ESSAS Annual Science Meeting

January 7 – 9, 2013

Hakodate, Hokkaido, Japan

Spatial Dynamics of Subarctic Marine Ecosystems

Contents

Welcome!

On behalf of the symposium conveners, organizers, and scientific steering committee, we welcome you to beautiful Hakodate, a city of bountiful nature and unique culture positioned between East and West. The Ecosystem Studies of Sub-Arctic Seas (ESSAS) 2013 Annual Science Meeting is being convened at the Hakodate Community Design Center in Hakodate, Japan. We bring together nearly 50 scientists from 7 countries to share their knowledge of and excitement about the study of subarctic marine ecosystems. The theme of this symposium "Spatial Dynamics of Subarctic Marine Ecosystems" encompasses a wide diversity of studies, including climate and physical oceanography, biogeochemistry, plankton, fish, seabirds, marine mammals, ecological modeling, and socio-economic interaction. Additionally, a session related to the new Japanese research project dealing with climate change in the Arctic is being held. During this 3-day meeting, 8 sessions will address the most recent advances in the study of how climate change will impact the subarctic seas and their diverse ecosystems. We look forward to the many excellent presentations that are planned, and encourage all participants to take advantage of this unique opportunity to exchange experiences and ideas with fellow marine scientists from around the world.

Welcome to Hakodate! This city is one of the first ports of international trade in Japan. As such, we have welcomed and been influenced by many world cultures. To this day, this influence can be seen and felt in the city streets, particularly in its Western quarters. The cityscapes and views of the night life from the top of Mt. Hakodate, together with the fresh and abundant seafood, and hot spas, are among the features that attract more than 4 million visitors annually. We wish you an enjoyable, stimulating, and productive meeting, and hope that you will use the occasion as an opportunity to explore Hakodate — the memories of which we trust will be warm and lasting.

Lastly, we wish to thank the ESSAS International Project Office and the numerous others who have worked closely with us to organize this event. This ASM has been made possible only through the hard work of local and international organizers, your participation, and generous financial support from our sponsors — for all of which we are greatly appreciative.

Yasunori Sakurai
ESSAS ASM Convener and Chair of the Local Organizing Committee

Sei-Ichi Saitoh, Yutaka Watanuki, Toru Hirawake, Takashi Yamamoto
Local Organizing Committee

Agenda

Monday 7 January

08:30 Registration

08:50 Welcome — ESSAS Co-Chairs Kenneth Drinkwater & Franz Mueter

Local arrangements and practical information Yasunori Sakurai

09:00 Session 1 — *Overview, Physics, Biogeochemistry (4)*
Chair: Takashi Kikuchi

09:00 Kikuchi, T.: *Overview of ECOARCS and preliminary results on 2012 field experiments in the Pacific side of the Arctic Ocean*

09:30 Nishino, S., Kikuchi, T., Hirawake, T., Yamamoto-Kawai, M. and Aoyama, M.: *Biogeochemistry in the hotspots of the Chukchi Sea*

09:50 Yamamoto-Kawai, M., Mifune, T., Nishino, S., Murata, A., Aoyama, M. and Kikuchi, T.: *Ocean acidification in the Chukchi Sea and Canada Basin*

10:10 Nagata, T., Uchimiya, M., Fukuda, H. and Ogawa, H.: *What we learn from prokaryote abundance and production in the Arctic Ocean*

10:30 ***Break (20 min)***

10:50 Session 2 — *Satellite Monitoring, Phytoplankton, Zooplankton (5)*
Chair: Toru Hirawake

10:50 Hirawake, T. and Fujiwara, A.: *Community structure and primary production of phytoplankton in sub-arctic and Arctic seas*

11:10 Kimoto, K., Sasaki, O., Kano, H., Wakita, M., Irino, T., Iwashita, T., Harada, N. and Honda, M.: *Seasonal carbonate dissolution at the water column in the North Pacific: The evidence from the Micro-focus X-ray CT Technology*

11:30 Iida, T., Mizobata, K. and **Saitoh, S.-I.**: *Interannual variability of coccolithophore in response to changes in water column stability in the eastern Bering Sea*

11:50 Onodera, J., Harada, N. Honda, M. and Tanaka, Y.: *Diatom sinking fluxes in the Northwind Abyssal Plain, 2010-2011*

12:10 Matsuno, K., Yamaguchi, A., Imai, I., Onodera, J., Chiba, S. and Harada, N.: *Seasonal changes in zooplankton community*

12:30 ***Lunch (80 min)***

13:50 **Session 3 — *Fish, Seabirds, Marine Mammals (4)***
Chair: Yutaka Watanuki

13:50 Okaji, K., Yamamoto, J. and **Sakurai, Y.**: *Community structure of demersal fish in the continental shelf areas of the Bering Sea and the Chukchi Sea during summer of 2007-2009*

14:10 **Yamamoto, T.**, Hoshina, K., Nishizawa, B., Meathrel, C. E., Phillips, R. A. and Watanuki, Y.: *Movement of short-tailed shearwaters with environmental gradient in the sub-Arctic Pacific and Arctic seas through summer to autumn*

14:30 **Mitani, Y.**, Mizuguchi, D., Otsuki, M. and Iwahara, Y.: *Acoustic monitoring and visual survey of marine mammals during summer in Chukchi Sea and Barrow Canyon*

14:50 **Sasaki, H.**, Sekiguchi, K., Mitani, Y. and Saitoh, S.-I.: *Cetacean habitat distribution in the eastern Bering Sea and Chukchi Sea during summer season*

15:10 ***Break (30 min)***

15:40 **Session 4 — *Ecological Modeling and Parameterization (4)***
Chairs: Enrique Curchister and Sei-Ichi Saitoh

15:40 **Watanabe, E.**, Kishi, M. J., Harada, N., Onodera, J. and Terui, T.: *Modeling study on biological hot spots in the western Arctic: Impact of shelf water transport*

16:00 **Terui, T.**, Watanabe, E., Kishi, M. J.: *Modeling study on biological hot spots in the western Arctic: Impacts of algae and amphipod*

16:20 **Fujiwara, A.**, Matsuno, K., Hirawake, T., Yamaguchi, A., Kikuchi, T. and Saitoh, S.-I.: *Grazing impact of the Arctic and Pacific copepods during late summer in the western Arctic Ocean*

16:40 Satoh, M., Itoh, F., Saruwatari, K., Harada, N., Suzuki, I. and **Shiraiwa, Y.**: *Mechanism how the Arctic and Sub-Arctic coccolithophorids adapt to temperature change*

17:00 ***End of Day***

18:00 **Reception**

Tuesday 8 January

09:00 **Session 5 — *Arctic-Subarctic Interactions (4)***
Chair: Kenneth Drinkwater

09:00 **Hunt, G. L. Jr.**, Blanchard, A. L., Boveng, P., Dalpadado, P., Drinkwater, K. F., Eisner, L., Hopcroft, R. R., Kovacs, K. M., Norcross, B. L., Renaud, P., Reigstad, M., Renner, M., Skjoldal, H-R., Whitehouse, A. and Woodgate, R. A.*: The Barents and Chukchi Seas: Comparison of two Arctic shelf ecosystems*

09:20 **Drinkwater, K. F.**: *On the role of advection on the interaction between the Arctic and subarctic seas: Comparing the Atlantic and Pacific Sectors*

09:40 **Hunt, G. L. Jr.**: *Results from the Ocean Sciences Meeting, Yeosu Workshop on comparisons between the Arctic and Antarctic ecosystems*

10:00 **Drinkwater, K.**: *Results from the Ocean Sciences Meeting, ICES Theme Session and Hiroshima Workshop on Arctic Subarctic Interactions*

10:20 ***Group Discussion***

10:30 ***Break (20 min)***

10:50 **Session 6 — *Human Dimensions: Fisheries and Fishing Communities in subpolar and polar regions (5)***
Chair: Catherine Chambers

10:50 **Hunt, G. L. Jr.**: *A comparison of the oceanography and geography of the Aleutian and Kuril Archipelagos*

11:10 **Fitzhugh, B.**: *Long-term comparative human ecodynamics in the North Pacific: a perspective on the role of archaeology in subarctic ecosystem studies*

11:30 **Shimizu, I.**: *Ecological and Economic Effects of Sea ice on Fisheries Resources in the Okhotsk Sea*

11:50 **Criddle, K. R.**: *Evolution of property rights in the Eastern Bering Sea pollock fishery*

12:10 **Chambers, C.**: *Small-scale fishing livelihoods and fisheries management: Overview from Iceland and Alaska*

12:30 ***Lunch (60 min)***

13:30 **Session 7 — *Bioenergics of Subpolar fishes: Regional presentations (4)***
Co-chairs: Ron Heintz and Trond Kristiansen

13:30 **Heintz, R. A.**, Siddon, E. and Farley, E. V.: *Climate effects on the nutritional condition and productivity of marine fish populations*

13:50 **Kooka, K.** and Yamamura, O.: *Winter feeding and nutritional condition of juvenile walleye pollock in the Doto area, northern Japan*

14:10 **Kishi, M. J.**: *A review of the NEMURO.FISH model applications to marine ecosystem investigations and its ability to evaluate responses of fish to future climate change - What will happen on the stock of chum salmon, walleye pollock, and common squid in the Northern Pacific?*

14:30 **Kristiansen, T.**, Stock, C., Drinkwater, K. and Curchitser, E. N.: *Modelling feeding ecology and survival of larval fish in sub-arctic ecosystems under climate change*

14:50 ***Group Discussion***

15:00 ***Break (30 min)***

15:30 ***WG Planning Meetings***

17:00 ***Adjourn***

Wednesday January 9

09:00 **Session 8 — *Spatial dynamics of subarctic and Arctic marine communities: The role of advection, temperature, and trophodynamics (6)***
Co-chairs: Franz Mueter, Erica Head, Kenneth Drinkwater

09:00 **Head, E. J. H.** and Pepin, P.: *Spatial and temporal variations in environmental conditions and the abundance and phenology of arctic and boreal Calanus (copepod) species on the Labrador and Newfoundland shelves (1960-2011)*

09:20 **Drinkwater, K.** and the NESSAR Team: *On the spatial variability in the physical and biological properties across the fronts in the Norwegian and Barents seas.*

09:40 **Basedow, S. L.**, Zhou, M., Tande, K. S., Wiedmann, I. and Reigstad, M.: *Spatial patterns of productivity and implications for carbon flux at the polar front, Barents Sea*

10:00 **Astthorsson, Ó. S.**: *Recent climate related changes in abundance and distribution of pelagic fish stocks in Icelandic waters*

10:20 **McKinnell, S.**: *Past and future sockeye salmon distributions in the North Pacific*

10:40 **Mueter, F. J.**, Litzou, M. A., Danielson, S. L. and Lauth, R. R.: *Spatial dynamics of groundfish on the eastern Bering Sea shelf: the roles of temperature, abundance and advection*

11:00 ***Break (10 min)***

11:10 ***Discussion on Future Directions*** Kenneth Drinkwater & Franz Mueter

12:30 ***Lunch (60 min)***

13:30 ***Afternoon open for working group discussions and other small-group meetings!***

15:00 ***Break (30 min)***

17:00 ***Adjourn***

Abstracts
of
Oral Presentations

Session 1

Overview, Physics, & Biogeochemistry

Session 1 — *Overview, Physics, and Biogeochemistry*

Chair: Takashi Kikuchi

Overview of ECOARCS and Preliminary Results on 2012 Field Experiments in the Pacific Side of the Arctic Ocean

Takashi Kikuchi

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The recent drastic decrease in Arctic summer sea ice may cause various environmental changes. However, it remains highly uncertain how sea ice variability affects the Arctic environments from physical, chemical, and biological points of view. Is the decrease in Arctic sea ice favorable or unfavorable for Arctic marine ecosystem? To clarify and predict influences of sea ice reduction on Arctic marine ecosystem, a research project "Ecosystem studies on the Arctic Ocean declining sea ice (ECOARCS)" was initiated under GRENE Arctic Climate Change Research Project. In the ECOARCS project, we focus on the Chukchi Sea of the Arctic Ocean, where various environmental changes have been accompanied by sea ice reduction. R/V Mirai and T/S Oshoro-Maru will conduct year-long hydrographic surveys to monitor physical, chemical, and biological variations in the so-called "hot spots" including mooring observation. To clarify the feeding behavior of higher trophic levels, we will also use bio-logging techniques. Furthermore, we are developing marine ecosystem models for the Arctic Ocean, which may be used to help diagnose ongoing changes in the Arctic marine ecosystem and to anticipate future changes. In 2012, a cruise onboard R/V Mirai (MR12-E03) mainly surveyed the Chukchi Sea, conducting multi-disciplinary observations, recovering mooring data, and sampling hot spots. This presentation will summarize preliminary results of the MR12-E03 cruise, and will outline future plans for the ECOARCS project.

Biogeochemistry in Hotspots of the Chukchi Sea

Shigeto Nishino[1], Takashi Kikuchi[1], Toru Hirawake[2], Michiyo Yamamoto-Kawai[3] and Michio Aoyama[4]

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[3]*Research Center for Advanced Science and Technology, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo 108-8477, Japan*
[4]*Meteorological Research Institute, Japan Meteorological Agency, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan*

During the R/V Mirai Arctic Ocean cruise in 2012, we conducted hydrographic surveys focused on three different types of biological hotspots: off Pt. Hope; Pt. Barrow; and along the Chukchi shelf slope. At the hotspot off Pt. Hope, bottom water is characterized by a dome-like structure with lower temperature, higher salinity, higher nutrients, and lower

oxygen compared with surrounding areas. Due to this dome-like structure with high nutrients, algal biomass and phytoplankton production could be large, and result in a biological hotspot. At the hotspot off Pt. Hope in 2012, we found that the ammonium (oxygen) concentration of bottom water was extremely high (low) compared to most years. This high (low) ammonium (oxygen) concentration could result from the decomposition of organic matter accumulated at the bottom of the Chukchi Sea. Therefore, regenerated production would be predominant at the hotspot off Pt. Hope. Whereas new production at the other hotspots off Pt. Barrow and along the Chukchi shelf slope would be largely influenced by contribution of nutrient supplies from deeper layers.

Ocean Acidification in the Chukchi Sea and Canada Basin

Michiyo Yamamoto-Kawai[1], Takahisa Mifune[1], Shigeto Nishino[2], Akihiko Murata[2], Michio Aoyama[3] and Takashi Kikuchi[2]

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Due to anthropogenically-induced ocean acidification and climate change, waters potentially corrosive to $CaCO_3$ shells and skeletons of organisms have been found in recent years in the Canada Basin and the Chukchi Sea. To better understand processes affecting $CaCO_3$ saturation state (Ω), we observed Ω by measuring dissolved inorganic carbon and total alkalinity during the cruise of the R/V Mirai in September-October 2012. Results are discussed with physical and biogeochemical properties such as salinity, temperature, nutrients and oxygen. Surface waters under-saturated with respect to $CaCO_3$ (aragonite) were found over the slope and basin, and at some stations on the southern shelf. Surface Ω was positively correlated with salinity, indicating that mixing with freshwater was a major factor determining Ω in surface waters. Deviations from this relationship were found at some stations in the southern Chukchi shelf where surface water has low (high) Ω relative to its high (low) salinity. Nutrients and other properties suggest that these stations are affected by mixing with bottom water or with local river water. At the bottom of the shelf and slope, $CaCO_3$ under-saturated water was formed by re-mineralization of organic matter. Especially low Ω was found in biological hotspots off Pt. Hope, off Pt. Barrow and on the slope. In these hotspots, bottom water was under-saturated with respect to both aragonite and calcite. This indicates that rich benthic communities in these hotspots are already experiencing potentially corrosive water. In the presentation, we will compare our results with previous observations in same region.

What we learn from Prokaryote Abundance and Production in the Arctic Ocean

Toshi Nagata[1], Mario Uchimiya[1, 2], Hideki Fukuda[1] and Hiroshi Ogawa[1]

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Data on heterotrophic prokaryote production and abundance can provide powerful insights into the mode and the extent of organic carbon (OC) supply and consumption in oceanic water columns. Such information is particularly valuable in Arctic seas where the OC supply regime is outstandingly complex and variable. Potential OC sources in Arctic waters include primary production of phytoplankton and ice algae, melting ice, river discharge, and water masses intruded from productive adjacent regions. Relative contributions of different OC sources probably vary widely across regions and over seasons. Clarifying spatiotemporal dynamics in OC supply and consumption is fundamentally important for improving our ability to predict responses of Arctic ecosystems to ongoing climate change. This talk presents our data on prokaryote production and abundance in the whole water column of the Canada Basin, western Arctic. In the upper layer, a large fraction (74%) of prokaryote production variability was accounted for by chlorophyll a, temperature and salinity. The negative relationship between prokaryote production and salinity was interpreted as a reflection of the enhanced OC delivery due to freshwater inputs. In deeper layers (100 – 3,000 m), prokaryote production was high in the Pacific origin water masses, indicating that OC was laterally introduced into the mesopelagic layer. Biomass, production and estimated carbon demand of prokaryote integrated over the deep water column indicated that organic carbon delivery to the Canada Basin's interior was low — being comparable to the lower range of the values reported in oligotrophic low latitude oceans.

Session 2

Satellite Monitoring, Phytoplankton, & Zooplankton

Session 2 — *Satellite Monitoring, Phytoplankton, Zooplankton*

Chair: Toru Hirawake

Community Structure and Primary Production of Phytoplankton in Sub-arctic and Arctic seas

Toru Hirawake[1] and Amane Fujiwara[2]

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Inter-annual changes in phytoplankton community structure and primary production in the western Arctic Ocean were assessed. Phytoplankton community structure was determined using cluster analysis based on the pigments composition. Primary productivity was monitored applying the light absorption based productivity model to satellite data. Remarkable inter-annual differences in distribution patterns of the groups were observed in the northern basin area. Haptophytes and other phytoplankton groups dominated and were widely distributed at the warm surface water in 2008, whereas prasinophytes dominated in cold water in 2009 and 2010. Primary productivity in August and September during the 2002–2010 period showed a trend of increase. The increase during 2007, a warmer year, was especially large — by a factor of 1.51–2.71 — compared with 2006. The significant temporal increase in productivity detected in this study differs from earlier studies that detected little, if any, change in the region. These changes in phytoplankton suggest that further sea ice decline and warming of water predicted in future may impact on ecosystem and carbon cycle in this region.

Seasonal Carbonate Dissolution at the Water Column in the North Pacific: the Evidence from the Micro-focus X-ray CT Technology

Katsunori Kimoto[1], Osamu Sasaki[2], Harumasa Kano[2], Masahide Wakita[1], Tomohisa Irino[3], Tomohiro Iwashita[4], Naomi Harada[1] and Makio Honda[1]

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It is generally recognized that the North Pacific is a CO_2 emission realm during the winter season, and that ocean acidification is increasing rapidly there. Accordingly, carbonate saturation (Ω) depth in the North Pacific is shallowest (≈150 meter water depth) of all the world's oceans. It is important to know the affect of ocean acidification on calcareous marine phytoplankton and zooplankton with regard to conservation of marine environments. We

recently developed a novel method to determine the shell density of calcareous zooplankton by using Micro-focus X-ray Computing Tomography (MXCT). MXCT can measure the surface morphology and inner structure of objects precisely. Furthermore, MXCT can also measure density of objects. To measure seasonal variations of shell density of plankton in nature, we used planktik foraminifera shells collected by the sediment trap deployed at Stn. K2 (47°N, 160°E, water depth: 5,900m) in the North-western Pacific between November 2008 and January 2010. The relative value of the X-ray absorption coefficient (CT number = shell density) for planktic foraminifers showed remarkably changed seasonally. Especially shell density had decreased in the 2009 winter season during January - March. We inferred that such changes of shell density are likely associated with carbonate saturation depth in the North Pacific. It was reported that vertical mixing of surface water increased at low pH levels, and high TCO_2 water upwelled during winter. Decreasing shell density of planktic foraminifers could be closely associated with oceanic physicochemical conditions during the winter season.

Interannual Variability of Coccolithophore in Response to Changes in Water Column Stability in the Eastern Bering Sea

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This study was conducted to examine spatio-temporal variability in coccolithophore (*Emiliania huxleyi)* blooms in the Bering Sea, and to determine which factors are responsible for the blooms. We found large-scale inter-annual and seasonal variability in areas of the *E. huxleyi* blooms using remote sensing, with massive blooms observed in the fall of 1997 and 2000. However, only small blooms have been observed in these areas since 2001. Here we propose that the key parameter for *E. huxleyi* blooms is the strength of density stratification resulting from two water masses which are formed during different seasons: the surface warm layer and the cold bottom water (CBW) layer. Warming of the CBW since 2001 has induced a weakening in the aforementioned stratification. With less stratification, the water column is much more easily mixed, resulting in an increased nutrient supply from subsurface layers during the summer. As a result, the phytoplankton community changed to diatoms. Conversely, strong stratification induced by warming of surface water and intensified cold bottom water may result in the development of the *E. huxleyi* blooms similar to those observed in 1997.

Diatom Sinking Fluxes in the Northwind Abyssal Plain, 2010-2011

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The full-year time-series monitoring of diatom sinking flux and diatom sinking flora were studied at Station NAPt (75°N 162°W, 1975 m water depth, 180 meter sampling depth) in the Northwind Abyssal Plain from October 2010 throughout September 2011. The high flux periods of sinking diatoms were observed in November-December 2010 and July-August 2011. Total diatom flux during the sampled period was 0.9×10^6 skeletons m^{-2} d^{-1}, which was one order lower than the diatom fluxes in the Bering Sea and the Subarctic North Pacific. During the high flux period in November-December, the dominant diatoms were the genus *Chaetoceros* (subgenus *Hyalochaete*) and their resting spores. The sea surface at Station NAPt had been monitored during this period, and the relative abundance of ice-algae diatoms was low. Light conditions for phytoplankton at Station NAPt in November-December are limited by polar night. The abundant diatom particles during winter were probably transported from the shelf side. The highest diatom flux (5.5×10^6 skeletons m^{-2} d^{-1}) was recorded in July. During July-August, *Fossula arctica*, *Fragilariopsis oceanica*, and *Fragilariopsis cylindrus* — which are common in sea-ice condition of the Arctic Ocean — were often encountered as ribbon-like colonies with chloroplasts. In this study results during summer were similar to the general seasonality of diatom production in the Arctic Ocean. The high diatom flux at Station NAPt in November-December, however, is a unique result that has not been reported in previous diatom flux studies in the Arctic Ocean.

Seasonal Changes in Zooplankton Community

Kohei Matsuno[1], Atsushi Yamaguchi[1], Ichiro Imai[1], Jonaotaro Onodera[2], Sanae Chiba[2] and Naomi Harada[2]

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Because of seasonal ice coverage, little information is available on seasonal changes in zooplankton communities of the Arctic Ocean. In the present study, we analyzed seasonal changes in swimming zooplankton collected using sediment traps rotated at 13−15 day intervals and moored at 180 m in the Northwind Abyssal Plain during October 2010−September 2011. Zooplankton flux ranged from 5−44 ind. m^{-2} day^{-1}, and was greatest in September−October. Copepods were the most dominant taxa (18−94%). Based on the zooplankton flux, cluster analysis classified samples into three groups (A−C). Occurrence of each group showed clear seasonality: group A was observed during July−October, group B was observed during November−January, and group C was observed during March−June. Each group was characteristically dominated by different species (*Calanus hyperboreus*, *Metridia longa*, *Heterorhabdus norvegicus,* and *Paraeuchaeta glacialis*). Population structure of *C. hyperboreus* was predominated by C6F throughout the year, and gonad development of mature specimens was only observed during February−April. For *M. longa* and *P. glacialis*, C6F dominated during January−May, and early copepodid stages were abundant during

June−October. *Heterorhabdus norvegicus* was dominated by C5 during November−February and C6F/M during March−May. Such seasonality in population structure of the dominant copepods is considered to be a reflection of their life cycles. Of particular note, the Pacific copepod *Neocalanus cristatus* C5 occurred throughout the year, and was most abundant during August−September when sea-ice coverage was minimal.

Session 3

Fish, Seabirds, Marine Mammals

Session 3 — *Fish, Seabirds, Marine Mammals*

Chair: Yutaka Watanuki

Community Structure of Demersal Fish in the Continental Shelf Areas of the Bering Sea and the Chukchi Sea during the Summer of 2007-2009

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Demersal fish play an important role in benthic food webs of continental shelf areas in the Bering Sea and the Chukchi Sea. The south-eastern Bering Sea is investigated inter-annually by the National Oceanic and Atmospheric (NOAA) National Marine Fisheries Service (NMFS) during research surveys in this area. However, little is known about the St. Lawrence island region and the Chukchi Sea. The objective of this study is to determine the community structure and predator-prey trophic relationships of demersal fish in these regions. Bottom trawl survey and CTD measurements were conducted by the Hokkaido University training ship "Oshoro-maru" during July-August 2007 and June-July 2008 and 2009. Cluster analyses of community structures for fish species were applied to group the sampled stations based on similarities in community structure. Based on these results, we discuss the relationship between cluster groups and environmental factors. Prey composition was calculated based on the wet weight of each prey and the trophic level of each fish species in each cluster group. To estimate the overlap of prey composition among fish species in each group, we applied cluster analysis to the prey composition of each fish species within the same previously obtained cluster group. Significant overlap was defined as having a similarity index over 60%.

Forty-eight fish species belonging to 11 families were collected during 2007-2009. Cluster groups were associated with bottom temperature, depth, current transport, and sediment type. A cold pool exists south of St. Lawrence Island, and fish species distribution changed accordingly to the presence of this cold pool. This suggests that the low temperature tolerance/intolerance — as a function of having antifreeze protein or not or due to the match/mismatch of optimum range of temperature for embryonic development — is a dominant factor controlling the distribution of demersal fish species in these regions. In the south-eastern Bering Sea, walleye Pollock — the dominant species in this area — preyed primarily on euphausiids which were the main prey for fish at higher trophic levels. Therefore, it is believed that walleye pollock is the key species connecting lower and higher trophic levels in this area. In both the St. Lawrence Island region and the Chukchi Sea arctic cod was the main prey item for fish species at higher trophic levels. Thus, indicating that arctic cod play a key role in food webs of these areas.

Movement of Short-tailed Shearwaters with Environmental Gradient in the sub-Arctic Pacific and Arctic Seas through Summer to Autumn

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Short-tailed shearwaters *Puffinus tenuirostris* are one of the most numerous seabirds. They feed on key species such as krill, fish, and squids. Shearwaters breed in Australia from October – March, and migrate to the North Pacific during the non-breeding season: April-September. Vessel survey data indicate that they range over the entire northern North Pacific. Recent indications are that some shearwaters occur in the Arctic Ocean, although their patterns of seasonal movement are little known. To examine how their movement patterns relate to seasonal marine environments, we tracked those breeding on Great Dog Island, Tasmania, during 2009/2010 (n = 19) and 2010/2011 (n = 24) using geo-locators. Individual birds showed three different patterns of habitat use. Nine stayed in the north-western Pacific-Okhotsk Sea (WEST), 15 stayed in the south-eastern Bering Sea (EAST), and 19 stayed in the north-western Pacific-Okhotsk Sea during the summer and moved into the Bering Sea in September (WEST TO EAST). Eight of EAST and 13 of WEST TO EAST moved into the southern Chukchi Sea in September. Northward movement appeared to coincide with the seasonal increase in sea surface temperature (SST) within these regions. Twelve out of 19 birds (63%) moved into Arctic Sea in 2010 while only 9 out of 24 birds (38%) did in 2011 when SST in south-eastern Bering Sea during September was lower. This is probably because their major prey, i.e. krill, become less available as warm surface water is likely to inhibit surface swarming.

Acoustic Monitoring and Visual Survey of Marine Mammals during Summer in the Chukchi Sea and Barrow Canyon

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Rapid climate change and sea ice decline in the Arctic are directly reducing the habitat available for ice-associated marine mammals. In contrast, seasonally migrating species are showing northward expansions in their range of distribution, which will have impacts on Arctic ecosystems. To quantify the impact of climate change on spatial and temporal distribution of marine mammals, we deployed and recovered automatic underwater sound monitoring systems (AUSOMS, Aqua-Sound Co., Ltd., Japan) with oceanographic moorings

in Barrow Canyon and the southern Chukchi Sea during July – September 2012 as part of the "Arctic Climate Change Research Project" within the framework of the GRENE (Green Network of Excellence) Program. In addition, a cetacean sighting survey was conducted from JAMSTEC R/V Mirai during September - October, 2012. In total, three species (bowhead whales, gray whales, and humpback whales) were identified. We will present some preliminary results from this project.

Cetacean Habitat Distribution in the Eastern Bering Sea and Chukchi Sea during the Summer Season

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Different cetacean species occur in the eastern Bering Sea and Chukchi Sea which play an integral role in these oceanic ecosystems. However, cetacean-targeted studies are few and hence knowledge of their habitats within them remains limited. In the present study, we explore the distribution of 5 cetacean species (Dall's porpoise, *Phocoena dalli*; Fin whale, *Balaenoptera physalus;* Minke whale, *Balaenoptera actorostrata;* Humpback whale; *Megaptera novaengliae;* and Gray whale, *Eschrichtius robustus*) in response to prevailing oceanographic conditions off the eastern Bering Sea and the Chukchi Sea using a habitat modeling approach. The models were based on Maximum entropy (Maxent) algorithm and simulations were forced by remotely-sensed environmental factors and sighting data. The environmental datasets include MODIS/AQUA-derived sea surface temperature (SST) and chlorophyll-a (Chl-a) and ETOPO1-derived bathymetry. While, occurrence data were obtained from Hokkaido University's North Pacific sighting surveys (2003 and 2005-2010) and IPY cruises (2007-2008). Maxent-generated habitat maps showed different spatio-temporal distribution patterns, reflecting differences in the relative importance of environmental parameters to preferred habitat conditions across species. Such distinct habitat patterns were observed between Minke and Gray whales off the study areas in August 2007, where preferred habitats for these species were largely influenced by SST and Chl-a, respectively.

Session 4

Ecological Modeling and Parameterization

Session 4 — *Ecological Modeling and Parameterization*

Chairs: Enrique Curchister and Sei-Ichi Saitoh

Modeling Study on Biological Hot Spots in the Western Arctic: Impact of Shelf Water Transport

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The western Arctic basin ecosystem is examined in view of Pacific water transport with heat and biogeochemical materials. The eddy-resolving coupled sea ice-ocean model (grid size ~ 2 km) demonstrates that early sea ice reduction during summer promotes eddy-induced transport of warm Pacific summer water from the Chukchi shelf to the Canada Basin. In a lower-trophic marine ecosystem configuration of the western Arctic model, Beaufort shelf-break warm eddies produce hot spots of primary productivity, which were detected by satellite remote sensing and ship-based measurements. One of the control mechanisms was found to be internal eddy dynamics such as turbulent vertical mixing with underlying nutrient-rich water. In addition, the time lag between the phytoplankton bloom following summertime sea ice retreat in the Chukchi shelf region and eddy generation north of the Barrow Canyon is an important index to determine biological regimes in the Beaufort Sea. Inter-annual variations in eddy performance probably have a significant impact on the bottom-up control of food chains. Possible future consequences proposed by a series of high-resolution (~ 5 km) modeling studies are enhancement of ocean heat intrusion and zooplankton activity in the downstream region of the Pacific water pathway, especially around the Northwind Ridge.

Modeling Study on Biological Hot Spots in the Western Arctic: Impacts of Algae and Amphipod

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A 1-box numerical model describing the lower trophic level ecosystem in the western Arctic Ocean (Chukchi Sea and Beaufort Sea) was developed to investigate the relationship between the timing of sea ice melting and ecosystem change. For this purpose, the model consists of thirteen state variables which include typical biology in the water column and sea ice. The primary producer in the model was divided to three components: “Ice Algae”, “Centric Diatoms”, and “Autotrophic Flagellates”. Ice algae are mainly pennate diatoms that have

adapted to low light intensity. Centric diatoms are the dominant species in the ice-edge bloom; they are adapted to strong light intensity. Autotrophic flagellates are a major phytoplankton group after the bloom, and they can also live under sea ice. Zooplankton species grazing these primary producers were categorized into "Amphipods", "Copepods", and "Heterotrophic Flagellates". Top predators in the model were "Nektons" including krill, arrow warm, and other predatory species. The model also includes other nutrient and detritus components. The idealized annual physical forcing (sea surface temperature, sea surface light intensity, and mixed layer depth) and sea ice condition at the Northwind Abyssal Plain (NAP) were given for the model. In the Arctic Ocean, amphipods and copepods are important food sources for higher trophic level animals such as marine mammals, sea birds, and fishes. We discuss the seasonal variation of zooplankton biomass simulated by the model, and the timing of sea ice melting on lower trophic levels of the ecosystem.

Grazing Impact of the Arctic and Pacific Copepods during Late Summer in the Western Arctic Ocean

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It has been suggested that recent ocean warming and the subsequent decline of sea ice has forced a northward shift in ecosystem structure of the western Arctic Ocean and adjacent seas. To understand underlying mechanisms of such changes and future implications, not only changes in species distribution, but also changes the relationship between trophic levels should be assessed. Focusing on lower trophic levels, we hypothesized that Pacific zooplankton advected from the south can survive and establish viable populations in the future warmer Arctic. The aim of this study is to assess difference in the impact of grazing between Arctic and Pacific copepods on phytoplankton communities.

On board experiments to assess the grazing impact of copepods was conducted during the late summers of 2010 and 2012. Clearance and ingestion rates were measured for three different size classes (>20 μm, 2–20 μm and <2 μm). Although there was no significant difference in grazing on >20μm phytoplankton, we found significantly higher grazing impact of Pacific copepods on 2–20 μm and <2 μm phytoplankton than the Arctic ones. Since it can hardly be expected that the copepods selectively feed on smaller phytoplankton, we suggest that Pacific copepods have lower grazing impact on micro-zooplankton. We suggest that lower grazing impact on micro-zooplankton of Pacific copepods consequently caused the decrease in smaller phytoplankton assemblages. Therefore, changes in zooplankton community composition possibly alters phytoplankton community composition during late summer in the western Arctic.

Mechanism for how Arctic and Sub-Arctic Coccolithophorids Adapt to Temperature Change

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The coccolithophore, *Emiliania huxleyi, is* widely distributed and is known as the most abundant bloom-forming coccolithophore. There are several strains of *E. huxleyi* isolated from distinct ocean region which may adapt to various environmental conditions. However, the physiological differences in strains of *E. huxleyi* remain obscure. In this study, we investigate how *E. huxleyi* responds to changes in temperature to simulate the response of coccolithophores to global warming, especially in arctic and sub-arctic regions. We successfully isolated *E. huxleyi* strains from high latitudes: subarctic MR57 (the Bering Sea), MR67N; and MR70 (the Arctic Sea). To compare, we used a strain isolated from the low latitude NIES 837 (the Great Barrier Reef). We found that the high latitude strains could acclimate to low temperatures such as 4-10˚C within about 3 days, and that high latitude strains possess a greater ability to acclimate to low temperatures than low latitude strains. Our study suggests that the increase in NPQ induced by low temperature stress is important to the acclimation process, and that regulation of photosynthetic electron transport at low temperatures is essential for the acclimation of *E. huxleyi*. We discuss the strategy and mechanism for coccolithophores acclimation to temperature increases in the Arctic Ocean.

Session 5

Arctic-Subarctic Interactions

Session 5 — *Arctic-Subarctic Interactions*

Chair: Kenneth Drinkwater

The Barents and Chukchi Seas: Comparison of Two Arctic Shelf Ecosystems

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The Barents and Chukchi Seas are high latitude, seasonally ice covered, Arctic shelf-seas. Both have strongly advective regimes, and receive water from the south. Water entering the Barents comes from the deep, ice-free, "warm" Norwegian Sea, and contains not only heat, but also a rich supply of zooplankton. Bering Sea water entering the Chukchi in spring and early summer is cold, and in spring, depleted of large, lipid-rich zooplankton. Although primary production on average is similar in the two seas, fish biomass density is an order of magnitude greater in the Barents than in the Chukchi Sea. The Barents Sea supports immense fisheries, whereas the Chukchi Sea does not. The density of cetaceans in the Barents Sea is about double that in the Chukchi Sea, as is the density of nesting seabirds, whereas, the density of pinnipeds in the Chukchi is about double that in the Barents Sea. In the Chukchi Sea, export of carbon to the benthos and benthic biomass may be greater. We hypothesize that the difference in fish abundance in the two seas is driven by differences in the heat and plankton advected into them, and the amount of primary production consumed in the upper water column. However, the critical difference between the Chukchi and Barents Seas is the pre-cooled water entering the Chukchi Sea from the south. This cold water, and the winter mixing of the Chukchi Sea as it becomes ice covered, results in water temperatures below the physiological limits of the commercially valuable fish that thrive in the southeastern Bering Sea. The shallow northern Bering and Chukchi Seas are expected to continue to be ice-covered in winter, water there will continue to be cold in winter and spring, and is likely to continue to be a barrier to the movement of temperate fish into the Chukchi Sea.

On the Role of Advection on the Interaction between the Arctic and Subarctic Seas: Comparing the Atlantic and Pacific Sectors

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A brief review of water mass advection between Arctic and Subarctic regions and the effects on their ecology will be presented. The influence of Arctic outflows through Fram Strait, the Barents Sea and the Canadian Archipelago on the subarctic regions and the inflow of Pacific waters through the Bering Strait and of Atlantic Waters through the Fram Strait and the Barents Sea on the Arctic will be discussed. In addition to describing temperature and freshwater fluxes between the two regions, the role of advection of sea ice from the Arctic and its associated flora and fauna to the Subarctic will be mentioned. Nutrient fluxes and influences on stratification will be presented in terms of their effects on phytoplankton production. Advection of water masses also transports zooplankton communities between the two regions, as well as some ichthyoplankton. Brief mention will be made on the role of fronts between outflowing Arctic Water and inflowing Pacific and Atlantic Water. Possible future changes in advective fluxes between the Arctic and Subarctic will be highlighted along with their possible effects on the marine ecosystem.

Results from the Ocean Sciences Meeting, Yeosu Workshop on comparisons between the Arctic and Antarctic ecosystems

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The IMBER Regional Programs ESSAS (ecosystem Studies of Sub-Arctic Seas) and ICED (Integrating Climate and Ecosystem Dynamics in the Southern Ocean) held a one-day joint workshop on "The effects of climate change on advective fluxes in high latitude regions" on 14 May, 2012 prior to the 2nd PICES/ICES/IOC Symposium on "Climate Change in the World's Oceans" in Yeosu, Korea. The workshop was Co-chaired by Ken Drinkwater, George Hunt, Eugene Murphy and Jinping Zhao, and was attended by 32 scientists from 10 different countries, with another 20 scientists contributing input to the workshop presentations. The goal of the workshop was to review the advection of water masses within and between polar and subpolar regions, examine their forcing mechanisms, and consider what their impact may be on the ecology of these high latitude regions. Presentations ranged from a discussion of how climate change may affect atmospheric circulation patterns and their forcing of currents and sea ice distribution in the Arctic and Antarctic, the transport of heat, nutrients and plankton to and from the polar and subpolar regions, and how these advective processes may affect upper trophic level organisms such as fish, seabirds, and marine mammals. Future activities considered included the production of a review paper and the formation of a

Working Group under IMBER to continue the comparisons of Arctic and Antarctic ecosystems.

Results from the Ocean Sciences Meeting, ICES Theme Session and Hiroshima Workshop on Arctic Subarctic Interactions.

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During the last year, the ESSAS Working Group on Arctic-Subarctic Interactions held a Poster Session at the Ocean Sciences Meeting in February at Salt Lake City, a Theme Session at the ICES Annual Science Conference in September at Bergen and a Workshop at the PICES Annual Science Meeting in October at Hiroshima. A brief review of some of the highlights from these activities will be presented. This includes studies on the physical oceanography, phytoplankton, zooplankton, and fisheries in both subarctic and arctic regions and the links between them. Studies cover both the Pacific and Atlantic subarctic and arctic regions.

Session 6

Human Dimensions: Fisheries and Fishing Communities in Subpolar and Polar Regions

Session 6 — *Human Dimensions: Fisheries and Fishing Communities in Subpolar and Polar Regions*

Chair: Catherine Chambers

A Comparison of the Oceanography and Geography of the Aleutian and Kuril Archipelagos

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The Kuril and Aleutian Archipelagos are long chains of islands in the sub-arctic North Pacific Ocean. The Kuril Islands run roughly north-south and separate the western North Pacific Ocean from the Sea of Okhotsk. The Aleutians span a 1,200 km arc that runs roughly east-west and separates the northern North Pacific Ocean from the Bering Sea. Both archipelagos are known for their strong winds and frequent storms, though the climate of the Kurile Islands is considerably colder due to their proximity to the Siberian mainland, the prevailing winds from the north, and the cold Kamchatka Current that flows south from the northern Bering Sea. In contrast, the Aleutian Islands are bathed in the relatively warm waters of the Gulf of Alaska that are carried westward in the Alaska Coastal Current and in the Alaskan Stream. As a result, all but the smallest bays of the Aleutians are ice free all winter, whereas the maximum ice coverage in the Sea of Okhotsk often extends beyond the Kuril Islands. Perhaps as a result of straight coasts and ice scour, the Kuril Islands apparently have a rather impoverished intertidal fauna, whereas that in the Aleutians is abundant and varied depending on whether the coastline is rocky and exposed or sheltered and with soft sediments. Tidal currents in the passes of both archipelagos mix nutrient-rich water from the depths to the surface, where once it re-stratifies, there is strong production. A wide variety of marine birds, marine mammals, and fish occur in both archipelagos, though there is considerable variation in the types and numbers of animals depending on where in the archipelagos one looks.

Long-term Comparative Human Eco-dynamics in the North Pacific: a Perspective on the Role of Archaeology in Subarctic Ecosystem Studies

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The North Pacific Rim has a long history of human habitation that is supported by ecological productivity in the marine system, and challenged by its spatio-temporal variability, as well as hazards associated with living adjacent to an active subduction zone and the open ocean. In this paper, I use a roughly 5,000-year record on the history of human settlement in the Kuril Islands to examine the relative sustainability of occupation in the remote sub-arctic North Pacific. I briefly examine the potential causes for population growth and decline in terms of geological, climatic, ecological, and social factors. These Kuril patterns are then compared to

the settlement history of the Aleutians. A case is then made for the need to engage in more integrated "human ecodynamic" science of the North Pacific, in which geologic, atmospheric, oceanographic/ecological, and anthropological dynamics are combined to better understand scales of vulnerability and resilience in past, present, and future systems. This presentation draws on the results of the recently completed Kuril Biocomplexity Project and highlights initial efforts to coordinate "Human Ecodynamics" research around the subarctic North Pacific, linking the insular Aleutian and Kuril regions to harness the comparative opportunities of a North Pacific scale paleo-biogeography. I argue that this effort to better understand long-term patterns in human ecodynamics has relevance to contemporary interests in marine ecological system responses to climate and human interactions, and that we stand to learn more about North Pacific ecological dynamics by bringing research of the past and the present into a more active communication.

Ecological and Economic Effects of Sea Ice on Fisheries Resources in the Okhotsk Sea

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Characteristics of subarctic and arctic waters in the Pacific Ocean include the effect of sea ice production. In the Okhotsk Sea and Bering Sea — the marginal seas of the subarctic waters — phytoplankton blooms occurring after sea-ice retreat have an impact at higher trophic levels. The long-term trend for biological productivity in the Okhotsk Sea ice area has been one of decrease. However, the sea ice concentration varies between years. The sea ice concentration is expressed using an accumulated (% day) concentration of sea ice area covered with an observation area on the Okhotsk coast of Hokkaido. Sea ice concentration has varying affects on fisheries production. In years of higher sea ice concentration, production rates for herring and walleye pollock have been greater than in years with lower sea ice concentration. In contrast, during years with lower sea ice concentration, production rates for scallops and arabesque greenling were higher than in years with higher sea ice concentration. Japanese salmon have been cultivated through hatchery enhancement programs. The return rate of matured salmon has been lower in the years when salmon fry migrated to sea immediately following retreat of the sea ice. In contrast, the salmon return rate has been more strongly correlated with the time of release for salmon fry than with the coastal sea ice concentrations. Consequently, it is important to establish the effect of variations between ecosystems to determine the economic value relative to sea ice environments.

Evolution of Property Rights in the Eastern Bering Sea Pollock Fishery

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The Eastern Bering Sea fishery for Alaska pollock (*Theragra chalcogramma*) is one of the largest fisheries in the world and has often been touted as an example of a sustainable fishery. While that may be true today, it has not always been so. The path to sustainability has been anything but smooth. It has been driven by a sequence of crises that were "solved" by the creation of property rights: national rights to control exploitation of stocks within the Exclusive Economic Zone, treaty rights to control exploitation in adjacent international waters, rights of preference afforded to domestic harvesters, catch shares allocated to Community Development Quota entities, catch shares allocated to inshore and offshore sectors, and, eventually, the right to sub-allocate catch shares within sectors. While fortuitous, the present structure of rights was not intended, not inevitable, nor is it ideal. Indeed, hidden within the present structure lie vulnerabilities to exogenous forcing. Whether the fishery remains sustainable will depend on whether the present rights structure is allowed to evolve in response to coming crises.

Small-scale Fishing Livelihoods and Fisheries Management: Overview from Iceland and Alaska

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Sub-Arctic marine fisheries consist of myriad ever-changing ecological, social, economic, and political factors that can create complicated management scenarios. At a time when fisheries managers in sub-Arctic nations face complex obstacles such as rapid climate change and continued over-fishing, Iceland and Alaska represent examples of successful economic and ecological management strategies. However, fisheries management that is effective in reaching economic or ecological goals may lead to unintended social and political consequences in small-scale fishing livelihoods and rural coastal communities. Because sub-Arctic fisheries support a wide variety of rural communities and small-scale fishing livelihoods, it is important to explore the demographics and experiences of the individuals engaged in fisheries to aid managers in designing scenarios that are effective, equitable, and culturally appropriate. Here, I present an overview of ongoing research with small boat fishermen in eight communities in Northwest Iceland. The research draws upon scholarship from common property theory and political ecology to better understand the opportunities and constraints that varying management schemes have on the social dimensions of fisheries. Additionally, I present preliminary results from a similar project exploring experiences of social, economic and environmental changes in fisheries in Kodiak, Alaska to lend a comparative aspect and look for overarching themes related to the cultural dimensions of sub-Arctic fisheries.

Session 7

Bioenergetics of Sub-polar Fishes: Regional Presentations

Session 7 — *Bioenergetics of Sub-polar Fishes: Regional Presentations*

Co-chairs: Ron Heintz and Trond Kristiansen

Climate Effects on the Nutritional Condition and Productivity of Marine Fish Populations

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This presentation describes how climate-induced changes in the quality of prey influence the nutritional condition and survival of walleye pollock (*Theragra chalcogramma*) from the south-eastern Bering Sea. Sea ice in the Bering Sea undergoes periods of relatively little coverage (warm) followed by periods of almost complete coverage (cold years). These oscillations influence the abundance and type of prey available to juvenile pollock. The impacts of these shifts on age-0 pollock have been monitored over the last ten years during fisheries surveys and stock assessments. Observations include the recruits-per-spawner (survival), abundance, size, diet, and energy content of pollock during the last warm (2003-2005) and cold phases (2007-2011). We combined these data with observations of the percent lipid-content in pollock prey collected in a warm (2005) and a cold (2009) year in order to reconstruct the percent lipid-content in pollock diets. Pollock were more abundant in warm years while prey was less abundant. Nevertheless, stomach fullness did not vary between warm and cold years, but diets in cool years had threefold more lipid-content than diets in warm years. Consequently, pollock had lower energy density in warm years compared with cool years. More importantly, there was a direct relationship between pollock energy content and survival. Climate-induced variations in prey abundance and quality were important determinants of pollock condition and productivity in the Bering Sea. Production of commercially valuable fish populations is likely to be altered by climate-induced changes in prey quality in addition to alterations in prey availability

Winter Feeding and Nutritional Condition of Juvenile Walleye Pollock in the Doto Area, Northern Japan

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Seasonal variation in body size, diet, prey consumption rate, and nutritional condition of juvenile walleye Pollock (*Theragra chalcogramma)* was examined to elucidate mechanisms underlying their first-winter survival on the continental shelf of the Doto area of northern Japan, based on monthly samples collected over 2 successive winter (2003/2004 and

2004/2005) seasons. Evidence of size-selective winter mortality was not found from the analysis of length-frequency distributions. Somatic growth, rather than size-selective mortality, is likely to be responsible for increases in body size during this period. Juvenile pollock fed mainly on euphausiids and copepods throughout the year, and the percentage of empty stomachs was very low (0.5–3.7%) even in winter. Prey consumption rates estimated by the bioenergetics model were 20–80% of maximum consumption rates. These results suggest that winter feeding opportunities are severely limited but not completely absent. During both 2-year periods, stored lipid mass was highest during autumn, but most lipids had been exhausted by the onset of winter. Although fish in the 2003/2004 winter had lower level of energy reserves, the energy levels nonetheless appeared to be far from causing mass-starvation mortality. During the 2004/2005 season, contrary to expectations, wild fish generally continued to accumulate protein mass while they tended to reduce lipid mass from late autumn through winter. In conclusion, it is suggested that juvenile pollock are able to avoid both starvation and predation by accumulating protein reserves on the continental shelf of the Doto area.

A Review of the NEMURO.FISH Model Applications to Marine Ecosystem Investigations and its Ability to Evaluate Responses of Fish to Future Climate Change - What will Happen to Stocks of Chum Salmon, Walleye Pollock, and Common Squid in the Northern Pacific?

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What will happen to commercial fish stocks in the Northern Pacific due to global warming? We forecast the future status of fish stock based on outputs from global atmosphere – ocean - terrestrial coupled model of A3 scenario. The Hokkaido stock of chum salmon will disappear by 2100, whereas the chum salmon stock in the Bering Sea may be maintained. The Honshu stock of walleye pollock will collapse by 2050, whereas the Hokkaido stock will decrease dramatically during the 21st century. The spawning season of Japanese common squid will occur one to two months earlier than the present season. NEMURO (North-pacific Ecosystem Model Used for Regional Oceanography) and NEMURO.FISH (NEMURO including Saury and Herring) — developed by PICES MODEL TT, Hashioka *et al*. (2007) — predicted changes in biomass at lower trophic levels in response to global warming. The bio-energetic model for common squid in the Japan Sea showed differences in growth as well as possible changes in the migration route for this species. We discuss possible future NEMURO applications to forecast ecological status.

Modelling Feeding Ecology and Survival of Larval Fish in Sub-arctic Ecosystems under Climate Change

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Understanding the bio-physical mechanisms that shape variability in fisheries recruitment is critical for estimating effects of climate change on fisheries. In this study, we coupled an Earth System Model (ESM) simulation with a mechanistic individual-based model (IBM) for larval fish to assess the effects of climate change on larval cod in the North Atlantic. ESM outputs were averaged over 5 regions spanning the current range of cod distribution. Under the SRES A2 (high emissions) scenario, surface ocean temperatures are projected to increase by > 1^{o}C for three of the five regions and stratification is expected to increase at all sites between 1950-1999 and 2050-2099. These changes are associated with decreased primary production by large (>5µm in equivalent spherical diameter (ESD)) phytoplankton and reduced meso-zooplankton biomass, which are the primary prey for larval cod. IBM simulations predict that larval cod will respond to these changes by spending more time searching for food higher in the water column. This behavioral response helps larvae to maintain growth rates for all but one of the sites despite reduced prey levels. However, it also makes them more vulnerable to predation, which leads to significant reductions in survival probability in all 5 regions unless piscivore biomass also declines in proportion to meso-zooplankton biomass. In contrast to past observed responses to climate variability in which warm anomalies led to better recruitment in cold-water stocks, our simulations suggest that reduced prey availability under climate change causes higher temperatures to have a negative impact on larval survival throughout the cod range. In the lower prey environment projected under climate change, the higher metabolic costs due to higher temperatures outweigh the advantages of higher growth potential, leading to negative effects on northern cod stocks.

Session 8

Spatial Dynamics of Subarctic and Arctic Marine Communities: The Role of Advection, Temperature, and Trophodynamics

Session 8 — *Spatial Dynamics of Subarctic and Arctic Marine Communities: The Role of Advection, Temperature, and Trophodynamics*

Co-chairs: Franz Mueter, Erica Head and Kenneth Drinkwater

Spatial and Temporal Variations in Environmental Conditions and the Abundance and Phenology of Arctic and Boreal *Calanus* (copepod) Species on the Labrador and Newfoundland Shelves (1960-2011)

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The Labrador/Newfoundland Shelf system is influenced by the flow of water from the Arctic via Hudson and Davis straits, which brings arctic copepods south of their normal distributional ranges. Ice covers the northern part of the region in winter and as it retreats north in spring, pelagic phytoplankton blooms occur. In the south, phytoplankton blooms occur when the water column stabilizes following winter vertical mixing. The timing of reproduction of the boreal copepod species, *Calanus finmarchicus*, a year-round resident of the study region, is generally thought to be linked to the timing of the spring bloom. Two arctic copepod species, *C. glacialis* and *C. hyperboreus*, which are probably transient seasonal residents in the study region, follow slightly different life-history strategies more adapted to conditions farther north. In this talk we will use data from a variety of sources, including measurements made by satellite (for sea surface temperature, chlorophyll concentration and sea ice extent), by continuous plankton recorders deployed from ships of opportunity (for phytoplankton and zooplankton abundance) and by Canadian researchers during *in situ* sampling programmes (AZMP and AZOMP, for hydrographic variables, chlorophyll concentration and zooplankton abundance) to investigate variations in environmental conditions and their influence on the two arctic and one boreal *Calanus* species at seasonal, inter-annual and inter-decadal time scales in two regions, Station 27 (S27, off St Johns, South Newfoundland Shelf) and Hamilton Bank (HB, South Labrador Shelf).

On the spatial variability in the physical and biological properties across the fronts in the Norwegian and Barents seas.

Kenneth F. Drinkwater and the NESSAR Team

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The IPY Project NESSAR (Norwegian Ecosystem Studies of Subarctic and Arctic Regions) carried out interdisciplinary field studies during 2007 and 2008 on the Jan Mayen Front in the Norwegian Sea and the Polar Front in the Barents Sea, both of which separate Atlantic and

Arctic waters. The investigations included the physical dynamics of the fronts, as well as the structure and function of the associated marine biology from their biogeochemistry and nutrient dynamics through plankton ecology up to fish. The fronts in both regions exhibit strong horizontal gradients in temperature and salinity but weak density gradients owing to density compensation of the water mass characteristics on both sides of the fronts. Intense interleaving of the water masses occurs at the front along isopycnals resulting in large variability in the vertical profiles of the temperature-salinity characteristics. However, turbulence levels are still relatively weak and not strong enough to create strong vertical mixing. As a result nutrient levels in the near surface layers remain low throughout the summer following the spring bloom. Measurements show little evidence for enhanced primary production or high phytoplankton biomass in either front. Small zooplankton appear to be more prominent at the front, and large zooplankton more prominent away from the front based on measurements in the Barents Sea. Capelin show a similar pattern of distribution with small individuals in the front and larger capelin away from the front — mainly in the Arctic waters. Comparisons between the two regions, as well as with fronts in other Nordic Seas will also be presented.

Spatial Patterns of Productivity and Implications for Carbon Flux at the Polar Front, Barents Sea

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Secondary production (2007 & 2011) and carbon flux (2011) were investigated along a transect crossing the polar front in the Barents Sea from Atlantic (AtW) to Arctic Waters (ArW). In August 2007, overall AtW were the most productive in terms of secondary production, and the same is indicated for 2011. In both years, extremely high production of small meso-zooplankton (mainly *Oithona* and *Fritillaria*) was estimated for patches in frontal waters (> 1 g C m^{-3} d^{-1}), but also high loss rates were estimated at the polar front, likely channeling a significant amount of carbon to the benthos and to pelagic predators like young capelin. The sedimentation to the benthos will be tested for the 2011 data. Productivity, and likely carbon flux, was highly patchy at the front, with implications for the quantitative assessment at the stations.

Data with high spatial resolution were collected by a laser optical plankton counter (LOPC) mounted on an undulating platform in 2007, and on a moving vessel profiler in 2011. They were supplied with net samples, grazing experiments (2007) and sediment trap sampling (2011). The quality of the LOPC data was thoroughly assessed, and particles were characterised based on their size and transparency in relation to net and trap samples at stations. Finally, the *in situ* LOPC data were followed up by biovolume spectrum theories to estimate vital rates, and by settling speed calculations to estimate carbon flux. Vital rates

estimated based on biovolume spectrum theories agreed generally well with estimates reported in the literature.

Recent Climate-related Changes in Abundance and Distribution of Pelagic Fish Stocks in Icelandic Waters

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The Icelandic marine ecosystem is a highly productive boreal/sub-arctic system which sustains extensive fisheries. Since the mid 1990s extended distribution of warm Atlantic water and marked warming has been observed in the North-east Atlantic Ocean and the waters around Iceland. At the same time marked changes have been manifested in the five major pelagic fish stocks inhabiting and/or migrating into the Icelandic area. Following peak yields for several years the Icelandic capelin (ICAP) has since the mid-2000s decreased and the distribution has shifted towards the East Greenland shelf. The Icelandic summer spawning herring (ISSH) since having collapsed in the late 1960s, and co-occurring extensive changes in distribution changes, recovered to historic high levels of abundance during the mid-2000s before again decreasing during the late-2000s — due in part to a parasitic outbreak. The Norwegian spring spawning herring (NSSH) has recovered from a collapse during the late 1960s and since the late 1990s has partly resumed migrations to former feeding grounds to the northeast of Iceland. During mid 1990s to mid 2000s the North-east Atlantic blue whiting (BW) produced a series of strong year classes and extended its distribution into Icelandic waters while more recently the stock has again decreased and distribution has become more southerly confined. Since the mid-2000s the North-east Atlantic mackerel (NEA-MAC) has migrated in unprecedented quantities into Icelandic waters resulting in significant fisheries within the Icelandic EEZ. These extensive changes in abundance and distribution are considered within the context of recent climate changes, interspecies competition, and carrying capacity of the Icelandic and nearby marine ecosystems.

Past and Future Sockeye Salmon Distributions in the North Pacific

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The sockeye is a subarctic species of Pacific salmon that tends to be found in cooler parts of the northern North Pacific. Populations reproduce in freshwater where the juveniles spend half of their life rearing in nursery lakes before migrating to sea for the remainder of their life. As a consequence of its preference for cooler temperatures, behavior, growth, and survival are thought to be vulnerable to a warming planet. Climate regime shifts have changed migratory behavior in the past. Some researchers have reported that the distribution of sockeye salmon on the high seas is precisely determined by sea surface temperature (SST). Some have speculated that the species will disappear from the North Pacific into the northern Bering Sea later in the 21st century due to rising ocean temperatures. This talk examines how sockeye

salmon in the Gulf of Alaska have behaved in the warm years of history to see where they were found. Model projections of SST suggest that a significantly warmer year of the past/present is equivalent to an average SST in the future. IPCC 4 model outputs are compared with present and future SSTs. Global models tend, however, to use highly smoothed SST fields that do not entertain a possibility that mesoscale processes may create locally cool surface temperatures (thermal refugia) in a generally warming ocean.

Spatial Dynamics of Groundfish on the Eastern Bering Sea Shelf: the Roles of Temperature, Abundance, and Advection

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The summer distribution of groundfish on the eastern Bering Sea shelf reflects complex responses to the availability of suitable prey and the abundance of predators and competitors. These spatial dynamics are modified by species-specific temperature preferences that can lead to pronounced changes in distribution in response to variable temperature conditions. Bottom temperatures over the middle domain (~ 50-100m) are largely determined by the extent of sea ice during the previous winter, which forms a "cold pool" of water on the shelf. The extent of this cold pool determines the southern limit for several Arctic species and constrains the northward expansion of subarctic species. The well-mixed waters of the inner domain (~ 0-50m) provide a corridor for the seasonal migration of shallow-water species to bypass the cold pool into the northern Bering Sea, while the deeper and consistently warmer waters of the outer shelf and slope provide a refuge for subarctic species. Advection may further modify the feeding distributions of Bering Sea fish and shellfish either indirectly, through the re-distribution of suitable prey and water masses, or directly by advecting early life stages or facilitating active migrations. Here we quantify the relative importance of density-dependent factors (abundance of conspecifics), temperature, and advection in regulating the spatial dynamics of groundfish species, and discuss the implications of climate change for their future distribution.

Abstracts
of
Poster Presentations

Visual survey of cetaceans in autumn in the Arctic

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Cetaceans play an important role in marine ecosystems as top predators. They are associated with specific environments such as sea ice, depth and sea surface temperature. Climate changes such as global warming will drastically change environments in the Arctic, so that we expect it will affect cetacean distributions in the Arctic. Our final goal is to make the habitat model of cetaceans by spatially analyzing the distributions and environmental information, and predicting the cetacean distributions in the future. To obtain the information about cetacean distributions, we conducted the cetacean sighting survey from JAMSTEC R/V Mirai in September and October, 2012. This survey was conducted for 83.8 hours in 19 days in the Chukchi Sea. In total, three species were identified: bowhead whale (2 animals in 2 groups), gray whale (64 animals in 34 groups), and humpback whale (14 animals in 6 groups). We will present some preliminary results from this survey.

The Pacific Arctic Group (PAG): A Pacific perspective on Arctic science

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The Pacific Arctic Group was imagined during the Arctic Science Summit Week of 2002 and formed during the International Arctic Science Committee (IASC) Council Meeting in April 2003 as a subunit of IASC with the mission to "Serve as a Pacific Arctic regional partnership to plan, coordinate, and collaborate on science activities of mutual interest". During the formative years the Group developed a number of science themes that it wished to pursue and adopted a mode of action based on two primary types of activities: 1) enhancement of individual national field programs by inclusion of an international component; and 2) creation of collaborative activities focused on synthesis of data and publication on topics of mutual interest. Descriptions of these activities are available through the PAG website located at http://pag.arcticportal.org. The PAG is now distinct from but affiliated with the IASC, and is evolving to meet the needs of its major members (Canada, China, Japan, Korea, Russia, and United States). During and subsequent to the International Polar Year 2007-2009, the PAG members increased efforts on Arctic marine science and are developing a rich set of data to describe the Pacific sector of the Arctic. Discussions within the group have identified new areas for potential collaboration, such as model-data fusion, distributed biological observatory, and studies at the northward-moving sea ice edge. This presentation will highlight some of the

accomplishments from these efforts and discuss the continuing role of the PAG in promoting international coordination of research in the Arctic.

The impact of sea ice melting on iron concentration in surface water in the southern Sea of Okhotsk

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Phytoplankton blooms occur in the Sea of Okhotsk during the sea ice melting season. Although it is known that sea ice plays important roles in the high productivity in this region, the mechanisms are not well understood. To elucidate roles of the sea ice in biogeochemical cycle in the Sea of Okhotsk, the concentrations of macro-nutrients (NO_3+NO_2, PO_4, SiO_2 and NH_4) and trace element (Fe) were measured for the sea ice, overlying snow and seawater samples collected in the southwestern region by using clean technique in early February 2010 and 2011. The concentrations of macro-nutrients in the sea ice, except for NH_4, were lower than those in the open surface water in the ice floe area (SWIF). Fe in the sea ice was heterogeneously distributed and enriched relative to the SWIF. It is considered that sea ice melting tends to induce the dilution of the macro-nutrients concentration of surface water, while it might be significant source of Fe to surface water in this region. We estimated total Fe flux into surface water from melting sea ice as 793 ± 193 μmol Fe m^{-2} $event^{-1}$ (one seasonal melting). The flux is comparable to reported amount of annual atmospheric Fe flux in the northwestern Pacific. Therefore, these results indicate that sea ice could change micro- and macro-nutrient conditions in this region during the melting season. We conclude that the sea ice melting has a significant impact on biogeochemical cycle in the Sea of Okhotsk, and would potentially contribute to phytoplankton growth.

Interactive effects of resource and temperature on bacterial production and respiration in Arctic surface waters

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Bacterial consumption of dissolved organic carbon (DOC) has two metabolic outcomes: bacterial production (BP) that provides cellular biomass to fuel microbial food webs and bacterial respiration (BR) that converts DOC to carbon dioxide. Although variations in BP and BR have been extensively examined in diverse marine environments, we lack sufficient knowledge on controls of BP and BR in the Arctic waters. This paucity of data hampers improvement of our ability to predict how Arctic ecosystems respond to climate change. The objective of this study was to examine how resource and temperature control BP and BR in the western Arctic. Bottle incubation experiments were conducted during the R/V 'Mirai' cruise (September–October, 2012) to examine the effect of resource addition (glucose or

ammonium, or both) and temperature elevation (ambient temperature + 5) to BP and BR. The most pronounced enhancement of BP and BR relative to control (1.9–6.0 fold) was found in the treatments in which both resource level and temperature were raised. Temperature-dependency (Q_{10}) of BP was 1.4–2.3 in the control, whereas the corresponding values were higher (2.5–4.7) in the treatments with the addition of resources. Bacterial growth efficiency, BP/(BP+BR), which varied in the range of 0.28–0.54, was lowest in the resource addition treatments without temperature elevation. Our results are generally consistent with the notion that resource and temperature interactively affect BP and BR, although they also suggest that these forces can alter, in a complex manner, the carbon flow pattern through DOC-bacteria pathway.

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ESSAS 2013 Annual Science Meeting

Hakodate, Japan

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