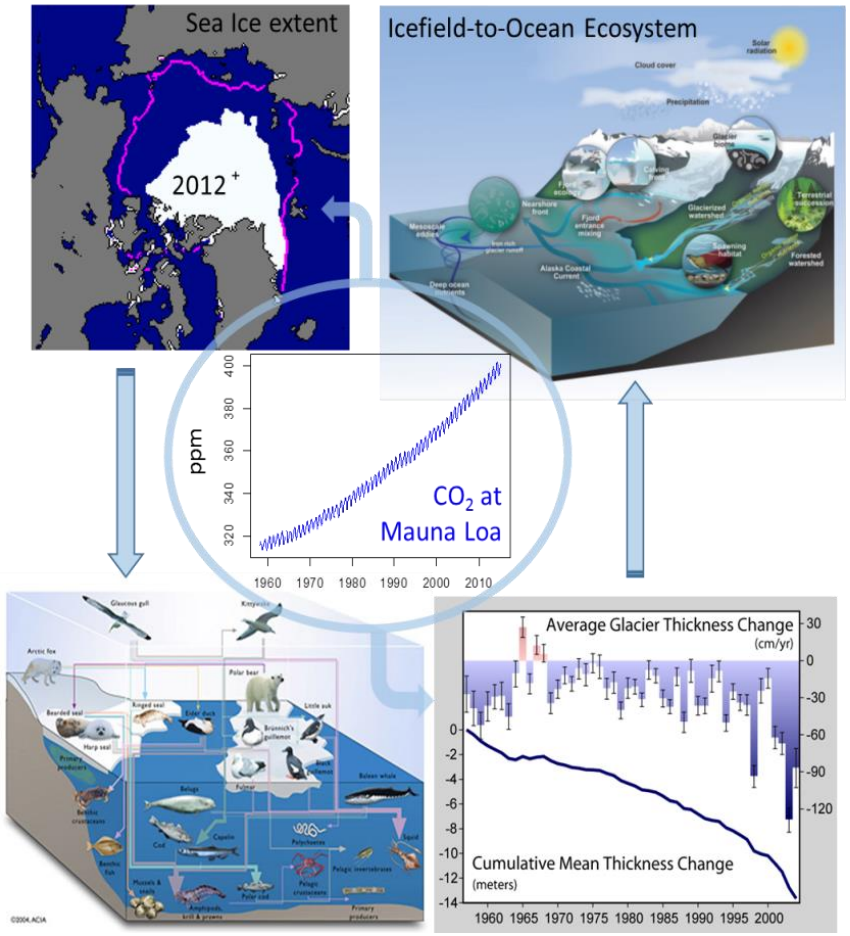
ESSAS Annual Science Meeting

June 15-17, 2015

The Role of Ice in the Sea



Hosted by
The UW Future of Ice Initiative
and
The School of Aquatic and Fishery Sciences

University of Washington, Seattle, Washington

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Mauna Loa CO2 data: NOAA Earth System Research Laboratory (http://www.esrl.noaa.gov/gmd/ccgg/trends/)

Sea Ice Extent: National Snow and Ice Data Center http://nsidc.org/data/seaice_index/

Icefield-to-Ocean Ecosystem: O'Neel, S., Hood, E., Bidlack, A.L., Fleming, S.W., Arimitsu, M.L., Arendt, A., Burgess, E., Sergeant, C.J., Beaudreau, A.H., Timm, K., Hayward, G.D., Reynolds, J.H., Pyare, S., 2015. Icefield-to-Ocean Linkages across the Northern Pacific Coastal Temperate Rainforest Ecosystem. BioScience. doi:10.1093/biosci/biv027

Glacier Thickness: Robert Rohde based on data archived by the World Glacier Monitoring Service at the National Snow and Ice Data Center (NSIDC): http://nsidc.org/data/

Arctic Marine Food Web: ACIA, 2004. Impacts of a warming Arctic. Arctic Climate Impact Assessment, Cambridge University Press, Cambridge, UK (http://www.acia.uaf.edu/)

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Seattle Municipal Archives, Photograph Collection
Item No: 103653
Description: Space Needle and Mount Rainier
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Original format: Digital Photograph
Web Address: http://clerk.ci.seattle.wa.us/~scripts/nph-brs.exe?s1=space+needle&S2=&S3=&l=100&Sect7=THUMBON&Sect6=HITOFF&Sect5=PHOT1&Sect4=AND&Sect3=PLURON&d=PHO2&p=1&u=%2F~public%2Fphot1.htm&r=90&f=G

Welcome

On behalf of the symposium conveners, organizers, and the ESSAS Scientific Steering Committee, we welcome you to beautiful Seattle and to the University of Washington's School of Aquatic and Fishery Sciences. The University, with its commitment to invest in knowledge about the polar regions through the campus-wide 'Future of Ice Initiative', is a fitting venue for the 2015 Ecosystem Studies of Sub-Arctic Seas (ESSAS) Annual Science Meeting on **The Role of Ice in the Sea**.

We are excited to welcome scientists from at least 11 countries with a range of expertise about sub-arctic and arctic marine ecosystems. The Symposium brings together experts on both glacier ice and sea ice from around the circumpolar north, and we look forward to an excellent mix of oral and poster presentations, organized around four main sessions (1) ***Humans, Ice and the Sea in the Subarctic and Arctic Past***, (2) ***Role of Sea Ice in the Arctic and Sub-Arctic***, (3) ***Ecological Role of Tidewater Glaciers***, and (4) ***Social Scientific Investigations of Changing Sea Ice Conditions***. In addition, we have a strong mix of contributed papers on the climate and ecology of subarctic marine ecosystems.

We encourage you to take advantage of this unique opportunity to catch up with colleagues and friends and to exchange information, experiences and ideas with fellow marine scientists from around the Arctic. We hope that you will also use the occasion as an opportunity to explore Seattle and its many delights. We will plan to have a list of interesting restaurants and cultural attractions that you may want to vist when not engaged in the meeting activities.

Finally, this meeting could not have happened without the help and support of many individuals and organizations. We thank the School of Aquatic and Fishery Sciences for letting us use their facilities and for their generous support of the meeting, and Monick Keo, of the Future of Ice Initiative, for her help with every aspect of setting up the meeting. She was indispensible to the Co-chairs! We thank the IMBER International Project Office for help with registration and abstract submissions and all of the session conveners for putting together an excellent program. Financial support for travel expenses for invited speakers and early career scientists was provided by the following organizations:

- **North Pacific Research Board**
- **Alaska Fisheries Science Center, NOAA**
- **North Pacific Fishery Management Council**
- **International Arctic Science Committee**
- **College of the Environment, UW**
- **Future of Ice Initiative, UW**
- **School of Aquatic and Fishery Sciences, UW**
- **School of Oceanography, UW**
- **School of Marine and Environmental Affairs, UW**
- **Applied Physics Laboratory, UW**
- **Program on Climate Change, UW**
- **Quaternary Research Center, UW**
- **Department of Anthropology, UW**
- **Canadian Studies Center, UW**

To a productive, stimulating, and enjoyable meeting!

Ken Drinkwater, Franz Mueter, and Sei-Ichi Saitoh

ESSAS Co-Chairs

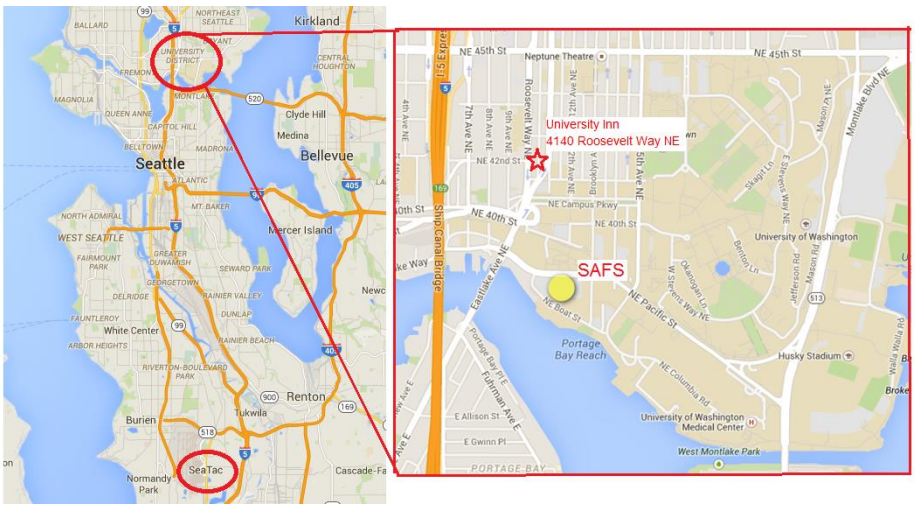
George Hunt (Co-chair), Ben Fitzhugh (Co-chair), Kristin Laidre, Jody Deming

Local Organizing Committee

Table of Contents

Meeting Information

Location: The meeting will take place in the main auditorium Room 102) at the School of Aquatic and Fishery Sciences (SAFS) (Fishery Sciences Building) of the University of Washington (See Map below or go to this link), which is located at 1122 NE Boat St, Seattle, WA 98105. The University Inn is located a few blocks to the North.



How to get there:

Follow the link for travel options to and from UW and SEA-TAC:
http://depts.washington.edu/rna2006/transportation.shtml

Note: Central Link Light Rail from SEA-TAC ends in downtown Seattle (Westlake), a taxi or bus will be needed for further transport to the University area. (http://www.soundtransit.org/)

Driving Directions

From I-5:

1. Exit 45th St going east (turn left from I-5 southbound, right from I-5 northbound).
2. Turn south (right) on 15th Ave, crossing Pacific
3. Turn right on Boat St; go ~1-1/2 blocks; school is on right.

From SR 520:

1. Exit Montlake Blvd going north (turn left from 520 eastbound, right from 520 westbound).
2. Get in left lane of Montlake; turn west (left) onto Pacific.
3. Turn south (left) onto 15th Ave.
4. Turn right on Boat St; go ~1-1/2 blocks; school is on right.

Registration:

The meeting will start with registration on Monday June 15 at 8am. The registration desk will also be open Tuesday and Wednesday morning from 8:00am.

Oral presentations:

All presentations will be in plenary session (no concurrent sessions). We kindly ask that you bring your presentation (PowerPoint or PDF) on a USB key. Assistance will be available to load your presentation.

If you are a MAC-user please make sure that your presentation will work properly on a PC.

Poster presentations and Poster session:

The maximum size of the poster is 32 in. wide x 44 in tall.

Social activities:

Welcoming Reception:

A Welcoming Reception will be held on Monday, June 15 at 17:45 in the Fishery Science Building (SAFS) lobby. ESSAS conference goers are invited to mingle and enjoy hors d'oeuvres and drinks. Sponsoring partners have been invited and a short program is planned, including welcoming remarks from the Dean of the UW College of the Environment, Lisa Graumlich, and a short presentation by Ben Fitzhugh, Director of the UW Quaternary Research Center. Poster presenters are invited to display their posters at both evening receptions. Heavy hors-d'oeuvres and wine, beer and soft drinks will be served.

Poster Reception:

The poster session and reception will take place Tuesday evening from 17:45 to approximately 20:00 in the lobby of the Fishery Sciences Building (SAFS). Heavy hors-doeuvres and wine, beer and soft drinks will be served.

Agenda

Day 1 (Monday, June 15)			Day 2 (Tuesday, June 16)			Day 3 (Wednesday, June 17)		
8:00	**Registration, Coffee**		**8:00**	**Registration, Coffee**		**8:00**	**Registration, Coffee**	
						8:30	Haynie (Intro)	S4
8:45	Welcome		9:00	Banas	S2	8:40	Ahmasuk	S4
9:10	de Vernal	S1	9:20	Nielsen	S2	9:10	Gallucci	S4
9:40	Friesen	S1	9:40	Planque	S2	9:30	Hoel	S4
10:10	Gemery	S1	10:00	Sasaki	S2	9:50	Fernandez	
10:30	Chikamoto	S1	10:20	Kunz	S2	10:05	Kaiser	S4
10:50	**Break**		**10:40**	**Break**		**10:20**	**Break**	S4
11:20	Lembke-Jene	S1	11:10	Astthorsson	S2	10:50	Criddle	S4
11:40	Savinetsky	S1	11:30	Laidre	S2	11:10	Baker	S4
12:00	Ólafsdóttir	S1	11:50	Boveng	S2	11:40	Haynie	S4
12:20	Katsuki	S1	12:10	Gaston	S2	**12:00**	**Lunch Break**	
12:40	**Lunch Break**		**12:30**	**Lunch Break**		13:30	Ding	S5
14:00	Overland	S2	14:00	O'Neel	S3	13:50	Ito	S5
14:20	Steele	S2	14:25	Cape	S3	14:10	Kimoto	S5
14:40	Lee	S2	14:50	Nielsen	S3	14:30	Decker	S5
15:00	Azetsu-Scott	S2	15:15	Hodson	S3	14:50	Hauser	S5
15:20	Hop	S2	**15:40**	**Break**		**15:10**	**Break**	
15:40	**Break**					15:40	Ohlberger	S5
16:00	Fujiwara	S2	16:10	Womble	S3	16:00	Lovvorn	S5
16:20	Laney	S2	16:30	Piatt	S3	16:20	Pörtner	S5
16:40	Eisner	S2	16:50	Arimitsu	S3	16:50	Open Discussion	S5
17:00	Jin	S2	17:10	Simon	S3			
17:20	Ashjian	S2				17:10	Closing Remarks	
17:45 - 20:00	**Reception**		**17:45 – 20:00**	**Poster Session**				

Monday, June 15

08:00 Registration and coffee----

8:45 ***Introduction and Opening Remarks***

ESSAS Co-Chairs, and George Hunt

Welcome by Professor Andre Punt, Director, School of Aquatic and Fishery Sciences

Session 1 - *Humans, Ice and the Sea in the Subarctic and Arctic Past*

Co-Chairs: Ben Fitzhugh, Naomi Harada, and Anne De Vernal

09:10 Anne de Vernal, Claude Hillaire-Marcel, and Marie-Michèle Ouellet-Bernier. *Linking marine records of sea ice cover and productivity changes with archeological archives in western Arctic and sub-Arctic regions*

09:40 Max Friesen. *The ultimate sea ice adaptation? Archaeological implications of Inuinnait (Copper Inuit) winter life on the sea ice*

10:10 Laura Gemery and Thomas M. Cronin. *Paleo-sea ice and Arctic ecosystem reconstruction using Ostracode ecology and shell chemistry*

10:30 Megumi O. Chikamoto, Axel Timmermann, Naomi Harada, and Yusuke Okazaki. *Understanding North Pacific deglacial CaCO3 peaks*

10:50 ***Break - 30 min***

11:20 Lester Lembke-Jene, Gerrit Lohmann, Lars Max, Dirk Nürnberg, Xung Gong, Patrick Scholz, Maria Winterfeld, and Ralf Tiedemann. *Spatial characteristics of deglacial and Holocene upper ocean temperatures, sea ice and productivity in the subarctic northwest Pacific*

11:40 Arkady Savinetsky, Ekaterina Gorlova, Bulat Khasanov, Olga Krylovich, Dmitrii Vasyukov. *Sea ice and marine productivity in the North Pacific marginal seas and coasts over the Late Holocene*

12:00 Guðbjörg Ásta Ólafsdóttir, Einar Eg Nielsen, Kristen M. Westfall, Ragnar Edvardsson, Jakob Hemmer-Hansen, Sara Bonanomi, W.P. Patterson, Thomas H. McGovern, Símun V. Arge, J. Bond, and Snæbjörn Pálsson. *Cod Story: multidisciplinary research on Atlantic cod, climate and historical fisheries in the North Atlantic*

12:20 Kota Katsuki, Takuya Itaki, Naomi Harada, Boo-Keun Khim, Masao Uchida, Ryuji Tada**.** *Response of sea-ice and primary production in the Bering Sea to solar irradiance cycles and pressure shift patterns since the last deglaciation*

12:40 ***Lunch - 80 min***

Session 2 - *Role of Sea Ice in the Arctic and Sub-Arctic*

Co-Chairs: Kristin Laidre and Ken Drinkwater

14:00 James Overland and Muyin Wang**.** *Large Arctic climate changes, regional impacts*

14:20 Michael Steele. *Sea ice retreat and its impact on the Arctic Ocean*

14:40 Craig M. Lee, Marin Doble, Wieslaw Maslowski, Tim Stanton, Mary-Louise Timmermans, Jim Thomson, Jeremy Wilkinson, and the ONR Marginal Ice Zone Team**.** *Dynamics of the Marginal Ice Zone*

15:00 Kumiko Azetsu-Scott, Brian Petrie and Craig Lee**.** *Decrease of carbonate saturation states by freshwater input from a variety of sources in Davis Strait*

15:20 Haakon Hop. *Arctic sea ice biota in a variable and rapidly melting environment*

15:40 ***Break - 20 min***

16:00 Amane Fujiwara, Kohei Matsuno, Toru Hirawake, Shigeto Nishino, Koji Suzuki, Ryosuke Futsuki, Hisatomo Waga, Takashi Kikuchi and Sei-Ichi Saitoh. *Response of phytoplankton community structure to the wind-induced mixing during fall on the Chukchi shelf*

16:20 Samuel Laney**.** *Seasonal trends in Arctic ice, light, and phytoplankton measured under perennial sea ice cover using autonomous profilers*

16:40 Lisa Eisner, Jeannette Gann, Carol Ladd, Kristin Cieciel and Calvin Mordy. *Late summer/early fall phytoplankton biomass in the eastern Bering Sea: spatial and temporal variations and factors affecting chlorophyll a concentrations*

17:00 Meibing Jin, Rubao Ji and Øystein Varpe**.** *Modeling long term changes in Arctic marine primary production in response to declining sea ice cover*

17:20 Carin Ashjian, Robert Campbell, Rubao Ji, Stephen Okkonen**.** *How might the biogeography of zooplankton change as the Arctic warms?*

17:45 – 20:00 Welcoming Reception in the Lobby of the Fishery Sciences Building

Welcome by Professor Lisa J. Graumlich, Dean, School of the Environment

Presentation by Professor Ben Fitzhugh, Director, Quaternary Research Center.

"Integrative Physical, Biological, and Social Ecodynamics of High Latitudes: ESSAS and the Future of Ice."

Early presentation of posters also welcome.

Tuesday, June 16

08:00 Registration and Coffee----

Session 2 Continued - Role of Sea Ice in the Arctic and Sub-Arctic

Co-Chairs: Erica Head and Carin Ashjian

09:00 Neil S. Banas**.** *Timing, not temperature: Disentangling pathways from climate change to phytoplankton, microzoooplankton, and copepods in recent models of the Bering Sea and Disko Bay, Greenland*

09:20 Torkel Gissel Nielsen, Signe Jung-Madsen and Eva Friis Møller. *Some like it hot -* Calanus *in Disko Bay*

09:40 Benjamin Planque*. Projecting the responses of fish populations to changes in ice conditions in the Barents Sea*

10:00 Yui Kono, Hiroko Sasaki, Yukari Kurihara, Amane Fujiwara, Jun Yamamoto and Yasunori Sakurai. *Distribution pattern of Arctic cod (*Boreogadus saida*) larvae in the northern Bering Sea and Chukchi Sea in the summers of 2008, 2009, and 2013*

10:20 Kristina Lore Kunz, Hans-Otto Pörtner, Rainer Knust and Felix Christopher Mark*. Ocean acidification and warming: the physiology of two gadoid species under future ocean water conditions*

10:40 ***Break - 30 min***

11:10 Olafur S. Astthorsson and Hedinn Valdimarsson. *Effects of the ice years, 1965-1971, on the sub-arctic ecosystem in the southern Iceland Sea*

11:30 Kristin L. Laidre, Harry Stern, Kit M. Kovacs, Lloyd Lowry, Sue E. Moore, Eric V. Regehr, Steven H. Ferguson, Øystein Wiig, Peter Boveng, Robyn P. Angliss, Erik W. Born, Dennis Litovka, Lori Quakenbush, Christian Lydersen, Dag Vongraven and Fernando Ugarte. *Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century*

11:50 Peter Boveng. *The role of seals in the ice: Quantifying the abundance, distribution, seasonal movements, and prey consumption in the Bering Sea*

12:10 Anthony J. Gaston. *Ice break-up and breeding among marine birds of the Eastern Canadian Arctic*

12:30 ***Lunch - 90 min***

Session 3 - *Ecological Role of Tidewater Glaciers*

Co-Chairs: Mayumi Arimitsu and Franz Mueter

14:00 Shad O'Neel, Eran Hood and Allison Bidlack. *Implications of biophysical linkages in Alaska's icefield-to-ocean-ecosystem*

14:25 Fiamma Straneo and Mattias Cape. *Greenland glacial fjord dynamics and their impacts on coastal ocean processes*

14:50 Torkel Gissel Nielsen**.** *Impact of ice cover and freshwater discharge on the pelagic food web*

15:15 Andy Hodson and Aga Nowak**.** *A conceptual model of inorganic nutrient delivery to glaciated Arctic and sub-Antarctic fjords*

15:40 ***Break - 30 min***

16:10 Jamie N. Womble, Robert W. McNabb, Anupma Prakash, Rudi Gens, Jay M. Ver Hoef and Scott M. Gende. *Assessing the availability of glacial ice as habitat for harbor seals in a tidewater glacial fjord*

16:30 John F. Piatt, Gary Drew and Mayumi Arimitsu**.** *Pagophilia in the age of global warming: The ice ecology of the "Glacier Murrelet"?*

16:50 Mayumi Arimitsu and John Piatt. *Scale-dependent influence of coastal glaciers on marine food webs in Alaska*

17:10 Malene Simon, Dorte Søgaard, John Mortensen, Kristine Arendt, Martin Blicher and Thomas Juul Pedersen**.** *Effects of sea ice on glaciers and the ecosystem of glacial fjords in Greenland*

17:45 – 20:00 ***Poster Session and Reception, lobby, Fishery Sciences Building***

Wednesday, June 17

08:00 Registration and coffee

Session 4 - *Social scientific investigations of changing sea ice conditions*

Co-chairs: Alan Haynie, Henry Huntington, and Keith Criddle

08:30 Alan Haynie. *Session Introduction*

08:40 Julie Raymond-Yakoubian and Brandon Ahmasuk. *The social role of sea ice in Bering Strait region communities*

09:10 Vincent Gallucci. *The multiple roles of ice and Inuit sustainability*

09:30 Alf Håkon Hoel. *The process towards a fisheries regime for the Central Arctic Ocean*

09:50 ***Break - 30 min***

10:20 Linda Fernandez and Brooks Kaiser. *Marine invasive species in the Arctic: Spatial economic and ecological consequences of sea-ice change (1)*

10:35 Brooks Kaiser and Linda Fernandez. *Marine invasive species in the Arctic: Spatial economic and ecological consequences of sea-ice change (2)*

10:50 Keith R. Criddle. *Managing hotspots of ship-resource encounters to ensure natural and cultural protections from emerging cruise tourism in Arctic Alaska*

11:10 Betsy Baker. *How lawyers and regulators think about Arctic sea ice: A science-based (r)evolution?*

11:40 Alan Haynie and Lisa Pfeiffer. *The role of sea ice and Bering Sea commercial fisheries*

12:00 ***Lunch - 90 min***

Session 5 – *Invited and Contributed Papers*

Chairs: George Hunt, Olafur Astthorsson, Sei-Ichi Saitoh

13:30 Qinghua Ding, John M. Wallace, David S. Battisti, Eric J. Steig, Ailie J. E. Gallant, Hyung Jin Kim and Lei Geng. *Tropical forcing of the recent rapid Arctic warming in northeastern Canada and Greenland*

13:50 Masato Ito, Kay I. Ohshima, Jun Nishioka, Yoshimu Kusumoto, Genta Mizuta and Yasushi Fukamachi. *Sediment upward dispersion and frazil ice formation by strong wind events -A possible mechanism of iron supply to sea ice*

14:10 Katsunori Kimoto, Naomi Harada, Jonaotaro Onodera, Osamu Sasaki, Haruhisa Kano, Yuichiro Tanaka, Shigeto Nishino and Michiyo Yamamoto-Kawai. *Shell dissociation of marine calcifers in the western Arctic Ocean estimated by micro X-ray Computing Tomography*

14:30 Mary Beth Decker, Richard Brodeur, Sangay Dorji, Kristin Cieciel, James Ruzicka and Caren Barcelo. *Jellyfish and forage fish spatial overlap on the eastern Bering Sea shelf*

14:50 Donna D.W. Hauser, Kristin L. Laidre, Sandra L. Parker-Stetter, John K. Horne, Robert S. Suydam and Pierre R. Richard. *Foraging dives by Pacific Arctic beluga whales (*Delphinapterus leucas*) in association with a primary prey species, Arctic cod (*Boreogadus saida*)*

15:10 ***Break - 30 min***

15:40 Jan Ohlberger. *Climate impacts and density regulation in Northeast Arctic cod*

16:00 James R. Lovvorn, Aariel R. Rocha, Stephen C. Jewett, Douglas Dasher, Steffen Oppel and Abby N. Powell. *Limits to benthic feeding by eiders in a vital Arctic migration corridor due to localized prey and changing sea ice*

16:20 Hans-O. Pörtner. *Impacts of climate change on ocean biology: Physiological underpinnings, projections and uncertainty*

16:50 ***Open Discussion***

17:10 ***Conference Wrap–Up***

Abstracts
of
Oral Presentations

Session 1, Monday, June 15

Humans, Ice and the Sea in the Subarctic and Arctic Past

Co-Chairs: Ben Fitzhugh, Naomi Harada, and Anne De Vernal

Linking marine records of sea ice cover and productivity changes with archeological archives in western Arctic and sub-Arctic regions

Anne de Vernal[1], Claude Hillaire-Marcel[1], and Marie-Michèle Ouellet-Bernier[1]

[1] *Université du Québec à Montréal, Montréal, Canada, devernal.anne@uqam.ca*

Marine sediment records from the continental margins of Arctic and subarctic regions provide indications about paleoclimate and paleoceanographic conditions based on an array of micropaleontological and geochemical tracers. Among those, organic-walled microfossils such as dinocysts permit a reconstruction of sea-surface temperature, productivity and sea ice cover. Such parameters are important environmental components in paleo-Eskimo life, especially sea ice cover as a determinant of transport and fishing behavior. Dinocyst data from sediment cores collected in the Western Arctic, from the Chukchi Sea to Baffin Bay, provide information on past conditions during the Holocene (last 11000 years). They illustrate large scale changes with minimum sea ice cover or longer sea-ice free seasons in the western Arctic close to the Bering Strait at ~ 4500 years BP, which corresponds to the main migration phase of early Eskimos in the Canadian Arctic towards Greenland. This time interval also corresponds to maximum occurrence of whale bones in the Canadian Arctic and to relatively mild conditions, as recorded in northern Baffin Bay from both marine and ice core records. In the Disko Bugt area, West Greenland, a significant cooling marked by sea-ice increase and marine productivity drop is recorded ~1500 year ago, which also corresponds to a major decline in paleo-Eskimos population and a shift from mid- to late Dorset culture.

The ultimate sea ice adaptation? Archaeological implications of Inuinnait (Copper Inuit) winter life on the sea ice

Max Friesen

University of Toronto, Toronto, Canada, max.friesen@utoronto.ca

Across the North American Arctic, Inuit societies used sea ice for a wide range of activities, ranging from sled transportation to hunting and fishing. Most remarkably, many spent part of each year living on the sea ice in snow houses. Perhaps the most profoundly ice-dependent group was the Inuinnait ('Copper Inuit') of the Coronation Gulf region in the central Canadian Arctic. Inuinnait lived on the sea ice for roughly half of each year, hunting seals at their breathing holes, with virtually no access to other resources. For arctic archaeologists, this ethnographically-described pattern presents a tantalizing model which might explain many aspects of past subsistence and settlement patterns. However, at the same time it is a source of frustration, given that sea-ice-based settlements will for the most part be archaeologically invisible. In this paper, the early twentieth century Inuinnait settlement pattern will be described, and its archaeological correlates discussed. It will conclude with an attempt to determine whether the region's Middle Dorset occupation (ca. 2000 BP) had a similar pattern of sea ice use.

Paleo-sea ice and Arctic ecosystem reconstruction using Ostracode ecology and shell chemistry

Laura Gemery[1] and Thomas M. Cronin[1]

[1] *United States Geological Survey, Reston, Virginia, USA, lgemery@usgs.gov*

Marine ostracodes from Arctic and subarctic continental shelves, slopes and deep ocean basins are used to evaluate the relationship between climate variability, Arctic Ocean circulation, presence or absence of sea ice and sea-ice ecosystems. Ostracodes are a meiofaunal, bivalved group of Crustacea, ranging in size from ~0.5 to 2.0 mm, which secrete a calcareous ($CaCO_3$) shell commonly preserved in sediments. Ostracode species have ecological limits controlled by temperature, salinity, oxygen, sea ice, food and other habitat-related factors, which make them useful in paleoecology. In addition, the chemistry (Mg/Ca ratios, stable isotopes) of their shells is used for paleoceanographic reconstructions, especially for bottom water temperatures. Ostracodes can be applied to paleoecology and paleoceanography using a newly expanded Arctic Ostracode Database - 2015, providing species census data from nearly 1200 surface sediment samples collected by various expeditions during the past 50 years. This database can be used to analyze modern ecological and biogeographic patterns and to conduct downcore paleoceanographic reconstructions using fossil assemblages from box cores, multicores, gravity cores and piston cores collected from today's Arctic Ocean. We will present maps of the modern

distributions of key Arctic species and discuss their ecological significance and biogeographic affinities. Key indicator species (and habitat requirements) include: *Acetabulastoma arcticum* (perennial sea ice), *Polycope* spp. (high productivity, marginal sea ice), *Krithe hunti* and *Henryhowella asperrima* (deep ocean water masses), *Cytheromorpha macchesneyi* (shallow, brackish water), *Rabilimis* spp. (near-shore environments), and *Acanthocythereis dunelmensis* (shallow, muddy substrates). We will review ostracode ecological trends in the Bering-Chukchi Seas over the last 50 years to evaluate whether an ecosystem "regime shift" is evident from geographic changes in dominant, ecologically sensitive species. In addition, we will present downcore Quaternary faunal assemblage and shell chemistry results from the Northwind, Mendeleev, and Lomonosov Ridges that document centennial to orbital-scale (glacial-interglacial) ocean variability in Arctic marine productivity, temperature and circulation.

Understanding North Pacific deglacial $CaCO_3$ peaks

Megumi O. Chikamoto[1], Axel Timmermann[1], Naomi Harada[2], and Yusuke Okazaki[3]

[1] *University of Hawai'i, Honolulu, Hawai'i, USA, megumich@hawaii.edu*
[2] *Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan*
[3] *Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan*

Numerous paleo proxy records from the subarctic Pacific Ocean show two very pronounced deglacial peaks in carbonate content for the Heinrich 1/ Bølling-Allerød transition (during 15 - 13 ka) and for the Younger Dryas/Pre-boreal transition (during 13 - 11 ka). Focusing on the Heinrich 1/ Bølling-Allerød transition, some model simulations capture the switch from unstratified to stratified conditions and from cold to warm North Pacific conditions through oceanic and atmospheric connections between Atlantic and Pacific Oceans. To test the impact of these two scenarios (ocean stratification and heat uptake during Bølling-Allerød) on calcite production or preservation, we conduct a series of idealized experiments using the Earth System Model Intermediate Complexity LOVECLIM. The first scenario (SC1) mimics the reduction and enhancement of ocean stratification in the North Pacific Ocean during Bølling-Allerød using anomalous freshwater forcing. The second scenario (SC2) simulates the Heinrich 1 cooling and subsequent rapid warming of the North Pacific Ocean by applying heat forcing. Despite the large difference in Pacific Ocean circulation between these two scenarios, both processes are consistent with the sedimentary calcite peak in the subarctic Pacific Ocean during Bølling-Allerød period. In the SC1, the calcite peak is due to the variation of the ratio of organic carbon to CaCO3 flux through increased alkalinity. On the other hand, in the SC2, the peak is obtained from the nutrient and insolation availability in association with the sea-ice retreat. These results suggest the possibility that the centennial-scale calcite peaks would be the result of surface biogeochemical responses to the climate transition, not by the deep circulation response.

Spatial characteristics of deglacial and Holocene upper ocean temperatures, sea ice and productivity in the subarctic northwest Pacific

Lester Lembke-Jene[1], Gerrit Lohmann[1], Lars Max[1], Hartmut Kuehn[1], Xun Gong[2], Maria Winterfeld[1], Dirk Nürnberg[3] and Ralf Tiedemann[1]

[1] *Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany, lester.lembke-jene@awi.de*

[2] *School of Earth and Ocean Sciences, University of Cardiff, Wales, United Kingdom*

[3] *GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany*

The subarctic North Pacific and its marginal seas constitute a key area of ongoing rapid environmental changes, as observed in instrumental records of sea surface temperature (SST), sea ice, or nutrient inventories in upper and mid-depth waters. However, knowledge about past climatic and oceanographic variability beyond instrumental time series is limited. Few datasets exist that resolve past conditions and establish baselines of natural variations in the oceanic environment over the current Holocene warm period. The proxydata-based part of our study focuses on a collection of sediment records with good geographic coverage in the Okhotsk Sea, the Bering Sea, and the open subarctic Northwest Pacific. Alkenone Uk37-based SST estimates in connection with Mg/Ca data from planktic foraminifera provide information about hydrography and upper ocean stratification, while information about sea ice variations is derived from organic biomarker and microfossil data. We extend existing surface sediment proxy compilations to enable and/or validate quantitative reconstructions of temperatures, sea ice and productivity. We aim to decipher spatial and temporal changes in North Pacific upper ocean temperature, stratification and sea ice patterns by comparing multi-proxy data to results from time slice reconstructions (Pre-industrial, 9,000 and 6,000 years before present) carried out with the MPI-COSMOS fully coupled Earth System Model. Our data suggest a more complex pattern than previously reported in SST, thermocline temperature and stratification, as well as in formation of sea ice. Our results differ e.g. from earlier studies advocating a simpler, hemispheric-wide SST anti-phasing between the Holocene North Atlantic and North Pacific. In contrast to most climate models, which have difficulties in explaining the spatial heterogeneity in the North Pacific Ocean, our new climate model results capture most of the large-scale structures in Northern Hemisphere temperature trends.

Sea ice and marine productivity in the North Pacific marginal seas and coasts over the Late Holocene

Arkady Savinetsky[1], Ekaterina Gorlova[1], Bulat Khasanov[1], Olga Krylovich[1], Dmitrii Vasyukov[1]

[1] *Severtsov Institute, Russian Academy of Sciences, Moscow, Russia, arkadybs@rambler.ru*

Pagophilic species of mammals and birds are good indicators of sea ice conditions. We identified tens of thousands bones of mammals and birds from ancient Eskimo settlements and reconstructed the population dynamics of some hunted species like bowhead, walrus, bearded and ringed seals. During the periods of increased temperature the abundance of some species was 2-3 times less. Analysis of stable isotopes of bone collagen showed that the trophic position of higher consumers rises during the periods of increased sea ice conditions and marine productivity.

CodStory: Multidisciplinary research on Atlantic cod, climate and historical fisheries in the North Atlantic

Guðbjörg Ásta Ólafsdóttir[1], Einar Eg Nielsen[2], Kristen M. Westfall[3], Ragnar Edvardsson[1], Jakob Hemmer-Hansen[2], Sara Bonanomi[2], William P. Patterson[4], Thomas H. McGovern[5], Símun V. Arge[6], J. Bond, and Snæbjörn Pálsson[1]

[1] *University of Iceland, Reykjavik, Iceland, gudbjorg.asta.olafsdottir@gmail.com*
[2] *Technical University of Denmark, Silkeborg, Denmark*
[3] *VÖR Marine Research Institute, Iceland*
[4] *University of Saskatchewan, Saskatoon, Saskatchewan, Canada*
[5] *CUNY Graduate Center, Anthropology Department, New York, NY, USA*
[6] *National Museum of the Faroe Islands, Tórshavn, Faroe Islands*

Genetic variation and stable isotope signatures of Atlantic cod were examined over the period of 1500-1910 AD using zoo-archaeological material from excavations of fishing sites in western Iceland. The results showed loss of genetic variation in Atlantic cod, most likely associated with a population size reduction, and a shift in stable isotope signatures of apex predators both coinciding with the cooling of the northern hemisphere, or the onset of the ?little ice age?. In the current phase of the project we increase the geographical range of samples by including zoo-archaeological material from new excavations in the Faroe Islands and previously excavated material from the Scottish isles. Moreover, we use high resolution genetic markers (SNPs) facilitating inference on both population structure and adaptive dynamics. The combined pattern of temporal-spatial genetic variation and stable isotopic signatures of Atlantic cod and seabird bones over this geographical range allows evaluation of the stability of contemporary patterns and may provide further answers to fundamental questions in evolutionary ecology and fisheries management. For example, how climatic fluctuations have affected the population size, distribution ranges, feeding migrations and population structure of Atlantic cod across the North Atlantic and if either climate change or associated changes in the marine ecosystem have resulted in genetic adaptation in Atlantic cod. Although the current aims relate primarily to evolutionary biology and fisheries ecology, the groundwork laid by the potential results, as well as the methodological developments in retrospective eco-genetics, will very likely allow further

multidisciplinary projects on human ecodynamics in the North Atlantic as well as trade networks and historical economy.

Response of sea-ice and primary production in the Bering Sea to solar irradiance cycles and pressure shift patterns since the last deglaciation

Kota Katsuki[1], Takuya Itaki[2], Naomi Harada[3], Boo-Keun Khim[4], Masao Uchida[5], Ryuji Tada[6]

[1] Korea Institute of Geoscience and Mineral Resources, South Korea, kkota@kigam.re.kr
[2] Institute of Geology and Geoinformation/AIST, Geologic Survey of Japan, Japan
[3] Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan
[4] Pusan National University, Busan, South Korea
[5] National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan
6 University of Tokyo, Tokyo, Japan

Detailed diatom records within core sediments from the southern Bering continental shelf (SBCS) and northern Bering Sea slope reveal that the Holocene evolution of sea-ice distribution is associated with low pressure patterns and feedback system of solar irradiance change during the Bølling-Allerød period. Previous studies found decadal climate variability possibly related to solar activity, although the details regarding the feedback with the ocean environment and ecosystem remain unknown. Here we explored the feedback system during the Bølling-Allerød period, based on laminated sediments in the northern Bering Sea. During this period, well-ventilated water was restricted to the upper intermediate layer, and oxygen-poor lower intermediate water preserved the laminated sediment. An 11-year cycle of diatom and radiolarian flux peaks was identified from the laminated interval. Increased fresh meltwater input and early sea-ice retreat in spring under the solar irradiance maximum follow the positive phase of Arctic Oscillation which impacted the primary production and volume of upper intermediate water production in the following winter. Strength of this 11 year solar irradiance effect might be further regulated by the pressure patterns of Pacific decadal oscillation (PDO). Not only such short-term oscillation but also long-term shift of PDO phase also affected the strong impact for sea-ice distribution and primary productivity in the Bering Sea. Holocene sea-ice distribution over the SBCS was mainly controlled by the location of the Aleutian Low variation. Early Holocene was characterized by extensive sea-ice distribution under two low-pressure cells, which covered the western Bering Sea and the Gulf of Alaska, respectively. Between 3000 and 7000 cal. yr BP, the low-pressure system over the Gulf of Alaska became weak, causing a reduction of total sea-ice mass over the SBCS. In the past 3000 years, due to the development of Aleutian Low, prevailing southwesterly winds have reduced further sea-ice cover over the SBCS.

Session 2, Monday, June 15

Role of Sea Ice in the Arctic and Sub-Arctic

Co-Chairs: Kristin Laidre and Ken Drinkwater

Large Arctic climate changes, regional impacts

James Overland[1] and Muyin Wang[2]

[1] *Pacific Marine Environmental Laboratory, NOAA, Seattle, WA, USA, james.e.overland@noaa.gov*
[2] *University of Washington, Seattle, WA*

Increasing temperatures and other changes continued in the Arctic over the last decade, even though the rate of global warming has decreased in part due to a cool Pacific Ocean. Thus Arctic temperatures have increased at least 3 times the rate of mid-latitude temperatures. Credibility for persistent Arctic change comes from multiple indicators which are now available for multiple decades. A major indicator is the loss of sea ice volume, as much as 70 % since 1980. Further, the spatial pattern of Arctic Amplification differs from patterns of natural variability. The role of the Arctic in the global climate system is based on multiple interacting feedbacks represented by these indicators as a causal basis for Arctic Amplification driven by modest global change. Many of these processes act on a regional basis and their non-linear interactions are not well captured by climate models. We apply a two-step approach for regional sea ice projections, taking the Pacific and Atlantic Arctic as examples. The sea ice free season north of Bering Strait is forecast to extend from 3 months now to 5 months by 2040. CMIP5 based sea ice decadal forecasts for the Barents Sea are not reliable based on uncertainties in model ocean circulation. Thus, the use of CMIP5 model projections for societally relevant decadal forecasts are regionally and question dependent.

Sea ice retreat and its impact on the Arctic Ocean

Michael Steele

University of Washington, Seattle, WA, USA, mas@apl.washington.edu

Sea ice in the Arctic Ocean is on the decline. This is most often measured using the September sea ice extent minimum, but other sea ice parameters also show this decline, and may have a greater impact on the ocean and its ecosystems. Here we discuss early season sea ice loss and its impact on upper ocean warming. We also touch on changes in upper ocean stratification and mixing that result from sea ice loss.

Dynamics of the Marginal Ice Zone

Craig M. Lee[1], Marin Doble[2], Wieslaw Maslowski[3], Tim Stanton[3], Mary-Louise Timmermans[4], Jim Thomson[1], Jeremy Wilkinson[5], and the ONR Marginal Ice Zone Team[3]

[1] *University of Washington, Seattle, WA, USA, craig@apl.washington.edu*
[2] *Pierre and Marie Curie University, Paris, France*
[3] *Naval Postgraduate School, Monterey, California, USA*
[4] *Woods Hole Oceanographic Institution, Woods Hole, MA, USA*
[5] *Scottish Association for Marine Science, Oban, Scotland, UK*

The observed reduction of Arctic summertime sea ice extent and expansion of the marginal ice zone (MIZ) have profound impacts on the balance of processes controlling sea ice evolution, including the introduction of several positive feedback mechanisms that may act to accelerate melting. Examples of such feedbacks include increased upper ocean warming though absorption of solar radiation, elevated internal wave energy and mixing that may entrain heat stored in subsurface water masses (e.g. the relatively warm Pacific Summer (PSW) and Atlantic (AW) waters) and elevated surface wave energy that acts to deform and fracture sea ice, all of which grow in importance with increasing open water extent. Investigations of MIZ dynamics must resolve the short spatial and temporal scales associated with the processes that govern the exchange of momentum, heat and freshwater near the atmosphere-ice-ocean interface while also achieving the spatial scope and temporal persistence required to characterize how the balance of processes shifts as a function of evolving open water fraction and open water fetch to the south. The recent Office of Naval Research (ONR) Marginal Ice Zone program employed an integrated system of autonomous platforms to provide high-resolution measurements that extend from open water, through the MIZ and deep into ice-covered regions while providing persistence to quantify evolution over an entire summertime melt season. This talk will provide an overview of the strategy developed by the ONR MIZ team and present early results from the 2014 field program.

Decrease of carbonate saturation states by freshwater input from a variety of sources in Davis Strait

Kumiko Azetsu-Scott[1], Brian Petrie[1] and Craig Lee[2]

[1] *DFO, Bedford Institute of Oceanography, Canada, kumiko.azetsu-scott@dfo-mpo.gc.ca*
[2] *Applied Physics Laboratory, University of Washington, Seattle, WA, USA*

Davis Strait connects the North Atlantic and the Arctic Ocean through the Canadian Arctic Archipelago (CAA) and Baffin Bay. The flows through the CAA are integrated at the Strait making it an ideal gateway to observe the interaction between the Arctic and the North Atlantic. The rapidly changing polar environment including melting sea ice, surface warming, enhanced transport of warm water from the south, and the Greenland ice sheet melt can influence air-sea CO2 flux, nutrient cycles and ocean acidification. CaCO3 saturation states (Ω) and pH together with freshwater composition using multiple chemical tracers were studied along Davis Strait. The distribution of dissolved inorganic carbon (DIC) and total alkalinity (TA), consequently Ω, were strongly influenced by water mass structure. Low Ω was associated with the Arctic outflow in the upper 300 m on the western side of the Strait, and extended to >50 km offshore. The Arctic outflow through the CAA has a high content of Pacific Water, which has a lower saturation state than the receiving Atlantic Water; ê is further lowered due to modification by ice-melt and fluvial input during its transit through the CAA and Baffin Bay. Glacial meltwater from the Greenland Ice Sheet is a major freshwater source on the West Greenland Shelf. In Disko Bay, a deep ocean fjord with a large outlet glacier in West Greenland, pH and Ω were comparatively low at the glacial front with a lower TA/DIC ratio than offshore. They increased as the salinity increased away from the glacial front. Accelerating melt of the Greenland Ice Sheet will affect the CaCO3 saturation state of waters on West Greenland Shelf and continuing monitoring is necessary.

Arctic sea ice biota in a variable and rapidly melting environment

Haakon Hop

Norwegian Polar Institute, Tromsø, Norway, haakon.hop@npolar.no

The sympagic, or ice-associated ecosystem, contains both ice algae and a specific fauna ranging from microscopic protozoans to polar bears. The ice algae grow on the underside of the ice and bloom about two months prior to the phytoplankton in the Arctic. Ice algae constitute an early food source for sympagic organisms, which time their life cycle to match the production of one or both of ice algae and phytoplankton. Sea ice also provides a platform as habitat for animals living in or on the ice. Some organisms depend on the ice for their entire life cycle

(autochthonous), whereas others utilize the sea ice during parts of their life cycle (allochthonous). The autochthonous macrofauna typically include ice amphipods, whereas ice-associated zooplankton and polar cod (*Boreogadus saida*) use the sea ice as seasonal habitat for shelter and feeding. The charismatic megafauna living on top of the ice include seabirds and marine mammals, such as Arctic seals, walrus and polar bear. Sea ice-derived organic matter continues to be an important early food source for sympagic, pelagic and benthic biota in the Arctic. However, sea ice habitats appear to be undergoing change with regard to availability and suitability for associated biota during their entire life cycles, as indicated by regional declines in abundance and biomass of certain taxa. Multiyear ice habitat is declining and pressure ridges in first-year ice may become increasingly important as refugia for sympagic organisms. Due to inter-annual decline in sea ice extent and thickness, particularly the disappearance of multi-year sea ice, this ecosystem may be permanently lost in < 50 years. The pelagic realm will then take completely over in an ice-free Arctic Ocean during summer, but will likely be productive only on the shelves and nutrient limited in the central Arctic Ocean.

Response of phytoplankton community structure to the wind-induced mixing during fall on the Chukchi shelf

Amane Fujiwara[1], Kohei Matsuno[2], Toru Hirawake[1], Shigeto Nishino[3], Koji Suzuki[1], Ryosuke Futsuki[1], Hisatomo Waga[1], Takashi Kikuchi[2] and Sei-Ichi Saitoh[1]

[1] *Hokkaido University, Hakodate, Hokkaido, Japan, amane@salmon.fish.hokudai.ac.jp*
[2] *National Institute of Polar Research, Tachikawa-shi, Tokyo, Japan*
[3] *Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan*

Recent sea ice decline alters not only the marine environment, but also atmospheric conditions in the Arctic Ocean. The number of storms has been increasing due to the shrinking of the sea ice area. As a result, the phytoplankton fall bloom has become more common due to the wind-induced mixing. However, changes in phytoplankton community composition during the storm event are totally unknown. Therefore, we tried to clarify the response of phytoplankton community structure to a strong wind event during fall and to infer the energy transfer from the phytoplankton to secondary producers by conducting a fixed-point observation (FPO) in the Northern Chukchi shelf. The FPO was carried out at 72.75 °N, 168.25 °W from 11 to 25 September 2013. We conducted CTD deployments with water sampling for nutrients and chlorophyll-*a* every 6-hours, and HPLC phytoplankton pigment samples were collected every 24-hours. Zooplankton were also collected with a NORPAC net every 6- or 12-hours. Phytoplankton community composition was inferred from the pigment signatures with cluster analysis. We also measured gut pigments in the copepod *Calanus glacialis* by a fluorometric method. The strong storm event was observed at the station on 19 September 2013. The wind-induced vertical mixing was strong enough to supply nutrients from below, and enhanced

chlorophyll-*a* was observed in the surface mixed layer (~25 m). The change in phytoplankton community composition was also found in the upper layer: diatoms became dominant in the algal community, instead of a community dominated by haptophytes and dinoflagellates. In addition, gut pigment contents in *C. glacialis* significantly increased after the storm. Our results revealed that the seasonal patterns of phytoplankton community composition could change due to storm events. Moreover, if the diatom-dominated fall blooms induced by storms become more prominent in the future, secondary producers may increase their recruitment by obtaining more energy before overwintering.

Seasonal trends in Arctic ice, light, and phytoplankton measured under perennial sea ice cover using autonomous profilers

Samuel Laney

Woods Hole Oceanographic Institution, Woods Hole, MA, USA, slaney@whoi.edu

Between 2011 and 2013 eight Ice-Tethered Profilers (ITPs) were outfitted with bio-optical/biogeochemical sensor suites and deployed in perennially ice-covered regions of the Arctic Ocean. These deployments represent an important new approach for obtaining biological and bio-physical observations of the changing Arctic in ocean ecosystems that are extremely difficult to sample over seasonal and annual scales. These ITPs were deployed in the central Arctic and Beaufort Gyre and carried sensors for chlorophyll fluorescence, optical scattering, CDOM fluorescence, and incident solar radiation. They have generated unique, long-term and high-resolution time series of under-ice irradiance, algal biomass, particulate scattering, and organic matter concentrations in the top 800m of the Arctic Ocean, with profiles conducted daily or better. Two of these systems operated for twelve months or longer, capturing the entire annual trend in these bio-optical properties in the central Arctic Ocean and Beaufort Sea respectively. These observations were used to estimate the timing and duration of the under-ice algal growing season, the subsequent export of particulate organic matter later in the season, and the occurrence of intermittent physical perturbations that affect biological and bio-optical distributions. The ITP's high-resolution profiling enables a more accurate temporal assessment of the timing and magnitude of intermittent events down to the time scale of less than a single day, in principle. These initial eight profilers provide some of the highest-resolution observations of the basic seasonality in fundamental biological and bio-physical dynamics in perennially ice-covered regions of the Arctic Ocean, and demonstrate the utility of autonomous long-term observing in the deep central Arctic.

Late summer/early fall phytoplankton biomass in the eastern Bering Sea: spatial and temporal variations and factors affecting chlorophyll a concentrations

Lisa Eisner[1], Jeannette Gann[2], Carol Ladd[1], Kristin Cieciel[2] and Calvin Mordy[3]

[1] *Alaska Fisheries Science Center, NOAA, Seattle, WA, USA, lisa.eisner@noaa.gov*
[2] *Alaska Fisheries Science Center, NOAA, Juneau, AK, USA*
[3] *Pacific Marine Environmental Laboratory, NOAA, Seattle, WA, USA*

The spatial and temporal variability of late summer/early fall phytoplankton biomass from in situ chlorophyll a (Chla) concentrations was investigated over a 10-year time period from 2003-2012 in the eastern Bering Sea, encompassing both warm, (2003-2005) and cold (2007-2012) temperature regimes. Warm temperature regimes were characterized by above average water temperatures and low seasonal sea ice extent and cold by below average temperatures and high sea ice extent. The highest phytoplankton biomass was observed near the Pribilof Islands and the southeastern shelf break where nutrients were high due to onshore flow from Pribilof and Bering Canyons. Lowest biomass was observed on the northeastern middle and inner shelf, north of Nunivak and St. Matthew Islands and south of St. Lawrence Island (~61- 63°N). In the southeastern Bering Sea, total phytoplankton biomass was significantly higher in warm compared to cold years on the outer shelf and portions of the middle shelf. Biomass of large phytoplankton was higher in warm years over most of the southern middle-shelf. On the southern middle shelf, wind mixing and temperature below the pycnocline had strong positive associations with integrated Chla (total and large-size fraction), explaining 85% of the variability in mean phytoplankton biomass. This indicates that biomass in summer and early fall is affected by wind-induced upwelling of nutrients to the surface and possibly by other bottom up effects such as temperature-mediated growth. Higher bottom temperature is related to reductions in sea ice extent which may elicit ecosystem responses such as reduced biomass of large crustacean zooplankton grazers, potentially due to the removal of ice algae, an important food resource for zooplankton in early spring. Overall, spatial and temporal variations in phytoplankton biomass are due to a combination of factors, from local inputs of nutrients related to mixing or advection, up to large scale ecosystem effects.

Modeling long term changes in Arctic marine primary production in response to declining sea ice cover

Meibing Jin[1], Rubao Ji[2] and Øystein Varpe[3]

[1] *IARC, University of Alaska Fairbanks, Fairbanks, AK, USA, mjin@alaska.edu*
[2] *Woods Hole Oceanographic Institution, Woods Hole, MA, USA*
[3] *University Centre in Svalbard, Longyearbyen, Spitsbergen, Norway*

The Arctic marine ecosystem is experiencing rapid changes in response to global warming, but a pan-Arctic quantification of long-term changes is still not available due to the limited spatial and temporal coverage of observations. Here we present results from a global coupled ice-ocean ecosystem model which was developed within the Community Earth System Model (CESM) ocean and sea ice modules, including the Parallel Ocean Program (POP) and the Los Alamos sea ice model (CICE). The model was forced by National Center for Environmental Prediction (NCEP) reanalysis data (1948-2009) and validated by observed ecosystem changes in order to produce a pan-Arctic quantification of long term changes in both ice algae and phytoplankton. We analyzed total production as well as its timing (phenology). The model suggests that the following ecosystem changes have taken place during the last 50 years (1960-2009): 1) A decreasing ice area and increasing ice algal and pelagic primary production (PP). The ocean PP increase was mainly due to the increase of ice-free areas as well as increased production rate associated with higher water temperature. The under ice PP was stable or slightly increasing. 2) See ice area decreased in all of the Arctic except for a small area to the north of Canada. Ice algal production decreased in the subarctic and coastal Arctic, but increased in the Arctic Basin under pack ice, which agrees with field observation by Boetius *et al.* (2013). 3) The sea surface temperature (SST) increased except for the area north of Greenland. The pelagic PP decreased in the Bering Sea shelf but increased in most of the Arctic. 4) Annual mean pelagic PP is significantly and negatively correlated with sea ice area, while ice algal PP and pelagic PP under ice are not correlated. 5) The changes in the peak timing of ice algal and phytoplankton blooms showed large spatial variability.

How might the biogeography of zooplankton change as the Arctic warms?

Carin Ashjian[1], Robert Campbell[2], Rubao Ji[3], Stephen Okkonen[4]

[1] *Woods Hole Oceanographic Institution, Woods Hole, MA, USA, cashjian@whoi.edu*
[2] *University of Rhode Island, Narragansett, RI, USA*
[3] *Woods Hole Oceanographic Institution, Woods Hole, MA, USA*
[4] *SFOS, University of Alaska Fairbanks, Kasilof, AK, USA*

The trends toward less sea ice and a longer open-water season may have significant impacts on the phenology of the Arctic marine ecosystem, including the timing of primary production and the resulting recruitment success of the secondary producers such as the copepod *Calanus glacialis*. These changes may in turn modify the geographic range over which populations of copepods are self-sustaining. Using *Calanus glacialis* as a model species, an individually-based copepod development model was coupled to a physical ocean model to explore the factors defining the observed distribution of this species. The length of the growth season was critical to the species' success, defined as the ability to develop to the diapausing stage C4 during a season. Higher ocean temperatures and a longer growth season increased the spatial distribution of *C. glacialis* slightly but it still was unable to successfully recruit in the central Arctic. Modeling studies such as this highlight our lack of understanding of winter conditions in the Arctic, particularly for a species such as *C. glacialis* with an obligate overwintering stage. In 2011, we conducted an early winter cruise in November-December 2011 on the USCGC Healy to the Chukchi and Bering Seas. Our objectives included identifying the overwintering habitat, activity, and grazing rates of *C. glacialis*. Surprisingly, *C. glacialis* did not appear to be in diapause on the shelves but rather retained low levels of activity including feeding on the very low available phytoplankton and microzooplankton stocks. Based on estimates of metabolically required lipid expenditures and observed lipid stores, *C. glacialis* may not successfully overwinter on the shallow Chukchi Shelf unless they can further reduce their metabolism as the season progresses. Future warmer overwintering conditions would certainly put them at greater risk.

Session 2 (continued), Tuesday, June 16

Role of Sea Ice in the Arctic and Sub-Arctic

Co-Chairs: Erica Head and Carin Ashjian

Timing, not temperature: Disentangling pathways from climate change to phytoplankton, microzoooplankton, and copepods in recent models of the Bering Sea and Disko Bay, Greenland

Neil S. Banas

University of Washington, Seattle, WA, USA, neil@ocean.washington.edu

Climate variability in subarctic seas brings simultaneous changes in water temperature, ice cover, turbulent mixing, and seasonal timing of all these variables. Here I present results from new numerical models of 1) primary production in the Bering Sea, 2) productivity of large copepods in the Bering Sea, and 3) copepod community structure in Disko Bay, Greenland designed to distinguish these pathways. The Bering Sea primary production model is a custom nutrient-phytoplankton-zooplankton model validated against a variety of biomass and rate data from the Bering Ecosystem Study (BEST) field program. Bering Sea and Disko Bay copepods were simulated using a new, optimal-life-history-based model ("Coltrane": Copepod Life-history Traits and Adaptation to Novel Environments) which was found to accurately reconstruct time series of *Calanus glacialis/marshallae* abundance in the Bering Sea in relation to temperature and ice cover, and the coexistence of three *Calanus* species/life-history strategies in Disko Bay. In each case, model experiments were conducted to assess the relative sensitivity of the plankton to effects of ice cover, light, and phenology on the one hand, and direct effects of temperature on growth rates and community metabolism on the other. In each case, the model suggests that increasing temperatures per se have minor or positive effects on the plankton functional group in question--the opposite of the tipping-point responses that have been hypothesized by others. At the same time, both primary and secondary production are shown to be highly sensitive to changes in ice cover and growing season length that are correlated with temperature on interannual and longer scales.

Some like it hot - *Calanus* in Disko Bay

Torkel Gissel Nielsen[1], Signe Jung-Madsen[1], Eva Friis Møller[2]

[1] *Technical University of Denmark, Charlottenlund, Denmark, tgin@aqua.dtu.dk*
[2] *Aarhus University, Roskilde, Denmark*

The ongoing temperature increase in the Arctic affects the succession patterns in the marine pelagic ecosystem. Reduction and earlier breakup of sea ice changes the initiation of the spring bloom. Along the Greenland coast three species of *Calanus* dominate the zooplankton; *C. hyperboreus*, *C. glacialis* and *C. finmarchicus. C. hyperboreus* and *C. glacialis* are large lipid rich Arctic species, whereas *C. finmarchicus* is a smaller North Atlantic species. During the last two decades we have investigated the *Calanus* community in the Disko Bay, western Greenland. *Calanus* are impacted by the environmental changes, directly through their physiological rates as egg production, development, growth, and metabolic cost and indirectly via the environment through changes in ice cover, salinity, and food availability. The *Calanus* species have different lifecycles and show different responses to increasing temperatures. The aim of this talk is to discuss possible effects of climate change on coexisting *Calanus* species. Our result from in situ and laboratory studies illustrates that *Calanus* in Disko Bay are well adapted to Arctic conditions with unpredictable pulses of food. All three species continue reproduction when starved. Pre-feeding history of *C. glacialis* and *C. finmarchicus* are important to the starvation response as it affects gonad maturation. Only *C. finmarchicus* that have previously fed will continue egg production during starvation, unlike *C. glacialis* that sustain egg production without food. This advantage however diminishes with increasing temperature. At temperatures above 5 °C both starved and fed *C. finmarchicus* can produce egg at a rate similar to *C. glacialis*. The reproduction by the winter spawner *C. hyperboreus* seemed to be endogenously controlled, as neither food nor temperature affect reproductive output. The eggs of *C. hyperboreus* develop relatively fast at low temperature, and nauplii can survive long periods of starvation.

Projecting the responses of fish populations to changes in ice conditions in the Barents Sea

Benjamin Planque

Institute of Marine Research, Tromsø, Norway, benjamin.planque@imr.no

Projecting the possible consequences of changes in sea ice conditions on fish populations is of particular importance for the management of fisheries in the Barents Sea. This presentation reviews some hypotheses about how changes in sea ice can directly or indirectly affect fish populations in the Barents Sea, and in which form these changes may be manifested. Changes in sea ice are expected to affect productivity, phenology, spatial distributions of individual fish populations as well as of their prey and predator species. In addition, changes in sea ice are

anticipated to be accompanied by concomitant changes in ocean temperature, circulation patterns and chemistry. These multiple complex processes and their interactions must be considered simultaneously in order to project the future state of fish populations. Three approaches can be used to handle such complexity: expert knowledge, process-based models and non-deterministic models. It is argued that each approach taken individually suffers severe limitations but that realistic projections may be achieved by using a combination of these.

Distribution pattern of Arctic cod (*Boreogadus saida*) larvae in the northern Bering Sea and Chukchi Sea in the summers of 2008, 2009, and 2013

Yui Kono, Hiroko Sasaki, Yukari Kurihara, Amane Fujiwara, Jun Yamamoto, and Yasunori Sakurai

Hokkaido University, Japan, hiro_sasaki@salmon.fish.hokudai.ac.jp

Arctic cod, *Boreogadus saida*, is a "key species" in the Arctic Ocean ecosystem. We examined the distribution pattern of *B. saida* and other fish larvae in relation to environmental conditions in the northern Bering and Chukchi seas during the summers of 2008, 2009 and 2013. Sampling was conducted on-board the T/S Oshoro Maru using a bongo net in all three years. A total of 1198 individuals comprising seven families and 17 species were collected, with *B. saida* (39%) and *Ammodytes hexapterus* (27%) dominating the catch. Based on the species composition (cluster analysis), the sampling stations were divided into three groups. Groups A, B, and C were typified by the presence of *Lepidopsetta bilineata*, *Lumpenus* sp., and *B. saida*, respectively. Group A was characterized by relatively high temperatures (mean 2.1 °C). Conversely, group B was characterized by low temperatures (mean -0.2 °C) and long duration from sea ice retreat timing (dSRT) (mean 50 days). Group C had similar temperatures and salinities compared with those of group B but had a shorter dSRT (mean 34.4 days). A number of *B. saida* were captured in the regions where temperatures ranged from -2 to 0 °C. Moreover, stations with a higher distribution of smaller sized larval *B. saida* were characterized by a short dSRT, whereas stations with a lower distribution and a larger size were characterized by a long dSRT. This highlights the influence of timing in sea ice retreat, which probably affects the recruitment of *B. saida* larvae.

Ocean acidification and warming: The physiology of two gadoid species under future ocean water conditions

Kristina Lore Kunz, Hans-Otto Pörtner, Rainer Knust and Felix Christopher Mark

Alfred Wegener Institute for Marine and Polar Research, Bremerhaven, Germany,
kristina.kunz@awi.de

In response to climate change, the oceans are experiencing a distinct warming trend in parallel with increasing acidification. Rising water temperatures are reported to provoke a distribution shift of Atlantic cod (*Gadus morhua*) to the north, entering the habitat of the endemic key species Polar cod (*Boreogadus saida*). Many investigations have focused on the effects of ocean warming on fish physiology. However, knowledge about the impact of the combined drivers ocean acidification and warming (OAW) is still scarce. In the present study, we investigated the competitive strengths of Polar cod and Atlantic cod which are influenced by a balanced energy budget in each of those species. Therefore, we investigated the combined effects of OAW on energy allocation in populations of both co-occurring gadoid species originating from their distribution boundaries. We incubated Polar cod and Atlantic cod under various control and projected temperature/PCO2 scenarios for four months. Growth and food consumption were recorded continuously, followed by measurements of standard and active metabolic rates of each specimen at the end of the experiment. A clear temperature effect on growth and food consumption was evident in both species, whereas a synergistic impact of OAW could not be detected. Despite reduced food intake in the cold, the ratio of weight gain and food intake of Polar cod was highest at low temperatures (0 °C). Atlantic cod showed progressively rising growth and food consumption with increasing temperatures in the range between 3 and 16 °C. The data indicate that Polar cod specializes on the low temperatures it faces in its natural habitat and thereby escapes competitive pressure. Atlantic cod rather displays high plasticity towards changing abiotic conditions but is less competitive in the cold. The data for growth and food consumption will be discussed in light of a varying metabolic energy demand under OAW conditions.

Effects of the ice years, 1965-1971, on the sub-arctic ecosystem in the southern Iceland Sea

Olafur S. Astthorsson and Hedinn Valdimarsson

Marine Research Institute, Reykjavík, Iceland, osa@hafro.is

The term “ice years” is used for the cold period that suddenly occurred and persisted north of Iceland during 1965-1971. Sea ice during this period was brought to the north coast of Iceland in greater quantities than during earlier and later decades. Flow of Atlantic Water onto the northern shelf was also reduced leading to lower salinity and temperatures. The initiation of this period has been connected to the Great Salinity Anomaly in the North Atlantic Ocean. In combination, this led to marked changes at all levels in the ecosystem in the southern Iceland Sea. Increased stratification resulted in reduced primary production, followed by reduction in zooplankton biomass and changes is species composition. Eventually fish catch was also affected (herring, salmon), as was the nutritional condition of cod. Further, these environmental changes along with heavy exploitation are believed to have contributed to changes in the migration pattern and eventual collapse of the Atlanto-Scandian herring and the subsequent increase in capelin. These oceanographic changes and effects on the ecosystem in the southern Iceland Sea are reviewed in the presentation.

Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century

Kristin L. Laidre[1], Harry Stern[1], Kit M. Kovacs[2], Lloyd Lowry[3], Sue E. Moore[4], Eric V. Regehr[5], Steven H. Ferguson[6], Øystein Wiig[7], Peter Boveng[8], Robyn P. Angliss[9], Erik W. Born[10], Dennis Litovka[11], Lori Quakenbush[12], Christian Lydersen[2], Dag Vongraven[2] and Fernando Ugarte[10]

[1] *University of Washington, Seattle, WA, USA, klaidre@uw.edu*
[2] *Norwegian Polar Institute, Tromso, Norway*
[3] *SFOS, University of Alaska Fairbanks, Kailua Kona, HI, USA*
[4] *NOAA Fisheries, Silver Spring, Maryland, USA*
[5] *U.S. Fish and Wildlife Service, Washington, D.C., USA*
[6] *Fisheries and Oceans Canada, Ottawa, Ontario, Canada*
[7] *Natural History Museum, Oslo, Norway*
[8] *Alaska Fisheries Science Center, NOAA, Seattle, WA, USA*
[9] *Northwest Fisheries Science Center, NOAA, Seattle, WA, USA*
[10] *Greenland Institute of Natural Resources, Nuuk, Sermersooq, Greenland*
[11] *ChukotTINRO, Anadyr, Chukotka, Russia*
[12] *Alaska Department of Fish and Game, Juneau, AK, USA*

Arctic marine mammals (AMMs) are icons of climate change, largely because of their close association with sea ice. However, neither a circumpolar assessment of AMM status nor a standardized metric of sea ice habitat change is available. We summarized available data on abundance and trend for each AMM species and recognized subpopulation. We also examined species diversity, the extent of human use, and temporal trends in sea ice habitat for 12 regions of the Arctic by calculating the dates of spring sea ice retreat and fall sea ice advance from satellite data (1979-2013). Estimates of AMM abundance varied greatly in quality, and few studies were long enough for trend analysis. Of the AMM subpopulations, 78% (61 of 78) are legally harvested for subsistence purposes. Changes in sea ice phenology have been profound. In all regions except the Bering Sea, the duration of the summer (i.e., reduced ice) period increased by 5 to 10 weeks and by >20 weeks in the Barents Sea between 1979 and 2013. In light of generally poor data, the importance of human use, and forecasted environmental changes in the 21st century, we recommend the following for effective AMM conservation: maintain and improve co-management by local, federal, and international partners; recognize spatial and temporal variability in AMM subpopulation response to climate change; implement monitoring programs with clear goals; mitigate cumulative impacts of increased human activity; and recognize the limits of current protected species legislation.

The role of seals in the ice: Quantifying the abundance, distribution, seasonal movements, and prey consumption in the Bering Sea

Peter Boveng

Alaska Fisheries Science Center, NOAA, Seattle, WA, USA, peter.boveng@noaa.gov

The number of bearded, ringed, spotted, and ribbon seals in the Bering Sea likely exceeds one million individuals during the period of ice cover in winter and spring. Numerical considerations alone justify their inclusion in studies and models of ecosystem dynamics, but these species are also important for their upper-trophic predatory roles and are essential for the nutrition and cultural well-being of Alaskan coastal communities. Unfortunately, there has been little quantitative documentation of the abundance, distribution, seasonal movements, and diets of ice-associated seals to enable inclusion of them in integrated ecosystem studies. In this presentation, I describe progress in acquiring that information. Recent aerial surveys of the Bering Sea will provide reliable estimates of abundance and distribution during spring, and tracking studies help to extend that inference to other seasons and sea basins. Quantitative information on diet composition may remain the most challenging element, but there is good documentation of the prey taxa consumed, and which prey are likely to be consumed in the greatest amounts. An understanding of these fundamental aspects of ice-seal ecology is essential for evaluating the species' prospects for persistence in a warming climate and diminished sea-ice regime.

Ice break-up and breeding among marine birds of the Eastern Canadian Arctic

Anthony J. Gaston

Environment Canada, Montréal, Canada, tonygastonconsult@gmail.com

Arctic waters extend far to the south in eastern Canada and complete winter ice cover is found throughout Hudson Bay, Davis Strait and the waters of the Labrador Shelf, so that seasonal ice-cover prevails over a great range of latitude. The break-up of winter ice cover enables reproduction by marine birds and historical evidence suggests that the timing has a strong effect both on date of egg-laying and on reproductive success. Although these relationships are well established, we know little about the causal connections between timing of breeding and reproductive success. In this paper I review studies of timing of breeding in relation to ice cover and examine processes that may connect reproductive success with date of egg-laying. I use these relationships to predict the likely consequences of advancing date of ice break-up and the retreating date of freeze-up on marine bird population dynamics.

Session 3, Tuesday, June 16

Ecological Role of Tidewater Glaciers

Co-Chairs: Mayumi Arimitsu and Franz Mueter

Implications of biophysical linkages in Alaska's icefield-to-ocean ecosystem

Shad O'Neel[1], Eran Hood[2] and Allison Bidlack[2]

[1] Alaska Science Center, United States Geologic Survey, Anchorage, AK, US, soneel@usgs.gov
[2] University of Alaska Southeast, Juneau, AK, USA

Rates of glacier mass loss in the northern Pacific coastal temperate rainforest (PCTR) are among the highest on Earth, and changes in glacier volume and extent will impact the flow regime and chemistry of coastal rivers, as well as the nearshore marine ecosystem of the Gulf of Alaska. Here we synthesize physical, chemical and biological linkages that characterize the northern PCTR ecosystem, with particular emphasis on the potential impacts of glacier change in the coastal mountain ranges on the surface-water hydrology, biogeochemistry, coastal oceanography and aquatic ecology. In this talk we focus on the unique biophysical linkages at tidewater glaciers, and the potential for ecosystem change as the deep-water calving fronts vanish. Developing an understanding of the links between physical (hydrological) drivers and ecological trajectories will thus allow for improved science-based resource management and economic decision-making over a range of management issues ranging from infrastructure, tourism and fisheries management. To advance our knowledge of the northern PCTR, we advocate for cross-disciplinary research bridging the icefield-to-ocean ecosystem that can be paired with long-term scientific records and designed to inform decision makers.

Greenland glacial fjord dynamics and their impacts on coastal ocean processes

Fiamma Straneo and Mattias Cape

Woods Hole Oceanographic Institution, Woods Hole, MA, USA, mcape@whoi.edu

Mass loss from the Greenland Ice Sheet (GrIS) quadrupled over the past two decades owing to increased surface melt and the widespread retreat and speedup of marine-terminating glaciers. These physical changes have sparked interest in Greenland's glacial fjords - the conduits between the large-scale ocean and the ice sheet - for two reasons. First, it is plausible that a sizable portion of the observed glacier acceleration and retreat was triggered by increased submarine melting of the glaciers' margins. Second, the melt water from Greenland must transit through the fjord before reaching Greenland's continental shelves - where it can impact the ocean circulation and the downstream marine ecosystems. Using data collected from several Greenland fjord/glacier systems we show that the freshwater discharge in these coastal waters is mediated by a complex interplay of atmospheric forcing, subglacial processes, as well as both shelf and fjord dynamics. In these strongly stratified waters dominated by relatively cold, fresh Polar Waters overlying warm, salty Atlantic Waters, the discharge of surface and submarine melt at depth can result in subsurface intrusions of a third water mass. These glacially modified waters ultimately govern the freshwater export both at the surface and at depth. Ocean circulation within the fjords, which results from the interplay between buoyancy-driven (i.e. driven by glacial inputs) and shelf-driven flows (a consequence of gradients between fjord and continental shelf waters), in turn regulates this export by controlling melt processes as well as the residence time of glacially modified waters in these systems. While freshwater input into surface waters can fundamentally impact the marine ecosystem via changes in water column stratification and the biochemistry of surface waters, a better understanding of variability within these systems is needed to constrain the consequences of GrIS mass loss on the coastal ocean.

Impact of ice cover and freshwater discharge on the pelagic food web

Torkel Gissel Nielsen

Technical University of Denmark, Charlottenlund, Denmark, tgin@aqua.dtu.dk

Located at the junction between the Greenland Ice Sheet and the ocean, Greenland fjords are dynamic outlets that are influenced by both terrestrial and marine processes. The hydrography and ice cover of the fjords and coastal zone will be influenced by enhanced freshwater discharge from the Ice Sheet in a warmer future. Increased freshwater outflow will impact the hydrography through freshening the surface layer, strengthening of stratification and changing the current velocity, all changes that alter the distribution, composition and production of the pelagic food web. Based on monitoring data from several locations in Greenland the impact of ice cover and

freshwater on the plankton succession will be discussed. To evaluate climate-mediated changes on the pelagic ecosystem two approaches were applied: 1) a comparison of ecosystems along a latitudinal gradient and 2) cruises along a transect from coastal waters to the ice sheet in The Godthåbsfjord, representing several climate scenarios from warm coastal water to cold water in front of the glacier. The studies in Godthåbsfjord revealed a characteristic zonation of the zooplankton community in relation to the different oceanographic regimes along the fjord. Our studies show a pronounced impact of ice cover and freshwater on the succession and composition of the pelagic food web. This knowledge of the food web structure in the land-ocean transition is crucial to consider if we want to understand how the carbon cycle and sequestration in the Arctic may change in a warmer future.

A conceptual model of inorganic nutrient delivery to glaciated Arctic and sub-Antarctic fjords

Andy Hodson and Aga Nowak

The University of Sheffield, Sheffield, UK, a.j.hodson@sheffield.ac.uk

At present, our capacity to predict changing land-ocean coupling in glaciated fjords is best developed in the context of freshwater fluxes associated with calving and meltwater runoff. By contrast, the nutrient content of these fluxes is very poorly understood and so we are not at all well-placed to consider marine ecosystem change. This presentation therefore attempts to improve the conceptual understanding of inorganic nutrient inputs to glaciated Arctic and sub-Antarctic fjords, with the aim of optimizing the development of predictive models for polar marine ecosystem change in the future. At fjord-head environments, we will show how tidewater glaciers are net exporters of NO3- and sediment-bound (or readily extractable) Fe, P and Si via subglacial runoff and calving. By contrast, dissolved NH4+ and PO43- are leached from snow packs but rapidly removed by assimilation and adsorption to suspended sediments. Away from the fjord head, we will show how the runoff nutrient delivery is dependent upon: 1) small tributary glaciers and their floodplains, and 2) wetlands that become established on till plains and raised glacio-marine sediments. It will be shown that 1) promotes biogeochemical processes not unlike those found in shallow acquifers or subglacial runoff, whilst 2) promotes anoxia and therefore microbially-mediated processes with very particular implications for the introduction of labile iron to the fjord system. In summary, the various terrestrial inputs of inorganic nutrients to glaciated fjords can be simplified into small fluxes of highly labile, aqueous products of microbially-mediated rock weathering, or large fluxes of sparingly labile nutrients associated with sediments derived from physical erosion. However, the relative importance of the two pathways can change markedly whilst tidewater glaciers retreat onto land and glacial tills accumulate organic matter and evolve into soils.

Assessing the availability of glacial ice as habitat for harbor seals in a tidewater glacial fjord

Jamie N. Womble[1], Robert W. McNabb[2], Anupma Prakash[2], Rudi Gens[2], Jay M. Ver Hoef[3] and Scott M. Gende[1]

[1] *Coastal Program, National Park Service, Washington, D.C., USA, jamie_womble@nps.gov*
[2] *University of Alaska Fairbanks, Fairbanks, AK, USA*
[3] *Alaska Fisheries Science Center, NOAA, Seattle, WA, USA*

Tidewater glaciers are a prominent landscape feature along the southern coasts of Alaska and play an important role in landscape and ecosystem processes. Tidewater glaciers calve icebergs into the marine environment, which then serve as habitat for large aggregations of harbor seals. Although tidewater glaciers are naturally dynamic, advancing and retreating in response to local climatic and fjord conditions, most of the ice sheets that feed tidewater glaciers in Alaska are thinning and, as a result, many of the tidewater glaciers are retreating. The rapid thinning and retreat of tidewater glaciers may impact harbor seals, which exhibit a high degree of fidelity to glacial fjords and rely upon glacial ice as a haulout substrate. However, the potential impacts of changes in ice coverage and characteristics and the relationship with the distribution and abundance of harbor seals are unknown. Our primary objectives were (1) to develop a semi-automated method for estimating ice cover and characteristics of ice used by seals from digital imagery and (2) to assess the relationship between the availability of ice and the spatial distribution and abundance of seals. We conducted aerial photographic surveys (n = 53) of seals and glacial ice in Johns Hopkins Inlet, Glacier Bay National Park during June and August from 2007 to 2014. Surveys were flown along a grid of 12 transects at an altitude of 1,000 ft. Non-overlapping digital photos were taken directly under the plane using a vertically aimed camera. Preliminary estimates of seal abundance were consistently higher during June than August. The spatial distribution of seals was also much more extensive during June and corresponded to more extensive ice coverage in the fjord. Understanding relationships between ice availability and seal distribution and abundance is a first step towards understanding how changes in tidewater glaciers may influence harbor seals.

Pagophilia in the age of global warming: The ice ecology of the "Glacier Murrelet"?

John F. Piatt, Gary Drew, and Mayumi Arimitsu

Alaska Science Center, United States Geologic Survey, Alaska, USA, jpiatt@usgs.gov

No other bird is as intimately associated with glacial ice as the Kittlitz's ("Glacier") Murrelet, a small member of the Auk family of seabirds which evolved in Beringia during the Pleistocene and thrives today in icy-cold environments. Present-day breeding populations are found exclusively in glacially modified coastal areas of the Gulf of Alaska (GOA) and Bering Sea. During summer, murrelets nest in glaciated landscapes and lay a single egg on bare rocks on mountain slopes up to about 2000 m in elevation and 50 km inland. Nesting adults forage at sea on energy-rich prey such as sand lance, capelin and krill, typically in glacially-modified marine waters where such prey are abundant. Satellite tagging and isotopic diet studies reveal that after breeding, murrelets from the GOA migrate up to 3500 km into the Bering, Chukchi and Beaufort seas, probably in search of dense forage fish schools. Many murrelets then overwinter in polynyas or along the sea-ice edge of the Bering Sea. Compared to other Auks, murrelets have a more limited capacity to buffer against food shortages, and the annual odyssey of Kittlitz's murrelets among three marine ecosystems - from glacier ice to sea ice - must be challenging. It also makes them among the most vulnerable of species to global warming, both on land and at sea, as warming temperatures have a negative influence on their terrestrial breeding habitats and marine food supplies.

Scale-dependent influence of coastal glaciers on marine food webs in Alaska

Mayumi Arimitsu and John Piatt

Alaska Science Center, United States Geologic Survey, Alaska, USA, marimitsu@usgs.gov

We examined the influence of Alaska's coastal glaciers on marine food webs at varying spatial scales. Glacial melt water provides a seasonal pulse of cold, fresh, nutrient-rich and sediment-laden water into coastal areas of Alaska. At local scales (< 10 km) phytoplankton production is limited by shallow light penetration beyond the surface lens of glacial runoff, but rich zooplankton and forage fish communities still occur in these plumes. Mesopelagic species occur close to the surface during daytime owing to low light availability in the shallow turbid layer. Light reduction in turbid waters and noisy ice acoustics may also limit visual and auditory cues for subsurface marine predators, while osmotic shock and upwelling of near-surface prey near calving glaciers can benefit surface-oriented seabird predators. At fjord-scales (10 - 100s km) glacial freshwater delivers nutrients and imparts optimum stratification necessary for prolonged phytoplankton production observed in some fjord systems. The crossroads of estuarine, oceanic influence and tidal interaction with complex fjord geometry creates productive waters for benthic

and pelagic communities. At basin-scales (100 - 1000s km), freshwater influx is a driver of the Alaska Coastal Current (ACC), which can be traced from the Gulf of Alaska coast into the Bering Sea. Large-scale primary productivity downstream of glaciers and in offshore areas of the Gulf is enhanced by iron-rich runoff into coastal areas, through cross-shelf transport of this runoff via ocean eddies, and by dust storms that carry iron-rich glacial silt into marine waters during the fall and winter. Abundant and diverse marine predator populations migrate long distances to feed and breed within the productive marine ecoregions along the path of the ACC. Most of Alaska's glaciers are receding rapidly, and we anticipate that continuing changes in volume and timing of freshwater runoff will affect marine food webs at all scales.

Effects of sea ice on glaciers and the ecosystem of glacial fjords in Greenland

Malene Simon[1], Dorte Søgaard[2], John Mortensen[3], Kristine Arendt[1], Martin Blicher[1] and Thomas Juul Pedersen[1]

[1] *Greenland Institute of Natural Resources, Aarhus University, Nuuk, Greenland, masi@natur.gl*
[2] *Department of Biology, University of Southern Denmark, Odense, Denmark*
[3] *Roskilde University, Roskilde, Denmark*

Reduction of the seasonal sea ice cover (spatial extent, duration, and thickness) and increased freshwater input from land are direct consequences of the ongoing warming in the Arctic. Both factors have the potential to directly or indirectly affect the magnitude and the seasonal dynamics of marine primary production, potentially leading to altered food conditions for secondary producers. In Greenland large calving retreats at some tidewater outlet glaciers have been correlated with the loss of sea ice. This indicates that the seasonal growth and decay of sea ice help to temporarily stabilize glacier termini from the Greenland Ice Sheet. However, the sea ice extent is expected to decline in fjords of Greenland as a consequence of ongoing global warming. Furthermore, the increased ablating of the Greenland Ice Sheet, as a response to global warming, is adding more freshwater to the surface water in the fjords and the coastal areas adjacent to Greenland. This might impact on surface water chemistry, physical oceanography and circulation modes within fjords. Such changes would have a strong influence on the biological processes in the coastal zone. Recent studies show how the runoff from the Greenland Ice Sheet determines the biological processes within fjords of Greenland both in terms of phytoplankton production and zooplankton dynamics. The special biological features of fjords propagate to higher levels in the food chain and changes in runoff affect the distribution of marine top predators, such as Greenland halibut and marine mammals.

Session 4, Wednesday, June 17

Social scientific investigations of changing sea ice conditions

Co-Chairs: Alan Haynie, Henry Huntington, and Keith Criddle

The social role of sea ice in Bering Strait region communities

Julie Raymond-Yakoubian and Brandon Ahmasuk

Kawerak Incorporated, Nome, AK, USA, bahmasuk@kawerak.org

For communities in the Bering Strait region of Alaska, sea ice plays many roles in their daily life during the months it is present. In this presentation we consider some of the various 'social roles' that sea ice plays in communities. These roles include familiar functions such as acting as a platform from which to hunt marine mammals, but also encompass a wide variety of other, less well-known roles. We will outline some of the various other functions of sea ice in many communities, such as its role as a transportation corridor, as a source of drinking water, and as a barrier against storms, among others. We will also outline some of the changes that Bering Strait region communities have experienced in terms of these lesser-known roles of sea ice and how these changes have and may impact communities.

The multiple roles of ice and Inuit sustainability

Vincent Gallucci

School of Aquatic and Fishery Science, Canadian (Arctic) Studies Center, Jackson School International Studies, University of Washington, Seattle, WA, USA, vgallucc@u.washington.edu

This paper takes an ecologic - economic - geopolitic - climate change perspective on the roles that ice plays in the Arctic. We view the indigenous people to be part of the ecology of the Arctic. We examine the potential changes in Arctic life for the people as a consequence of climate change induced changes in environment as well as changes induced by the presence of indigenous people. The sustainability of indigenous people and their resilience in the face of climate change are considered. The indigenous population's options are especially interesting as a consequence of their role as permanent participant on the Arctic Council. In this capacity they are in a position to strike independent relations with nation states such as the new Asian permanent observers, as well as relations with the nation states on the Arctic Council, as well as nations not members of the Council. It is likely that the future success of the population rests on its position on the Council and its ability to use this position to its advantage.

The process towards a fisheries regime for the Central Arctic Ocean

Alf Håkon Hoel

Institute of Marine Research, Tromso, Norway, alf.haakon.hoel@imr.no

Preceded by numerous informal meetings, the formal process on fish stocks in the Central Arctic Ocean was initiated by the five coastal states in 2010. Since then, two scientific meetings (the third will be held in April 2015) and three meetings of the five coastal states have been held. The presentation describes the process and discusses possible outcomes.

Marine invasive species in the Arctic: Spatial economic and ecological consequences of sea-ice change

Speaker 1 - Linda Fernandez, and

Virginia Commonwealth University, Richmond, Virginia, USA, lmfernandez@vcu.edu

Speaker 2 - Brooks Kaiser

Department of Environmental and Business Economics, University of Southern Denmark, Esbjerg, Denmark, baka@sam.sdu.dk

The rapidly evolving reduction of sea ice in the Arctic is opening windows for both economic and ecological change. To date, the ice and related ecological conditions have served as a cost-effective, natural barrier to the introduction of invasive marine species through both human and ecological pathways. As the sea ice transforms and economic activity increases with the search for minerals, oil and gas, new shipping routes, exotic tourism and recreation experiences, and new fishery resources, the attendant externalities associated with these marine uses are expected to increase as well. We analyze the threat of marine invasive species, and other related threats (noise, collisions), accompanying increased shipping and marine infrastructure vectors in Arctic waters to the ecosystem, including marine mammals and their habitat. With these externalities, the threats of ecosystem and economic losses due to inadequate policy are imminent and costly. Current policy efforts, such as the proposed Polar Code additions to the International Convention for the Prevention of Pollution from Ships (MARPOL), fall short of requirements for successful policy targeting marine invasive species by opting for existing ratified agreements that forestall interest in further strengthening actions to curb externalities at higher immediate cost, despite the high likelihood of higher net benefits over the long run. Optimal policy must integrate ecology and economic behavior, along with risk and uncertainty in the changing environmental and economic conditions of the Arctic, to avoid placing short term potential economic gains ahead of long term value derived from maintaining resilient and functioning Arctic ecosystem productivity and values.

Managing hotspots of ship-resource encounters to ensure natural and cultural protections from emerging cruise tourism in Arctic Alaska

Keith R. Criddle

School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, USA, kcriddle@alaska.edu

Recent reductions in sea ice extent have led to increases in marine traffic in the Arctic. Commercialization of the Arctic threatens to outpace the development of international agreements to regulate traffic and associated levels of interaction with marine mammals and seabirds, exhaust and wastewater emissions, and discharges of marine debris. Unlike cargo craft which select routes to minimize transit costs and risk of foundering, cruise ships actively seek areas of particular scenic value and opportunity to encounter wildlife. Consequently, the operation of cruise ships presents unique risk to the environment and cultural heritage sites. At the same time, because their business depends on a pristine environment, cruise ship operators may be particularly responsive to voluntary adoption of best management practices that offset potential cultural and environmental risks. In Glacier Bay National Park, this has led to the cooperative development of best management practices that go beyond the mandates of existing environmental regulation. Compared to environmental regulation which is slow to be modified, best management practices are easily adjusted to reflect changing conditions on the water. This paper explores processes for development of best management practices for cruise ship operations in Arctic Alaska.

How lawyers and regulators think about Arctic sea ice: A science-based (r)evolution?

Betsy Baker

University of Washington School of Law, Seattle, WA, USA, bbbak@uw.edu, and: Vermont Law School, South Royalton, VT, USA bbaker@vermontlaw.edu

Eroding coastlines and rapidly diminishing sea ice in the Arctic have multiple legal repercussions for federal, state and some local authorities' regulation of marine areas. This talk focuses on three aspects of Arctic sea ice to which lawyers and regulators are beginning to turn their attention, nationally and internationally. 1) Regulating multiple uses of sea ice in national law. The treatment of sea ice in U.S. and Canadian law has failed adequately to allocate and manage demands on Arctic sea ice among competing uses. Decision makers have generally categorized sea ice as a) land or b) water, a binary approach that ignores its unique characteristics and the services it provides to many different users. Agency action and related litigation in the United States demonstrate sea ice user conflicts and highlight the tendency of U.S. law to protect only one type of user at a time. In Canada, two recent Inuit Land Claims

Agreements create zones that encompass sea ice. Both systems, prompted by scientific understandings of sea ice and its role in arctic ecosystems, are beginning to acknowledge sea ice as a component of larger systems and as a resource with multiple uses and users. 2) Arctic sea ice and ecologically and biologically significant areas (EBSAs) under the Convention on Biological Diversity. The presentation will report on the latest developments under the CBD to describe marine EBSAs for arctic sea ice through the application of scientific criteria. 3) Changing coastlines and maritime zones. Is "the existence of land the source of authority over the ocean,"(D. Caron) or over sea ice? What are the (legal) sources of authority over the ice? Should baselines be ambulatory or fixed? What does the Law of the Sea Convention say about changing coastlines and the baselines they support? The presentation will touch briefly on answers to these questions.

The role of sea ice and Bering Sea commercial fisheries

Alan Haynie[1] and Lisa Pfeiffer[2]

[1] *Alaska Fisheries Science Center, NOAA, Seattle, WA, USA, alan.haynie@noaa.gov*
[2] *Northwest Fisheries Science Center, NOAA, Seattle, WA, USA*

The two largest volume commercial fisheries in the US Bering Sea are the pollock and Pacific cod fisheries. In this talk, we build upon work that independently examined the impact of climate change on the pollock and Pacific cod catcher processor fisheries. We examine how both fisheries have adjusted to economic and environmental variation since 2000. For pollock, the mean location of winter fishing has varied little in warm and cold years, but there has been a northward shift in summer pollock biomass and fishing. This shift is related to the colder than average climate conditions in the latter part of the decade. For Pacific cod, the timing and location of winter fishing has shifted dramatically since 2000.This shift is related to the extent of seasonal sea ice and the timing of its descent and retreat. The summer Pacific cod fishery also shifted to the north, although the timing of the season remained constant. Climate affects relative spatial catch-per-unit-effort (CPUE) in both fisheries by causing a cold pool (water less than 2øC that persists into the summer) that sub-arctic species such as pollock and Pacific cod avoid. We also discuss the relationship between sea ice and fisher behavior in the Amendment 80 multi-species groundfish trawl fishery. Understanding the relationship between fishing location, environmental variables including the distribution of sea ice, and economic factors is essential to predicting the effects of future warming on fisheries. The impacts of climate on Bering Sea fish and fisheries can be surprisingly different. We discuss key differences in our understanding of fisher behavior, climate conditions, and spatial changes in fish abundance.

Session 5, Wednesday, June 17

Invited and Contributed Papers

Co-Chairs: George Hunt, Olafur Astthorsson, Sei-Ichi Saitoh

Tropical forcing of the recent rapid Arctic warming in northeastern Canada and Greenland

Qinghua Ding[1], John M. Wallace[1], David S. Battisti[1], Eric J. Steig[1], Ailie J. E. Gallant[2], Hyung Jin Kim[3] and Lei Geng[1]

[1] *University of Washington, Seattle, WA, USA, qinghua@uw.edu*
[2] *Monash University, Victoria, Australia*
[3] *APEC Climate Center, Busan, South Korea*

Rapid Arctic warming and sea ice reduction in the Arctic Ocean are widely attributed to anthropogenic climate change. The Arctic warming exceeds the global average warming due to feedbacks that include sea ice reduction and other dynamical and radiative feedbacks. We show that the most prominent annual mean surface and tropospheric warming in the Arctic since 1979 has occurred in northeastern Canada and Greenland. In this region, much of the year-to-year temperature variability is associated with the leading mode of large-scale circulation variability in the North Atlantic, the North Atlantic Oscillation (NAO). We show that the recent warming in this region is strongly associated with a negative trend in the NAO, which is a response to anomalous Rossby wave-train activity originating in the tropical Pacific. Atmospheric model experiments forced by prescribed tropical sea surface temperatures simulate the observed circulation changes and associated tropospheric and surface warming over northeastern Canada and Greenland. Experiments from the Coupled Model Intercomparison Project Phase 5 (CMIP5) models with prescribed anthropogenic forcing show no similar NAO-related circulation changes or associated tropospheric warming. This suggests that a substantial portion of recent warming in the northeastern Canada and Greenland sector of the Arctic arises from unforced natural variability.

Sediment upward dispersion and frazil ice formation by strong wind events -A possible mechanism of iron supply to sea ice

Masato Ito, Kay I. Ohshima, Jun Nishioka, Yoshimu Kusumoto, Genta Mizuta and Yasushi Fukamachi

Hokkaido University, Japan, itoh-m@lowtem.hokudai.ac.jp

Iron released from melting sea ice has the potential for a great impact on phytoplankton blooms in the Sea of Okhotsk. Major sources of iron incorporated into sea ice are considered to be sedimentary particles, although the detailed process of the incorporation has not been clarified. As a likely process, some laboratory studies reported that upward-dispersed sediment is directly entrained into frazil or grease ice. However, there have been no in-situ measurements which observed such a process because of logistical challenges in polar oceans and the lack of methods for the detection of frazil ice/sedimentary particle. Recently, it has been reported that in-situ observations can detect suspended frazil ice or sedimentary particles in a water column using acoustical backscatter strength data obtained by an ADCP. In the Sea of Okhotsk, mooring observations with ADCPs were conducted in 1999-2000 off Sakhalin coast. In this study, we reanalyzed these ADCP data, focusing on the acoustical backscatter strength, along with a satellite and meteorological data. At two mooring sites (depths of 90 and 110 m) about ~40 km apart, frazil ice-like strong signals were detected in depths shallower than ~20 m at times of strong winds of ~20 m/s, when the edge of sea ice cover or new ice region were located around the mooring sites. Subsequently, at both sites, other strong signals were detected in the whole water column that was associated with the intensification near the bottom of strong southward currents of 1.0-1.5 m/s. We interpret these signals as sedimentary particles dispersed upward from the bottom. If this is the case, these particles would interact with frazil ice. This is likely the first *in-situ* observation that suggests the entrainment of re-suspended sediment into frazil ice as a mechanism of the process of iron supply to sea ice.

Shell dissociation of marine calcifers in the western Arctic Ocean estimated by micro X-ray Computing Tomography

Katsunori Kimoto[1], Naomi Harada[1], Jonaotaro Onodera[1], Osamu Sasaki[2], Haruhisa Kano[1], Yuichiro Tanaka[1], Shigeto Nishino[1] and Michiyo Yamamoto-Kawai[3]

[1] *Japan Agency for Marine-Earth Science & Technology, Yokosuka, Japan, haradan@jamstec.go.jp*
[2] *Tohoku University Museum, Sendai, Japan*
[3] *Tokyo University of Marine Science and Technology, Tokyo, Japan*

The dissolution of atmospheric CO_2 with seawater reduces pH and carbonate ions. In the western Arctic Ocean, there are regions of surface water that are already corrosive to aragonite. It is urgently required to understand the effect of ocean acidification on marine calcifying organisms for conservation of marine ecosystems. Pteropods, having aragonite shells, are one of the most sensitive to ocean acidification, and are key species in the food webs of polar regions. Unfortunately, there is no common quantification method to evaluate the response of micro- or nano-size marine organisms to acidification. Thus, we have developed a more sophisticated quantification method for micro size plankton using a Micro-focus X-ray Computing Tomography (MXCT) technique. MXCT can produce virtual cross-section 16-bit images and measures of X-ray attenuation by an object. The X-ray attenuation of an object has a linear relationship to an object's density. We digitized CT numbers of calcite from box-cell values and defined carbonate CT number to know relative shell density. MXCT can evaluate the shell density and its inner structure of objects precisely. Using MXCT, we estimated shell dissociation of pteropods collected from the time-series sediment trap observations at the Northwind abyssal plain in the western Arctic Ocean (Stn. NAP, 75°N, 162°W). Pteropod shell density changed seasonally and decreased in the early winter (November). Our results may indicate that living marine calcifiers are affected by acidification in the Arctic Ocean. Their biological responses to ocean acidification are not simple, and the mechanism causing the seasonal change in the shell density is still unknown.

Jellyfish and forage fish spatial overlap on the eastern Bering Sea shelf

Mary Beth Decker[1], Richard Brodeur[2], Sangay Dorji[1], Kristin Cieciel[3], James Ruzicka[4] and Caren Barcelo[5]

[1] *Yale University, New Haven, CT, USA, marybeth.decker@yale.edu*
[2] *Northwest Fisheries Science Center, NOAA, Newport, OR, USA*
[3] *Alaska Fisheries Science Center, NOAA, Juneau, AK, USA*
[4] *Hatfield Marine Science Center, Oregon State University, Newport, OR, USA*
[5] *College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR*

The eastern Bering Sea (EBS) is a productive, economically valuable ecosystem, supporting rich populations of zooplankton, forage fish, groundfish, crabs, marine birds and mammals. While planktivorous forage fishes are a critical link between plankton and higher trophic levels, jellyfish tend to not support many predator groups. Thus, competition between forage species and jellyfish can affect forage fish production and ultimately upper trophic level production. To determine the potential competition between the dominant jellyfish and forage fishes, we measured the spatial overlap of forage fish and jellyfish in the EBS by comparing spatial distributions observed in annual fishery surveys. We determined the center of gravity of the distributions of several important jellyfish and each of the fish species and compared their overlap using the Global Index of Collocation. Overlap significance was tested using a Cramér-von Mises randomization. We also examined the degree of jellyfish-forage fish spatial overlap using geostatistical methods, and we evaluated annual differences in overlap during 2004-2012, a time that includes periods of warming and cooling. Over all, Bering Sea jellyfish have relatively low spatial overlap with dominant forage fishes; however areas of high overlap occur in some years. Jellyfish distributions were most similar to capelin, herring and pollock. In locations where jellyfish-fish overlap is high, predation by jellyfish on fish and fish prey may be an important factor in the dynamics of commercially important fish species.

Foraging dives by Pacific Arctic beluga whales (*Delphinapterus leucas*) in association with a primary prey species, Arctic cod (*Boreogadus saida*)

Donna D.W. Hauser[1], Kristin L. Laidre[1], Sandra L. Parker-Stetter[1], John K. Horne[1], Robert S. Suydam[1] and Pierre R. Richard[2]

[1] *University of Washington, Seattle, WA, USA, dhauser@uw.edu*
[2] *University of Manitoba, Winnipeg, Manitoba, Canada*

Foraging marine mammals trade off net energy gained relative to the energetic cost of reaching various depths when foraging. Our study examined foraging behavior by two populations of beluga whales (*Delphinapterus leucas*) in the Pacific Arctic using satellite tags equipped with time-depth recorders attached to 30 whales between 1997 and 2012. We also estimated vertically integrated densities of Arctic cod (*Boreogadus saida*), based on an acoustic survey conducted in the western Beaufort Sea, to test how beluga dive behavior in the survey area related to observed vertical distributions of Arctic cod. Dive behavior varied among regions and, in some cases, between populations. Maximum and mode dive depths suggested that Eastern Chukchi Sea (ECS) and Eastern Beaufort Sea (BS) belugas were regularly diving to the seafloor in the Chukchi and Bering seas, while more pelagic diving was common in Barrow Canyon, along slope margins of the Beaufort Sea, and in Canada Basin. Maximum daily depths recorded for 6 ECS tags also significantly varied regionally, with depths >900 m recorded in Canada Basin. In the western Beaufort Sea, Arctic cod were most abundant at 200-300 m and ECS beluga foraging corresponded to these depths. The number of dives to depths targeted by belugas were significantly related to Arctic cod density within 200-300 m. These results are consistent with the hypothesis that Arctic cod are a primary prey item for Pacific Arctic belugas and that foraging belugas dive to depths that maximize prey encounters.

Climate impacts and density regulation in Northeast Arctic cod

Jan Ohlberger

University of Washington, Seattle, WA, USA, janohl@uw.edu

This talk will focus on the effects of climate variability and density regulation on the dynamics of Northeast Arctic cod. NEA cod is currently the world's most abundant stock of Atlantic cod (*Gadus morhua*) and sustains a large and profitable fishery. I will give a brief overview of climate effects on NEA cod and present results from a life-cycle model that was developed to characterize the impact of environmental variation and intrinsic density-dependent processes on cod population dynamics. The model incorporates survey data on all life-stages, from eggs to spawners, as well as commercial catch records covering a time period of more than 50 years.

Results show that environmental impacts such as temperature variation affect the production of eggs and survival of larvae, while density-dependent survival occurs at the juvenile life-stage prior to maturation. Compensatory density dependence among juveniles mediates the impact of climate variation and other stochastic processes operating earlier in life, and acts to stabilize temporal variation in the abundance of older life-stages. While the results suggest moderate positive effects of rising temperatures on cod survival, shifts in cod distribution and indirect effects through altered species interactions may be more important for the response of NEA cod to future climate change.

Limits to benthic feeding by eiders in a vital Arctic migration corridor due to localized prey and changing sea ice

James R. Lovvorn[1], Aariel R. Rocha[1], Stephen C. Jewett[2], Douglas Dasher[2], Steffen Oppel[3] and Abby N. Powell[4]

[1] *Southern Illinois University, Carbondale, IL, USA, lovvorn@siu.edu*
[2] *University of Alaska Fairbanks, Fairbanks, AK, USA*
[3] *Royal Society for the Protection of Birds, Sandy, Bedfordshire, UK*
[4] *AK Cooperative Fish & Wildlife Research Unit, USGS, Fairbanks, AK, USA*

Four species of threatened or declining eider ducks that nest in the Arctic migrate through the northeast Chukchi Sea, where anticipated industrial development may require prioritizing areas for conservation. In this nearshore corridor (10 to 40 m depth), the eiders' access to benthic prey is restricted to variable areas of open water within sea ice. For the most abundant species, the king eider (*Somateria spectabilis*), stable isotopes in blood cells, muscle, and potential prey indicate that these eiders ate mainly bivalves when traversing this corridor. Bivalves there were much smaller than the same taxa in deeper areas of the northern Bering Sea, likely due to higher mortality rates caused by ice scour in shallow water; future decrease in seasonal duration of fast ice may increase this effect. Computer simulations suggested that if these eiders forage for >15 h/day, they can feed profitably at bivalve densities >200 m^2 regardless of water depth or availability of ice for resting. Sampling in 2010-2012 showed that large areas of profitable prey densities occurred only in certain locations throughout the migration corridor. Satellite data in April-May over 13 years (2001-2013) indicated that access to major feeding areas through sea ice in different segments of the corridor can vary from 0-100% between months and years. In a warming and increasingly variable climate, unpredictability of access may be enhanced by greater effects of shifting winds on unconsolidated ice. Our results indicate the importance of maintaining a range of potential feeding areas throughout the migration corridor to ensure prey availability in all years. Spatial planning of nearshore industrial development in the Arctic, including commercial shipping, pipeline construction, and the risk of released oil, should consider these effects of high environmental variability on the adequacy of habitats targeted for conservation

Impacts of climate change on ocean biology: Physiological underpinnings, projections and uncertainty

Hans-O. Pörtner

Alfred Wegener Institute for Marine and Polar Research, Bremerhaven, Germany, hans.poertner@awi.de

Understanding thermal ranges and limitations of organisms becomes important in light of climate change and its effects on ecosystems. This understanding supports efforts to project climate-induced shifts in the distribution and productivity of marine species. For animals, the integrative concept of oxygen and capacity limited thermal tolerance (OCLTT) has successfully characterized the earliest thermal limits to performance and the consequences of such limits or the width of thermal windows at ecosystem level. Relevant indicators have been identified across various aquatic animal species: Anaerobic mitochondrial pathways indicate oxygen deficiency at thermal extremes. Oxygen recordings in (mostly venous) body fluids provide evidence for hypoxemia leading towards anaerobiosis. Steady state temperature dependent performance profiles trace the resulting thermal window and indicate the key role for aerobic metabolism in supporting steady state performances, from growth to exercise and reproduction. An underlying set of molecular to whole organism mechanisms defines oxygen demand and the capacity of oxygen supply and whole organism functional performance. At thermal extremes further mechanisms support passive tolerance. Acid-base disturbances and reduced oxygen supply link temperature effects to CO2- or hypoxia-induced constraints and thereby integrate the effects of the key climate drivers. Accordingly, temperature-induced constraints in the capacity of oxygen supply systems and in demand define animal limits, leading either to the observed biogeographical shifts following the moving isotherms, or to a reduction in the maximum body sizes of species, or both. Mechanisms of evolutionary adaptation are presently unable to keep animals in place. Such assessments require consideration of how OCLTT principles were modulated on evolutionary timescales, e.g. in permanently cold polar waters or in hypoxic habitats characterized by the interaction of multiple drivers. The role of physiological processes in reducing uncertainty about projected impacts will be discussed.

Abstracts
of
Poster Presentations

Session 1 - *Humans, Ice and the Sea in the Subarctic and Arctic Past*

Holocene climate change and human adaptations to seasonally frozen seas and coasts of the North Pacific

Ben Fitzhugh, Cecelia Bitz, Kana Nagashima, Jason Addison, Bruce Finney, Nicole Misarti, Naomi Harada, Mike Etnier, Catherine West, and Pat Anderson

University of Washington, Seattle, WA, USA, fitzhugh@uw.edu

This poster considers potential relationships between human adaptation, Holocene climate variability, sea ice, and marine ecosystem dynamics in the past. Archaeological evidence suggests that settlement of the seasonally frozen coasts of the Sea of Okhotsk, Bering Sea and Chukchi Sea occurred only in the mid to late Holocene, while the settlement of the ice-free Northeast Pacific (greater Gulf of Alaska region) occurred 9500 years ago or even earlier. By the late Holocene, maritime hunting and fishing strategies were essential to lifestyles around the Subarctic and Arctic coasts. These strategies were key prerequisites to the settlement of the High Arctic regions of Canada and Greenland. The dependence on marine subsistence meant that fluctuations in marine ecological productivity created hazards for human settlers. Archaeological evidence suggests significant differences in human population stability on either side of the Subarctic Pacific. This variability may relate to climate induced fluctuations in marine resources in combination with the availability of alternative riverine or terrestrial resource access. This poster assembles information from paleoclimate models, proxy data on paleoclimate and productivity from terrestrial and marine systems, and archaeological observations from the greater North Pacific to explore these relationships and their possible environmental causes.

Archaeological excavations at the Medieval Fishing Station at Gufusk lar, Western Iceland

Frank Feeley

CUNY Graduate Center, Anthropology Department, New York, NY, USA, ffeeley@gradcenter.cuny.edu

During the medieval era a series of large fishing stations were constructed around Iceland to service the robust trade of dried cod fish with continental European merchants. The best preserved of these stations is on the farm of Gufusk lar in western Iceland where a joint team of archaeologists from the City University of New York and The Institute of Archaeology, Iceland have excavated since 2008.

The case for history: Reconstructing northern environments using historical documents

Dagomar Degroot

Georgetown University, Washington, D.C., dagomard@gmail.com

Between approximately 1250 and 1850 CE, average temperatures across the Northern Hemisphere declined by 0.5°C, relative to their twentieth-century averages. Interdisciplinary researchers have identified this so-called 'Little Ice Age" (LIA) using both historical documentary evidence and scientific proxy and model data. However, documentary sources have been far less important for reconstructions of the LIA in the far north. This poster argues that accounts of the Arctic environment written by European explorers and traders can not only contribute to climate reconstructions, but also to research that identifies links between climate change and human history. The poster analyzes the kinds of documents that can be used for climate reconstructions, and explains both their shortcomings and unique value. To illustrate how documents can inform reconstructions of northern environments, it demonstrates how environmental information in a ship logbook can be quantified and mapped. Finally, it reveals how a combination of documentary and scientific sources can shed new light on the ways in which climate change influences human activity, past and present.

Cetacean Utilization in the pre-modern European North Atlantic

George Hambrecht, Vicki Szabo, Cecilia Anderung, Frank Feeley, Ramona Harrison, Konrad Smiarowski, Seth Brewington, Megan Hicks, Thomas McGovern

University of Maryland, College Park, MD, USA, ghambrec@umd.edu

Little has been said about the utilization of cetaceans in Norse and early modern Scandinavian North Atlantic (Greenland, Iceland, the Faroes) contexts. This poster presents the beginnings of a synthesis of the archaeological remains of cetaceans found on sites from these regions and time periods. The nature of the archaeological remains do not leave much room for answering questions about procurement strategies but it does generate interesting questions as to distribution of cetacean based resources as well as the variety of processing strategies. Zooarchaeological analysis as well as first forays into aDNA analysis of the archaeological evidence will be discussed.

Session 2 - *Role of Sea Ice in the Arctic and Sub-Arctic*

Early ice retreat may cause *Calanus glacialis* biogeographic boundary shift in the Arctic Ocean

Zhixuan Feng, Rubao Ji, Carin Ashjian, Jinlun Zhang and Robert Campbell

Woods Hole Oceanographic Institute, Woods Hole, MA, USA, zfeng@whoi.edu

The Arctic Ocean has seen earlier ice retreat in recent years that may lead to changes in the biogeographic distribution of Arctic organisms including calanoid copepods. We used a pan-Arctic three-dimensional individual-based model to study the impact of earlier ice retreat on the distribution of *Calanus glacialis*, one of the dominant Arctic endemic zooplankton species. We focused our analyses on two factors of *C. glacialis* development: spawning time and food availability. Model runs are conducted in two distinctive years: (1) 1991, a normal sea ice year, and (2) 2007, a well-known year of early ice retreat. Our results suggest that egg-spawning timing is a key factor for *C. glacialis* development in subsequent naupliar and copepodite stages. Although early ice retreat may induce early egg spawning, these early offspring may not survive for prolonged periods without food after attaining their first feeding stage N3. Late spawning may cause *C. glacialis* to miss part of the ascending phytoplankton bloom phase, and to shorten its growth season length. Food availability during phytoplankton bloom period is found to be the most critical factor. Feeding on phytoplankton in the subsurface chlorophyll maximum is an important behavioral strategy to increase the developmental rate, lengthen the growth season, and maximize the environmental fitness of these organisms. Model comparisons between 1991 and 2007 suggest that timing of ice retreat may impact copepod biogeographic distributions by changing timing of reproduction and also food conditions in the growth season.

Reproduction in *Calanus finmarchicus* populations in seasonally ice-covered versus ice-free regions of the Labrador Sea

Erica Head, Marc Ringuette, Wendy Gentleman

Fisheries and Oceans Canada, Dartmouth, NS, Canada, erica.head@dfo-mpo.gc.ca

The Labrador Shelf (LSh) and northern Newfoundland Shelf (NSh) are ice-covered during the winter months, while the central Labrador Sea (CLS) is ice-free year-round. On the LSh and NSh, as the ice melts and retreats northward, it causes density-driven stratification and intense phytoplankton blooms, typically in May. In the CLS, by contrast, stratification is via solar warming and phytoplankton blooms are generally in June. *Calanus finmarchicus* overwinter at depth in the CLS, with females appearing at the surface by May, when they are more abundant in

the CLS than on the LSh and NSh. Once at the surface the females must feed before producing eggs, which are released into the water column where some develop into nauplii, while others are consumed by predators, sink or disintegrate. In May 2010, 2013 and 2014 and June 2012 we measured egg production rates for female *C. finmarchicus* from shelf and offshore regions using three different methods. Here, we present the results of this comparison and, using our "best" method, we examine the combined effects of food, temperature and female size and abundance on reproductive rates for shelf and central basin populations. As well, we show how estimates of survivorship rates for the early stages differ between the shelf and central basin, and discuss the implications of the differing reproduction and mortality rates for *C. finmarchicus* recruitment in the ice-influenced versus ice-free regions.

Biogeochemical cycling of particulate trace elements in the western Arctic Basin

Peter L. Morton and Benjamin S. Twining

Florida State University, Tallahassee, FL, USA, pmorton@fsu.edu

As part of the 2015 U.S. GEOTRACES cruise to the western Arctic Basin, we will study the cycling of bioactive (e.g., Cd, Zn and Ni) and lithogenic (e.g., Fe, Mn, and Al) type elements in marine particles. The cruise will traverse the Bering Sea, Chukchi Sea, Canada Basin, and eventually reach the North Pole. Suspended particulate matter samples will be collected using the GEOTRACES rosette, filtered using 0.2 µm, 25 mm Supor filters, and analyzed for total concentrations by inductively coupled plasma-mass spectrometry following total digestion. Particulate samples will also be collected from sea ice and shelf sediments. Complementary biological samples will be analyzed by synchrotron x-ray fluorescence, to investigate the trace metal distributions in single-celled microorganisms. Applying these techniques in concert will establish the trace metal quotas in Arctic phytoplankton and help resolve the biogenic and lithogenic composition of suspended and sea ice particles. Ultimately, these data will be shared with other cruise participants studying stable and radioisotopes, dissolved chemicals, and atmospheric deposition to quantify the sources, sinks and cycling of trace elements in the Arctic Ocean.

Diets and body condition of Arctic cod (*Boreogadus saida*) in the northern Bering Sea and Chukchi Sea

Tsubasa Nakano, Kohei Matsuno, Bungo Nishizawa, Yuka Iwahara, Yoko Mitani, Jun Yamamoto, Yasunori Sakurai, Yutaka Watanuki

Hokkaido University, Japan, hiro_sasaki@salmon.fish.hokudai.ac.jp

We compared the stomach contents and the body condition of Arctic cod (*Boreogadus saida*) occurring between the northern Bering Sea (NB), southern Chukchi Sea (SC), and central Chukchi Sea (CC). The Arctic cod were sampled using bottom trawling and their potential prey species were sampled using plankton net and Smith-McIntyre grab. Arctic cod fed mainly on appendicularians in the NB and SC, where they were available, while in the CC, they fed on copepods, euphausiids, and gammariids. The stomach fullness index of Arctic cods was higher in the NB and SC than CC, while their body condition index did not differ among these regions. The lower lipid content of appendicularians compared with that of the other prey species is the most plausible explanation for this inconsistency.

Interannual variation of solar heating in the Chukchi Sea

Hiromichi Ueno, Naoki Ohta, Motoyo Itoh, Takashi Kikuchi, Shigeto Nishino, Kohei Mizobata, Eiji Watanabe, Misaki Onuka

Hokkaido University, Japan, ueno@fish.hokudai.ac.jp

Interannual variation of solar heating in the Chukchi Sea was investigated through analysis of satellite-derived sea ice concentrations and incident shortwave radiation of reanalysis products during 1999-2010. Annual solar heating integrated in the Chukchi Sea varied interannually from 4.6 to 7.4 x 10^20 J, which was considerably larger than the annual northward heat flux through the Bering Strait. This suggests that the Chukchi Sea is the area where the Pacific Water from the Bering Sea is strongly modified, affecting the interannual variation of the heat transport to the interior Arctic basin. Interannual variation in the latent, sensible, longwave radiation fluxes and the heat of sea ice melting in the Chukchi Sea are small compared with the heat transport from the Bering Strait as well as the solar heat input in the Chukchi Sea.

The role of sea ice in phenology of Chinook salmon of the Yukon River, Alaska: Results of an operational forecast to support fishery management

Phil Mundy[1], Bryce Mecum[2], Stephanie Schmidt[3]

[1] *Alaska Fisheries Science Center, NOAA, Juneau, Alaska, USA, phil.mundy@noaa.gov*
[2] *School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, Alaska, USA*
[3] *Alaska Department of Fish and Game, Anchorage, Alaska, USA*

Researchers from NOAA Fisheries and the Alaska Department of Fish and Game, with the support of the Alaska Ocean Observing System, have identified a combination of spring conditions that is closely related to the timing of Chinook salmon on the Yukon delta. Using percent spring ice cover between St. Lawrence Island and the Yukon delta, April air temperatures in Nome, and marine surface temperatures just offshore of the delta in May, the team predicted the timing of the run in the last two seasons to within three days of the actual timing before the start of each run. The operational forecast is issued six to seven week sin advance of the mid-point of the salmon migration, which greatly aids managers of subsistence and commercial harvests. Forecast models were developed using 54 years of chinook timing observations from the Yukon River delta.

Session 3 - *Ecological Role of Tidewater Glaciers*

FATE: Fertilizing Arctic fjords - The missing link in Polar change

Aga Nowak

University of Sheffield, United Kingdom, a.nowak@sheffield.ac.uk

FATE is an interdisciplinary study of the High Arctic environment as it responds to deglaciation. It links freshwater hydrology, biogeochemistry, microbiology and oceanography to make a crucial contribution to our understanding of how terrestrial processes influence shallow marine Arctic ecosystems. Therefore, an extensive field and laboratory program enables FATE to quantify the fertilization of High Arctic fjord ecosystems by freshwater inputs both under present conditions and in response to continued climate change. Determination of all nutrients (in runoff and fjord waters) and biological production creates an unprecedented level of conceptual understanding for this changing land-ocean interaction. This poster will firstly present long term biogeochemical flux data from a glaciated Arctic catchment to show the potential impact of meltwater on downstream marine ecosystems. Secondly, a carefully designed fjord sampling

campaign will be used to show how the response of near shore coastal environments to that inflow can be established, using the state of the art, custom-made ROV. The long term freshwater hydrochemical dataset will also be used to reveal how deglaciation and sea level change influences delivery of nutrients to fjords over longer time scales.

Session 5 – *Invited and Contributed Papers*

Salinity variability along the eastern continental shelf of Canada and the United States, 1973-2013

James J. Bisagni

University of Massachusetts Dartmouth, Dartmouth, MA, USA, jbisagni@umassd.edu

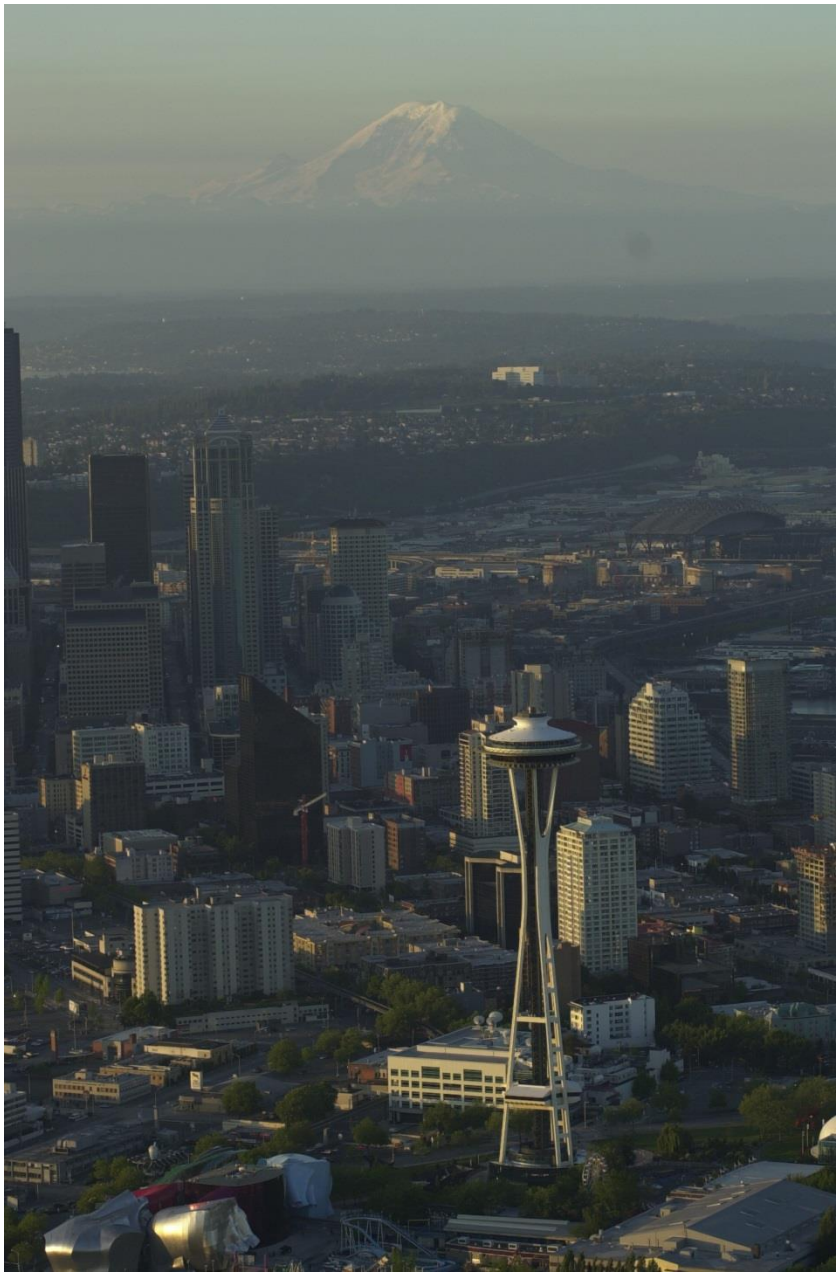
Continental shelf waters located off the east coast of Canada and the United States are part of an along-shelf current system that is comprised of colder, less-saline waters from high latitudes, along with input from rivers. A 41-year analysis (1973-2013) of near-surface salinity using two hydrographic datasets (BIO "Climate" and MEDS) allowed an examination of near-surface salinity within 11 sub-regions, extending from Newfoundland to the DelMarVa/Hatteras shelf. Global mean salinities are lowest within the Gulf of St. Lawrence (30.49) and highest on the DelMarVa/Hatteras shelf (32.72), with largest annual variability within the Gulf of St. Lawrence (ΔS ~2.5). Large annual variability also occurs on the Newfoundland (ΔS ~1.9), Middle Atlantic Bight (ΔS ~2.0), and DelMarVa/Hatteras (ΔS ~2.3) shelves. Long-term trends computed from annual mean near surface salinity were detected along the Newfoundland shelf (+0.011 y-1), western Scotian shelf (-0.007 y-1), Gulf of Maine (-0.014 y-1), Georges Bank (-0.011 y-1), and DelMarVa/Hatteras shelf (+0.024 y-1). A long-term quadratic fit to annual mean salinity from the eastern Scotian shelf displays a salinity increase through 1992 (+0.026 y-1), decreasing thereafter until 2013 (-0.028 y-1). A quadratic fit for the western Grand Banks displays a salinity increase through 2007 (+0.022 y-1), decreasing thereafter (-0.006 y-1). Annual mean salinities from the eastern and Tail of the Grand Banks, Gulf of St. Lawrence, and Middle Atlantic Bight displayed no long-term trends. Inter-annual variability (IAV) of near-surface salinity residuals shows similar small mean squared error (mse) of 0.02-0.04 (relative to each sub-region's respective model fit or mean value) for the four northern-most sub-regions and appear to be coherent. IAV (mse) of near-surface salinity increases for the Gulf of St. Lawrence (~0.19), eastern and western Scotian shelf (~0.09-0.06), Gulf of Maine and Georges Bank (~0.08-0.06), Middle Atlantic Bight (~0.19), and is largest for the DelMarVa/Hatteras shelf (~0.36), with coherent temporal fluctuations between these more southern 7 sub-regions.

Copepods in Greenlandic waters: Patterns and changes during the last decades

Eva Friis Møller, Mikael Sejr, Kristine Arendt, Torkel Gissel Nielsen

Aarhus University, Copenhagen, Denmark, efm@bios.au.dk

The phenology and production of zooplankton is crucial for both higher trophic levels and the biological pump. To understand the Arctic ecosystems it is important to recognize the dynamics of the key zooplankton species, e.g. the copepods *Calanus finmarchicus, C. glacialis* and *C. hyperboreus*. Here we present data on copepods and oceanography collected during research and monitoring in two different Greenlandic fjord systems, Disko Bay (69°14'N, 53°23'W) and Young Sound (74°18'N, 20°10'W) from 1992 to 2014. Both systems are influenced by glacier runoff, and have experienced reduced ice-cover during the last decades. We analyze data on copepod biomass and community composition with the aim to understand the processes driving the observed patterns.



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