ESSAS Annual Science Meeting
March 7–9, 2016

Scientific Challenges in a Changing Arctic & Subarctic

Session descriptions

- Challenges to the Climate Sciences in a Changing Arctic & Subarctic –Observations & Models
- Challenges to the Ecological and Ecosystem Sciences in a Changing Arctic & Subarctic
- Challenges to the Biogeochemical Sciences in a Changing Arctic & Subarctic
- Challenges to the Humanities and Socio-economic Sciences for Sustainability
- Pre/Historical Ecology of Subarctic Marine Ecosystems

Hosted by

Research and Development Center for Global Change
& Institute of Arctic Climate and Environment Reserch,
Japan Agency for Marine-Earth Science and Technology

JAMSTEC

In cooperation with:

Abstract book edited by JAMSTEC members Naomi Harada and Koji Sugie, with feedback from Carmen García-Comas.

Welcome

On behalf of the symposium conveners, organizers, and the Ecosystem Studies of Sub-Arctic and Arctic Seas (ESSAS) Scientific Committee, we welcome you to Yokohama city and to the Yokohama World Porters to participate in the ESSAS Annual Science Meeting. The theme title of the 2016 ESSAS Annual Science Meeting is "Scientific Challenges in a Changing Arctic & Subarctic".

Background of meeting

The decline of biodiversity (the biomass, composition, and distribution of species) on Earth reflects the fact that the ability of the Earth to sustain biodiversity in a dynamic environment has been seriously compromised by environmental stressors such as climate change and ocean acidification. Furthermore, the reduction of sea ice in the Arctic Ocean, which has progressed more rapidly than previously predicted, could exacerbate several environmental stresses, including ocean warming, acidification, and stratification. This meeting will focus on the observed and projected changes of the climate and the marine environment in the Arctic and Subarctic, as well as on the biological responses to these changes. Questions to be addressed will be: how did the ancient climate and marine environment of the Arctic and its marginal subarctic regions change over time? How are the climate and marine environment of the Subarctic and Arctic regions changing during the current Anthropocene? How do marine organisms in Subarctic and Arctic regions respond to multiple environmental stressors? Active discussions will be encouraged to enhance our understanding of observed and anticipated changes and to explore how the natural sciences, humanities and socio-economic sciences can address and adapt to these challenges.

The symposium will consist of five sessions: (1) **Challenges to the climate sciences in a changing Arctic & Subarctic –observations & models**, (2) **Challenges to the ecological and ecosystem sciences in a changing Arctic & Subarctic**, (3) **Challenges to the biogeochemical sciences in a changing Arctic & Subarctic**, (4) **Challenges to the humanities and socio-economic sciences for sustainability**, and (5) **Pre/Historical Ecology of Subarctic Marine Ecosystems**. In addition, we have a special session of contributed ESSAS papers and public lecture during the meeting. Please enjoy cutting-edge and multidisciplinary contents at the 2016 ESSAS Annual Science Meeting!

Finally, we want to acknowledge all participants and the unconditional support of many individuals to achieve a successful meeting. We also thank the Yokohama World Porters for the use of their conference room in such a beautiful location.

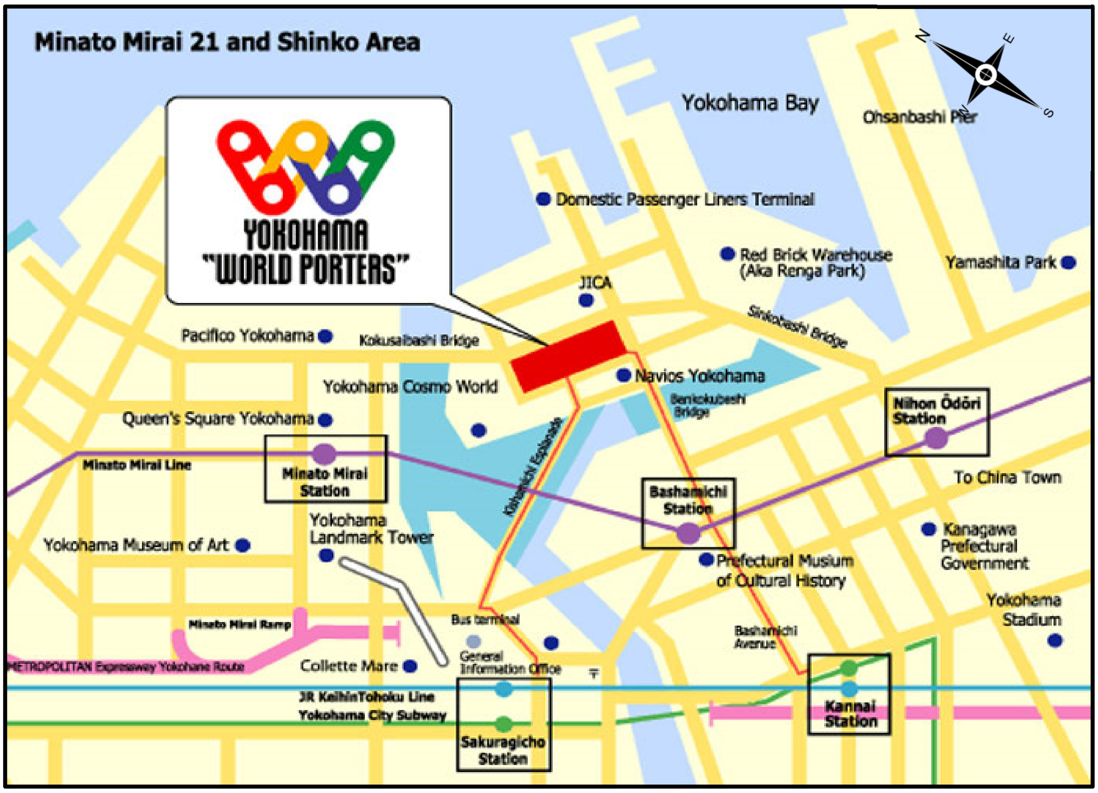
ESSAS Co-Chair: Ken Drinkwater, Franz Mueter, and Sei-Ichi Saitoh
Local Organizing Committee: Naomi Harada, and Sei-Ichi Saito

Table of Contents

Area Information

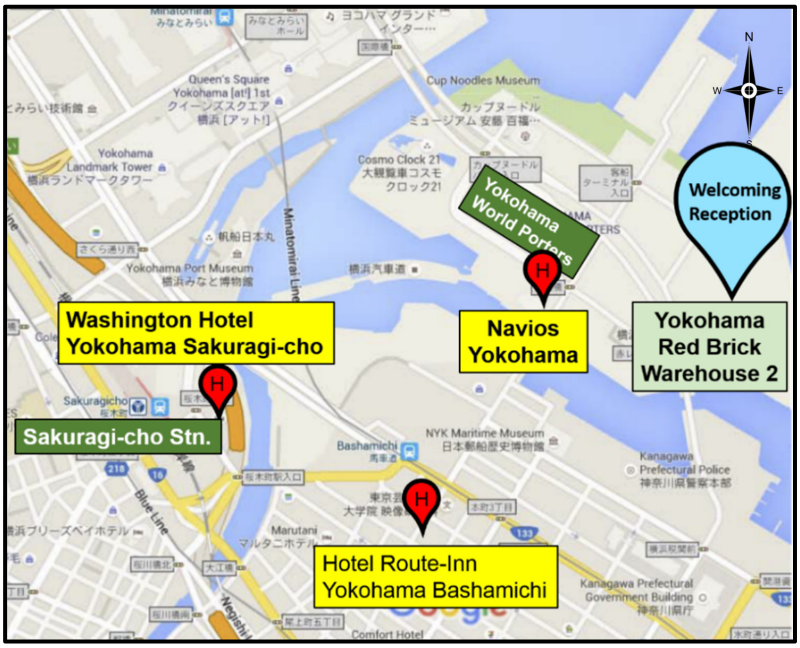
Venue

The meeting will take place at the Yokohama World Porters (http://www.yim.co.jp /foreign/access_en/) at Sakuragi-cho, Yokohama. Access to the Yokohama World Porters permitted from 9:00 AM.



Hotels

There are many Hotels around the area. Only three Hotels listed in the ESSAS website are shown in this map.



Welcoming Reception

Please join us at the restaurant Fisherman's Market, Yokohama Red Brick Warehouse 2 on Monday, 7 March at 19:00.

Directions to the hotel and venue

There are two airports in Tokyo area (Haneda and Narita). You can get from the airports to the hotels in Sakuragi-cho, Yokohama, either by train or by bus. Shuttle buses to the Minatomirai area take about 30 minutes from Haneda airport and 90 minutes from Narita airport.

From Haneda airport

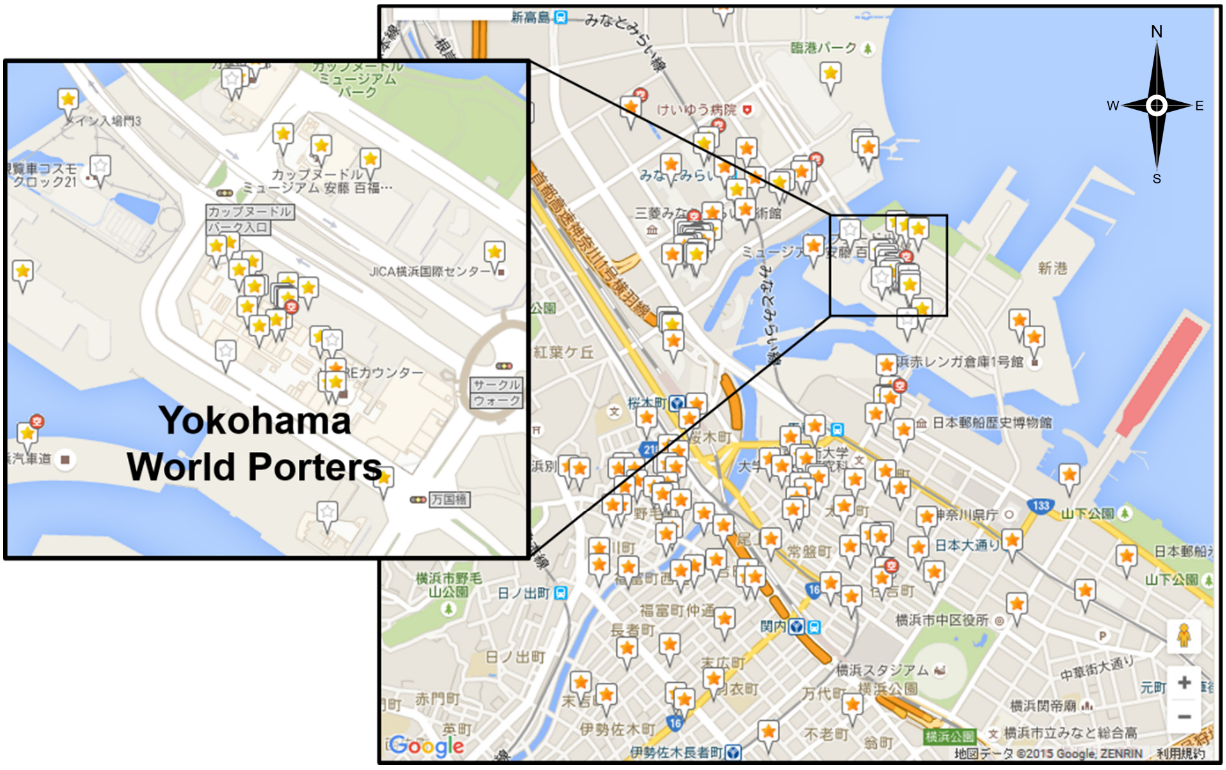
- Bus: The most convenient. Keikyu limousine bus to Yamashita-Koen Park/Minatomirai area/Yokohama Red brick Warehouse (one-way ticket: 720JPY). The bus operates from 8:40 to 20:45 every 30 min (but every hour after 17:00). Ticket counter on the 1st floor.
- Train: Keikyu line towards Shin-Zushi. Get off at Yokohama Station (one-way ticket: 480 JPY). Two options from Yokohama station: take subway Minatomirai Line towards Motomachi-Chukagai. Get off at Minatomirai Station (one-way ticket: 180 JPY); or take JR Negishi-line towards Isogo and get off one stop after, at Sakuragicho Station (one-way ticket: 140 JPY).

From Narita airport

- Bus: Keikyu limousine bus to Yokohama-Grand Inter Continental Hotel (one-way ticket: 3,600JPY; round-trip ticket: 6,000JPY). Ticket counter on the 1st floor of the airport (in front of the exit of baggage claim area). Get off at Yokohama-Bay-Hotel-Tokyu.
- Train: Narita Express (regular one-way ticket: 4,300JPY; **especial 50% discount for foreigners upon showing the passport** at the N'EX ticket boot). Get off at Yokohama Station. Two options from Yokohama station: take subway Minatomirai Line towards Motomachi-Chukagai. Get off at Minatomirai Station (one-way ticket: 180JPY); or take JR Negishi-line towards Isogo and get off one stop after, at Sakuragicho Station (one-way ticket: 140 JPY).

Restaurants around the area

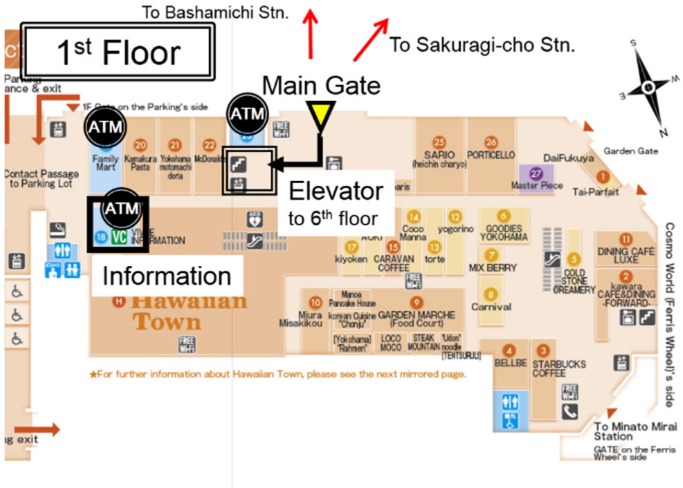
You can find many restaurants on the top floors of the department stores occupying the Minatomirai area. See ranked restaurants at Tabelog (http://tabelog.com/en/kanagawa/), with a wider offer in Japanese language (http://tabelog.com/kanagawa/), our apologies. Please enjoy your stay at our wonderful Yokohama city.



Meeting Information

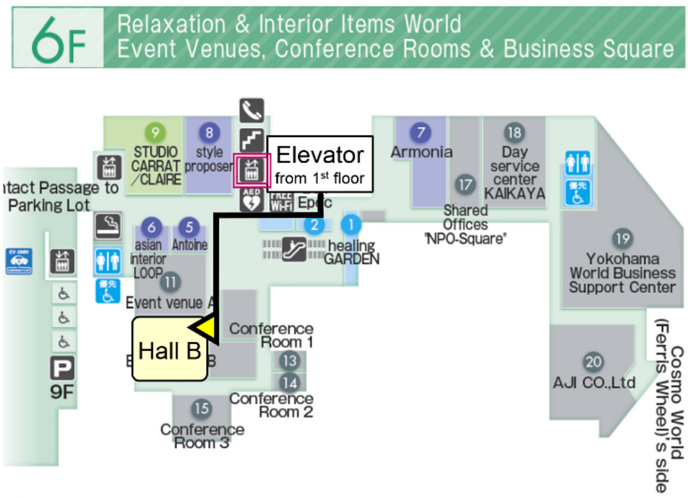
Registration

Registration starts on Monday, 7 March at 9:00. The registration desk will also be open on Tuesday morning from 9:00. Notice that the access to the Yokohama World Porters is not permitted before 9:00 AM. Please pay the fee (10,000 JPY and 3,000 JPY for students) in cash (Japanese yen) at the registration desk on the 6th floor. Some ATMs are available on the first floor.



Oral Presentation Guidelines

Presentation time including Q & A is 20 min, and 30 min for invited speakers. All oral presentations will be given in plenary sessions at Hall B (6th floor) of the Yokohama World Porters. It is encouraged to <u>bring your own laptop for your presentation</u>. If you bring your presentation file in a USB key, we will provide a shared PC. Yet, we strongly encourage a previous check for viruses in your USB key with an updated anti-virus software.



Poster Presentation Guidelines

Maximum poster dimensions are 90 cm (ca. 35 in.) wide and 120 cm (ca. 47 in.) tall. Poster sessions will take place after oral sessions on Monday (16:40–18:00) and Tuesday (16:00–17:30), at Hall B too. Posters can be set at any time during the meeting on the available poster boards, and **must be removed** by 18:00 on Tuesday, 8 March.

Lunch

Japanese lunch boxes or sandwiches and a bottle of Japanese tea will be provided. These are included in the registration fee.

Welcoming Reception

A Welcoming Reception will be held on Monday, 7 March at 19:00. It will take place at Fisherman's Market, 3rd floor of the Yokohama Red Brick Warehouse 2, a 10-minute walk from the Yokohama World Porters (http://www.yokohama-akarenga.jp/en/).

ESSAS Dinner

Upon registration. We are planning to go to Sirius, 70F sky lounge, in the Yokohama Royal Park Hotel (http://www.yrph.com/index. html). (approx. budget ~10,000 JPY, not included in the registration fee).

Schedule

Day 1 (Mon., 7 March)		Day 2 (Tue., 8 March)		Day 3 (Wed., 9 March)	
9:00	**Registration**	**9:00**	**Registration**	9:20	Onodera J.
10:00	McKechnie I.*	10:00	Wakita M.*	9:40	Abe Y.
10:30	Hamada S.	10:30	Iwasaki S.	10:00	Mueter F.
10:50	Fitzhugh B.	10:50	Kimoto K.	**10:20–10:50 Coffee break**	
11:10–11:30 Coffee break		11:10	Honda C.M.	10:50	Yamamura O.*
11:30	Nagashima K.	**11:30–13:00 Lunch** (Included in registration fee)		11:20	Haynie A.
11:50	Asahara Y.*	13:00	Azetsu-Scott K.	**11:40–13:10 Lunch** (Included in registration fee)	
12:20–13:50 Lunch (Included in registration fee)		13:20	Yasunaka S.	13:10	Ashjian J.C.*
13:50	Osafune S.*	13:40	Siswanto E.	13:40	Saito R.
14:20	Tsubouchi T.	**14:00–14:30 Coffee break**		14:00	Børsheim K.Y.
14:40	Drinkwater K.	14:30	Sugie K.	**14:20–14:50 Coffee break**	
15:00–15:20 Coffee break		14:50	Sundby S.	14:50	Kitamura M.
15:20	Mizobata K.	15:10	Drinkwater K.	15:10	Ito S.
15:40	Watanabe E.	**15:30–16:00 Coffee break**		**15:30–16:00 Break & Preparation**	
16:00	Overland J.	16:00–17:30 Poster session		16:00–17:00 Town Hall Meeting	
16:20–16:40 Coffee break					
16:40–18:00 Poster session		19:00–21:00 ESSAS Dinner (**NOT** included in registration fee)			
19:00–21:00 Welcoming Reception (included in registration fee)					

*: Invited speaker

List of Titles

Day 1 (Monday, March 7)

9:00–10:00 Registration

Session: Pre/Historical Ecology of Subarctic Marine Ecosystems

Conveners: Ben Fitzhugh & Kana Nagashima

10:00–10:30	Iain McKechnie
[Invited]	*The Archaeology and Historical Ecology of Pacific Herring in the Northeast Pacific Ocean*
10:30–10:50	Shingo Hamada, Thomas F. Thornton, Rika Shinkai & Junko Habu
	Economies in the North Pacific
10:50–11:10	Ben Fitzhugh, M. Yoneda, J. Habu, J. Taylor, G. Kamenov, Rika Shinkai & J. Krigbaum
	Okhotsk culture mobility in the context of maritime subsistence and seasonally frozen coasts
11:10–11:30	Coffee Break
11:30–11:50	Kana Nagashima, Yoshiaki Suzuki, Yukari Hara, Yasunori Kurosaki, Ryuji Tada, Takeshi Nakagawa & SG06/12 members
	Decadal to millennial-scale Asian dust transport changes and its possible impact on ocean biogeochemistry
11:50–12:20	Yoshihiro Asahara, Tomoki Yasuda, Seiya Takeuchi & Fumi Takeuchi
[Invited]	*Paleo- and modern environmental analysis based on chemical and Sr-Nd isotopic compositions of aluminosilicate detritus in the Arctic and Sub-Arctic Seas*
12:20–13:50	Lunch

Session: Challenges to the Climate Sciences in a Changing Arctic & Subarctic – Observations & Models

Conveners: Takashi Kikuchi & Ken Drinkwater

13:50–14:20	Satoshi Osafune
[Invited]	*The 18.6 year modulation of localized tidal mixing as a possible cause of bidecadal variability in the North Pacific*
14:20–14:40	Takamasa Tsubouchi, Sheldon Bacon & Alberto Naveira Garabato
	Observed seasonal variation of the Arctic Ocean heat and fresh water transports
14:40–15:00	Ken Drinkwater
	Ocean changes in the northern North Atlantic and the Arctic: global warming or AMO?

15:00–15:20	Coffee Break
15:20–15:40	Kohei Mizobata & Hirari Satoh Validation/calibration of sea surface salinity estimated by L-band microwave radiometers SAC-D/Aquarius in the Pacific sector of the Arctic Ocean
15:40–16:00	Eiji Watanabe, Jonaotaro Onodera, Motoyo Itoh, Shigeto Nishino & Takashi Kikuchi *Overwinter transport of subsurface warm water toward the Arctic Chukchi borderland*
16:00–16:20	James Overland, M Wang, N Soreide & S Moore *The immediacy of Arctic change*
16:20–16:40	Coffee Break
16:40–18:00	Poster Session (11 posters)
19:00–21:00	Reception (included in registration fee; see page 7)

Day 2 (Tuesday, March 8)

9:00–10:00 Registration

***Session*: Challenges to the Biogeochemical Sciences in a Changing Arctic & Subarctic**

Conveners: Kumiko Azetsu-Scott & Naomi Harada

10:00–10:30 **[Invited]**	Masahide Wakita, Akira Nagano, Tetsuichi Fujiki & Shuichi Watanabe *Ocean acidification in the surface water of subarctic western North Pacific Ocean and the impact on biological production*
10:30–10:50	Shinya Iwasaki, Katsunori Kimoto, Osamu Sasaki & Harumasa Kano *Investigation in impact of seawater condition on planktic foraminiferal (*Globigerina bulloides*) calcification by X-ray micro-computed tomography*
10:50–11:10	Katsunori Kimoto, Yuriko Nakamura, Jonaotaro Onodera, Osamu Sasaki, Harumasa Kano & Naomi Harada *Shell dissolution of Arctic Pteropods between 2010 and 2012: Coupling of timeseries observations and micro X-ray CT analysis*
11:10–11:30	Makio C. Honda, Hajime Kawakami, Kazuhiko Matsumoto & Eko Siswanto *Decadal change in biogenic materials' flux in the North Pacific Western Subarctic Gyre based on the trend analysis of time-series sediment trap data between 1998-2014*
11:30–13:00	Lunch
13:00–13:20	Kumiko Azetsu-Scott & the Atlantic Zone Offshore Monitoring Program Team *Decadal change in carbon chemistry in the Labrador Sea*

13:20–13:40	Sayaka Yasunaka, Akihiko Murata, Eiji Watanabe, Melissa Chierici, Agneta Fransson, Steven van Heuven, Mario Hoppema, Masao Ishii, Truls Johannessen, Naohiro Kosugi, Siv K. Lauvset, Jeremy T. Mathis, Shigeto Nishino, Abdirahman M. Omar, Are Olsen, Daisuke Sasano, Taro Takahashi & Rik Wanninkhof *Mapping of the air-sea CO_2 flux in the Arctic: Basin-wide distribution and seasonal to inteannual variability*
13:40–14:00	Eko Siswanto *Phytoplankton biomass trend in the Arctic and subarctic regions within a decade and half of modern ocean color missions*
14:00–14:30	Coffee Break

Session: Challenges to the Ecological and Ecosystem Sciences in a Changing Arctic & Subarctic

Conveners: Sei-ichi Saito & Franz Mueter

14:30–14:50	Koji Sugie, Naomi Harada & Akihiko Murata *Effects of CO_2 and temperature on the phytoplankton community in the western and eastern North Pacific*
14:50–15:10	Svein Sundby, Kenneth F. Drinkwater & Olav S. Kjesbu *The North Atlantic spring-bloom system - where the changing climate meets the winter dark.*
15:10–15:30	Ken Drinkwater *Projection of future climate change on plankton in the Atlantic sector of the Arctic*
15:30–16:00	Coffee Break
16:00–17:30	Poster Session (11 posters)
19:00–21:00	ESSAS Dinner (**NOT** included in registration fee. See page 8)

Day 3 (Wednesday, March 9)

Session: Challenges to the Ecological and Ecosystem Sciences in a Changing Arctic & Subarctic

Conveners: Sei-ichi Saito & Franz Mueter

9:20–9:40	Jonaotaro Onodera, Eiji Watanabe, Shigeto Nishino, Makio C. Honda & Naomi Harada *Ocean acidification in the surface water of subarctic western North Pacific Ocean and the impact on biological production Diatom settling flux and sea surface hydrography at the southeastern slope of Chukchi Abyssal Plain in 2012‐2013*

9:40–10:00	Yoshiyuki, Abe, Atsushi Yamaguchi, Toru Kobari, Barbara Niehoff, Atsushi Tsuda & Ichiro Imai *Weight-specific growth rates of large-sized oceanic copepods during phytoplankton bloom*
10:00–10:20	Franz Mueter, Benjamin Laurel, Ed Farley, Ron Heintz & Jen Marsh *Northern gadids in a changing climate: winners and losers*
10:20–10:50	Coffee Break

***Session*: Challenges to the Humanities and Socio-Economic Sciences for Sustainability**

Conveners: Alan Haynie & Mitsutaku Makino

10:50–11:20 **[Invited]**	Orio Yamamura, Kaoru Hattori & Takeomi Isono *Management of Steller sea lions off the western coast of the Hokkaido Island: mitigating the threat to the sustainability of local fishery*
11:20–11:40	Alan Haynie *Social and natural science integration in the Bering Sea Project: an economist's perspective*
11:40–13:10	Lunch

***Session*: Contributed ESSAS papers**

Convener: George Hunt

13:10–13:40 **[Invited]**	Carin J. Ashjian, Robert G. Campbell, Rubao Ji, Stephen R. Okkonnen, Robert S. Pickart & Frank Bahr *How might the biogeography of zooplankton change as the Arctic warms?*
13:40–14:00	Rui Saito, Ichiro Yasuda, Kosei Komatsu, Hiromu Ishiyama & Hiromichi Ueno *The impact of Aleutian eddies on lower trophic level production south of western Aleutian Islands*
14:00–14:20	Knut Yngve Børsheim *Increased melting of permafrost may lead to decreased total primary production*
14:20–14:50	Coffee Break
14:50–15:10	Minoru Kitamura, Makio C Honda, Yuichiro Kumamoto, Hajime Kawakami, Yasunori Hamajima, Michio Aoyama, Tatsuo Aono & Miho Fukuda *Fukushima-derived radiocesium in oceanic zooplankton*
15:10–15:30	Shin-ichi Ito, Kenneth A. Rose, Bernard A. Megrey, Jake Schweigert, Douglas Hay, Francisco E. Werner & Maki Noguchi Aita *Geographic variation in Pacific herring growth in response to regime shifts in the North Pacific Ocean*
15:30–16:00	Break & Preparation
16:00–17:00	Town Hall Meeting (in Japanese)

Abstracts of Oral Presentations

Day 1: Monday March 7th

Session: Pre/Historical Ecology of Subarctic Marine Ecosystems

The archaeology and historical ecology of Pacific herring in the northeast Pacific Ocean

Iain McKechnie

For many Indigenous peoples throughout the North Pacific Rim, the right and ability to fish is inseparably linked to their history, social relations, economy, and physical well-being. In Northwestern North America, salmon (*Oncorhynchus* spp.) is widely recognized as a highly valued food fish and powerfully illustrates the numerous linkages between people, cultural identity, and coastal environments. However, the emphasis on salmon has been disproportionate relative to the large number of other fisheries in the northeast Pacific, particularly smaller 'forage fish' such as anchovy (*Engraulis mordax*), smelts (Osmeridae), and herring (*Clupea pallasii*). In this presentation, I examine archaeological fisheries data from over 220 archaeological sites from the western US and Canada (42˚- 58˚ latitude) and consider these ancient records in the context of historical documents and accounts from Indigenous peoples. This analysis reveals that Pacific herring is among the most ubiquitous and abundant fish species throughout the archaeological record of this large coastal region. This further supports a host of other historical and oral historical observations documenting a long-term decline of industrial herring fisheries since the late 19th century and demonstrates that herring was a foundational food fish central to economic and social systems of coastal communities in the northeast Pacific. I conclude that archaeological fisheries data can help inform and extend historical baselines in coastal ecosystems and better contextualize the degree of contemporary change in the world's oceans.

15

Shifting the Herring Baselines: Seascapes and Potentials of Small-Scale Economies in the North Pacific

Shingo Hamada, Thomas F. Thornton, Rika Shinkai & Junko Habu

Seascaping, which can be defined as an intentional and unintentional modification of coastal environments by human actors, may enhance ecosystem services by promoting the accessibility and availability of aquatic resources without affecting biodiversity. While coastal environmental changes are salient since the era of industrialization up to present, except for indigenous clam gardens, little has been discussed in the process of seascaping in the prehistoric and historic North Pacific. Taking Pacific herring (*Clupea pallasii*) in northern Japan and southeast Alaska as a case study, the aims of this presentation are threefold; 1) to provide an overview of our Small-Scale Economy Project, which uses diversity, networks, and local autonomy as key concepts for our understanding of the resilience of past and present socioeconomic systems across the North Pacific; 2) to examine an applicability of historical ecology as a framework that captures both short- and long-term human-environment interactions, and; 3) to discuss how the investigation of pelagic fish such as herring shows us an appropriate scale and key limits for resilient coastal economies. Our ethnographic study in southeast Alaska suggests how indigenous food tradition embodies an accumulated knowledge and practice of adaptive strategies while our case study from Hokkaido highlights both potential and limitations of community-based fisheries cooperatives for sustainable seascaping. At a broader historical ecology level, zooarchaeology offers insights on long-term changes in coastal foodways in relation to seascapes. A variety of indicators of environmental changes in our interdisciplinary small-scale economy research emphasize the phenomenon of shifting baselines which blurs the impacts of large-scale extractive fisheries economies on local and regional socio-ecological systems.

Okhotsk culture mobility in the context of maritime subsistence and seasonally frozen coasts

Ben Fitzhugh, M. Yoneda, J. Habu, J. Taylor, G. Kamenov, Rika Shinkai, and J. Krigbaum

We examine maritime Okhotsk culture with respect to residential mobility and subsistence using isotopic data derived from human and associated animal tooth enamel. Broadly contemporary archaeological sites in northern Hokkaido and associated islands from 500–1300 C.E. (Common Era or A.D.) permit study of the relative insularity and nature of contact between people from these disparate locales. Do inferredpatterns of human mobility and migration relate to perceived differences in maritime subsistence for people living across Okhotsk territory? We approach this problem in the

context of marine ecology, Okhotsk subsistence variability and the presence/absence of winter sea ice. Our goal is to evaluate existing models of Okhotsk migration and mobility using combined isotopic analyses.

The extent to which Okhotsk groups were interconnected is a long-standing question, particularly because Okhotsk people seemed not to interact much with non-Okhotsk neighbors. Our study supplements previous isotopic work using archaeological human and animal remains from Hokkaido and surrounding islands. To address these questions, we use light stable isotopes of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) and heavy ('radiogenic') isotopes of lead (Pb) and strontium (Sr). Stable isotopes of carbon and oxygen from tooth enamel are well-established proxies of total diet and body water, respectively, as they help to identify patterns of consumption of foods and waters during the time of tooth mineralization. Such data can help distinguish maritime diets and may be used in combined analyses with radiogenic isotope ratios of strontium ($^{87}Sr/^{86}Sr$) and Pb ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$) to infer patterns of residential mobility and potential movement of individuals. Strontium and lead isotope ratios are useful to infer prehistoric movement because these isotopes remain unchanged as they pass from bedrock to biosphere, and thus their ratios measured in tooth enamel can be mapped to local/regional geology of an individual's childhood.

We focus on geographically and ecologically diverse sites including: Hamanaka 1 and Kafukai 1 on Rebun Island, off the northern tip of Hokkaido; Susuya on the southern tip of Sakhalin Island north of Hokkaido; Moyoro in eastern Hokkaido, near the Shiretoko Peninsula; and Ainu Creek in the Kuril Islands. Occupants of Rebun were obligate maritime harvesters, although they also imported/raised and consumed pigs, dogs, and bears. In eastern Hokkaido, Okhotsk people could access terrestrial foods and large populations of ice-adapted marine resources. The southern coast of the Sea of Okhotsk is highly productive in spring and early summer with nutrients supplied from multiple sources (Okhotsk Gyre, Amur River, and Sea of Japan via Soya Strait). Settled nutrients are brought to the surface by ice scour and spring storms, further feeding primary production. This nutrient soup is carried into the Kurils where additional productivity arises from tidal mixing and the Kuroshio-Oyashio confluence. Marine mammal and sea bird populations thrive there.

Human tooth enamel was sampled from Hamanaka 1 ($n = 10$), Susuya ($n = 3$), Moyoro ($n = 21$), and Ainu Creek ($n = 3$). Fauna sampled include dogs ($n = 5$) from Hamanaka 2; dog ($n = 10$) and fox ($n = 10$) from Moyoro; and dog ($n = 3$), pig ($n = 12$) and bear ($n = 13$) from Kafukai 1 (on Rebun Island). Human samples all exhibit similar mean $\delta^{13}C$ values for Hamanaka (−9.47‰ ± 0.67), Moyoro (−9.80‰ ± 0.60), Susuyu (−10.97‰ ± 1.45), and Ainu Creek (−10.07‰ ± 0.66). These data are consistent with a maritime subsistence of fish and sea mammals, and correlate with dogs sampled: Hamanaka dog (−9.04‰ ± 1.97), Moyoro dog (−9.30‰ ± 0.81), and Kafukai 1 dog (−8.16‰ ± 1.37). $\delta^{18}O$ data are broadly comparable for all humans sampled: Hamanaka (−9.09‰ ± 0.82), Moyoro (−8.82‰ ± 0.61), Susuyu (−8.77‰ ± 1.79), and Ainu Creek (−6.26‰ ± 0.07). ^{18}O enrichment (less negative $\delta^{18}O$ values) is observed for the Ainu Creek sample, which suggests potentially different precipitation patterns or a different water regime from the other Okhotsk sites sampled. For sampled dogs, ^{18}O enrichment is also observed for Hamanaka (−4.91‰ ± 0.98), Moyoro (−7.13‰ ± 0.86), and Kafukai 1 (−6.18‰ ± 0.49). This disparity in $\delta^{18}O$ values between humans and dogs likely relates to dog physiology (dogs are 'panters' and humans are 'sweaters') not environmental patterning of $\delta^{18}O$ values.

Turning to Sr ratios ($^{87}Sr/^{86}Sr$), Hamanaka (avg. = 0.708942 ± 0.000064) and Ainu Creek (avg. 0.708936 ± 0.000010) indicate less variation compared to Moyoro (avg. 0.708449 ± 0.000191) and Susuyu (avg. 0.708936 ± 0.000430). A similar pattern for the human samples can be seen with the $^{20n}Pb/^{204}Pb$ ratios (data not summarized), whereby Hamanaka (n = 9) exhibits less variation than the Moyoro sample (n = 21), but the small Susuyu sample (n = 3) albeit quite varied overlaps with the $^{20n}Pb/^{204}Pb$ range observed at Hamanaka. Interestingly for Pb ratios, the Moyoro dogs (n = 7) cluster with the Hamanaka human sample while the single Hamanaka dog groups with the Moyoro human sample. Only one Ainu Creek sample provided sufficient Pb ratios to report, and this clearly partitions outside the range of variation of all other samples assayed. These data suggest greater heterogeneity (less 'insularity') for populations from Moyoro compared to those from northern Hokkaido, especially Hamanaka 1. The Susuyu sample (Sakahlin Island) shows variation consistent with connectivity between northern Hokkaido and eastern Hokkaido, but not with the Kuril Islands.

Our data suggest that northern Okhotsk (Rebun Island) populations were relatively local or regional in their movements, staying within northern Hokkaido, at least during their childhood years (during tooth enamel development). Data from eastern Okhotsk (Moyoro site), by contrast strongly imply immigration for some individuals after childhood from northern Hokkaido or elsewhere. Thus non-local individuals are represented in the larger Moyoro sample in addition to local individuals living in the region. These results suggest that northern Okhotsk group either spilled surplus population east or people left the north in search of better conditions in the east. This leads us to hypothesize that eastern Hokkaido marine ecosystems may have offered better or more stable opportunities for Okhotsk people in the later first millennium. Better chronological control of these samples and more paleoecological research is needed to sort out these possibilities. We interpret the results in terms of the significant differences in ecological opportunities between the two regions.

Decadal to millennial-scale Asian dust transport changes and its possible impact on ocean biogeochemistry

Kana Nagashima, Yoshiaki Suzuki, Yukari Hara, Yasunori Kurosaki, Ryuji Tada, Takeshi Nakagawa & SG06/12 members

Knowledge of decadal to longer-scale variations in Asian dust transport is critical to determine the interactions between Asian dust and natural environment. Here we present temporal changes in the depositional flux of aeolian dust recorded in sediments from Lake Suigetsu, central Japan, during the last century. The result exhibits its decadal-scale change in harmony with latitudinal change of the westerly path in spring. Decadal-scale westerly change probably causes north–south shifts of the dominant dust transport path, which potentially affect North Pacific biogeochemistry by changing the spatial distribution of iron input. We will also present the preliminary result of the depositional flux of aeolian dust reconstruction from Lake Suigetsu expanded to the last several thousand years, and discuss decadal to millennial-scale changes in dust transport and related climate and biogeochemical changes.

Paleo- and modern environmental analysis based on chemical and Sr-Nd isotopic compositions of aluminosilicate detritus in the Arctic and Sub-Arctic Seas

Yoshihiro Asahara, Tomoki Yasuda, Seiya Takeuchi & Fumi Takeuchi

Provenance analysis of terrigenous material in marine sediment and suspended matter provides information about a paleo- and modern environment such as atmospheric and ocean circulations and climate change on continent. It also figures out a relationship between terrigenous input and biological productivity in ocean. Radiogenic isotopes such as strontium ($^{87}Sr/^{86}Sr$) and neodymium ($^{143}Nd/^{144}Nd$) in detrital (aluminosilicate) fraction of marine sediments and suspended particles are valuable indicators for identifying the geographical provenance of the terrigenous material (e.g., Dasch, 1969; Grousset et al., 1988; Asahara et al., 1999). Because the isotope ratios in detritus, especially Nd isotope, are not significantly altered by the process of weathering, transportation and deposition. In this presentation, regional and temporal variations for Sr and Nd isotopes of marine sediments and suspended particles in the Arctic Ocean, the Bering Sea and the Sea of Okhotsk are discussed.

1. Yukon derived sediment to the Bering Sea and Chukchi Sea in the Arctic

Chemical and Sr-Nd isotope analyses of the detrital fractions extracted from the continental shelf sediments in the Bering and Chukchi Seas were applied to examine regional and temporal changes in the inflow and transportation of terrigenous material. Regional distributions show lower Sr isotope ratios and higher εNd values in the eastern Bering Sea ($^{87}Sr/^{86}Sr$=0.7045–0.7109; ε_{Nd} =–8.6 to +3.0), and higher Sr isotope ratios and lower εNd values in the Chukchi Sea (0.7106–0.7150; –10.1 to –8.3). In addition, chemical compositions such as Rb and Sr contents and rare earth element (REE) patterns changed noticeably across the Bering Strait. These variations mean that the sediments in the Bering and Chukchi Seas have clearly distinct sources. The detritus in the eastern Bering Sea mainly consists of two components: the continental material from the Yukon River basin in the Alaskan mainland (0.708–0.709; –9 to –8), and the Aleutian-arc volcanics transported northward by the Alaska Coastal and Bering Shelf Waters (0.703; +6 to +10). The detritus in the Chukchi Sea is mainly derived from northeastern (NE) Siberia (0.711; –9) and Bering Strait inflow, essentially from the Yukon River, and additionally from the MacKenzie River basin including the Canadian Shield (0.732–0.734; –14). The eastern Bering sediments over the past 100 years (multiple core sediment) show slight variations of the Sr isotope ratio and relatively wide variations of the ε_{Nd} value, and the variations and trends of the time-series sediments in the Sr–Nd isotope diagram are probably controlled by changes in the grain size of the detritus from the Yukon River basin. Some of the ε_{Nd} time-series show periodic fluctuations correlating with the annual mean surface air temperature (SAT) for the Arctic: the εNd value is low in the high SAT period, and high in the low SAT period. In the warm period, the Yukon River was likely to supply a higher amount of the fine-grain material with a relatively low ε_{Nd} value such as surficial overburden, probably because partial melting of continental glaciers and permafrosts in the Alaskan mainland increased.

2. Suspended particulate matter in the western part of the Canada Basin, the Arctic Ocean

Chemical and Sr-Nd isotope analyses were applied in order to reveal provenance of detrital fraction in suspended particulate matter (SPM) collected in the western part of Canada Basin in the Arctic Ocean (75°N, 162°W, 180 m depth) for one-year period between October 2010 and September 2011. The chemical compositions such as REE pattern and V/Ga ratio and the $^{87}Sr/^{86}Sr$–ε_{Nd} and $^{147}Sm/^{144}Nd$–ε_{Nd} diagrams suggest that the SPM detritus is mainly composed of the MacKenzie River material which is carried by the Beaufort Gyre. They also suggest that the Yukon derived material (0.708–0.709; –9 to –8) and the NE Siberia material (0.711; –9) contribute to the SPM. The seasonal variation shows higher Sr isotope ratios and lower εNd values in January–March 2011 (0.726–0.727; –12) and lower Sr isotope ratios and higher ε_{Nd} values in November 2010 and April–August 2011 (0.720–0.722; –11 to –10). Combination of these isotopic and chemical data and the SPM flux suggests that the flux of the Yukon derived material and the NE Siberia material to the Canada Basin increases in November 2010 and April–August 2011. The Chukchi Sea shelf sediments derived mainly from the Yukon River and NE Siberia materials are possibly resuspended and transported to the Canadian Basin by brine rejection, storm-mixing (Woodgate et al., 2005) or shelf-break eddies (Watanabe et al., 2014) in November 2010 and April–August 2011.

3. Terrigenous input from the Amur River to the Sea of Okhotsk (OS) and the western subarctic Pacific (WSP)

Primary productivity is high in the Sea of Okhotsk (OS), most likely because of terrigenous input from the Amur River that includes dissolved matter and suspended matter. And the western subarctic Pacific (WSP) is one of High Nutrient Low Chlorophyll (HNLC) regions, and the most important source of iron in the WSP has been thought to be terrigenous matter from the Amur River together with the Asian dust (e.g. Nishioka et al., 2007). To reveal the transport processes of the fluvial materials in the OS, the Sr and Nd isotopes of the detritus in the surface sediments and suspended matter were investigated. The regional variations of the isotopes indicate that the detritus has three main sources: Amur River detritus, with a high $^{87}Sr/^{86}Sr$ ratio (0.711–0.715) and relatively low ε_{Nd} value (–8 to –7); volcanic detritus derived from the Okhotsk-Chukotka volcanic belt to the north of the OS, with a low $^{87}Sr/^{86}Sr$ ratio (0.703) and high εNd value (+7 to +8); and detritus from the sedimentary rocks north of Sakhalin Island, with a high $^{87}Sr/^{86}Sr$ ratio (0.709–0.710) and low ε_{Nd} value (–10 to –9). The results indicate that the Amur River detritus is dispersed across the northwestern continental shelf and further transported southward along the east coast of Sakhalin while flowing out of the shelf. The Amur River detritus flowing out of the shelf is mixed with the Okhotsk-Chukotoka volcanic material transported from the northern area of the OS by the Okhotsk Sea intermediate water (OSIW). It is possible that the OSIW entrains the Amur River material, which then circulates in the OS and partly flows out to the WSP.

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Session: Challenges to the Climate Sciences in a Changing Arctic & Subarctic – observations & Models –

The 18.6 year modulation of localized tidal mixing as a possible cause of bidecadal variability in the North Pacific

Satoshi Osafune

Bidecadal variability dominates long-term ocean and climate variability in the North Pacific, and likely influences biogeochemical cycle and ecosystem in the region. Thus, it is important to understand the mechanism that underlies the bidecadal variability in order to gain a better understanding of the natural variability. One possible cause is the 18.6-year period nodal tidal cycle, which is related to the precession of the moon's ascending node. This cycle modulates the amplitudes of diurnal tide up to 20%, and the diurnal tide induces strong vertical mixing in the ocean poleward of 30° around the steep topographic features. This means that a large modulation of the localized strong vertical mixing in 18.6 year period occurs in the subarctic seas. Focusing on the localized strong mixing induced around the Kuril Straits and the Aleutian Passes, located between the subarctic North Pacific and its marginal seas, I investigated the possible impacts of its 18.6 year modulation on water-mass properties and climate during the past decade. I will review the series of studies with other related studies.

Observed seasonal variation of the Arctic Ocean heat and fresh water transports

Takamasa Tsubouchi, Sheldon Bacon & Alberto Naveira Garabato

The Arctic Ocean has been accumulating fresh water (FW) over last decades [Rabe et al. 2014 GRL], which has a potential impact on deep water formation in the high latitude North Atlantic. In order to observe oceanic heat and FW exchanges between the Arctic and surrounding seas, five research groups in the world maintain the Arctic boundary mooring observation lines in Davis Strait, Fram Strait, Barents sea opening (BSO) and Bering Strait over many years.

Tsubouchi et al. [2012 JGR] is the first study to estimate a synoptic view of pan-Arctic heat and FW transports in summer 2005 using box inverse model. Followed by Tsubouchi et al. [2012], this study aims to establish an "observation based" full annual cycle of pan-Arctic boundary transports from September 2005 to September 2006. The oceanic transports are estimated based on 135 moored instruments across the pan-Arctic boundary. Sea ice transports are estimated based on PIOMAS data [Zhang and Rothrock, 2003 JGR]. Monthly initial net volume transport is 1.0 ± 3.1 (Sv), and that of FW imbalance is 23 ± 92 (mSv). 12 months volume and salt conserved velocity fields are generated using box-inverse model. The obtained volume transports are reasonable both in magnitude and variation across the four Arctic gateways: −2.1 ± 0.7 (Sv) in Davis Strait, −1.1 ± 1.2 (Sv) in Fram Strait, 2.3 ± 1.2 (Sv) in BSO and 0.7 ± 0.7 (Sv) in Bering Strait. Sea ice volume transport is −58 ± 37 (mSv). The associated oceanic and sea ice heat transports are 154 ± 44 (TW) and 22 ± 15 (TW), respectively. The associated oceanic and sea ice FW transports are 155 ± 65 (mSv) and 48 ± 32 (mSv), respectively.

This study also aims to address important questions to design future sustained pan-Arctic observation lines quantifying the uncertainties associated with the results. The specific questions are: (1) Does current configuration of pan-Arctic mooring array monitor the major oceanic heat and FW exchanges between the Arctic Ocean and surrounding Oceans? (2) Where is the most efficient place to add additional instruments to increase the accuracy of measurements?

Ocean changes in the northern North Atlantic and the Arctic: global warming or AMO?

Ken Drinkwater

Major changes have been occurring in the physical characteristics of the waters in the NE Atlantic, in particular the Nordic and Barents seas as well as the Arctic Ocean. Temperatures have increased significantly, the most noticeable effect of which is the reduction in sea ice coverage. These changes have been consistent with, and often been attributed to, anthropogenic warming. However, the long term natural variability associated with the Atlantic Multidecadal Oscillation (AMO), which exhibits an approximate 60-80 year variability, is also important in these regions. Recent years has seen a positive phase of the AMO that is associated with warming. In this talk I will review some of the changes that have taken place, not only in ocean temperatures and sea ice, but in other physical properties to determine the relative importance of natural variability and anthropogenic warming as the cause of the changes in the northern North Atlantic and the Arctic.

Validation/calibration of sea surface salinity estimated by L-band microwave radiometers SAC-D/Aquarius in the Pacific sector of the Arctic Ocean

Kohei Mizobata & Hirari Satoh

One of the challenges in the Arctic Ocean is to understand precise and higher resolution of freshwater distribution for understanding hydrological cycle and ocean acidification. Basically, freshwater distribution is based on hydrographic surveys so that seasonal or inter-annual variability only has been discussed. One of the powerful solutions to elucidate short-term and fine scale variability of freshwater distribution is satellite remote sensing. Now, L-band (1.413GHz) microwave radiometers on earth observing satellites, such as ESA's SMOS and NASA's SAC-D/Aquarius, have provided estimated seas surface salinity (SSS). Using in-situ measurements, we validated and corrected the NSIDC Level-3 Aquarius SSS in the summer of 2012 and 2013. Corrected SSS showed relatively high SSS band-like feature in the northern Chukchi Sea and SSS fronts in the Chukchi Border Land area. Although L-band data is not available in sea ice area, our results indicate that estimated SSS can be used for ice-ocean climate studies (e.g., providing initial condition of salinity to estimate the amount of dense water).

Overwinter transport of subsurface warm water toward the Arctic Chukchi borderland

Eiji Watanabe, Jonaotaro Onodera, Motoyo Itoh, Shigeto Nishino & Takashi Kikuchi

Ocean heat transport is a possible important factor for recent sea ice decline, especially in the western Arctic Ocean. It has been indicated that vertical hydrographic profiles in the Canada Basin were characterized by three temperature maxima. The near-surface temperature maximum was the shallowest one arising from summer solar heat absorption and subsequent autumn Ekman downwelling. The subsurface temperature maximum reflected intrusion of Pacific summer water. The deepest maximum was located in the Atlantic layer. Substantial parts of upper ocean heat would eventually affect sea ice freezing/melting. However, spatial and temporal variabilities of these warm layers still remain uncertainties. In this study, a pan-Arctic sea ice-ocean modeling was performed to address overwinter transport of subsurface warm water. The horizontal grid size was approximately 5 km to resolve mesoscale eddies and narrow jets. In the interannual experiments from 2001 to 2014, strong easterly winter winds in the southern part of the prevailed Beaufort High sometimes produced a westward shelf-break jet along the northern edge of Chukchi shelf. Warm eddies generated north of

the Barrow Canyon were still located east of the Northwind Ridge. Therefore, the subsurface warming event observed in the Chukchi Abyssal Plain, where the bottom-tethered year-long moorings have been deployed by JAMSTEC field campaign, would have been attributed to shelf-break jet streams rather than eddy-induced transports. These situations suggest that lateral advection of shelf-origin warm water is a key factor for the subsurface warming in the CAP region. Interannual variability in ocean heat loss from these layers will also be reported.

The immediacy of Arctic change

James Overland, M Wang, N Soreide & S Moore

For the foreseeable future [out to 2040], continuing rapid environmental changes in the Arctic and subarctic are very likely, and the appropriate response is to plan for adaptation to meet these mean and extreme event challenges. Ongoing temperature changes in the Arctic are double relative to lower latitudes, a process known as Arctic Amplification due to multiple interacting feedbacks driven by modest global change. Even if global temperature increases are contained to +2°C by 2040, Arctic (North of 60° N) monthly mean temperatures in fall will increase by +4°C. The Arctic is likely to be sea ice free during summer before 2040, but with the sea ice free duration limited to < 5 months. Snow cover will be absent in May and June on most land masses. Arctic climate is now interacting strongly with the subarctic and mid-latitudes. Extreme temperature events, as a combination of mean temperature increases combined with natural variability, will become especially common in subarctic seas, nearing and exceeding previous thresholds. Such an event was the +4°C anomalies for Alaska and adjacent waters in late 2014 and early 2015 related to recent warm Pacific sea surface temperatures. In November-December 2015 the northern Barents Sea was sea ice free with temperature anomalies of greater than +5°C. Baffin Bay had cold temperature anomalies the end of 2015, in contrast to warm anomalies earlier in the decade. Species in subarctic seas have different environmental niches and thus will be sensitive to different aspects of rapid Arctic change, as well as overall ecosystem and food web shifts.

Day 2: Tuesday, March 8th

Session: Challenges to the Biogeochemical Sciences in a Changing Arctic & Subarctic

Ocean acidification in the surface water of subarctic western North Pacific Ocean and the impact on biological production

Masahide Wakita, Akira Nagano, Tetsuichi Fujiki & Shuichi Watanabe

The subarctic western North Pacific Ocean is characterized by the high primary productivity and abundant marine resources. In the winter mixed layer of this region, pH decreased from 1997 to 2011 because of reduction of CO_2 emission in winter by an increase in TA (Wakita et al., 2010, 2013). However, this detection of the pH decrease only in the winter is not enough to clarify the impact of acidification on biological production and ecosystems.

We investigate progression of acidification in the surface water by examining the temporal changes of pH using the CO_2 system data sets previously observed at stations KNOT and K2 from 1997 to 2015. In order to estimate mean rate of temporal change by using observations during various seasons in different year, we eliminated the seasonal bias according to Takahashi et al. (2006). By comparison, we estimate the winter mixed layer of parameters from the temperature minimum layer following Wakita et al. (2013).

The pH decrease (−0.0015 ± 0.0004 /yr) and $x$$CO_2$ (1.3 ± 0.4 ppm /yr) increase from deseasonalized anomaly were similar to those in the winter (−0.0008 ± 0.0003 /yr; 0.9 ± 0.3 ppm /yr). Deseasonalized salinity-normalized TA increase in the surface water (0.4 µmol/kg/yr) agreed with that in the winter (0.5 µmol/kg/yr), while the increases of deseasonalized salinity-normalized DIC (1.5 µmol/kg/yr) and nitrate (0.20 µmol/kg/yr) were significantly higher than those in the winter (0.7 µmol/kg/yr; 0.06 µmol/kg/yr).

This TA increase in the surface water suppresses oceanic acidification and CO_2 uptake by anthropogenic CO_2 increase in this region ($CaCO_3$ Counter Pump). The impact of this effect on acidification might be larger in winter, because deseasonalized carbonate decrease (−0.8 µmol/kg/yr) was higher than that in the winter (−0.2 µmol/kg/yr). In addition, the higher increases of deseasonalized DIC and nutrients indicate that seasonal variations didn't remain unchanged, and DIC and nutrient accumulated over time. It suggests the reduction of net community production.

Investigation in impact of seawater condition on planktic foraminiferal (*Globigerina bulloides*) calcification by X-ray micro-computed tomography

Shinya Iwasaki, Katsunori Kimoto, Osamu Sasaki & Harumasa Kano

The amount of CO_2 gas, which have been discharged by human activity, have been absorbed into ocean surface waters and have resulted in the decrease of the oceanic pH. This ocean acidification is likely to prevent the production of calcium carbonate by marine organisms and to have serious consequence for marine ecosystems in the near future. Planktic foraminifera dwell in the whole ocean and their tests are major component of ocean carbonates. Therefore, investigations in the response of planktic foraminiferal test calcification to ocean acidification are informative for estimating the influence of ocean acidification in the near future. Calcification of planktic foraminiferal test is supposed to be controlled by seawater carbonate ion concentration. However, because density, wall thickness and growth rate of individual foraminiferal test could not be estimated by previous methods, little is known about the impact from ocean acidification on foraminiferal test condition, which indicates test weight, density, wall thickness, and growth rate. Recent progress in X-ray micro-computed tomography (XMCT) has allowed researchers to observe the three-dimensional (3-D) skeletal structures of microorganisms. Furthermore, XMCT enable us to estimate the test condition of foraminifera (size, wall thickness, volume, density, etc.) in quantitatively, and it may be a suitable method for identifying the foraminiferal test condition in detail than the previous methods. In order to estimate the impact of seawater condition on foraminiferal calcification in detail, we corrected living planktic foraminifera (*G. bulloides*) by plankton tow at the western North Pacific and measured foraminiferal test conditions (test weight, density, thickness of test wall and growth rate) by XMCT. We also measured seawater conditions (temperature, [CO_3^{2-}], etc.) where planktic foraminifera dwelled, and compared them with measured foraminiferal test condition. As the results of observation in test conditions of *G. bulloides*, weights of test showed positive correlation with wall thickness and negative correlation with test density. This suggests that the measurement in weight of living foraminiferal test, which has been employed in previous studies, mainly indicates variation in wall thickness, not variation in test density. Furthermore, comparison between test condition of *G. bulloides* and ambient seawater condition (carbonate ion concentration) suggests that density of foraminiferal test, which is measured by XMCT, might be a useful proxy to estimate the effect of ocean acidification rather than previous methods.

27

Shell dissolution of Arctic Pteropods between 2010 and 2012: Coupling of timeseries observations and micro X-ray CT analysis

Katsunori Kimoto, Yuriko Nakamura, Jonaotaro Onodera, Osamu Sasaki, Harumasa Kano & Naomi Harada

Progress of ocean acidification in the Arctic Ocean will give negative impacts on marine ecosystems, particularly on the species with shells and skeletons of calcium carbonate. However, the aspects of damages caused by acidifying ocean is far less clear than observable physicochemical parameters. We focused on aragonitic shelled pteropod *Limacina helicina* recovered by sediment traps deployed at the Northwind Abyssal Plain (St. NAP: 75°N, 162°W, water depth: 1,975m) in the Arctic Ocean, and observed relative shell density (RSD) of individual shells by Micro X-ray Computed Tomography for 2 year-round samples from 2010 to 2012.

RSD of individual pteropod shells showed large variations, and their timeseries fluctuation patterns were different between two years. The strongest dissolution occurred in early winter (Nov to Jan, 2010) through two years and the shell density was 25 % lower than those of complete shells. However, such strong dissolution never occurred through 2012. During the sea ice covered periods, pteropod shells were essentially well-preserved. Yearly differences of shell dissolution of pteropods may reflect property of surface water and suggest complicated fluctuation of carbonate chemistry in the Arctic Ocean.

Decadal change in biogenic materials' flux in the North Pacific Western Subarctic Gyre based on the trend analysis of time-series sediment trap data between 1998-2014

Makio C. Honda, Hajime Kawakami, Kazuhiko Matsumoto & Eko Siswanto

The efficiency of the biological pump, which is one of oceanic mechanisms of uptake of atmospheric CO_2, in the North Pacific Western Subarctic Gyre (NPWSG) has been reported to be higher than in other parts of the world ocean; this high efficiency has been attributed to the fact that diatoms dominate the phytoplankton community in this area and play a pivotal role in the uptake of atmospheric CO_2 and transport of CO_2 to the ocean interior. However, the efficiency of this pump might be altered by "multiple stressors" such as the warming, freshening, deoxygenation and acidification of the ocean observed during the last several decades. In the NPWSG, several decadal changes in oceanography such as decreases of subsurface dissolved oxygen / nutrient concentrations in the surface mixed layer / primary productivity and increases of small phytoplankton abundance have been reported. In addition, it has been certified that ocean acidification is ongoing.

One of the key components of the biological pump is the vertical transport of particulate materials to the ocean interior. Time-series (TS) sediment trap experiments facilitate understanding of the flux and chemical composition of settling particles and their seasonal and annual variability. Thus TS sediment trap experiments are among the most important observations for studying the biological pump and have been conducted all over the ocean since the late 1980s. There are limited papers to document decadal change in particulate materials' vertical flux based on analysis of TS sediment trap data. In the North Atlantic, it was reported that the ratio of biogenic opal (Opal) flux to $CaCO_3$ flux has been decreasing. Unfortunately this result was not always statistically significant and obtained from data set with long hiatus. In the NPWSG, at station KNOT (44°N, 155°E), it was reported that $CaCO_3$ flux tended to decrease between 1989-2008. However $CaCO_3$ flux did not always decrease after 2000. Thus it was important to investigate the decadal change in settling particles in the NPWSG with longer TS sediment trap data.

TS sediment trap experiments have been conducted at 4810 m at station K2 (47°N, 160°E) since 2005. TS sediment trap experiments at ~ 5000 m were also conducted near K2 in the NPWSG between 1998–2001 (station 50N: 50°N, 165°E, trap depth: 5060-5090 m) and 2002-2003 (station K1: 51°N, 165°E, trap depth: 4820 m). If these data can be compiled, long-term (17 years) trend analysis was possible. Based on general oceanographic classification, these stations seemed to be located in the same domain. However statistical analysis (t-test) on annual amplitude of nutrients obtained from National Institute for Environmental Studies-hosted database "SOOP" gridded products resulted in significant difference between stations: annual amplitude of salinity-normalized nutrients (n-NO_3 and n-$Si(OH)_4$) at K2 between 2001–2004 was ~ 20-30 % larger than these at stations 50N and K1. Thus, assuming that the ratio of annual amplitude of n-NO_3 and n-$Si(OH)_4$ at K2 to that at 50N or K1 can be applied as the ratios of organic carbon (OC) flux and Opal flux between stations, OC flux and Opal flux at 50N and K1 were corrected to these at K2 with these ratio between 2001-2004, and then the trend analysis was conducted for monthly anomaly of OC flux and Opal flux obtained from 17 years. As a result, weak but significant decadal increase in OC flux was detected ($p < 0.001$). Though decadal change for Opal flux was not statistically significant, time-series Opal flux also tended to increase. In addition, monthly anomaly of Opal flux correlated positively with that of OC flux ($r = 0.92$). Interestingly, the annual amplitudes of n-NO_3 and n-$Si(OH)_4$ between 2001–2010 showed weak but significant increase trend at K2, and these at 50N and K1 tended to come closer to that at K2. In addition, salinity at three stations showed the weak but significant decrease trend. On the other hand, using climatological carbonate chemistry data, salinity-normalized alkalinities between stations K2, 50N and K1 were compared in order to suspect potential difference in $CaCO_3$ flux between stations. However, there was not significant difference between stations. Thus time-series $CaCO_3$ flux data from 50N, K1 and K2 were compiled without any correction and trend analysis was conducted. As a result, the $CaCO_3$ flux also showed weak but significant long-term increase trend, although ocean acidification is ongoing at K2 and a significant decrease in the $CaCO_3$ flux for 1989–2008 was reported at station KNOT.

Based on satellite data trend analysis, surface chlorophyll-a north of ~45°N tended to increase between 1997–2013. In addition, weak but significant decadal increase of sea surface temperature (SST) was observed. Although significant decrease of surface mixed layer depth was not always detected at around K2, possible scenario of relation between increases of biogenic materials' flux (fluxes of OC, Opal and $CaCO_3$) and SST is that increase SST upgrades phytoplankton growth rate and / or strengthens magnitude of stratification accompanied by decrease salinity resulting improvement of light condition for phytoplankton. In addition, weak but significant increase of the satellite-based aerosol optical thickness was also detected. Recently, increase of one of anthropogenic eolian dust, aerosol < 2.5 μm (PM2.5), has become social problem in the global scale and, especially in Japan, cross-border pollution of it from the Asia continent is crucial problem. It has been predicted that anthropogenic eolian dust originating from fossil-fuel combustion and biomass burning will increase in future. It has been reported that anthropogenic eolian dusts include more soluble/bioavailable Fe than natural eolian dust. It might be one of possible triggers to enhance ocean productivity and settling particle in the NPWSG.

Finally, biogenic materials' flux tended to increase weakly for the last 17 years and might be associated with weak but significant increases of SST and eolian dust input. However, long-term variability consists of linear trends and natural oscillations such as the Pacific Decadal Oscillation. In order to improve our ability to predict the effect of climate change on ecosystem and biogeochemical cycle, more longer time-series biogeochemical observations in various domains are strongly requested.

Decadal change in carbon chemistry in the Labrador Sea

Kumiko Azetsu-Scott & the Atlantic Zone Offshore Monitoring Program Team

The Labrador Sea is one of two sites in the North Atlantic that produce intermediate and deep water by winter convection which extends from 500 m to over 2000 m depth depending on atmospheric conditions and stratification in the water column. This convection produces Labrador Sea Water (LSW), a well-ventilated, relatively homogeneous water mass. LSW is characterized by low salinity and temperature, and provides an important vehicle for the transport of atmospheric gases, including carbon dioxide, feeding the intermediate depths of the North Atlantic. The North East Atlantic Deep Water (NEADW) and Denmark Strait Overflow Water (DSOW) that were formed in the Nordic seas flow into the region under the LSW. Consequently, all of the water masses in the Labrador Sea are relatively young (<20 years) and inventories of anthropogenic gases are high.

A time series study from 1996 to 2014 shows the steady increase of dissolved inorganic carbon (DIC) concentrations in all water masses in the Labrador Sea. In the newly ventilated LSW, the DIC concentration increased by 0.87 μmol/kg^3/year and pH_{total} decreased by 0.003/year. The total alkalinity was correlated negatively with salinity during 1993 to 2002, and became positively correlated with salinity after 2003, which implies a large shift in freshwater sources influencing the newly ventilated LSW.

Mapping of the air-sea CO_2 flux in the Arctic: Basin-wide distribution and seasonal to inteannual variability

Sayaka Yasunaka, Akihiko Murata, Eiji Watanabe, Melissa Chierici, Agneta Fransson, Steven van Heuven, Mario Hoppema, Masao Ishii, Truls Johannessen, Naohiro Kosugi, Siv K. Lauvset, Jeremy T. Mathis, Shigeto Nishino, Abdirahman M. Omar, Are Olsen, Daisuke Sasano, Taro Takahashi & Rik Wanninkhof

We produced 204 monthly maps of the air–sea CO_2 flux in the Arctic Ocean and its adjacent seas (north of 60°N) from January 1997 to December 2013, using the partial pressure of CO_2 in surface water (pCO_{2w}) estimates by a self-organizing map technique. The pCO_{2w} data were measured by shipboard underway measurements and calculated from alkalinity and total inorganic carbon of surface water samples. Subsequently, we investigated the basin-wide distribution and seasonal to interannual variability of the CO_2 fluxes. The pCO_{2w} undersaturation combined with less ice-cover and strong winds drives a flux of CO_2 into the Greenland/Norwegian, Barents and Chukchi seas, averaging 11 ± 3 mmol m^{-2}, 10 ± 4 mmol m^{-2} day^{-1}, and 4 ± 4 mmol m^{-2} day^{-1}, respectively, over the

17 year period. Annual CO_2 uptake of the Arctic Ocean was estimated to be 152 ± 173 Tg C yr^{-1}. The seasonal variability of the CO_2 flux depends mainly on wind variability, and partly on sea-ice coverage. In winter, the CO_2 influx was large in the Greenland/Norwegian Sea because of strong winds, but small in the Chukchi Sea because of sea ice. In contrast, interannual variability was mostly related to the air–sea pCO_2 differences and partly to wind speed and sea-ice changes. In recent years, the CO_2 uptake in the Greenland/Norwegian Sea has increased and that in the southern part of the Barents Sea decreased due to increased and decreased air–sea pCO_2 differences, respectively.

Phytoplankton biomass trend in the Arctic and subarctic regions within a decade and half of modern ocean color missions

Eko Siswanto

The Arctic Ocean is expected to experience dramatic changes due to global warming more than any other biomes on Earth (Wassmann, 2011). While spatially-averaged analyses (e.g., Pabi et al. 2008; Arrigo and Dijken 2011) shown that a large portion of the Arctic Ocean phytoplankton primary productivity has tended to increase, detail spatial feature of biological productivity trend and its underlying factor in the Arctic, as well as in the subarctic region are not well documented. Siswanto et al. (2016) has recently shown that phytoplankton biomass in the northwestern Pacific subarctic region south of 54°N has tended to increase and it was ascribed to warming ocean trend in the recent 16 years, but that in the subarctic region north of 54°N was not investigated. In this work, the Arctic and subarctic regions (hereafter AnSARs) were revisited to discern detail spatial feature of trend of phytoplankton chlorophyll-*a* concentration (Chl, main determinant of ocean primary productivity, Pabi et al. 2008), and the probable underlying factors within a decade and half of modern ocean color missions.

A 17-year satellite Chl data retrieved by the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer-Aqua (MODIS) were used in tandem with other satellite-derived or reanalyzed geophysical data. Geophysical data used here include sea surface temperature (SST, retrieved by the Advanced Very High Resolution Radiometer), photosynthetically available radiation (PAR, retrieved by SeaWiFS and MODIS), and mixed layer depth (MLD, reanalyzed by the CMCC-Global Ocean Reanalysis System). Because, large portion of the AnSARs within the period from March to October are not observable by ocean color sensors, trend analysis was conducted for the period from April to September. In addition, analysis was also conducted for different seasons, i.e., spring (April-May-June) and summer (July-August-September) following Cohen et al. (2009).

Prior to spatiotemporal analyses, seasonal cycles of Chl and geophysical variable were removed by subtracting their climatological means from their time-series. A robust regression was then applied to identify the trend whose significance was statistically defined by using nonparametric Mann-Kendall test with 95% confidence level ($p<0.05$) (e.g., Salmi et al. 2002; Kahru et al. 2011). Besides directly comparing the trends between Chl and geophysical variables, a multiple linear regression analysis (MLRA) between Chl and geophysical variables was also conducted to assess the probable factors (inferred from the partial regression coefficient of geophysical variable) underlying the observed Chl trends. The significance of partial regression coefficient was also defined within 95% confidence level.

During the spring, phytoplankton Chl in the areas of northern Bering Sea, northern Sea of Okhotsk, Greenland-Norwegian-Barents Seas, northern Alaskan gyre, Baffin Bay, and subarctic region of the Atlantic sector exhibited declining trend. Most of those areas were characterized by SST increase, implying that warmed ocean in spring there was likely not able to drive phytoplankton positive net growth to increase. The PAR and MLD also showed no spatially consistent trends with Chl trend. Increasing trend of Chl could be observed in the areas such as south of Iceland, and southern Bering Sea.

Unlike during the spring, Chl in most part in the AnSARs during the summer exhibited increasing trend which was accompanied by SST increasing trend. Increasing trend of summer SST might drive an increasing trend of summer phytoplankton positive net growth within the period of observation. Moreover, the trends of increasing PAR and shoaling MLD indicated that the mean light availability within MLD tended to increase. Those trends of geophysical variables might change environmental condition in away favorable for positive net growth of phytoplankton as depicted by Chl increase. Declining trends of Chl were observed mainly in the eastern Bering Sea, Norwegian Sea, and the seas off UK and Ireland.

The spatial pattern of Chl trend when including both spring and summer resembled that of spring Chl trend, implying that overall spring-summer Chl trend was a reflection of spring trend. Overall, the areas of eastern Bering Sea, northern Sea of Okhotsk, seas off Norway, UK, Ireland, and the seas along the Siberian coast have shown declining trend of Chl. The rest areas in the AnSARs have shown Chl increasing trend. Observing the partial regression coefficients of geophysical variables resulted from MLRA using both spring and summer datasets, the observed Chl trend was likely regulated by trends of both SST and mean light availability within the MLD. Trend of sea ice concentration retrieved by multi-sensors of passive microwave band will also be analyzed, as it is of important in determining annual primary productivity particularly within the minimum and maximum sea ice extent area (Pabi et al. 2008; Arrigo and Dijken 2011). The observed significant trends of Chl and geophysical variables indicated that environmental conditions in the AnSARs have changed, and this might influence not only low-trophic level but also high-trophic level marine organisms.

Session: Challenges to the Ecological and Ecosystem Sciences in a Changing Arctic & Subarctic

Effects of CO_2 and temperature on the phytoplankton community in the western and eastern North Pacific

Koji Sugie, Naomi Harada & Akihiko Murata

Increasing atmospheric CO_2 could increase acidity and temperature in the ocean via physical and chemical interactions between atmosphere and seawater. These environmental changes can modulate ecosystem processes in the ocean. Here we tested the effects of CO_2 and temperature on the plankton community in the western and eastern subarctic North Pacific, aboard R/V Mirai during summer 2014. The CO_2 levels of seawater samples were set at present (in situ condition), ~500 µatm CO_2, and/or ~800 µatm CO_2, which were incubated in two temperature (in situ and +4°C) conditions. High temperature significantly enhanced the net specific growth rate of phytoplankton in the western experiment, whereas the growth was not increased in the eastern experiment. The effect of high CO_2 condition on the growth rate was inconsistent between the two experiments; did not affect on the western phytoplankton community, and significantly decreased with increasing CO_2 from 520 to 950 µatm only under low temperature conditions of the eastern experiment. Particulate organic carbon and nitrogen dynamics were not significantly changed, but biogenic silica to chlorophyll-*a* (BSi:Chl-*a*) and biogenic silica to particulate nitrogen (BSi:PN) ratios were significantly affected in response to the both CO_2 and temperature changes. High CO_2 conditions often increased BSi:Chl-*a* in both western and eastern experiment, suggesting that diatom growth or their silicification was enhanced by the increase in CO_2 levels. However, the high temperature was negatively affected on BSi:Chl-*a* and BSi:PN ratios in the eastern experiment. These findings suggest that the high temperature often modulate phytoplankton rate process, and the following both high CO_2 levels and high temperature modify the quality (size and composition) of phytoplankton community in the North Pacific. These changes in phytoplankton dynamics are important factors modulating ecosystem processes in the ocean.

The North Atlantic spring-bloom system - where the changing climate meets the winter dark.

Svein Sundby, Kenneth F. Drinkwater & Olav S. Kjesbu

Poleward displacements of marine species in general and increased abundance of boreal species in Arctic and subarctic seas are major responses to the recent decades of warming. Similar responses were also observed in the Atlantic subarctic seas during the mid 20th century warming from 1920s to the 1950s. Future anthropogenic global warming throughout the 21st century is suggested to continue poleward displacement of marine species. However, a major constraint to onward displacement of marine species has not been considered up to now. The extreme seasonal light cycle at high latitudes, i.e. beyond about 65º, has developed endemic organisms with specific life cycles different from organisms in lower-latitude ecosystems. Due to the winter dark in these high-latitude ecosystems phytoplankton production is too low to sustain herbivore winter feeding. In response, high-latitude herbivore zooplankton, such as *Calanus finmarchicus*, has developed a particular life cycle with intense spring feeding, accumulation of lipids, and overwintering at large depths. Endemic planktivore fish, such as the Norwegian spring-spawning herring, which in turn feeds on *C. finmarchicus*, has developed similar feeding, lipid deposition, and overwintering strategy. Lower-latitude temperate herbivore species, such as *Calanus helgolandicus*, lack such attributes since they have been able to feed year around. We hypothesize that the latitudinal-specific bloom dynamics determined by the destined and stable latitudinal-dependent seasonal light cycle represents a fundamental barrier at high latitudes to the onward climate change-induced migration of temperate-adapted planktivores from lower latitudes, unless they are able to adapt over a relatively short time interval (i.e within the present century) by depositing lipids and undertake overwintering. Although piscivorous organisms at higher trophic levels are able to feed during winter dark, they will need to tune their spawning period to the time of the year when their planktonic offspring has feeding conditions to survive. Hence, spring-spawning behavior dominates among all organisms through the entire food web at high latitudes. We define the regional belt as "the critical latitudes" where spring-spawning behavior dominates through the food web and where planktivorous organisms have developed lipid accumulation during feeding season and overwintering at greater depths during the dark season. Observations in the Northeast Atlantic on spatial distribution of lipid-accumulating planktivorous organisms and location of spring-spawning fish species indicate that the critical latitude is located in the region in the vicinity of the polar circles. This northernmost part of the North Atlantic is unique as it is the only part of the world oceans with ice-free, open-water conditions under the extreme light cycle of winter dark and summer midnight sun. In the northern North Pacific a similar light cycle only exists to the north of the Bering Strait within the Polar Ocean, and in the Southern Hemisphere the Antarctic continent occupies similar southern latitudes.

Present IPCC projections on climate change indicate increased primary production in high-latitude marine ecosystem. It is further assumed that such increase also will cascade into higher productivity at higher trophic levels. Up to the present, this has also occurred in the Arctic and Subarctic region. However, projections based on extrapolation of past changes should be considered with care. If species from south are unable to adapt to the Arctic light cycle with lipid deposition and overwintering high-latitude marine production will rather decrease.

Projection of future climate change on plankton in the Atlantic sector of the Arctic

Ken Drinkwater

Climate change is expected to have its greatest impact in the Arctic. Temperatures will rise and sea-ice coverage will decline. Indeed, they have already been occurring. These and other associated changes will have a great impact on the marine ecosystems. In this talk I will discuss potential changes in the plankton communities under climate change. Phytoplankton production in the Barents Sea and the Arctic is generally expected to increase because of decreased ice coverage that in turn increases light levels in the ocean and lengthens the growing season. Blooms will occur earlier and more production might occur later in the year due to injection of nutrients due to wind-induced mixing. Phytoplankton species will also decrease in size. Zooplankton are expected to initially increase slightly in the Barents Sea although in the longer term they may decrease. There may be shift in distribution northwards and some boreal species are expected to be carried by the currents into the Arctic. Most of these species are unlikely to complete their life histories in the Arctic but instead will be consumed or die in the Arctic.

Day 3: Wednesday, March 9th

Session: Challenges to the Ecological and Ecosystem Sciences in a Changing Arctic & Subarctic

Diatom settling flux and sea surface hydrography at the southeastern slope of Chukchi Abyssal Plain in 2012–2013

Jonaotaro Onodera, Eiji Watanabe, Shigeto Nishino, Makio C. Honda & Naomi Harada

The recent variation of sea-surface circulation has influenced to temporal changes of nutrients and chlorophyll-a distribution in the Chukchi borderland. In order to monitor the relationship between hydrographic condition and phytoplankton, we have observed diatom assemblages in sediment trap samples obtained at Station CAP12t (75°12.37'N 172°32.92'W, 447 m water depth, 264 m trap depth) in the southeastern slope of Chukchi Abyssal Plain from October 2012 to September 2013. As the preliminary results, settling flux of diatom valves was the highest in October 2012. The planktic genus *Chaetoceros* and their spore were dominant in the diatom assemblage of fall 2012. Settling fluxes of total mass, lithogenic material, and biogenic opal showed clear maximum in March 2013. Slight increase of diatom flux was observed in March. Many uncountable fragments of diatom valves were contained in the sample representing significant input of allochthonous materials. Summer increase of settling diatom flux was observed with increased fecal pellets and appendicularian house in late July to early August 2013. Then, settling diatom flux diminished after late August to September 2013. Major diatoms in late July were sea-ice related pennate taxa such as the genera *Pleurosigma*, *Pinnularia*, and *Nitzschia*. The increase of these sea-ice related diatoms might temporally support zooplankton community under sea ice.

Weight-specific growth rates of large-sized oceanic copepods during phytoplankton bloom

Yoshiyuki, Abe, Atsushi Yamaguchi, Toru Kobari, Barbara Niehoff, Atsushi Tsuda & Ichiro Imai

Growth rates of marine copepods are important issue for understanding population dynamics, energy flow and material budgets in marine ecosystem. Growth rate of copepods is expressed by weight-specific growth rate (*g*). The *g* of copepods is measured by two methods: laboratory rearing methods (artificial cohort method and molt rate [MR] method) and natural cohort (NC) method analysis on field population. The NC methods were used traditionally, however this method has difficulty to trace growth of same cohort under field condition with fine temporal resolution. From these reasons, laboratory rearing MR methods are commonly used for estimation of *g* of copepods. The NC method is mainly applied for copepods in the embayment and mesocosm experiments, which possible to collect data on same population with fine-temporal resolution. If we collect high-temporal resolution data on copepods, it may possible to evaluate *g* of copepods by NC method even for oceanic species.

In the Oyahsio region, western subarctic Pacific, occurrence of a large phytoplankton bloom is common during spring. Approximately half of the annual primary production is concentrated within one or two months during spring. During the spring bloom, the dominant oceanic copepods are known to achieve rapid growth and reproduction. To evaluate the biological responses to the spring phytoplankton bloom, high-frequency samplings were conducted at a fixed station in the Oyashio region (OECOS). During OECOS project, *g* of laze-sized oceanic copepods were measured by MR method based on ship-board rearing (Kobari et al. 2010). In the present study, *g* of same copepods were evaluated by NC method based on samples by high-frequency time-series, and compared with the *g* values between two methods. Further, we gathered the oceanic copepod population data from other high-frequency time-series during phytoplankton bloom in the North Atlantic (St. M) and North Pacific (SEEDS I, SEEDS II and SERIES). Based on these data, we estimated *g* of the dominant large-sized oceanic copepods during phytoplankton bloom by NC method and evaluated characteristics of *g* of oceanic copepods during phytoplankton bloom.

During OECOS project, mesozooplankton samples were collected daily at a single station (42°00’N, 145°15’E, depth ca. 4,000 m) in the Oyashio region, western subarctic Pacific during 9-14 March and 5-30 April 2007. Twin-NORPAC net (100 and 335 µm mesh, 45 cm diameter) with flowmeters were towed vertically from 500 m depth to the surface. After collection, the samples were immediately preserved with v/v 5% borax-buffered formalin–seawater. The environmental parameters of temperature, salinity and chlorophyll *a* (chl. *a*) fluorescence were measured with a CTD cast at each sampling. Sampling details of those at St. M in the North Atlantic and iron fertilize experiments in the North Pacific are presented in Niehoff et al. (1999) and Tsuda et al. (2005, 2006, 2007, 2009), respectively. In the land laboratory, the dominant large-sized oceanic copepods were sorted from samples and enumerated with each developmental stage under stereomicroscope. For each sampling date, mean copepodid stages (MCS) were calculated (with exception of C6 data for *Neocalanus* spp.). Using regressions between carbon mass (CM, µg C ind.$^{-1}$) and copepodid stage (CS), CM was estimated by MCS at each sampling date. Weight-specific growth rates (*g*, day^{-1}) were calculated as:

$g = \ln (CMx+t / CMx) / t$

where CMx is individual carbon mass at date x, t is sampling interval (day). For *g* based on MR method, details of laboratory rearing and calculation were published elsewhere (Kobari et al. 2010).

During the sampling period, temperature at sampling layer ranged between 5–6°C for St. M, 1–6°C for OECOS, 8.38±0.13°C (mean±1sd) for SEEDS I, 8.10±0.07°C for SEEDS II and 6.27±0.54°C for SERIES. The peak chl. *a* value at each time-series was the highest for SEEDS I (18 mg m^{-3}), followed with OECOS (0.22–7.3 mg m^{-3}), SERIES (1.4–6.0 mg m^{-3}), St. M (3 mg m^{-3}) and SEEDS II (0.80–2.48 mg m^{-3}). During phytoplankton bloom, *Calanus finmarchicus* in the North Atlantic and *Eucalanus bungii* in the North Pacific achieved reproduction and growth of the newly-recruited generation. For *Neocalanus cristatus* and *N. plumchrus* in the North Pacific, since their reproduction occurred at deep layer in much earlier season, only growth of copepodid stages were observed at surface layer during spring.

From NC method during OECOS period, mean *g* of *E. bungii* C1–C3 and C3–C5, *N. cristatus* C1–C5 and *N. plumchrus* C1–C5 were calculated as: 0.061, 0.029, 0.064 and 0.039 day^{-1}, respectively. From MR method during OECOS period, mean *g* of *E. bungii* C2, *N. cristatus* C3 and *N. plumchrus* C3, C4 were reported as: 0.04, 0.06, 0.03 and 0.02 day^{-1}, respectively. From these results, no significant differences were detected for *g* of same copepods between NC and MR methods ($p > 0.99$ for *E. bungii* one-way ANOVA, $p > 0.60$-0.91 for *Neocalanus* spp., U-test). From the other locations, *g* of each species was calculated as: 0.044±0.253 day^{-1} (mean±1sd) for *C. finmarchicus* in the North Atlantic, 0.013–0.071 (range) day^{-1} for *E. bungii* and 0.002–0.116 day^{-1} for *N. cristatus* in the North Pacific.

During the phytoplankton bloom, *g* of oceanic copepods ranged between 0.002 (*N. cristatus* in SEEDSII) and 0.210 (*C. finmarchicus* egg–C3 at St. M). Within the species, *g* of newly-recruited generation was much (ca. five-times) higher than those of reproductive generation for *C. finmarchicus* and *E. bungii*. For small-sized neritic copepods, it is well known that *g* is higher for early developmental stage than the late developmental stage within the species. Thus, the observed ontogenetic patterns for *g* of large-sized oceanic copepods in this study are well corresponded with those of small-sized neritic copepods. For *Neocalanus* spp. which perform growth during phytoplankton bloom, the highest *g* values (0.116) was observed for *N. cristatus* during SEEDS I, which characterized with the highest chl. *a* peak through the various studies. From spatial comparison in *g* based on MR method, *g* of *N. flemingeri* / *plumchrus* is reported to be increased with increasing chl. *a* within the range of 0-14 mg m^{-3}. Thus, within chl. *a* concentration range in this study (0.2–18 mg m^{-3}), the *g* of *Neocalanus* spp. may controlled by the magnitude of ambient phytoplankton bloom.

39

Northern gadids in a changing climate: winners and losers

Franz Mueter, Benjamin Laurel, Ed Farley, Ron Heintz & Jen Marsh

Four species of gadids are common in Bering Sea and Chukchi Sea. Two of these, walleye pollock (*Gadus chalcogrammus*) and Pacific cod (*Gadus macrocephalus*), are boreal species that support large commercial fisheries in the Bering Sea. Arctic cod (*Boreogadus saida*) and saffron cod are the most abundant gadids in the Chukchi Sea, where they provide important prey for upper trophic level predators. Arctic cod are also common in the northern Bering Sea and can range far south along the eastern Bering Sea shelf during years with an extensive cold pool. In contrast, saffron cod (*Eleginus gracilis*) are common throughout the region in relatively shallow waters (typically < 60m). These four species exhibit remarkably different growth responses to temperature and hence their relative abundance, particularly in the northern Bering Sea and Chukchi Sea, may be expected to change dramatically in a warming climate. As the cold pool on the Bering Sea shelf retreats, so do cold-adapted Arctic cod, as they may be unable to compete with more southern species as these expand northward. However, the shallow shelf and continued winter-time cooling implies a limit to the northward expansion of boreal gadids in the foreseeable future and in spite of the advection of juvenile pollock into the Chukchi Sea and evidence of overwintering north of Bering Strait, they are not expected to establish self-sustaining populations in these areas. Instead, saffron cod as well as capelin (*Mallotus villosus*) are likely to be the main competitors of Arctic cod in the North, and are likely to increase relative to Arctic cod because of their much wider temperature tolerance and their growth advantage in waters that will warm earlier in the spring and reach higher temperatures in the summer. Both walleye pollock and Pacific cod are expected to decline in the southeastern Bering Sea due to changes in the quality and quantity of prey under warmer conditions. This is likely to lead to substantial reductions in their biomass, as their ability to take advantage of high production of suitable prey in more northern areas is uncertain and may be limited. We will review the distribution, abundance, and population dynamics of gadid in the Pacific Arctic, as well as differences in temperature-dependent growth that will affect their responses to climate warming.

Session: Challenges to the Humanities and Socio-Economic Sciences for Sustainability

Management of Steller sea lions off the western coast of the Hokkaido Island: mitigating the threat to the sustainability of local fishery

Orio Yamamura, Kaoru Hattori & Takeomi Isono (Hokkaido National Fishery Research Institute)

The coastal fishery has long conflicted with Steller sea lions (SSLs) on the western coast of the Hokkaido Island. SSLs are protected throughout the coastal countries of subarctic Pacific, and have been designated as “endangered” by International Union for Conservation of Nature and Natural Resources (IUCN) and the Japanese Ministry of Environment (JME).

In 2012, both IUCN and JME degraded SSLs to “near threatened” reflecting their recovery in their natal rookeries in the Okhotsk Sea. In response to the degrading and in the purpose of mitigating fishery conflicts, Japan Fishery Agency (JFA) shifted their priority of SSL management from “population recovery” to “population control” in 2014, by setting the target population level in 2024 as 60% of the present (2012) level.

The winter off the western North Pacific has been mild in the last 2 decades. This climate condition not only helped SSL’s recovery but also aversely affected the stock condition of the major fishery resources (i.e. walleye pollock, hokke mackerel and sand lance) through recruitment failures.

In addition to the poor stock conditions, fish prices have been continuously declining due to the nationwide reduction of fish consumption and economical stagnation.

Reflecting such difficult situation, the number of fishermen has decreased by 40% during these two decades, while the fishery production decreased by 60%. Thus, the damages due to SSLs are one of the heavy burdens threatening the sustainability of the fishing village along the western coast of the Hokkaido Island.

41

Social and natural science integration in the Bering Sea Project: an economist's perspective

Alan Haynie

One of the largest interdisciplinary projects conducted to date that was focused on climate change and the marine environment was the Bering Sea Project, which combined the Bering Sea Ecosystem Study (BEST) and Bering Sea Integrated Ecosystem Research Program (BSIERP). The intent of the Bering Sea Project was to increase knowledge across a wide range of disciplines to enable us to collectively better understand and make predictions about the impacts of climate change on the Bering Sea ecosystem. The project included over 100 principal investigators and lasted approximately seven years from conception to the completion of retrospective studies. Social science and economics were included in several areas of the Bering Sea Project, from local traditional knowledge, to integrated ecosystem models, to econometric analyses of large commercial fisheries. We discuss the initial manner in which the economics elements of the Project were developed, challenges that arose, and how the economics components of the project evolved in light of changes and findings from other elements of the project. Finally, we offer general recommendations for how to better include economics in large interdisciplinary studies that involve social science, economics, and natural sciences.

Session: Contributed ESSAS Papers

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

Carin J. Ashjian, Robert G. Campbell, Rubao Ji, Stephen R. Okkonen, Robert S. Pickart & Frank Bahr

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 *C. 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 temperature 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. Here we use data from two bio-physical surveys of the Chukchi Sea -- one in early-winter 2011 and the other in late-spring 2104 -- to describe the planktonic distributions and relate them to the seasonal hydrographic conditions and to identify the overwintering habitat, activity, and grazing rates of *C. glacialis*. Surprisingly, *C. glacialis* did not appear to be in diapause on the shelves during winter but rather retained low levels of activity including feeding on the very low available phytoplankton and microzooplankton stocks. Early in the late-spring 2014 cruise, *C. glacialis* were initially present in low abundance and as adults and C5 copepodids only but during the latter portion of the cruise, high abundances of meroplankton, including the previously absent younger copepodid stages of the copepod *C. glacialis*, were observed in the mid-Chukchi Sea associated with movement of water from the south, renewing *C. glacialis* populations on the shelf. 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 and populations must be renewed annually. Future warmer overwintering conditions would certainly put them at greater risk.

43

The impact of Aleutian eddies on lower trophic level production south of western Aleutian Islands

Rui Saito, Ichiro Yasuda, Kosei Komatsu, Hiromu Ishiyama & Hiromichi Ueno

"Mesoscale anticyclonic eddies called Aleutian eddies are formed in Alaskan Stream region south of western Aleutian Islands and propagate in the western direction through the western subarctic gyre. In the present study, we demonstrated influence of Aleutian eddies on lower trophic level production south of western Aleutian Islands and in the western subarctic gyre. We described the temporal change of an Aleutian eddy which was formed in December 2009 south of Aleutian Islands and propagated westward through the western subarctic gyre. Sea surface chlorophyll inside the eddy was lower between January and June 2010 while sea surface temperature was lower. As sea surface temperature increased during the summer, sea surface chlorophyll became higher. During the autumn phytoplankton bloom, while the eddy was located within the western subarctic gyre and was not influenced by coastal water, the sea surface chlorophyll was greater. These results suggested presence of Aleutian eddies in the western subarctic gyre presumably increased the lower trophic level production. We will also demonstrate the process of greater lower trophic level productions within Aleutian eddies.

Increased melting of permafrost may lead to decreased total primary production

Knut Yngve Børsheim

The landscape around the Polar Ocean contains vast amounts of organic material fixed in marshlands and tundra. A rise in temperature of these regions can cause melting of the permafrost and some of this organic material will be carried by the general runoff into the sea. It is known that organic material from land has long turnover times in the Polar Ocean, and the outflows from the Polar Basin, for example the East Greenland Current, carry terrestrial organic material all the way from the Fram Strait to the Denmark Strait (Amon et al. 2003. J. Geophys. Res. 108).

I measured bacterial production rates in water profiles collected along 75˚N in 1996 and 2006. The results show that at the edge of the East Greenland Sea Current, bacterial production rates are conspicuously higher than in adjacent areas. As a percentage of total primary production in the euphotic zone, bacterial production in the Nordic Seas is roughly 10%. However, at the edge of the

East Greenland Current bacterial production is 30% compared to the total primary production. I hypothesize that the stimulation of bacterial production rates along the current is fuelled by the organic material carried off the Arctic landscape. The heterotrophic part of the carbon cycle needs mineral nutrients, with a higher proportion of nitrogen and phosphorus compared to the primary producers. We have understood that adding organic material to the ocean will decrease total production (Thingstad et al. 2008 Nature 455). Presently, the annual production rate in the Greenland Sea is slightly higher than in the adjacent Norwegian Sea, and the latter region supports large fisheries. However, the almost pristine water of the Greenland Sea is a mixture of waters off the Polar Ocean and the Atlantic, and if the melting of tundra increases, it can be expected to tip production balance of the region towards bacteria.

Fukushima-derived radiocesium in oceanic zooplankton

Minoru Kitamura, Makio C Honda, Yuichiro Kumamoto, Hajime Kawakami, Yasunori Hamajima, Michio Aoyama, Tatsuo Aono & Miho Fukuda

The magnitude of the 9.0 Tohoku earthquake and the ensuing tsunami on March 11, 2011, inflicted heavy damage on the Fukushima Dai-ichi nuclear power plant (FNPP1). Fission products were emitted, falling over a broad range in the northern hemisphere, and water contaminated with radionuclides leaked into the ocean. The radionuclides emitted from FNPP1 were also detected from terrestrial biota not only in Japan but also North America and Europe. As compared with the terrestrial research, however, studies on the influences of the FNPP1 accident to marine biota have been scarce. In this study, we described temporal change of the Fukushima-derived radiocesium in oceanic zooplankton in the western North Pacific Ocean. Zooplankton samplings were conducted at a time-series station K2 (47°N, 160°E, 2100 km from FNPP1) together with several subtropical stations for comparison, during seven cruises from April 2011 to July 2014. Zooplanktons were collected by stratified net samplings (surface mixed layer and from thermocline to 200 m) or oblique tows between 0 and 200 m. Collected zooplankton were frozen at –20°C after separation from fish. After the cruise, frozen zooplankton were dried at 60°C and pulverized. Some pulverized samples with low radiocesium activity were further burned at up to 600°C, and ash were used for radiocesium measurement. ^{134}Cs and ^{137}Cs radioactivities in the dry or ash samples were measured by gamma-ray spectrometry using a Ge detector. Radiocesium in the seawater sample was concentrated by an improved ammonium phosphomolybdate (AMP) method and was quantitatively separated from seawater by coprecipitation with AMP/Cs. Radiocesium activity in AMP/Cs compound was also measured by gamma-ray spectrometry using a Ge detector. Both ^{134}Cs and ^{137}Cs were detected in all zooplankton samples through the study period except samples collected from a station (25°N, 160°E) during June 2014. Because of its short half-lives, ^{134}Cs detected in our samples could only be derived from the FNPP1 accident. The highest ^{137}Cs activity concentrations (61.4 Bq kg-dry^{-1} at K2 and 71.5 Bq kg-dry^{-1} at subtropical region) in zooplankton were observed one month after the accident. These values were two orders of magnitude higher than ^{137}Cs activity in zooplankton collected off Japan before the accident (180 mBq kg-dry^{-1}). The radiocesium activity concentrations in oceanic zooplankton were temporally decreased. At K2, ^{137}Cs values decreased down to the pre-accident level three years after the accident. However, ^{137}Cs activity concentrations in zooplankton at subtropical stations were still one order of magnitude higher in June 2014 compared with the pre-accident level. In the subtropical region, a subsurface radiocesium maximum was found in the water column. And activity concentrations of radiocesium in seawater at subtropical stations were slightly higher than those at K2. The higher activity concentrations of radiocesium in the subtropical zooplankton in summer of 2014 were probably due to the higher radiocesium activities in seawater. At K2, radiocesium activity concentrations in subsurface zooplankton were higher than those in surface zooplankton while such phenomenon was not observed in subtropical region. Stable isotope ratios of nitrogen in bulk zooplankton samples collected from K2 suggested that trophic level of the subsurface zooplankton community was higher than surface one. The higher radiocesium activity concentrations in subsurface zooplankton were probably due to biological accumulation. At K2, decrease of radiocesium activities in zooplankton from April to July 2011 were slow although rapid decrease was observed in the subtropical region. This was probably due to different life time of zooplankton between subarctic and subtropical regions, because subarctic zooplankton had longer life time compared with subtropical species.

Geographic variation in Pacific herring growth in response to regime shifts in the North Pacific Ocean

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Pacific herring populations at eight North Pacific Rim locations were simulated to compare basin-wide geographic variations in age-specific growth due to environmental influences on marine productivity and population-specific responses to regime shifts. Temperature and zooplankton abundance from a three-dimensional lower-trophic ecosystem model (NEMURO: North Pacific Ecosystem Model for Understanding Regional Oceanography) simulation from 1948 to 2002 were used as inputs to a herring bioenergetics growth model. Herring populations from California, the west coast of Vancouver Island (WCVI), Prince William Sound (PWS), Togiak Alaska, the western Bering

Sea (WBS), the Sea of Okhotsk (SO), Sakhalin, and Peter the Great Bay (PGB) were examined. The half-saturation coefficients of herring feeding were calibrated to climatological conditions at each of the eight locations to reproduce averaged size-at-age data. The depth of averaging used for water temperature and zooplankton, and the maximum consumption rate parameter, were made specific to each location. Using the calibrated half-saturation coefficients, the 1948–2002 period was then simulated using daily values of water temperature and zooplankton densities interpolated from monthly model output. To detect regime shifts in simulated temperatures, zooplankton and herring growth rates, we applied sequential t-test analyses on the 54 years of hindcast simulation values. The detected shifts of herring age-5 growth showed closest match (69%) to the regime shift years (1957/58, 1970/71, 1976/77, 1988/89, 1998/99). We explored relationships among locations using cluster and principal component analyses. The first principal component of water temperature showed good correspondence to the Pacific Decadal Oscillation and all zooplankton groups showed a pan-Pacific decrease after the 1976/77 regime shift. However, the first principal component of herring growth rate showed decreased growth at the SO, PWS, WCVI and California locations and increased growth at the Sakhalin, WBS and Togiak locations after 1977. The SO location belonged to the same cluster as the location in with the eastern North Pacific. The calibrated half-saturation coefficients affected the degree to which growth was sensitive to interannual variation in water temperature versus zooplankton. For example, the half-saturation values for the SO location resulted in very efficient feeding that shifted the sensitivity of herring growth from food to temperature. The model results demonstrate how geographic specificity of bioenergetics parameters, coupled with location-specific variation in temperature and food, can combine to determine local and regional responses of fish growth to climate forcing. The presentation is based on Ito et al. (2015), Progress in Oceanography, doi:10.1016/j.pocean.2015.05.022.

Abstracts of Poster Presentations

Wintertime sea-ice carbonate system and influence of sea-ice processes and glacial freshwater discharge during two contrasting years in a West-Spitsbergen fjord

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We investigated the sea-ice carbonate (or CO_2) system in Tempelfjorden (West Spitsbergen) and the influence of different processes such as brine rejection from sea-ice formation, calcium carbonate precipitation and glacial freshwater discharge during two winters in March/April 2012 and 2013. March/April 2012 was milder than April 2013 with later sea-ice formation and thinner ice. The two contrasting years clearly showed that the influence of freshwater affected the chemical and physical characteristics of the sea ice. We found large variability of sea-ice total alkalinity (AT), total dissolved inorganic carbon (CT), $p$$CO_2$, dissolved inorganic nutrients, oxygen isotopic ratio ($\delta^{18}O$), and freshwater fractions, from the glacier front to the outer part of the fjord. Processes within the sea ice such as calcium carbonate formation (ikaite) and brine rejection also affected the sea-ice carbon chemistry. The variability in the sea ice showed the lowest AT in March/April 2012 near the glacier front coinciding with the highest freshwater fractions (glacial water). Relatively high AT in relation to salinity was observed mainly in March/April 2012, which could either be a result of ikaite precipitation in the sea ice (dissolved during analysis) or calcite and dolomite minerals originating from the bedrock/glacial freshwater. We found crystals of ikaite, calcite and aragonite (forms of calcium carbonate) in the snow/frost flowers in April 2013 as a result of to sea-ice processes.

Time-series observation for an assessment of ocean acidification in the subarctic western North Pacific

Tetsuichi Fujiki, Minoru Kitamura, Katsunori Kimoto, Naomi Harada, Masahide Wakita & Yoshiyuki Nakano

One goal in marine ecosystem research is to gain a better understanding of how plankton community is affected by environmental changes including ocean acidification. To achieve this goal, ship-based studies have been carried out since 1997 in the subarctic western North Pacific (SWNP), which is a region with progression of ocean acidification. However, the ship-based studies of the open ocean have been limited in their ability to conduct high-frequency observations for understanding the response of plankton community to environmental changes. To overcome the problem, we developed a hybrid profiling buoy system that consists mainly of an underwater profiling buoy system, a remote automatic water sampler, a hybrid pH sensor, an acoustic Doppler current profiler and a sediment trap. Time-series observation with the buoy system was begun in 2015 at station K2 (47°N, 160°E), which is located near the center of the SWNP. Here, we show a brief overview of the ocean acidification research in the SWNP.

Iron supply processes associated with melting of seasonal sea ice in the sub-polar marginal sea; the Sea of Okhotsk

Naoya Kanna, Takenobu Toyota & Jun Nishioka

In marginal ice zones, there is considerable interest in the role of melting of sea ice as a potential trigger and accelerant for phytoplankton blooms. To reveal impact of melting of sea ice on phytoplankton growth, we focused on supply processes of iron, an essential micronutrient, to surface waters associated with melting of sea ice in the Okhotsk Sea. Results from hydrographic observations in the southern Okhotsk Sea in late-November (absence of sea ice) and in mid-February (presence of sea ice) indicated that a striking temporal increase of Fe concentration in surface mixed-layer from November to February, which coincided with a decrease in seawater salinity. A three-component mixing scheme of seawater, sea ice melt water, and Amur River water using relationship between alkalinity and salinity showed that the low salinity in the mixed-layer was affected by the sea ice melt water. Additionally, we investigated iron nutritional status of phytoplankton in the ice covered area of the southern Okhotsk Sea by shipboard incubation experiment. The surface water used for the incubation experiment was affected by sea ice melting because of the surface salinity of 29.2. The growth of large-sized (>10 μm) phytoplankton in unamended control corresponded to that enhanced by a 1.0 nM inorganic iron addition, as compared with a strong ligand DFB addition for reducing the biological iron availability. This result clearly indicates that biological available iron existed in the ice covered surface water and therefore the large-sized phytoplankton was not stressed by low iron availability. Overall, our results provide an insight for understanding iron supply processes associated with sea ice melting and contribution of iron derived from sea ice to phytoplankton growth in the marginal ice zone.

49

Foraging ecology of thick-billed murres in the southeastern Bering Sea: inter-annual variability in relation to upper-ocean thermal structure

N. Kokubun, T. Yamamoto, D. Kikuchi, N. Sato, Y. Watanuki, A. S. Kitaysky & A. Takahashi

Southeastern Bering Sea has experienced a series of warm and cold regimes during recent decades. Such changes in the upper ocean thermal structures likely affect the plankton and nekton communities and then higher trophic level predators such as seabirds. To understand the effect of ocean thermal regimes on seabirds, we studied the foraging ecology of thick-billed murres at St George Island, Pribilof Islands, over 6 years (2004, 2006–07, 2013–15). For each year, we monitored the diving behaviour of murres and water temperature of upper-water column where murres foraged, by using bird-borne accelerometers. Their foraging locations were also monitored with GPS data loggers, during the recent 3 years (2013–15). The water column temperatures where murres foraged varied largely among the 6 years – mean water temperature at depth (> 40m) was highest in 2015 (6.5°C) and lowest in 2007 (2.4°C). Murres foraged mainly in the stratified waters, and dived to the depths near thermocline depth (17–54% of dives), but also to deeper depths independent of thermocline (36% of dives) in the coldest year 2007. They tended to forage at farther locations from the colony in the colder 2013 than in the warmer 2014 and 2015. Squids were important chick diet in the colder years, but forage fish such as pollock were important in the warmer years. We discuss how on-shelf upper-ocean thermal structures affect the foraging ecology of murres via changes in the spatial and depth distribution of prey.

The Arctic Ocean Carbon Sink

Graeme MacGilchrist, Alberto Naveira Garabato, Takamasa Tsubouchi, Sheldon Bacon & Sinhue Torres-Valdés

We present observation based estimates of the transport of dissolved inorganic carbon (DIC) across the four main Arctic Ocean gateways (Davis Strait, Fram Strait, Barents Sea Opening and Bering Strait). Combining a recently derived velocity field at these boundaries with measurements of DIC, we calculated a net summertime pan-Arctic export of 231 ± 49 Tg C yr^{-1}. On an annual basis, we estimate that at least 166 ± 60 Tg C yr^{-1} of this is due to uptake of CO_2 from the atmosphere, although time-dependent changes in carbon storage are not quantified. To further understand the region's role as a carbon sink, we calculated the volume-conserved net DIC transport from beneath a prescribed mixed layer depth of 50 m, referred to as 'interior transport', revealing an export of 61 ± 23 Tg C yr^{-1}. Applying a carbon framework to infer the sources of interior transport implied that this export is primarily due to the sinking and remineralisation of organic matter, highlighting the importance of the biological pump. We qualitatively show that present day net interior transport is limited by the accumulation of anthropogenic carbon, imported in Atlantic Water.

In situ high accurate pH sensor for a monitoring of ocean acidification

Yoshiyuki Nakano, Takeshi Egashira, Tetsuya Miwa & Hideshi Kimoto

Ocean acidification has many far reaching impacts on plankton community in the arctic and subarctic ocean. There is great need of quality instrumentation to assess and monitor the changing seawater pH. To meet the need, we have developed the in situ high accurate pH sensor (Hybrid pH sensor: HpHS) for the long-term seawater pH monitoring.

The HpHS has two types of pH sensors (i.e. potentiometric pH sensor and spectrophotometric pH sensor). The spectrophotometric pH sensor can measure pH correctly and stably, however it needs large power consumption and a lot of reagents in a long period of observation. The pH sensor used m-cresol purple (mCP) as an indicator of pH. We can choose both coefficients before deployment. On the other hand, although the potentiometric pH sensor is low power consumption and high-speed response (within 10 seconds), drifts in the pH of the potentiometric measurements may possibly occur for a long-term observation. The HpHS can measure in situ pH correctly and stably combining advantage of both pH sensors.

The HpHS consists of an aluminum pressure housing with optical cell (main unit) and an aluminum silicon-oil filled, pressure-compensated vessel containing pumps and valves (diaphragm pump and valve unit) and pressure-compensated reagents bags (pH indicator, pure water and Tris buffer or certified reference material: CRM) with an ability to resist water pressure to 3000 m depth. The main unit holds system control boards, pump drivers, data storage (micro SD card), LED right source, photodiode, optical cell and pressure proof windows. The HpHS also has an aluminum pressure housing that holds a rechargeable lithium-ion battery or a lithium battery for the power supply (DC 24 V).

The HpHS is correcting the value of the potentiometric pH sensor (measuring frequently) by the value of the spectrophotometric pH sensor (measuring less frequently). It is possible to calibrate in situ with Tris buffer or CRM on the spectrophotometric pH sensor. Therefore, the drifts in the value of potentiometric pH measurements can be compensated using the pH value obtained from the spectrophotometric pH measurements. Thereby, the sensor can measure accurately the value of pH over a long period of time with low power consumption.

Coupled 1-D physical-biological model study of phytoplankton production at two contrasting time-series stations in the western North Pacific

Yoshikazu Sasai, Chisato Yoshikawa, S. Lan Smith, Taketo Hashioka, Kazuhiko Matsumoto, Masahide Wakita, Kosei Sasaoka & Makio C. Honda

51

A vertical one-dimensional physical-biological model is applied to clarify the mechanisms controlling the seasonality and interannual variability of primary production in the surface layer at two contrasting time-series stations, K2 (in the subarctic gyre) and S1 (in the subtropical gyre), in the western North Pacific. Using forcing based on realistic atmospheric and oceanic data, the model reproduces seasonal differences in the degree to which different controlling factors affect primary production between these two stations, primarily as a result of differences in the physical environment. At station K2, light intensity is an important factor controlling primary production in summer. After April, the mixed layer depth (MLD) becomes shallow, resulting in higher average light intensity, and the water column remains stratified until September; these sustain high primary production during this period. In contrast, at station S1, the supply of nutrients via entrainment is vital to sustaining production, because light intensity remains sufficient throughout the year. In summer, the relationship between nutricline depth and euphotic layer is a controlling factor. The simulations forced by the different atmospheric conditions for each year, respectively, show different MLD. In the 2012 simulation, the deep winter MLD (200m) enhances primary production in the surface layer as compared to the other two years (2010 and 2011) simulations.

The jellyfish buffet: seabirds find fine dining among jellyfish in the Bering Sea

Nobuhiko Sato, Nobuo Kokubun, Takashi Yamamoto, Dale M. Kikuchi, Yutaka Watanuki, Alexander S. Kitaysky & Akinori Takahashi

High levels of jellyfish biomass have been reported in marine ecosystems around the world, which is often referred to as a ‘jellyfish bloom’. Jellyfish bloom are generally thought to have indirect negative impacts on marine top predators through changes in the trophic pathway by consuming the large amount of prey. However, high densities of jellyfish in the water column may affect the foraging behaviour of marine predators more directly, and the effects may not always be negative. Here, we show novel observations of foraging interactions among seabirds, jellyfish and fish in the Bering Sea, by using bird-borne video logger. Our bird-borne video observation showed that large jellyfish *Chrysaora melanaster* are prevalent in where thick-billed murres forage. Birds approached jellyfish and fed on fish swimming around tentacles, which correspond to 8.0–41.4 % of all feeding events. We suggest that recent jellyfish blooms create new feeding opportunities for some diving predators by concentrating forage fish. These observations suggest that the impacts of jellyfish blooms on marine ecosystems are more complex than previously anticipated and may be beneficial at least to some seabirds.

Nitrification and its influence on biogeochemical cycles from the equatorial Pacific to the Arctic Ocean

Takuhei Shiozaki, Minoru Ijichi, Kazuo Isobe, Fuminori Hashihama, Ken-ichi Nakamura, Makoto Ehama, Ken-ichi Hayashizaki, Kazutaka Takahashi, Koji Hamasaki & Ken Furuya

Nitrification is a central process in the marine nitrogen cycle, however, the controlling factors and the influence on biogeochemical cycles has not been well understood. Nitrification is a two-step process consisting of ammonia oxidation (ammonium to nitrite) followed by nitrite oxidation (nitrite to nitrate), and each step is carried out by different microbes. The first step of nitrification is the rate-limiting process, and it was formerly thought to be performed almost entirely by ammonia-oxidizing bacteria (AOB). Therefore, the limiting factors of nitrification in the ocean were thought to be tightly coupled with the physiological characteristics of AOB (Ward, 2002). However, ammonia-oxidizing archaea (AOA) belonging to the phylum Thaumarchaeota were discovered in the 2000s (Könneke et al., 2005; Brochier-Armanet et al., 2008), and subsequent studies found that AOA outnumber AOB in various regions, indicating that AOA could be a major ammonia-oxidizing organism (AOO) in the ocean (Wuchter et al., 2006; Beman et al., 2008, 2012). A genome analysis (Walker et al., 2010) demonstrated that AOA has different metabolic systems than AOB, suggesting that limiting factors for AOA could be different from those for AOB.

Observation were conducted on board the R/V Hakuho-maru from the equatorial Pacific to the Arctic Ocean during summer (June–August) in 2014. Water samples were collected using an acid-cleaned bucket and Niskin-X from the layers of 100–0.1% of surface irradiance and from 200m. Nutrients (NO_3^-, NH_4+, NO_2^-) concentration at below 0.1 μM was analyzed by a supersensitive colorimetric system (detection limits, ~3 nM) (Hashihama et al., 2009, 2015; Kodama et al., 2015). Primary production, nitrate assimilation, and ammonia oxidation were evaluated using isotopic techniques (Shiozaki et al.,2009; Isobe et al., 2011). Michaelis-Menten kinetics experiments for ammonia oxidation were conducted using samples collected from the 0.1% light depth. DNA samples were collected from all depths and RNA were only from the 0.1% light depth. The qPCR and RT-qPCR analysis was targeted on the AOA phylotypes of shallow and deep clade and the AOB (βAOB).

The gene and transcript abundances for ammonia oxidation indicated that the shallow clade AOA were the major ammonia oxidizers throughout the study regions. The ratio of AOA to βAOB changed significantly with region, and it was related to ammonium concentration. While AOO was detected even in the surface water, ammonia oxidation occurred mainly below the 1% light depth throughout the study region, indicating that it would be susceptible to light environment. The peak of ammonia oxidation was below the subsurface chlorophyll maximum and varied from 2.87 to 67.1 nmol N L^{-1} d^{-1}. The maximum values in the subtropical region (average: 14.2 nmol N L^{-1} d^{-1}) tended to be lower than those in the adjacent regions. The maximum ammonia oxidation was also markedly low in the high-nutrient low-chlorophyll subarctic region (10.2 nmol N L^{-1} d^{-1}). The highest ammonia oxidation value (67.1 nmol N L^{-1} d^{-1}) occurred at a station in the Bering Sea Green Belt, which is defined as a highly productive region along the edge of the continental shelf of the Bering Sea

(Springer et al., 1996). The maximum values in the shallow Bering and Chukchi Sea shelves (bottom ≤67 m) (under detection limit to 5.62 nmol N L^{-1} d^{-1}) were considerably lower compared to that at the station in the Bering Sea Green Belt.

Ammonia oxidation accounted for up to 87.4% (average 55.6%) of the rate of nitrate assimilation in the subtropical oligotrophic region, suggesting that the greater part of nitrate in the euphotic zone was regenerated nitrogen derived from nitrification. However, in the shallow Bering and Chukchi Sea shelves, the percentage was small (0–4.74%) because ammonia oxidation and the abundance of ammonia oxidizers were low, the light environment being one possible explanation for the low activity. Consequently, ammonium generated by the decomposition of organic matter would not be efficiently converted into nitrate and thus it accumulated. Ammonium accumulation caused by low nitrification has been revealed in a lake (Rudd et al., 1988), suggesting that ammonium can also accumulate in the ocean when nitrification activity declines.

With the exception of the shallow bottom stations, depth-integrated ammonia oxidation was positively correlated with depth-integrated primary production. Ammonia oxidation was low in the high-nutrient low-chlorophyll subarctic region and high in the Bering Sea Green Belt, and primary production in both was influenced by micronutrient supply. An ammonium kinetics experiment demonstrated that ammonia oxidation did not increase significantly with the addition of 31–1560 nM ammonium at most stations except in the Bering Sea Green Belt. Thus, the relationship between ammonia oxidation and primary production does not simply indicate that ammonia oxidation increased with ammonium supply through decomposition of organic matter produced by primary production but that ammonia oxidation might also be controlled by micronutrient availability (probably copper) as with primary production. This was likely related with the fact that AOA, which require copper for ammonia oxidation (Walker et al., 2010; Hollibaugh et al., 2011), were dominant in the study regions.

N-ICE2015: Multi-disciplinary study of the young sea ice system north of Svalbard from winter to summer

Harald Steen, Mats A. Granskog, Pedro Duarte, Philipp Assmy, Stephen Hudson, Sebastian Gerland, Gunnar Spreen & Lars H. Smedsrud

The Arctic Ocean is shifting to a new regime with a thinner and smaller sea-ice area cover. Until now, winter sea ice extent has changed less than during summer, as the heat loss to the atmosphere during autumn and winter is large enough form an ice cover in most regions. The insulating snow cover also heavily influences the winter ice growth. Consequently, the older, thicker multi-year sea ice has been replace by a younger and thinner sea.

These large changes in the sea ice cover may have dramatic consequences for ecosystems, energy fluxes and ultimately atmospheric circulation and the Northern Hemisphere climate. To study the effects of the changing Arctic the Norwegian Polar Institute, together with national and international partners, launched from January 11 to June 24, 2015 the Norwegian Young Sea ICE cruise 2015 (N-ICE2015). N-ICE2015 was a multi-disciplinary cruise aimed at simultaneously studying the effect of the Arctic Ocean changes in the sea ice, the atmosphere, in radiation, in ecosystems. as well as water chemistry. R/V Lance was frozen into the drift ice north of Svalbard at about N83 E25 and drifted passively southwards with the ice until she was broken loose. When she was loose, R/V Lance was brought back north to a similar starting position. While fast in the ice, she served as a living and working platform for 100 scientist and engineers from 11 countries. One aim of N-ICE2015 is to present a comprehensive data-set on the first year ice dominated system available for the scientific community describing the state and changes of the Arctic sea ice system from freezing to melt. Analyzing the data is progressing and some first results will be presented.

Terrigenous fluxes of pollen, insect scale and land plant palynodebris observed by sediment traps deployed in the subarctic Pacific

Hideto Tsutsui, Kozo Takahashi, Kazumi Matsuoka, Richard W. Jordan & Sumito Yamamoto

From 1990 to 2009, sediment traps were deployed and recovered in the subarctic Pacific (Station SA; 49°N, 174°W) during each summer, allowing the long-term observation of particle fluxes. This sediment trap captured the pollen, land plant debris and insect scale fluxes during 1994 to 2009 at Station SA. The pollen fluxes peaked primarily in May (and sporadically also in April and June) and September-October. The snow and ice occurred for six months from October to May. The production locations, residence time, routes and mode of transport of the organic particles are important factors. The pollen fluxes observed during April to June appeared to have originated from the Western Alaska, but during the rest of years they appeared to have been from the eastern Russia. That pollen and other organic debris were conveyed by wind over long distance across the ocean. Recently, the sea water temperature of the study area is rising up. The calcareous nannoplankton fluxes of 19 years from the 1990 are increasing in the sediment trap. Those organic fluxes also have possibilities which are related with the environmental condition changes.

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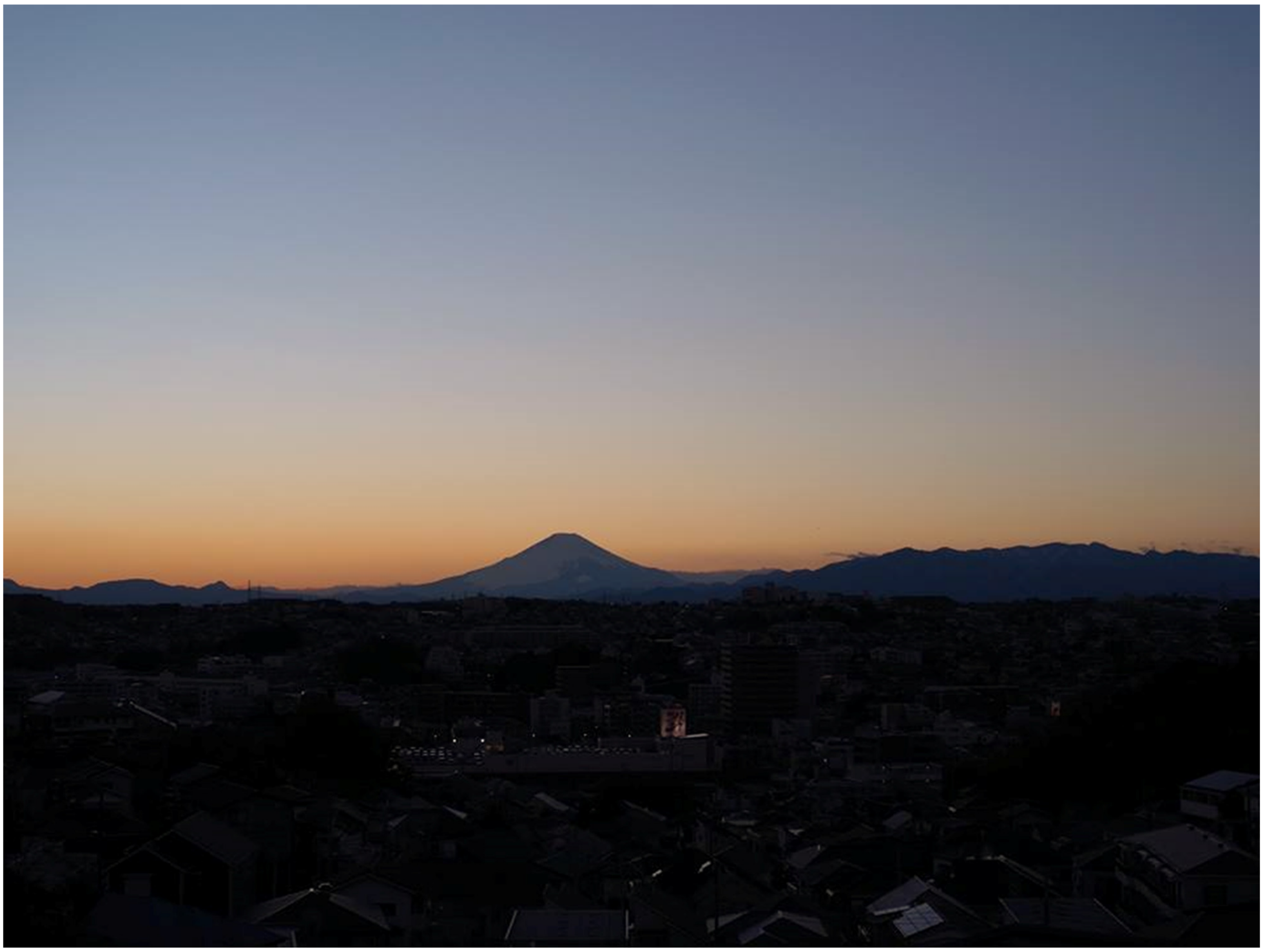


Ecosystem Studies
ESSAS
of Sub-Arctic Seas