable individual entitlements to shares of the allowable catch increase profitability that helps fishermen adapt to modest adverse changes in stock abundance, exvessel prices, and input costs but their fragility to larger perturbations is increased. In addition, while catch shares increase choice and therefore resilience from the perspective of individuals, catch shares can increase or decrease the resilience of fishery dependent communities.

Abstracts
Poster Presentations

S1 Posters

S1-P1

Mercury distribution in air and bottom sediments of the Chukchi Sea

Maksim **Ivanov** and A.S. Astakhov

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Our investigation used grabs and core sediment samples from cruises of the R/V *Professor Khromov* in 2004, 2006, together with sediment samples from the R/V *Professor Khromov* cruise in 2002. The description and initial analysis of core sediments were carried out by standard techniques. For mercury analyses we used a mercury Zeeman atomic absorption spectrometer with high frequency modulation of light polarization RA-915+ (manufactured by Lumex Ltd, Russia) with a RP-91C pyrolysis attachment, without sample pretreatment. The distribution of mercury in core sediments is characterized by low variability and mainly low levels. It is occurs in homogeneous sediment and is not due to anthropogenic pollution. The distribution of mercury in surface sediments of the Chukchi Sea is shows two areas with increased levels: namely, Gerald`s canyon and the adjacent shelf and the southwestern area adjoining Cape Hope. The distribution of mercury was not related to the distribution sediment types *i.e.* grain-size composition, organic matter, biogenic opal and hydrocarbon gases over the large scale. There was, however, a correlation between mercury content and clay grain-size fraction and opal contents in the area of Gerald`s canyon and to the south. Near the Cape Hope there was no such correlation. The area of Gerald`s canyon corresponds to the area of greatest depth (up to 103m), suggesting a small probability that it was ever occupied by permafrost. The prevailing sediment type here is sandy mud with high admixture of biogenic opal and the low content of organic matter. The Canyon is located on the presumably tectonic active riftogenic structure of the Chukchi Graben, suggesting that here mercury emission occurs naturally from the Earth's Crust. The maximal mercury content is in the northern part of the investigation area (station 85B) of the canyon, bordering the oil-bearing region of the North Chukchi Depression. Mercury values in the air in the Chukchi and Bering Seas averaged 1.6 -2.1 ng m^{-3}.

S1-P2

Topographical generated eddies in Antarctic and Subantarctic waters near Southern Ocean submarine ridges

Vladimir B. Darnitskiy[1] and Maxim A. **Ishchenko**[2]

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At high latitudes near the Antarctic topographic eddies are not as frequent as at mid-latitudes. On a cruise of the R/V *Professor Mesjatsev* in the Indian Ocean in 1979, a hydrographic survey around the Western-Australian ridge showed a circulation pattern consistent with that theorized by McCartney (1975). In the Atlantic sector of the Southern Ocean in 1981, however, during the Weddell Polynya Expedition (An ice-hole of Weddell sea - 81), anticyclonic and cyclonic eddies formed a downward-dissipating water column over seamount Maud. Also over seamount Maud, a series of CTD-XBT deployments in summer 1983-1986 and current meter data from 5 stations, collected between April and December 1986, showed large localized volumes of cold sub-surface water with a horizontal extent of 150-200km, which were constrained by Taylor columns Based on repeat surveys carried out by a *TINRO* R/V around one of the 20 underwater mountains in the Eltanin Fracture Zone (the Pulkovskay seamount and others), the effects of topographical eddies on the distribution of planktonic communities and migration of fishes near seamount summits were tracked. Changes in water structure near the peaks were registered, which may result in periodic changes in the general level of biological productivity, depending on the distribution of subantarctic and subtropical waters. Intra-daily, daily and inter-daily wave-forming processes result in internal periodic waves, causing fluctuations in hydrographic features: in particular in nutrient concentrations, resulting in changes in local plankton biomass. Over certain periods biological productivity levels around seamounts can be comparable to the productivity associated with the main climatic fronts of the Southern Ocean, due to the upwelling of nutrient-rich water from intermediate depths into the photic layer. Topographically generated eddies near the subtropical Lord Howe rise and Norfolk ridge, the subantarctic Eltanin Fracture Zone seamounts and the New Zealand plateau waters and the variability of their inner structure and ecological peculiarities will be discussed, as well as the peculiarities of annual variability of local topographically generated frontogeneses.

S1-P6

The influence of surface winds on Circumpolar Deep Water transport and ice shelf basal melt along the western Antarctic Peninsula

Eileen E. **Hofmann**, Michael S. Dinniman and John M. Klinck

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Circumpolar Deep Water (CDW), characterized by temperatures greater than 0°C, can be found below about 200m along the continental shelf break around most of Antarctica. The interaction of the Antarctic Circumpolar Current (ACC) with the outer shelf bathymetry coupled with surface wind forcing results in transport of this warm water mass onto the continental shelf. This water mass extends into the inner shelf region along the western Antarctic Peninsula (WAP) where it comes into contact with the base of floating ice shelves, providing heat for basal melting. A high resolution (4km) regional coupled ocean/sea-ice/ice shelf model was implemented for the WAP coastal ocean to examine the effects of changes in the winds and ACC transport on across-shelf CDW transport and ice shelf basal melt. Increased wind strength and ACC transport increased the amount of CDW transported onto the WAP continental shelf, but did not necessarily increase the CDW flux underneath the ice shelves. The basal melt underneath the deeper ice shelves actually decreased with increased wind strength. Increased mixing due to stronger winds removed more heat than the additional heat gained from increased CDW volume transport. A simple budget indicated that the iron provided to the WAP shelf by increased CDW transport could significantly affect biological productivity of this region. The simulation results suggest that the projected strengthening of the polar westerlies may have important effects on the WAP continental shelf, and that the relationship between CDW, ice shelf basal melting, and nutrient supply is not simple.

S1-P7

Developing integrated models of Southern Ocean food webs

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To understand the current status of Southern Ocean ecosystems and make reliable projections of the impacts of past and future change first requires a fundamental understanding of the factors that determine both the structure and operation of the food webs at multiple scales. This knowledge is needed to inform model development in order to generate realistic projections that are firmly grounded in ecological knowledge. Here we consider the main ecological and modelling challenges faced in developing integrated analyses of the responses of Southern Ocean ecosystems to change, and propose steps to be taken towards the generation of large-scale models. Ecological research in the Southern Ocean is often centred on key species or localised systems, a tendency which is reflected in much of the modelling effort to date. To build on this, a systematic analysis of regional food web structure and function is required. At the same time, a range of mechanistic models that vary in resolution of ecological processes are needed to consider links across physical scales, biogeochemical cycles and feedbacks and the central role of zooplankton. Developing methodologies for scenario testing through a range of trophic levels of the effects of past and future changes will facilitate consideration of the underlying complexity of interactions and the uncertainty involved. To deal with the complex nature of interactions determining ecosystem structure and function will require new approaches, which we propose should be developed within a scale-based framework that emphasizes both physical and ecological scaling.

S1-P8

The IMBER Project

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The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) Project is a decade-long international project of the International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee on Oceanic Research (SCOR). IMBER has a focus on ocean biogeochemical cycles and ecosystems, which is reflected in the primary project goal of investigating the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades. IMBER research is structured around four themes that consider 1) the transformation and transport of elements involved in biogeochemical cycle interactions with food web dynamics, 2) how marine biogeochemical cycles and ecosystems respond to global change, 3) the capacity of the ocean to control the climate system via atmospheric composition and ocean heat, and 4) the implication of changes in the open ocean for human society. IMBER research is conducted via working groups, collaborations with other programmes, and regional research programmes. Two IMBER regional programmes, the Ecosystem Studies of Sub-Arctic Seas (ESSAS) and the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED), are focused in the Arctic and Southern Ocean, respectively, and provide a framework for furthering the science results in these regions. This poster provides an overview of IMBER, highlights science results from ESSAS and ICED, and indicates potential linkages between these IMBER regional programmes.

S1-P9

Marine climate change ecology: A meta-database for assessing impacts

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As part of an ongoing National Center for Ecological Analysis and Synthesis (NCEAS) working group on climate impacts on marine ecosystems, designed in part to synthesize information for the next IPCC assessment report (AR5), we compiled information from 91 peer-reviewed publications and created a meta-database on marine bird – climate interactions. Here we present details of this database. The studies provide 2,599 records of seabird-climate interactions based on variables such as SST or sea ice extent (SIE); other data included location and duration of study, and results of trend analyses on climate and seabird variables. Data from a total of 24 seas and oceanic "regions" and 95 species are summarized. The database facilitates global investigations of specific topics in marine climate change ecology. For example, expected effects of climate change include an increase in the length of the growing season in upwelling, sub-arctic, and polar seas. Logically, this would lead to the prediction that seabird breeding dates should advance, but has this been routinely observed? Moreover, with this database we can examine assumptions of models by asking generalized questions of seabird-climate interactions such as: "is the relationship of SST and seabirds generally positive or negative?" The meta-database also can be used to identify geographic gaps in global studies and evaluate ways in which studies of climate impacts on marine ecosystems can be improved. This poster supports an oral presentation summarizing analysis of aspects of this meta-database (see Sydeman *et al.*).

S2 Posters

S2-P1

Apex predators and hot spot persistence in the southeast Bering Sea

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From concurrent surveys of whales, birds and prey, we examined distributions of two seabird species, the surface-feeding black-legged kittiwake and the pursuit-diving thick-billed murre, and two baleen whale species, the humpback whale and the fin whale, in relation to two key prey, age-1 walleye pollock and euphausiids. Euphausiids were widespread and their hot spots often persistent. In contrast, age-1 pollock were more concentrated and their hot spots persistent only on coarse scales. We found that thick-billed murres foraged at prey hot spots near (within about 100 km) their island colonies and largely avoided more distant hot spots. In contrast, black-legged kittiwakes were widespread foragers and the persistence of their hot spots was weakly correlated with the persistence of euphausiid hot spots and coarse scale age-1 pollock hot spots regardless of location. Humpback whales were concentrated only where euphausiids were also concentrated, and further, only in locations where euphausiid hot spots were persistent. We found no association of fin whales with hot spots; the reason for the lack of association for this species compared to the other species is unknown. Thus, the relationship between predators and prey generally fit our hypothesis that slower predators are more responsive to persistent hot spots, although less efficient flyers that are tied to a colony such as murres may be limited in their ability to track and access hot spots.

S2-P2

Spatial distribution of groundfish in the northern Bering Sea in relation to environmental variation and feeding habitat

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This study was to assess the impacts on benthic fish distribution in response to environmental change and prey availability in the northern Bering Sea. Groundfish samples were collected in spring 2006 and 2007 in the northern Bering Sea around St. Lawrence Island (SLI). The structure of the entire community of benthic fish was examined and multivariate analyses (cluster analysis, multidimensional scaling) were used to predict ecologically based relationships between environmental factors and fish community structure in the northern Bering Sea. Arctic cod (*Boreogadus saida*), Bering flounder (*Hippoglossoides robustus*), and snailfish (Liparidae) were the dominant species south of SLI, whereas Arctic alligatorfish (*Ulcina olrikii*) and Arctic staghorn sculpin (*Gymnocanthus tricuspis*), or shorthorn sculpin (*Myoxocephalus scorpius*) were dominant north of SLI. The results indicate that bottom water (or water column) chlorophyll *a* and sediment parameters had greater influence on fish distribution in 2006 (cold, pre-bloom conditions), whereas bottom water temperature and sediment grain size were more important in 2007 (warm, bloom conditions) among a total of 14 environmental variables that were analyzed. These findings suggest strong linkages between physical conditions (*e.g.* water temperature and hydrography as it affects sediment grain size) and biological conditions (*e.g.* bloom status) in structuring fish communities in the northern Bering Sea. The diet and feeding relationship of dominant groundfish in the northern Bering Sea were studied using stomach content data. All of Bering flounder had empty stomachs. Benthic amphipods were the primary prey for Arctic cod, snailfish, Arctic staghorn sculpin, and Arctic alligatorfish, while crabs were the primary prey for shorthorn sculpin. High diet overlap was found among some fish species; however, competition was likely reduced by differences in feeding strategies and available food resources.

S2-P3

Seasonal predictability of the properties of cold bottom waters on the Bering Sea shelf

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A coupled sea ice–ocean model (the Bering Ecosystem STudy ice–ocean Modeling and Assimilation System or BESTMAS), combined with observational and reanalysis data (trawl surveys of bottom water temperature, satellite sea ice concentration/extent, and the NCEP/NCAR reanalysis surface air temperature), is used to explore the seasonal predictability of the properties of cold bottom waters on the Bering Sea shelf through numerical simulations as well as statistical analyses. Good agreement between observations and BESTMAS results suggests the possibility of numerical seasonal predictions of the bottom layer properties. Significant correlations between various winter air–ice–sea parameters and spring-summer bottom layer properties suggest a basis for statistical seasonal predictions.

S2-P4

Distribution of diatom resting stages in bottom sediments of the eastern Bering Sea in the summer of 2009

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Diatoms are very important primary producers within marine ecosystems. It is well known that coastal diatom species form resting stage cells when the environment is unfavorable, and information on diatom resting stages is fundamentally important to understanding the population dynamics of diatoms including blooms. The distribution of viable resting stage cells of diatoms in sediments in the eastern Bering Sea in July 2009 was estimated by the most probable number (MPN) method. The number of resting stage diatoms was extremely high (3.1×10^2 - 7.1×10^5 MPN cm^{-3} wet sediments), and the densities of resting stage diatoms were almost equal to those of eutrophic sea areas like the Inland Sea of Japan where red tides often occur. The numerically dominant species were *Chaetoceros diadema*, *C. socialis*, *C. furcellatus*, *Thalassiosira nordenskioeldii* and *T. gravida*. Most of these species are dominant during the spring phytoplankton bloom in the water column of the eastern Bering Sea. In winter season, the eastern Bering Sea experiences strong storms and convection, which cause strong vertical mixing, and the resting stage cells presumably are resuspended into the water column, suggesting an important role as a seed-population for the next blooms. It should be noted that also found in the sediments were relatively high numbers of ice algae species (the genera *Fragilaria*, *Fragiloriopsis* (*Nitzschia*), *Pinnularia* and *Attheya*). The resting stages of these species might also function as seed-populations.

S2-P5

Inter-annual changes in the zooplankton biomass during summers of 1994-2009 and zooplankton community structure in 2006 in the Bering Sea shelf

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To evaluate inter-annual changes in zooplankton biomass, we investigated zooplankton wet mass in the Bering Sea shelf during summers of 1994-2009. Spatial changes in zooplankton community structure were also evaluated for summer of 2006. Zooplankton samples were collected by vertical tow of NORPAC net at total of 438 stations (9-49 stations in each year) during 21 June-8 August of 1994-2009. In the laboratory, zooplankton wet mass was measured, calanoid copepods were identified to species, and copepodid stage identification was made for abundant large copepod *Calanus marshallae*. Zooplankton biomass showed three distinct inter-annual changes. Thus, zooplankton biomass was moderate and normal during 1994-1997, lower during 2000-2005 and higher during 2006-2009. The inter-annual changes in the zooplankton biomass were related with the water temperature conditions. The temperature in upper 20m water column was higher during 2000-2005, but was lower during 2006-2009. Zooplankton community in summer of 2006 was divided into 4 groups, and their distribution well separated horizontally: termed Basin, Outer shelf, Middle shelf and Inner-Middle shelf. Calanoid copepods dominated throughout the region, and the dominant species varied with region: *Eucalanus bungii* in Basin, *Acartia longiremis* in Outer shelf, *Pseudocalanus* spp. in Middle shelf and Inner-Middle shelf. The Population structure of *C. marshallae* was also varied with region, and adult females were predominated in Middle and Inner-Middle shelf.

S2-P6

Correlation between mesopelagic fish abundance and PDO in the upper pelagic northwestern Pacific Ocean

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Mesopelagic fish play a great role in the ecosystem of the northwestern Pacific Ocean, because their abundance is almost 10 times higher than that of all commercially exploited marine fish stocks and they appear to be competitors and prey for valuable fisheries species (*e.g.* Pacific salmon).

We estimated annual abundance of mesopelagic fish (AMF) occur along the pathways of Pacific salmon in the upper epipelagic layer (UEL, 0-50m) of the Russian EEZ in the North Pacific Ocean during night (when the sun is 12º below horizon) for the last 30 years. AMF highly correlated with PDO fluctuations.

The highest correlation (R=-0.99) appeared between PDO and *Scopelosaurus harryi's* average abundance in the western Bering Sea (wBS) during September, but these fish were registered in catches only during 5 years. The second highest correlation (R=-0.93) was found between PDO and *Stenobrachius leucopsarus* at the same time and place. Correlation between PDO and spatially variable AMF was lower, but also significant (R~-0.6 for both species). *S. leucopsarus* took the 3rd place in the given fish community after *Oncorhynchus* species, and total annual fluctuations of AMF correlated with PDO significantly (R=-0.57) in the wBS.

In waters east off Kuril Islands and Kamchatka the highest correlation between AMF and PDO was noticed in August during May (R=-0.60). *S. leucopsarus* dominated among mesopelagic fish in the UEL in September. Time series of all main groups of mesopelagic fish and share of AMF in the ichtyocenosis of UPL showed decreased during recent decade.

S2-P7

Long-term monitoring of sinking diatom fluxes at Stations AB and SA in the Bering Sea and the central Subarctic Pacific, 1990-2006

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Long-term monitoring of diatom fluxes during 1990–2006 was conducted at Station AB in the Bering Sea (53.5N177W; trap depth at about 3200 m) and Station SA (49N174W; trap at about 4800 m) in the central subarctic Pacific in order to decipher the relationships between sinking diatoms and environmental conditions in the upper water masses. The total diatom flux at Station AB was generally twice as high as that at Station SA. The dominant species in the sinking flora was primarily *Neodenticula seminae* at both stations, which was a significant contributor to the vertical export of organic carbon into oceanic interior. The flora at Station AB was represented by relatively abundant coastal taxa including *Chaetoceros* resting spores. These results suggest more favorable conditions for diatom production at Station AB than at Station SA. The seasonality and the flux level of the diatoms in each year was not the same at both stations, suggesting the influence of inter-annual oceanographic variation. Although it is difficult to compare the monthly flux data and oceanographic data such as SST, primarily due to the difficulty in sinking time estimation, the cumulative annual fluxes of total diatoms at both stations are apparently related to the variation in the mean annual depth of mixed layer at least for the first 8 years. At Station SA, the annual mean of total diatom flux showed a negative correlation with the Pacific Decadal Oscillation Index during 1990-1998, suggesting a significant relationship between the surface water turbidity and diatom production.

S2-P8

Distribution and recent changes of coccolithophore (*Emiliania huxleyi*) blooms in the eastern Bering Sea shelf

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During the late summer of 1997, most of the continental shelf in the southeastern Bering Sea was covered by aquamarine-colored waters as a result of massive blooms of the coccolithophore, *Emiliania huxleyi* (*E. huxleyi*). Since then, *E. huxleyi* blooms in the eastern Bering Sea have become common. This study was conducted to examine recent spatio-temporal variability in *E. huxleyi* blooms in the eastern Bering Sea and to determine what factors are responsible for the blooms. In this study, we used the dataset from the satellite ocean color sensors, SeaWiFS (Sea-viewing Wide Field-of-view Sensor) and MODIS (MODerate resolution Imaging Spectroradiometer) from September 1997, to detect the *E. huxleyi* blooms. Those occur in the middle of the continental shelf where the water depth is 20 to 100m. We found large interannual and seasonal variability in the area of the *E. huxleyi* blooms. Massive blooms were observed in the late spring of 1998 and 2000, and in the fall of 1997 and 2000. The blooms have begun to peak in September from 2001, and there have been no blooms observed in June. Since 2001, the blooms have been limited to a small area in the middle shelf region. The mechanism responsible for the development of the *E. huxleyi* blooms was an eruptive warming of sea surface layer. This warming resulted in strong stratification of the surface layer in 1997 and 1998, which decreased the amount of nutrients supplied by storms. Cold bottom water, which is remnant of the winter cooling in the middle of the shelf, has been relatively warmer than usual since 2002, resulting in weak stratification during summer. Therefore, the water column is much more easily mixed by storm, inducing nutrient-rich diatom-favorable condition in the summer. This is likely to be responsible for the recent decrease in *E. huxleyi* blooms in the eastern Bering Sea shelf.

S2-P9

Temperature and population density effects on the spatial distribution of groundfishes and crabs in the eastern Bering Sea shelf

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Several studies have shown that spatial distributions of eastern Bering Sea (EBS) shelf groundfishes and crabs change in response to bottom temperature, density dependent factors, or both; however, studies are for a limited number of taxa and analyses have not yet included the recent cold trend that began in 2006. This study considers the spatial extent of the cold bottom layer and the population density of each species to explain inter-annual variability in the distribution of 30 different taxa using EBS bottom trawl survey data for the years 1982-2010. Generalized additive models (GAM's) use local (LIC) and global (GIC) indices of collocation as dependent variables to determine the effects of between-year differences in the cold pool area and standardized area swept estimates of population density by species. Two additional independent variables, survey vessel and year, are also factored into GAM analyses to account for errors associated with conducting bottom trawl surveys on different vessels over all survey years. More than half of the species investigated show significant effects of the annual difference in cold pool area on the LIC, GIC, or both, and a majority of taxa showed significant effects of inter-annual variability in population density. The general trend for most species was increasing local heterogeneity in the spatial distribution (LIC) and decreased spatial overlap of populations (GIC) as differences in cold pool area increased. In instances where inter-annual variability in population density affected spatial indices, a majority of taxa showed decreases in the statistical measures of spatial distribution.

S2-P10

Growth of Norton Sound and Kuskokwim River, Alaska chum salmon in relation to climatic factors and inter- and intra-specific competition

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Questions remain about how ocean climate shifts influence salmon survival and abundance. In addition, questions exist regarding the ocean's capacity to support the large number of hatchery salmon released each year in addition to wild salmon, and recent studies have documented trends toward smaller adult salmon. These questions are difficult to examine because sampling salmon at sea is difficult, and few long-term time series exist. We present results of recent studies designed to test hypotheses related to how climatic factors affect growth of chum salmon in western Alaska and the Bering Sea and whether interactions with Asian pink and chum salmon have affected the growth of these salmon. We created indices of growth for age 0.3 and 0.4 Norton Sound and Kuskokwim River chum salmon by year (mid-1960s-2006) by measuring annual and seasonal growth. We examined the relationship between growth and several environmental indices as well as the effect of Asian pink salmon abundance and Asian chum salmon abundance on growth. Generalized linear modeling indicated a negative correlation with the North Pacific Index, pink salmon abundance and Asian chum by gender for the third year of growth for both systems. During the first growth year in both areas, there was a significant negative correlation between ice cover and growth. Additional factors affecting growth were SST, mixing, and the North Pacific Index. Use of a general additive model yielded similar results. These studies provide examples of how scale measurements can be used to reconstruct salmon growth trends in the ocean as a means to test otherwise problematic hypotheses.

S2-P11

Local and traditional knowledge of the eastern Bering Sea ecosystem

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Five Alaska Native communities have been involved in the Bering Sea Integrated Ecosystem Research Program (BSIERP): Akutan, St. Paul, Togiak, Emmonak, and Savoonga. In each community, subsistence harvest levels were documented along with local and traditional knowledge of the ecosystem. Results to date indicate variability in harvest levels over time, but no clear pattern across all five communities. The cultural and nutritional importance of marine harvests remains high, with per capita production exceeding 100kg in many communities. The species harvested range throughout the Bering Sea, Gulf of Alaska, Chukchi Sea, and in some cases Beaufort Sea. Communities therefore draw on a vast area of marine productivity for their hunting and fishing. Despite the many changes observed by community residents, hunters and fishers are accustomed to a high degree of variability, and have not found the changes to be a major challenge to date. By contrast, changing human patterns and demands, including interactions with commercial fisheries and rising fuel costs, cause considerable concern. Ecosystem change is most apparent in the north by changing sea ice, and across the region by lower predictability of weather and related phenomena. Comparisons and contrasts with the results of biological and physical research under BSIERP are beginning and will be presented as available.

S2-P12

Conceptual model of energy allocation in walleye pollock (*Theragra chalcogramma*) from larvae to age-1

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Walleye pollock (*Theragra chalcogramma*) support the largest commercial fishery in the United States and are an ecologically important component of the eastern Bering Sea (EBS) ecosystem. Multiple forcing mechanisms during the early life stages of pollock result in variable recruitment. Relating the seasonal progression of energy content and allocation to the distribution and abundance of pollock allows for detection of spatial and temporal trends in pollock condition and provides critical information for the prediction of overwinter survival and recruitment to age-1. Larval, juvenile, and age-1 pollock were collected in the EBS from May to September 2008-2010. Fish condition was determined through quantification of energy density (kJ/g) and proximate composition (% lipid, protein, moisture) with variation in energy density driven by variability in percent lipid. Energy densities were relatively low during larval development in early summer, indicating energy allocation to growth and development. Lipid acquisition rates increased ten fold as pollock reached the juvenile form, with allocation to storage leading to higher energy densities in fall. A physiologically and ecologically important shift occurs after larval development is complete (~25mm SL) when pollock begin allocating energy reserves to storage for overwinter survival. Interannual variation in energy allocation strategies, and thus fish condition, was examined in relation to variability in available prey composition across years. We hypothesize fish condition is dependent on oceanographic conditions and prey availability during a short critical period in early fall for lipid storage.

S2-P13

North Pacific Polar Front: Trans-ocean link/barrier/blender and its impact on the Gulf of Alaska, Aleutians, and Bering Sea ecosystems

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The North Pacific Polar Front is the boundary of the Subarctic Zone that features a well-defined subsurface temperature minimum, a remnant of wintertime convective cooling. The current associated with the Polar Front acts as a conduit for advective anomalies of temperature, salinity, and nutrients that originate off the coasts of Siberia and Japan. Therefore, the Gulf of Alaska (GOA), Aleutians, and eastern Bering Sea ecosystems are on the receiving end of large-scale atmospheric and oceanic perturbations that occur in the Northwest Pacific. These perturbations propagate along the Polar Front into the GOA where the front retroflects and extends westward along the shelf break to the Aleutians and into the Bering Sea. Thus, the Polar Front Current acts as a link connecting ecosystems of the West Subarctic Gyre, East Subarctic Gyre, Aleutians, and eastern Bering Sea. While being a major ecological barrier that encircles the Subarctic Zone, the Polar Front acts as a blender through meander growth and ring spawning, thereby facilitating cross-frontal transfer of properties and organisms. Along its entire extent from Hokkaido into the GOA, the Polar Front shifts north-south interannually, exhibiting especially regular multi-year oscillations over the Emperor Mountains. Farther east, the Polar Front Retroflection shifts east-west on the multi-year time scale. These shifts must profoundly affect the GOA ecosystem, including the Alaskan Shelf, although this effect is not quantified yet. The Polar Front experienced rapid warming since 1978 at the depth of temperature minimum, an evidence of rapid amelioration of winter climate.

S2-P14

Seabirds and their prey during late summer and fall in the Bering Sea: Energetic bottleneck or cornucopia?

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For seabirds, fall is a critical period that sets the stage for over-winter survival and subsequent reproductive fitness, yet, in the Bering Sea there is little information on post-breeding seabird-prey interactions. As part of BSIERP, we conducted surveys of seabird (visual transects) and prey (acoustics and trawl) distribution and abundance in the Bering Sea from March to November, 2006-2010, completing >80,000km of transects. Seabird species richness and total density were highest during late August through September, when post-breeders, non-breeders, juveniles, and migrants from southern oceans concurrently occupied offshore waters. In some years, this period coincided with a high abundance of age-0 and age-1 walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephala*), as well as forage species such as capelin (*Mallotus villosus*), and euphausiids (Euphausiidae). We used data collected concurrently during BASIS surveys in the southeastern Bering Sea to examine late summer/fall relationships between seabird and prey abundance and distribution, as well as physical properties that may influence those relationships. Depending on environmental conditions, prey species can be energy- rich in the fall, as they build reserves for the subarctic winter. In addition, during 'cold' years such as 2009 and 2010, large schools of capelin were patchily distributed and attracted seabird feeding aggregations. We propose that this post-breeding period of high seabird abundance can coincide with high prey abundance and quality, but it could also be an energetic bottleneck during years when warm water conditions result in dispersed or energy-poor prey.

S2-P15

Cetacean distribution on the Eastern Bering Sea shelf in June and July of 2002, 2008, and 2010

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As part of the Bering Sea Project, cetacean surveys were conducted to describe abundance and distribution on the SE Bering Sea shelf. Three marine mammal observers conducted visual surveys along transect lines sampled during the NOAA walleye pollock assessment survey in June and July of 2008 and 2010. Distribution and abundance is compared to results from a similar survey conducted in 2002; patterns largely match those previously observed. Abundance estimates for 2002, 2008 and 2010 were as follows: 1,570 (CV=0.51), 4,269 (CV=0.31), and 449 (CV=0.38) fin whales, 450 (CV=0.77), 835 (CV=0.79), and 111 (CV=0.94) humpback whales, 808 (CV=0.44), 389 (CV=0.68), and 542 (CV=0.92) minke whales, 46,248 (CV=0.23), 30,388 (CV=0.41), and 3,810 (CV=0.34) Dall's porpoise, and 5,901 (CV=0.73), 6,448 (CV=0.41), and 276 (CV=0.71) harbor porpoise. Abundances are examined by oceanographic domain and year. Fin whales were well distributed in the outer domain in 2008 and 2010, but were sparse in 2002. Humpback whales were consistently concentrated in coastal waters north of Unimak Pass. Minke whales were concentrated in the outer domain except for 2002 when they were also found east of the Pribilofs Islands. In 2002, Dall's porpoise were sighted on the western edge of the middle domain and in the outer domain, but shifted west out of the middle domain in 2008 and possibly in 2010. In 2002 and 2008, harbor porpoise were consistently found in the middle domain with scattered sightings in the outer domain. In 2010, there was a multi-species mix of sightings between Navarin and Pervenets Canyons.

S2-P16

Phytoplankton biomass and size structure during late summer/early fall in the eastern Being Sea

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The BASIS (Bering-Arctic-Subarctic-Integrated Systems) program conducted fisheries oceanography surveys in the eastern Bering Sea during mid-August to early October from 2003-2009, covering 3 warm and 4 cold years. Chlorophyll *a* (total and size-fractionated discrete samples) and chlorophyll *a* fluorescence from CTD profiles will be used to describe spatial and yearly variations in total phytoplankton biomass and shifts in size structure of late summer/fall phytoplankton assemblages. Data will be used to evaluate variations between warm and cold years, across domains (Inner-Middle-Outer), and between N-S regions. Results will be used to further characterize primary production and ecosystem dynamics during the critical late summer/ fall period prior to the over-wintering of key forage fish (*e.g.* juvenile pollock, salmon).

S2-P17

Rates of net community and gross photosynthetic production on the Eastern Bering Sea shelf as estimated from O_2/Ar ratios and triple O isotopes under non-steady state conditions

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Changes in the Bering Sea ecosystem observed in recent decades have been correlated with climate-related variability of the regional environment. Understanding of the mechanisms behind the observed correlative relationship requires a better knowledge of factors influencing the magnitude and fate of the primary production in this sub-polar ecosystem.

We determined rates of Net Community Production (NCP) and Gross Photosynthetic Production (GPP) in spring blooms in the marginal ice zones on the Bering Sea shelf, based on O_2/Ar ratios measured in spring 2007 and 2008 with an Equilibrator Inlet Mass Spectrometer and triple oxygen isotope composition measured on discrete samples collected from the mixed layer. As spring blooms are inherently non-steady state phenomena, the rates of NCP and GPP were obtained using a time-dependent biogeochemical model, which was calibrated using a suite of repeat measurements at several locations. Maximum daily NCP rates in the marginal ice zone blooms were up to 800 mmol-O_2*$m^{-2}d^{-1}$ in spring 2007 and up to 500 mmol-O_2*$m^{-2}d^{-1}$ in spring of 2008. Constraining the rates of GPP from modeling of the triple O isotope of dissolved O_2, we found the range of NCP/GPP ratios (stoichiometrically equivalent to the efficiency of organic C export, or e-ratio) from 0.2 to 0.6, with higher NCP/GPP found at the bloom maxima. A strong inverse correlation between the mixed layer depth and the magnitude of NCP/GPP ratios is suggestive of a mechanistic link between hydrographic properties of the water column and export of the primary production within marginal zone ice blooms.

S2-P18

A nearshore survey of fishes and invertebrates in northern Bristol Bay, eastern Bering Sea, Alaska

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A great deal of research has been conducted in the eastern Bering Sea, but little of this effort has been directed towards nearshore areas (defined here as areas of less than 20m depth). These areas can be important as nursery areas for juvenile groundfishes, seasonal habitats for forage fishes and other animals, and as a link between the terrestrial and marine environments. From July 26 to August 8, 2009, I conducted a nearshore survey in several areas of northern Bristol Bay: Nushagak, Kulukak, Nunavachak, and Ungalikthluk Bays, and along both sides of the Nushagak Peninsula. A chartered 32-ft. gillnetter was used to deploy a bottom trawl and a surface trawl, and a skiff was used to deploy beach seines. Rainbow smelt (*Osmerus mordax*) and shrimps of the family Crangonidae were the most abundant and ubiquitous species encountered, occurring in almost every trawl and seine haul. Species composition of the catches changed with longitude (*i.e.*, as we moved west from Nushagak Bay). There were also substantial differences between inner and outer regions of bays. Juvenile yellowfin sole (*Limanda aspera*), an important commercial species in Alaska, were abundant in Kulukak and Nunavachak bays. This study demonstrated the importance of nearshore sampling, as species such as *O. mordax* are almost unknown in surveys conducted further offshore and potential nursery areas for many groundfish species have yet to be identified. In addition, the project shows that a small but properly-equipped vessel provides an inexpensive means of gathering this valuable information.

S2-P19

Physiological ecology of *Calanus* in the Bering Sea during spring sea-ice conditions: Feeding, reproduction, and population genetics

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Our goal is to understand the impact of changing sea ice conditions on planktonic food web structure and function by describing mesozooplankton-microzooplankton trophic linkages and the fate of phytoplankton blooms in the Bering Sea during spring sea-ice conditions. During three research cruises in April-May 2008, 2009 and May-June 2010 as part of the BEST-BSIERP program, we conducted experiments with dominant mesozooplankton to determine grazing rates on phytoplankton, ice algae, and microzooplankton and egg production rates (EPR) of reproductively active dominant copepod species. Copepods in the genus *Calanus* exhibited a saturating feeding response to increasing chlorophyll concentration. However, they strongly preferred microzooplankton to phytoplankton/ice-algae, even at high chlorophyll concentrations, when feeding on natural assemblages. Based on enriched treatments with ice-algae, it appeared that they could significantly increase their ingestion rates by feeding in close association with the ice. The EPR of *Calanus* in 2008 and 2009 was asymptotically related to both ingestion rate and ambient food concentration, indicating that reproduction depended on ingested food. However, in 2010, about a month later in the season, EPR was significantly higher and unrelated to ingestion or ambient food concentration. There was no evidence of egg-hatching inhibition due to feeding on diatom blooms; hatching success was 75-100% at all locations. In addition, sequence analysis of several different genes revealed a strong latitudinal gradient in the *Calanus* population/species structure. *Calanus glacialis* was found to be present on the shelf in much higher abundance and over a much greater area than previously thought.

S2-P20

Interactions among Pacific salmons *Oncorhynchus* spp. in the Bering Sea Basin: Evidence from diets and stable isotopes

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The biennial variation in pink salmon abundance is a prevailing phenomenon in the subarctic North Pacific Ocean and its adjacent seas, which has been suggested to affect a wide range of trophic levels including its congeners. The objective of the present study was to determine whether the variation affects diet, trophic level and nutritional performance of the plantivorous sockeye and chum salmon. We compared diet composition, body condition and stable carbon and nitrate isotope ratios in fish muscles among July (summer) and September (autumn) of 2002 and 2003 in the central basin of the Bering Sea.

Of the four periods, pink salmon was abundant only in summer 2003. The diet of pink salmon was relatively diverse, but its most important prey was euphausiids (>40% in DW composition). During this period, small- (≤45cm FL) and large- (>45cm FL) sized sockeye salmon and large-sized (>50cm FL) chum salmon decreased the share of euphausiids in their diets when compared with summer 2002. This fact suggests that the existence of pink salmon decreased their opportunities for ingesting euphausiids.

However, there was no apparent interannual difference in body condition and stable isotope compositions of both species in the autumn. Therefore, we concluded that pink salmon do affect feeding of other planktivorous salmon species, but their effect does not continue throughout the feeding season, perhaps because of the high productivity of the Bering Sea.

S2-P21

Going off the deep end – Faunal diversity in Bering Sea marginal ice zone submarine canyons

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Submarine canyons globally are recognized as rare habitats, occupying <4% of the world seafloor and serve as conduits for organic and inorganic matter moving between deep basins and continental shelves. Carbon flux rates and physical processes within canyons often support high biomass and diversity. We examined faunal species diversity and distributions in upper depths of the world's largest undersea canyon, Zhemchug Canyon, and nearby Pribilof Canyon in the Bering Sea, Alaska.

Sixty years of disparate geological, hydrographic and biological records were synthesized, updated and augmented by *in situ* submersible and ROV surveys of upper canyon depths in 2007, plus multiple bathymetric surveys covering patches of canyon geography from 1998-2010. Results refine the unique gyre-generating geomorphology and affirm that seabed heterogeneity studded by sea –ice conveyed "dropstones" are distinguishing physical features of these massive undersea chasms.

Canyon epibenthic megafaunal species assemblages differ substantially from the vast adjacent shelf, and are more characteristic of Pacific and Gulf of Alaska shallow water taxa than of surrounding Bering Sea waters. Multiple flooding events, past ocean circulation, seasonal sea ice over the shelf and the Beringian land mass appear to have limited northward distribution of many species to the canyon upper edges – defined by sea level during the last glacial maximum. Molluscs, echinoderm, porifera and anthozoan species exhibit diversity unreported for the region. These findings further clarify the role of canyon epibenthic habitats in supporting fishery species and contributing to productivity of the Bering Sea through functioning as thermal refugia, biocultivators, and diversity havens.

S2-P22

Updated analysis of flatfish recruitment response to climate variability and ocean conditions in the Eastern Bering Sea

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This study provides an updated retrospective analysis of the relationship of physical oceanography and biology and recruitment of three Eastern Bering Sea flatfish stocks: flathead sole (*Hippoglossoides elassodon*), northern rock sole (*Lepidopsetta polyxystra*), and arrowtooth flounder (*Atheresthes stomias*) for the period 1978 - 2006. Temporal trends in flatfish production in the Eastern Bering Sea are consistent with the hypothesis that decadal scale climate variability influences marine survival during the early life history period. Although density-dependence (spawning stock size) is statistically significant in a Ricker model of flatfish recruitment which includes environmental terms, wind-driven advection of flatfish larvae to favorable nursery grounds was also found to coincide with years of above-average recruitment through the use of an ocean surface current simulation model (OSCURS). Ocean forcing of Bristol Bay surface waters during springtime was mostly shoreward (eastward) during the 1980s and again in the early 2000s and was seaward (westerly) during the 1990s, corresponding with periods of good and poor recruitment. Distance from shore and water depth at the endpoint of 90 day drift periods (estimated time of settlement) were also found to correspond with flatfish productivity. Results were applied to IPCC future springtime wind scenarios to predict the future impact of climate on northern rock sole productivity.

S3 Posters

S3-P1

Why fish eggs are bigger towards high latitudes - Evolution within boundaries

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Pelagic fish eggs are small, with an average diameter of 1.1 mm, but with a large range of variation from 0.7 to 3.5 mm, implying that the volume of the eggs range over more than two orders of magnitude. No relationship between adult size and egg size are found among fishes spawning pelagic eggs. The small size of pelagic eggs has puzzled numerous authors, but has not yet been given a satisfactory explanation. We hypothesize that there exists a natural boundary that imposes a strong selection against large pelagic eggs. Due to the nature of viscous forces, the terminal velocity of a large egg is higher than that of a small egg, provided identical density. Hence, large eggs will rapidly end up at the ocean surface where they are exposed to damaging levels of UV-light, waves and predation. Thus, we suggest that the properties of viscous forces can explain the small size of pelagic eggs, and that bigger eggs can exist at high latitudes and in the Arctic because of the high viscosity in these regions.

S3-P2

Evaluation of uncertainty of Pacific saury (*Cololabis saira*) responses to future climate change

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An ecosystem based bioenergetics model NEMURO.FISH (North Pacific Ecosystem Model for Understanding Regional Oceanography. For Including Saury and Herring) was used to investigate responses of Pacific saury (Cololabis saira) to global warming. The model is composed of three ocean domain boxes, which represent the subtropical, mixed water and subarctic regions, and saury is assumed to migrate between these boxes. The model is forced by the sea surface temperature (SST) of global warming conditions generated by climate model outputs which contributed to IPCC-AR4 (Intergovernmental Panel on Climate Change 4th Assessment Report). Twelve climate models, which reproduced the Pacific Decadal Oscillation, were selected and B1, A1B, A2 carbon emission scenarios were used. Totally, thirty-three ensemble simulations were conducted and twenty-four (73%) results showed a decrease of wet weight of Pacific saury. The migration pattern was modified by increased SST and reduced size of saury in eleven (33%) cases. In these cases, higher SST in the mixed water region under global warming prevented the southern migration of saury in the first winter and delayed it in the second winter. As a result, egg production was enhanced by the higher availability of prey plankton in the mixed water region. A case study to separate the direct temperature effects was conducted, in which prey plankton density was assumed to be the same as the control run. The results suggest that a SST increase (especially in the mixed water region) will directly reduce juvenile growth while a prey plankton density decrease has an influence on the growth of adults and migration pattern, and hence egg production.

S3-P3

Forage-euphausiid abundance in space and time: Seasonal patterns

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FEAST (Forage-Euphausiid Abundance in Space and Time) is the multispecies bioenergetics module for forage and predatory fish species of a vertically integrated model that uses ROMS (Regional Ocean Modeling System) for the Northeast Pacific and Bering Sea as a platform. With a spatial resolution of a 10km resolution, the vertical model includes FEAST coupled to an NPZ (Nutrient-Phytoplankton-Zooplakton) and an Economics module. FEAST models 13 fish species (walleye pollock, arrowtooth flounder, Pacific cod, Pacific herring, salmon, capelin, sandlance, eulachon, myctophids, squids, shrimp, crabs and epifauna) which have a two way interaction with 5 groups in the NPZ model (small/large copepods, oceanic/ shelf euphausiids, and benthos). Additionally, temperature and advection from the ROMS model are used in the bioenergetics and movement components. The operating hypothesis in FEAST is that forage fish and macrozooplankton (*e.g.* euphausiids) are tightly coupled in a two-way interaction, and the dynamics of this interaction under different climate scenarios is a strong structuring element for the ecosystem as a whole. The vertically integrated model as a whole serves as the operating model for Management Strategy Evaluation. We will show results from fish growth, and seasonal spatial consumption patterns. This modeling is part of the The Bering Sea Project which joins the BEST-BSIERP programs funded by the NSF and NPRB.

S3-P4

A simple model for estimating the rate of predation of arrowtooth flounder on walleye pollock on the Bering Sea shelf over the first half of the 21st Century

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Empirical relationships between the extent of the Bering Sea shelf summer "cold pool" (bottom water ≤2°C in the middle domain) and maximum sea ice extent and sea level pressure allow projections of the cold pool from global climate model simulations. The present study uses these projections to predict future spatial distributions of arrowtooth flounder (*Atheresthes sp.)* in the Bering Sea assuming these populations are controlled in large part by habitat limitations related to the cold pool. The predictions of spatial distributions are then used to gauge the probable trends and variations in their rate of predation on walleye pollock (*Theragra chalcogramma*). Walleye pollock population growth rates are expected to be sensitive to predation rate, and the method described here uses population projections as a means to quantify the influence of arrowtooth flounder predation upon future walleye pollock abundance. The model is simple, which means it is feasible for it to be run under a full range of potential climate forcing scenarios. The ensemble of runs allows evaluation of how uncertainty of future climatic conditions may affect projected predation of arrowtooth flounder on walleye pollock.

S3-P5

Model realism and model validation: An oceanographer's view of the North Atlantic circulation through the eyes of the ROMS

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Numerical models of ocean circulation can be evaluated using two approaches. First, models are expected to capture all major physical processes that matter within a range of space-time scales. The ability of a model to incorporate key physical processes and internal consistency of the model parameters are two major criteria used by a physicist. Second, a model is supposed to simulate the observed state of the ocean and resolve its major structural elements such as currents, fronts and eddies. This is an oceanographer's view. The great majority of modeling studies emphasizes the physicist's view, whereas studies of model realism from an oceanographer's perspective are fewer. The present study fills this gap with observational validation of a model (ROMS). The large-to-meso-scale pattern of the North Atlantic circulation emerging from the ROMS is amply validated with observed data from seven subregions, selected mostly from the Subarctic. Simulated surface velocity fields compare favorably with circulation patterns inferred from oceanographic surveys, surface drifters, and satellite-derived climatology of SST fronts. Numerous meso-scale details of circulation portrayed by the ROMS have only recently been described from observed data. The stunning degree of the model realism affirmed over the North Atlantic gives credibility to those rare modeling results that contradict conventional wisdom, *e.g.*, the double-jet structure of the northward segment of the Irminger Current. This allows addressing quantitative aspects of the model simulation of ocean circulation, such as current speed, width, vertical extent, and fluxes of water, heat, and salt.

S3-P6

Modeled and observed modes of biophysical variability on the Bering Sea shelf

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Coupled physical/biological models can be used to downscale global climate change to the ecology of subarctic regions, and to explore the bottom-up and top-down effects of that change on the spatial structure of subarctic ecosystems - for example, the relative dominance of pelagic vs. benthic food webs in relation to ice cover. Here we utilize a multivariate statistical approach to extract the emergent properties of a coupled physical/biological simulation of the Bering Sea, and explore how these properties compare with the observed system. Specifically, we employ multivariate Empirical Orthogonal Function (EOF) analysis to derive the interannual covariance among physical and biological patterns from our simulation; these are compared with EOFs derived from spatially gridded measurements of the region, collected during the multi-year BASIS and BSIERP field programs. Ultimately this analysis helps to quantify the greater predictability of spatially and trophically averaged properties of the Bering Sea, as compared to univariate time series from a single location.

S4 / S9 Posters

S4-P1

Interannual variability of *Neocalanus flemingeri* and *N. plumchrus* in Shelikof Strait, Alaska

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The copepod species *Neocalanus flemingeri* and *N. plumchrus* are abundant, nutrient-rich prey for fish, seabirds and marine mammals in the Gulf of Alaska. Their developmental cycles are temporally offset, making it important to be able to distinguish the species as they may be available as prey to different predators and at different times. Little is known about how these species seasonally overlap in the coastal Gulf of Alaska. Species and stage composition were analyzed from one station in Shelikof Strait, Alaska during the first week of May for eight years between 1985 and 2001. *Neocalanus flemingeri* had a higher concentration than *N. plumchrus* among the years analyzed (p=002). The concentration of both species was relatively high in the mid 1980's and decreased in the early 1990's, after the regime shifted to warmer conditions in 1989. Concentrations increased from 1991-1996 and decreased again after the regime shifted to cooler conditions in 1998. There was a significant difference in the proportion of CIV and CV copepodites for *Neocalanus plumchrus* (p=025), but not for *N. flemingeri* (p=529) among years. There was no evidence from stage composition data of a change in the phenology of these species as observed for Ocean Station Papa and the Vancouver Island continental margin. There was a single anomalous year, 1996, which had a higher concentration of *Neocalanus plumchrus* stage CV than all other years, and this occurred when there were higher than average sea surface temperatures upstream of the study area in the northern Gulf of Alaska at GAK1.

S4-P2

Influence of elevated CO_2 concentrations on reproductive success and early nauplii development of the copepod *Acartia bifilosa* in the Baltic Sea

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In light of climate change, the research community has raised concerns about the impact of ocean acidification on marine organisms. Crustaceans, including copepods, may be a particularly sensitive group as they are dependent on calcite for mineralization of their chitin-based exoskeleton after moulting. Their growth and reproductive success can also be affected directly by increased pCO_2, as it increases the risk of hypercapnia, *i.e.* elevated CO_2 in the blood. In copepods, as in most marine invertebrates, early developmental stages and reproductive stages are believed to be more vulnerable to ocean acidification. Given the chemical and physical properties of calcium carbonate, the effect of anthropogenic CO_2 on the seawater will be much stronger in arctic or sub-arctic low salinity areas, than in warmer high salinity areas. The Baltic Sea is a semi-enclosed brackish water body at relatively high latitudes, where only a few species dominate the coastal zooplankton. In this study we used a Baltic copepod, *Acartia bifilosa* (Calanoida) to study effects of elevated CO_2 on egg production rate, hatching success and development of early nauplii stages (up to nauplii stage II). Results and potential ecological impact of the findings will be discussed in the light of anticipated CO_2 levels over the next 100 years.

S4-P3

Organic carbon flux and seabed nutrient regeneration in fjord to abyssal settings of the sub-polar North Atlantic

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Along the European arctic margin biological production and fluxes to the seabed vary in response to ecological regimes sensitive to seasonal sea ice distribution. There are distinct annual cycles of production and particulate fluxes in the water column which depend on shifts in the position of the marginal ice zone and on local circulation. Using pore water geochemical profiles we examined organic fluxes and diagenesis at the seabed along the western margin of Svalbard, northwest of Norway in the Atlantic. We collected data from 2007 to 2010 for summers, and one early spring season. We sampled settings from coastal fjords to the abyssal plain of the Fram Straits. At each station we recovered multicores which we put into a temperature controlled bath for high resolution probing with oxygen micro-electrodes, and we also extracted pore water from parallel multicores for geochemical analysis. Our objective was to characterize organic fluxes and examine the distribution of benthic fauna in relation to variability in sediment pore water chemical properties. In all settings bottom waters were near saturation for oxygen. We found that organic carbon fluxes were high within fjords and on the continental shelf leading to large oxygen consumption and diagenetic fluxes at the seabed. Fluxes into and out of the sediments dropped rapidly down the continental slope and were small at greater than 2200 m, indicating strong recycling in the water column. On the shelf and in fjords the seabed fluxes in early spring were, surprisingly, similar to those of the summer season.

S4-P4

Food web structure and epibenthic megafauna in the Chukchi Sea: A temporal comparison

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The Russian-American-Long-term-Census-of-the-Arctic (RUSALCA) aims at building a time series of data on environmental and biotic conditions in the Chukchi Sea shelf ecosystem, an area experiencing substantial climate change. Here we present a first comparison of food web structure and of epibenthic abundance and biomass between 2004 and 2009. Food web structure based on carbon stable isotope ratios in 2004 differed, with benthic organisms in the eastern (Alaska Coastal Water, ACW) Chukchi Sea feeding more on terrestrial materials than in the western part (Anadyr Water, AW). Similar patterns were found in 2009, but a $\delta^{13}C$ depleted food source in the AW indicates freshwater influence in that region in 2009. No changes in trophic position based on $\delta^{15}N$ ratios were found between the two time periods, indicating stable food webs. Quantitative data on the epibenthic megafauna were taken from a total of 60 beam trawl samples taken in 2004 and 2007-2009, including 8 resampling stations. Gross abundance and biomass estimates ranged from 229-70,879 ind. 1000 m^{-2}, and from 1628-217,023 g wet wt 1000 m^{-2}, respectively. Abundance and biomass were dominated by echinoderms (66 and 45%, respectively) and crustaceans (17 and 31%, respectively). Of the total 165 taxa identified, 45 were mollusks and 33 were crustaceans. Comparisons between 2009 and 2004 and with previous studies suggest an increase in overall epibenthic biomass (since 1976), including an increase in the biomass of one of dominant species, snow crab (*Chionoecetes opilio*).

S4-P5

Denitrification in Bering Sea shelf sediments

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We have investigated the N deficit in Bering Sea shelf waters, i.e. the deficit relative to the mean oceanic N:P using N-star (N-star=N–16PO_4+2.9; where N=[NO_3+NO_2+NH_4]). An approximately north-south section along the 70 m isobath revealed a persistent Ndeficit. During the spring the deficit was about 700 mmoles N m^{-2} in the north, decreasing to 400 mmoles N m^{-2} in the south, whereas during the summer, the deficit decreased to 550 mmoles N m^{-2} in the north and 200 mmoles N m^{-2} in the south. During spring the water column was mainly well mixed while in the summer a well-developed mixed layer persisted throughout the study region. Interestingly, the bulk of the decrease in the nitrate deficit from winter to summer took place in the mixed layer, while the nitrate deficit in the lower layer remained more or less constant. The decrease in nitrate deficit in the surface layer is likely due to some combination of advection of low deficit water from the coast or open Bering Sea and non-Redfield nutrient uptake. Over the winter, the nitrate deficit in the surface was reestablished by to sedimentary denitrification and some advection from offshore. During 2010 we determined sedimentary denitrification rates at 15 stations located throughout the shelf. Denitrification rate averaged about 0.5 mmoles N m^{-2} d^{-1} in spring 2010 and were likely higher during the summer. This denitrification rate would be sufficient to reestablish half to possibly all of the observed deficit.

S5 Posters

S5-P1

Year-to-year changes of mesozooplankton biomass, community and size spectra in the Chukchi Sea during summers of 1991/92 and 2007/08

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To evaluate the effect of drastic sea-ice reduction on zooplankton, we studied year-to-year changes of the zooplankton community structure as analyzed by an Optical Plankton Counter (OPC) in the Chukchi Sea during summers of 1991, 1992 (when the sea ice was extended) and in 2007 and 2008 (when the sea ice was reduced). Zooplankton abundance and biomass ranged from 5,000 to 1,170,000 ind. m^{-2} and 0.25 to 9.74 g DM m^{-2}, respectively, with those north of the Lisburne Peninsula in 2007 being the least. Based on the zooplankton biomass size composition, zooplankton communities were classified into four groups (A−D) by cluster analysis. Distribution of each group was separated geographically and interannually. Zooplankton communities in south of Lisburne Peninsula were not changed (group A) throughout four years, while those in norths of Lisburne Peninsula were changed: group B (normal) in 1991/92, and group D (low biomass) in 2007, and group C (dominated by barnacle larvae) in 2008. Thus, the effects of sea ice reduction on zooplankton in the Chukchi Sea were greater in the north of Lisburne Peninsula. Analysis of Normalized Biomass Size Spectra (NBSS) with groups revealed that the slopes of group A and C (−1.27) were greater than the open sea: North Pacific (−1.13) and Atlantic Ocean (−1.14), that indicate group A and C was high productive. While slopes of group B and D (−1.04 to −1.08) were similar to tropical ocean (−0.97 to −1.00), that indicate group B and D were low productive.

S5-P2

Culture-independent and -dependent methods to investigate the diversity of planktonic bacteria in the northern Bering Sea

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The diversity of bacterioplankton in the northern Bering Sea was investigated using a combination of molecular and culture-based methods. Community fingerprint analysis using polymerase chain reaction-denaturing gradient gel electrophoresis revealed that there was an apparent difference in the bacterioplankton community composition between sampling locations in the area. 16S rRNA gene clone libraries for surface and bottom water at a single station on the continental shelf were established. Sequences fell into 21 major lineages of the domain *Bacteria*, including *Proteobacteria* (Alpha, Beta, Gamma and Delta), *Bacteroidetes*, *Actinobacteria*, *Firmicutes*, *Acidobacteria*, *Planctomycetes*, *Verrucomicrobia*, *Fusobacteria*, *Chlamydiae*, *Chloroflexi*, *Chlorobi*, *Spirochaetes*, *Cyanobacteria* (or chloroplasts of algae), and candidate divisions OP8, OP11, TM6, TM7 and WS3. *Actinobacteria* formed the dominant bacterial lineage in both surface and bottom water, and the *Alphaproteobacteria* was another dominant fraction in surface water. A large fraction of the retrieved sequences (18.3 and 21.5% for surface and bottom water, respectively) showed similarity values lower than 97% to reported sequences. A total of 232 heterotrophic bacterial strains were isolated from the water and 81% were found to show extracellular proteolytic activity. Phylogenetic analysis revealed that the isolates fell into three bacterial groups, including the *Gammaproteobacteria*, *Actinobacteria* and *Firmicutes*. The most common genus in both the bacterial isolates and protease-producing bacteria was *Pseudoalteromonas* (65.9 and 80.9%, respectively). Divergence of bacterial community composition in the northern Bering Sea was mainly triggered by the dominance of *Actinobacteria* and reflected a bacterial community different from that currently known for marine bacterioplankton communities in other polar regions.

S5-P3

Environmental influences on the distribution of heterotrophic bacteria in the Bering Sea and Arctic Ocean during summer 2008

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Heterotrophic bacterial (HB) abundance and distribution in the subarctic Pacific Bering Sea and Arctic Ocean were investigated during the summer of 2008 as part of the 3rd Chinese National Arctic Research Expedition (CHINARE 3, Arctic). HB abundances in the subarctic ocean areas were higher than those in the Arctic Ocean, abundances in continental shelf areas were higher than those in basin areas, and abundances in ice-free areas were higher than those in sea ice-covered areas. Based on the relationship between HB abundance and nutrient factors, the entire investigation area from the Bering Sea to the central Arctic Ocean can be divided into four main areas: 1) Bering Basin: HB abundance was higher than those in the Canada Basin but lower than those in the continental shelf area of the Bering Sea; HB abundances were mainly influenced by water temperature; 2) Continental shelf area of the Bering Sea: This area had the highest HB abundance, and a relatively complicated environmental situation resulted in no significant controlling factors of HB abundance; 3) Continental shelf area of the Chukchi Sea: HB abundance was similar to that in the continental shelf area of the Bering Sea; water temperature and DOC together may determine the HB abundance; 4) Basin area of the Arctic Ocean: HB abundance was lower than those in other ocean areas, and DOC was the main controlling factor. Comparatively, salinity and nutrients had minor influence on the HB abundance among all the environmental parameters investigated.

S5-P4

Drift, age and origin of capelin larvae in Icelandic waters

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Capelin larvae drift from their spawning grounds with clockwise currents around Iceland. The 0-group capelin found north and east of Iceland in the fall are commonly believed to originate at the main spawning grounds off the south and west coasts. In 2007 samples were collected off the south and west coasts in April and all around Iceland in May. In August, pelagic 0-group capelin were sampled off the west, north and east coasts and in the Iceland Sea. The spawning time appeared to be similar in all locations, but the eggs take 3-4 weeks longer to hatch at the north and east coasts because of the low bottom temperature. Age readings indicate that the size difference of capelin larvae by areas is mainly explained by difference in age and not by difference in growth rates. Back-calculated hatch dates indicate that many of the capelin larvae in the north and east originate in local spawning and that inflow of Atlantic water onto the shelf north of Iceland was limited in 2007. Judging from the hatchdate distribution of the surviving larvae in the Iceland sea in August and an average driftspeed of 3 nmd^{-1} the surviviors were larvae hatched in May at the southwest coast and larvae hatched in May and later at the northwest coast. There are indications of an earlier and/or more northerly spawning in 2007 as compared to a 1904 survey. In recent years, more capelin larvae have been found north of 68°N in August surveys.

S5-P6

Circulation and hydrography over the Kolbeinsey Ridge

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As part of the Icelandic national ESSAS program on the Iceland Sea ecosystem the circulation and hydrography over the Kolbeinsey Ridge was studied. A moored profiler was deployed west of the ridge at 68°N close to the 1000m isobath. The instrument returned high resolution profiles of conductivity, temperature and current components twice daily, from 100m down to about 1000m depth from the beginning of September 2007 until the end of October 2008. In June 2008 vessel mounted ADCP measurements were made on a transect crossing the Kolbeinsey Ridge together with CTD measurements. In the regular Iceland Sea cruises CTD sections were taken along 68°N crossing the Kolbeinsey Ridge. The water masses in the vicinity of the Kolbeinsey ridge are discussed in relation to the circulation. Attention is paid to seasonal variations, the presence of Atlantic water and composition and circulation of deep water. The Kolbeinsey Ridge has a strong influence on the hydrography. It channels Atlantic water into the Iceland Sea along its western side. This is then brought eastwards into the area east of the ridge where there appears to be a semi permanent anticyclonic gyre that may act as a retention area for capelin larvae. The current measured with the moored profiler shows a barotropic southward flow that is consistent with the Northwest Icelandic jet carrying deep water towards the Denmark Strait sill.

S5-P7

Trophic interactions of the pelagic ecosystem in the Iceland Sea as evaluated by fatty acid and stable isotopes analyses

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A trophic study was carried out in August 2007 and 2008 on the pelagic ecosystem in the sub-arctic Iceland Sea, north of Iceland. Carbon and nitrogen stable isotopes and fatty acid biomarkers were used to study trophic linkages and trohphic ecology of the most important pelagic species in this ecosystem with special emphasis on capelin (*Mallotus villosus*). According to ^{15}N enrichment it is concluded that there are 3-4 trophic levels in this pelagic ecosystem excluding birds and mammals. The primarily herbivorous copepod *Calanus hyperboreus* occupies the lowest trophic level of the animal species studied but adults of capelin and blue whiting (*Micromesistius poutassou*) the highest. *Calanus* spp. proved to be an important diet component of most of the studied species. The euphausiid species *Thysanoessa inermis* and *T. longicaudata* are exceptions however as *Calanus* spp. are of minor importance in their diet. The chaetognath, *Eukrohnia hamata*, is a pure carnivore, feeding heavily on *Calanus* spp., while most of the other zooplankton species studied, practice omnivorous-carnivorous feeding mode. Young *T. inermis* is important food component for larvae of capelin and the amphipod species *Themisto libellula* is important in the diet of adult capelin. The importance of *Calanus* spp. or *Calanus* derived diet increases with the size of capelin. Adults of capelin and blue whiting share the same feeding habits and could therefore be competing for food. This study is a part of an ecological study in the Iceland Sea, with field work lasting from 2006-2008.

S5-P8

Effect of the frontal area north of Iceland on small-scale plankton distribution

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The effect of the subarctic front north of Iceland on plankton distribution was studied by towing a digital autonomous colour VPR (Seascan Inc) along a ~37km long transect running perpendicular to it in mid May 2008. The VPR was undulated up and down along the transect from surface to 100–200m depth in a tow-yo fashion while the ship cruised at slow speed (~2 knots). The boundary between the cold and warm water and the gradual southwards deepening of the isolines was clearly visible. The results showed marked differences in abundance and composition of plankton and marine snow from north to south, with the subarctic front clearly influencing the distribution of plankton and particles. Thus copepods (mainly *Calanus hyperboreus* and *C. finmarchicus*) were much more abundant north of the front than south of it. Egg bearing *Pseudocalanus* spp. stayed relatively deep with highest concentrations in the cold water north of the frontal region. *Phaeocystis* sp. was confined to the relatively warm surface waters south of the front, whereas marine snow was recorded in highest densities near the interface between the warm and cold water (in the picnocline). Attempts were made to relate the VPR observations with acoustic registrations using SIMRAD EK500 at 38 kHz and 120 kHz. Initial results were inconclusive, but further work is in progress.

S5-P9

Capelin in the Iceland Sea: Long-term patterns in life history and physical processes

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Capelin (*Mallotus villosus*) has been investigated continuously since the early 1970s, including the Iceland Sea Ecosystem Program 2006-2008, with the main objective to estimate its life history and abundance at different live stages. During this period the stock has fluctuated strongly. During the same period, the hydrographic conditions in Iceland Sea and adjacent waters have also varied strongly. In this paper we focus on trends in available time series, both biological and environmental series with the aim to explain recent changes in capelin life history. The available time series include 0-group distribution in August 1972-2003, growth parameters since 1980, distribution of juvenile and adult capelin (age 1+) since 1992, and repeated hydrography. Analyses of growth parameters generally indicate the absence of trends in growth during the last three decades. On the other hand, distribution of O-group capelin became gradually less attached to the Icelandic continental shelf in the late 1990s, and increasingly westerly and northerly since 2003. This pattern is significantly correlated to year class strength. During the last decade, the distribution of older capelin has become more westerly and southerly and in the paper we focus also on the possible correlation between the hydrographic changes and the distributions of both O-group and older capelin (age 1-3).

S5-P10

Coordinating international research on Southern Ocean ecosystems: Implementation of the ICED programme

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Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) was established during the International Polar Year (IPY) to address the need for circumpolar analyses of Southern Ocean climate and ecosystem dynamics. Such an approach is necessary to assess the likely responses of Southern Ocean ecosystems to change in order to support the management and protection of the ecosystem services of this globally important ocean. Furthermore because of its sensitivity, contrasts and relatively simple ecological structure, the Southern Ocean serves as both a model system for developing methods for global application and an early warning of the effects of change. This integrated circumpolar approach requires international cooperation and coordination to link national capacity and bring together expertise on ecosystem, climate and biogeochemical processes. In taking IPY momentum forwards, ICED has a multidisciplinary community assembled, the ICED Science Plan and Implementation Strategy has been internationally endorsed and the programme formally adopted by IMBER (Integrated Marine Biogeochemistry and Ecosystem Research). Here we outline progress to date and future plans. We discuss the generation of new circumpolar datasets, the planning of coordinated field activities, and advances in model development to understand and predict Southern Ocean ecosystem variability and change. Collaborations have been initiated with scientists outside the Antarctic to explore changing ecosystems at both poles and in the Earth System context. The integration and coordination of Southern Ocean ecosystem research and analyses through ICED will improve projections of the impacts of global change on Southern Ocean ecosystems, creating a lasting IPY legacy.

S5-P11

Influence of the biology and behaviour of forage fish on top predators in northeastern Newfoundland

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Forage species lie at the core of marine food webs, providing essential linkages for energy transfer among trophic levels. Capelin (*Mallotus villosus*) is the focal forage fish in the Northwest Atlantic on which top predators rely for prey. Our vessel-based research during July-August 2000-09 discovered deep-water (17-40m) spawning sites of capelin on the northeast Newfoundland coast, where capelin were thought to primarily spawn on beaches. Deep-water spawning sites were spatially and temporally persistent among years, resulting in predictably high abundances of capelin and predators, or biological hotspots. Combining vessel-based capelin and predator density and distributional patterns (2000-09) with colony-based measures of seabird diets and bio-physical monitoring of temperature and spawning (2003-09), we explored the importance of hotspot formation on chick-rearing seabirds. The timing of capelin spawning was earlier in years when temperature during gonad development (February-June) was warmer (r^2=0.650, p=0.053). When spawning was early in warmer years, hotspots were absent during chick-rearing. This resulted in a significant decrease in the percentage of capelin delivered to chicks of Northern Gannets (*Sula bassana*; r^2=0.780, p=0.020). This also led to a significant decrease in the percentage of energy-rich gravid capelin delivered to chicks of Common Murres (*Uria aalge*; r^2=0.790, p=0.017), which resulted in lower fledging condition. Overall, warming ocean climate leading to a temporal mismatch of hotspots and seabird chick-rearing periods will result in prey switching, alternate foraging strategies and negative energetic consequences.

S5-P12

Opposite regimes of atmospheric circulation over the East Arctic and hydrological conditions of the west Chukchi Sea shelf in summer 2007 and 2003

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Oceanographic observations in the western part of the Chukchi Sea are sparse and results sometimes are controversial. The water circulation patterns and origin of surface thermal fronts in the coastal area are largely determined by atmospheric forcing. These depend on whether the low or high is centered over the east Arctic seas. They were particularly revealed during the summers of 2003 and 2007 as the patterns of atmospheric circulation were stable for a long time but were in opposite directions in the two years. Fortunately TINRO surveys were carried out in these years. Different features such as the coastal upwelling, the Siberian Coastal Current (SCC), a freshening and record breaking temperature of the sea surface become apparent depending on regime of atmospheric circulation. Thermal fronts occurred in both cases and were determined by upwelling or SCC water extension. Also in 2007, ice cover in the eastern Arctic was at an historical minimum and we'll briefly touch upon some aspects associated with this event.

S6 Posters

S6-P1

Influence of climate variability and change on the ecosystems of the Barents Sea and adjacent waters: Review and synthesis of recent studies from the NESSAS project

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The aim of the Norwegian Ecosystem Studies of Sub-Arctic Seas (NESSAS) Project was to quantify the impact of climate variability on the structure and function of the marine ecosystem of the Barents Sea and vicinity in order to predict the ecosystem responses to possible future climate change. New insights were provided on the role of large-scale atmospheric forcing on the physical oceanography including the effect of Arctic and Atlantic cyclones on the variability of the ice extent in the Barents Sea. The NAO was also shown to influence shrimp recruitment in the Barents Sea and primary production in the Nordic Seas. The importance of long term climate variability (*e.g.* the Atlantic Multidecadal Oscillation; 60-80 year period) was stressed leading to significant changes in fish production, shifts in distribution and changes in spawning sites in the Barents Sea as well as other northern Atlantic ecosystems. Results from comparative studies between several US ecosystems and those of the Norwegian and Barents Seas include evidence of increased primary productivity in the Barents Sea in recent years and the poleward movement of zooplankton and fish. Possible ecosystem scenarios for the Barents Sea under anthropogenic-induced future climate change were developed including expectations of structural and functional changes due to distributional changes of many species. Of particular note is the likelihood of increases in the productivity of several fish species, including cod and herring, which potentially could result in higher fisheries yields.

S6-P2

Barents Sea Ecosystem Resilience under global environmental change

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The influence of climate warming on the Barents Sea ecosystem is documented by the long-term ocean temperature increase observed since the 1960s and the projected increases of up to 3°C by 2050. The impact of climate warming on Barents Sea communities can be exacerbated by fisheries. The Barents Sea Ecosystem Resilience under Global Environmental Change (BarEcoRe) project addresses the effects of climate warming on the structure, dynamics and resilience of the Barents Sea ecosystem, integrated with the effect of fishery. Detection and forecasting of changes in ecosystem resilience and robustness under global warming and fisheries will be based on a broad battery of inferential tools including multivariate analyses of spatio-temporal changes in community structure, retrospective and prospective modelling of populations distributions, mapping of life history and feeding traits affecting species vulnerability, analysis of trophic interactions and food web structure, and early warning signals of abrupt changes detecting reductions in ecosystem resilience. The main outputs of the project, including a vulnerable species list, mapping of future populations distributions under warming scenarios, characterization of regime shifts, reliable early warning signals of abrupt ecosystem changes, provide tools needed for management of the Barents Sea ecosystem under global environmental change.

S6-P3

Laboratory studies on response to temperature change of Walleye Pollock larvae

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Temperature selectivity of Walleye Pollock larvae was examined. Hatching larvae were obtained and incubated in 5ºC from spawned eggs in captivity or artificial fertilization and reared on rotifers as food item. Responses of the larvae to the temperature were observed in acryl cylinders (80cm x 10cm) which can independently change the temperature of upper and lower half of cylinders. To obtain clear the responses to the temperatures, this study also used the particular environment that cooler temperature water mass occurs at the upper half of the cylinder by control salinity. Larvae, at each of several development stages, were moved into a cylinder filled with 5ºC seawater and after 2 hours acclimation the temperatures of upper and lower half of the cylinders were changed. 1-2 days old yolk-sac larvae showed little response to the temperatures change probably due to the large ratio of the yolk sac to the body size. While, later 5-6 days old yolk-sac larvae showed avoidance from the cold (<3ºC) and warm (>12ºC) water masses. Similarly, feeding larvae (ca 6.7 mm SL) showed temperature selectivity avoiding the warm or cold waters, however, the response was not clear when the difference in temperature was small. Further result will be shown at the meeting.

S7 Poster

S7-P2

Pribilof Islands, Alaska community based King Crab Ecological and Economic Research Program

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Alaska's Pribilof Islands lie at the extreme southern extent of the seasonal Arctic sea ice zone and are in the core area for Bering Sea king crab distributions. Pribilof communities enjoyed economic prosperity from king crab fisheries in the 1980s and 1990s through their involvement in processing, harvesting and activities associated with these lucrative fisheries. Two key species, the Pribilof Blue King Crab (*Paralithodes platypus*) and Red King Crab (*Paralithodescamtschaticus*) stocks have declined precipitously. Pribilof blue king crab harvests exceeded 11 million pounds in the 1980s but fisheries were closed in the 1990s; the stock was declared overfished in 2002. The multimillion dollar red king crab fishery was reduced in the 1990s and is now closed.

Students of the Pribilof Island School District examined the economic value of crab fisheries and initiated ecological studies in 2007 to address gaps in knowledge on early life history stages of king crab, their habitat needs and effects of environmental variables on young crab. Nearshore plankton tows, larvae traps, juvenile crab intertidal surveys and subtidal investigations using pots, Remotely Operated Vehicles and other technology confirm that pelagic larvae are scarce but juvenile king crab continue to occupy waters of Pribilof Domain. Yet the lack of recovery for *Paralithodes* king crab remains unclear, and examination of effects of climate, fisheries, habitat integrity and other aspects of crab ecology are being pursued. Results of this continuing research are informing local, state, federal and hatchery efforts torestore Pribilof king crab populations and their economic contribution to Pribilof communities in the future.

S8 Posters

S8-P1

Effects of temperature and gadoid predation on snow crab recruitment: Comparisons between the Bering Sea and Atlantic Canada

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For eastern Bering Sea snow crab (*Chionoecetes opilio*), recruitment drives much of the overall population variability. However, what causes large changes in recruitment strength is poorly known. Changes in snow crab recruitment may be driven by fluctuations in spawning biomass, competition with other species, predation on larvae or juveniles, and/or environmental pressures. Pacific cod (*Gadus macrocephalus*) is a dominant gadoid fish in the eastern Bering Sea and is known to prey on crab. Here we use a regression approach to examine the effects of snow crab spawning stock biomass, water temperature, and Pacific cod biomass on snow crab recruitment.

Several competing ordinary least squares and generalized least squares models (to account for residual auto-correlation) were considered in initial analyses. Model selection was based on the small-sample Akaike Information Criterion and for models with similar AICc values the most parsimonious model was selected. Results from the final model showed that spawning stock biomass and temperature each had a negative impact on snow crab. However, Pacific cod biomass had no apparent effect on snow crab recruitment.

Finally, we contrast these results with those of similar studies on snow crab in the Newfoundland/Labrador shelf and Gulf of St. Lawrence regions. Overall, colder conditions appear to increase recruitment in all ecosystems but the effects of spawning stock biomass and gadoid predation differed among areas.

S8-P2

Decadal shift in the diets of walleye pollock in the Oyashio area

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Diets of walleye pollock along the southeastern coast of Hokkaido Island (Doto area) have been analyzed using a total of >15,000 specimens collected in 1989-1992 and 1995-2009, to explore interdecadal difference between the 1990s (Yamamura *et al.*, 2002) and the 2000s. It was summarized as: 1) the increase in incidence and gravimetric contribution of cannibalism from the 1990s to the 2000s with a seasonal shift from spring to autumn and winter, and 2) increase in gravimetric contribution of appendicularia (*Oikopleura* spp.) in spring (2000s) and decrease of micronekton (myctophid *Diaphus theta* and firefly squid *Watasenia scintillans*). This dietary shift was accompanied by a sharp decline in body condition factor ($CF=BW/BL^3*10^6$), especially in immature fish (from 9.3 to 8.1 in 201-300 mmSL fish and from 9.1 to 8.0 in 301-400 mm SL fish). These results suggest that bottom-up control (*i.e.* the change in prey environment) also affects population dynamics of walleye pollock via top-down control (cannibalism).

S8-P3

Recruitment mechanisms of eastern Bering Sea Tanner crab, *Chionoecetes bairdi*

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The eastern Bering Sea (EBS) population of Tanner crab, Chionoecetes bairdi, has experienced large-scale fluctuations, mainly owing to wide swings in recruitment strength. While mechanisms responsible for these fluctuations are of significant ecological interest, there are strong economic motivations, as well, because this crab population once supported one of the most lucrative commercial crab fisheries in the world. The objective of this study was to elucidate potential biophysical mechanisms that regulate survival of larval and juvenile Tanner crab. To this end, statistical analyses were conducted using generalized least squares (GLS) corrected for first order autocorrelations. We examined mechanisms operating during three key life history stages, including: (1) effects of parental female Tanner crab abundance and mean bottom temperature affecting maturation processes, (2) directional winds and sea surface temperature affecting advection and prey (zooplankton) availability, respectively, during the pelagic larval stage, and (3) predator abundances (Pacific cod, yellow fin sole and flathead sole) affecting survival of the early juvenile stage. Mechanisms were evaluated based on their ability to explain interannual variability in time series of juvenile recruitment to the 30-50 mm carapace width size range. Using GLS methods, we evaluated evidence for these mechanisms for Tanner crab aggregated for the entire EBS region and disaggregated over two sub-regions, east and west of 166ºW longitude. Statistically significant ($P<0.05$) results were found for mature female abundance, wind component vectors and Pacific cod and flathead sole abundances. We are currently exploring these relationships in more detail using a Regional Ocean Modeling System.

W1 Poster

W1-P1

Spatial variability of warm eddies in western boundary of Canada Basin: Biochemical implication

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Physical and biochemical oceanographic data were intensively collected along the Northwind Ridge (NwR) and western boundary of Canada Basin (CB) between July and August, 2010. Through the water mass identification, Pacific-origin warm water was identified in the depth of 30-150m, forming the strong warm eddies. In particular, warm eddies were found near the peak of NwR and the continental slope of CB. The nutrient distribution and chlorophyll *a* concentration generally matched with the location of warm eddies. Nitrate was the limiting factor of phytoplankton growth, and generally small-sized cells were mostly dominated. However, warm eddy area was characterized by large-sized cells (*e.g.*, diatom). In the context of warm eddies vs. biomass bloom, during the presentation, the spatial variability in temperature and salinity and biochemical responses (*i.e.*, nutrient and plankton biomass) will be presented. Furthermore, microscopic observation and pigment analysis for phytoplankton community study will be discussed.

W2 Posters

W2-P1

Oceanography and large zooplankton within a bowhead whale feeding area in the Northwest Sea of Okhotsk

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The biological–physical oceanographic characteristics, which produce a favourable feeding environment for the bowhead whale (*Balaena mysticetus*) in the northwest Sea of Okhotsk, are examined. Our goals are to understand the impact of climate change on this critical feeding area for the Okhotsk Sea bowhead whales. The region is rapidly warming, likely resulting in ecosystem changes. Bowhead whales, as the top predators, are linked via zooplankton to this entire marine food chain. Understanding of seasonal and inter-annual variability in the physical mechanisms influencing sea conditions and the resulting distribution of large zooplankton are necessary to predict the impact of climate change. Among the zooplankton in the Okhotsk Sea shelf the arctic grazer *Calanus glacialis* and shelled pteropod *Limacina helicina* play key roles in the pelagic food web. They are a food source for predators such as fishes, whales and birds. The present work combined satellite observations with physical measurements (CTD, currents) and zooplankton sampling. Satellite data and in situ observations revealed anticyclonic eddies in the bays and regional cyclonic circulation in the shelf waters of the northwest Okhotsk Sea. Cyclonic circulation was established due to seasonal change in wind. Intensified cyclonic gyre allowed low salinity water to flow northward, which strengthened stratification in the surface layer. The seaward transfer of coastal water is the important factor for high Chl-*a* concentration due to enhancement of stratification. The cyclonic circulation determines the distribution of a key species of the ecosystem and retains the pelagic mollusk *Limacina helicina* within this gyre.

W2-P2

Magnitude and spatial variability of the phytoplankton bloom in the changing Sea of Okhotsk

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The northern Sea of Okhotsk exhibits strong seasonality and the combination of sea-ice melt, solar radiation and temperature results in a short production period. Extreme tidal mixing introduces nutrients into the pycnocline and refuels the phytoplankton in the upper layer. Direct oceanographic measurements for the period from 1993 to 2010 and satellite data (images of AVHRR and MODIS radiometers) were used to study the circulation of the northern Sea of Okhotsk and the magnitude and timing of phytoplankton bloom. Satellite data, along with observations of currents, revealed an anticyclonic eddy in the Sakhalin Bay. The Bay has a large discharge of warm freshwater from the Amur River, and therefore is considered as a region of the strong freshwater influence. The salinity in the upper layer in the Bay is significantly reduced and its temperature is approximately 15°C higher than the cold and dense shelf water. A growing anticyclonic eddy accumulates a large fraction of the river discharge and significantly reduces fresh water transport in the coastal current away from the river mouth. Low salinity water contributes to the cyclonic gyre in the north-western Okhotsk Sea, which strengthens stratification in the upper layer. This seasonal transport of low salinity water is an important factor for determining the phytoplankton distribution and magnitude of the bloom. Hydrographic studies showed high undersurface chlorophyll *a* concentrations on the perimeter of this cyclonic gyre, a result that indicates the impact of the freshwater. We use these observations to describe the primary features of the circulation and its impacts on the coastal ecosystem.

W3 Poster

W3-P1

Mortality estimation of the copepod *Calanus finmarchicus* in the Gulf of Maine using the VLT method and molting incubations to estimate development rates

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The planktonic copepod, *Calanus finmarchicus*, is widely distributed in the subarctic North Atlantic and predominant in the mesozooplankton community of the Gulf of Maine. It is of particular interest as a major food source in coastal Gulf of Maine waters for the endangered northern right whale as well as stocks of herring, mackerel and cod. Development of accurate coupled biophysical models to forecast distribution and abundance of this species requires better life history models. Mortality is often used as a closure term in these models because of the difficulty in measuring it. In the Vertical Life Table (VLT) method for estimating mortality, calculations are made using information on the stage structure of the population and development rates. Development rates from temperature dependent functions determined in the laboratory are not necessarily representative of food conditions and diapause periods that may occur seasonally in the sea. One possible solution to this problem is the use of short-term incubations of copepodid stages immediately after capture to observe the progressing stage structure, from which molting rates are calculated. Here we employ this method in a study of Gulf of Maine *C. finmarchicus* mortality as a function of season, stage and distance from shore.

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