ESSAS Report Series **Number 5**

Report on the

2nd ESSAS Open Science Meeting

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

Seattle, Washington, USA
22 – 26 May, 2011

Compilers
Margaret M. McBride, Ken Drinkwater, George Hunt, and Franz Mueter

October 2011

Table of Contents

1.0 Introduction

The GLOBEC/IMBER Regional Program *Ecosystem Studies of Sub-Arctic Seas* (ESSAS) was established in 2005 to addresses the need to understand how climate change affects and will affect marine ecosystems of the Sub-Arctic Seas and their sustainability. The Sub-Arctic Seas support stocks of commercial fish that generate a major portion of the fish landings in the nations bordering them. They also support subsistence fishers along their coasts, and vast numbers of marine birds and mammals. Climate-forced changes in these systems will have major economic and societal impact. ESSAS conducts research to compare, quantify, and predict the impact of climate variability and global climate change on the productivity and sustainability of Sub-Arctic marine ecosystems.

ESSAS recently held its second Open Science Meeting (OSM) entitled "*Comparative studies of climate effects on polar and sub-polar ocean ecosystems: Progress in observation and prediction*", on May 22–26, 2011, in Seattle, Washington, USA. The meeting's co-chairs were George L. Hunt, Jr. (USA), Olafur S. Astthorsson (Iceland) and Michio Kishi (Japan) and were supported by a Scientific Steering Committee (Appendix 8.1). The meeting was co-sponsored by the international organizations, PICES (North Pacific Marine Science Organization), ICES (International Council for the Exploration of the Sea), IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) and GOOS (Global Ocean Observing System), as well as several U.S. marine science organizations (Appendix 8.1). The meeting was attended by 195 scientists (of whom 23 were early career scientists and 28 were students) from 13 countries (see Appendix 8.2 for a list of the attendees). There were 98 oral and 61 poster presentations. The OSM presented an opportunity to showcase the progress made both in ESSAS working groups, and in the national and multi-national programs affiliated with ESSAS. It helped to identify remaining knowledge gaps, and pointed toward future research needs within ESSAS. It also provided an excellent opportunity to envision ways that ESSAS can interact with IMBER, ICES, PICES and other international programs in future comparative ecosystem studies. It is expected that four special volumes of referred journals will result from the ESSAS OSM (see 7.0 Publications).

2.0 Meeting Format

The OSM was structured into:

<u>Three 1-day Workshops</u>

- Workshop 1: Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas
- Workshop 2: Arctic-Sub-Arctic interactions
- Workshop 3: Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects

<u>Two ½-day Workshops</u>

- Workshop 4: Comparative analyses of gadid and crustacean dynamics across subarctic ecosystems
- Workshop 5: Comparative analyses of marine bird and mammal responses to climate change, and

<u>Nine Theme Sessions</u>

- Session 1: Comparative studies of polar and sub-polar ecosystems

- Session 2: New observations and understanding of eastern and western Bering Sea ecosystems
- Session 3: Modeling marine ecosystem dynamics in high latitude regions
- Sessions 4/9: Nutrients, biogeochemistry and acidification in a changing climate
- Session 5: New insights from the International Polar Year (IPY) studies
- Session 6: National ESSAS programs: Recent advances and contribution
- Session 7: Anticipating socio-economic and policy consequences of global changes in sub-polar and polar marine ecosystems
- Session 8: Interactions between gadoids and crustaceans: The roles of climate, predation, and fisheries

Invited speakers gave presentations during 1 of the 4 plenary sessions held each morning.

The OSM began with a series of three 1-day workshops:

- The workshop on "*Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas*" was organized by the ICES/PICES Working Group on *Forecasting Climate Change Impacts on Fish and Shellfish* (WG-FCCIFS). This workshop reviewed 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 were discussed and compared to expected conditions based on climate scenarios.
- The workshop on "*Arctic–Sub Arctic interactions*", co-sponsored by ESSAS and ASOF (Arctic–Subarctic Ocean Fluxes), brought together several diverse groups studying the fluxes between the Arctic and the Sub-Arctic and their biophysical effects. Following presentations, discussion focused upon some of our knowledge gaps, what research could be carried out to address these gaps, and how the research on these issues can be better coordinated.
- The workshop on "*Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects*" brought 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, especially *Calanus* copepods.

Two additional half-day workshops were held:

- The ESSAS Working Group on *Gadid–Crustacean Interactions* convened a workshop on "*Comparative analyses of gadid and crustacean dynamics across sub-Arctic ecosystems*" to summarize and synthesize the main findings to date of their work and to discuss future directions for this Working Group.
- The workshop on "*Comparative analyses of marine bird and mammal responses to climate change*" focused on how to best integrate on-going and new research on marine birds and mammals into long-term PICES and ESSAS programs and objectives.

Instead of the usual introductory speeches by dignitaries, OSM plenary sessions began with 8 elementary and junior high students from the Pribilof Islands of St. Paul and St. George off the coast of mainland Alaska, USA, who gave a joint presentation entitled "*Discovering the Pribilof Domain*". The human inhabitants of these islands, who are mostly of Aleut

descent, depend almost exclusively upon the sea for their food and livelihood. The students attend Marine Science Camps during the summer where, with guidance from their teacher/scientist Michelle Ridgway, they have conducted studies into the marine ecosystem around their islands using some of the latest oceanographic techniques. Their presentation addressed the climate of the Pribilofs; physical oceanography surrounding the islands; phytoplankton and zooplankton; principal fish and shellfish species and their life histories; marine mammals; and socio-economic consequences of fish and fisheries. During their studies of the flora and fauna, they discovered the second-known population of a species of large brown marine algae, *Aureophycus*, near St. George Island. The students have integrated traditional knowledge with conventional scientific knowledge to learn more about their marine ecosystem. They also presented a poster on their research.

Each day began with plenary talks by invited speakers who covered various aspects of the 3 parallel theme sessions held in the afternoon. The list of plenary and parallel theme session speakers and the titles of their talks are provided in Appendix 8.3. On the last day brief summaries from each of the workshops and the parallel topic sessions were given by one of the session co-chairs in order to inform all of the participants of some of the main findings under each topic. Following these reports, a special musical presentation was given by a group from Norway known as "Science Fair". Led by Oded Ben-Horin (vocals), and with Svein Folkvord on bass and Stein Inge Brækhus on drums, they perform science-inspired music at scientific meetings and conferences. At the ESSAS OSM they preformed a number of pieces, some of which were based on their impressions gathered during the meeting. In addition, two of the Pribilof students joined in and sang 2 songs. The wrap-up to the OSM was provided in the form of 3 special invited lectures, one on phytoplankton production by Kevin Arrigo, one on fish and fisheries by Steve Murawski, and one on human dimensions by Keith Criddle.

Most of the presentations, including those of the students from the Pribilofs, are posted on the OSM website at: http://pices.int/publications/presentations/2011-ESASS/ESSAS-2011-presentations.aspx.

Sixty-one posters were on display throughout the meeting, with each covering some aspect of one of the workshop or theme session topics; all workshops and theme sessions were represented. A dedicated poster session was held on Wednesday evening during which the many participants were able to discuss the science and results behind the posters. The session with the most posters was that on results from the Bering Sea, which was bolstered by a good turnout from the local oceanographic community in Seattle.

3.0 Workshop Reports

3.1 Workshop 1 - Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas

Conveners:

Anne Hollowed (USA) and Harold Loeng (Norway)

Invited Speakers:

Trond Kristiansen (Norway) and Hyunju Seo (Korea)

The ICES/PICES Workshop on Biological Consequences of Decreases in Sea Ice in Arctic and Sub-Arctic Seas (WKBCASAS) met in Seattle, Washington, USA, on 22 May 2011. The objective of this meeting was to assess the biological consequences of decreased sea ice and possible changes in water temperature in Arctic and Sub-arctic seas. Workshop participants reviewed life history information and habitat associations of commercial species of fish and shellfish to assess the risk of immigration and settlement of new biological populations in the Arctic Ocean 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 were developed and compared to expected conditions based on climate scenarios. Opportunities for cooperation in information sharing between groups charged with managing the Arctic was discussed and reported to scientists within ESSAS as well as PICES and ICES.

The meeting was well attended with 34 participants from 9 countries (Annex 1 and 2). The session consisted of 6 oral presentations and 1 poster, including invited presentations by Trond Kristiansen and Hyunju Seo. Trond Kristiansen used an Individual Based Model (IBM) to evaluate the implications of climate change on four spawning grounds of Atlantic cod. His work revealed the importance of temperature on larval growth and the importance of phenology with respect to matching the emergence of first feeding larvae with the spring bloom. Projections of future ocean conditions indicated that the small zooplankton will increase and large zooplankton will decrease under future climate conditions. Hyunju Seo predicted future impacts of climate change on chum salmon. Her model incorporated relationships previously identified from a retrospective model of the effect of global warming and density-dependence on Hokkaido chum salmon from the 1940s to the early-2000s. Her results suggest that currently global warming is positively affecting chum salmon by increasing the growth rate at age 1+ and survival of Hokkaido chum salmon through the warmer sea surface temperature during summer and fall in the Okhotsk Sea. Over time, population density-dependent effects on the growth rate of chum salmon at age 3+ and expected changes to the maturation schedule changes are predicted because of limited carrying capacity. In the future, global warming is expected to negatively affect chum salmon survival by decreasing the carrying capacity and reducing the habitat area in the North Pacific Ocean.

Key questions

Participants were asked to consider the following questions:

- *How will the productivity of Arctic ecosystems change?*
- *What criteria need to be fulfilled in order to get commercial fishing in the Arctic Ocean and the surrounding shelf seas in the future?*
- *What species are most likely to migrate successfully to the Arctic to establish self-sustaining populations?*
- *How are successful migrations likely to alter Arctic marine ecosystems?*
- *What research is needed to understand these ecosystem changes and the impacts of commercial fishing on them?*

Expected Physical and Lower Trophic Level Changes

The morning discussion session focused on the question: *How will climate change impact the productivity of the Arctic and sub-arctic seas?* Oceanographers reported that quality of

the models and the techniques for assessing the adequacy of IPCC models for use in the Arctic have been improved since the release of the 4th assessment report (AR4) of the Intergovernmental Panel on Climate Change Assessment (IPCC). Further research is needed to model the synergistic effects of decadal to multi-decadal variability and climate change to shifts in ocean conditions. The group noted that a fruitful line of research would be to examine ocean/ecosystem responses to the warming trend from the 1930s to 1950s to learn how ocean systems respond to warming. A key observation was that the Arctic has lost much of its old, thick ice that tended to persist through summer. This finding indicates that the pace of sea ice retreat in summer is occurring more quickly than was projected by global climate models. Ice will continue to form in the fall, and is expected to persist until late (mid) spring; this will influence the duration of the growing season. The heat content of the Arctic is influenced by solar heating and Atlantic water inflow. A question for the future is whether Atlantic Water will intrude onto the shelf areas in the Arctic Ocean. The influence of large-scale circulation patterns on stratification in the Arctic will also influence the rate of warming in the Atlantic Arctic area. The ability of global climate models to predict sub-surface water temperatures in the Arctic and sub-Arctic is limited.

Lower trophic level species will respond to changing ocean conditions. The Arctic will continue to be dark and cold for several months of the year and these conditions will continue to deter the invasion of new species to the region, and this will continue to limit the total annual production in the region. Reductions in the sea ice extent and thickness in summer in the Arctic Ocean could prolong the growing season and increase stratification. Coupled biophysical models indicate that future ocean conditions will favor the production of small phytoplankton and will reduce the production of large phytoplankton. Ice algae will continue to be important in selected regions but this contribution may represent a smaller fraction of the total annual open ocean production in the future. Shifts in the timing of ice algal blooms may impact the match of prey with the emergence of zooplankton. It is unclear how future climate conditions will impact advection of zooplankton (copepods and euphausiids) into the region; and whether these conditions will allow overwintering of these species in the region.

Selection Criteria

The afternoon discussion focused on the question: *What criteria need to be fulfilled in order to get commercial fishing in the Arctic Ocean and the surrounding shelf seas in the future?* The group addressed this question by compiling a list of commercial species and considering the likelihood that these species would extend their range into the Arctic (Table 1). This discussion revealed that fish employed diverse survival strategies, which made them likely or unlikely candidates for the range extensions into the Arctic.

This exercise revealed a suite of key attributes for consideration:

- Species capable of rapid growth to survive during short growing season;
- Species exhibiting physiological characteristics to survive in cold conditions, e.g. blood antifreeze in polar cod and Alaska plaice;
- Species exhibiting a broad spawning range, with low site fidelity;
- Species with a diverse prey base.

The group noted that even if a species exhibits several or all of the attributes listed above, the colonization of new regions may not occur unless the thermal windows are suitable for survival at key life stages, and the advective corridors are available for immigration to the new region. Comparison of the advective corridors for colonization in the Atlantic and Pacific sides of the Arctic shows that the flows into the Arctic are much stronger on the Atlantic side. Further comparisons show that the currents are more favorable to immigration on eastern boundaries. Distances between similar habitat types are relatively small. Topography also appears to influence the probability of immigration. On the Pacific side, the shallow shelves may serve as a barrier to immigration, because of either the presence of cold pools (remnant cold water at depth from winter ice cover) or due to depth preferences of fish and shellfish.

Although fish that exhibit these characteristics may be more likely to immigrate into the Arctic, the processes governing survival are complex spatially and temporally. Considerable uncertainty remains as to whether these species will be able to colonize the Arctic successfully. Many species have evolved temporal patterns of feeding and reproductive behaviour that maximize survival. If climate change shifts the temporal match with key aspects of the life history, survival may be impacted. Several species exhibit seasonal migrations, if the quality or quantity of habitat is changed, these spawning and feeding migrations may be unsuccessful. Over time, fish often adopt strategies to avoid predation or to partition the limited resources. These strategies result in complex zoogeographic patterns, which allow co-existence. Climate change may influence the effectiveness of these strategies, and species that colonize the Arctic may disrupt the balance of predator and prey.

After considerable discussion the group agreed to attempt applying the criteria identified above to the species in their regions to compile a list of species that would be candidates for colonization of new regions in Arctic and sub-arctic seas. Workshop co-conveners will work with workshop participants to develop a paper that synthesizes this information as a potential contribution to the symposium volume.

Recommendations for Research

The final session of the workshop was devoted to the question: *What research is needed to understand these ecosystem changes and the impacts of commercial fishing on them?*
The group identified the following suite of key research activities:

- Study the role of seasonal light and ice on ecosystem production and fish/zooplankton phenology;
- Resolve impacts on Atlantic inflow to Arctic;
- Conduct periodic fish/plankton surveys to monitor shifts in their distributional and abundance patterns;
- Conduct laboratory/field research on tolerance of biota under multiple stressors: acidification, temperature, and fishing;
- Continue studies of zooplankton community dynamics, with special emphasis to the ratio of boreal/arctic and large/small species;
- Conduct food spectra analysis to assess species interactions.

Table 1. Preliminary assessment of colonization probability of new regions for northern commercial fish and shellfish species

Species	Current northern concentrations	Candidate for movement into the Arctic?	Life History Characteristics
Atlantic cod *(Gadus morhua)*	N. Atlantic, Barents Sea	Maybe	Dependent on increased zooplankton production, larval stages capable of surviving in cold conditions, species would have to establish new spawning grounds. Evidence of expansion of spawning grounds in NE Arctic cod. Dynamic life history with flexible growth and maturation characteristics.
Atlantic mackerel *(Scomber scombrus)*	N. Atlantic	Maybe	Pelagic life history with broad migrations
Herring *(Clupea harengus pallasi)*	N. Atlantic and Barents Sea, Bering Sea	Maybe	Prefer water masses with temperature higher than 2^{o} C, but might migrate into frontal areas during the feeding season. Northward migration will depend both on temperature and zooplankton abundance.
Red king crab *(Paralithodes camtschaticus)*	Eastern and western Bering Sea & Barents Sea (introduced)	Maybe	Introduced in Barents Sea. Opportunistic feeder.
Yellowfin sole *(Limanda aspera)*	Bering Sea	Maybe	Diverse demersal diet, already inhabits shallow shelves in the northern Bering Sea, spawns in summer
Sebastes spp.	Bering Sea and N. Atlantic	Maybe for Atlantic redfish, unlikely for most Pacific rockfish	Resides in deep water and unlikely to cross Bering Strait, apparent fidelity to spawning sites, larval dispersal less than 100km
Arrowtooth flounder *(Atheresthes stomias)*	Bering Sea	Unlikely	Deepwater species less likely to cross Bering Strait, possible prey limitations.
Chinook salmon *(Onchorynchus tshawytscha)*	Bering Sea	Unlikely	Extended freshwater life history
Coho salmon *(Onchorynchus kisutch)*	Bering Sea	Unlikely	Extended freshwater life history
Flathead sole *(Hippoglossoides elassodon)*	Bering Sea, Chukchi Sea	Unlikely	Deeper water species less likely to cross Bering Strait.
Northern rock sole *(Lepidopsetta polyxystra)*	Bering Sea	Unlikely	Reliance on a small group of key prey species. Strong spawning site fidelity
Pacific cod (*Gadus macrocephalus)*	Bering Sea	Unlikely	Eclectic prey-base (a positive trait), avoids ice (thermal barrier), would compete as

			juveniles with arctic cod a cold adapted species.
Pacific halibut *(Hippoglossus stenolepis)*	Bering Sea	Unlikely	Deeper water spawner, less likely to cross Bering Strait.
Sockeye salmon *(Onchorynchus nerka)*	Bering Sea	Unlikely	Extended freshwater life history
Walleye pollock (*Theragra chalcogramma*)	Bering Sea	Unlikely	Avoids ice in winter (thermal barrier), avoids cold pool as age-0 and adult in summer, would compete with polar cod which is cold adapted
Alaska plaice *(Pleuronectes quadrituberculatus)*	Arctic Ocean, Chukchi Sea, and Bering Sea	Likely	Demersal diet, 38% of Bering Sea population resides in northern regions, has glycol-protein in blood that acts as anti-freeze
Bering flounder	Bering Sea and Chukchi Sea, Arctic Ocean	Likely	Already resides in Arctic Ocean, demersal diet.
Capelin *(Mallotus villosus)*	Bering Sea, Barents Sea, Chukchi Sea, Arctic Ocean	Likely	Capable of rapid growth, already resides in Arctic Ocean.
Chum salmon *(Onchorynchus keta)*	Bering Sea, Chukchi Sea and Arctic Ocean	Likely	Already spawning in Arctic Ocean
Greenland halibut *(Reinhardtius hippoglossoides)*	N. Atlantic, Bering Sea, Arctic Ocean	Likely	Piscivore and could consume polar cod, broad spatial distribution, currently spawn in deepwater in northern regions of the Bering Sea and has been observed in the Arctic
Kamchatka flounder *(Atheresthes evermanni)*	Bering Sea	Likely	Currently found in northern Bering Sea, Chukchi Sea and Arctic Ocean
Pink salmon *(Onchorynchus gorbuscha)*	Bering Sea, Chukchi Sea and Arctic Ocean	Likely	Already spawning in Arctic Ocean
Polar cod *(Boreogadus saida)*	Bering Sea, Chukchi Sea, Arctic Ocean, Barents Sea	Likely	Already inhabits Arctic Ocean, capable of rapid growth, has glycol-protein in blood that acts as anti-freeze.
Snow crab *(Chionoectes opilio)*	Arctic Ocean, Bering Sea and Western Canada	Likely	This species is already present in the Arctic

Table 2. List of participants.

	First	Last	E-mail	Organization	Nation
1	Skip	McKinnell	Skip.Mckinnell@pices.int	PICES	Canada
2	Bill	Montevecchi	Mont@mun.ca	Memorial University, Newfounland	Canada
3	Adi	Kellermann	Adi@ices.dk	ICES	Denmark
4	Michael	Klages	Michael.Klages@awi.de	Alfred Wegener Institute for Polar and Marine Research	Germany

5	Olafur	Astthorsson	osa@hafro.is	Marine Research Institute Iceland	Iceland
6	Toru	Hirawake	Hirawake@salmon.fish.hokudai.ac.jp	Hokkaido University	Japan
7	Takahiro	Iida	Iida@nipr.acjp	NIPR	Japan
8	Kenshi	Kuma	Kuma@fish.hokudai.ac.jp	Hokkaido University	Japan
9	Kohie	Mizobatat	Mizobata@kaiyodai.ac.jp	Tokyo University of Marine Science and Technology	Japan
10	Suam	Kim	Suamkim@pknu.ac.kr	Pukyong National University	Korea
11	HyunJu	Seo	uagiri@hanmail.net	NFRDI	Korea
12	Trond	Kristiansen	Trond.Kristiansen@imr.no	Institute of Marine Research	Norway
13	Harald	Loeng	Harald.Loeng@imr.no	Institute of Marine Research	Norway
14	Margaret	McBride	Margret.Mcbride@imr.no	ESSAS Project Office Institute of Marine Research	Norway
15	Svein	Sundby	Svein.Sundby@imr.no	Institute of Marine Research	Norway
16	Sen Tok	Kim	Kimst@sakhniro.ru	Sakhalin Research Institute of Fisheries and Oceanography	Russia
17	Vladimir	Kulik	Kulik@tinro.ru	TINRO-Center	Russia
18	Daria	Martynova	daria.martynova@gmail.com	White Sea Biological Station, Zoological Institute, Russian Academy of Sciences	Russia
19	Michael	Dagg	Mdagg@lumcon.edu	Louisiana Universities Marine Consortium	U.S.A
20	Matthew	Baker	Matthew.Baker@noaa.gov	University of Washington/NOAA	U.S.A.
21	Kate	Hedstrom	kshedstrom@alaska.edu	University of Alaska Fairbanks	U.S.A.
22	Kathy	Kuletz	Kathy_Kuletz@fws.gov	US Fish and Wildlife Service	U.S.A.
23	Paul	Spencer	Paul.Spencer@noaa.gov	NOAA/NMFS/AFSC	U.S.A.
24	Steven	Barbeaux	Steve.Barbeaux@noaa.gov	NOAA/NMFS/AFSC	USA
25	Nicholas	Bond	Nicholas.Bond@noaa.gov	University of Washington	USA
26	Enrique	Churchister	Enrique@marine.rutgers.edu	Rutgers University	USA
27	Anne	Hollowed	Anne.Hollowed@noaa.gov	NOAA/NMFS/AFSC	USA
28	James	Ianelli	Jim.Ianelli@noaa.gov	NOAA/NMFS/AFSC	USA
29	William	Karp	Bill.Karp@noaa.gov	NOAA/NMFS/AFSC	USA
30	Frank	Morado	Frank.Morado@noaa.gov	NOAA/NMFS/AFSC	USA
31	Kotaro	Ono	Kotarono@uw.edu	University of Washington	USA
32	James	Overland	Jim.Overland@noaa.gov	NOAA/OAR/PMEL:	USA
33	Michael	Sigler	Mike.Sigler@noaa.gov	NOAA/NMFS/AFSC	USA
34	Thomas	Wilderbuer	Tom.Wilderbuer@noaa.gov	NOAA/NMFS/AFSC	USA

3.2 **Workshop 2 - Arctic-Subarctic Interactions**

Convenors:

Kenneth F. Drinkwater (Norway) and Thomas Haine (USA)

The workshop on Arctic-Subarctic Interactions was attended by 33 scientists from Canada, China, Denmark, Germany, Greenland, Japan, Norway, Russia and the USA. The aim was to identify gaps in our understanding of the effects of the interactions between the Arctic and the Subarctic on the physical, biogeochemistry and biological components of the ecosystems and to highlight what research should be carried out during the next few years to fill some of these gaps. The specific aims were to:

- develop testable hypotheses related to Arctic-Subarctic interactions;

- develop a coordinated research plan on biophysical effects of Arctic-Subarctic interactions to test these hypotheses;
- promote cooperation and coordination in the research related to Arctic-Subarctic interactions; and
- consider possible other related follow-up activities to promote research into linkages between the Arctic and Subarctic.

The workshop built upon the work of: the Arctic-Subarctic Ocean Fluxes (ASOF) community that has focused on quantifying the volume, freshwater and heat fluxes around the Arctic; the successful IPY session on *Arctic-Subarctic connections: Ecosystems and biodiversity* at the Oslo IPY Conference in June of 2010; 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 studying the effects of the Bering Sea on the Western Arctic; and other interested scientists.

The workshop consisted of a series of presentations followed by discussion. In the morning 3 talks were given. Tom Haine provided a review of the achievements of the ASOF program regarding monitoring the fluxes at the entrances to the Arctic. He indicated that heat and freshwater are accumulating in the Arctic but noted that in spite of the many ASOF achievements the volume, heat and salt budgets were not completely resolved. To address biophysical interactions he suggested augmenting present and planned physical oceanographic moorings with biological instrumentation, collaborative proposals with training for students and young scientists in the fields of both physical and biological oceanography, and greater use of models. Eddy Carmack (Canada) highlighted the intense vertical salinity stratification in the Arctic and the strong fronts between the arctic and subarctic waters in both the Pacific and the Atlantic. He noted the recent changes in the Arctic including stronger meridional winds, melting ice, warmer temperatures, build-up of freshwater, increasing pH, and lower abundance of larger size plankton and higher abundance of small size plankton. Chuck Greene (USA) discussed the importance of the Arctic flows on the ecosystems of the NW Atlantic south to the Gulf of Maine and Middle Atlantic Bight, including effects on plankton through to whales.

Jackie Grebmeier and Ken Drinkwater then led a discussion on “What are the important gaps in our knowledge?” Some of the main points were:

- The heat, salt and mass budgets into the Arctic still do not balance. Better quantification of the temporal variability of the flows and exchanges through the Canadian Archipelago will require continued monitoring.
- Increased knowledge is required on basic biology including the community structure and species distributions as well as trophic interactions and the ecosystem function in the Subarctic and especially in the Arctic. While this is true for both the pelagic and benthic realms, less is known for the latter. Since most data are limited to the summertime, there was a call for year-round studies.
- The responses of the marine Subarctic, Arctic and their interaction to climate change are ongoing important issues, especially the need for quantitative estimates. We lack understanding of the key environmental factors that will influence and determine Arctic-Subarctic interactions. Questions that remain unclear include the following.

  - Will vertical stratification increase or decrease in the Arctic and the Subarctic?
  - How will stratification change seasonally and what effect will it have on nutrient concentrations and hence primary production?
  - Will the boundary currents in both regions remain the same or will they decrease or increase, and if so by how much?
  - How will species invasions and differential rates of moving northward under warming conditions affect biodiversity?
- Ocean acidification and changes in pH are increasing at a rapid rate and concern is expressed on their effect on the marine environment. Most studies to date have been short term (days to several weeks) under very high pH conditions and have resulted in conflicting results. There is a need for longer-term studies under different pH levels. For application to the Arctic and Subarctic regions, these should be done under temperatures appropriate for these regions.
- Large changes in the atmospheric conditions have been observed in the past to trigger lagged changes in the salinity characteristics in the NW Atlantic, e.g. the Great Salinity Anomalies. Recent atmospheric changes provide the opportunity to test model predictions of what should happen, i.e. pathways of water mass anomalies and their timing.
- Mixing of species between the Atlantic and the Pacific is expected to occur and increase under climate change. What are the conditions under which this will actually occur and what effect will it have on the invaded ecosystems?

In the afternoon Rebecca Woodgate (USA) gave a presentation on the measured fluxes through the Bering Strait including an 8 mooring array across the Strait that will continue into 2013. She highlighted the importance of the heat fluxes on the sea-ice melt and discussed influences on the biology, in particular increased phytoplankton production behind islands. She also discussed work on marine mammal observations using hydrophones in the Strait. Jackie Grebmeier (USA) discussed biological effects of exchange through Bering Strait. She noted that decreasing sea ice and increasing heat and freshwater transport into the Pacific Arctic have been key factors in the changes to the marine ecosystems and biodiversity. The continental shelves in the northern Bering and Chukchi seas are experiencing earlier retreat and/or later advancement of sea ice. Benthic feeders such as seaducks, gray whales and walruses have changed migration patterns and their habitat use in response to the changing ice conditions. She also speculated that changes in the timing of the primary production, zooplankton grazing and export to the benthos will change the trophic structure, carbon cycling and transport from the shelves to the basins. Peter Rhines (USA) discussed changes in the subpolar regions of the North Atlantic over the last 20 years or more including freshening of the deep waters, slowing of the subpolar gyre and invasion of warm waters from the south. He also presented recent results showing the importance of atmospheric blocking over the northern regions of the North Atlantic to the air and sea temperatures. Freshwater fluxes from off the Greenland Shelf were shown to initiate spring blooms in the eastern Labrador Sea. Marit Reigstad (Norway) dealt with the role of the Arctic outflow on the East Greenland Shelf. Sea ice drifts from the Arctic into the East Greenland area and with the deceasing amount of multi-year ice, the abundances of associated fauna such as amphipods will decrease. Lower nutrient concentrations, POC and zooplankton are advected from the Arctic to the subarctic compared to the reverse situation, i.e. from the subarctic to the Arctic. While

there is relatively low phytoplankton production off Greenland, the microbial community production is important, especially during spring

Peter Rhines and Marit Reigstad then led the discussion on how we might address the important questions and gaps in our knowledge. A number of suggestions were made (not in any order of priority):

- Retrospective analyses targeted to examine the interaction between the arctic and the subarctic. Several datasets could be used including hydrographic data for a T,S analysis, published data on chemical tracers including nutrients and radionuculides, and drifter studies.
- Compare and contrast the fronts between the arctic and subarctic and their role on marine ecology, including community structure and production. Fronts in both the Atlantic and the Pacific should be compared.
- Closer cooperation with atmospheric scientists in order to keep abreast of the new atmospheric indices (such as blocking in the Atlantic).
- Greater use of models to examine testable hypotheses. Examples given included modelling the expected path and fate of the recent salinity anomaly (GSA) that has recently been observed in the high latitudes of the North Atlantic, and compare the predicted response with observations.

While the first two initial goals of the workshop, i.e. development of specific testable hypotheses and a coordinated research plan were not reached, it was agreed that further cooperation and coordination should be undertaken and that ESSAS could help facilitate that. As a first step, it was suggested that a theme session lead by ESSAS and ASOF on Arctic-Subarctic interactions be proposed for the 2012 Ocean Sciences Meeting.

Table 1. Arctic-Subarctic Interactions Workshop Participants

	First	Last	E-mail	Organization	Nation
1	James	Bisagni	jbisagni@umassd.edu	U. of Massuschesutts Dartmouth	USA
2	Charles	Greene	Chg2@cornell.edu	Cornell University	USA
3	Steingrimur	Jonsson	steing@unak.is	U. of Akureyri	Iceland
4	David	Mountain	moluntain@email.arizona.edu	U. of Arizona	USA
5	Benjamin	Planque	benjamin.planque@imr.no	Institute of Marine Research, Tromsø	Norway
6	Rebecca	Woodgate	woodgate@apl.washington.edu	U. of Washington	USA
7	Sue	Moore	sue.moore@noaa.gov	Alaska Fisheries Science Center	USA
8	Michiyo	Yamamoto-Kawai	michiyo@kaiyodai.ac.jp	Tokoyo University	Japan
9	Jackie	Gredmeier	jgrebmei@umces.edu	U. of Maryland	USA
10	Carin	Ashjian	cashjian@whoi.edu	Wood's Hole (WHOI)	USA
11	Michael	Carroll	mc@akvaplan.niva.no	Akvaplan Niva, Tromsø	Norway
12	Jessica	Cross	jncross@alaska.edu	U. of Alaska, Fairbanks	USA
13	Thomas	Juul-Pedersen	thpe@natur.gl	Greenland Inst. of Natural Resources	Greenland
14	Seth	Danielson	seth@ims.uaf.edu	U. of Alaska, Fairbanks	USA
15	Konstantin	Rogachev	rogachev@poi.dvo.ru	Pacific Oceanological Institute	Russia
16	Sei-Ichi	Saitoh	ssaitoh@salmon.fish.hokudai.ac.jp	Hokkaido University, Hakodate	Japan

17	Eddy	Carmack	eddy.carmack@dfo-mpo.gc.ca	Institute of Ocean Sciences, DFO	Canada
18	Marit	Reigstad	marit.reigstad@uit.no	U. of Tromsø	Norway
19	Peter	Rhines	rhines@uw.edu	U. of Washington	USA
20	Ken	Drinkwater	ken.drinkwater@imr.no	Institute of Marine Research, Bergen	Norway
21	Juergen	Alheit	Juergen.alheit@io-warnemuende.de	Leibniz Institute for Baltic Sea Research	Germany
22	Igor	Belkin	igormbelkin@gmail.com	U. of Rhode Island	USA
23	Bill	Montevecchi	mont@mun.ca	Memorial University	Canada
24	Dag	Slagstad	Dag.slagstad@sintef.no	SINTEF	Norway
25	Keisuke	Uchimoto	uchimoto@lowtem.hokudai.ac. jp	Hokkaido University, Sapporo	Japan
26	Lisa	Eisner	Lisa.eisner@noaa.gov	Alaska Fisheries Science Center	USA
27	Kenshi	Kuma	kuma@fish.hokudai.ac.jp	Hokkaido University, Hakodate	Japan
28	Humio	Mitsudera	humiom@lowtem.hokudai.ac.jp	Hokkaido University, Sapporo	Japan
29	Kai	Wieland	kw@aqua.dtu.dk	DTU Aqua, Hirtshals	Denmark
30	Yngve	Børsheim	yngve.borsheim@imr.no	Institute of Marine Research, Bergen	Norway
31	Kjell Arne	Mork	kjell.arne.mork@imr.no	Institute of Marine Research, Bergen	Norway
32	Mathieu	Richaud	mathieu@csufresno.edu	Fresno State University	USA
33	Thomas	Haine	thomas.haine@jhu.edu	Johns Hopkins University	USA

3.3 Workshop 3-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) and Jaimie Pierson (USA)

This workshop consisted of eight presentations on zooplankton life history in polar and sub-polar ecosystems. The initial schedule provided for discussion before lunch and in the afternoon before the end of the workshop. However, due to the vigorous discussion following the presentations, the schedule was amended to accommodate longer time for the presentations. The majority of presentations and discussion focused on copepods, in particular the genus *Calanus*, although Tracy Shaw presented work on euphausiids on the Oregon coast, which generated much discussion. Stephane Plourde was unable to attend the workshop, but his presentation was given my James Pierson. An additional change to the schedule included a presentation by Cameron Thompson, who was scheduled for a poster presentation but also gave an oral presentation about his work on mortality estimation.

Overarching themes that emerged from the presentations and discussion included:

1. The need for better and more comprehensive vital rate data from laboratory experiments for such parameters as (a) development rates and (b) egg production rates.
2. Advection is still a missing part of many field and modeling studies, but is likely important in understanding life history dynamics in open ocean and shelf ecosystems.
3. A better understanding and means of parameterizing the stochasticity of the key rate parameters in numerical models of zooplankton life histories is imperative.

Andrew Leising presented model results for four species of *Calanus* and showed some examples of how various species may respond to different forcing. This model utilizes the lipid accumulation window hypothesis to drive dormancy timing in the *Calanus* species. Bill Peterson then showed some data on the timing of life history events in *Calanus marshallae* on the Oregon coast, in relation to local conditions and climate cycles. Of particular interest is the Pacific Decadal Oscillation (PDO) which may have driven the decadal and longer period patterns observed in the *C. marshallae* abundance and timing. Tracy Shaw presented data on the cross-shelf and seasonal variation in *Euphausia pacifica* and *Thysanoessa spinifera* stage composition. These two species are found separated temporally and spatially, with *E. pacifica* found more often in deeper, warmer waters spawning in summer, whereas *T. spinifera* is often found in cooler, shallower waters and spawns earlier in the year than *E. pacifica*. James Pierson presented some ideas on the types of metrics that should be used to compare life histories of different zooplankton, and how the choice of metrics may affect the interpretation of the results. Cameron Thompson presented work on a novel method of calculating mortality using the vertical life table (VLT) approach, along with short-term incubations to directly estimate development rate. Erica Head further compared different methods of calculating mortality rates for data from the Northwest Atlantic. Atsushi Tsuda hypothesized that *Neocalanus* spp. are adapted to oceanic conditions that do not experience blooms, whereas *Calanus* spp. are adapted to conditions that favor consistent blooms. His data were primarily from the eastern Pacific, but included analysis of metadata from other regions where these species are dominant. Finally, Nick Record showed a means of parameterizing life history models using a "compupod", or virtual copepod that has emergent but constrained parameter values. This technique can be used to explore the parameter-space available to certain species, or to determine the characteristics that might be favored under certain conditions.

Overall, the workshop was highly successful and provided a dynamic and open exchange of ideas and data. One general consensus point was that much of our data on zooplankton vital rates that were generated in lab experiments prior to the middle 1990s are likely suspect. This is because many experiments were done with laboratory-cultured diatoms, and in many cases with the species *Thalassiosira weissflogi*, and it has since been shown that laboratory cultures affect reproductive success in some copepod species. It was suggested that development and growth rate experiments be repeated to address concerns about how previous work was conducted. In addition, these experiments should be conducted in such a way as to better constrain the variability in the vital rate parameters within a population and between individuals. One concern that was raised is that the parameters determined for a species in one region may not represent the full variation or the central tendency of the parameter for populations that are separated by large distances.

The workshop concluded with a social event including many of the participants and other interested attendees from the ESSAS conference.

3.4 Workshop 4 - Comparative analyses of gadid and crustacean dynamics across subarctic ecosystems

Co-Convenors:

Earl Dawe (Canada) and Franz J. Mueter (USA)

The workshop met for a half day morning session . The purpose was 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. While the focus was intended to be on studies conducted under the auspices of ESSAS Working Group 4, the workshop was open to anyone conducting comparative analyses on fish and crustacean stocks in subarctic seas. As a secondary goal, participants discussed future directions for comparative studies of fish and crustacean resources across subarctic systems and the future of Working Group 4.

The meeting participants included available WG members, as well as invited speakers for the symposium theme session (Patrick Ouellet and Lobo Oransanz) and other presenters to the theme session (Gordon Kruse, Stephanie Boudreau, and Laurinda Marcello). The meeting also welcomed Michelle Ridgway and her group of young high school students from the Pribilof Islands. This group was keenly interested in interactions involving fishes and crustaceans.

Stephanie Boudreau delivered an invited presentation on 'the roles of large benthic decapods in marine ecosystems'. This was followed by a presentation by Franz Mueter on the state of knowledge regarding gadid-crustacean interactions and the relative effects of various bottom-up versus top-down factors on their abundance. The ensuing discussion focused on how these forcing factors varied among subarctic ecosystems. The group then discussed which of the presentations for the upcoming theme session might be contributed to the Marine Ecology Progress Series (MEPS) theme section. Finally, the group discussed the future of Working Group 4. It was generally agreed that the 2011 ASM and OSM represented the completion of the activities of this WG over the past 3 years, and that the WG might dissolve or transform into another WG with modified objectives. There was some interest among members to continue work on gadoid-crustacean interactions with a focus on spatial dynamics. New analyses conducted under the working group so far were focused on a fairly basic analysis of aggregate time series from each region, which largely ignored spatial dynamics. Several working group members and observers highlighted the importance of spatial dynamics and there was a strong interest in comparing spatial patterns and dynamics across systems. The overarching question that might be addressed by a future group would be: How does climate affect the spatial distribution of crustacean and gadid stocks in sub-arctic systems and how, in turn, does that affect predator-prey interactions between these groups?

3.5 Workshop 5 - *Comparative analyses of marine bird and mammal responses to climate change*

Co-Convenors:

Rolf Ream (USA), William J. Sydeman (USA) and Yutaka Watanuki (Japan)

The primary objective of this workshop was to focus integration of ongoing and new research on marine birds and mammals into long-term PICES and ESSAS programs and strategies. Specifically, we are producing a strategic vision and plan for activities of the PICES Advisory Panel for Marine Birds and Mammals (AP-MBM) for the next 3-5 years. Specific workshop objectives included (1) producing an outline of potential new goals on 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 included some oral presentations, but the emphasis was on discussion leading to planning documents.

Activities and Outcomes

The afternoon meeting convened with introductions of workshop participants, followed by Bill Sydeman giving an overview of the objectives of the workshop and the history of AP-MBM relative to PICES. Two scientific presentations were made and these led to spirited discussions. Yutaka Watanuki then presented background information and current materials to lead conversations regarding the future role of AP-MBM in PICES. Specifically, Dr. Watanuki summarized past activities of AP-MBM, described the objectives of the new PICES science plan (FUTURE) that the AP should be responsive to, discussed the terms of reference for the AP, and gave an overview of potential topics for future AP-MBM activities.

Presentations:

1. Dr. Martin Renner presented a paper, “Changes in the distribution of hotspots of pelagic seabird species diversity and abundance in the Bering Sea and North Pacific over four decades” based on analysis of the Pacific Pelagic Seabird Database. Martin and his colleagues examined spatial distribution of seabird diversity and evaluated changes in spatial diversity over time. A future goal is to identify possible “indicator” species responsible for the observed changes in spatial diversity. There was some discussion of best/appropriate spatial scale that should be used in this type of study; it was pointed out that the most utility would come from relating spatial scale to other species/datasets (fish, plankton, oceanography).
2. Dr. Sydeman presented a paper, “Global meta-analysis of seabird-climate relationships”, in which he and colleagues examined published research on ecological indicators of climate change/variability in seabirds, to address whether seabirds can be used as reliable indicators of marine ecosystem change due to climate or human activities.

Discussion topics regarding the future role of MBM-AP in PICES (presented by Watanuki):

1. Past activities of AP-MBM

a. Hunt, Kato and McKinnell. 2000. Predation by marine birds and mammals in the sub-arctic Northern Pacific Ocean. PICES Scientific Report No. 14
b. Sydeman and Janssen. 2009. Marine ecosystems, climate and phenology. Theme Section in Marine Ecology Progress Series.
c. Sydeman, Brodeur, Bychkov, Grimes, and McKinnell. 2006. Top predator "hot-spots" in the North Pacific. Deep-Sea Res. II.

2. Vision of FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems), which MBM-AP should be responsive to.
   - Understanding climate change (COVE) and anthropogenic impacts (AICE) on marine ecosystems in the PICES region.
   - Forecasting future ecosystem change (SOFE)
   - Better communication with society (SOFE)
3. AP-MBM Terms of Reference
   - Provide information and scientific expertise to BIO and the FUTURE program, and, when necessary, to other scientific and technical committees with regard to the biology and ecological roles of marine mammals and seabirds in the PICES region.
   - Identify important problems, scientific questions, and knowledge gaps in assessing the roles of marine mammals and seabirds in marine ecosystems.
   - Assemble relevant information on the biology of marine mammals and seabirds and disseminate it to the PICES community through scientific reports and symposia.
   - Develop strategies to improve collaborative, interdisciplinary research with marine mammal and seabird researchers and the PICES scientific community.
4. List of Potential topics for future AP-MBM activities
   - Spatial ecology and conservation (with attention to hotspots, LME, MPA, IBA, and IEA)
   - Marine climate impacts on MBM through food web
   - MBM as predictive indicator of forage prey
   - MBM as an indicator of temporal and spatial variation of pollutants
   - MBM as consumers and their role as a trigger of trophic cascade

Discussion

General Points: Advisory Panels in PICES are functional for 3 yrs. Activities of AP can have long term vision, but specific activities need to be addressed with respect to a 3 yr limit of AP. Products that are selected for inclusion in the plan should identify leaders and the timing of specific activities.

Terms of Reference should be updated. Terms 2 and 3 should identify a couple of specific projects. Term 4 needs to be more specific.

Some possible products to work into activities:

1. Identify factors/mechanisms that impact MBM (feeds into activity 2 of the potential topics for future MBM activities). Provide a retrospective review of climate/anthropogenic change—what are the important factors?
2. Workshop on the analysis of climate change/variability effects on MBM to assess appropriate metrics and analytical approaches, to emphasize the need to relate MBM metrics to climate metrics, and to address non-linear change.

3. Contribution to North Pacific status report should be listed as an activity (feeds into background for activities 1 and 2).
4. Workshop on methodology for dealing with at-sea data.

Immediate plans, post-meeting activities, and relevance

A three year plan for AP-MBM in support of PICES will be submitted to the BIO Committee by the end of August. During and immediately following the ESSAS meeting, Drs. Watanuki, Ream, and Sydeman prepared a tentative plan that included the 5 proposed topics discussed at the Workshop. The tentative plan was circulated to the members of the AP-MBM who were not at the ESSAS conference for comments, evaluation and rating of the proposed topics, and to suggest leaders for activities related to the topics. *Spatial Ecology and Conservation* was selected as the top priority topic that the AP-MBM will focus on in its new plan. The second- and third-rated topics (*Marine Climate Impacts on MBMs Through Food Web*, and MBMs as *Indicators of Temporal and Spatial Variations of Pollutants*) will likely be included as sub-topics of Spatial Ecology and Conservation, under the rationale that knowledge of MBM habitat use will contribute to the FUTURE mission of understanding climate change and anthropogenic impacts on marine ecosystems in the PICES region. Thus, the AP may pursue future workshops or sessions concentrating on climate impacts or pollutants and, by incorporating spatial aspects into the topics, these activities will contribute to, and be augmented by, the primary focus of spatial ecology . The W5 Workshop at ESSAS was very productive; the AP-MBM members received great input and advice from the workshop attendees and made great strides toward completing a new three year activity plan. The activity plan is currently being finalized for submission in August.

Participants:

Bill Sydeman, Farallon Institute
Yutaka Watanuki, Hokkaido University
Rolf Ream, NMFS
Martin Renner, UW
Sadie Wright, ADFG
Kathy Kuletz, USFWS
Tom Van Pelt, NPRB
Stephani Zador, NOAA
Jaime Forcada, British Antarctic Survey
Skip McKinnell, PICES
George Hunt, UW/ESSAS
Francis Weise, NPRB
Mike Dagg, LUMCON
Alex Bychkov, PICES
Adi Kellerman, ICES
Bill Montevecchi, Memorial University
Atsushi Tsuda, AORI/UT (BIO Chair, PICES)

4.0 Theme Session Reports

4.1 Session 1 - Comparative studies of polar and subpolar ecosystems

Co-Convenors:

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

Invited Speakers:

Jackie Grebmeier (USA), Suam Kim (Korea), Marit Reigstad (Norway)

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, and seabirds) were presented. The session included sixteen oral presentations, including three invited talks, and three posters. There were contributions by scientists from eight different countries, with the host country (USA) having the largest number (8 oral, 3 poster). A wide range of topics was covered including ecosystem modeling, hydrography, biogeochemistry, benthic-pelagic coupling, lower trophic level processes, fisheries, whales and seabirds. Nearly all included some reference to already observed or anticipated effects of climate change and most involved regional comparisons. Below is a synopsis of the main findings.

In the Bering Sea in recent years there has been considerable variability in the timing of sea-ice retreat, but in the Chukchi Sea the duration of ice cover has been consistently shorter in both spring and fall. Distributions of benthic organisms are changing, with probable impacts for the grey whales, walrus and sea-birds that feed on them. In addition, the earlier retreat of sea-ice means that walrus, which use it to haul out, are either being confined to more northerly regions, where food sources may be less suitable, or are hauling out and pupping on land, with probable increased mortality for adults and pups.

In the Northwest Atlantic an increased contribution of low salinity Arctic outflow in the early 1990s, due to changes in Arctic circulation, led to increased stratification and changes in plankton dynamics as far south as Georges Bank and the Gulf of Maine. Changes in copepod production in the Gulf of Maine have been linked to reproductive success in the right whale population that feeds on *Calanus finmarchicus*, which aggregate in dense near-bottom layers in summer. Bowhead whales in Disko Bay (West Greenland) also feed on near-bottom aggregations of *Calanus* spp. before their spring arousal, and nearer the surface after their ascent, although the bowheads are displaced by humpbacks coming to feed on capelin in early summer, before the *Calanus* spp. population reaches its annual biomass maximum.

The sub-arctic Pacific gyre appears to be a source for carbon dioxide to the atmosphere in winter and a sink in summer, whereas the reverse is true for the sub-tropical gyre. Arctic and Antarctic regions can both act as sinks for part of the year, although how these areas will respond to climate change and reduced sea-ice is not clear.

Regional variations in ecosystem structure within the lower trophic levels, together with environmental factors, such as ice-cover, depth and vertical mixing, lead to differences in the proportion of photosynthetically-fixed carbon that sinks to the benthos in sub-arctic regions of the Northeast Atlantic (e.g. Barents Sea, Fram Strait). As well, sedimentation

rates were higher in the sub-arctic Pacific gyre, where diatoms were dominant, than in the sub-tropical Pacific gyre, where they were not, even though measured primary production rates were similar.

Large oceanic copepods in sub-arctic and sub-tropical Pacific regions have adapted to intermittent food supplies by residing at depth in times of low food and by ensuring their offspring are in the surface layers at times when food is plentiful. High near-surface densities of krill are often localized near physical features (e.g. fronts, shelf-breaks) at both low and high latitudes (e.g. California Current, Antarctic). These hotspots attract predators, such as seabirds, fish and marine mammals. In the Antarctic krill rely on sea-ice, to provide food (ice-algae) and as an overwintering haven, and they rely on circulation processes to carry them along the Antarctic Peninsula and offshore. In recent years reduced ice cover in the Antarctic has led to reduced krill abundance in the Scotia Sea. This has impacted predators such as fur seals, which have shown reduced growth rates, and penguins, which have had reduced chick survival.

It has been suggested that monitoring seabirds provides a way of assessing the effects of climate change on marine ecosystems, since they effectively integrate what is happening at lower trophic levels. Assembly of a meta-database of existing information on climate/seabird interactions has, however, revealed that while sea-bird numbers are consistently positively related to sea-ice cover, they show no consistent relationships with other climate indices (e.g. sea-surface temperature).

A comparison of Northwest (NW) and Northeast (NE) Pacific fisheries revealed: the total biomass is higher in the NW than the NE; the number of species (diversity) is higher in the NW than the NE; the NW is dominated by pelagic fish species and the NE by demersals; the NE species are generally longer-lived than the NW species, and; the incidence of invertebrate “outbreaks” (including jellyfish) has been more frequent in the NW. Several North Pacific (pink salmon), Barents Sea and North Sea (cod, herring) fish stocks have shown inter-decadal changes that appear to be linked to climate indices (e.g. AMO, Atlantic Multi-decadal Oscillation). One suggestion is that changes in the dynamics of plankton production may be involved. Surplus production modeling has shown that over 11 regions, including the Barents Sea, the Norwegian Sea, the Labrador/Newfoundland Shelf, the Bering Sea and the Gulf of Alaska, maximum sustainable yields (MSYs) for species aggregates are lower than those for the sums of the MSYs for the individual species and that the relationship between fishery yield and primary production is not straightforward.

4.2 Session 2 - New observations and understanding of eastern and western Bering Sea ecosystems

Co-Convenors:
Rodger Harvey (USA), Oleg N. Katugin (Russia), Sang Heon Lee (Korea) and Mike Sigler (USA)
Invited Speakers:
Gennady Khen (Russia), Franz J. Mueter (USA) and Phyllis Stabeno (USA)

This session on “New observations and understanding of eastern and western Bering Sea ecosystems” was convened by Mike Sigler (NOAA) and Rodger Harvey (Old Dominion University). The session primarily reported results from the Bering Sea Project (BEST-BSIERP). There were 17 presentations and 21 posters. There was an element of review in

many of the talks, but given the highly varied audience and large international contingent, it served well to establish connections and linkages. The Bering Sea session was well attended with good interaction and questions. Six notable results were:

- The northern Bering Sea remained cold during summers of a recent warm period, implying that this region will remain cold during summers in the future as climate warms on average (Phyllis Stabeno, USA).
- There are natural controls on calcium carbonate saturation and pH on the Bering Sea shelf. If the effect of anthropogenic CO2 is removed, no under-saturated water would be present on the Bering Sea shelf (Jeremy Mathis, USA).
- The high abundance of krill in cold years may in part be due to the nutritional boost they get from ice algae. *Thysanoessa raschii* were visually observed to feed directly on the underside of the ice in tightly packed swarms and may be adapted to 'gorging' on ice algae and ice edge blooms. (Evelyn Lessard, USA).
- Young-of-the Year (YOY) pollock start winter with low energy reserves in warm years And YOY whole body energy content is related to recruitment at age-1. (Ron Heintz, USA).
- Kittiwakes adjusted over-night foraging behavior in response to shifts in distribution and availability of age-1 pollock (Rosana Paredes, USA).
- Movements and dive behavior of ribbon and spotted seals in the Bering Sea indicate seasonal variation in areas and depths utilized (Peter Boveng, USA).
- Pursuing insights gathered from traditional knowledge interviews; local interviews suggest wind and ice affect Savoonga walrus hunt (George Noongwook, USA).
- Sea ice-derived iron enhances ice edge bloom (Raymond Sambrotto, USA).

4.3 Session 3 - 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), Dag Slagstad (Norway) and Takeshi Okunishi (Japan)

The purpose of this session was to highlight different approaches to modeling the impacts of climate variability on high latitude marine ecosystems and their ability to support sustainable ecosystem services. A total of 12 talks and 6 posters were presented on different types of models from minimalist to end-to-end models. Diane Lavoie (Canada) in her invited talk discussed different types of models in her study of climate change and variability on the productivity of the Beaufort Sea in the Arctic and the Gulf of St. Lawrence in eastern Canada. In the former region a 1 dimensional NPZD model was used to develop future scenarios of primary production while in the latter region dynamical downscaling was used. Dag Slagstad (Norway) presented results from a coupled biophysical model of the Barents Sea and the Arctic. He found that there will be a northward shift in the distribution of Calanus species but C. finmarchicus still will not inhabit the Arctic Ocean. Increased stratification in the Norwegian and southern Barents Sea will limit nutrient replenishment limiting primary production there. Takeshi Okunishi (Japan) presented an Individual Based Model (IBM) for the Japanese sardine. He was able to simulate the observed transport of eggs and larvae as well as the well as the feeding location of the juveniles in a region of high chlorophyll concentrations. Two other IBM studies were

presented. Trond Kristiansen (Norway) found that increased temperatures under climate change would product a negative effect on Atlantic cod larvae in the southern regions of its distribution but positive in the north. Frode Vikebø (Norway) used an IBM to investigate recruitment of herring in the Norwegian Sea and found that the distribution of larvae depends significantly upon the vertical distribution and hatching date. Statistical models of jellyfish abundance in the Bering Sea were presented (Mary Beth Decker, USA), which suggest food availability is a prime driver of variability in jellyfish abundance. In another study using statistical models, the poster by Paul Spencer et al. (USA) examined the rate of predation of arrowtooth flounder on walleye Pollock in the Berings Sea under climate change.

Comparison of model results with observations were addressed in three presentations. Temperature and salinity fields in the Bering Sea were compared using a variety of statistical methods (Seth Danielson, USA) and Empirical Orthogonal Functions (EOFs) were used in comparisons of biophysical patterns on the Bering Sea Shelf (Albert Hermann et al., USA). Igor Belkin (USA) and colleagues compared results from the ROMS for the North Atlantic and found good correspondence with observations. The use of super-individuals to model zooplankton in the Norwegian Sea (Geir Huse, Norway) and an Eulerian model extending from nutrients to fish for the Baltic Sea (Wolfgang Fennel, Germany) were examples on new approaches and applications that were presented. Shin-ichi Ito and colleagues dealt with the uncertainty in the growth of Pacific saury off Japan under climate change and they indicated that future temperature increases will reduce juvenile growth of saury. Daniel Howell (Norway) suggested the impossibility of predicting future recruitment with any degree of certainty and highlighted the need for a robust management system that can cope with unpredictable changes in recruitment. Ensemble forecasting of complex ecosystems was also suggested using size spectra models (Neil Banas, USA) while Benjamin Planque (Norway) showed that a minimal model using first principles was able to reproduce several of the main features of the ecosystem dynamics in the Barents Sea. Two end-to-end models were presented. Kate Hedstrom (USA) described one such model that has been developed for the California Current that goes from physics to fish to fishers while the poster by Kerim Aydin and co-authors described a multispecies bioenergetics module for an end-to-end model. In an interesting poster, Kjersti Busch and Svein Sundby (Norway) hypothesized that the small size of pelagic eggs may be related to viscous forces.

4.4 Sessions 4 & 9 (Merged) - Nutrient, biogeochemistry and acidification in a changing climate

Co-Conveners

Knut Yngve Børsheim (Norway), Al Devol (USA) Michiyo Yamamoto-Kawai (Japan), Humio Mitsudera (Japan), and Jean-Eric Tremblay (Canada)

Invited Speakers

Lou Codispoti (USA), Eva Falck (Norway), Shigeto Nishino (Japan)

This session combined the topics of nutrient dynamics and ocean acidification into one dealing with biogeochemical processes. In regards to nutrients and the sources of macro- and micro-nutrients in the sub-Arctic seas, it sought to address the following questions:

- 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?

The topic of ocean acidification was meant to highlight how the pH in the subarctic and Arctic seas are changing and what this will mean to the biota.

Lou Codispoti provided an overview of nutrient levels and productivity in the Arctic and Sub-Arctic regions. The Arctic nutrient regime is heterogeneous with large differences in Atlantic and Pacific inputs, including concentration levels, inflowing depths and nitrate to phosphate ratios. Because of the strong salinity induced stratification, seasonal re- supply of nutrients to the surface layer by mixing is reduced and a large build-up of ammonium occurs during and after blooms. Estimates of net community production from seasonal changes in phosphate and nitrate in Arctic regions indicated spatial differences of 2 orders of magnitude with the lowest in the central Arctic Ocean and the highest in the Bering Sea. These estimates should be much smaller than primary production measurements from incubations but are not suggesting that the incubation method underestimates production. Eva Falk (Norway) used the low nitrate to phosphate ratios of Pacific water to trace its transport through Fram Strait in along the east coast of Greenland. Three papers examined sources of iron, a micro-nutrient required for primary production. The Sea of Okhotsk is a source of iron for the Northwest Pacific through brine rejection and circulation patterns (Keisuke Uchimoto, Japan). A subsurface dissolved iron maximum in the upper halocline layer in the Canada Basin in associated with a humic type fluorescent dissolved organic matter was the first confirmation of lateral iron transport into the basin from the shelves (Kenshi Kuma, Japan). Along sections of the Gulf of Alaska, iron is derived from glacial derived particulate matter (John Crusius, USA). Another paper on iron showed that on the Bering Shelf iron oxide reduction in the sediments is a significant pathway for the degradation of organic matter in the northern and middle shelf regions (Margaret Esch, USA). Sediments were also shown to play an important role in the spatial and temporal pattern of the nitrate deficit in the Bering Sea through denitrification and some advection from offshore (Allan Devol, USA). Humio Mitsudera (Japan) discussed upwelling associated with barotropic currents over a sill off the coast of Hokkaido, which in turn supports high primary production in summer. Examining nitrogen cycling on the eastern Bering Sea shelf through nitrogen and oxygen isotope ratios of nitrate, Julie Granger (USA) found that denitrification in the sediments was the dominant driver of fixed nitrogen loss on the shelf rather than through advection. Tore Johannessen (Norway) suggested that zooplankton predation may actually stimulate growth of algae rather than limit it.

Michiyou Tamamoto-Kawai (Japan) ocean acidification and particular the changes in the calcium carbonate saturation rate. In sampling conducted in the Arctic in 2008 the surface waters were found to be undersaturated with respect to aragonite. This has resulted from melting sea ice and high atmospheric CO_2 levels, with a smaller contribution from the higher temperatures. Increased CO_2 in the Arctic surface sea waters was also reported (Zhongyong Gao, China) from summer sampling between 1999 and 2010. The increase in surface *p*CO2 may in future reduce the CO_2 flux into the ocean.

4.5 Session 5 - New insights from the International Polar Year (IPY) studies

Co-Convenors:
Kenneth F. Drinkwater (Norway), William A. Montevecchi (Canada), Sei-ichi Saitoh (Japan) and Jinping Zhao (China)
Invited Speakers:
Eddy C. Carmack (Canada), Anthony Gaston (Canada) and Naomi Harada (Japan)

ESSAS organized and led the IPY consortium Ecosystem Studies of Subarctic and Arctic Regions (ESSAR) that consisted of 11 projects and 9 countries. This theme session was held to present the results from these and other IPY studies. In total, 23 presentations were made, three of which were invited oral talks, another 9 were oral presentations in the contributed afternoon parallel session, and 11 were posters. The session began in the morning plenary with results from the high Arctic. Eddy Carmack (Canada) spoke on Canada's 3 Oceans (C3O) project that collected data from Vancouver in the Pacific to Halifax in the Atlantic and traversed the Canadian Archipelago. Highlighted as a baseline study to use for future comparisons, the project also found significant new results. He stressed the connectiveness between the different oceans and the significant role played by the Arctic in terms of the global hydrological and thermohaline cycles. He noted the more rapid rate of change in the physical environment in the Arctic than previously predicted by models of future change and that the observed changes are producing measureable impacts on the biogeochemistry and biology of the regions. These included increases in the aragonite concentrations and increasing abundance of smaller size plankton and decrease in the larger size plankton. Tony Gaston (Canada) presented results from seabird studies in Canada's high Arctic. He reported that the timing of ice break-up in Hudson Bay has advanced by 3 weeks in nearly 3 decades, while the timing of egg-laying by thick-billed murres has advanced by only 6 days. The resulting timing mis-match has resulted in decreased growth rates of chicks, with chicks growing best when the gap between ice break-up and egg laying was least. Also, changes in nestling diets from ice-associated Arctic cod to other fish coincided with an abrupt reduction in the sea ice in the mid-1990s. Naomi Harada (Japan) was the third invited speaker and she led off the afternoon session. Focusing upon blooms of the coccolithophore *Emiliania huxleyi* in Bering Sea, she noted their detection with the SeaWiffs satellite beginning in 1997 and that their annual occurrence has resulted in trophic-level changes. Analysis of alkenone in the shelf sediments suggests that *E. huxleyi* blooms actually have been presence since the late 1970s. Aleutian Low activity and sea surface salinity trends over the past decades imply that the warming and freshening of Bering Sea waters are crucial for the promotion of *E. huxleyi* blooms in the Bering Sea, although this has not been confirmed.

The contributed presentations covered all aspects of the ecosystem from physics to seabirds and geographically from the Arctic to most of the subarctic seas. The role of atmospheric circulation on the ocean currents and location of thermal fronts in the Chukchi Sea was explored in a poster (Gennady Khen, Russia). A talk on light measurements in the high Arctic revealed that Ice cover has a notable effect on light levels within horizontal distances up to 30 m from the ice edge but varies with depth and light frequency (Tao Li, China). It affects upwelling radiance in sea water more than downwelling irradiance. Two posters discussed bacteria. The diversity of bacterioplankton in the northern Bering Sea was investigated using a combination of molecular and culture-based methods (Yinxin Zeng, China). *Actinobacteria* formed the dominant bacterial lineage in both surface and

bottom water with *Alphaproteobacteria* another dominant fraction in surface water. This bacterial community differs from that in other polar regions. In the second study, heterotrophic bacterial abundance was found to be higher in the Bering Sea than in the Arctic Ocean (Ling Lin, China). Controlling factors varied between basins and shelves as well as regionally. Temperature and DOC accounted for most of this variability while salinity and nutrients played minor roles. In a study focused on the Bering Sea and adjacent Arctic regions, a new model of primary production taking into account inherent optical properties (IOPs) was presented that adjusts for particulate matter in the water (Toru Hirawake, Japan). The results more closely match observations than from previous models. Moving up the food chain a study of the effect of sea-ice reduction on zooplankton in the Chukchi Sea and how the biomass size composition varied spatially was presented in a poster (Kohei Matsuno, Japan).

Two oral presentations and five posters provided results from the Iceland Sea Ecosystem (ISE) project. The first talk (Hedin Valdimarsson, Iceland) presented the physical oceanographic conditions during the study (2006-2008) documenting increased temperatures and salinities owing to the greater influence of Atlantic Waters in the Iceland Sea both through Denmark Strait in the south and over the Jan Mayen Ridge in the northeast. At the same time sea-ice coverage has decreased noticeably within the Iceland Sea. A poster described the detailed circulation and possible retention areas for capelin larvae in the area of the Kolbeinsey Ridge in the Iceland Sea (Steingrumur Jonsson, Iceland). The second talk (Astthor Gislason, Iceland) addressed the abundance, composition and development of zooplankton in relation to hydrographic features. 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. A poster presented studies using towed instrumentation that showed the subarctic front is a strong boundary for zooplankton distributions (Astthor Gislason, Iceland). Three posters presented results on capelin, the principal focus of the ISE Project. Capelin larval drift studies (Konrad Thorisson, Iceland) revealed larvae in the north and east originate from local spawning sites. Also, there are indications of an earlier and/or more northerly spawning around Iceland in recent years. A study on the Iceland Sea pelagic ecosystem (Hildur Petursdottir, Iceland) concluded that there are 3-4 trophic levels excluding birds and mammals, with herbivorous copepods, primarily *Calanus hyperboreus*, occupying the lowest trophic level while capelin and blue whiting are in the highest level. The adults of these two species share similar prey and therefore are competitors. The final poster (Olafur Palsson, Iceland) presented distributional changes in the capelin. 0-group and 1-3 year olds shifted from the Icelandic continental shelf towards East Greenland in the late 1990s and since 2003, respectively, which are thought to be related to changes in both biomass and environmental conditions.

Two papers were presented from the Norwegian ESSAR project. The first current meter measurements ever taken on the Jan Mayen Ridge, which separates the Norwegian and Iceland Seas, indicated a weak net flow of Atlantic Water from the Norwegian Sea to the Iceland Sea south of the island of Jan Mayen (Kjell Arne Mork, Norway). A second mooring located in a canyon crossing the Ridge farther south, the flow in the upper 600 m was from the Norwegian Sea to the Iceland Sea during winter and vice versa during summer. Near

bottom there was a net flow of deep water from the Norwegian Sea into the Iceland Sea throughout the year. The second NESSAR paper (Michael Carroll, Norway) reported that bivalve shell growth rates were highest in Atlantic water despite greater depths compared to those in Arctic water or at the Polar Front. Periods of higher and lower growth coincided with variations of the North Atlantic Oscillation (accounted for 43% of interannual variance).

Surveys of cetaceans in the eastern Bering Sea and Chukchi Sea indicated different species were associated with different hydrographic and plankton characteristics (Hiroko Sasaki, Japan). Three seabird presentations were made. Underwater video cameras were used to help model the bioenergetics of the common eiders in eastern Hudson Bay whose habitat is changing through changes in river runoff because of hydroelectric developments (Joel Heath, Canada). These changes are threatening the eider populations and the Inuit people of the islands that depend upon them. In another study, several seabird species off eastern Canada were equipped with tracking devices to investigate their different feeding strategies and diet analysis examined the role of changing environmental conditions on the types of prey (William Montevecchi, Canada). Examples, of the detrimental anthropogenic effects on seabirds caused by inshore sea ice entrapment, hunting, by-catch in gillnets, ship-source pollution and offshore oil platforms were provided. In the third study (Gail Davoren, Canada), deep-water (17-40m) capelin spawning sites were discovered off the northeast Newfoundland coast, species preyed upon by many species of seabirds. The poster showed the timing of capelin spawning was earlier in warm years and capelin spawning hotspots tended to be absent during chick rearing, which resulted in a significant decrease in the percentage of capelin delivered to either northern gannets or common murre chicks and lower fledging condition.

One poster by Rachael Cavanagh (UK) presented the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) project that aims towards a circumpolar analyses of Southern Ocean climate and ecosystem dynamics. The Southern Ocean is considered to serve as both a model system for developing methods for global application and an early warning of the effects of climate change.

While a synthesis of the many and varied studies undertaken during IPY is not possible at this stage, it is clear that much has been learned but that we still have far to go to understand these ecosystems.

4.6 Session 6 - National ESSAS Programs: Recent advances and contributions

Co-Convenors:
Olafur S. Astthorsson (Iceland), Yasunori Sakurai (Japan), Svein Sundby (Norway) and Kai Wieland (Denmark)
Invited Speakers:
Sen Tok Kim (Russia) and Orio Yamamura (Japan)

This session had 10 oral presentations and 3 poster contributions. There was one presentation on the Sea of Okhotsk. One presentation addressed the Bering, Chukchi Sea, and Beaufort Seas. Two presentations addressed the Labrador/West Greenland area. Two presentations were on the seas around Iceland (Icelandic and Irminger Seas). Four

presentations addressed the Barents and Norwegian Seas. Of the 3 poster presentations there was one on the Japanese waters and two one the Barents Sea.

Three of the presentations showed indications/evidence of inverse relationships between planktivorous fishes and the zooplankton which they feed upon. Olafur Palsson with colleagues presented the mean annual biomass of phytoplankton, zooplankton (in the form of mesozooplankton and macrozooplankton) and capelin in Icelandic waters for the period 2006-2008. Capelin was at a very low level during this period with 140 000 tons, while standing stock of the meso- and macrozooplankton was estimated to 18 mill. tons, hence indicating an extremely low ratio of capelin to zooplankton of 1:130. No time series was presented, but this high ratio indicates that the limited period presented had a very low trophic transfer efficiency (TTE) for the level from zooplankton to planktivorous fish. Padmini Dalpadado and colleagues showed time series of mesozooplankton in the Barents Sea for the period 1983 - 2010. In general, the abundances varied inversely with the sum of the abundance of the planktivorous fish species capelin, polar cod, herring, blue whiting and 0-group fish.

Olafur Astthorsson and colleagues showed the zooplankton biomass during the period 1982-2010 in Icelandic waters. This is a region at the fringes of the distributions of the Norwegian spring-spawning herring, the blue whiting and Northeast Atlantic mackerel. The zooplankton biomass here apparently was not affected by the present high abundance of these planktivorous fishes. However, he showed from Norwegian investigations that the zooplankton biomass in the Norwegian Sea has dropped to approximately 20% of the abundance in 1995. This is the core areas of feeding of these planktivorous fishes, which currently are at the highest recorded spawning stock biomass of 15 million tons.

Three of the presentations addressed processes related to fronts and eddies. Ken Drinkwater and colleagues reported on an investigation on the plankton production along the polar front in the Norwegian Sea and the importance as summer feeding area for the Norwegian spring-spawning herring. Surprisingly, they found that this passive polar front (strong thermal front but not a density front) in the Norwegian Sea was not associated with higher productivity of plankton. Sünnje Basedow and colleagues studied the ice edge bloom in the Barents Sea. Higher abundance of phytoplankton was apparent at a surface salinity front but the highest abundance was found well into the low-salinity Arctic water. Konstantin Rogachev found the highest concentration of the pelagic mollusk *Limacina helicina* within mesoscale gyres near the coasts of the Okhotsk Sea.

During recent warm years in the Nordic Seas Atlantic mackerel has migrated into Icelandic waters for summer feeding. Olafur Astthorsson and colleagues showed old mackerel records from Icelandic waters from 1890 until present. The records show that mackerel abundance has varied along with the Atlantic Multi-decadal Oscillation (AMO), being high in warm periods and low in cold periods.

Lower trophic levels in the Greenland and Labrador marine ecosystems have responded to recent warming. Erica Head and colleagues showed an earlier start of the spring bloom and an increase in the young stages of *Calanus finmarchicus*, and in Greenland fjords Thomas

Juul-Pedersen and Søren Rysgaard showed an abrupt shift in the zooplankton community from *C. hyperboreus* to *C. finmarchicus* in recent years.

George Hunt analyzed the ecosystem structure of the Bering, Chukchi and Beaufort Seas from physics and plankton to fish, mammals and sea birds. Cluster analysis showed that the ecosystem that deviated most from the others was the Beaufort Sea. This was a rather surprising result to the present reporter, since it might be assumed that the Bering Strait is a significant barrier in an ecosystem sense. The reason why the Beaufort Sea stands out separately might be linked to several physical features. Among the most pronounced differences is bottom topography where the Beaufort Sea has a particularly narrow shelf and a deep adjacent polar basin.

Jinping Zhao and Ken Drinkwater explored how the Arctic Oscillation (AO) is linked to physical processes of the Nordic Seas. It appears that the increase in the AO and decreases in sea-level pressure (SLP) occurred about 14 months prior to increases in the Norwegian Sea long wave radiation and latent heat fluxes. Hence, it was concluded that the AO is leading the climate processes in the Nordic Seas and not vice versa.

3.7 Session 7 - Anticipating Socioeconomic and Policy Consequences of Global Changes in Sub-Polar and Polar Marine Ecosystems

Co-Convenors:
Keith Criddle (USA), David Fluharty (USA), Mitsutaku Makino (Japan) and Ian Perry (Canada)
Invited Speakers:
Anthony Charles (Canada), Mitsutaku Makino (Japan) and James McGoodwin (USA)

This session was headlined by three plenary speakers (Makino, McGoodwin, and Charles). The session itself included nine presentations and one poster. This session was intended as an invitation to social scientists to engage with the ESSAS community and an opportunity for members of the ESSAS community to be introduced to social science dimensions of social-ecological systems. The plenary speakers spoke on the human dimensions of climate change on fisheries in Japan (Mitsutaku Makino, Japan), the effects of ecosystem change on the resilience of high-latitude fishing communities (James McGoodwin, USA), and the role that choices of policy instruments have on stabilizing or destabilizing social-ecological systems undergoing climate-induced change (Anthony Charles, Canada). These themes were further developed during the session.

Dave Fluharty (USA) discussed the need for and potential indicators to be used in social and economic assessment of arctic communities. Fluharty extended this discussion with a presentation on behalf of Alf Håkon Hoel (Norway), sharing the principal finding of Arctic Climate Impact Assessment (2005): 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. Alan Haynie (USA) and Lisa Pfieffer (USA) presented preliminary results of efforts to model the location choice responses of fishermen as moderated by shifts in the abundance and distribution of cod and pollock stocks in the eastern Bering Sea. James Strong (USA) and Keith Criddle (USA) also described models of the pollock fishery, focusing on evolving product markets, the role of fuel costs and policy measures on the profitability of shore-based and at-sea production modes, and the role that climate will play in the

management of straddling stocks. Dave Fraser (USA) presented a fisherman's perspective on the impact of policy changes and fluctuations in fish stocks play in the viability of a remote coastal community, Adak.

Small communities cannot follow shifts in fish stocks or relocate away from restricted spatial management measures. Moreover, small fishery-dependent communities have little opportunity for economic diversification. The consequences of climate-induced changes in social-ecological systems will manifest themselves most prominently in communities least able to weather loss of their resource base. In the concluding plenary session, Criddle reiterated this point with examples of fisheries management strategies that have contributed to the resilience or fragility of social ecological systems. Henry Huntington (USA) returned focus to the arctic with a review of recent actions by the U.S. and Canada to forestall the development of large-scale commercial fisheries until such time as the magnitude and character of the resource base is better documented and the response of arctic marine ecosystems to climate change is better understood. Makino concluded the session on behalf of Alida Bundy (Canada) and Ian Perry (Canada) with a discussion of progress and developments under the IMBER Working Group.

This was a well-attended session that generated excellent dialogue between the presenters and the audience. Participants expressed interest in coordinating a themed session on cod and pollock fisheries at the next ESSAS meeting. The purpose of the session would be to bring together physical, biological, and social scientists in a single session that would look at those social-ecological systems through the diverse lenses of the various disciplines.

3.8 Session 8 - *Interactions between gadoids and crustaceans: the roles of climate, predation and fisheries*

Co-Convenors:
AnneDorte Burmeister (Greenland), Earl Dawe (Canada), Franz J. Mueter (USA) and Olafur Palsson (Iceland)
Invited Speakers:
Patrick Ouellet (Canada) and José M. (Lobo) Orensanz

In total, 15 presentations were featured during this theme session, including two invited presentations during the morning plenary session, 10 contributed presentations during the afternoon parallel session, and 3 posters. Presentations included case studies as well as comparative analyses across subarctic ecosystems. Several presentations found strong evidence for direct negative effects of warm temperatures on survival of early benthic stages of snow crab across systems (Lucinda Marcello, USA; Stephanie Boudreau, Canada), while Gorden Kruse (USA) hypothesized that indirect climate effects on distribution of adult red king crab may affect transport of larvae to suitable spawning locations. No consistent effect of mean temperature conditions on survival of Northern shrimp was reported (Marcello; Boudreau), but shrimp survival may be positively affected by warm temperatures in West Greenland (e.g. Kai Wieland, Denmark). Previous meta-analyses suggest that Northern shrimp time their spawning such that hatching coincides with the spring bloom under average conditions (Koeller et al. 2009, Science, Vol. 324: 791). The importance of bloom timing was confirmed by Patrick Ouellet (Canada) who showed that hatching consistently occurs after the onset of the bloom and close to the bloom maximum

in the Gulf of St. Lawrence and that larval survival is positively associated with bloom duration, bloom timing, and with the rate of warming.

Diet studies of Pacific and Atlantic cod suggest that shrimp, as well as fish and, to a lesser extent, crab are an important component of the diet of cod. Pacific cod diets were relatively consistent across seasons in the Gulf of Alaska (Dan Urban, USA) but varied greatly between inshore and offshore waters off Iceland (Ingeborg Jonsdottir, Iceland). Cod diets in Newfoundland/ Labrador also varied inter-annually with a shift from capelin-dominated diets in the 1980s to shrimp-dominated diets since the mid-1990s (Earl Dawe, Canada), following the collapse of capelin and other fish stocks in the region.

Temperature affects growth (size) and fecundity of snow crab in complex ways with both males and females achieving a larger size at terminal molt due to a higher molting frequency under warm temperatures (AnnDorte Burmeister, Greenland; Dawe). The effect was more pronounced in females (Dawe). These effects on growth imply that cold temperatures reduce recruitment into the fishery because fewer males recruit to harvestable size. However, the overall effect of colder temperatures on recruitment is positive (Marcello), implying that positive effects on early survival dominate recruitment dynamics.

Across systems and species, there was relatively weak evidence that gadid predation controls the dynamics of Northern shrimp, snow crab, or king crab (Marcello; Dawe; Orensanz; Kruse), although apparent predation of cod on crustaceans off Newfoundland was locally important for snow crab, but less so for Northern shrimp (Matthew Windle, Canada). Clearly, spatial dynamics are key to understanding population dynamics of crab and shrimp stocks. For example, ontogenetic changes in distribution of snow crab in the Bering Sea affect predation and recruitment to suitable nursery areas (Orensanz) and observed shifts in distribution of shrimp (Wieland) and crab (Kruse) with temperature affect the potential for predator-prey interactions.

5.0 Wrap-up Session

The wrap-up consisted of three invited presentations.

- The first was by Dr. Kevin Arrigo (Stanford University, USA), who discussed the impact of climate change on lower trophic levels in polar and sub-polar seas in a talk entitled "*Phytoplankton production in the Bering Sea and Arctic Ocean: A Satellite remote sensing study*". He showed that sea surface temperatures (SSTs) in the Bering Sea have warmed over last 30 years, but there has been no trend in sea-ice cover or primary production. The exception has been the Chirikov Basin where annual primary production increased by 40% from 1998 to 2007. Dr. Arrigo speculated that in the future, a warmer, more ice-free Bering Sea is likely to be more productive than today. In the Arctic, changes in sea-ice extent and duration have resulted in a 20% increase in primary production over the last 12 years, and with reductions in sea ice, Arctic productivity could increase even more in the future. However, he noted that much work is needed before we will have reliable quantitative predictions.

- The second presenter was Dr. Steve Murawski (University of South Florida, USA) who spoke on "*Understanding ecosystem processes: The key to predicting climate effects*". He noted that global patterns and ecological gradients of productivity, species richness, species distributions, and their variability form the patterns of adaptation of biodiversity to the Earth's climate, and pointed out just how complicated it will be to forecast future warming-induced impacts. Complex co-evolved dynamics defy simple depiction with single drivers. Dr. Murawski stressed the value of the comparative approach for studying ecosystem responses to variations in ocean climate and as a powerful method for inferring biophysical processes. He went on to state that much of the "first order" science done up to now has shown just how complicated things are, and pointed the way towards a mix of comparative studies, paleoecology, and laboratory analyses that are needed to advance the field — reductionist approaches will not reveal complex interactions. There is the need to understand how species respond not only on a taxonomic basis, but in the presence of other species, *i.e*., competitors, prey and predators. He noted the importance to assemble the global patterns of environmental information and biological data, including biological responses to environmental change, and wondered who will take on this important work.

- The final speaker was Dr. Keith Criddle (University of Alaska Fairbanks, USA), whose presentation was entitled "*Adaptation and mal-adaptation: Factors that influence the fitness of fisheries and fishing-dependent communities*". Using examples from the salmon, halibut and pollock fisheries off Alaska, he showed that the fitness of fisheries and fishery-dependent communities depend on the characteristics of social, economic, and legal systems that determine who is allowed to fish and how fishing takes place, as well as the attributes of the stock. The unique legal foundations, culture, and traditions of each nation or state affect the range of viable alternative fishery governance structures. There are tradeoffs between economic efficiencies gained through management measures such as single species individual fishing quotas (IFQs) and heightened exposure to factors that affect individual stocks, associated product markets, *etc*. In contrast, generalist fleets trade reduced economic efficiency and possible losses of management precision 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 which helps fishermen adapt to modest adverse changes in stock abundance, vessel prices, and input costs, but their vulnerability to larger perturbations is increased. 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.

6.0 Awards

Awards were given for the best young scientists' presentations:

- Honorable mention went to Kristin L. Laidre (University of Washington) for her talk entitled "*Climate Change and Baleen Whale Trophic Cascades in Greenland"*. She described tagging and tracking studies of bowhead and humpback whales off West Greenland done in conjunction with the Greenland Institute of Natural Resources.
- The award for the best presentation went to Joel Heath from the University of British Columbia for his talk on *Winter Ecology of Common Eiders in Polynya and Floe Edge*

Habitats in Eastern Hudson Bay, Nunavut. He gave a fascinating account using underwater video to help model the bioenergetics of the eiders. He also described the changing environmental conditions for these birds around the Belcher Islands through changes in river runoff because of hydroelectric developments. These changes are threatening the eider populations and hence the Inuit people of the islands that depend upon them.

- Special awards were also given to the students from the Pribilof Islands for their presentation and participation in the OSM.

Awards were also given to the best posters by young scientists:

- Runner up in the Poster presentation went to Laurinda Marcello at the University of Alaska Fairbanks for her poster on the *Effects of temperature and gadoid predation snow crab recruitment: Comparisons between the Bering Sea and Atlantic Canada*. She and her co-authors found that temperature change seems to be a more important and consistent factor controlling snow crab recruitment than that of gadoid predation. It is still unclear whether the temperature effect is through direct forcing or indirectly, e.g. through temperature effects on their prey or predators.
- The best Poster presentation award was given to Xuehua Cui from the University of Tennessee for her poster on *Spatial distribution of groundfish in the northern Bering Sea in relation to environmental variation and feeding habitat*. Her study suggested strong linkages between physical conditions (*e.g.* water temperature and hydrography) and biological conditions (*e.g.* bloom status) in structuring fish communities in the northern Bering Sea.

7.0 Publications

Papers from the OSM theme sessions will appear in a special volume of the ICES *Journal of Marine Science*. This issue will be dedicated to our colleague and good friend, Dr. Bernard Megrey — a long time member of the ESSAS Scientific Steering Committee (SSC) and co-leader of the ESSAS Working Group on *Modeling Ecosystem Response* — who unfortunately passed away unexpectedly last October.

Papers from the Workshop on Gadid–crustacean Interactions will appear together as a special section in *Marine Ecology Progress Series*.

Papers from the theme session "*New observations and understanding of eastern and western Bering Sea ecosystems*" will be published in a special issue of *Deep-Sea Research II*,

Papers from the session on "*Modeling marine ecosystem dynamics in high latitude regions*" will appear in the *Journal of Marine Systems*. This special issue will also be dedicated to Dr. Bernard Megrey. Papers on modeling from some of Bern's former colleagues who did not attend the OSM will be considered for this special issue in addition to those from the meeting.

8.0 Appendices

Appendix 8.1: Organizers and Sponsors

Symposium Conveners

- George L. Hunt, Jr. (*University of Washington, USA)*
- Olafur S. Astthorsson (*Marine Research Institute, Iceland)*
- Michio J. Kishi (*Hokkaido University, Japan)*

Scientific Steering Committee

- Kenneth Denman (*VENUS Project, University of Victoria, Canada)*
- Kenneth F. Drinkwater (*Institute of Marine Science, Norway)*
- Erica Head (*Bedford Institute of Oceanography, Fisheries and Oceans Canada)*
- George L. Hunt, Jr.(*University of Washington, USA)*
- Shin-ichi Ito (*Tohoku National Fisheries Research Institute, Japan; PICES Representative)*
- James Overland *(NOAA Pacific Marine Environmental Laboratory, USA)*
- Sei-ichi Saitoh (*Hokkaido University, Japan)*
- Michael Sigler (*NOAA Alaska Fisheries Science Center, USA; BEST/BISERP Representative)*
- Yvonne Walther (*Institute of Marine Research, Sweden; ICES Representative)*
- Paul Wassmann (*University of Tromsø, Norway)*

Local Organizers

- George L. Hunt, Jr. (*University of Washington, USA)*
- PICES Secretariat

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

Appendix 8.2: Registered Participants

Argentina **Lobo Orensanz** CENPAT Bvd Brown s/n Puerto Madryn, Chubut 9120 Argentina lobo@u.washington.edu	**Greg Crawford** Faculty of Science and Technology Vancouver Island University 900 Fifth St. Nanaimo, BC V9R 5S5 Canada crawfordg@viu.ca	**Diane Lavoie** Fisheries and Oceans Canada Maurice-Lamontagne Institute 850 Route de la Mer Mont-Joli, QC G5H3Z4 Canada Diane.Lavoie@dfo-mpo.gc.ca
Canada **Stephanie A. Boudreau** Biology Department Dalhousie University 1355 Oxford St. Halifax, NS B3H 4J1 Canada s.boudreau@dal.ca	**Earl Dawe** Fisheries and Oceans Canada 80 East White Hills Rd. St. John's, NL A1C 5X1 Canada Earl.Dawe@dfo-mpo.gc.ca	**Skip McKinnell** Deputy Executive Secretary PICES Secretariat 9860 W. Saanich Rd., P.O. Box 6000 Sidney, BC V8L 4B2 Canada mckinnell@pices.int
Eddy C. Carmack Fisheries and Oceans Canada Institute of Ocean Sciences P.O. Box 6000 Sidney, BC V8L 4B2 Canada Eddy.Carmack@dfo-mpo.gc.ca	**Anthony Gaston** Environment Canada National Wildlife Research Centre 1125 Col By Dr. Ottawa, ON K1A 0H3 Canada tonygastonconsult@gmail.com	**William Alan Montevecchi** Psychology, Biology and Ocean Sciences Memorial University of Newfoundland Elizabeth Ave. St. John's, NL A1B 3X9 Canada mont@mun.ca
Anthony Charles Environmental Studies / School of Business Saint Mary's University 923 Robie St. Halifax, NS B3H3C3 Canada tony.charles@smu.ca	**Erica Head** Fisheries and Oceans Canada Bedford Institute of Oceanography P.O. Box 1006 Dartmouth, NS B2Y 4A2 Canada Erica.Head@dfo-mpo.gc.ca	**Patrick Ouellet** Fisheries and Oceans Canada 850 Route de la Mer Mont-Joli, QC G5H3Z4 Canada patrick.ouellet@dfo-mpo.gc.ca
James Christian Fisheries and Oceans Canada Canadian Centre for Climate Modelling and Analysis c/o University of Victoria, P.O. Box 3065 Victoria, BC V8W 3V6 Canada jim.christian@ec.gc.ca	**Joel P. Heath** University of British Columbia 121-1984 Mathematics Rd. Vancouver, BC V6T 1Z2 Canada heath.joel@gmail.com	**Rosana Paredes** Fisheries and Wiildlife Oregon State University 1070 Llanfair Cres. Brentwood Bay, BC V8M1G2 Canada rosana.paredes@mun.ca

Appendix 8.2 Registered Participants *(Continued)*

## *Canada (Continued)* ***Ian Perry*** *Fisheries and Oceans Canada* *Pacific Biological Station* *3190 Hammond Bay Rd.* *Nanaimo, BC V9T 6N7* *Canada* *Ian.Perry@dfo-mpo.gc.ca*	***Jiadi Wang*** *Division of Exchange and Cooperation Service* *Chinese Academy of Fishery Sciences, Ministry of Agriculture, PRC* *150 Qingtacun* *Beijing, 100141* *China, PR* *wangjiadi1983@yahoo.com.cn*	***Jinping Zhao*** *College of Physical and Environmental Oceanography* *Ocean University of China* *238 Songling Rd.* *Qingdao, 266100* *China, PR* *jpzhao@ouc.edu.cn*
Matthew J. S. Windle *Department of Biology* *Marine Institute, Memorial University* *P.O. Box 4920* *St. John's, NL 5R3* *Canada* *matthew.windle@gmail.com*	***Yamin Wang*** *College of Ocean* *Shandong University at Weihai* *180 Wenhuaxi Rd.* *Weihai, Shandong 264209* *China, PR* *wangyamin@sdu.edu.cn*	## *Denmark* ***Adolf K. Kellermann*** *Head Science Programme* *International Council for the Exploration of the Sea (ICES)* *44-46 H.C. Andersens Blvd.* *Copenhagen, DK-1553* *Denmark* *adi@ices.dk*
Julia Yazvenko *Database and Web Administrator* *PICES Secretariat* *9860 W. Saanich Rd., P.O. Box 6000* *Sidney, BC V8L 4B2* *Canada* *secretariat@pices.int*	***Yinxin Zeng*** *Polar Biological Science Division* *Polar Research Institute of China* *451 Jinqiao Rd.* *Shanghai, 200136* *China, PR* *yxzeng@yahoo.com*	***Kai Wieland*** *Section for Monitoring* *DTU Aqua* *P.O. Box 101* *Hirtshals, 9850* *Denmark* *kw@aqua.dtu.dk*
## *China, Peoples Republic* ***Zhongyong Gao*** *Key Lab. of Global Change and Marine-Atmospheric Chemistry* *Third Institute of Oceanography, SOA* *178 Daxue Rd.* *Xiamen, Fujian 361005* *China, PR* *zgao@263.net*	***Liyang Zhan*** *178 Daxue Rd.* *Xiamen, 361005* *China, PR* *jumpcut@sohu.com*	## *Finland* ***Towe Holmborn*** *ARONIA Coastal Zone Research Team* *Novia University of Applied Sciences* *9 Raseborgsvägen* *Ekenäs, 10600* *Finland* *toweh@hotmail.com*
Tao Li *College of Physical and Environmental Oceanography* *Ocean University of China* *238 Songling Rd.* *Qingdao, Shandong 266100* *China, PR* *litaoocean@gmail.com*	***Fang Zhang*** *Biological Department* *Polar Research Institute of China* *451 Jinqiao Rd.* *Shanghai, 200136* *China, PR* *zhangfang@pric.gov.cn*	## *Germany* ***Juergen Alheit*** *Biological Oceanography* *Leibniz Institute for Baltic Sea Research, IOW* *15 Seestr.* *Warnemuende, 18119* *Germany* *juergen.alheit@io-warnemuende.de*

Appendix 8.2 Registered Participants *(Continued)*

Germany (Continued) **Wolfgang Fennel** Leibniz Institute for Baltic Sea Research, IOW 15 Seestr. Rostock, 18119 Germany wolfgang.fennel@io-warnemuende.de	***Iceland*** **Olafur S. Astthorsson** Marine Research Institute Iceland Skúlagata 4, P.O. Box 1390 Reykjavik Iceland osa@hafro.is	**Hildur Petursdottir** Ecology Department Marine Research Institute Iceland 4 Skúlagata Reykjavík, 101/121 Iceland hildur@hafro.is
Michael Klages Deep-Sea Ecology Alfred Wegener Institute for Polar and Marine Research 12 Am Handelshafen Bremerhaven, 27570 Germany michael.klages@awi.de	**Astthor Gislason** Marine Research Institute Iceland Skulagata 4, P.O. Box 1390 Reykjavik, 121 Iceland astthor@hafro.is	***Japan*** **Sangdeok Chung** Graduate School of Science and Technology Nagasaki University 1-14 Bunkyo-machi Nagasaki, Nagasaki 852-8521 Japan d710183l@cc.nagasaki-u.ac.jp
Christian Moellmann Institute for Hydrobiology and Fisheries Science University of Hamburg 133 Grosse Elbstrasse Hamburg, D-22767 Germany christian.moellmann@uni-hamburg.de	**Ingibjorg G. Jonsdottir** Marine Research Institute Iceland Skúlagata 4, P.O. Box 1390 Reykjavik, 101 Iceland ingibj@hafro.is	**Naomi Harada** Research Institute for Global Change Japan Agency for Marine-Earth Science and Technology (JAMSTEC), FRA 2-15 Natsushima-cho Yokosuka, 237-0061 Japan haradan@jamstec.go.jp
Greenland **AnnDorte Burmeister** Dep Fish and Shellfish Greenland Institute of Natural Resources Kivioq 2, P.O. Box 570 Nuuk, 3900 Greenland anbu@natur.gl	**Steingrimur Jonsson** Marine Research Institute Iceland Borgir v/Nordurslod Akureyri, 600 Iceland steing@unak.is	**Toru Hirawake** Faculty of Fisheries Sciences Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-8611 Japan hirawake@salmon.fish.hokudai.ac.jp
Thomas Juul-Pedersen Greenland Climate Research Centre c/o Greenland Institute of Natural Resources, P.O. Box Nuuk, DK-3900 Greenland thpe@natur.gl	**Ólafur K. Pálsson** Marine Research Institute Iceland Skúlagata 4, P.O. Box 1390 Reykjavík, 121 Iceland okp@hafro.is	**Makio Honda** Research Institute for Global Change Japan Agency for Marine-Earth Science and Technology (JAMSTEC), FRA 2-15 Natsushima-cho Yokosuka, Kanagawa 237-0061 Japan hondam@jamstec.go.jp

Appendix 8.2 Registered Participants *(Continued)*

Japan (Continued) **Takahiro Iida** Bioscience Group National Institute of Polar Research, Japan 0-3 Midoricho Tachikawa, Tokyo 1908518 Japan iida@nipr.ac.jp	**Kohei Matsuno** Fisheries Science Hokkaido University 3-1-1 Minatomachi Hakodate, Hokkaido 041-8611 Japan k.matsuno@fish.hokudai.ac.jp	**Sei-Ichi Saitoh** Graduate School of Fisheries Sciences Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-8611 Japan ssaitoh@salmon.fish.hokudai.ac.jp
Michio J. Kishi Graduate School of Environmental Science Hokkaido University N10W5 Kita-ku Sapporo, Hokkaido 060-0810 Japan mjkishi@nifty.com	**Shigeto Nishino** Research Institute for Global Change JAMSTEC 2-15 Natsushima-cho Yokosuka, Kanagawa 237-0061 Japan nishinos@jamstec.go.jp	**Yasunori Sakurai** Graduate School of Fisheries Sciences Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-8611 Japan sakurai@fish.hokudai.ac.jp
Kenshi Kuma Faculty of Fisheries Sciences Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-8611 Japan kuma@fish.hokudai.ac.jp	**Takeshi Okunishi** National Research Institute of Fisheries Science, FRA 2-12-4 Fukuura, Kanazawa-ku Yokohama, Kanagawa 236-8648 Japan okunishi@affrc.go.jp	**Hiroko Sasaki** Satellite Oceanography Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-0822 Japan hiro_sasaki@salmon.fish.hokudai.ac.jp
Mitsutaku Makino Fisheries Research Agency 2-12-4 Fukuura Yokohama, Kanagawa 236-8648 Japan mmakino@affrc.go.jp	**Jonaotaro Onodera** Research Institute for Global Change Japan Agency for Marine-Earth Science and Technology (JAMSTEC), FRA 2-15 Natsushima-cho Yokosuka, 237-0061 Japan onoderaj@jamstec.go.jp	**Hiroko Sasaki** Satellite Oceanography Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-0822 Japan hiro_sasaki@salmon.fish.hokudai.ac.jp
Kohei Matsuno Fisheries Science Hokkaido University 3-1-1 Minatomachi Hakodate, Hokkaido 041-8611 Japan k.matsuno@fish.hokudai.ac.jp	**Rui Saito** Graduate School of Fisheries Sciences Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 041-8611 Japan ruis@fish.hokudai.ac.jp	**Katsumi Takayama** Japan Sea National Fisheries Research Institute Fisheries Research Agency 1-5939-22 Suido-cho Niigata, Niigata 951-8121 Japan katsumit@affrc.go.jp

Appendix 8.2 Registered Participants *(Continued)*

Japan (Continued) **Atsushi Tsuda** Atmosphere and Ocean Research Institute University of Tokyo 5-1-5 Kashiwanoha Kashiwa, Chiba 277-8564 Japan tsuda@aori.u-tokyo.ac.jp	***Korea*** **Ho Kyung Ha** Polar Climate Sciences Korea Polar Research Institute 7-50 Songdo Techno Park Incheon, 406-840 Korea ha@kopri.re.kr	**Joo Eun Yoon** Phytoplankton Ecology KORDI 1270 Sadong Ansan, 426-744 Korea eliterem@kordi.re.kr
Keisuke Uchimoto Institute of Low Temperature Science Hokkaido University N19W8 Kita-ku Sapporo, 060-0819 Japan uchimoto@lowtem.hokudai.ac.jp	**Suam Kim** Dept. of Marine Biology Pukyong National University 599-1 Daeyeon 3-dong, Nam-gu Busan, 608-737 Korea suamkim@pknu.ac.kr	***Malaysia*** **Chern Chung Chuah** Centre for Marine and Coastal Studies Science University Malaysia Centre for Marine and Coastal Studies Penang, Pulau Pinang 11800 Malaysia methane.ch3@gmail.com
Yutaka Watanuki Graduate School of Fisheries Sciences Hokkaido University 3-1-1 Minato-cho Hakodate, Hokkaido 040-8611 Japan ywata@fish.hokudai.ac.jp	**Young Nam Kim** Division of Climate Research Korea Polar Research Institute 7-50 Songdo-dong, Yeonsu-gu Incheon, 406-840 Korea ynk@kopri.re.kr	***Norway*** **Sünnje Linnéa Basedow** Faculty of Biosciences and Aquaculture University of Nordland Mørkvedtråkket 30 Bodø, 8049 Norway sunnje.basedow@uin.no
Michiyo Yamamoto-Kawai Tokyo University of Marine Science and Technology 4-5-7 Konan Minato-ku, Tokyo 108-8477 Japan michiyo@kaiyodai.ac.jp	**Jae-Bong Lee** Fisheries Resources Management National Fisheries R&D Institute (NFRDI) 512-1 Haean-ro Busan, 619-705 Korea leejb@nfrdi.go.kr	**Knut Yngve Børsheim** Oceanography and Climate Department Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, NO-5817 Norway yngve.borsheim@imr.no
Orio Yamamura Hokkaido National Fisheries Research Institute, FRA 116 Katsurakoi Kushiro, Hokkaido 085-0802 Japan orioy@affrc.go.jp	**Hyunju Seo** Institute of Fisheries Science Pukyong National University 599-1 Daeyeon 3-dong, Nam-gu Busan, 608-737 Korea uagiri@hanmail.net	**Michael L. Carroll** Akvaplan-niva Fram Center for Climate and Environment Tromsø, N9100 Norway mc@akvaplan.niva.no

Appendix 8.2 Registered Participants *(Continued)*

Norway (Continued) **Padmini Dalpadado** Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, 5817 Norway padmini.dalpadado@imr.no	**Tore Johannnessen** Flødevigen Institute of Marine Research (IMR) 20 Nye Flødevigveien His, 4817 Norway torejo@imr.no	**Benjamin Planque** Institute of Marine Research (IMR) 6404 Postboks Tromsø, 9294 Norway benjamin.planque@imr.no
Ken Drinkwater Oceanography Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, N-5817 Norway ken.drinkwater@imr.no	**Trond Kristiansen** Oceanography Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, 5817 Norway trond.kristiansen@imr.no	**Marit Reigstad** Department of Arctic and Marine Biology University of Tromsø NFH Bldg. Tromsø, 9037 Norway marit.reigstad@uit.no
Joël M. Durant CEES, Departement of Biology Univerity of Oslo P.O. Box 1066, Blindern Oslo, NO-0316 Norway joel.durant@bio.uio.no	**Harald Loeng** Oceanography Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, 5817 Norway harald.loeng@imr.no	**Dag Slagstad** SINTEF Fisheries and Aquaculture Brattørkaia 17C Trondheim, N-7465 Norway dag.slagstad@sintef.no
Daniel Howell Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, 5817 Norway daniel.howell@imr.no	**Margaret M. McBride** ESSAS Project Office Institute of Marine Research (IMR) P.O. Box 1870 Nordnes, Nordnesgaten 33 Bergen, N - 5011 Norway margaret.mcbride@imr.no	**Svein Sundby** Institute of Marine Research (IMR) 33 Nordnesgaten Bergen, N-5817 Norway svein.sundby@imr.no
Geir Huse Oceanography Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, N-5817 Norway geir.huse@imr.no	**Kjell Arne Mork** Oceanography Institute of Marine Research (IMR) P.O. Box 1870 Nordnes Bergen, 5817 Norway kjell.arne.mork@imr.no	**Frode Vikebo** Institute of Marine Research (IMR) 1870 Nordnes Bergen, 5817 Norway frovik@imr.no

Appendix 8.2 Registered Participants *(Continued)*

Russia **Maksim Ivanov** V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS 43 Baltiyskaya St. Vladivostok, Primorsky Kray 690041 Russia kirov-max@mail.ru	**Artur Maiss** Kamchatka League of Independent Experts N/Tereshkovoi 1 Petropavlovsk-Kamchatski, 683038 Russia koryak@yandex.ru	***U.S.A.*** **Beverly Agler** Commerical Fisheries Alaska Department of Fish and Game 10107 Bentwood Pl. Juneau, AK 99801 U.S.A. bev.agler@alaska.gov
Gennady V. Khen Pacific Research Institute of Fisheries and Oceanography (TINRO-Center) 4 Shevchenko Alley Vladivostok, Primorsky Kray 690950 Russia gennady1@tinro.ru	**Daria Martynova** White Sea Biological Station Zoological Institute, Russian Academy of Sciences 1 University emb St. Petersburg, 199034 Russia daria.martynova@gmail.com	**Kevin Robert Arrigo** Environmental Earth Syatem Science Stanford University 473 Via Ortega Stanford, CA 94305 U.S.A. arrigo@stanford.edu
Sen Tok Kim Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO) 112-37 Purkaeva St. Yuzhno-Sakhalinsk, 693006 Russia future007@rambler.ru	**Konstantin A. Rogachev** Ocean Physics V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS 43 Baltiyskaya St. Vladivostok, Primorsky Kray 690041 Russia rogachev@poi.dvo.ru	**Carin J. Ashjian** Biology Department Woods Hole Oceanographic Institution (WHOI) MS № 33 Woods Hole, MA 02543 U.S.A. cashjian@whoi.edu
Andrey S. Krovnin Laboratory of Climatic Bases of Bioproductivity Russian Federal Research Institute of Fisheries and Oceanography (VNIRO) 17 V. Krasnoselskaya St. Moscow, 107140 Russia akrovnin@vniro.ru	**Natalia V. Shlyk** V.I. Il'ichev Pacific Oceanological Institute (POI), FEB RAS 43 Baltiyskaya St. Vladivostok, Primorsky Kray 690041 Russia shl@poi.dvo.ru	**Neil S. Banas** Applied Physics Laboratory University of Washington Campus Box 355640 Seattle, WA 98195 U.S.A. neil@apl.washington.edu
Vladimir V. Kulik Laboratory of Applied Biocenology Pacific Research Institute of Fisheries and Oceanography (TINRO-Center) 4 Shevchenko Alley Vladivostok, Primorsky Kray 690091 Russia vladicon82@gmail.com	***United Kingdom*** **Jaume Forcada** British Antarctic Survey High Cross, Madingley Rd. Cambridge, CB3 0ET United Kingdom jfor@bas.ac.uk	**Igor Belkin** Graduate School of Oceanography University of Rhode Island 215 South Ferry Rd. Narragansett, RI 02882 U.S.A. igormbelkin@gmail.com

Appendix 8.2 **Registered Participants** *(Continued)*

U.S.A. (Continued) **James John Bisagni** SMAST/DEOS UMass Dartmouth 200 Mill Rd., Suite 325 Fairhaven, MA 02719 U.S.A. jbisagni@umassd.edu	**Peter Boveng** National Marine Mammal Laboratory Alaska Fisheries Science Center, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. peter.boveng@noaa.gov	**Xuehua Cui** Ecology and Evolutionary Biology University of Tennessee 1906 Greenland Way #304 Knoxville, TN 37932 U.S.A. cuixuehua@gmail.com
Bodil A. Bluhm School of Fisheries and Ocean Sciences University of Alaska, Fairbanks 905 N. Koyukuk Dr. Fairbanks, AK 99775 U.S.A. bluhm@ims.uaf.edu	**Louis A. Codispoti** Horn Point Laboratory University of Maryland Center for Environmental Science P.O. Box 775 Cambridge, MD 21613-0775 U.S.A. codispot@hpl.umces.edu	**Seth Danielson** UAF/SFOS 905 N. Koyukuk Dr. Fairbanks, AK 99775-7220 U.S.A. seth@ims.uaf.edu
Nicholas A. Bond Joint Institute for the Study of Atmosphere and Ocean (JISAO) University of Washington 7600 Sand Point Way NE Seattle, WA 98195-4925 U.S.A. nicholas.bond@noaa.gov	**Keith R. Criddle** Fisheries Academic Program University of Alaska, Fairbanks 17101 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. kcriddle@sfos.uaf.edu	**Mary Beth Decker** Ecology and Evolutionary Biology Yale University 165 Prospect St. New Haven , CT 06520 U.S.A. marybeth.decker@yale.edu
Alyssa J. Bourdukofsky St. Paul Island School P.O. Box 905 St. Paul Island, AK 99660 U.S.A. alyssab@psd-k12.org	**Jessica Cross** Chemical Oceanography University of Alaska, Fairbanks 905 N. Koyukuk Dr. Fairbanks, AK 99775 U.S.A. jncross@alaska.edu	**Michael Dirks** Pribilof School District 930 Tolstoi Blvd. St. Paul Island, 99660 U.S.A. kushint@psd-k12.org
Caitlin Olga Bourdukofsky St. Paul Island School P.O. Box 905 St. Paul Island, AK 99660 U.S.A. caitlinb@psd-k12.org	**John Crusius** Woods Hole Coastal & Marine Science Center US Geological Survey 384 Woods Hole Rd. Woods Hole, 02543 U.S.A. jcrusius@usgs.gov	**Janet Duffy-Anderson** FOCI Program Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. Janet.Duffy-Anderson@noaa.gov

Appendix 8.2 Registered Participants *(Continued)*

U.S.A. (Continued)		
Lisa B. Eisner TSMRI/Auke Bay Laboratories Alaska Fisheries Science Center, NMFS, NOAA 17109 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. lisa.eisner@noaa.gov	**Nancy Ann Friday** Cetacean Assessment and Ecology Program National Marine Mammal Laboratory 7600 Sand Point Way NE Seattle, WA 98115-6349 U.S.A. Nancy.Friday@noaa.gov	**Ron Heintz** Auke Bay Laboratories NOAA Alaska Fisheries Science Center 17109 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. ron.heintz@noaa.gov
Andronika Vassa Emanoff St. Paul Island School P.O. Box 905 St. Paul Island, AK 99660 U.S.A. andronika_vassa_emanoff@yahoo.com	**Sarah K. Gaichas** Resource Ecology and Ecosystem Modeling Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. Sarah.Gaichas@noaa.gov	**Albert J. Hermann** Joint Institute for the Study of Atmosphere and Ocean (JISAO) University of Washington 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. Albert.J.Hermann@noaa.gov
Maggie Esch 4429 Lakeway Dr. Bellingham, WA 98229 U.S.A. maggiesch@charter.net	**Vladlena V. Gertseva** Northwest Fisheries Science Center NOAA Fisheries 2032 SE OSU Dr. Newport, OR 97365 U.S.A. vladlena.gertseva@noaa.gov	**Eileen E. Hofmann** Center for Coastal Physical Oceanography Old Dominion University 4111 Monarch Way Norfolk, VA 23508 U.S.A. hofmann@ccpo.odu.edu
David Lincoln Fluharty School of Marine Affairs University of Washington 3707 Brooklyn Ave. NE Seattle, WA 98105 U.S.A. fluharty@u.washington.edu	**Rolf Gradinger** School of Fisheries and Ocean Sciences 245 O Neill Bldg. Fairbanks, AK 99775-7220 U.S.A. rgradinger@ims.uaf.edu	**Anne B. Hollowed** Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115-6349 U.S.A. Anne.Hollowed@noaa.gov
Dave Fraser IMARIBA West 93 Prospect Port Ludlow, WA 98365 U.S.A. dfraser@olympus.net	**Julie Granger** Geosciences Princeton University Geosciences Dept., Guyot Hall Princeton, NJ 08544 U.S.A. jgranger@princeton.edu	**George L. Hunt, Jr.** School of Aquatic and Fishery Sciences University of Washington P.O. Box 355020 Seattle, WA 98195 U.S.A. geohunt2@u.washington.edu

Appendix 8.2 **Registered Participants** *(Continued)*

U.S.A. (Continued) **Henry P. Huntington** Arctic Program Pew Environment Group 23834 The Clearing Dr. Eagle River, AK 99577 U.S.A. hhuntington@pewtrusts.org	**Jacqueline Mary Grebmeier** Chesapeake Biological Laboratory University of Maryland Center for Environmental Science 1 Williams St. Solomons, MD 20688 U.S.A. jgrebmei@umces.edu	**Andrew W. Leising** Environmental Research Division Southwest Fisheries Science Center, NMFS, NOAA 1352 Lighthouse Ave. Pacific Grove, CA 93950 U.S.A. andrew.leising@noaa.gov
Steven Jerome Isaac St. Paul Island School P.O. Box 905 St. Paul Island, AK 99660 U.S.A. lil_steven_snp@yahoo.com	**Charles H. Greene** EAS Cornell 4120 Snee Hall Ithaca, NY 14853 U.S.A. chg2@cornell.edu	**Anthony Lekanof** 930 Tolstoi Blvd. St. Paul Island, 99660 U.S.A. jamie_stacks@psd-k12.org
Meibing Jin International Arctic Research Center University of Alaska, Fairbanks 930 Koyukuk Dr. Fairbanks, AK 99775-7340 U.S.A. ffjm@uaf.edu	**Colleen E. Harpold** Alaska Fisheries Science Center, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. colleen.harpold@noaa.gov	**Chelsea Lekanof** Pribilof School District 930 Tolstoi Blvd. St. Paul Island, 99660 U.S.A. rodgersb@psd-k12.org
William Karp NOAA National Marine Fisheries Service 7600 Sand Point Way NE, Bldg. 4, F/AKC Seattle, WA 98115 U.S.A. pam.moen@noaa.gov	**Alan C. Haynie** Alaska Fisheries Science Center, NOAA 7600 Sand Point Way NE, Bldg. 4 Seattle, WA 98115 U.S.A. Alan.Haynie@noaa.gov	**William Lekanof** St. Paul Island School PO Box 907 St. Paul Island, AK 99660 U.S.A. williaml@psd-k12.org
Stan Kotwicki Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. stan.kotwicki@noaa.gov	**Katherine Hedstrom** Arctic Region Supercomputing Center University of Alaska, Fairbanks 909 Koyukuk Dr, Suite 105 Fairbanks, AK 99775 U.S.A. kate@arsc.edu	**Evelyn Lessard** School of Oceanography University of Washington P.O. Box 357940 Seattle, WA 98195 U.S.A. elessard@u.washington.edu

Appendix 8.2 **Registered Participants** *(Continued)*

U.S.A. (Continued) **Cara Lestenkof-Mandregan** Pribilof School District 930 Tolstoi Blvd. St. Paul Island, 99660 U.S.A. jstacks1@yahoo.com	**Gordon H. Kruse** University of Alaska Fairbanks School of Fisheries and Ocean Sciences 17101 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. Gordon.Kruse@alaska.edu	**Danielle Merculief** 930 Tolstoi Blvd. St. Paul Island, AK 99660 U.S.A. stacksj@psd-k12.org
Paul Loubere Geology and Environmental Geosciences Northern Illinois University Davis Hall Northern Illinois University DeKalb, IL 60115 U.S.A. ploubere@niu.edu	**Kathy J. Kuletz** Migratory Bird Management U.S. Fish and Wildlife Service 1011 E. Tudor Rd. Anchorage, AK 99503 U.S.A. kkuletz@gmail.com	**David Mountain** P.O. Box 32855 Tucson, AZ 85751 U.S.A. dmountain@capecod.net
Laurinda Marcello School of Fisheries and Ocean Sciences University of Alaska, Fairbanks 17101 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. laurinda.marcello@alaska.edu	**Tonia L. Kushin** Pribilof School District 14 Egan St., P.O. Box 12 St. Paul Island, AK 99660 U.S.A. gurnard2@excite.com	**Franz J. Mueter** School of Fisheries and Ocean Sciences, Juneau Center University of Alaska, Fairbanks 17109 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. fmueter@alaska.edu
Jeremy Troy Mathis Institute of Marine Science University of Alaska, Fairbanks 245 O'Neill Bldg. Fairbanks, AK 99775 U.S.A. jmathis@sfos.uaf.edu	**Carol Ladd** Pacific Marine Environmental Laboratory National Oceanic and Atmospheric Administration (NOAA) 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. Carol.Ladd@noaa.gov	**Steven A. Murawski** College of Marine Science University of South Florida St. Petersburg, FL, 33741 U.S.A. smurawski@usf.edu
James McGoodwin Institute of Arctic and Alpine Research 450 UCB, 1560 30th St. Boulder, CO 80309 U.S.A. james.mcgoodwin@colorado.edu	**Kristin Laidre** Polar Science Center University of Washington 1013 NE 40th St. Seattle, WA 98105 U.S.A. klaidre@u.washington.edu	**Jeffrey M. Napp** Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115-6349 U.S.A. Jeff.Napp@noaa.gov

Appendix 8.2 Registered Participants *(Continued)*

U.S.A. (Continued) **Olav A. Ormseth** Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. olav.ormseth@noaa.gov	**James J. Pierson** Horn Point Laboratory University of Maryland Center for Environmental Science 2020 Horns Point Rd. Cambridge, MD 21613 U.S.A. jpierson@umces.edu	**Peter B. Rhines** Oceanography University of Washington 1492 Boat St. Seattle, WA 98195 U.S.A. rhines@ocean.washington.edu
Ivonne Ortiz Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE, Bldg. 4 Seattle, WA 98115 U.S.A. ivonne@u.washington.edu	**Maria Prokopenko** Earth Sciences University of Souther California 3651 Trousedale Pkwy, ZHS-117 Los Angeles, 90089 U.S.A. prokopen@usc.edu	**Jonathan Richar** School of Fisheries and Ocean Sciences University of Alaska, Fairbanks 17101 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. jirichar@alaska.edu
Sandra Parker-Stetter School of Aquatic and Fishery Sciences University of Washington P.O. Box 355020 Seattle, WA 98195-5020 U.S.A. slps@uw.edu	**Joshua Prokopiof** 930 Tolstoi Blvd. St. Paul Island, 99660 U.S.A. stacksm@psd-k12.org	**Mathieu Richaud** Earth and Environmental Sciences Fresno State 2576 E. San Ramon Ave. Fresno, CA 93740 U.S.A. mathieu@csufresno.edu
William T. Peterson Northwest Fisheries Science Center (NWFSC) 2030 SE Marine Science Dr. Newport, OR 97365 U.S.A. Bill.Peterson@noaa.gov	**Nicholas R. Record** School of Marine Sciences University of Maine 350 Commercial St. Portland, ME 04101 U.S.A. nrecord@gmri.org	**Michelle Ridgway** Marine Research Oceanus Alaska P.O. Box 211470 Auke Bay, AK 99821 U.S.A. mishridgway@gmail.com
Lisa Pfeiffer Alaska Fisheries Science Center, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. lisa.pfeiffer@noaa.gov	**Martin Renner** School of Aquatic and Fishery Sciences University of Washington 95 Sterling Highway, Suite 1 Homer, AK 99603 U.S.A. mrenner@gmx.com	**Jeffrey A. Runge** School of Marine Sciences/Gulf of Maine Research Institute University of Maine 350 Commercial St. Portland, ME 04101 U.S.A. jrunge@gmri.org

Appendix 8.2 Registered Participants *(Continued)*

U.S.A. (Continued) **Ray Sambrotto** Lamont-Doherty Earth Observatroy Columbia University 61 Rt. 9W Palisades, 10964 U.S.A. sambrott@ldeo.columbia.edu	**Elizabeth Calvert Siddon** School of Fisheries and Ocean Sciences University of Alaska, Fairbanks 17101 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. ecsiddon@alaska.edu	**Duane Stevenson** Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE, Bldg. 4 Seattle, WA 98115 U.S.A. duane.stevenson@noaa.gov
Jarrod Santora Farallon Institute for Advanced Ecosystem Research P.O. Box 750756 Petaluma, CA 94952 U.S.A. jasantora@gmail.com	**Michael Sigler** NOAA Alaska Fisheries Science Center 17109 Pt. Lena Loop Rd. Juneau, AK 99801 U.S.A. Mike.Sigler@noaa.gov	**James Strong** University of Alaska, Fairbanks 7507 1/2 Aurora Ave N. Seattle, WA 98103 U.S.A. jameswstrong@gmail.com
C. Tracy Shaw Cooperative Institute for Marine Resources Studies, HMSC Oregon State University 2030 SE Marine Science Dr. Newport, OR 97365 U.S.A. tracy.shaw@noaa.gov	**Paul Spencer** Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. paul.spencer@noaa.gov	**William J. Sydeman** Farallon Institute for Advanced Ecosystem Research P.O. Box 750756 Petaluma, CA 94975 U.S.A. wsydeman@comcast.net
David Shull Environmental Sciences Western Washington University 516 High St. MS-9181 Bellingham, WA 98225 U.S.A. david.shull@wwu.edu	**Emilie Springer** Anthropology University of Alaska, Fairbanks P.O. Box 2882 Homer, AK 99603 U.S.A. esspringer@alaska.edu	**Cameron Richard Thompson** School of Marine Sciences University of Maine 5706 Aubert Hall, RM 360 Orono, ME 04469 U.S.A. cameronrsthompson@gmail.com
Shareef Siddeek Commercial Fisheries Alaska Department of Fish and Game 1255 W. 8th St., P.O. Box 115526 Juneau, AK 99811-5526 U.S.A. shareef.siddeek@alaska.gov	**Phyllis J. Stabeno** Ocean Environment Research, PMEL Pac. Marine Environmental Lab, OAR, NOAA 7600 Sand Point Way NE Seattle, WA 98115-0070 U.S.A. phyllis.stabeno@noaa.gov	**Sarah Ann Thompson** Farallon Institute for Advanced Ecosystem Research 101 H St. Suite Q Petaluma, CA 94952 U.S.A. farlowia@gmail.com

Appendix 8.2 **Registered Participants** *(Continued)*

U.S.A. (Continued) **Daniel Urban** NOAA Fisheries 301 Research Court Kodiak, AK 99615 U.S.A. dan.urban@noaa.gov	**Jinlun Zhang** Applied Physics Laboratory University of Washington 1013 NE 40th St. Seattle, WA 98105 U.S.A.
Thomas Van Pelt North Pacific Research Board (NPRB) 1007 West 3rd Ave., Suite 100 Anchorage, AK 99501 U.S.A. tvanpelt@nprb.org	
Francis Karl Wiese North Pacific Research Board (NPRB) 1007 West 3rd Ave., Suite 100 Anchorage, AK 99501 U.S.A. francis.wiese@nprb.org	
Thomas Wilderbuer Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE Seattle, WA 98115 U.S.A. Tom.Wilderbuer@noaa.gov	
Stephani G. Zador Resource Ecology and Ecosystem Management Alaska Fisheries Science Center, NMFS, NOAA 7600 Sand Point Way NE, Bldg. 4 Seattle, WA 98115 U.S.A. stephani.zador@noaa.gov	

Appendix 8.3 Meeting Timetable / Agendas

Meeting Timetable

<table>
<tr><td colspan="5">Sunday, May 22</td></tr>
<tr><td>09:00
12:30</td><td rowspan="2">Workshop 1</td><td rowspan="2">Workshop 2</td><td rowspan="2">Workshop 3</td><td>Workshop 4</td></tr>
<tr><td>13:30
17:30</td><td>Workshop 5</td></tr>
<tr><td colspan="5">Monday, May 23</td></tr>
<tr><td>08:30
09:00</td><td colspan="4">OPENING SESSION</td></tr>
<tr><td>09:00
12:30</td><td colspan="4">Plenary</td></tr>
<tr><td>14:00
18:15</td><td>Session 2 (Day 1)</td><td colspan="2">Session 4 & 9</td><td>Session 5</td></tr>
<tr><td colspan="5">Tuesday, May 24</td></tr>
<tr><td>08:30
12:30</td><td colspan="4">Plenary</td></tr>
<tr><td>14:00
18:15</td><td>Session 1 (Day 1)</td><td colspan="2">Session 6</td><td>Session 8</td></tr>
<tr><td colspan="5">Wednesday, May 25</td></tr>
<tr><td>08:30
12:30</td><td colspan="4">Plenary</td></tr>
<tr><td>14:00
15:55</td><td>Session 1 (Day 2)</td><td rowspan="2">Session 3</td><td rowspan="2">Session 7</td></tr>
<tr><td>16:05
18:00</td><td>Session 2 (Day 2)</td></tr>
<tr><td>18:00
21:00</td><td colspan="4">Poster Session</td></tr>
<tr><td colspan="5">Thursday, May 26</td></tr>
<tr><td></td><td colspan="4">Closing Session</td></tr>
<tr><td>08:30
12:00</td><td colspan="4">Overview and Awards</td></tr>
<tr><td>13:30
15:00</td><td colspan="4">Plenary Talks</td></tr>
<tr><td>15:00
15:30</td><td colspan="4">Concluding Remarks</td></tr>
</table>

Appendix 8.3 *(Continued)*

Workshop 1

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

May 23

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

Appendix 8.3 *(Continued)*

Workshop 2
Arctic-Sub-Arctic interactions
May 22

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

Workshop 3
Zooplankton life histories: Developing metrics to compare field observations and model results in order to predict climate effects
May 22

9:00 ***Introduction by Convenors***
9:20 **Andrew Leising and James Pierson**
Is *Calanus pacificus* just a warmer-adapted *Calanus finmarchicus*? (W3-7397)

Appendix 8.3 *(Continued)*

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

Workshop 4
Comparative analyses of gadid and crustacean dynamics across subarctic Ecosystems
May 22

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

Appendix 8.3 *(Continued)*

Workshop 5
Comparative analyses of Marine bird and mammal responses to climate change
May 22

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

Appendix 8.3 *(Continued)*

May 23 Agenda — Opening Day Plenary

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 24 Agenda — Day 2 Plenary

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 25 Agenda – Day 3 Plenary

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 26 Agenda - Closing Day Plenary

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

Appendix 8.3

Session 1
Comparative studies of polar and sub-polar ecosystems
May 24

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

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

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

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

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

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

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

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

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

18:05 Discussion

May 25

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

14:05 **Igor M. Belkin**
Polar Fronts: Major ecosystem boundaries in the North Atlantic, North Pacific, and Southern Ocean

14:25 **Atsushi Tsuda, Shinji Shimode and Kazutaka Takahashi**
Comparative study of the life histories of *Eucalanidae* copepods in the subtropical and subarctic Pacific

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
15:05 **William J. Sydeman, Sarah Ann Thompson, Jarrod A. Santora and Julie A. Thayer**
A meta-analysis of seabird-climate relationships
15:25 **Kristin L. Laidre and Mads Peter Heide-Jørgensen**
Climate change and baleen whale trophic cascades in Greenland
15:45 Discussion
15:55 Session ends

Session 2
New observations and understanding of eastern and western Bering Sea Ecosystems
May 23

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
14:35 **Jessica Cross and Jeremy Mathis**
Controls on in carbonate mineral saturation states and ocean acidification on the southeastern Bering Sea shelf
14:55 **Rolf Gradinger, Katrin Iken and Bodil A. Bluhm**
Sedimentation processes under the seasonal sea ice of the Bering Sea
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
15:35 **David H. Shull, Allan H. Devol and Margaret S. Esch**
Bioturbation and organic carbon mineralization pathways in Bering Shelf sediments

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
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
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
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
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
18:05 Discussion
18:15 Session ends

May 25

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
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

16:50 **George Noongwook and Henry P. Huntington**
Ecosystem influences on hunting success in Savoonga, Alaska

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

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

17:50 Discussion

18:00 Session ends

Session 3
Modeling marine ecosystem dynamics in high latitude regions
May 25

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

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

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

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

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

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

16:10 **Wolfgang Fennel and H. Radtke**
An Eulerian nutrient to fish model

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

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

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

17:30 **Benjamin Planque and U. Lindstrøm**
A minimal Barents Sea ecosystem model from first principles

17:50 Discussion

18:00 Session end

Session 4 and Session 9 merged
Nutrients, biogeochemistry and acidification in a changing climate

May 23

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

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

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

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

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

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

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

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

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

17:45 Discussion

18:15 Session ends

Session 5
New insights from the International Polar Year (IPY) studies
May 23

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

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

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

15:15 **Héðinn Valdimarsson and Steingrímur Jónsson**
Hydrographic conditions and circulation in the Iceland Sea during the Iceland Sea ecosystem study

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

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

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

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

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

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

18:05 Discussion

18:15 Session ends

Session 6
National ESSAS programs: Recent advances and contribution
May 24

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

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

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

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

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

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

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

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)

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

17:45 **Konstantin Rogachev**
Hydrographic control of marine ecosystem in the shelf waters of the northern Sea of Okhotsk

18:05 Discussion
18:15 Session ends

Session 7
Anticipating socio-economic and policy consequences of global changes in sub-polar and polar marine ecosystems
May 25

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

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
16:30 **Keith R. Criddle**
Cooperative and noncooperative strategies for management of Bering Sea pollock
16:50 **Dave Fraser**
Rationalization, randomness and romance: A fisher's response to change in dynamic biophysical, socio-political, and economic systems
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
17:30 **Alida Bundy and Ian Perry**
Understanding the human dimensions of marine global change: The IMBER Working Group
17:50 Discussion
18:00 Session ends

Session 8
Interactions between gadoids and crustaceans: The roles of climate, predation, and fisheries
May 24

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
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
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

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

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

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

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

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

18:05 Discussion

18:15 Session ends