First International RACArctic Workshop

Resilience and Adaptive Capacity of Arctic Marine Systems under a Changing Climate

March 1 – 3, 2016
Hakodate Research Center for Fisheries and Oceans

Edited by

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Organized by

Arctic Research Center, Hokkaido University

Sponsored by

Japan Science and Technology Agency (JST)
National Science Foundation (NSF)
Research Council of Norway (RCN)

Objectives:

We will synthesize information from completed and ongoing regional studies conducted by Japan, USA, and Norway to examine how variability and trends in advection, temperature, sea-ice dynamics, and ocean acidification in the Subarctic to Arctic transition zone may affect future marine ecosystems of the Pacific and Atlantic Arctic, their resource management, and socio-economics. We will investigate how Arctic fish populations and their prey may respond and adapt to multiple environmental stressors and how their responses may affect existing and future fisheries, subsistence harvests, fisheries management, and the socio-economic systems that depend upon them. We will bring together natural and social scientists, with stakeholders from the fishing industry, regional management bodies, governments and coastal communities in at least three workshops to assess whether the biological, management and socio-economic systems have the resilience and adaptive capacity to cope with anticipated changes. These workshops will: 1) review and synthesize impacts of climate change on components of Arctic marine ecosystems; 2) compare and contrast the impacts in the Atlantic and Pacific sectors of the Arctic; 3) identify major issues of concern, including threats and opportunities, from both biological and socio-economic perspectives; 4) review the ability of current management frameworks to adapt to likely future changes; and 5) assess the resilience and adaptive capacity of fish, fisheries, other living resources, resource-dependent communities, and management institutions to future climate change. In each workshop, investigators will review and synthesize results from the different national research projects that are most relevant to addressing workshop objectives. Workshops will build on each other with the third workshop identifying and beginning the writing of synthesis papers for primary journals, and short summaries for stakeholders that will assess the resilience and adaptive capacity of natural and human Arctic marine systems to future climate change.

Co-convener
Sei-Ichi Saitoh
Franz Mueter
Ken Drinkwater

Contents

1. Overview and Program

Date: March 1 -3, 2016

【March 1 (Tue)】
RACArctic Stakeholders Meeting: with simultaneous translation

【March 2 (Wed)】
RACArctic Science Meeting (Day 1)

【March 3 (Thu)】
RACArctic Science Meeting (Day 2)

【Venue】
Hakodate Research Center for Fisheries and Oceans
20-5, Benten-cho, Hakodate, Hokkaido, 040-0051, Japan

【Organizer】
Arctic Research Center, Hokkaido University

RACArctic Stakeholders Meeting Agenda

March 1 (all day with simultaneous translation)

08:30	Registration and refreshment
09:00	Welcome and Introduction – Sei-Ichi Saitoh
09:05	RACArctic Project – General and Meeting Objectives
09:15	Keynote Lecture – Takashi Kikuchi
	Climate change and physical/chemical process in the Arctic
10:00	Keynote Lecture – Franz Mueter)
	Climate change and response of marine ecosystem in the Arctic
10:45	Break
11:00	Introduction of stakeholders
11:10	Stakeholders workshop (1) – Selection of discussion points
12:00	Lunch
13:30	Stakeholders workshop (2) – Needs and problems
15:00	Break
15:30	Stakeholders workshop (3) – Future perspectives
16:30	Review and general discussion
17:00	End of Day’s Meeting
18:00 - 20:00	Welcome party

RACArctic Science Meeting Agenda

Day 1 (March 2)

09:00 Welcome and Introductions - Sei-Ichi Saitoh
09:15 RACArctic Project – General and Meeting Objectives
09:30 Introduction to the Arctic
10:00 Physical and Chemical Oceanography plus Climate, includes Nutrients and OA
Eiji Watanabe: Sea ice-ocean modeling analyses of shelf-basin interaction and biological production in western Arctic
Seth Danielson: Oceanography of the North Pacific and Pacific Arctic: A mechanistic view of atmospheric drivers, oceanic pathways & change through time
Randi Ingvaldsen: Oceanography of the Atlantic Arctic, with notes on Climate, Nutrients and Ocean Acidification

10:30 Break

11:00 Physical and Chemical Oceanography plus Climate Continued

12:00 Lunch

13:30 Plankton, includes OA impacts
Atsushi Yamaguchi: Changes in zooplankton in the Arctic Ocean Alternation by transported Pacific zooplankton
Amane Fujiwara: Response of phytoplankton community structure to recent sea ice decline in the western Arctic
Hisatomo Waga: The relationship between phytoplankton and benthic community in the Pacific Arctic region
George Hunt: Climate variability and its effects on the southeastern Bering Sea Ecosystem: Timing of sea ice retreat, zooplankton production, and upper-trophic-level responses
Ken Drinkwater: Assessing Climate Change and Ocean Acidification Effects on the Lower Trophic Levels in the Atlantic Sector of the Arctic

15:00 Break

15:30 Fish
Yutaka Watanuki: Polar cod is one of the key species in Arctic marine ecosystems
Seokjin Yoon and Hiromichi Ueno: Potential habitat for chum salmon (*Oncorhynchus keta*) in the Western Arctic based on a bioenergetics model coupled with a three-dimensional lower trophic ecosystem model
Franz Mueter & Mike Sigler: Responses of Fish and Shellfish to Climate Change in a Changing Arctic

Jan Erik Stiansen: Fish Distribution and Abundance in the Atlantic Sector

17:00 Review and general discussion

17:30 End of Day's Meeting

18:30 – 20:30 Meeting Reception

Day 2 (March 3)

09:00 Resilience of ecological communities
Benjamin Planque: Ecosystem Resilience in the Barents Sea - What is it and how can it be measured?

09:30 Fisheries
Franz Mueter: Ecosystem-based Fishery Management in the Eastern Bering Sea
Alan Haynie: Modeling Fisher Behavior under Changing Policies, Economics, and Environmental Conditions
Arne Eide: Climate change and Fisheries economics: Management challenges in the Barents Sea cod fishery

10:30 Break

11:00 Fisheries, Continued

12:00 Lunch

13:00 Fisheries Management and Governance
Mitsutaku Makino: Fisheries adaptation to Climate Change:
Case of the Shiretoko World Natural Heritage
Franz Mueter: Brief overview of Management Framework
Steve Kasperski: (presented by Alan Haynie) : Assessing climate change vulnerability in Alaska's fishing communities
Henry Huntington: Vulnerability and Resilience in Alaska Coastal Communities

15:00 Break

15:30 Review and general discussion
- User Input and concerns
- Planning intersession work
- Deadlines

17:00 End of Meeting

18:30 – 20:30 Meeting Dinner

2. RACArctic Stakeholders Meeting

2-1. Introduction – Sei-Ichi Saitoh

Saitoh:

Good morning. My name is Sei-Ichi Saitoh, and I am the Lead PI of this RACArctic project. I would like to introduce the co-PIs Franz Mueter and Ken Drinkwater. On behalf of the members of RACArctic, we express our profound gratitude for your participation in this international RACArctic meeting. This is the first meeting for RACArctic project. It is a continuous 3-day meeting comprised of today's stakeholders meeting and the science meeting on day 2 and 3, where we are to discuss on resilience and adaptive capacity of Arctic marine systems and the changing climate issues. Today, we are going to have the stakeholders meeting involving various fields. We especially invited stakeholders from Japan. Later I would like to introduce each stakeholder representative.

Yesterday, the wind was very strong and we couldn't access this venue due to the high wave, but, today, it is getting a little bit calmer. Maybe "RAC" in RACArctic means "luck" as well. So, lucky-Arctic, RACArctic meeting opens now. First of all, I would like to explain the overview of RACArctic project. May I switch to Japanese from now?

RACArctic means "resilience and adaptive capacity of Arctic marine system under changing climate". Resilience and adaptive capacity are the key topics. This project is funded by Belmont Forum. Until last year there was an international project called IGBP, but from this year, Future Earth Project took it over and the funding agency for this project is Belmont Forum. Two years ago, this foundation put out calls for proposals for Arctic research, and 10 out of 47 proposals were selected, including RACArctic. This is called "matching fund" and JST provides a fund for the Japanese team. The counterpart in the U.S. is National Science Foundation and that in Norway is Research Council of Norway. Let me explain the overview of RACArctic project. This is a collaborative project, involving three countries: Japan, Norway and the U.S. I am the Lead PI and Dr. Franz Mueter from the U.S. and Dr. Ken Drinkwater from Norway are the co-leads. Three of us also co-chair the program called ESSAS, "the Ecosystem Studies of Sub-arctic and Arctic Seas", which is a regional program of IMBER.

Let me introduce the members from each country: Japan, Norway and USA. Ken Drinkwater and Franz Mueter are the leads in Norway and U.S. respectively. From Japan, Dr. Harada and Dr. Kikuchi of JAMSTEC are participating. Dr. Kikuchi will be the first speaker today. Dr. Watanuki and Dr. Makino are here today as well. Dr. Takakura and Dr. Hirawake unfortunately will not be able to attend. Now, I introduce the members from Norway. The lead is Ken Drinkwater, and Arne Eide, Ingvaldsen, Chierici, Planque, and Stiansen are also here. From the United States, Franz Mueter is the lead, and George Hunt, Huntington, Sigler and Haynie are the members – not only natural scientists but also social scientists are involved, which is quite interdisciplinary. The goal of this project is to review and synthesize results from previous research projects.

For this purpose, we will have three international workshops. It is the way this project will proceed. We will try to evaluate the resilience and the adaptive capacity of the ecosystems in the changing Arctic environment. Norway explores the Atlantic Arctic and Japan and the U.S. study the Pacific Arctic sector.

I will introduce three objectives. The first one is review and synthesize. First of all, we will see the physical and chemical oceanography aspects and how marine environment has changed. We will also explore how the food web and the food supply has changed. We deal with the ocean acidification issue as well. When the phytoplankton bloom begins is also one of our concerns. Also, we will see the compositions of species and plankton. We will explore other topics such as temperature changes and advections.

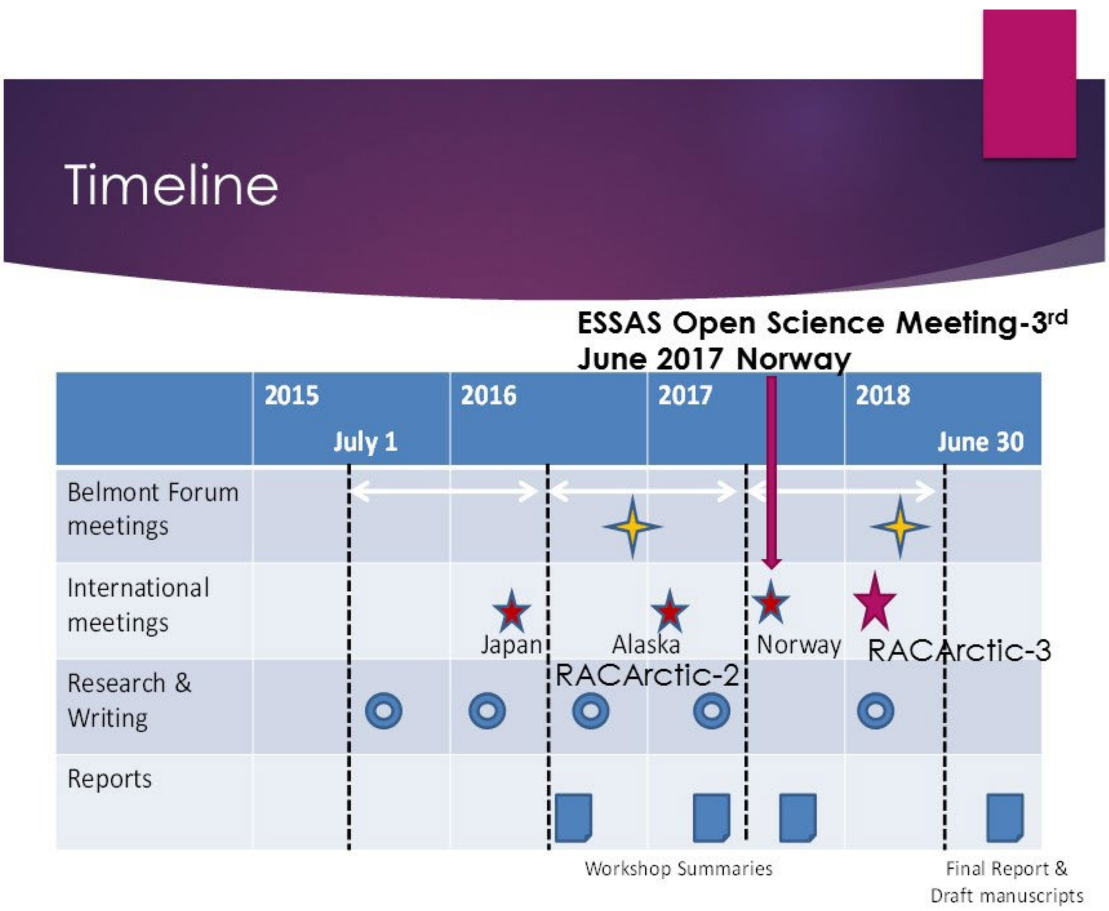
Particularly, most of the members of RACArctic are fisheries oceanographers. They are experts who have looked into the responses of fishery resources to the environmental changes in the transition zone between the sub-arctic and the Arctic. In this context, they are looking into the changes in spatial distribution of fisheries resources, particularly the formation of new fishery resources and fish populations in the Arctic under the changing climate. At the same time, how fishing industry responds to these changes in fish distribution (i.e. what is the way they should take?), is also one of the themes. We have to clarify how vulnerable the marine ecosystem in the Arctic is and how it affects the fish and, in the end, the human beings. Another theme of this project is the physical factors and primary productivity which affect ecosystems in the Arctic. The purpose of this project is not only research, but interaction and co-working with stakeholders. In that sense, because we will especially talk about fish today, we invited and involved the fishery cooperatives, the fishing industries. So, co-working is very important for us. Various management issues should be discussed as well. This project involves Norway, Japan and the U.S., and what it means geographically is that we can make a comparison between the Pacific side and the Atlantic side, the Pacific Arctic and the Atlantic Arctic. In this sense, our target area is the Pan-Arctic. Especially the U.S. defines the Bering Sea as the Arctic region, so it is also included in our target area.

This is the structure of project. It is comprised of Norway, Japan and the U.S. The leaders are me, Franz Mueter and Ken Drinkwater. We will provide the synthesized research results for stakeholders and we will together evaluate the vulnerability and the resilience of the Arctic marine ecosystem and discuss in what aspects we can utilize our achievements in the industry' s future.

There are some differences among the three countries. For example, Norway and the U.S. are included in the Arctic, whereas Japan is not. In Norway and the U.S., we have to consider the indigenous people as well. On the other hand, when we think about fisheries, we have a common group of stakeholders.

Regarding the shipping industry, Japan and Norway have some similarities; there's a logistic route between Europe and East Asia, which both Norway and Japan are making use of. Depending on the countries, we have different types of stakeholders, but we also have common stakeholders. We will deliver our research results to each stakeholder to formulate the future research themes.

Anyway, we will have three workshops. Probably, in Alaska, we will have the workshop with the communities of the Atlantic side. Today's meeting in Japan is the first workshop for this project. Stakeholders from Japan include various sectors. From fishing industry, NISSUI is here. Unfortunately Maruha Nichiro couldn't make it because of the business commitment. We also have a food supply company, ARCS Group, and as shipping and information service companies, Mitsui O.S.K Lines, Nippon Yusen and Weathernews are here today. Also, fisheries cooperatives are also one of the participants as well as NPO, Sasakawa Peace Foundation/Ocean Policy Research Institute, Japan Fisheries Association (Dainihon-Suisankai), Hokkaido government and local government of Hokkaido. And national government, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of Economy, Trade and Industry and the Fisheries Agency are joining us. Office of Naval Research in the U.S. and the Norwegian Embassy are also attending today. The second workshop will be held at the same period next year in Alaska. In that case, the U.S. will take lead and North Pacific marine resource council – the resource management body will participate in the workshop. And, the final workshop will be held in Norway in 2018. This is the timetable. Now, we are here in Japan; and, next year, Alaska; and, finally, in Norway. In between, we will have the ESSAS open science meeting next year 2017 in June in Tromso, Norway. I would like to conclude my overview of RACArctic. Thank you very much.



2-2. Keynote Lecture 1
Climate change and physical/chemical process in the Arctic – Takashi Kikuchi

Saitoh:

So, we will not take questions so that we can go to the next presentation, Dr. Kikuchi. He will talk about the research results in Japan.

Kikuchi:

Okay. At first, thank you very much Professor Saitoh to give me a very good opportunity for this presentation. And also, thank you very much for coming to Hakodate for this workshop. Some of the scientists, I met with them at New Orleans last week, so we had a long trip from New Orleans to Hakodate here, so please enjoy staying at Japan as well. Okay. So, my name is Takashi Kikuchi. I am working at the Japan Agency for Marine-Earth Science and Technology. I am mainly a physical oceanographer, but recently working with not only physical oceanographers, but also, climate scientists, chemical – biogeochemical scientists and marine ecosystem scientists.

This time, Professor Saitoh gave me a title about "Climate Change and Physical and Chemical Processes in the Arctic" for this workshop. And he would like me to talk about some things as introduction of this workshop. Therefore, at first, I would like to talk about global warming and Arctic environmental changes especially for sea-ice changes in the Arctic Ocean. And, later part, I would like to talk about the biological hotspots in the Pacific Arctic Region, especially on how these features are formed and maintained from the physical oceanographic point of view. Because I am a physical oceanographer, not a biological scientist, so I'd like to mainly focus on physical oceanography. And, from this point, I am sorry, I'd like to talk and have this presentation in Japanese. Sorry for inconvenience for scientist, and stakeholders from foreign countries.

As for global warming, you may have already seen this slide. In 2100, this is what the temperature at that time will be and how the temperature change will be. So, this was calculated by the Earth simulator and published in the IPCC report. So, by 2100, the global temperature will increase 2 to 3 degrees compared to what it is now, especially in the Arctic, as indicated by the colors, so it is plus 8 to plus 12. You can see that there is much higher increase in surface temperature in the Arctic.

We collected past data and investigated how the temperature has changed. We can find this figure in the third IPCC Assessment Report, which was published more than 10 years before. Over the last 1,000 years, temperature change in the Northern Hemisphere from AC 1000 to AC 2000 was recorded from many kinds of observational data. In the first 900 years, the surface temperature was decreasing slowly. But since the industrial revolution, the surface temperature increased about 1-degree. In the next slide, I would like to expand this graph and see the temperature change from 1890 to last year. This was reported by Japanese meteorological agency in February 1st, 2016. As I said, since the industrial revolution, the temperature increased + 0.7 degree in recent 100 years with some of decadal variability. In the 21st century, the

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Climate change and physical & chemical processes in the Arctic

Takashi Kikuchi (IACE/JAMSTEC)
Institute of Arctic Climate and Environment Research
Japan Agency for Marine Earth Science and Technology

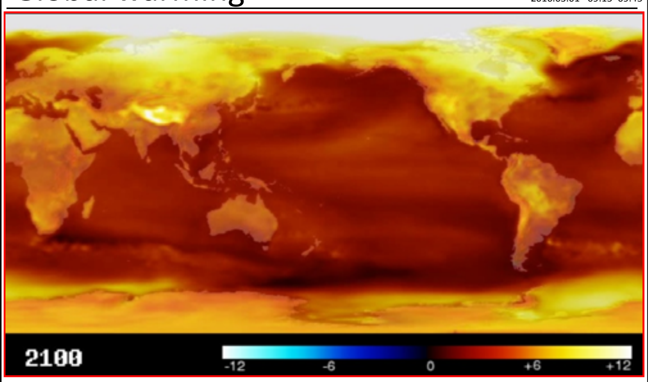
With kind inputs from lots of my friends. . . Thanks a lot.

The First RACArctic Workshop in Hakodate on March 1-3, 2016

Climate change and physical & chemical processes in the Arctic

1. Global warming & Arctic environmental change
2. ECOARCS/GRENE-Arctic project(JFY2011-2015)
3. Biological hotspot in the Pacific Arctic Region
   How to form/maintain biological hotspot from physical points of view.
4. Impact on sea ice reduction (for P.P.)

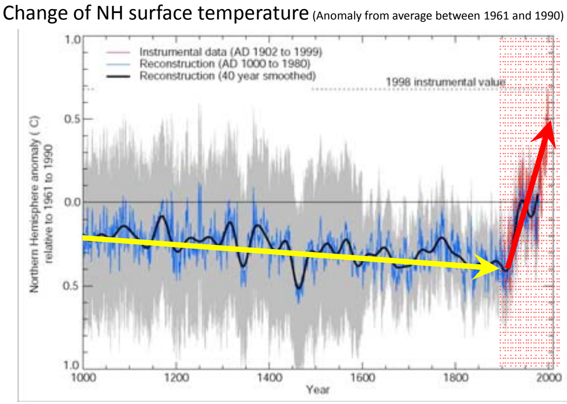
Global warming



Possible surface temperature response in 2011 simulated by Earth Simulator

Global warming

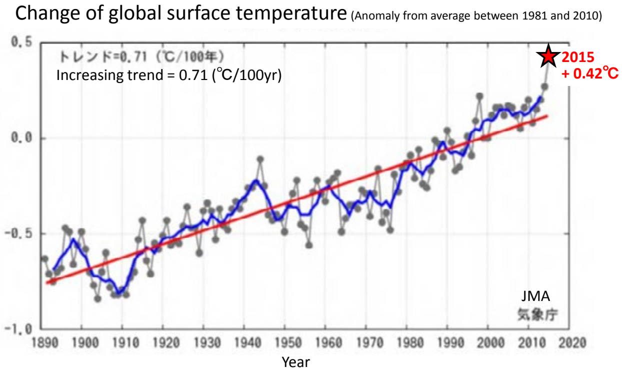
Change of NH surface temperature (Anomaly from average between 1961 and 1990)



IPCC AR3, Climate Change 2001

Global warming

Change of global surface temperature (Anomaly from average between 1981 and 2010)

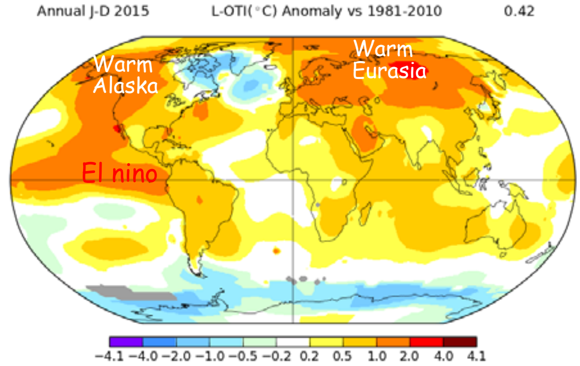


"Global surface temperature in 2015 is the highest since 1890"

Press release from Japanese Meteorological Agency (JMA) on February 1, 2016

Global warming

Distribution of global surface temperature anomaly in 2015



From GISS Surface Temperature Analysis, NASA (http://data.giss.nasa.gov/gistemp/maps/)

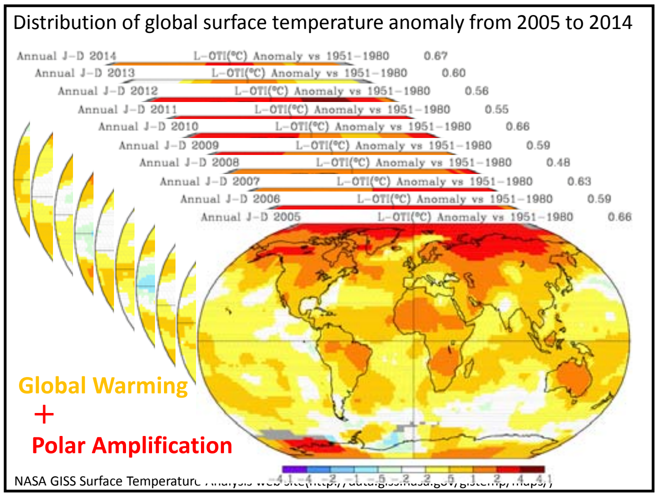
temperature increase seemed to have stopped. It appears that it has stopped increasing. However, 2014 and 2015, for two consecutive years, highest temperature was recorded again.

Global surface temperature in 2015 is much higher than before, as reported "Global surface temperature in 2015 is the highest since 1819". You can see that the global warming is truly progressing. Next slide, the distribution of the temperature increase in 2015 is shown in the map. The primary factor was the El Niño phenomenon. This was one of the biggest El Niño events. It was extended for a long duration. Besides that, temperature in Alaska, in Siberia, Arctic – these areas were also very warm. In the previous year, 2014, the mean temperature was also high. And, Alaska and Arctic Regions recorded higher temperatures than usual. We reflect such distribution maps in 2013, 2012, 2011, 2010, 2009, 2008, 2009, 2008, 2007, 2006, and 2005. What I would like to show you is that, during this period when the global surface temperature was always high – let's look at the area with the high temperature and it was at the Arctic. So, simply global warming is not simply progressing, but, polar amplification plays an important role of warming in the Arctic.

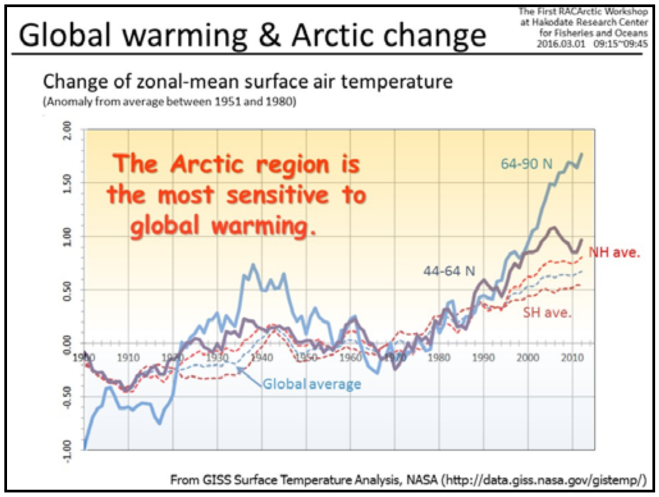
So, I would like to show you a different figure about surface temperature changes on some latitude bands since 1900. The three dotted lines in blue and red show those of global, Northern Hemisphere, and Southern Hemisphere, respectively. These temperature changes are about 0.7 degree increase in 100 years. In the same figure, surface temperature changes between north of Japan, 44 degree N and 64 degree N is shown in purple. And then, From 64 to 90 N is in blue. Clearly, you can see that the temperature increases are clearly noticeable in the sub-arctic and arctic regions, so Arctic region is the most sensitive to global warming.

Now, NOAA, U.S. National Oceanic and Atmospheric Administration, released "Arctic Report Card" every December. We, some of Japanese scientists, contribute to Arctic report card. And, the issue in December 2015, this was included in the report.

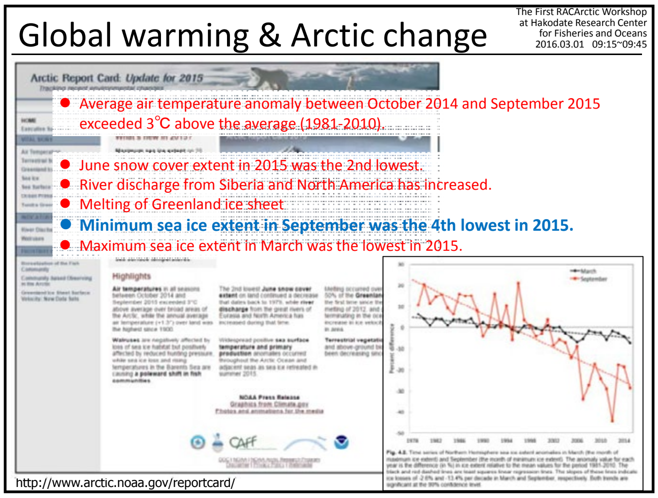
In the Arctic, it is – the temperature increase is more than 3 degrees C and this is extended for over one year since October 2014. Here it says 2015 September, but it is continuing after that, so more than 3-degree increase is seen in the Arctic. So, snow and ice conditions are influenced. For example, snow cover is the second lowest, river inflow into the Arctic is increasing, and melting of ice sheet in Greenland is progressing. And then, the Arctic sea ice extent in September was the fourth lowest recorded. Moreover, sea-ice extent in winter was the lowest in 2015. So here I would like to now talk about sea-ice reduction. I show the 4 maps of sea ice distribution corresponding to years 2002, 2005, 2007, 2012 and each figure represents the minimum records of sea ice extent at that moment, respectively. In 2012, a considerable sea ice reduction is seen. So, clearly, in summertime, sea-ice is decreasing in the Arctic and this is shown here. In 1979 to present time, the minimum sea-ice extent is – before 2000, the reduction – there is a slight reduction and if you consider, so in a matter of one decade, 460,000 square kilometers per decade. This is 1.3 times the size of Japan. If we continue to draw a line, then, in mid-22 century, we have no ice. So global warming is progressing. We didn't see that the sea ice would disappear. However, since 2000, the curve is sharply dropping, 1,500,000 square kilometers would be decreased in a decade after 2000. So, if you go at this pace,



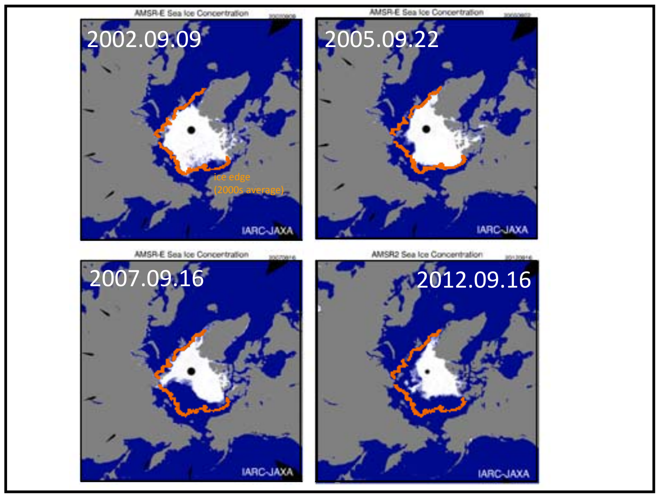
Distribution of global surface temperature anomaly from 2005 to 2014
Annual J–D 2014 L–OTI(°C) Anomaly vs 1951–1980 0.67
Annual J–D 2013 L–OTI(°C) Anomaly vs 1951–1980 0.60
Annual J–D 2012 L–OTI(°C) Anomaly vs 1951–1980 0.56
Annual J–D 2011 L–OTI(°C) Anomaly vs 1951–1980 0.55
Annual J–D 2010 L–OTI(°C) Anomaly vs 1951–1980 0.66
Annual J–D 2009 L–OTI(°C) Anomaly vs 1951–1980 0.59
Annual J–D 2008 L–OTI(°C) Anomaly vs 1951–1980 0.48
Annual J–D 2007 L–OTI(°C) Anomaly vs 1951–1980 0.63
Annual J–D 2006 L–OTI(°C) Anomaly vs 1951–1980 0.59
Annual J–D 2005 L–OTI(°C) Anomaly vs 1951–1980 0.66
Global Warming
+
Polar Amplification
NASA GISS Surface Temperature



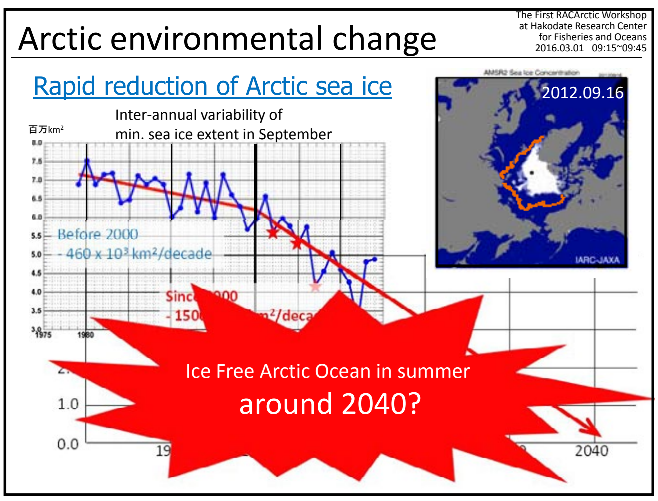
Global warming & Arctic change
The First RACArctic Workshop at Hakodate Research Center for Fisheries and Oceans 2016.03.01 09:15~09:45
Change of zonal-mean surface air temperature
(Anomaly from average between 1951 and 1980)
The Arctic region is the most sensitive to global warming.
64-90 N
NH ave.
44-64 N
SH ave.
Global average
From GISS Surface Temperature Analysis, NASA (http://data.giss.nasa.gov/gistemp/)



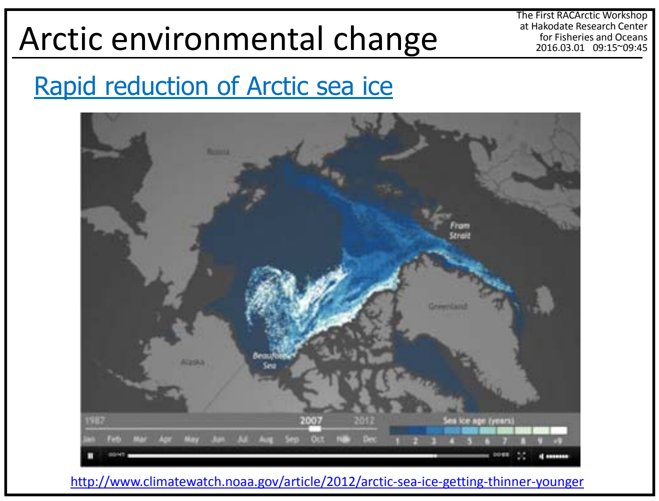
Global warming & Arctic change
The First RACArctic Workshop at Hakodate Research Center for Fisheries and Oceans 2016.03.01 09:15~09:45
Arctic Report Card: Update for 2015
● Average air temperature anomaly between October 2014 and September 2015 exceeded 3℃ above the average (1981-2010).
● June snow cover extent in 2015 was the 2nd lowest.
● River discharge from Siberia and North America has increased.
● Melting of Greenland ice sheet
● Minimum sea ice extent in September was the 4th lowest in 2015.
● Maximum sea ice extent in March was the lowest in 2015.
http://www.arctic.noaa.gov/reportcard/



2002.09.09
2005.09.22
2007.09.16
2012.09.16
IARC-JAXA



Arctic environmental change
The First RACArctic Workshop at Hakodate Research Center for Fisheries and Oceans 2016.03.01 09:15~09:45
Rapid reduction of Arctic sea ice
Inter-annual variability of min. sea ice extent in September
百万km²
Before 2000
- 460 x 10³ km²/decade
2012.09.16
IARC-JAXA
Ice Free Arctic Ocean in summer
around 2040?
2040



Arctic environmental change
The First RACArctic Workshop at Hakodate Research Center for Fisheries and Oceans 2016.03.01 09:15~09:45
Rapid reduction of Arctic sea ice
http://www.climatewatch.noaa.gov/article/2012/arctic-sea-ice-getting-thinner-younger

there would be no sea ice or Arctic would be ice free in 2040. This is a simple illustration of what's happening.

And another interesting description is this is reported by American researchers, the Arctic ice age 1987, since, changes of sea-ice age was indicated and how to calculate sea ice age is – sea ice turns one year of age when it becomes the smallest in size in summer. So that's how we calculated for sea ice age during the first year, second year, third year, fourth year sea ice. So, before 2000, the middle of Arctic Ocean was very white, but the white area is decreasing. In 2008 and 2009, there is no white color in the middle, hardly. So, the Arctic sea ice – the thickness is – corresponds to the sea-ice age and this is also decreasing. And this is compiling some of the reports. 1879, the initial stage is very thick – most of sea ice are four or fifth years of age or older; in 2008 and 2010, very thin – the thickness of ice has decreased to 1 to 1.5 meters. About 30 years ago, the thickness was 3 to 4 meters. But, presently, it's only 1 to 1.5 meters.

And the information about thickness and area, we can calculate sea-ice volume, whichi is reported by the US scientists –from University of Washington. This is a seasonal change of sea ice volume from January to December. For example, 1979, January, the amount of ice it's increasing; in summer, decreasing; and it returns. The top blue line shows 1979's sea ice volume. Prior to that, winter in '07, drawing lines; and then, '12 – until 2012, in blue, so sea ice reduction is not only observed in summertime. The volume of sea ice is low. But also, in wintertime, sea ice is decreasing. The ice volume in winter is 33% decrease in 33 years. This will not go at the same pace. However, the sea ice is obviously reducing. In contrast, summer sea ice, in 33 years, there is an 80% decrease. And if things go at this pace, then, we will find ice free Arctic Ocean by 2020, the time of Tokyo Olympics. Personally, I don't believe that this will happen. However, sea ice is reducing – is definite – from the perspective of volume and area, that can be said clearly.

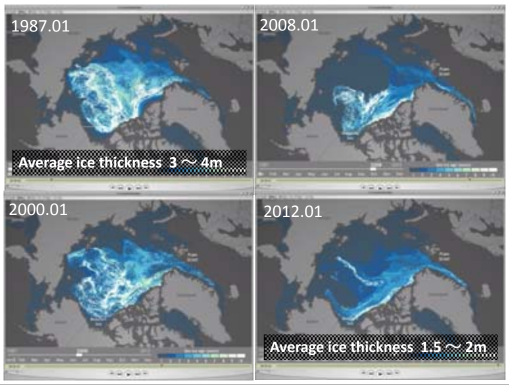
So, Arctic report card indicates that temperature is increasing, primary production is increasing, and fish community is shifting toward the North Pole. And also, IPCC report global warming is increasing and temperature is increasing in the Arctic. Precipitation is also increasing in the Arctic and the ocean acidification on the sea surface, pH value in the Arctic and the Sub-Arctic is reducing. In various ways, the ocean and, globally, everywhere, it is being affected. In that situation, the Arctic is very sensitive to global warming. Also, global warming is accelerating in ecosystem and shipping and social science. There is a great impact on these various areas, so we should do the Arctic research right now.

Since 2011, in Japan, we started GRENE Arctic Project, GRENE Network of Excellence Program Arctic Climate Change Research Project. Seven research themes were set up: Numerical simulation, terrestrial ecosystem, atmospheric studies, cryosphere, greenhouse gas, marine ecosystem, and sea ice prediction. I am in-charge of marine ecosystem research project. Sea ice extent has been decreasing and the environmental condition has changed. And also, phytoplankton and zooplankton has been affected by such environmental changes. And also, the distribution of phytoplankton has been changed. Moreover, the benthos, fish and other top-level predators' activities, i.e., the sea birds and the polar bears, has been affected. So, we conducted research project, to understand such changes in Arctic marine ecosystem, particularly focused on increasing

Arctic environmental change

The First RACArctic Workshop
at Hakodate Research Center
for Fisheries and Oceans
2016.03.01 09:15~09:45

Rapid reduction of Arctic sea ice



Arctic environmental change

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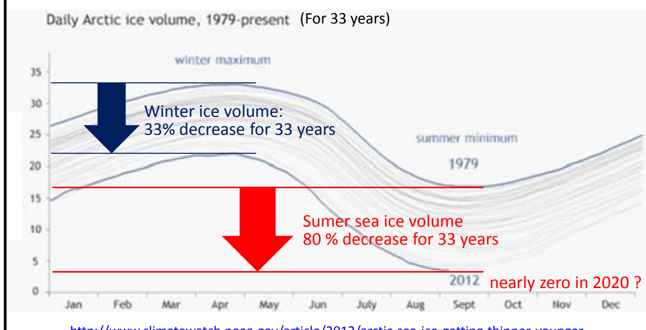
Rapid reduction of Arctic sea ice



http://www.climatewatch.noaa.gov/article/2012/arctic-sea-ice-getting-thinner-younger
M. Scott and R. Lindsey (2012)

Arctic environmental change

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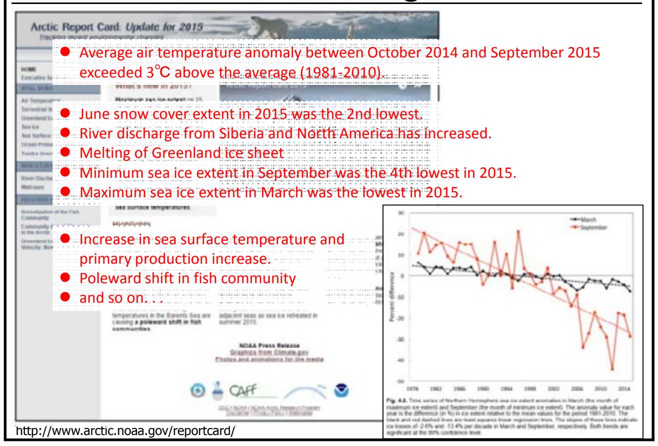
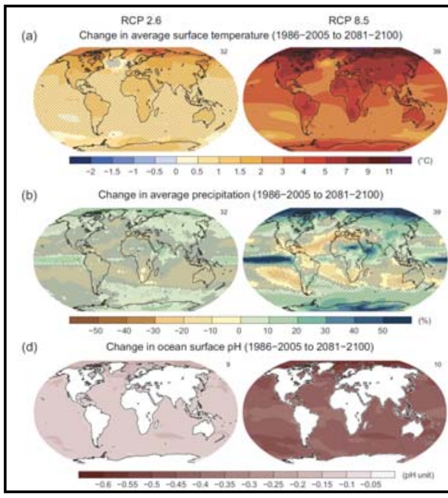


- Average air temperature anomaly between October 2014 and September 2015 exceeded 3°C above the average (1981-2010).
- June snow cover extent in 2015 was the 2nd lowest.
- River discharge from Siberia and North America has increased.
- Melting of Greenland ice sheet
- Minimum sea ice extent in September was the 4th lowest in 2015.
- Maximum sea ice extent in March was the lowest in 2015.
- Increase in sea surface temperature and primary production increase.
- Poleward shift in fish community
- and so on. . .

http://www.arctic.noaa.gov/reportcard/



Global warming

Increase in SAT,
Increase in precipitation,
Decrease in ocean surface pH
in the Arctic

IPCC, 2013:
Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Arctic environmental change

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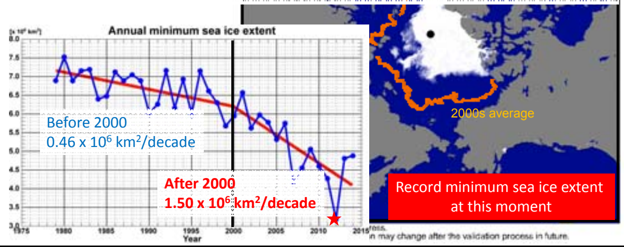
Why should we study the Arctic Ocean now?

The answers are. . .

1) the Arctic Ocean is particularly sensitive to global climate change,
2) the Arctic Ocean environment is changing faster than expected, and
3) the impacts of the Arctic climate/ environmental changes are expected to be large for many issues, e.g., global climate, ecosystem, shipping, resources, social science, human life, and so on.



GRENE-Arctic project

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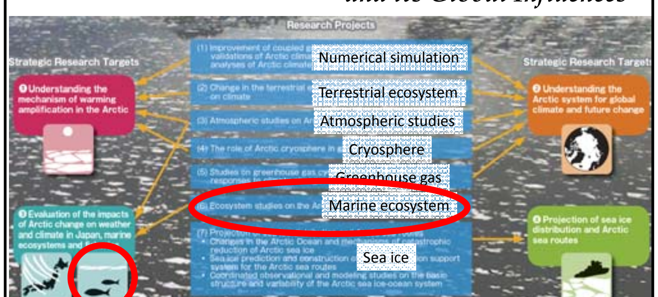
Green Network of Excellence Program
Arctic Climate Change Research Project (GRENE-Arctic: FY2011-2015)

"Rapid Change of the Arctic Climate System and its Global Influences"



primary production, progress on Arctic ocean acidification and also changes of dominant species in Arctic Ocean. Again, we are conducting multi-disciplinary research including physical, chemical, and biological oceanography.

As Professor Saitoh mentioned before my talk, our target area is the Pacific sector of the Arctic Ocean. People from Norway are mainly concentrating on the Atlantic sector of the Arctic Ocean. So, what kind of things are happening in the Atlantic Ocean? It is very interesting. One of Norway marine scientists used the word, "Atlantification". So this is a very interesting wording. It means that ocean warming, salinization, and advection of Atlantic species into the Barents Sea has been progressing. So this is very interesting phenomenon, Atlantification. So how about Pacific sector of the Arctic Ocean?

We use T/S Oshoro-maru (Hokkaido University) to conduct observational research on marine ecosystem. Also, we conduct R/V Mirai Arctic cruise in the Pacific sector of the Arctic Ocean. From the result of the research cruises, there is no "Pacification", but rather, we found big impacts on sea-ice reduction in the Pacific sector. It is about freshening, warming and ocean acidification due to the sea ice melt. We are focusing on those topics in our research project. But because of limited time frame of my talk, I cannot mention all of the things here in my presentation. So, in the workshop, it will be tomorrow, Drs. Ueno, Watanabe, Fujiwara, Sasaki, Mr. Waga and other researchers will give presentations, so please listen to their presentations to know about the details of their research that we have conducted.

Because I am physical oceanographer, I would like to talk about biological hotspots from physical oceanographic points of view. So, at first, let me explain briefly about biological hotspots. In biological hotspot, primary production is high and biological activity is high. And also, there was a high diversity, usually. In the Arctic, however, there are not so much biodiversity. The important things are the topography, water temperature and nutrient supply that has been provided in this region, so please look at this one.

These figures are presented by Dr. Jacqueline Grebmeier, one of the most active US biological scientist. These show distributions of primary production and oxygen consumption at the bottom. So, if you look at this, this is Hope Valley in the Southern Chukchi Sea, the Barrow Canyon and also the Northern Bering Sea. There are biological hotspot, where we can find high primary production and oxygen consumption. Why are there biological hotspots in these regions?

In the Oshoro-maru Arctic cruise in July 2013, we used ROV to find the biological conditions at sea bottom. This slide show that at the edge of sea ice along the Alaska offshore of Barrow. You can see the sand dollars, a kind of sea urchin. Also, you can see basket stars, a kind of star fish. We find this one. I heard that we cannot eat them, but there are some animals – creature that can eat them. So we found that there are such kind of creatures near ice, so we go down to the South. Next, here is Hope Valley – this is a place called Hope Valley. We found a lot of fluffy things in the sea. This is appendicularians called otamaboya in Japanese. This is a jelly-shaped plankton and it create a house and then are floating in the sea. We found that polar cod eats appendicularians and this is a kind of dietary food for cod. And then, we go down to the south further. This is at the north of the Bering Strait. And you can also see the house-based appendicularians and you can see lots of crabs. Because I am a physical oceanographer, I am not sure this is a red snow crab or

ECOARCS/GRENE-Arctic

GRENE Arctic Project
Strategic research target 3b:
GRENE北極気候変動研究分野
戦略目標3b

Evaluation of
the effects of Arctic change on
marine ecosystems and fisheries
北極域における環境変動が
水産資源等に及ぼす影響の評価

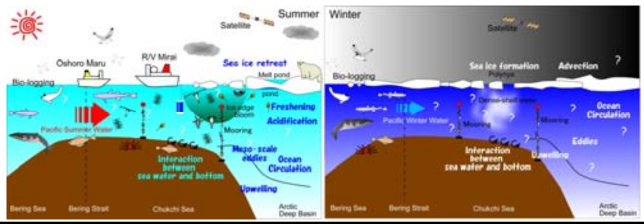
Ecosystem studies of the Arctic Ocean
declining Sea ice (ECOARCS)

ECOARCS/GRENE-Arctic

For better understanding of changes in Arctic climate and ecosystems,
we will conduct multi-disciplinary studies examining not only biological but also physical and chemical aspects of the drastically changing Arctic environments.

Key Topics:

1. **Increase in primary production?**
2. **Progress on Arctic Ocean Acidification?**
3. **Changes of dominant species?**



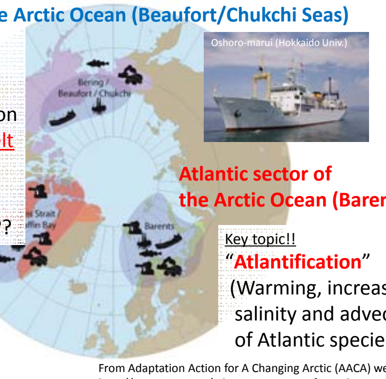
ECOARCS/GRENE-Arctic

Changes of the Arctic marine ecosystem

Pacific sector of the Arctic Ocean (Beaufort/Chukchi Seas)

Key topic!!
Freshening,
Warming, and
Ocean Acidification
due to sea ice melt

? **Pacification** ??
? Advection of
Pacific species ??



Atlantic sector of the Arctic Ocean (Barents Sea)

Key topic!!
"**Atlantification**"
(Warming, increase in salinity and advection of Atlantic species)

From Adaptation Action for A Changing Arctic (AACA) website
http://www.amap.no/adaptation-actions-for-a-changing-arctic-part-c

ECOARCS/GRENE-Arctic

Field Activities

R/V Mirai 2012 Arctic Cruise

TS Oshoro-maru 2013 Arctic Cruise

Collaboration with
CCGS ice-breakers
&
Year-long mooring
observations

Biologging in the PAR region

Scientific results - Key Findings

- Enhancement/reduction of biological pump depends on ocean circulation & sea-ice reduction.
- Formation of biological hotspot in the southern Chukchi Sea.
- Progress of Arctic Ocean Acidification in the PAR
- Increase in primary production ?
  - ✓ Increase in primary production ? (Ice Algae)
- Fate of Pacific zooplankton in the Chukchi Sea
- Changes of higher trophic level

And more other research topics . . .

Scientific results - Key Findings

RACArctic Science meeting on March 2-3

- Physical and Chemical Oceanography
  E. Watanabe
- Plankton, including OA impacts
  A. Yamaguchi, A. Fujiwara, and H. Waga
- Fish
  H. Sasaki, Y. Watanuki, and Y. Sakurai
  S. Yoon and H. Ueno

My talk:
How to form/maintain biological hotspots in the PAR
mainly from physical oceanographic points of view

Biological hotspots in the PAR

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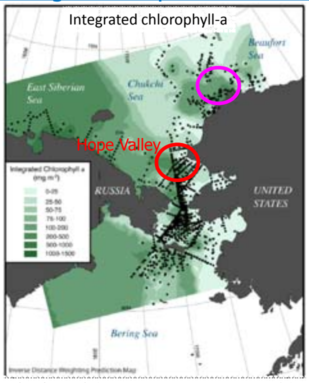
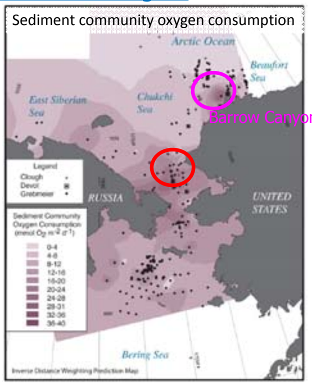
Biological hotspot in the Pacific Arctic Region

Integrated chlorophyll-a



Sediment community oxygen consumption



Grebmeier et al. (2006, *Progress in Oceanography*)

Biological hotspots in the PAR

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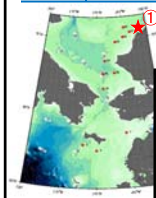
Biological hotspot in the Pacific Arctic Region



TS Oshoro-maru (Univ. Hokkaido) 2013 Arctic cruise (mid July, 2013)
Remote Operated Vehicle (ROV) observation in the Chukchi Sea

①:
Alaskan coast near Barrow
Sand Dollars (タコノマクラ、花びら模様のある平べったいウニ)
Basket Stars (テヅルモヅル類(クモヒト))が見られる。

Biological hotspots in the PAR

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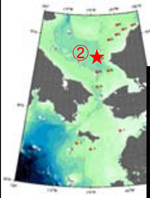
Biological hotspot in the Pacific Arctic Region



TS Oshoro-maru (Univ. Hokkaido) 2013 Arctic cruise (mid July, 2013)
Remote Operated Vehicle (ROV) observation in the Chukchi Sea

②: Hope Valley

Biological hotspots in the PAR

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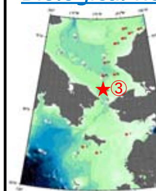
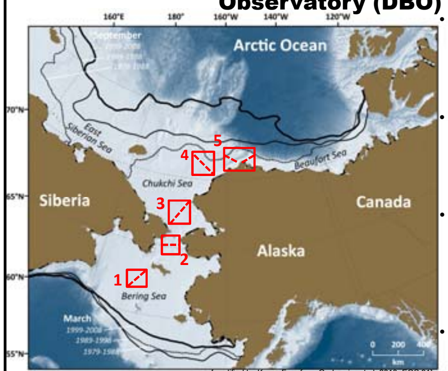
Biological hotspot in the Pacific Arctic Region



TS Oshoro-maru (Univ. Hokkaido) 2013 Arctic cruise (mid July, 2013)
Remote Operated Vehicle (ROV) observation in the Chukchi Sea

③: North of Bering Strait

Linking Physics to Biology: the Distributed Biological Observatory (DBO)



[modified by Karen Frey from Grebmeier et al. 2010, EOS 91]

- DBO sites (red boxes) are regional "hotspot" transect lines and stations located along a latitudinal gradient
- DBO sites are considered to exhibit high productivity, biodiversity, and overall rates of change
- DBO sites will serve as a change detection array for the identification and consistent monitoring of biophysical responses
- Sites occuppied by national and international entities with shared data plan

IASC

Biological hotspots in the PAR

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What are important factors
to form/maintain
such biological hotspots
in the Pacific Arctic Region
from physical points of view ?

king crab – but I can say that there are many, many crabs around here. So I think that we are – people approaching to them so they are running away. So we have been doing collaborative research among American, Canadian, Russian, Korean, Chinese, and Japanese researchers to monitor the environmental condition at such biological hotspot in the Pacific sector of the Arctic Ocean. So we found a lot of very interesting results from those researches.

So, I would like to talk about what are the important factors to maintain such biological hotspots in the Pacific Arctic region from a physical point of view. This is the same slide shown before. Let me think about this – there are – whether they have sea ice or not, so what kind of bottom topography they have, how about the wind, how about the current. So, I would like to focus on these four things: Sea ice, sea bottom topography, wind and current.

First is about sea ice. The sea ice is declining in the Arctic Ocean, not only in the summer, but also in the winter. And in the Bering Sea, not much reduction – but depending on the region, sometimes sea melt and sea freezing occur, so I would like to talk about what kind of impacts do they have.

When the sea ice melt, the seawater will be diluted because of the freshwater from melted ice. When there are a lot of diluted water, then, the surface density will be much lower than the sub-surface layer. Strong stratification prevents mixing between the upper layer and sub-surface layer. So even if there are a lot of nutrient in the sub-surface / deeper layer, but it wouldn't come up to the surface, it is not good for biological activities. As for the solar radiation, if there was no ice, the sunlight can penetrate into ocean, so it will be good for biological activities.

Next, we think about sea ice formation. What kind of things will happen during the sea ice formation? When sea ice is formed, dense water is formed due to brine rejection from sea ice, which will increase mixing in the water column, resulting to subsequent increase of oxygen in the water. And then, vertical mixing will proceed and mix the nutrient from the bottom with the waters in the upper part of the ocean. It will enhance biological activities in next season. In contrast, if the sea ice covers the surface, the solar radiation will not penetrate into ocean, so this is not good for biological activities.

This figure shows an evolution of seasonal mixed layer related to seasonal cycle of sea ice in the Arctic; and at the end of winter, the ice covers the ocean. And because of the solar radiation, the ice will start melting. Sea ice melts, and it will become warm and fresh at surface layer, and the mixing will be suppressed. From late fall to winter, ice will be formed again, and dense water will be formed and the water column will be mixed. Then, the next year, it will be good for biological activity. This is the seasonal cycle of sea ice and ocean condition in the Arctic.

Important point on sea ice formation is about where sea ice is created mostly. There are some regions, so-called "polynya", which is persistent and recurrent areas of open water and/or thin ice within sea ice zones. In this figure, here is Bering Strait and St. Lawrence Island and this is Hope Valley. It is on March 6, 2014. At that time, strong north-east wind was blowing. And then, here and there, there are no ice area, polynya, and a lot of sea ice were formed here and enhance vertical mixing. And then, they have heavy water. Such a vertical mixing plays an important role to increase in concentration of dissolved oxygen and

Biological hotspots in the PAR

Biological hotspot:
high primary production & biological activity
(biodiversity as well)

Necessary condition:
Lightening, Temperature, Nutrients, and . . .

Physical constrains:
Sea ice, Bottom topography
Wind, Current system, & more

Biological hotspots in the PAR

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1. Sea Ice

Sea melt
- Freshwater input:
  → Dilution effect
  → Strengthen stratification
  (Suppress vertical mixing)
- Improvement of lightening condition
  → Warming

Sea ice formation
- Dense water formation/DO source
- Enhance vertical mixing/ interaction with bottom sediment
- Prevent solar radiation input

Biological hotspots in the PAR

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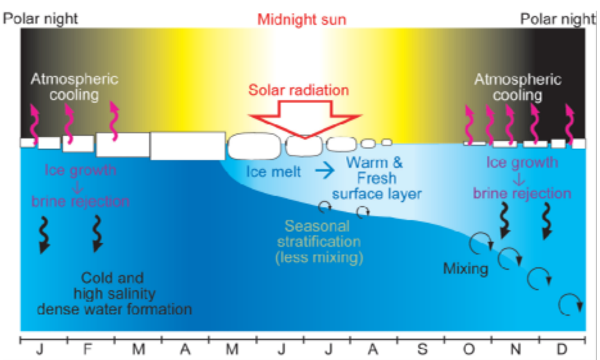
1. Sea Ice

Evolution of seasonal mixed layer related to seasonal cycle of sea ice in the Arctic



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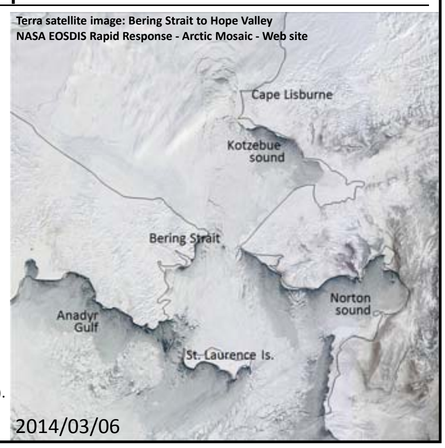
1. Sea Ice

Polynyas are persistent and recurrent areas of open water and/or thin ice within sea ice zones.

Polynyas are responsible for the formation of sea ice and cold saline water during ice-covered periods. These features contribute not only for maintenance of strong stratification of the Arctic Ocean but also as one of important mechanisms to supply nutrients, irons, minerals, and other chemical constituents (e.g., Codispoti et al., 2005; Hioki et al., 2014).



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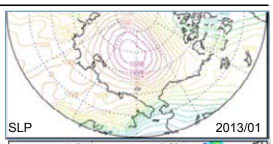
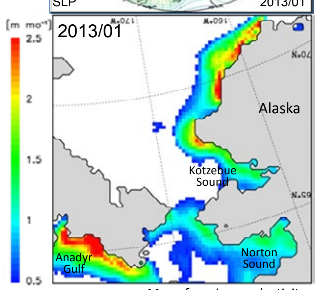
1. Sea Ice

There are several active and large polynyas in the Bering and Chukchi Sea as follows; the northeastern Chukchi Sea off Alaskan coast, Kotzebue Sound, Norton Sound, southern coast of St. Lawrence Island and Anadyr Gulf.





Map of sea ice productivity
(Courtesy from Dr. Tamura (NIPR))

Biological hotspots in the PAR

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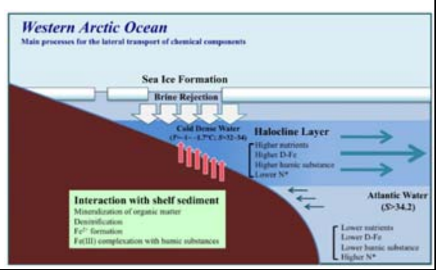
1. Sea Ice

Polynyas are responsible for the formation of sea ice and cold saline water during ice-covered periods. These features contribute not only for maintenance of strong stratification of the Arctic Ocean but also as one of important mechanisms to supply nutrients, irons, minerals, and other chemical constituents to the Arctic basins through an interaction of the cold saline water with the sediment at the bottom of the shelf. These processes are necessary for Arctic marine ecosystem functioning (e.g., Codispoti et al., 2005; Hioki et al., 2014).



Hioki et al., 2014, *Scientific Reports* nutrients in the water column. Where are these locations? As I said, these are in the Anadyr Gulf, in the south of St. Lawrence Island, and near Barrow, Alaska. In these areas, the sea ice formations become active and the mixing is activated. And, next year, these waters will be very useful for biological activities. This slide state the same thing.

The next slide – let me talk about bottom topography. If it is flat, nothing happens. But in the ocean, there are depressions and rise, the sea mount, for example. Then, what is happening in those topographies. First, let me talk about depressions. In the ocean, physical, the counterclockwise current circulation tends to be generated in this topography. The convergence flow can be created at the bottom layer and, in the center, many things accumulate – dense water sediments – many things are accumulated in the center, in other words. Here, is a very favorable condition, with very high nutrient, therefore high density of benthos.

On the other hand, the rise part, this kind of bottom sediment accumulation does not happen. But, in this case, the vertical mixing will be enhanced. And then, the high salinity water in the bottom layer will be upwelled to the surface. It has various effects for the creatures on the surface layer. It's very favorable condition in the surface layer. The biological activity, what kind of activities can happen? We can expect it from the bottom topography.

Between continental shelf and deep basin, there is a shelf slope – shelf break region. Here is also favorable area for vertical mixing. For example, Bering shelf slope from the south – this is the south Bering slope and the current toward the north. The mixing is happening here and the water come up from the bottom and around here a phytoplankton bloom occurs. And the Beaufort shelf break – this is the Arctic Ocean on the right-hand side and then this is Alaskan Coast. And there is an eastward current and the Beaufort circulation has a westward current. Various mixing happens, creating the favorable environment for marine creatures.

And, now, wind –What kind of effect wind cause? Mixing? Mixing is good for this part of the story. The nutrient-rich water in sub-surface layer will be mixed. But wind itself has a more complex effect. For example, let's assume that the wind blows on the sea ice here. What will happen? Then, this is the wind direction. There is an open water and ice water, where convergence and divergence could happen. When ice edge upwelling happens, nutrient-rich water will be supplied to the upper layer. And what will happen? Let's think about the correlations, the upwelling and down-welling will happen.

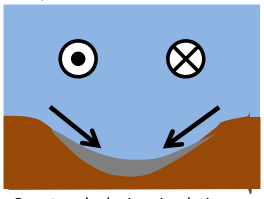
Let's look at this slide and think about a combination effect with bottom topography. There is a shelf slope covered with ice. Now, wind blows. And when the wind blows with the coast on its left, what will happen? On the surface, the ice and seawater will move toward offshore. As I said, the surface water will go out creating polynya and water will be mixed. The warm water comes from outside and there is ice at the top of this region, so cold water and warm water will be mixed. This condition is very good for biological creatures. And where are the locations? Dr. Hirano and his colleagues investigated this combined effect off Barrow, Alaska. The polynya here, such location, February 22, 2012. The blue is 2010. The blue area is open water. The strong wind blows and creating this kind of features. And this is 2013. The warm water comes up from the bottom and mixing happens – creating very interesting features and favorable conditions for the biological production.

Lastly, let me talk about the current system. In the Pacific Arctic Region, water flows from the

Biological hotspots in the PAR

2. Bottom topography

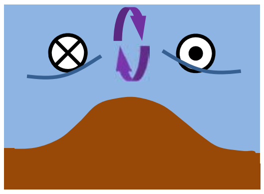
Depression (Pan, Canyon, Valley)



Counter-clockwise circulation
Convergent flow at the bottom layer
→ Transportation of dense-water, nutrients, bottom sediment, and more into this area

➡ It is likely to be a favorable condition especially for benthos

Rise (ridge, sea mount)



Clock-wise circulation
Strong vertical mixing
→ Nutrients supply to surface (euphotic zone) over the rise

➡ Phys. & chemical conditions over the rise are likely to enhance biological activity.

Biological hotspots in the PAR

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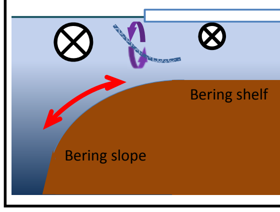
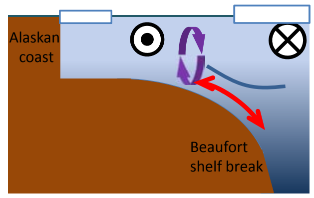
2. Bottom topography

Shelf slope, shelf break:
Upwelling / mixing of deeper water mass with shelf water
→ Possible area to be biological hotspot

Bering shelf slope
- Bering slope current
- Bering shelf water
- Cold pool?



Beaufort shelf break
- Alaskan coastal water/current
- (Offshore) Beaufort Gyre



Biological hotspots in the PAR

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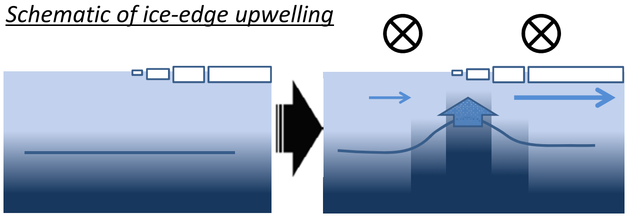
3. Wind

- ✓ enhance mixing and nutrient supply from lower layer.
- ✓ cause ice edge upwelling/downwelling. (combined effect with sea ice)
- ✓ cause upwelling/downwelling in the shelf slope area. (combined effect with bottom topography)

Schematic of ice-edge upwelling



Biological hotspots in the PAR

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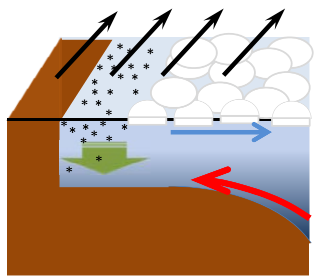
3'. Wind (combined effect with bottom topography)

IF wind blows along coast on the right side,
➡ surface water (and sea ice) move offshore.



- ◆ Coastal polynya is formed and it enhance sea ice formation.
- ◆ Offshore lower water comes onto coastal area by upwelling.

It may have strong impacts to marine ecosystem, e.g., as a preconditioning of spring bloom.

Biological hotspots in the PAR

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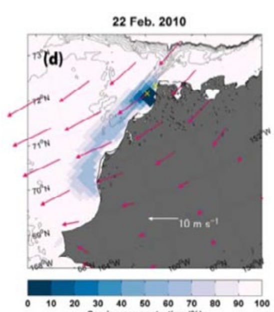
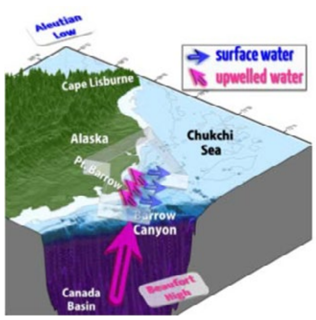
3'. Wind (combined effect with bottom topography)

A wind-driven, hybrid latent and sensible heat coastal polynya off Barrow, Alaska (Hirano et al., 2016, J. Geophys. Res.-Oceans)





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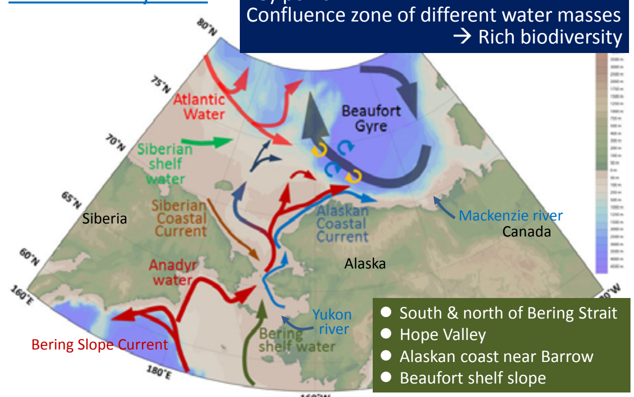
4. Current system

Key point:
Confluence zone of different water masses
→ Rich biodiversity



- South & north of Bering Strait
- Hope Valley
- Alaskan coast near Barrow
- Beaufort shelf slope

Pacific toward the Arctic Ocean. And then, the Pacific-origin water masses are transported toward the Atlantic Ocean. The various water masses indicated are color coded in this figure. What kind of waters are mixed? Where is the confluence zone? Confluence zone is, in other words, related to biodiversity and water mixing. Where are the locations? When we look at that, the north and south Bering Strait, Hope Valley, Alaskan coastal area, shelf slopes are the key locations we found out. This is a schematic view.

Here is a temperature distribution on September 5, 2009. Close to active polynya and depressions, rise, shelf breaks, such specific bottom topography can be seen, where the upwelling and confluence of different water masses are likely to happen. Then, for example, south of St. Lawrence Island, south of Bering Strait, north of Bering Strait, Hope Valley or Alaskan coast, Beaufort shelf slope – those areas are very favorable areas. Let me show you the examples of our observation result.

In 2012, we conducted observational cruise using our R/V MIRAI. Here is a meridional section across the Chukchi Sea. Here, Bering Strait, Hope Valley here and in the north shelf slopes and deeper basin, the 100-meter and 10 meter isobaths. The ammonia concentration, dissolved oxygen concentration and water temperature are shown in this slide. This is Hope Valley, where we can find very high concentration of ammonia in water mass. And shelf slope region has similar condition as well. It's not on this slide, but we observed very active biological activities. Oxygen is consumed a lot. As a result, we can understand very active biological activities

Then, lastly, I'd like to talk about what is happening – what is the impact of sea ice reduction. And the ice edge bloom happens, spring bloom. It is called ice edge bloom. And what is important here is the solar radiation input and supply of nutrient. Now, what happens if sea ice decline? This is the first case. The sea ice retreat causes an increase in input of solar radiation. And if we have enough nutrient; the primary production is enhanced. But it's not necessarily like that. This is another case. Case two, the ice retreat, but here is the melt water. It has a dilution effect and stratification between surface and sub-surface layers becomes strong. Then, the primary productivity stays low.

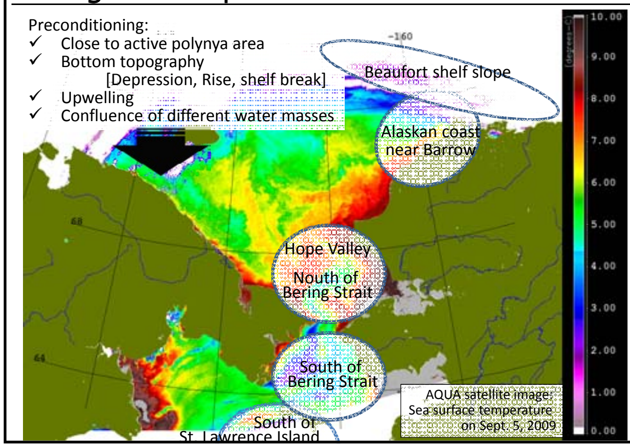
And what is happening here? Let me show you about continental shelf region. First, Bering Sea to Chukchi Sea, there is a continental shelf. Dr. Hirawake examined it using satellite data from 2000 to 2012. In September and October, the primary production has been increasing. And Dr. Fujiwara examined how the primary production increased in these regions. The larger phytoplankton becomes dominant in the Bering Sea and Chukchi Sea related with sea ice retreat. They have higher primary production.

On the other hand, further north, it's a basin area. Here is a nutrient distribution for 2002 and '03. The nutrient off Barrow Alaska, Canadian Basin were low. Looks the same, but with the sea ice retreat in 2010, the Canadian Basin has low nutrient whereas Siberian side has a very high nutrient. With this high nutrient, the primary production increased. On the other hand, in the Canadian side, because of the melt water, i.e., with the effect of the melt water, the primary production decreased. So, while observing the primary production, we should examine the effects of the sea ice reduction.

So, how the hotspot, biological hotspot is created and how it is impacted? I talked a lot, I believe. Tomorrow, we will have other presentations. They will talk about this more in detail. Thank you very much

Biological hotspots in the PAR

Preconditioning:
- ✓ Close to active polynya area
- ✓ Bottom topography
  [Depression, Rise, shelf break]
- ✓ Upwelling
- ✓ Confluence of different water masses



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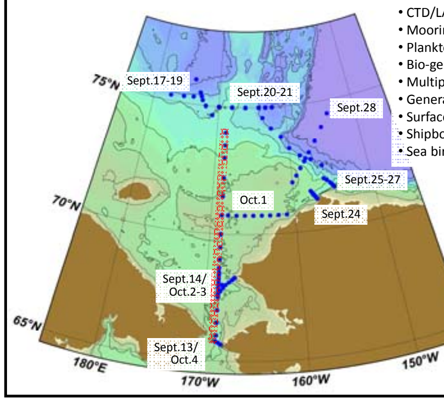
R/V Mirai Arctic cruise in September-October 2012

- CTD/LADCP/water sampling & XCTD
- Mooring recovery/deployment
- Plankton net sampling
- Bio-geochemical measurements
- Multiple corer sampling
- General meteorological monitoring
- Surface water sampling/monitoring
- Shipboard ADCP monitoring
- Sea bird and marine mammal survey



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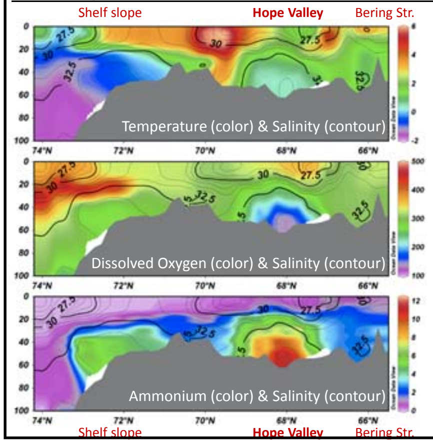

Hope Valley Area (Sept. 2012)

- Dome-like structure
- Low Temperature
- High Salinity
- Low Dissolved Oxygen
- High Nutrient
- High Chl-*a* concentration
- High biological activity

Linking Physics to Biology: the Distributed Biological Observatory (DBO)

- **DBO sites (red boxes) are regional "hotspot" transect lines and stations located along a latitudinal gradient**
- **DBO sites are considered to exhibit high productivity, biodiversity, and overall rates of change**
- **DBO sites will serve as a change detection array for the identification and consistent monitoring of biophysical responses**
- **Sites occupied by national and international entities with shared data plan**

IASC

Impact of sea ice reduction

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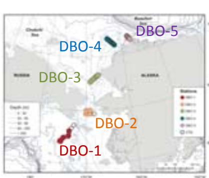
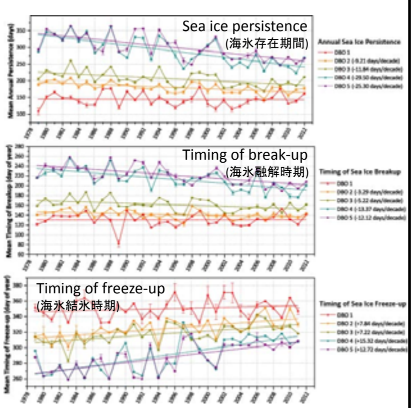
Sea ice condition

In the Pacific Arctic Region,
- period of sea ice persistence is getting shorter,
- spring sea ice breaks up earlier than before, and
- freeze-up in late fall to early winter starts later than before.





(Courtesy from Dr. Grebmeier (U. Maryland))

Impact of sea ice reduction

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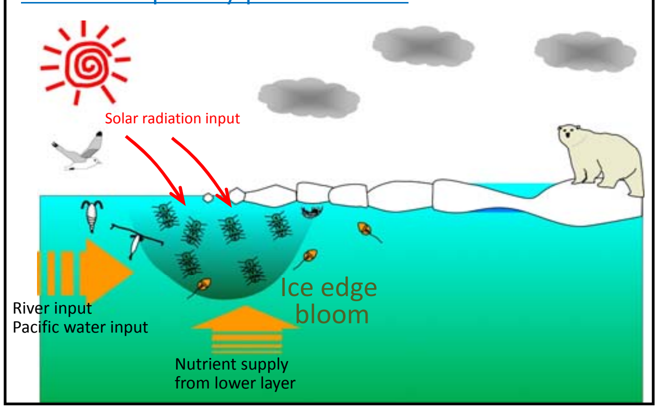
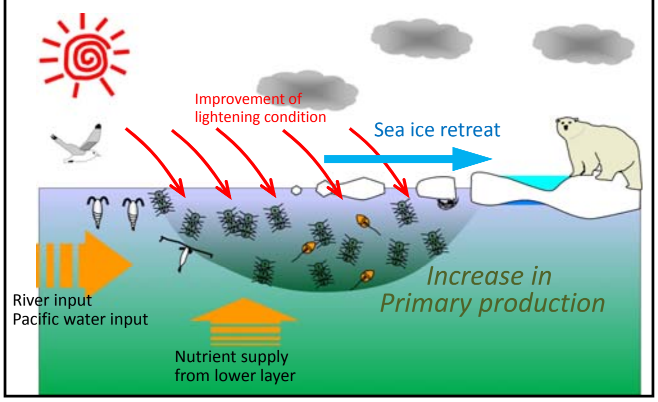
Increase in primary production ???



Impact of sea ice reduction

Schematic of spring (ice-edge) bloom after sea ice retreat: case 1



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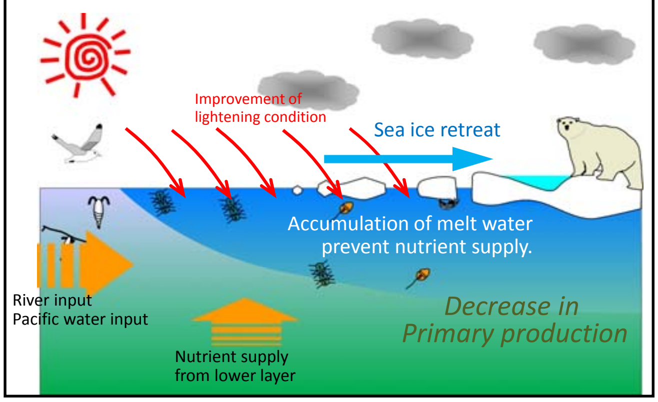
Impact of sea ice reduction

Schematic of spring (ice-edge) bloom after sea ice retreat: case 2



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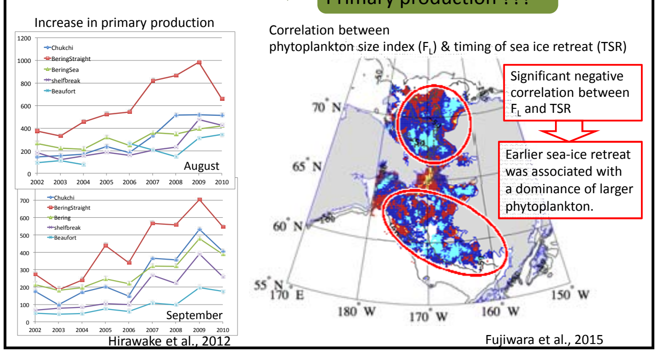
Impact of sea ice reduction

Increase in primary production

Timing of sea ice retreat → Size of phytoplankton ??? Primary production ???



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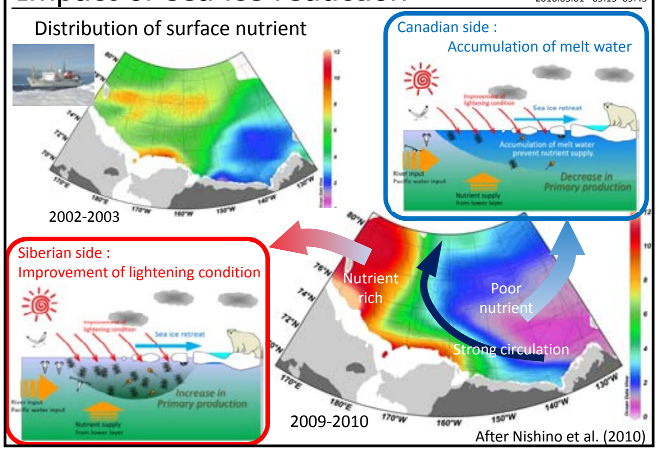
Impact of sea ice reduction



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Scientific results - Key Findings

RACArctic Science meeting on March 2-3

- Physical and Chemical Oceanography
  E. Watanabe (numerical experiments)
- Plankton, including OA impacts
  A. Yamaguchi, A. Fujiwara, and H. Waga
- Fish
  H. Sasaki, Y. Watanuki, and Y. Sakurai
  S. Yoon and H. Ueno

My talk:
How to form/maintain biological hotspots in the PAR
mainly from physical oceanographic points of view

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Thank you for your attentions

for listening. If you have any questions, later I will take it. Thank you very much.

Saitoh:

Thank you very much, Mr. Kikuchi. Today, we have simultaneous interpretation. If you have any questions, please use microphone, otherwise, the interpreters cannot hear your question. And when you make question, please state your name and affiliation. Now, if you have any, I'd like to take questions from the floor. Dr. Harada?

Harada:

Dr. Kikuchi, thank you very much for your presentation. Probably everyone would like to know. Let me ask one question. When sea ice retreat, melt, the lighting condition getting better and raising the productivity and nutrient – there is an area the nutrient supply is prevented. You mentioned about it. The Canadian Basin, for example, and East Siberian Sea, they originally have low productivity and high productivity, respectively. And the contrast will be strengthened because of the sea ice retreat. Is this what you are saying or biological hotspot location will change or can be changed in the future?

Kikuchi:

Thank you very much for your question. Yes, exactly, it is correct what you said. Originally, at the Siberian side, because of the river discharge, that area – originally, productivity was higher. Especially Canadian basin, the river discharge – the freshwater accumulated and, with this, the plankton getting smaller and primary productivity is getting lower. With regard to hotspot in the basin, probably other factors are related. Here, this area, as you know, there is the Chukchi Borderland. In this area, compared to the other region, the mixing can easily happen. With this aspect, this is – have more favorable environment for marine life.

2-3. Keynote Lecture 2

Climate change and response of marine ecosystem in the Arctic – Franz Mueter and Ken Drinkwater

Saitoh:

So there will be some time before the beginning of the stakeholder's meeting, other questions will be entertained. I would like to invite Dr. Franz Mueter. Next speaker is made by Dr. Franz Mueter and Dr. Ken Drinkwater and it will be given by Dr. Mueter.

Mueter:

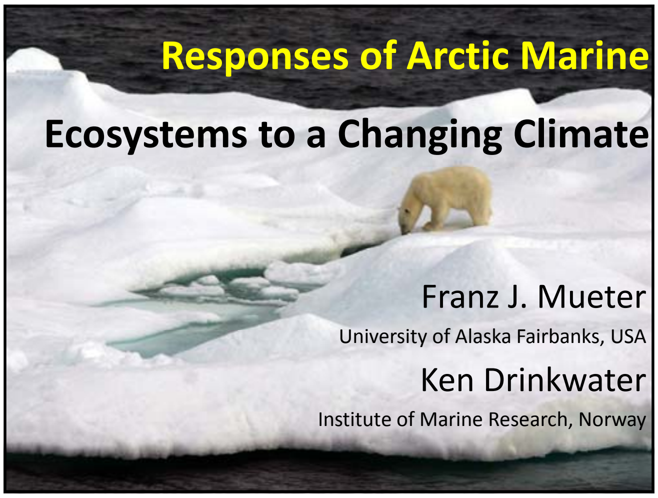
Good morning. So I will switch to English now. Thank you for participating in this meeting because we are actually very interested in your feedback on some of these observations that we, as scientists, have made. I will follow up on Dr. Kikuchi's talk by looking at the effects on biological communities and some of the ideas here will be very familiar and his presentation was a great introduction to this talk. This is a polar view of the Arctic Region and we are right here on the edge of the map. I will focus mostly on the Pacific Arctic Region, but show some examples also from the Barents Sea.

This is a map of the fishing effort in different large marine ecosystems in terms of vessel days with the darker colors showing more effort. And the Arctic, north of about the 10-degree isotherm actually accounts for about 10% of the global catch, which is about equally divided between the Barents Sea, Norwegian Sea, Greenland, Iceland Region and the Eastern Bering Sea.

The largest fisheries, as you know from this map, are located along these inflow shelves here on both sides of the Arctic as the nutrient-rich waters from the more Sub-Arctic areas flow into the Arctic in those regions. In the Pacific Arctic, the large commercial fisheries are almost all confined to this area in the Southeast Bering Sea with no or very little commercial fishing north of that.

So, I will look at some of the commercial fisheries in that region, the Southeast Bering Sea, first. These are some of the commercial groundfish species in the Pacific Arctic, the three largest fisheries on groundfish are walleye pollock, Pacific cod and yellowfin sole. And, together, they account for much of the catch from that region. By far the largest fishery is for walleye pollock, followed by, as I mentioned, Pacific cod and yellowfin sole.

The fisheries – this is the total catch for the Eastern Bering Sea, and that's a large part of the total landings in Alaska, which ranges from about 2.2 to 2.8 million tons. In the Bering Sea and Aleutian Islands together we also have a total limit on how much can be removed from the area, as an ecosystem-based precautionary measure, and the catches have generally been well below that, averaging about 1.5 million tons. There are also large crab fisheries, including these three species that undergo large cycles in abundance over time and, most recently, the catches have been around 60,000 to 80,000 tons total. There are also some pelagic fisheries, particularly for salmon. The area includes the world's largest sockeye salmon fishery. There is a fishery for Pacific herring, but, otherwise there is a ban on the fishing of forage fish species in the area – other



Responses of Arctic Marine Ecosystems to a Changing Climate

Franz J. Mueter
University of Alaska Fairbanks, USA
Ken Drinkwater
Institute of Marine Research, Norway

Arctic Region

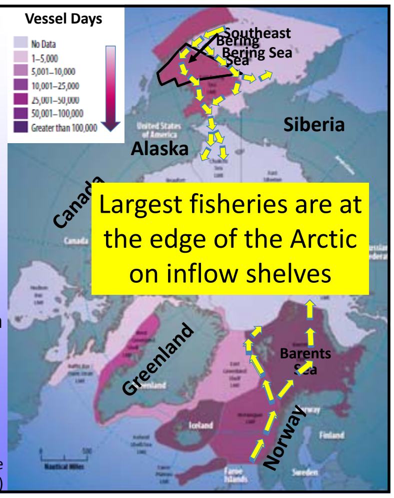
- Focus on **Pacific Arctic Region**
- Some examples from Atlantic Arctic (Barents Sea)

Arctic Fisheries

Fishing vessel days by region

- Arctic fisheries harvest ~ 10% of global catch
- About 1/3 each in:
  - Barents / Norwegian Sea
  - Iceland / Greenland
  - Bering Sea

Source: Arctic Marine Shipping Assessment (AMSA)



COMMERCIAL FISHERIES IN THE SOUTHEAST BERING SEA

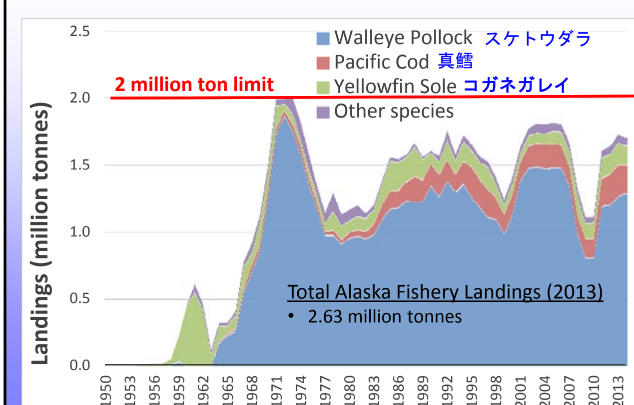
Commercial Groundfish Species Pacific Arctic

スケトウダラ
Walleye Pollock
Gadus chalcogrammus

真鱈
Pacific Cod
Gadus macrocephalus

コガネガレイ
Yellowfin Sole
Limanda aspera

Groundfish Landings: 1954-2014



forage fish species including krill, osmeridae, sand lance, and lanternfishes. Again, that's a precautionary measure to make sure that there is enough prey for other species available.

Some of the fisheries and the products that are produced are listed here. The major fisheries are conducted using either pelagic trawls (primarily for pollock), bottom trawls, longlines, pot gear, gillnets and purse seines, which are used for herring only in that region.

The products typically include roe, fillets and surimi. And all of these major species here are really part of the global market for whitefish, salmon and crab, so the fishery does not take place in isolation. I'm going to switch now to talk about the role of sea ice in this ecosystem which is, of course, as you saw from Dr. Kikuchi's talk, a major driver of variability in the production, distribution and abundance of plankton and also fish.

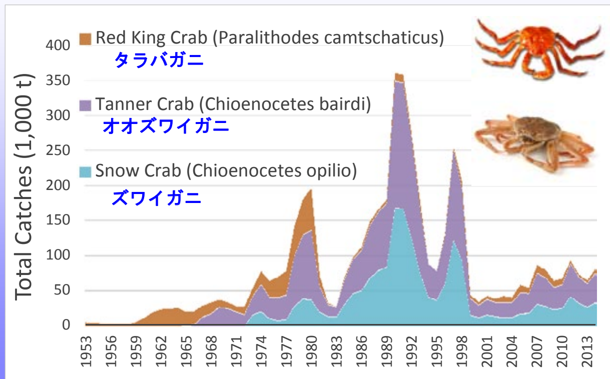
The pattern of variability in ice conditions changes quite dramatically from the high Arctic to the Sub-Arctic. And the variability in the Sub-Arctic and the Bering Sea is also largely decoupled from what happens in the high Arctic. For this presentation here, I consider three regions that can be characterized by their patterns of variability: First, the Southeast Bering Sea where those large fisheries are located. In this area, ice cover is extremely variable from year to year with no ice in some years and complete ice cover in other years, so it has very large inter-annual variability. And the expectation is that we will continue to see large variability but probably more periods with ice-free winters. Then, second, I will talk about the Northern Bering Sea and Chukchi Sea, a region of extreme seasonal variability with near 100% ice coverage in winter and no ice at all in summer, but there will always be ice in the winter and no ice in the summer. And that region is undergoing large changes in phenology, in the timing of ice melt and ice advance. Then, finally, I will talk a little bit about the Arctic Basin that, for now, still has variable amounts of the older multi-year ice as Dr. Kikuchi showed as well. But it is expected to be completely ice free in the summer within a few decades.

So, I will start with the Southeast Bering Sea where we see extreme interannual variability. This illustrates the variability for one warm year on the left and a cold year on the right. This image, on the right, shows the ice cover just a few weeks ago. So, there's a large difference in the southern extent of the ice between years, which can be over 600 kilometers in some cases. That's a very large area that, in some years, has ice cover and in other years does not.

As Dr. Kikuchi also illustrated, ice formation in that area leads to complete cooling of the entire water column as the water mixes under the ice. That leads to cold water on the bottom that remains on the shelf throughout the following summer and is referred to as the cold pool. So, I will talk a little bit about the variability in ice conditions and how that affects fish through variability in the cold pool. This shows the difference in the extent of the cold pool that results from ice cover in winter between a cold year and a warm year. The cold pool here is in the dark blue colors. And the cold pool in this cold year on the right tends to displace a lot of the fish species to the outer edge of the shelf because they cannot tolerate the very cold water in the center. In the warm year, on the other end, these fish can spread out to the north into the now warmer regions.

We have seen evidence for a general northward shift in distribution across many species in that

Crab fisheries

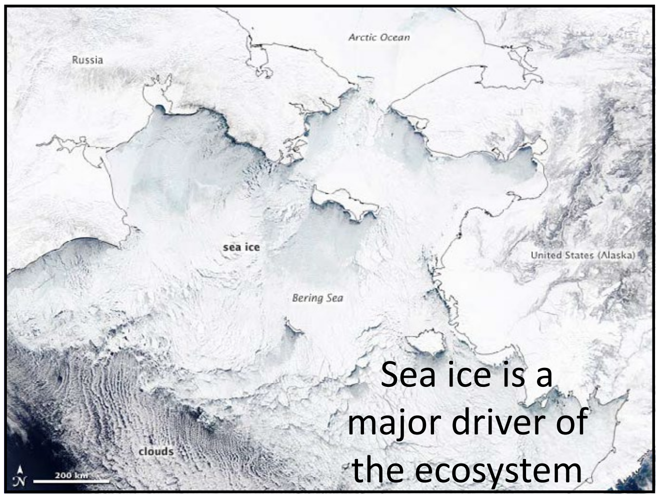


Pelagic fisheries

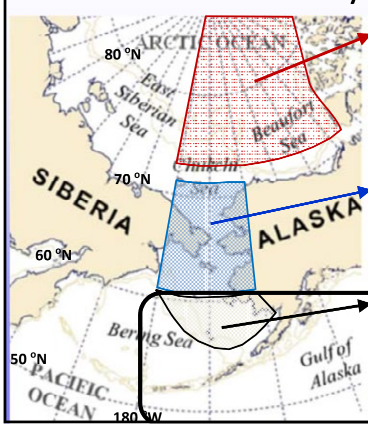
- Salmon:  紅鮭
  - World's largest sockeye salmon (*Oncorhynchus nerka*) fishery (30-60 million fish)
- Pacific herring (*Clupea pallasi*) ニシン  
- Directed fishing for other forage species is banned
  - Euphausiacea (krill)
  - Osmeridae (smelt-like fish)
  - Ammodytidae (sand lance)
  - Myctophidae (lanternfishes)
  - Others...

Fisheries, products & market forces

- Major fisheries conducted using pelagic trawls (pollock), bottom trawls (flatfish, cod), longlines (cod, halibut, sablefish), pots (cod, sablefish), gillnets (salmon) and purse seines (herring).
- Products include roe, fillets and surimi
- All of the major species are part of the global market for whitefish, salmon and crab



Patterns of variability in ice conditions



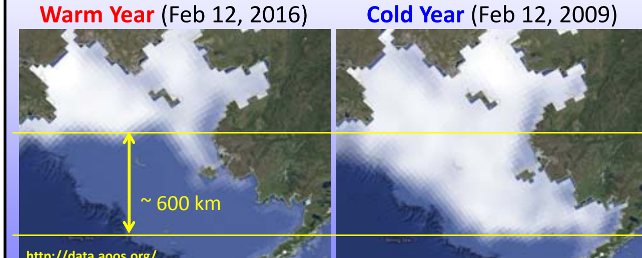
Declining (multi-year) ice
- Interannual variability in minimum ice extent
- Changing phenology (earlier melt, later freeze-up)

Extreme seasonal variability
- Near 100% cover in winter
- No ice in summer
- Changing phenology

Extreme interannual variability
- No ice in summer
- Winter ice cover extremely variable (0% - near 100%)

Interannual variability in Bering Sea ice cover

Warm Year (Feb 12, 2016) **Cold Year** (Feb 12, 2009)



- Ice formation leads to cooling of entire water column under the ice
- Variable 'Cold Pool' remains on shelf through following summer

region. This shows examples of a number of those shifts and you' ll note that the shift is highly variable between different species. Some actually go south, but most tend to go north. This is over a period of warming of about 25 years.

In recent years, we' ve actually had a number of cold years and the fish have shifted south again. One more thing I wanted to mention here, the average shift over that 25-year period was about 30 kilometers to the north. So that raised the question, of course, will these fishes continue to shift northward as the climate warms? This is a transect of temperatures from the south along the middle shelf to the north. And these temperatures in purple and blue are colder temperatures with the coldest temperatures in black and the surface layer warmer waters in yellow.

So, we actually now believe that at least the groundfish species will not spread much further north because they are essentially blocked by this wall of very cold water that remains on portions of the shelf in the summer, and will always re-form in the winter. However, in the surface water, a lot of the juvenile fishes that reside in these surface waters or pelagic adult fishes can move far to the north to undergo feeding migrations. But, again, because the water turns over every winter and mixes completely and gets cold when the ice forms, they have to leave the area before winter.

I will show a few examples also from the Barents Sea, which is much more Sub-Arctic. The influence on ice cover here comes mostly from strong advective currents that enter the Barents Sea from the south. And so, there' s large variability in the ice conditions that' s related to the inflow of this relatively warm water into the Barents Sea from the south. And when the advection is stronger and/or the temperature of the inflowing water is higher, the ice cover will be reduced. There has been a long-term decrease in the Barents Sea ice cover over the period of record with much lower ice extent in recent years. That, of course, impacts fish.

This contrasts a cold year - on the left - with a warm year on the right and shows the distribution of capelin, an important forage species in that region that also supports a fishery. And you can see that, in the cold year, the distribution was much further to the south. In the warm year, these fish extend much further to the north during the summer or during the summer feeding period. Similarly, Atlantic cod, which like to feed on capelin and plankton, and other fish in that region were distributed much further to the north in this warm year on the right in 2013. Like other species, these cod undergo long-distance feeding migrations in the summer into these regions and will go further north if there are favorable feeding conditions when prey are abundant. So, the recent warm years have led to fairly favorable conditions. There are high abundances of suitable prey and, as a result, the Atlantic cod have been observed further north and also have increased in abundance, along with a few other species in that area that have also increased in recent years through a combination of favorable feeding conditions and, for Atlantic cod, a more precautionary management approach.

One of these species, the beaked redfish has become a well-known example of a species that' s likely to expand into new areas of the Barents Sea and along the slope of the Arctic Basin as the climate warms and may, indeed, establish new spawning populations along the shelf edge here or the shelf break and slope.

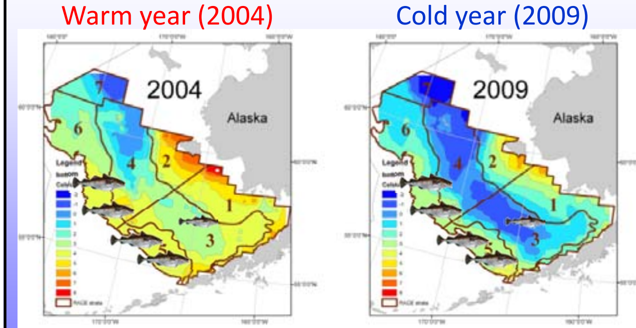
So, now, I will talk a little bit about how warming affects the productivity and abundance of fishes;

VARIABILITY IN ICE CONDITIONS AND CHANGES IN FISH DISTRIBUTION

Ice extent and the 'cold pool'

Bottom temperatures on the shelf during summer

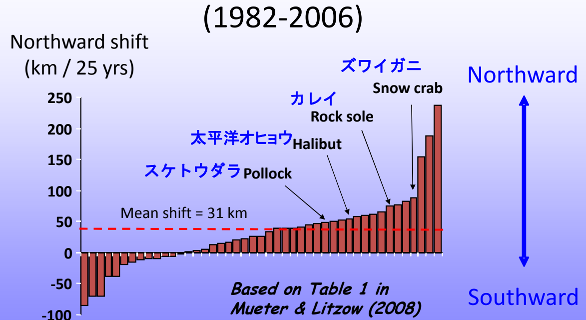
Warm year (2004) Cold year (2009)



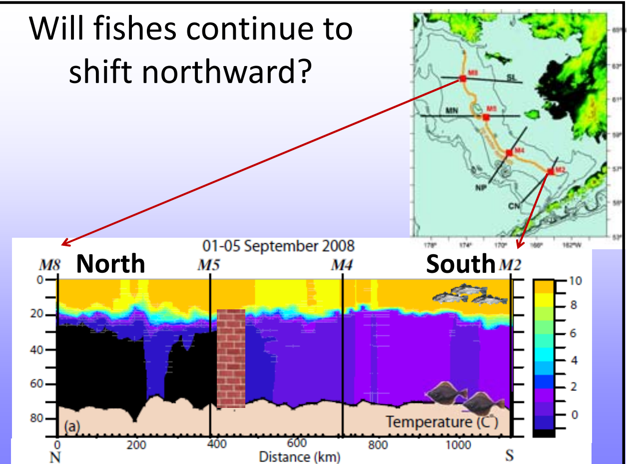
- Cold bottom water displaces many fish to outer shelf
- Fish expand to North following low ice years with small cold pool

Maps from Bob Lauth

North-South shifts in distribution of 45 species during period of warming (1982-2006)



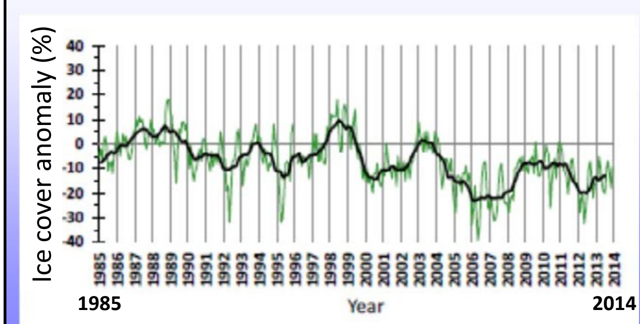
Will fishes continue to shift northward?



Modified from Stabeno et al. (2012)

Expansion of fish into warmer, ice-free waters in the Atlantic Arctic Region

Barents Sea Ice extent anomaly



IMR/PINRO

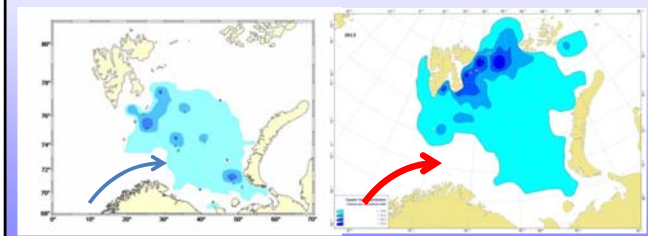
カラフトシシャモ

Barents Sea

Capelin (*Mallotus villosus*) distribution

Cold Year: 2003
(less advection, more ice)

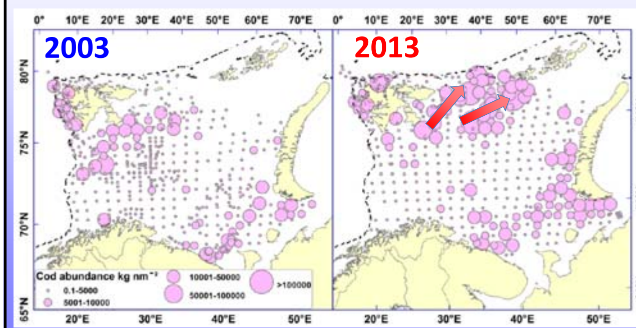
Warm Year: 2013
(more advection, less ice)



Institute of Marine Research 2014

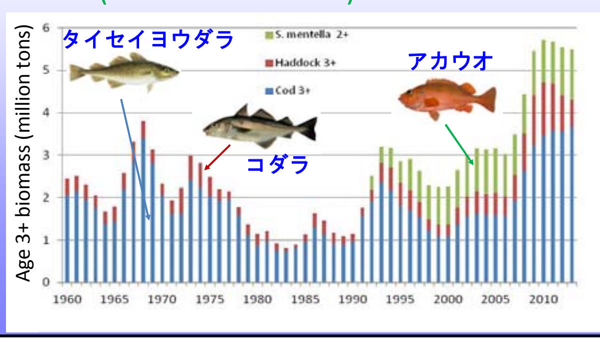
タイセイヨウダラ

Atlantic Cod (*Gadus morhua*) summer feeding distribution

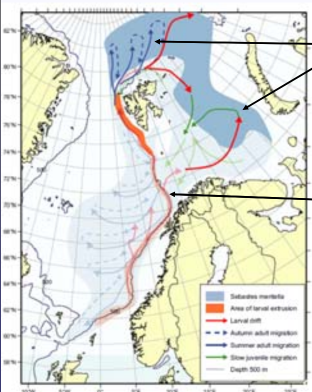


Kjesbu et al 2014

Biomass of Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and redfisch (*Sebastes mentella*) in the Barents Sea



Hypothesized expansion of beaked redfish (*Sebastes mentella*) アカウオ



Potential expansion and migration routes (solid)

Current distribution and migration routes (shaded)

Nedreaas et al. (2011)

EFFECTS OF WARMING ON THE PRODUCTIVITY AND ABUNDANCE OF FISHES: "WINNERS" AND "LOSERS"

"Winners" and "Losers" in the Bering Sea

- Some evidence from field measurements and satellite observations that primary production in the Bering Sea is higher in warm years
- However, associated changes in the food web in warm years may be bad for walleye pollock:

  Earlier ice melt / warm summer:
  - → fewer large, lipid-rich zooplankton prey
    - → lower energy reserves of young pollock and increased predation
      - → reduced overwinter survival
        - → lower abundance of pollock following a period of warm years

スケトウダラ

that is, who may be more likely to win in the competition for resources and who is more likely to lose and to maybe decrease in abundance. So we have some evidence from both field measurements and satellite observations that primary production at the base of the food chain is higher in warm years. We originally thought the higher productivity would enhance the survival and abundance of some of the pelagic species. However, the associated changes in the food web that we have observed through fairly intense field programs and modeling work in recent years may be bad for pelagic species like walleye pollock. Here I am briefly summarizing the evidence for that, or the chain of events that lead to that conclusion.

During periods where we have an earlier ice melt and a warm summer, there tend to be fewer large, lipid-rich zooplankton prey that form the main prey for walleye pollock and this leads to lower energy reserves for young pollock in the fall. They have less fat, which they store for the winter, to make it through the following winter when there's very little food. That has led to reduced over-winter survival, poor overall survival and, ultimately, low abundances of pollock following a period of warm years. This is one story that we think we understand fairly well. We have also done projections into the future based on climate models that tell us possible future temperatures over the next 30 to 40 years. And the indications are that walleye pollock may decrease by as much as 20 to 30% over that time period, but there is a lot of uncertainty in these projections.

Here are some other examples of possible winners and maybe some likely losers. Salmon and Pacific herring both tend to do better under warm conditions, when they tend to have higher growth and survival. For flatfish, the story is a little more mixed, but there are some indications that they may do better under warmer conditions in the future. The likely losers are walleye pollock, as I just mentioned, and Pacific cod, which have very similar dynamics. Some of the same observations of poor prey conditions in warm years leading to poor condition of young Pacific cod have been observed in that species.

Red king crab are influenced by temperature and don't necessarily thrive in higher temperatures, but are also negatively impacted by ocean acidification. There have been both lab studies showing the impact of ocean acidification on the growth and survival of young red king crab, and modeling studies to show that, if ocean acidification continues as anticipated, red king crab may also decline in the future. Snow crab are a very Arctic species, so the area in the southeast Bering Sea is the southern extent of their distribution where the fishery takes place. And, in warm years, they are almost certain to decline, which we have seen repeatedly. This is in part because the young crab larvae like colder temperatures and need colder temperatures to grow.

So, I will next move to the area just to the north, towards the southern region of the Arctic. And this is the area where we see extreme seasonal variability, again, from near complete ice cover every winter to no ice at all in the summer. And, in this region, the phenology of the ice melt and freeze-up have been changing, which has consequences for the timing, and some of the characteristics, of the phytoplankton bloom and some of that repeats what Dr. Kikuchi talked about.

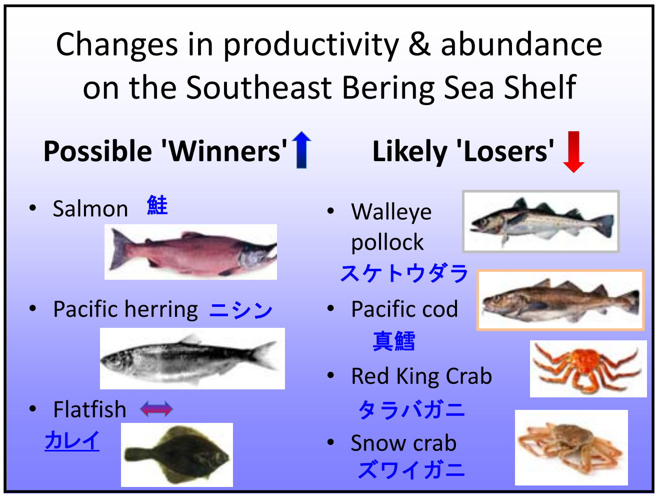
So, this illustrates the extreme seasonal variability in one seasonal cycle. We see in the wintertime almost complete ice coverage over the region and then a relatively rapid melt season. There is no ice in the summer and then ice freezing again in the fall. What has happened in the most recent year is that the ice has maybe started melting a little earlier, but, most importantly, melts a lot faster – that is it decreases a lot faster from full coverage to no-or-little coverage.

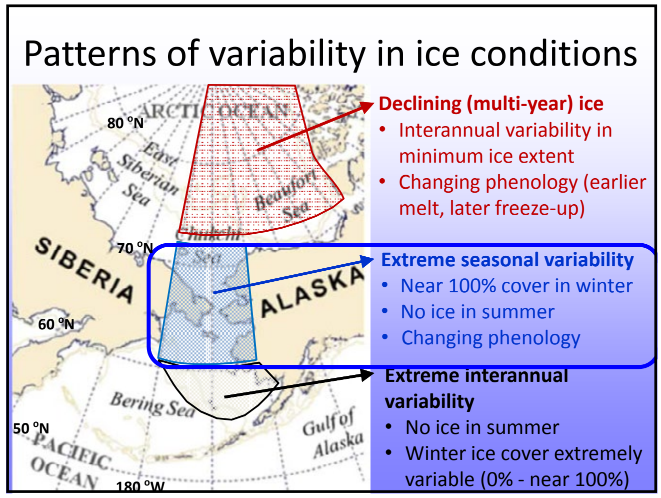
Similarly, in the fall, the onset of freeze-up has been delayed substantially and then the ice freezes very rapidly. And this is illustrated here in the transition periods from over 80% ice cover to less than 20% ice cover in the spring and that period has declined by about a month over this timeframe. And, similarly, the fall freezing period tends to be shorter overall, but also has declined over time by about the same amount. So that has implication for the bloom dynamics in that region and for the ecosystem as a whole, and the upper trophic levels. This is kind of a simplified schematic of the blooms in either warm or cold water and I will start with the colder water. This illustrates the spring bloom that may either be associated with ice or come later when the water column stratifies thermally. If the bloom occurs in cold water, much of that production tends to sink down to the bottom and we see that in the Northern Bering Sea and the Chukchi Sea. It fuels a very rich benthic food web and feeds larger, epibenthic organisms and also diving birds and mammals like walrus that dive in these areas and feed on the bottom.

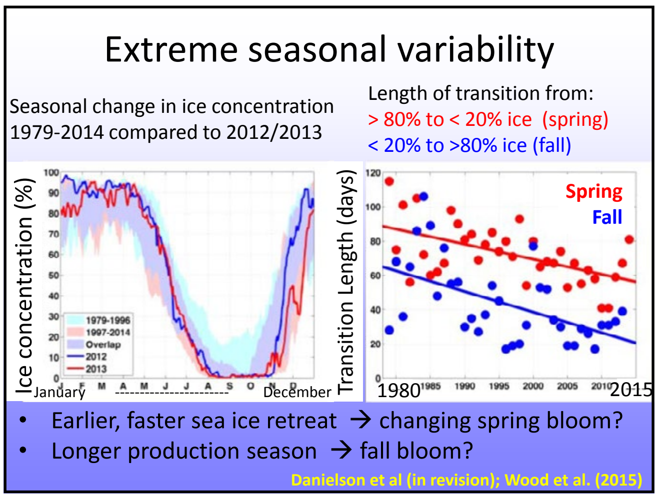
On the other hand, in warm years, when the bloom occurs in warm water, more of the production can be grazed upon by zooplankton. When it is too cold, these can't grow fast enough to take advantage of the bloom, which is why it sinks down. In warm years, the zooplankton can graze the phytoplankton and, in turn, feed pelagic animals like juvenile walleye pollock potentially, but also seabirds and marine mammals like bowhead whales. And we do have some evidence in the Northern Bering Sea and, particularly, the Chukchi Sea Region for increased pelagic productivity. There has been an increase in zooplankton abundances over time that then feed plankton feeding seabirds, which also have increased in that region. And the condition of bowhead whales has improved over time as is shown here. This is a body condition index that, over the last 20 years has increased in bowhead whales, potentially reflecting better feeding conditions.

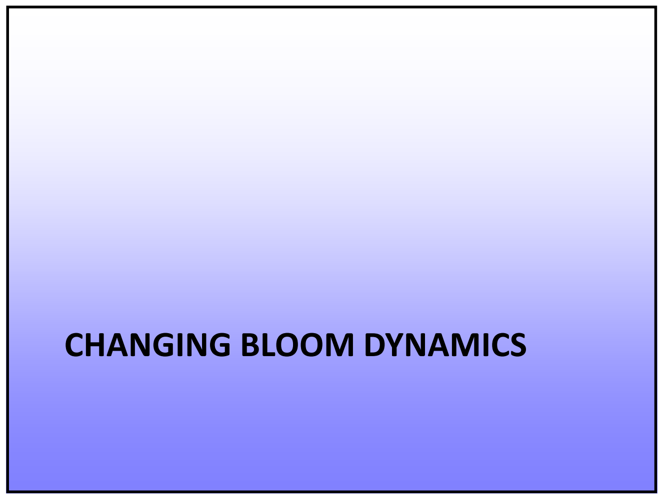
So, there have not only been changes in the timing and the temperature of the spring bloom, but there is also evidence that the frequency of fall blooms has increased. We generally have a gradient from the north to the south or south to the north – I will start in the south, where, in temperate or boreal regions, we typically observe a spring phytoplankton bloom when the water warms up and the light conditions are favorable. The bloom gets grazed down in the summer and we typically see a late fall bloom when the water is mixed by fall storms, bringing additional nutrients into the surface layer. And this schematic is based on data that, for example, for the Southeast Bering Sea show this type of bloom, with a spring bloom and a late fall bloom. Where we have sea ice, we typically get an under-ice bloom that can start well before the ice melts. Then, when the ice melts, we get a single, peaked, ice-associated bloom and that's typical, for example, for the Barents Sea where we see a single peak.

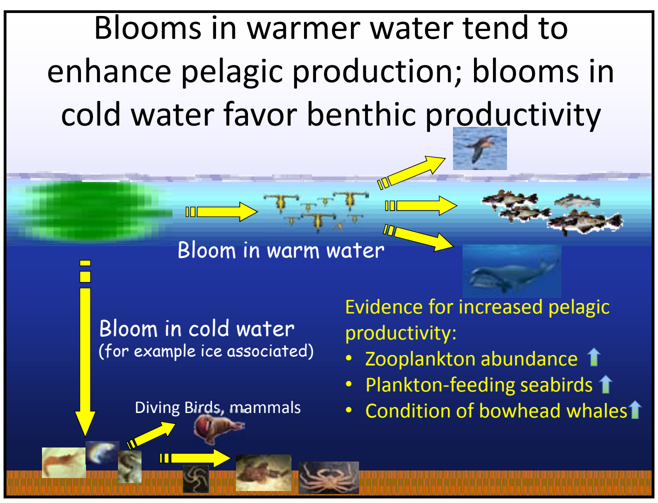
And then there are other regions in some parts of the high Arctic where the ice retreats very late and nutrient levels may be relatively low, and where we get a flat bloom throughout the season as observed in parts of the Arctic Basin. So we can think of the spatial gradient from the north to the south also as a gradient over time. If we take a northern location in the present day, this may serve as a guide to what that location may look like in the future under warming. And that is, indeed, what has been observed. There is a higher frequency now of fall blooms occurring throughout the Arctic, which has been documented in many parts of

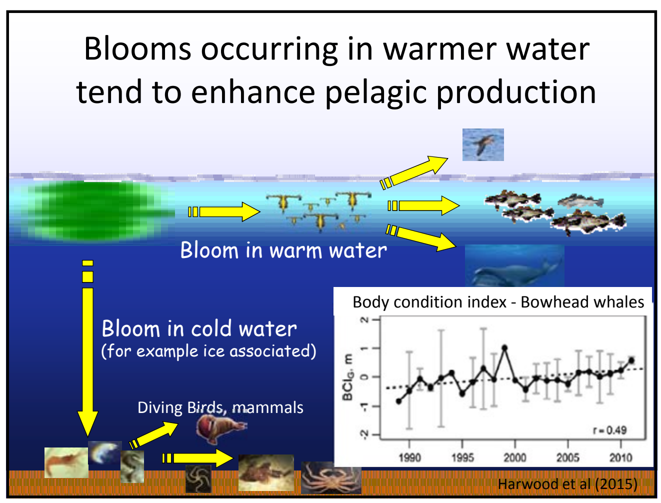

Changes in productivity & abundance on the Southeast Bering Sea Shelf
Possible 'Winners'
Likely 'Losers'
Salmon 鮭
Pacific herring ニシン
Flatfish
カレイ
Walleye pollock
スケトウダラ
Pacific cod
真鱈
Red King Crab
タラバガニ
Snow crab
ズワイガニ


Patterns of variability in ice conditions
Declining (multi-year) ice
Interannual variability in minimum ice extent
Changing phenology (earlier melt, later freeze-up)
Extreme seasonal variability
Near 100% cover in winter
No ice in summer
Changing phenology
Extreme interannual variability
No ice in summer
Winter ice cover extremely variable (0% - near 100%)
ARCTIC OCEAN
East Siberian Sea
Beaufort Sea
SIBERIA
ALASKA
Bering Sea
Gulf of Alaska
PACIFIC OCEAN
80 °N
70 °N
60 °N
50 °N
180 °W


Extreme seasonal variability
Seasonal change in ice concentration 1979-2014 compared to 2012/2013
Length of transition from:
> 80% to < 20% ice (spring)
< 20% to >80% ice (fall)
Ice concentration (%)
Transition Length (days)
1979-1996
1997-2014
Overlap
2012
2013
January
December
Spring
Fall
1980
2015
Earlier, faster sea ice retreat → changing spring bloom?
Longer production season → fall bloom?
Danielson et al (in revision); Wood et al. (2015)


CHANGING BLOOM DYNAMICS


Blooms in warmer water tend to enhance pelagic production; blooms in cold water favor benthic productivity
Bloom in warm water
Bloom in cold water
(for example ice associated)
Diving Birds, mammals
Evidence for increased pelagic productivity:
Zooplankton abundance
Plankton-feeding seabirds
Condition of bowhead whales


Blooms occurring in warmer water tend to enhance pelagic production
Bloom in warm water
Bloom in cold water
(for example ice associated)
Diving Birds, mammals
Body condition index - Bowhead whales
1990
1995
2000
2005
2010
r = 0.49
Harwood et al (2015)

the Arctic, but it does, of course, require input of new nutrients into the surface layer. There are a number of mechanisms that can lead to that; for example, increased storm activity over now ice-free waters that were formerly ice covered and where storms can mix nutrients into the surface layer; upwelling, like Dr. Kikuchi showed, along the shelf edge or along the ice; eddies along the shelf break and in the basin; and recycling of nutrients on the shelf itself.

So, there are various mechanisms that can explain the increased frequency of fall blooms that has been documented. However, there are very large uncertainties with respect to the under-ice bloom. Many of the trends that have been observed are based on satellite data, but the satellite cannot see under the ice and there has been some recent work that suggests that about 80% of the production in the Northern Chukchi Sea, for example, may occur under the ice before the ice disappears.

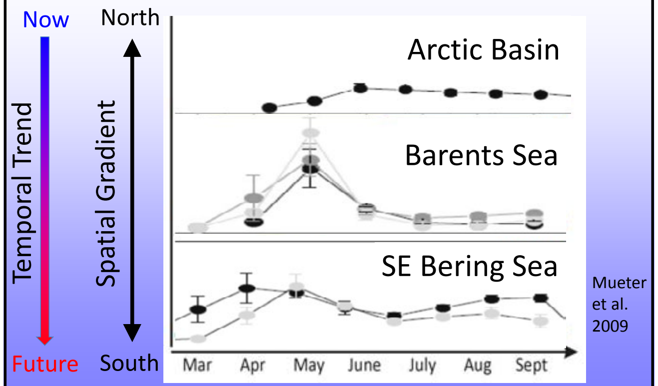
Moreover, even if production does increase, the smaller phytoplankton and zooplankton that we typically see in warmer conditions may result in a less-efficient transfer of energy to fish, birds and marine mammals because more energy gets lost as heat along the way. Similar to what we have seen in the Southeast Bering Sea, this mechanism could be operating in this area as well.

So, finally, let me take a quick look at the Arctic basin, where some of these same dynamics in terms of earlier melt and a later freeze-up tend to play out, but where we have the additional challenge of a rapidly disappearing habitat associated with multi-year ice. You already saw this figure that shows the decreasing ice cover that has been observed in the winter, for example in March, which is typically the month where the ice extent is largest. And there has been a substantial decrease in ice extent in March, but, more substantially, in the summertime in September, when the ice is at its minimum. Sea ice is an important habitat and there are ice communities that evolve along as the ice growth and that's illustrated at the top here. Initially, the communities are relatively simple and, as the ice ages, it becomes a more complex community with larger predators and a higher diversity of species in these brine channels in the ice. Over several years, once we start getting multi-year ice, the ice provides a much more complex habitat and that really is a very unique habitat and also a rapidly-disappearing habitat that we don't really know very much about, and may not learn much about if it indeed disappears in a couple of decades.

Larger animals like the walrus and also polar bears, of course, also depend on ice as a platform for feeding or hunting. And the loss of their usual habitat could potentially be catastrophic for those animals. That's just an image of the under-ice community. Primary production in the high Arctic, as Dr. Kikuchi alluded to, and changes in primary production in that region are very uncertain. While we expect a longer ice-free season, we do need a mechanism to get additional nutrients into the surface layer for enhanced production. And the models that we have now to examine productivity in the high Arctic, while also very uncertain, do suggest little, if any, evidence that the nutrient availability will increase over much of the Arctic Basin, particularly in the Canadian basin and the Western Pacific Arctic Region, with the exception that along the Continental slope there are various mechanisms that can mix nutrients into the surface layer.

So, the question for us has also been, of course, is there a potential for commercial fisheries to develop in the Arctic Basin? And I will primarily talk about the Pacific side for now. While there isn't a complete consensus,

Changing fall bloom dynamics



Modified from Leu *et al.* (2011)

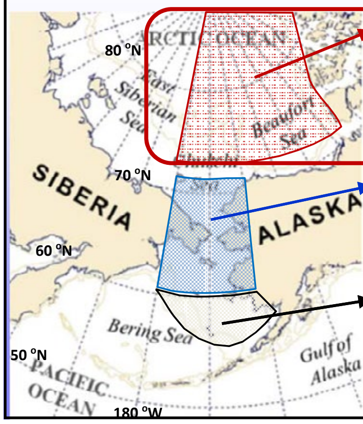
Changes in bloom dynamics

- **Increased frequency of fall blooms** has been documented in many parts of the Arctic, which requires **input of new nutrients**
- Possible mechanisms:
  - ➢ Increased storm activity over open water can mix new nutrients into surface waters
  - ➢ Upwelling of nutrient-rich waters along shelf break
  - ➢ Eddies along shelf break and in basin
  - ➢ Recycling of nutrients on shelf

Changes in annual net primary production

- Large uncertainties with respect to under-ice production and subsurface production
  - For example, over 80% of production in the northern Chukchi Sea may occur under the ice and is not "seen" by satellites
- Even if production increases, smaller phytoplankton and zooplankton may result in less efficient transfer of energy to fish, birds and mammals

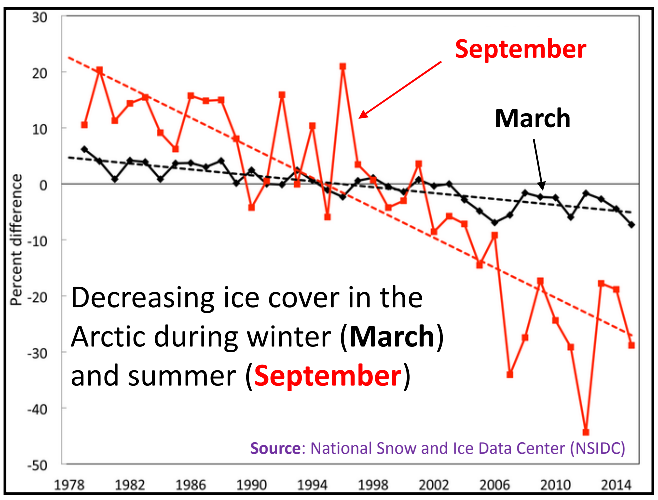
Patterns of variability in ice conditions



Declining (multi-year) ice
- Interannual variability in minimum ice extent
- Changing phenology (earlier melt, later freeze-up)

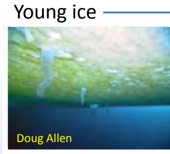
Extreme seasonal variability
- No ice in summer
- Near 100% in winter
- Changing phenology

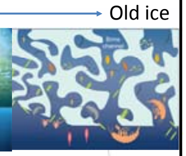
Extreme interannual variability
- No ice in summer
- Winter ice cover extremely variable (0% - near 100%)



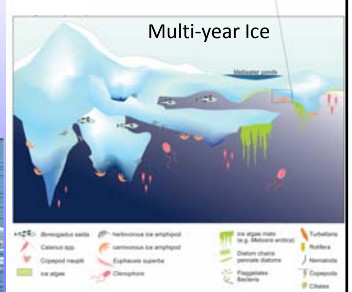
Sea Ice as Habitat

Young ice → Old ice





- Ice communities evolve with the age of the ice
- Multi-year ice provides more complex habitat
- Unique and rapidly disappearing habitat



Hunt et al. (In Revision)

I think it is fair to say that most experts now believe that a commercial fishery, at least in the Western Arctic Basin and on the Pacific side is very unlikely to develop in the foreseeable future. And that's in part because of this shallow shelf region in the Northern Bering Sea and Chukchi Sea that freezes over every year – every winter – and resets the entire water column to very cold conditions and keeps out the southern, more boreal species.

So, to summarize, the commercial fisheries in at least Alaska's Arctic and Sub-Arctic will likely remain limited to the Southeast Bering Sea Region with possibly some northward expansion into the Northern Bering Sea, but that can't go very far north because of the continued cold conditions in the winter. Primary production may increase on the Bering Sea shelf, although that's very uncertain too because of the unknown importance of the under-ice bloom. But fishery yields are likely to decrease due to a less efficient transfer of energy to fish as we saw in walleye pollock. Summer phytoplankton production on the Northern Bering Sea and in the Chukchi Sea on the shelf and along the slope is likely to increase, due to a longer ice-free season, as long as there are mechanisms for nutrient enrichment to get nutrients into the surface layer.

On the shelf in that region, the water column production is likely to increase whereas benthic production is likely to decrease. So that would benefit plankton feeders like planktivorous birds and bowhead whales, among others, but would potentially harm demersal feeders like walrus, diving birds and also grey whales who feed on the bottom in the Northern Bering Sea and in the Southern Chukchi Sea, because of potentially reduced prey on the bottom. And that, of course, potentially impacts subsistence harvest of those mammals in those regions and the communities in those regions.

And then, finally, we believe that development of any – at least a large commercial fishery - north of Bering Strait in the Pacific Arctic is highly unlikely. There is maybe more potential for that on the Atlantic side and I believe we will be discussing that over the next few days maybe. And that is all I have, so thank you for your attention.

Saitoh:

Thank you very much for your presentation in the climate change. There's winners and losers and that was very interesting. Let's take questions from the floor if we have questions. Please? George?

Hunt:

Thank you for a very nice talk. One thing you didn't mention is the possibility of changes in the flow through Bering Strait. And, since that is a major source of both nutrients and zooplankton, do you think that could have an important impact on the possibility of production in at least the Southern Chukchi Sea?

Mueter:

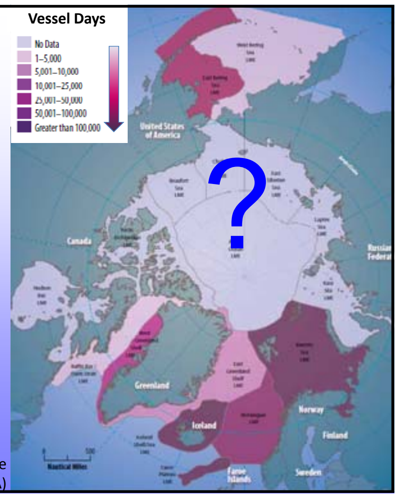
Yes. Thank you for the question. And that is actually something that I have thought about a bit and had originally intended to include in here. There has been – over the short term, over the last decade roughly - an increase in flow through Bering Strait. That is, of course, a very short time period and we don't really know what might happen over the long term although I think Seth Danielson will talk about that a little bit

Primary Production in the High Arctic

- Large uncertainties in the Arctic Basin
  - ➢ Longer ice-free season, but additional nutrients are required for enhanced production
  - ➢ Models suggest little if any increase in nutrient availability, except along the continental slope

Commercial fisheries in the Arctic Basin?

- Most experts believe that a commercial fishery in the Western Arctic Basin is unlikely in the foreseeable future



Source: Arctic Marine Shipping Assessment (AMSA)

Summary (1)

- Commercial fisheries in Alaska's Arctic/Subarctic will likely remain limited to the Southeast Bering Sea (with some northward expansion)
- Primary production may increase on the Bering Sea shelf, but fishery yields are likely to decrease due to a less efficient transfer of energy to fish
- Summer phytoplankton production on the Northern Bering Sea / Chukchi Sea shelf and along the slope is likely to increase due to a longer ice-free season, but requires mechanisms for nutrient enrichment

Summary (2)

- On the shelf, water-column production likely to increase; benthic production likely to decrease
  - Plankton feeders (e.g. planktivorous birds, bowhead whales) would benefit
  - Demersal feeders (walrus, diving birds, grey whales) would have reduced feeding opportunities
  - Potential impacts on subsistence harvests of mammals
- Development of any large commercial fishery north of Bering Strait highly unlikely

tomorrow. And, if I can, without stealing Seth's thunder, some of the models seem to suggest that the sea level in the Arctic will rise, which would reduce the sea-level difference between the Bering Sea, the Pacific and the Arctic and potentially reduce flow through Bering Strait.

So, there's a lot of uncertainty that has a large impact on what happens in the Chukchi Sea because much of what fuels the food web there in terms of nutrients and also the inflow of phytoplankton and zooplankton into that region comes from the Bering Sea, so there is a substantial portion of the productivity in the Chukchi Sea that is of advective origin. Advection there is not quite as important as on the Atlantic side, but maybe that's debatable. But the Barents Sea ecosystem also depends to a large extent on advection.

Saitoh:

Yes?

Planque:

Benjamin Planque from the Institute of Marine Research in Norway. I heard you mentioned a ban on forage fish and invertebrate species fishing in the Southeast Bering Sea. I wonder how that fits with the current discussion on balanced harvesting, that is fishing different levels in the food web, if there's been discussions on this aspect and if there are views on the future of fishing in the Southeast Bering Sea in that respect.

Mueter:

Yes. Again, thank you for that question. What Benjamin is alluding to is that there have been a number of studies recently that have suggested that if you spread your catches throughout the food web, so you'd catch some of the lower tropic level species and the middle trophic level species and upper trophic levels in proportion to their biomass that that might potentially give you a more resilient system and also potentially lead to higher catches.

We have not had those discussions in the Eastern Bering Sea really. I suspect that we probably will at some point. This forage fish ban has been in place for quite a while. Historically there were no fisheries for other forage species besides herring, and one could argue that juvenile pollock also are an important forage species in that region. But since there were no other fisheries, the ban was put in as a precautionary measure to close the area to all fishing for forage species. I don't know the full history of that measure, but it's been in place for some time and unlikely to be changed anytime soon.

Saitoh:

Thank you very much.

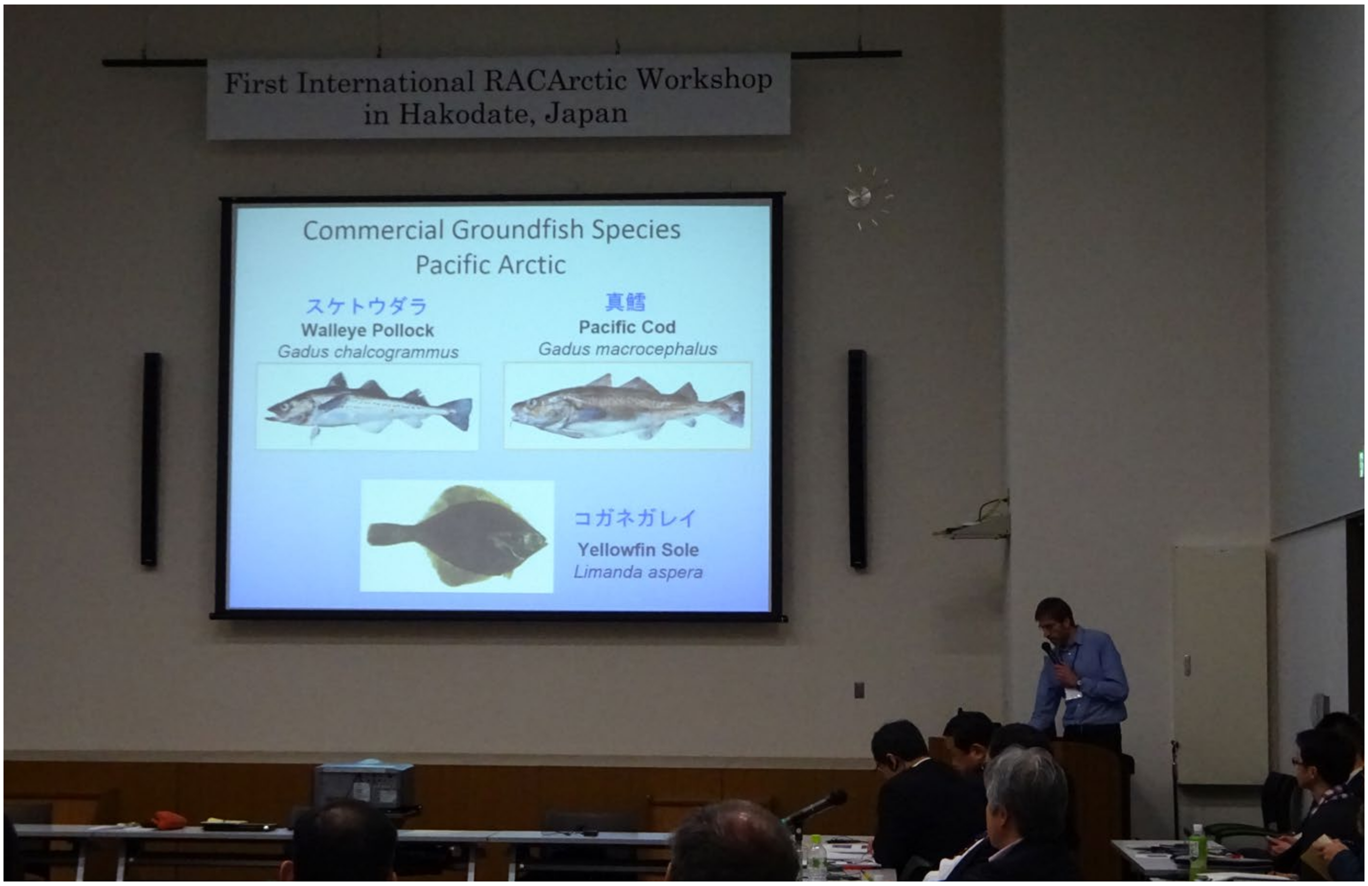
Harada:

I can understand why the winners and losers could exist. My question is on the food of salmon which is pteropods and is considered as one of the winners in your presentation. Pteropods, on the other hand, are affected by ocean acidification. Could this species still be considered a winner under ocean acidification?

Mueter:

Yes, thank you for that question. Pink salmon in that area have a high proportion of pteropods in their diet. Sockeye salmon, I don't know the diet composition, but I believe they have a more varied diet. In general, pink and sockeye salmon have a relatively varied diet in most regions. You make a very important point in that prey can be affected by ocean acidification and that can certainly have an effect on the predators, including many of these commercial species, and we simply don't know at this point how that might play out. I only mentioned red king crab because we have both the laboratory studies and evidence from modeling that acidification will have a negative impact on their populations.

For salmon, I can't say for sure, but my feeling is that the temperature effect on increased growth and survival, which really has to do with better growth and survival of the juveniles as they enter the ocean – when they first enter the ocean – is probably more important than ocean acidification at this point. But once we pass some other thresholds in terms of ocean acidification, who knows?



2-4. Stakeholders Workshop

(1) – Selection of discussion points

Moderator:

We will now start the stakeholder's meeting. In the last session, Mr. Kikuchi and Mr. Mueter spoke about ecosystems in the Arctic, the issues and the factors. And it was looked at from various points of view.

We still have time for questions from this morning's talk. We would like to have some questions from stakeholders at this time. Now, I would like to ask the stakeholders to introduce themselves, giving your name and organization.

Ishikawa:

I work as an adviser of Nippon Suisan*, my name is Ishikawa. Thank you very much for the invitation to this meeting. I would like to brief you on our company and our needs and requests. I am sorry that we have a shortage of English brochures. If you need one, please take one.

* NIPPON SUISAN KAISHA, LTD. is a Japan-based company engaged in five business segments. The Marine Products segment is engaged in fishing, cultivation, processing and sale of seafood products. The Food segment manufactures and sells processed food products such as frozen food products and shelf-stable food products, among others. The Logistics segment is engaged in the refrigeration storage of marine products, as well as the transportation of frozen and chilled products. The Fine Chemical segment manufactures and sells pharmaceuticals, health food and pharmaceutical materials. The Others segment is engaged in the construction and repair of ships, as well as the marine transportation and engineering business.

Matsuo:

I am from Arcs Group, my name is Matsuo. I was on Oshoro Maru and Ushio Maru vessels for training when I was student. The Arcs Group is a super market. For 25 years, we have been buying fish. We have been to Norway and Alaska to buy fish and, since we are now looking at the overall fish production, this is a very good learning opportunity for me.

Goda:

My name is Goda. I'm from Nippon Yusen. My department is planning. Some of the research topics in our department are on the Northern Sea Route, exclusive economic zone and offshore industry. Our company's interest in the Arctic is a little different from what I heard this morning. However, marine products are generally very costly, and transportation costs are very high. It's very interesting to hear that there is great environmental variability happening in this area.

Sagawa:

My name is Sagawa from Weathernews. Our company is a private weather company. We offer navigation information including weather and sea ice conditions to vessels navigating the Northern Sea Route. I have been on vessels going through the Arctic region, and I am very interested in the present situation in the Arctic and how it will change in the future.

Kashiwagi:

My name is Kashiwagi from Mitsui O.S.K. Lines. We have been participating in Yamal project in the Arctic Sea Route. In the past few years, we have been participating in survey projects.

Otsuka:

I am from North Japan Port Consultants. My name is Otsuka. Since 1990, we have been looking at ways to utilize the Arctic Ocean and ice covered waters and also looking into the social and environmental impacts as well as other technical issues in the region. We are interested in marine resources and utilization potential in the Arctic.

Grandum:

Thank you very much. My name is Svein Grandum from the technology and higher education section at the Norwegian Embassy in Tokyo. Thank you very much for inviting me to this RACArctic meeting. From the Norwegian government side, we have a strong emphasis on the Arctic, on polar research as well as marine research. I think your Belmont Forum cooperation here is very important, of course both from a multilateral, but also from a bilateral point of view.

We will host together with our Japanese partner an Arctic Science and Innovation week this June. So for us as organizer, this is a very important event for the preparation of that meeting, also for the bilateral arena. Thank you very much.

Furukawa:

Good morning. I'm Yoko Furukawa from U.S. Office of Naval Research. This sheet of paper shows that my name is listed under Japan. If you don't mind, it's USA. The Office of Naval Research is interested in scientific research and, also in a lot of things that you've talked about this morning that are related to environmental change, the changes in ice coverage, and as well as primary production, fisheries and so on. I'm very glad to be here. Thank you.

Tsunoda:

I am Tsunoda from Sasakawa Peace Foundation. This organization was originally named the Ocean Policy Research Foundation, but last April, the name was changed. Sasakawa Peace Foundation has been interested historically in the Arctic. So over 20 years, we have been involved in various kinds of research. In the afternoon, we'll be given an opportunity to introduce our research. I, myself, am a physical oceanographer. Other than Arctic climate change, ocean acidification has emerged to be another interesting topic since last year. This morning's presentations were very interesting. I look forward to presenting information about our organization later today.

Morishita:

My name is Morishita. I am interested in this meeting in two ways. One is my title, the Director of National Research Institute of Far Seas Fisheries, which is under the Fisheries Research Agency. The other is on the policy issues; I am leading the negotiations for new fisheries management in the Arctic open waters. I am also the Chairman of the scientific steering committee of the North Pacific Fisheries Commission. I am very interested to know the thoughts of the stakeholders in Japan as to what's happening in the Northern Seas right now.

Omori:

Good morning. My name is Ryo Omori from the Fisheries Agency. I'm from the policy side. I am in charge of the Northern Sea Route negotiations. Also, we are looking into how marine products will change in the Arctic Ocean.

Toyofuku:

My name is Toyofuku from Hokkaido Federation of Fisheries Cooperative Association. We see changes in the fish varieties available. Species have migrated or located somewhere else. The fish environment or changes in ocean currents have impacts on where fish are moving in the ocean. Today, I look forward to an interesting opportunity to exchange views.

Nishimura:

My name is Nishimura from the Japan Fisheries Association. We are the central agency for fisheries for Japan. Everything will be relevant to us. Personally, I am interested in international and environmental issues. I have been previously involved with the Convention on International Trade and Endangered Species of wild fauna and flora (CITES), which is otherwise known as the Washington convention. I have also earlier worked on tuna and shark utilization. Now, I am working with fisheries eco-label, which is a certification for marine products.

Moderator:

Thank you for your introductions. There are a few presentations that will be presented. Right now, we would like to create an opportunity to entertain more questions about the two presentations given in the morning. Are there any other questions asking for more details about the two presentations in the morning?

Morishita:

Yes, I have a question. Franz Mueter talked about sea level, its trends and relationship to climate change. Are there any data on this? That's one question. And related to that, are the changes in sea currents happening as a result of climate change? Lastly, is there any information about fishing activity in the Arctic Seas, especially on subsistence fisheries among indigenous people? In Norway, the NEAFC, North East Atlantic Fisheries Commission managed these fishing activities. That kind of information could be shared. I think once that information is available to everyone, then we can also discuss including that information.

Mueter:

Thank you for that question. I will pass the microphone to Seth Danielson to address the question about the changes in sea level height and currents. But in response to your question or comment on subsistence fisheries in Alaska, there are of course a number of subsistence fisheries along the coast, and there is fairly widespread concern over the effects of the disappearing ice or early ice melt and less ice, particularly on the subsistence harvest of marine mammals. In the Arctic region, there are small subsistence fisheries for coastal fish species, but in the offshore region, as you probably know, the U.S. has closed the federal waters to fishing, to any commercial fisheries at the moment. To address your question about the potential changes in currents and sea level height, I will pass the microphone to Seth Danielson.

Danielson:

I am Seth Danielson from University of Alaska in Fairbanks. I'm a physical oceanographer. There are some studies, model projections, multiple model projections for sea level changes around the globe. I will be presenting some of this in detail tomorrow, but I can summarize it for you now. The Beaufort Gyre region in the Canada Basin, just north of Alaska, is projected to rise more quickly than the sea level heights in the North Pacific, which would imply that the flows that are forced from the Pacific Ocean into the Arctic through Bering Strait would tend to decrease. However, there are also anticipated changes in the wind field which would tend to counteract that, so the sign of the change of the flows to Bering Strait is not clear. The question relating to currents is similar. There are projections for changes in the Aleutian Low and the strength of some of the winds in the Western Arctic and the Bering Sea, partly because ocean-atmosphere feedbacks change under the conditions of more open water when compared to ice covered waters. We would expect some change in the wind field, particularly strengthening winds when you have open water as opposed to sea ice underneath the atmosphere. These are some of the winds that could act to increase the flows through Bering Strait. I can say that there is a lot of uncertainty in some of the sea level projections. The sea level height changes that are projected for the future, the models tend to agree on the sign of the change, but the variability is very strong. And it's generally related to warming of the waters in the Beaufort Gyre and an accumulation of water within the Gyre itself for this change in sea level.

Moderator:

For the subsistence fishery of indigenous people, do we have any opinions from Norway? Do you have any expertise about indigenous subsistence fishery activity?

Planque:

Benjamin Planque from the IMR. The issue of subsistence fishing in Norway is relatively minor in comparison to what is happening on the Pacific side. Most of the fishing is commercial or recreational fishing rather than indigenous people fishing. You referred to the North East Atlantic Fisheries Commission. That Commission is handling the management in international waters, which are partly in the Norwegian Sea, and partly in the Barents Sea. Most of the area where there is legislation is under Norwegian and Russian jurisdiction.

Morishita:

Thank you for answering the questions. As for the indigenous subsistence fishery in Canada and the Russian Far East, we do not know what are they doing there. We understand, but we don't have data for the indigenous peoples' subsistence harvests, especially in Russia. Without baseline data, we cannot understand the changes there. Also, I heard that the target species is Arctic cod. For Arctic cod, they have data in the coastal areas in many countries for resource evaluation, but it's not enough for understanding the global trend. We have data on marine mammals. So for Russia and Canada, do we have marine mammal data? Also, as for the indigenous subsistence fishery, we have data from Greenland. They have a lot of activities in Canada. We need to have baseline data from an Arctic point of view, and so we would like to make use of this kind of forum. We would like to collect data which would be good for our research.

Moderator:

We are working together with the United States and Canada, but especially with Norway and Russia, which are directly facing the Arctic and have long coastlines. When we think about the Arctic and the Arctic point of view, we need data from Russia. At Hokkaido University, we plan to have a joint center that will be located in Russia. We will try to establish a joint center in Russia to collect data. This facility will be used by many institutes, including Hokkaido University, and also other institutions including the National Institute of Polar Research. We would like to conduct research working together with Hokkaido University. We would like to establish such resource centers in one or two places to collect data so that the stakeholders can have the results of research from those institutes. I would like to know if you have any results or data. So, are there any questions?

Ishikawa:

From me, I would like to ask you Professor Saitoh if you could explain the plan of your research. Actually, the other day, we had an economic federation, which Professor Saitoh came to. He explained about his project, and thank you very much for your explanation. At that time, I asked you several questions about marine resources in the Arctic region where you conduct surveys. You have surveys from the point of view of natural science. You said that there were many things to be solved and there are many things that you have to understand.

But there was a declaration in five countries in Oslo. There are many issues concerning the regulations of many countries toward commercial fishing activities. There are trends in commercial activities to think about, and I think there is a research team in Japan. In this project, probably from the scientific and social points of view, I hope that you will conduct research on the possibility of commercial fishing. What do you think about that?

Moderator:

It is easy to talk about multidisciplinary research that includes the natural and social sciences, but it is very difficult to conduct multidisciplinary research. We have social scientists from Norway and the United States, but I have only one person from Japan University to answer that question. Could you give us some comments on this question?

Ohnishi:

Thank you very much. I'm Ohnishi Fujio from Nihon University. In terms of research on the Arctic, there are many fewer social scientists dedicated to this field than there are natural scientists. Under the ArCS project funded by the ministry of science, we started interdisciplinary work between the social and natural sciences. Then, little by little, we hope that researchers will gather and work together on Arctic issues. Now, we are about to start working on fisheries in the Arctic regions. This March 30th to 31st, we will go to South Korea, and then researchers from Japan, Korea, China and the northern countries will have a workshop about setting up a framework of regulations. Many researchers from Japan will be there, and I will also participate in that workshop. I hope that we will work together under this team in the future. Thank you very much.

Chi:

My name is Naomi Chi from Hokkaido University. I'm a member of the ArCS project at Hokkaido University. I just wanted to add a short comment to Professor Ohnishi. As Professor Ohnishi just mentioned, the collaboration in terms of social science is still very limited. However, we are in the midst of creating a joint collaboration and research collaboration on issues like sustainable development of indigenous peoples in the Arctic, also on land claims and diplomatic reform policy issues concerning the Arctic. There are various aspects we need to work on. We just need to have a forum for us, like you have here for the natural sciences. We don't have that yet for social sciences. We are in the midst of working on it. In April, we're going to have another joint workshop in Canada, in Victoria, and we're going to talk about the possibility of a joint collaboration with Canadian Universities and Hokkaido University in terms of social sciences research on the Arctic. We will keep you posted.

Moderator:

Thank you very much. If you have any questions on other topics, thank you very much.

Morishita:

I have similar questions. As for the Northern Sea Route, the negotiations about the Northern Sea Route have started between governments. Last December, the first convention was held for the Oslo announcement, where five countries participated. The next meeting will be held in April, in Washington, D.C. It is already on the website of NOAA in U.S., where you can get some information about it. In America, several drafts have been proposed already. The idea is that, as someone has previously stated, for the time being in the northern area, commercial fishing will not likely happen. That is a common agreement among researchers. The Japanese researchers have the same point of view. However, considering the physical conditions, with the receding ice, illegal or uncontrolled fishing could happen. We cannot deny this possibility. We need some precautionary measures against this, and this is the purpose of the Oslo Declaration. Just like the five countries, we need to discuss and find the common ground internationally. In the future, commercial fishing could be possible. We should not just ban it; we need to devise a scheme for what is sustainable fishing.

In the scientific committee, we had a discussion meeting last March with the previous group of researchers. We will meet again in Norway in the fall, around the end of September. Most parts of the Arctic region are within 200 nautical miles of some country, including America, Russia, Denmark and Greenland. Within 200 nautical miles of their shores, only those countries can fish. Other than that, indigenous fishing can be allowed. Another idea is, as previously mentioned, an Arctic fishing control organization. In the uncontrolled region around the North Pole, there is a wedge shaped area of uncontrolled ocean and that is the target area. So far, there is no large scale commercial fishing there.

The intergovernmental discussion, the Arctic five plus Japan and other countries totaling 10 countries, will continue the discussion, and we will take precautionary measures as a regulation framework. We have issues on the international laws. My research is covering the Antarctic region, which has an Antarctic Treaty. With regards to the Arctic, we have challenges to form a new paradigm for the Arctic. It is a very interesting area to discuss. So together with scientific information, we can expect that kind of discussion will continue. Another topic is shipping, the marine transport. So far, today's main topic is fishing, but energy resources could be another topic.

Moderator:

Thank you very much, a very valuable opinion and comment. Mr. Goda, please.

Goda:

I'm Goda from Nippon Yusen. I would like to ask something to scientists or probably to the government. I have three points. First one is about the fisheries, the changes in fisheries in the northern area. Thank you very much for your input. When we think about business, we need data for decision making. It should not be a one-time survey, but should be done on a regular basis. We need continuous annual data at frequent intervals and not every 5 or 10 years. If we can have a public database where we can access and get information, it will be very useful for the business sector to make decisions. Second, the Arctic Circle is over each country's border. When we talk about the coastal areas of the Arctic Ocean, there are two types of region within and outside the Arctic Circle. We often talk about the economic development and increase in population in the Arctic Circle, water resources and mineral resources in the Arctic Circle. We often mention the Arctic Circle, but in the business sector, what is troublesome is the lack of data. Various data are taken by the government, but those are mostly from the sub-Arctic area, and Arctic Circle remains very uncertain. Scientist often say, this kind of thing is happening in certain areas. The periodic update of the data cannot be expected for that region. It's very difficult for us. The field of market research iss very important in the business sector. Probably, we should do that as our responsibility, but if we can have the data, continuous and periodic data for that region, it will be very helpful. The third thing is something to request from the humanities and social scientists. In the Arctic Ocean, not only Arctic Ocean, we often mention sustainable growth. Always the environment comes first and not business. Many scientists think, the environment first. In Japan, when we talk with the humanities and social scientists, I feel that sustainability is very important. I think it is variable of course. In Norway, the Ship Owners' Association often has proposed the best practices and the best rules. Regarding a business sector conducting the best practices with the best rules, the Japanese understanding is different from that in other parts of the world. That's what I feel. If a scientist could look at the business sectors a little bit more, then that will be good.

In the case, that we will do business with people in the Arctic region, including indigenous people, together we could be partners, creating some cooperative or joint venture. We can make a profit with them. That's one possible form of business. When they think about business in the Arctic region, we need to seek a common understanding from both sides. We should understand sustainability and put a value on that. Also, I would like the people in the Arctic region to understand business. People familiar with the Arctic region could work together with us and also people outside of the Arctic region should consider that. I'd like people to further understand about business. In short, in the same way that we understand and respect sustainability, we hope that people in the Arctic region will understand business. In this regard, I think social scientists who are familiar with the region could serve as a bridge between us.

Moderator:

Thank you very much for your comment. Continuous observations are needed and that kind of information should be accessible anytime. You mentioned about continuous observations in Arctic and that the data in the sub-regions are not enough. That's a challenge. Social scientists were also requested to understand more about business. I think we need to work on these points under the framework of the ArCS project.

Now, Mr. Toyofuku from Gyoren Fisheries Cooperatives has to leave. What kind of a support should be provided for the fishing sector in Hokkaido with regard to climate change? Do you have any request? What kind of information do you need, as a fisheries sector?

Toyofuku:

As I mentioned before, we see the changes in the fish species that we are catching. Sometimes, we catch different fish species (e.g. yellowtail and dolphin fish) from what was previously present on the fishing grounds. We need scientific information as to why this has happened. There is a lot of information about changes, including the impacts of ocean acidification on marine life. Those were very informative. The temperature changes, and the sea ice retreat, those were very important information for us. If I can have such kinds of information, that will be very helpful for fisheries in Hokkaido. If you have any additional information about those points, I would like to have it.

Moderator:

Thank you very much for your question. Now, it's time to close this morning's session. In the afternoon, if you have presentations to make, we would like to accommodate you.

(2) – Needs and problems

Moderator:

Thank you very much for coming back. Now we will resume the stakeholders meeting. I will Chair this session and my name is Makino. In the morning, we had two presentations and after that we had a brief period for entertaining questions from the stakeholders and we will continue to do so now. We would like to give opportunities to those that did not have the opportunity to speak this morning. Mr. Tsunoda from the Sasakawa Peace Foundation has prepared a presentation. So, we would like to hear his presentation.

Tsunoda:

My name is Tsunoda from Ocean Policy Research Institute. Last year, I was at the Mitsubishi Research Institute, and I was researching about business. Then later I joined the Sasakawa Peace Foundation, in particular, the Ocean Policy Research Institute. As I already mentioned, my background is from the natural sciences, physical oceanography. After graduating, I did research on the Redfield ratio, between physics and biological science and marine information business. I have known Professor Saitoh for 10 years.

Now as for the Ocean Policy Research Institute, I would like to introduce some of our major activities. As I mentioned earlier, our research institution was called Ocean Policy Research Foundation and last year we joined Sasakawa Peace Foundation and our assets are ¥140 billion. So, it's a large foundation. We can now focus on international projects as well. And now what are we doing more concretely? We are focusing on maritime policies and other issues. We are also interested in issues on the South Pacific Islands. ICM, Integrated Coastal Management is also one of our projects.

Education is also important and we are also supporting the World Maritime University. So, how can we supply information? To that end, we are issuing newsletters and writing a white paper on oceans. And we are doing research on climate change and also on the Arctic Ocean, including the Northern Sea Route. We have these various research activities. Now, I would like to focus on the Arctic Ocean. Since 1993, from 1993 to 1995, we have been doing the research on this area. To study the possibility of a Northern Sea Route, we have collaborated with Russia and Norway and have jointly supported the International Northern Sea Route Program. This program has shown that year-round navigation would be possible in the Arctic in the future. In parallel with INSROP, we established a domestic project called JANSROP. From 2002 to 2006, we studied the utilization of the Northern Sea Route.

We also focused on GIS. As for Russian's energy and mineral resources, the numerical data were made available in collaboration with the partner countries. In the morning, we discussed the need for basic data. Based on the GIS results, the Arctic Council issued the Arctic Marine Shipping Assessment in its 2009 Report. This INSROP GIS was highly evaluated and reported in the Arctic Council's report. There are some of our results in the INSROP/JANSROP documents, and various other papers have been published. However, in those days, sea ice was expected to remain thick in summer until around 2050, and commercial navigation was expected to be possible only after 2050. But the speed of sea ice melting has been faster than previous predictions. Therefore, we decided to gather more information. In Japan, the awareness of the importance of the Northern Sea Route is still low. Therefore, for example, from 2010 to 2011, we established the Japan Arctic Conference. Experts from various areas came and joined us to organize this and we made proposals in the following eight areas.

More concretely, since last year, we are doing two things. One is on the business side, the Arctic utilization - utilizing the Arctic area for business. How can we promote business, and we are targeting to come up with measures and a roadmap for this purpose. The merits of the NSR must be understood by Japanese business companies. We are inviting Arctic coastal nations, including Russia, Norway and the United States, to our international seminars and workshops, and we are also conducting workshops for the governance of the Arctic Ocean.

The Arctic Council invited Japan as an observer, and, as an observer, the importance of non-Arctic nations is increased, and forums are needed for exchange of information. We need to create a forum for the principal members of the Arctic Council and observer nations in Asia, so that we can discuss the governance of the Arctic area. These are examples of the activities we are doing for the Arctic.

In the morning, the ocean acidification issue has been mentioned several times. Now I would like to talk about this. So, for climate change, we have a five-year project that started in 2015. On February 17, we will hold the first symposium, inviting Prof. Jean-Pierre Gattuso from France, Executive Director Yoshihisa Shirayama from JAMSTEC, and President Masanori Miyahara from the Fisheries Research Agency. We have discussed ocean acidification, and there are many things that we don't understand about it. How can we improve awareness of these issues in our society? We are working on that as well. For your reference, for example, we will not be able to eat sea urchin when ocean acidification progresses further. There will be less and less sashimi or sushi to eat in the future. It is important that we provide this kind of information for the public, balanced information. The diagram I am showing is just one example of how we can provide this kind of information for the public.

Moderator:

Thank you very much. That was very useful information on the Institute of GIS and your data. We should have a linkup between GIS and the Arctic Conference Japan. And the issues that they are announcing, and what they are doing, is very useful for our needs, too. And are there any questions for Mr. Tsunoda's presentation, anything that you want to confirm? If you have a question please raise your hand, if not, thank you very much Mr. Tsunoda. Next, in the handout, there is information about Nippon Suisan. Mr. Ishikawa from Nippon Suisan Kaisha will make a few comments.

Ishikawa:

Thank you for giving me this opportunity. I might not have enough copies. I'm sorry for that. Please look at the profile of our company, and the same brochure would be available at our website, both in Japanese and English. Today I would like to introduce our company and our interest in the Arctic.

Why are we interested? I would like to share that with you today. If you do have this brochure, please look at page seven. This is the outline of our company. It was established in 1911, over 100 years ago

OPRI | THE OCEAN POLICY RESEARCH INSTITUTE

海洋政策研究所は、その前身である「海洋政策研究財団」の時代から、海洋ガバナンスに関する国際的な議論に積極的に参画し、海洋の総合的管理と持続可能な開発に関する様々な問題について、問題提起と社会への発信、政策研究、政策提言とその実現に向けた活動など、シンクタンクとして活動を展開してきた。昨年4月、笹川平和財団と合併して新笹川平和財団海洋政策研究所となったことを契機として、さらに、政策提言とその実現のための行動を強化し、「シンク･アンド･ドゥタンク（Think ＆ Do Tank）」を目指して、新たな取り組みを進めています。

The Ocean Policy Research Institute (OPRI), continuing the work of its predecessor, the Ocean Policy Research Foundation (OPRF), has developed as a think tank through actively participating in international discussions on ocean governance, identifying issues and carrying out information dissemination and policy research, and making policy recommendations and supporting activities toward their implementation on a variety of problems in ocean governance and sustainable development. On its merger with the Sasakawa Peace Foundation last April, to become the New Sasakawa Peace Foundation's Ocean Policy Research Institute, it aims to become a Think & Do Tank, by rededicating itself to policy recommendation and implementation activities and undertaking new initiatives.

International Northern Sea Route Program (INSROP)

Sub-programs in Phase I (1993-1995)
- I. Natural Conditions and Ice Navigation
- II. Environmental Factors and Challenges
- III. Trade and Commercial Shipping Aspects of the NSR
- IV. Political, Legal, Cultural and Strategic Factors

Additional programs in Phase II (1997-1999)
- ・Integration of the outcomes in Phase I (167 peer-reviewed Working Papers)
- ・Formulation of an INSROP GIS

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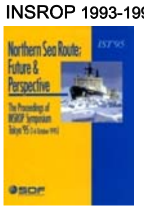
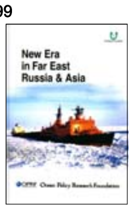
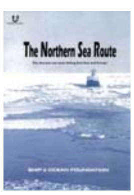
Outcomes of OPRF's Arctic projects

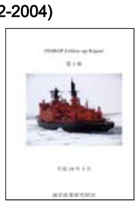
INSROP 1993-1999



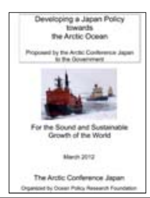




JANSROP II (2002-2004)



Arctic Conference Japan (2010-2011)



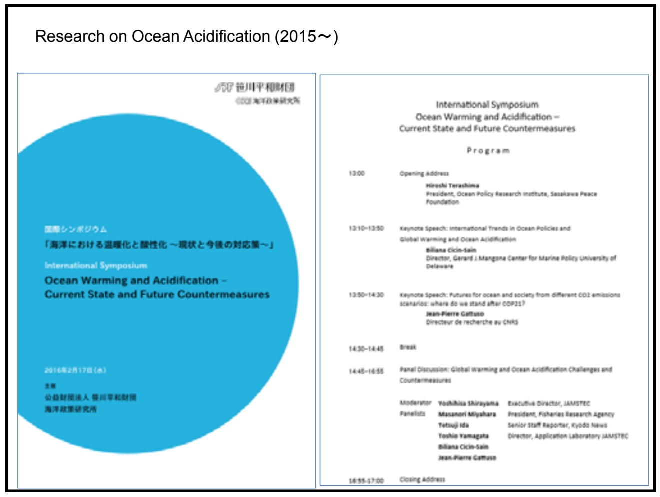
Eight Recommendations for Japan's Arctic Policy

The Arctic Conference Japan
March, 2012

For the sustainable use of the Arctic Ocean,

The Conference urges the Government to:

1. establish the Nation's Arctic policy and a joint chiefs of staff,
2. bolster every research activity in the Arctic,
3. actively take part in protection and preservation of the environment,
4. participate much more directly in Arctic natural resources development,
5. promptly respond to logistical changes in the seaborne trade by the opening of Arctic seaways,
6. design a new national security program via the Arctic seaways and shipping,
7. contribute largely to the establishment of an order of the Arctic Ocean, and
8. make haste to strengthen Japan-Arctic states dialogues, in particular Japan-Russia one.



and at the time Japanese vessels were only made of wood. Later we imported steel ships from UK, and we launched coastal fishing. That was our beginning back in 1911. And gradually we expanded the fishing grounds that we used and the size of the fishing vessels. At that time, the 200 nautical miles did not exist, so we also explored the Bering Sea and also North Pacific Ocean areas for fishing grounds.

However, after the 200 nautical mile was established, we could no longer fish under the Japanese flag. Therefore, we started a joint venture company, and we had partnerships with local companies in many countries. As you can see in this brochure on pages seven and eight, we have companies in 26 countries and also we have 97 group companies. So, now we can continue fishing, and then process and distribute marine products all over the world using this global network.

If you have the brochure, please look at pages five and six. As I mentioned we have a lot of activities in many countries and in North America. There is a company called UniSea. You can see the logo of UniSea on page six and you can see a picture of Dutch Harbor in Alaska, United States. As Dr. Mueter pointed out, this port has the largest catches in the world. In South America, there is aquaculture for salmon and a company for fishing. And in Asia/Oceania, for example, we have a company called Sealord in New Zealand, and you can see a picture of that vessel. And there we work together with the Maori people. There is group that represents the Maori people, and we work with them. We set up a joint company with them, and we are fishing in this area. Also in Europe, as you can see on this page, we have companies for processing and distributing marine products. People from overseas may know some of the companies on these pages. Maybe you have seen a product that was produced in those companies. So we have those companies around the world. We work

together with those companies. The theme of today's session is the Arctic and regarding this, in Dutch Harbor, we are processing cod and Alaska pollock. We have listened to the stories of those people who work in Arctic field, and also in the Bering Sea, and they are also influenced by global warming. And they have a decreasing number of fish in those areas. The distribution of fish is also shifting from south to the north, that' s what I've heard.

In the future, I'm not sure how the fishing in the Arctic Ocean will proceed. We do not have a prospect of that yet as a private company. I think there will be a period later when we can have commercial fishing in this region, in the Arctic Ocean. We will try to develop our activity in the Arctic Ocean, too. As I mentioned, a little bit before, we have established a joint company with the local and aboriginal people, so we would like to develop a partnership with these people in the future too, to conduct our business. For now, the environment might not be right for developing a partnership with them, but we would like to proceed little by little together with the researchers. Thank you very much for this session today.

Moderator:

Thank you very much, Mr. Ishikawa, for your comments. If you have any questions or comments, please raise your hand.

Hunt:

Thank you very much for your presentation. Do you have any joint venture with the Russians in the Bering Sea, either the Western Bering Sea or the Central Bering Sea, for getting fish from those places?

Ishikawa:

Thank you very much for your question. We import marine products from Russia. Our Japanese company imports marine products from Russian companies, but we don't have any joint fishing companies with Russia.

Moderator:

Thank you very much. So you have business with indigenous people. How do you do business with them? You have a very valuable experience in New Zealand and also in Russia. Are there any joint companies in Norway or United State that have joint companies with Russia? Do you have any knowledge about that?

Eide:

I am Arne Eide from the Arctic University of Tromso. In Norway, there is certainly joint co-operation in management, but in fisheries operation, to my knowledge, no. There are co-operations in a sense that a number of Russian vessels have delivered fish in Norwegian ports. They have cooperation with Norwegian businesses in that sense. But for joint venture companies in the sea, I think it will be impossible according to Norwegian law, and possibly also because of Russian law.

Haynie:

Hi, Alan Haynie, Northern Fisheries, Alaska Fisheries Science Center. I don't know of any joint ventures with the Russians in the U.S. I heard someone mention, not long ago, a Russian-Chinese joint venture, but I'm not sure whether it is focused on development in Russian waters or beyond.

Moderator:

Thank you very much for your explanations. As Mr. Morishita says, in the Arctic Ocean, large portions of the coastal areas are within the EEZ of Arctic countries. The information on these areas is limited. So information on who utilizes the EEZ areas for fisheries or other activities should be important baseline information. Thank you very much Mr. Ishikawa. So next? Is there anyone who havesn't raised your voice? So please give us comments. First, Mr. Nishimura from Japan Fisheries Association.

Nishimura:

I am from Japan Fisheries Association. This is a central organization for fisheries in Japan. I talked about my personal comments for the talks in the morning and about how Japan Fisheries Association can contribute to this kind of workshop. From the discussion we have had this afternoon and in the morning, I have listened to your talk and first we have discussed issues of climate change, and then we have discussed issues of resources. I learned about the influences of climate change on marine resources and also the improbable development of fishing activities in the Arctic in the near future. Even if fishing activity will be possible in the future, the open ocean area in the Arctic is limited. So, it is very difficult for us to start fishing there as of yet.

However, as the presentation by Nissui showed, even if it is not directly related to the Japanese fishery, we can have joint ventures or we can work together in the field of processing and probably we can connect indirectly with the fishery in the Arctic region in the future. But at the present, as an industry, it is too early for us to join. But if we have information and if you can give us data, we can work with you, even though it might not lead to a business at once. I think it's for the future, but we would like to have information for future cooperation.

Another thing is that people often think that industry and business care very little about the environment. This is a common notion about industries. Some groups or organizations provide environmental information as a form of their business. However, one of our goals is to supply food to the people. Therefore, I would like to ask for your understanding for our industry. If there is a possibility for fishing in Arctic region, and if you set up conventions and a framework, then we would like to make use of resources in the Arctic region, and we would also like to protect the resources in the Arctic region. Thank you very much.

Moderator:

If you have any questions, please raise your hand. Thank you. Thank you very much Mr. Nishimura. I would like to have another comment from Mr. Matsuo and then to move on to the other sectors. Mr. Matsuo is from the fishing industry, representing the processing and logistics industries.

Matsuo:

Thank you. I am Matsuo. I'm in the supermarket business. It's a rare chance for me to join this kind of meeting. I heard that somebody mentioned that business is a representation of evil. However, after Tohoku earthquake, the value of the retail industry has been appraised. Recently we have had some chances to join this kind of meeting, but usually there is a tendency that we just discussed about something very regular, very usual. It could be a very practical topic, but please allow me to make a comment. The morning session was very informative for me. In the fishing businesses in the supermarkets, we cannot see anything until we actually have a catch. When I go to the morning market, until we see actual fish there, we cannot say what kind of fish we can get today.

Now, it is winter and we have drifting ice. In Russia, the Amur River is frozen and it is very rich in plankton and nutrients. This is possibly due to the formation of a dense water mass that initiates vertical mixing. In such a nutrient-rich environment, primary production is enhanced and further creates favorable conditions for crabs and flatfishes. However, people in the fishing retail business really don't know about the correct information. So, we need to take some collaborative work. Probably, Japan lags behind in this sense. We understand the idea of sustainable fishing, but when we think about the actual business, we cannot give a full consideration for environmental or sustainability issues. In Japan, I think some sectors and people are really struggling to establish the sustainable business. Once we can establish that part, it will start to move. First, we need to disseminate the ideas or theories of sustainability. All presentations or comments are very informative for me. Thank you very much.

Moderator:

So for researchers, his comment was very encouraging. Thank you very much. Do you have any questions or comments? Ms. Harada?

Harada:

I'm Harada from JAMSTEC. For researchers, this kind of meeting is a first experience and very exciting. I' m happy to have joined this meeting. In the future, if we can have a chance to meet with the people in the business frontline, it would be very useful. We have scientific information and we need to effectively and actively communicate this with stakeholders. Can you give me some input about what groups of people require this kind of information?

Matsuo:

There are two. One group is, especially, Hokkaido, which accounts for one-fourth of the entire Japanese catch, and more than 55% of exports. 75% of Hokkaido' s fishing is from aquaculture. We have a lot of know-how, but it stays among the producers. It's not really linked with the retailers. How can we make it more productive or profitable? We talk about this quite often. If we can make more collaborative work with producers and retailers, then we can make the industry beneficial for both consumers and producers. Another thing is, and probably this is an issue for the Ministry of Agriculture and Fisheries, for example, in aquaculture, we need a local Governor's permission, but we can only work in that local area. For example, we have very few fish resources, but to catch them, we need permission from the Ministry. But the producers or the business sectors want to have this industry. So we have to work and involve all relevant sectors to make it more accessible.

Moderator:

Thank you very much for your practical ideas and advice. Now we are talking about fishing sector. Let's focus on the fishing sector. Is there anybody who wants to state anymore comments? No? Go ahead.

Huntington:

Hi, Henry Huntington from Alaska, and part of the RACArctic project. This is to me a fascinating discussion, particularly because many of the things that people are saying sound very much like the things I've heard in similar discussions in Alaska, even within indigenous communities. Chief among those is the idea that what people want from those of us in the research world is information. And I've heard that many times. At a meeting I was at recently, someone from one of the small villages in Alaska said that we don't want you coming here studying things we already know, and telling us things we already understand. Don't tell us what we are seeing. We want something new. We want information that we can't get from other places.

The question that I've had, and I think it's a challenge, I believe it was Mr. Goda who said that it was – it's hard for scientists to understand the way business people look at the world and vice versa. And I appreciate Mr. Nishimura's comment that the benefits may not be obvious, or we may not realize the benefits immediately. But it may take some time to learn how to communicate and to learn what works. But my question is, what kind of information? A few of us discussed that at lunch. Scientists collect a lot of information and often in fine detail. Probably that's not what people are interested in. On the other hand – something that's very general, that says, well, the world has warmed by 0.4 degree Celsius is not terribly useful either. So what kind of information is needed, and in what form would it be useful? Thank you.

Moderator:

Thank you very much Mr. Huntington. I totally agree with you. What kinds of information we need, what kinds of information are required, in what way researchers should provide that information to relevant sectors, and in what way can it be very easy to utilize, those are the important questions. It's very interesting that the same discussion was made in Alaska. Do you have any other comment? Go ahead.

Ohnishi:

I'm Ohnishi from Nihon University. As Mr. Huntington said, we have discussed during lunch, for example, that the people in the business field want to know whether fish is available or not available in a certain area. However, if you ask the scientist about it, they know only about their own field. They do not have 100% of all information, just part of the story. In that case how we can fill in the gap? What kind of function we can have to fill in the gap; can we make a certain framework for this? It is important. This project is useful in that sense. Such meetings should continue periodically, not just be a one-time event. Thank you very much.

Moderator:

This is the first meeting for us. What kind of gap? The identification of the gaps is getting clear in this room now. If we can clear up, clarify those gaps, then we can think about how we can find a solution. After this, we would like to have opinions from the sectors other than fishery, but before this, I'd like to have a question or comment about the fishery, fishing industry. Okay. Among stakeholders, the sectors other than fisheries, we have several people. Now, we have officials from the Ministry of Economy, Trade and Industry. Could you give us a comment?

Fujie:

I'm from the Ministry of Economy, Trade and Industry. All the trains had stopped, but I managed to take a plane to come here. Our job is to support businesses. In that sense, I'm in-charge of the collaborations among business, academia and government. Now, we heard about how we can fill up the gap between business and academia, which is very impressive. The theme about the Arctic is difficult to directly connect to business. However, in the future, in Japan, particularly in Hokkaido, it will be a very important topic. That's why I'm here today. This is not about finishing something in a couple of years, but this requires a long-term perspective. So, I would like to continue to support this effort. Thank you very much.

Moderator:

Thank you very much for braving the weather. Thank you very much for joining us today. Now from the logistics industry. Mr. Kashiwagi do you have any comments, needs?

Kashiwagi:

My name is Kashiwagi from Mitsui O.S.K. Lines. If you ask me about the needs, there is a lot of information needed. As for Northern Sea Route, we need navigational charts, information on the weather, and, if there is a sea ice, then we need information on sea ice. From where and how this information is made available, that is the question. When it comes to sea ice, we need information about its thickness and about sea routes along the coast of different countries, the services available along the coast, what kind of support is available, from what organizations, those would be our interests. As for any other, we have been talking about environment issues. For the shipping industry, there is GHG like SO_2 and NO_2 and different regulations are in place with which we need to comply. I'm wondering if there are special regulations for the Arctic area. I'm not here to deny if there are any rules. Business is usually a short-term thing, but experts are always looking from the longer perspective, from the perspective of the benefit of humanity. I think they can give us wisdom and advice, so that we can promote environmental protection and conservation. That kind of advice would be beneficial so that we can come up with appropriate regulations.

Moderator:

Thank you very much. That was very valuable advice. Are there any comments or questions about what Mr. Kashiwagi just said? If there are any questions, you can raise your hand, later also. As for information on weather and sea ice, any overall comments?

Sagawa:

We are providing weather information to the people of Mitsui O.S.K. Lines and Nippon Yusen, not just for the Arctic but also global information. A few years ago, commercial shipping started in the Arctic. There, navigation is getting easier with the decreasing sea ice, but there still remains a great risk. Our priority is safety and also, aside from economic factors, I think safety is our utmost concern. In order to realize safe navigation, I would like to ask about your observational data. Information on ice conditions would be very useful. There are other risks involved in the Arctic. For example, reduction of sea ice leads to the generation of waves. This situation has not been observed before, and we don't know what will happen in the future. Ocean and waves are studied separately, but if we can see joint advancement in these areas, then we can promote even safer navigation in the Arctic.

Moderator:

Thank you very much. Any questions for Mr. Sagawa? Then we will sum up later. There is a question.

Huntington:

Because Mr. Sagawa is involved in the business of providing information to industry, I'm curious what lessons you have for those of us who are not used to doing that? How did you find out what kind of information people wanted? How long did it take for you to be able to provide the right kind of information for the people in the shipping industry?

Sagawa:

During the discussion I have been thinking, it's not an easy question. We do provide information to various companies, but in what way, and what kind of information should be provided, are things that we have been learning by trial and error. It's difficult to set up a clear goal, but the data have been made public in different places, many areas. One of the objectives of the GRENE Arctic project is to provide the information, and in fact it's doing it on the web. In different ways we have tried, and we're creating opportunities to expose the data to users. In that way, I hope we can find better means to provide information.

Moderator:

Thank you very much. As Mr. Goda from Nippon Yusen mentioned, there are much data available in the world. A great amount of information from various research areas is actually available. What we need is a place where related data are integrated so that users can come to a specific site to find the necessary information. We perhaps need a place where we can provide the correct information. Mr. Tsunoda?

Tsunoda:

Thank you Mr. Sagawa. You find that the waves are now forming. How do waves influence the large-sized commercial vessels and other structures such as oil platforms?

Sagawa:

No, we don't even understand that. We don't even know what kind of waves or size of waves are there. Very few data are available from observation. Waves can be observed from satellites, but the satellites do not pass over the Arctic area. The Jason-2. It is at 67 degrees North, and that's the Northernmost wave-detecting satellite. We can use models to calculate wave heights, but we don't know actuality what is happening. Since a large open area is being created, low pressure or strong winds could influence not just the large commercial vessels but also the small fishing vessels.

Tsunoda:

I think there are places in the north of Scotland where large waves have already been observed. Will it be like this?

Sagawa:

In the sub-Arctic area, weather conditions are severe. In winter, there are stronger winds and the Bering Sea is rough, but if you go up to the Arctic Ocean, you don't have big low pressure areas. It's not so severe there, but we do observe storms, so it's on a case to case basis.

Harada:

With the reduction of sea ice along the coast, the frequency of eddies has increased according to the model calculations. This kind of information is frequently presented, and we have had discussions about it. An eddy can be a mechanism for supplying nutrients, thereby allowing phytoplankton and zooplankton to increase, and this, in turn, will increase the production of forage species. Therefore, it is important to provide this information on the website and also public seminars. Even for seminars or workshops among researchers that we hold for ourselves, stakeholders can be invited. We can make announcements for these various events. It is my strong feeling that Mr. Kikuchi's and Franz's presentations are the kind of information generally talked about in our community, and this information has the same value for you as well. We understood that it has the same value as we feel. We need to create more opportunities and forums for us to gather and exchange information.

Moderator:

Thank you very much. Mr. Goda please.

Goda:

The neeed for exchange of information is not limited to projects of the Arctic region. Actually,in the past, we did not think that maritime research would lead to efficiency of navigation. We thought these two would be different things. Therefore, I noticed from what Dr. Harada just said that scientific findings can contribute to business and industries. The increase in eddy frequency is not limited to the Arctic, but goes on elsewhere outside the Arctic. Even if the sea route is established, a weather forecast one week ahead is very unclear. A vessel is an asset of billions of yen, and its value depends on the speed and fuel efficiency and consumption. However, if its speed is decreased by 30% due to climate change, the value is also decreased by 30%. In order to avoid this, we have used the services of weather companies' services, such as those of Mr. Sagawa's company. We have already done this in the general ocean. It has been made possible through the effective translation of scientific information to a form which the common public can easily understand. I realized today that the discussion on wind and waves affecting navigation routes has already been discussed in academic meetings. We would like to learn more about this information in meetings between the business community and scientists, as such information is important for the business communities. Thank you.

Chi:

Social scientists often say something not concrete, and sometimes we are criticized for that. What I thought about your discussion is that it's important to invite people from industry to academic meetings. However, if you look at things from another aspect, I think it is very important for us to work together. We are in different fields, in different sectors, but we should work together as members in a larger community. Wwe need to think together about the risks each member has to deal with, and try together to manage these risks. If we look at things like this, then we can shorten the distance between us. This is the first time for me to come to this kind of session. I'm not good at science, but I have listened to your discussion to understand the science and to figure out how I can integrate it with my research. There is a risk, and I would like to explain it to the people who don't know about it. As a member of society, we would like to start our collaboration.

Moderator:

Thank you very much. Mr. Morishita please.

Morishita:

Thank you very much for your various comments. They remind me that after the incident at the nuclear power plant in Fukushima, Japanese marine products suffered a radiation contamination, so to say, and consumption was decreased. We tried to increase the consumption of marine products, and through this attempt, we realized that we have to think about how to convey information. When we think about information, information is a kind of good commercial product. If we consider scientists as producers of information, then people who want to have information, including the fishing industries, are consumers. There should be market research in this system, so that information providers and consumers will be connected.

The scientists conduct their great research and then write papers. However, if there is no market research for selling this information, the providers cannot deliver it to the consumers. People who want to have that information cannot get it. As I mentioned earlier, there was contamination in Fukushima and Japanese people might remember that they heard a lot of technical terms on TV which they hadn't heard before. We had to explain these terms to the general public and to the foreign people who have purchased Japanese marine products. This is where market research was required. We couldn't make them understand by simply saying "this is so, and this is safe". We had to explain the situation in detail, but on the other hand they didn't know what they should know. In the end, their concern couldn't be relieved unless there was no doubt about contamination at all. They could accept only zero tolerance, which was an unfortunate situation for all concerned.

We have to remove the large distance between the people who provide the information and those who receive the information. I use the word market research, but both producers and consumers have to make efforts to understand each other. People in the shipping or fishery industry should want to have information, and we have to provide them with it. Producers of information, scientists, have to provide information in understandable ways for the consumers. By doing so, the scientists and the consumers of information can remove the communication gap between them.

In Fukushima's case, consumers and buyers of Japanese fish in the end had to, and tried to, understand more about the contamination of fish. At the same time researchers had to, and tried to, figure out how to explain the concept of radiation half-life. For example, they were able to explain the concept of half-life in comparison with the x-ray or some other things that general people have in their daily lives. Now the Arctic region has become a totally new market for us due to climate change, and totally new information should be released for people to use. As Mr. Makino mentioned, there is lots of information for the experts, but it's not something that non-scientists can understand.

People who want to use information, people of the shipping industry and the fisheries industry, just say they want to have information without knowing what kind of information they really want to have. Because of this lack, this there is a gap in terms of information transfer. I think this kind of workshop is very good for removing the gap. There is information which people want to get in terms of biology, in terms of shipping, in terms of trends and baselines. First we need to release information in these markets, and then we need to see if it is suitable for each of the markets, and make adjustments accordingly. Maybe it's like systems engineering, and I think this approach has good prospects. Here today we have many people from various academic fields, from various industrial fields, and from various sections in the government. If there is something we don't have today, it's the view of systems engineering, the perspective of looking at things comprehensively. We have various experts here, and this is like an orchestra playing a symphony. There are many players here to play each of the instruments. However, we don't understand what kind of music we should play. We don't have a conductor or a concert master in our orchestra. We have to figure out what to add to this orchestra. I think this is one of the challenges we have in this workshop, thank you.

Moderator:

Thank you. We would like to have comments from stakeholders. Mr. Otsuka if you have any comments?

Otsuka:

I'm from the North Japan Port Consultants. Let me introduce the kinds of things I have done, and the kinds of things I will do in the future. First, how can we make use of regions with sea ice? When we do shipping or oil exploitation in those areas, what kinds of risks do we have, what kinds of solutions should we have for those issues? This is the starting point of my research. The ice circumstances have changed in the Arctic, and hence there have emerged a lot of changes in terms shipping. That's why I started the study of the Northern Sea Route, where I have to think about economic impacts, types of cargo, safety, and risks. Under the framework of the GRENE Arctic project in Japan, I have been trying to develop a model of Arctic shipping to identify which routes are the safest, the most economical and time-saving, taking other research themes such as sea ice, weather forecasts, and the marine environment into consideration.

East Asia and northern Europe have been geographically very far apart, but the Northern Sea Route can make them closer. What kind of impact will it have in terms of business, politics, and any other fields? People in both regions are now interested in this Northern Sea Route. Especially, people in Norway are actively interested in the Northern Sea Route, and we have been working together with them. Since East Asia is very far from Norway, people in Norway should be curious to know what kind of policies the countries in Asia will have, and what kinds of economic and political impacts they will have on northern Europe. On the other hand, Japan is also curious to know about the Arctic, and we will visit Murmansk in Russia for a discussion about the fishing industry. Will the fish caught in the Arctic Ocean be available? Can we bring the fish caught in the Pacific Ocean to Europe, or can we bring the fish caught in the Atlantic Ocean to Asia, or to Japan? We will think about these kind of topics related to the Northern Sea Route.

Moderator:

Thank you very much. It was very valuable information and your experience is remarkable. Do you have any questions or something you want to confirm? George?

Hunt:

We have talked about commercial fishing and we've talked about major shipping of a commercial sort, but we haven't mentioned tourism. Although tourism is likely to involve a very small number of ships, these ships have a habit of wanting to go to very sensitive places, because the tourists want to see the animals or the birds or the beautiful scenery. I know there have been several problems in the Antarctic. I know that in the North of Norway, up in Spitsbergen, there is a small amount of tourism now. But has Japan thought about the possibility of having Japanese ships going up to the Arctic for tourism, and what the implications of that might be?

Moderator:

Probably this is a topic for Mitsui and Nippon Yusen, and you have very gorgeous vessels.

Goda:

Yes, what you're saying is very correct. Until last year March, Nippon Yusen had a Crystal Cruise Company – the United States Company, but we sold it to a Hong Kong Company. We heard that they will take a cruise through the Northwest Passage this summer. Actually, we originally planned that when we had that company. We now have only one vessel for tourism, which is called Asuka II. It is a passenger cruise ship. In January, it went to the Antarctic Peninsula for Japanese people, since they are very interested in visiting polar areas and we have a lot of demand. It's not necessarily a Japanese company, but Japanese customers are interested and they have a lot of demand for polar cruises.

We really understand, as you said, both Polar Regions, Arctic and Antarctic, are vulnerable in terms of the environment. There are a lot of people on the cruise ships, but in the coastal destinations, there are only small populations present. When something happens, it will cause a lot of troubles to these remote polar communities. We have to consider that. Regardless of whether there is a convention or certain regulations, as a business protocol, we need to establish appropriate frameworks; when we're doing tourism business, we understand that. As you mentioned, there is a great likelihood of cruises visiting polar areas since we have a lot of interest and demand.

Moderator:

Mr. Morishita?

Morishita:

A little bit of information. We have the Antarctic Treaty System for the Antarctic, and we have a protocol for and a convention to protect animals in the Antarctic. We also have the London Convention, and it requires a report to be made when a cruise ship enters the Antarctic. If an accident happens, it will be reviewed in the COP. In the Southern Hemisphere, each country has a responsibility for search and rescue. However, in the Arctic, these kinds of conventions or rules or regulations are less well developed compared to the Antarctic. Therefore, in terms of international laws, this should be an issue to be solved. It's not a matter only for Japan. On the other hand, each country has its own EZZ of 200 nautical miles in the Arctic. Some countries have very strict domestic rules for conservation of the environment and they, like the United States, are keen on setting such rules regarding the Arctic, whereas other countries do not. We of course do not have common regulations on international waters in the Arctic.

Moderator:

Thank you very much for your information.

Tsunoda:

Here is an example from Hokkaido. Nearly 10 years ago, in the Shiretoko area, which is designated as world heritage site, there was a certain seabird species called "Cepphus carbo". To protect this species, tourism was restricted in the area where the birds nest. However, in terms of regional development, the rule is reviewed every five years, so tourism is not totally banned. As long as tourists follow the rules, tourists can enter that area and have a chance to look at the birds. This shows we can wisely protect the environment and promote business at the same time.

Moderator:

Thank you very much.

Ishikawa:

Let me express my request. As Mr. Morishita mentioned, in the Arctic area we are in the process of establishing certain rules. There are lots of regulations for the protection of the environment when we use vessels in the Arctic, and there will be a lots of new rules. I have heard that many countries are working together to establish a Marine Protected Area (MPA). If it will be established, what kind of regulations will be included? Will tourism be banned, and how much restriction will be imposed on the navigation of vessels? Those are my interests. Especially the environmental regulations, they should be based on scientific findings. Therefore, you scientists are very close to that part and you know a lot about what kind of scientific data are used to establish such rules. Please provide us with such information in the future.

Moderator:

Thank you very much for your request. Before the coffee break, probably I can take two more comments.

Grandum:

Thank you very much. I'm not sure if I'm a stakeholder of an equal to our gentlemen around the table, gentlemen and gentle women. But from an embassy point of view, it's interesting to see the needs being well described from the stakeholders. I think we also share similar needs in many other countries. There is a need for an inter-disciplinary approach for many of these issues. Having a workshop like the one today, I think, is an excellent way of actually putting those issues on the table. Sharing data is very simple, but it can also be complicated. Coming back to Goda-san's excellent comment on the need for information, we need to know what data to share, what is available, what is not available, what is comparable and what is not comparable in order to be useful for the stakeholders. So yes, I'm a layman in this area, so I'm not sure if I can really go into details. But it's really interesting to see how you're approaching this from the needs from the stakeholder's side and also to encourage scientists to try to find new solutions to those needs.

Moderator:

Thank you very much. Ms. Furukawa.

Furukawa:

It is interesting to realize that the same kinds of stakeholders we see in the U.S. are also here, and what kinds of information to share and how to share the information are also issues in the United States as well. As a stakeholder, the U.S. has three pillars in its National Arctic strategy. One is peace and stability, the security and stability of the region. The second is responsible stewardship of the Arctic region, and the third is to strengthen international cooperation. As we engage in Arctic issues and see how the Arctic's environment is changing, we always keep in mind those three things.

On the other hand, as a stakeholder, the U.S. Navy is most interested in the sea ice. When we consider stakeholders as a consumer, we, the consumers want information of the sea ice situation and its prediction. So those are things that we're really interested in. Also, we are pursuing research on those things as well. We are on both the side of the consumer as well on the producing side, as the producer of the data. With those things in mind I think today's discussion has been very interesting. Thank you.

Moderator:

Thank you very much Ms. Furukawa. In the U.S., the same kind of discussion has been undertaken. It's very interesting. After the coffee break we will have a wrap-up session and discussion. Before the coffee break, one more comment from Mr. Fujie. Do you have any remarks, as officials from the Ministry of Economy Trade and Industry?

Fujie:

I have to leave now but I would liketo make these last comments. We talked about how to fill the gap between academia and industry. If we can have this kind of discussion, it will be very useful, and important for mutual understanding. I will try to be here on time, when this kind of workshop is held again. Someone mentioned tourism, and for our Ministry, this is one area we are very interested in, along with fisheries and the shipping industry. If there are any of our policies that can be of assistance to you, please let us know. As someone mentioned, we have to have rules in place first of all. If there is a possibility of industrial utilization of the Arctic, then I think there is room for our support in your endeavor to deepen our understanding.

Moderator:

Thank you very much. So during this session we have received comments. We will now have a coffee break. The last session is a wrap-up session. So, it will resume at 3:40.

(3) – Future perspectives

Moderator:

Thank you very much for returning. We will start the last session. Now we will summarize the discussion which has taken place, and then we will ask for your comments and opinions about what

- SHとして、必要な基礎データ、欲しい情報はいろいろある。

We can identify the data needs and data gaps

→ 沿岸漁業データ、海氷、波、渦、それらの予測、国際法・規制・MPAのうごき、資源量評価、魚種分布変化予測、そのメカニズム、ツーリズムのうごき、など。(Catch data by local subsistence fisheries, sea ice, wave, eddy, their forecast, international regulations, resource assessment, fish distribution, their mechanisms, eco-tourism trend, etc.etc.)

・情報は商品。エンドユーザー（SH）のマーケットリサーチが必要。

Information is a commodity, therefore the market research is indispensable

１）SHにとって重要な情報が散在。ビジネスに必要な情報をまとめてみられるような仕組みがほしい。Information is dispatched in society. We need some platform to summarize them.

２）学会内の"常識"を社会にもっと頻繁に分り易く伝える場と工夫がほしい。

The common sense in academics is not that in society. More frequent communication or outreach is needed.

３）情報利用者側と情報生産者の双方の努力が必要。

Both the information users and information producers need efforts.

・米・諾でのSH会議でも類似した内容が指摘されている。

Similar discussions are observed in US and Norway

今後の展望: Perspectives

- SHにとって重要な情報をどう特定するか？SHの間の差は？

How to identify the important information for each SH?

- SHにとって分り易い形式をどう特定するか？分り易いとは？

What form is "understandable" for each SH?

- SHとの連携可能性（モニタリング？）

Possibility of co-working with research and SH (monitoring?)

- メディアの役割・使い方

Role of mass media, and how to use it.

- この会議の成果のフィードバックのあり方。つづけ方（順応的）
- How the outcome of this SH meeting should be feedbacked? Our adaptive capacity.
- 研究資金の調達（Funding）

could happen in the future. Thank you very much for your attendance today and results of today's discussion have been summarized in one slide.

The first point is that stakeholders from various sectors have participated and shared their information. We have identified data needs and data gaps as well as what kinds of basic data are useful, what kinds of data are lacking, although the details are still quite vague. For the first stakeholder meeting, I think this has been one of good, fruitful results. Based on our results, I think we can come up with researches more beneficial to stakeholders in the future.

I have listed some of the topics we discussed today. Statistical catch data from local fisheries in the Arctic areas were requested, and some people claimed that sea-ice wave and eddy forecasts is necessary. There is a need for data on resource assessments and fish distributions and the mechanisms controlling these natural responses. Regarding tourism, needs of each nation and what kind of tourism is actually being operated right now were also discussed. This is just a list of what was discussed. What is important is, as Mr. Morishita said, that information is a product and researchers are producers of this information. Therefore we need to do market research to make the product beneficial to consumers such as stakeholders and the public, not just limited to Japanese citizens. If I may comment further, important information spreads out in society and we need some platform to summarize it so that stakeholders can get all the information they need for business. Then, what information is important for each stakeholder and how does it differ among different stakeholders?

There should be a place where common knowledge in academia is also provided for stakeholders in an intelligible way. More frequent communication or outreach is needed. It was mentioned that both the information users and information producers need efforts to understand each other for the sake of better communication. What was most impressive for me is that in Norway, and also in the United States, similar discussions have been done at stakeholders' meeting. It was indicated by Mr. Huntington and Ms. Furukawa. This is just an overall outline of what was discussed. If there are any items that you feel that we should include on this list please let us know. Thank you.

Ishikawa:

Today this was a very useful, valuable and a good opportunity for us, as stakeholders, to give comments. What I realize is that most of the stakeholders present here today are from the business side. If we want to start a business in the Arctic, discussion is indispensable among the general consumers, the environmental conservation organizations and stakeholders. Very sensitive issues are involved in this particular area. This kind of forum was a good opportunity to meet with other stakeholders to get their valuable information. That was a good point.

Moderator:

Are there any other comments?

Drinkwater:

Ken Drinkwater from the Institute of Marine Research in Norway. One thing that we haven't talked about at all today is funding, and I hate to bring it up but the Arctic and northern latitudes are areas that are very expensive in which to collect the data that everyone wants. Hopefully, governments are doing their bit. But I was wondering, if in terms of the businesses, if there's anything that perhaps could be done. As George had mentioned to me, even a strong voice to your governments emphasizing that you really need these data would put a little bit more pressure on governments to help with the funding.

Moderator:

Thank you very much. So that was about funding. It should be discussed under future perspectives, which will be taken up later. Any other comments or anything that you feel a need to raise right now? If there are any – yes, please. Huntington?

Huntington:

Two things struck me: one of which is up here and the other which may not be. One was, that Mr. Matsuo pointed out there's a big difference between catching a fish and selling a fish. And I think the same is true in science. There's a big difference between producing science and consuming science, and Yoko Furukawa made that point as well.

Most of us in academics are used to producing science, we're not really used to the consumption end and perhaps that's like catching a fish, coming close to land, throwing the fish up on the beach and saying, "There," and wondering why nothing else happens. So I think that, as Mr. Morishita had said, there's a distance we have to narrow. On our side, we can pay more attention to the consumption of science, not just the production of science.

But the other thing Mr. Sagawa had said that referred to the trial and error in learning how to provide information that people can use. I don't know if that expression is the same in Japanese, but certainly in English, trial and error has two parts. First is trial. You have to try, so it's important to try. The second part is unfortunate because it's error. And if we just do it, trial and error, then we end with error and probably if we do it again, we may still wind up in error but we have to keep doing it until it becomes trial and success. So, I think it's great to have a discussion once- but I hope we can do it again and keep doing it until we can move from the repeated error into that kind of success. I really appreciate everybody here, I've learned a great deal today and I really appreciate all of the comments and the insights from everybody around the table. So thank you very much.

Moderator:

Thank you very much, Alan.

Haynie:

Alan Haynie, NOAA Fisheries. Yes, thank you all for all the interesting comments and questions. It's wonderful to be able to talk to all of you. To talk a little about process, I guess I have a couple of comments about some experiences that I have had. Henry Huntington, George Hunt, Franz Mueter, Seth and I were all involved in this long-term Bering Sea Integrated Ecosystem research program. You could argue about how long it was, a six or seven-years long project, where we conducted a lot of ecosystem science. Henry and I were both involved. I'm an economist and Henry is an anthropologist. We saw this range from oceanographers to social scientists.

It was really this process of meeting to discuss our work, again and again in a project, where we really got to understand the way that people think about problems, the data that they use, the modeling approaches. I really encourage this approach for these types of problems, to set up the kind of an environment where you have long-term relationships, where you have time to learn things. Connected to this, in the United States, we have another process, and you can tell me if you have anything like this in other areas in Japan or in Norway, but we have a Fishery Management Council process. In Alaska, there is the North Pacific Fishery Management Council, where the representatives from industry, from government, from other stakeholders sit on the council; they are appointed by the Governors of the states of Alaska, Oregon, and Washington, as well as by the federal government. They make many of the management decisions for fisheries in the federal waters of Alaska, they function like a legislature for fisheries, but they' re constrained by the laws of the United States so that there is a scientific process that' s very formal. One of the things that' s very good about this system is there's a standard process by which a proposal is put forward; we have annual reviews of the assessments that the public can see and make comments on. Over time, many members of the public have become incredibly knowledgeable and sophisticated in knowing what data are important to them and what kinds of questions to ask of scientists. We think it' s really an incredibly well-functioning process through which scientists can' t go away by themselves and have secrets. Everybody has to air their dirty laundry and the public can – I don' t know what that means if you say that in Japanese, but, we have this process where you can really improve the models on which we make fishery management decisions, and anyone can raise public comments and there's a lot of transparency to the process. I think these are a couple of examples frrom my experience with having this type of long-term communication that has worked quite well. Thank you very much.

<u>Moderator:</u>

Thank you very much for comments from all of you. We would like to discuss on those comments. First, as Mr. Huntington says, there are gaps between people who get the information and produce information. Important information is different among researchers and stakeholders. What form is understandable for each stakeholder? How do we bridge the gap? I think this is one of the very important topics for us.

As Mr. Huntington or Alan said in their comments, we need to talk about the feedback of the outcome of this stakeholder meeting. How can we strengthen our relationship between the researchers and the stakeholders? As Mr. Ishikawa pointed out, how can we reflect the opinions from general public and stakeholders? How can we send out the outcome to society and the stakeholders who are not sitting on this table and get a feedback from them? We need to think about role of mass media and how to use it. If we have extra time, we would like to also talk about how stakeholders and people from business world can contribute to our research. If we put a CTDs on vessels, we can obtain a lot of data. Regarding the fishing industry, along the coast of Japan, we have 200,000 fishing vessels. These vessels provide statistical data of fish catches which serves as basic information when thinking about shifts in the ecosystems. People on business side have a lot of important data and we can analyze it and conduct researches based on it. Therefore it's a very important for us to work together.

Now we have five topics here as future perspectives. First I would like to have comment from you on this overall agenda. Then we would like to have a comment on each topic. Mr. Morishita, please.

Morishita:

Thank you very much. Maybe this is a concept to cover all of those topics. Mr. Huntington mentioned "trial and error". More precisely, I have an image of adaptive management, an adaptive approach, a spiral image with multiple trials and decreasing error, rather than mere repetition of trial and error. This kind of business or research is necessarily accompanied by a lot of uncertainties, which is not an issue only pertained to the Arctic. In addition, since we don't understand each other enough, we have to communicate with each other and adjust ourselves sometimes.

In such case we had better not aim for A plus from the beginning, but we have to start from D or C, and then we should try to reach C plus and then B minus. In this way you have to repeat the same thing again and again to improve, which I think is a very important process when we do this kind of thing. Concretely speaking, for example, when you try to give feedback and you fail, you might think you need to adjust. Though this is an important approach, it is also very important to set objectives or goals first. Then we can set-up indicators accordingly, and we monitor and evaluate them, and then re-evaluate the indicators and in this way we improve little by little.

It is not easy to figure out what information we should seek or what form is understandable for each stakeholder. It is very difficult question; we cannot get a correct answer only for a short time. It might be either trial and error or adaptive approach, but anyway we need time to come up with the solution. Probably the goal will be changed on the way. In this way we need to have a concept to cover all of these things. Then it will be easier to see the whole picture.

Moderator:

Thank you very much. I am a bit surprised at your opinion that it is a matter of how we can be more adaptive and resilient. Mr. Morishita's opinion is about bullet one and bullet two. We can discuss on those two points at once. There is a difference about intelligibility of information between stakeholders and scientists. The problem is how we should cope with it. How people prioritize the information is different among industries too. He mentioned trial and error and it's very important to keep on repeating and learning. Any other comments on this?

Hunt:

As a teacher, I knew that I had to give my students some information before they could ask good questions. And I think that's true for the communication we need here, that both sides have to learn the language, and the vocabulary of the other side, and learn how to ask for information as well as to give information. And so, when industry or the public comes to the scientist, the more they know about what we do, the better their questions of us will be. The more they can extract from us. And likewise, the more we know about the problems faced by industry stakeholders, the better we can say, "Oh, we know something about that." And we don't spend time on things that are irrelevant, but we find the ways to cope. So, both sides have to educate the other about what they need and what they have to offer and that takes dialogue and I think that's really a very valuable part of what has happened here. Thank you.

Moderator:

Thank you very much. How about a comment from the stakeholders? I want to ask Mr. Sagawa from Weathernews.

Sagawa:

Let me repeat what I said. What we do is not just provide information but support decision making. If you look at things from this point of view, it will be easier to understand. From a long-term perspective, shipping companies have to decide whether they will send ships to the Arctic in next summer, and from a short-term perspective, they have to decide which route to take and when to send a ship, what to do tomorrow or day after tomorrow. We need to provide information which support these kind of decision makings, whether they can send a ship or not. Otherwise they cannot know what to do even if they get a good picture from sattelites. As for fishery, we don't provide a lot of services to fishing industry but I guess they need information on when and how much they can catch fish.

Moderator:

Thank you. Go ahead, Mr. Saitoh.

Saitoh:

I would like to talk a bit about providing information to the fishery industry. Basically we provide the information to fishermen to support their decision making. There are roughly two types of fishing: offshore fishing industry and aquaculture. For those engaged in the offshore fishing, it's important to know when and where to fish and how much they can get. Therefore how we express and explain this kind of information is very important in turn.

For example, in the scallop culture business, the 20 degree threshold is very important for scallop culture. If the temperature go up over 23 degrees, the scallop will die. So we put orange color on a chart for water temperatures at 20 degrees centigrade and red color at 23 degrees. This makes it easier to notice when it reaches 20 degrees, and they can know it is very dangerous if it reaches 23 degrees. I think it's very important for us to communicate in this way, for example.

Tsunoda:

I think it is very important to have people like Mr. Saitoh and Mr. Sagawa here, who are engaged in this kind of business. However, when we think about services which Mr. Saitoh and Mr. Sagawa are providing, in which they translate information so that the public can easily understand it, and which are well-established as business, should scientists necessarily plunge into this field? We have to split up the work, otherwise private sectors would be squeezed.

People engaged in this kind of business might draw out very useful information from scientists through good communication with them. On the other hand, though it is not useful in terms of business, there should be some important scientific data which should be made public

Moderator:

Thank you very much. Any other comments? Mr. Nishimura, please.

Nishimura:

Intelligibility of information depends on who is the stakeholder, or who is the user of the information. Aside from this matter, I would like to talk about one example. There is a system called "Ecolabel", and I often ask consumers various questions about this, such as "is this brochure easy to understand for you?" Like this, we ask the representatives of the public to look at the information we provide. We tend to use very simple words, but sometimes it makes things even more difficult. In such cases, technical terms are rather preferred. Therefore sometimes we should directly ask the public or consumers for their opinions.

Moderator:

Thank you very much. Any other comments?

Matsuo:

I'm Matsuo from ARCS Group. When we think about information and business, the priority is on information. With information we can make decisions about business. Weathernews attends various kind of meetings. Sometimes people do not know what can creates business, but through these discussions they are seeking new businesses. When it comes to the Arctic, people sometimes think that only coastal states which can catch fish are relevant, like Norway, Denmark, Russia and the US, and they tend to think Japan is not relevant. However we should think what kind of business in the Arctic Japan can be involved in. First, we need information and then we will decide. For example, we have some unfamiliar fish from Ethiopia that we are trying to sell, a rich resource of fish. If we can be successful in selling this, it can be a good business. However without information, people just think we have a weird fish here and they will not buy it. Hence we need information first.

Moderator:

Thank you. Yes, please.

Goda:

I'm Goda. I have two points I would like to mention. Information is a tool for decision making, which we buy from Mr. Sagawa's company. In this case users know to some extent what they are buying. In our business sector, it can be expressed in terms of money.

Let me present two examples. First one is, when the IMO approved regulations on emissions of SO2 and NO2 from ships, the relevant people in our company reported to the head of their sector what was being discussed at the IMO. The head was provided the information on the regulations that SO2 must be lower than this percentage or NO2 must be under that percentage. However he was originally from the sales division and he didn't understand it at all. This information means that, for example, the heavy oil with high SO2 could not be used as fuel oil anymore and we had no choice but to use light oil which cost twice as much. Unless we translate the information in this way, people of the sales division could not understand what these regulations really meant. In such a case, who should be the translator to convey the information? Internal people or external specialists, that's the question.

The second case is about the Asuka II – during the discussion today there was a proposal that the measurement tools should be attached to the Asuka II cruise ship. There was a proposal of the same kind once from JAXA. They wanted to inspect or improve the artificial satellite catching signals from AIS. For this purpose they wanted to get the information which vessels were sending. During the discussion with JAXA, we knew what can be done with the satellite: it could get images from all over the world, from wherever you like. I told them, "then please sell us those photos taken by the satellite. We will pay; it's far cheaper than we actually travel there to get that information" Later they told me that they never expected that we would talk about paying money for the information. They never imagined that their technology could create money. I'm not really sure which side should come closer to the other side, science or business side, or even someone else in-between. This is another case.

Moderator:

Now he mentioned money. Even if researchers do not think that their information is worth money, it can be very valuable from the viewpoint of business. Then let's talk about funding. We have not so far discussed money, funding. It's also relevant to the continuation of these meetings, conferences. About funding, do you have any ideas or comments? How is the situation in the U.S. or Norway for funding for research?

Drinkwater:

A lot of our funds in Norway are through the Norwegian Research Council, and they put out calls for proposals, for example for Arctic work. Scientists at the universities or independent groups, or ourselves at the Institute of Marine Research, which is government funded, can all apply. The funding has been relatively good, I would say. With the downturn in the oil, Norway's hurting a little bit but we're still doing relatively well. I think we can always do with more funding. There are certainly lots of problems out there to solve, there's lots of data to be collected and we do need funding for that, and also, for meetings sometimes, including meetings between businesses and stakeholders and scientists. As I say, we can always do with more funds.

Moderator:

Does anyone have a comment from the U.S.?

Mueter:

Yes, thank you. For the U.S., I want to give one example of the funding of applied research. I work in fisheries, of course, and there are a number of different funding agencies that may support fisheries research, but much of the research in and around Alaska in fisheries has been funded by a non-governmental organization that has a very applied focus. And that organization, and many other organizations, have in recent years put a strong emphasis on outreach, on producing products that are relevant to stakeholders and end users. It is often a requirement of a grant to include outreach products. I think that has helped to address some of the problems and questions that have come up here today, that there is a need to bridge that gap between industry stakeholders and academia. I think that is a potentially good mechanism that funding agencies put more emphasis on outreach, on making research relevant to the end users, and that could be a way to help bridge that gap.

Moderator:

Ms. Furukawa, please.

Furukawa:

In the U.S., funding agencies are often stakeholders at the same time. For example, the US Navy and the fishery industry often fund Arctic research or fisheries research in order to collect data. We fund a lot of research on sea-ice and physical oceanography, for example, because we need those data. And perhaps a lot of outreach too. People who live in the area, they need to know what's going to happen next winter or next summer. Therefore they're a part of the decision making in what kind of studies they want to fund. Perhaps, it goes back to how to share the information with the stakeholders. If the stakeholders are also part of the decision-making in what kind of studies to fund, then that relationship will get a lot easier.

Moderator:

Thank you very much. I wanted to mention the same kind of thing. The stakeholders, the general public, and the business sectors all pay tax. Those funds are given to public organizations, research institutions and universities to conduct research. Since JST or MEXT (Ministry of Education, Culture, Sports, Science and Technology) allocate those taxpayers' money, taxpayers have the right to claim this research is important or that research result is useful. If their voice reaches the government, the government can decide which research proposal to accept based on it. If this kind of system is explicitly established, it might be interesting. Now in the end, the every topic can lead to this point. How can we effectively get the feedback on the outcome of this meeting and how can we adaptively continue and improve it? We also need to improve relationships, contents of research and environments for research. In the end, it will lead to enhancement of the sustainability of human beings. So far we haven't discussed the media roles. Is there somebody who want to speak about this? Alan, please.

Haynie:

Just a very quick comment that at NOAA, we have recently recognized that it's important to take the research that we're doing and help the public know more about it. I think that's happening in different science organizations and universities around the country. We are using Facebook and new, different types of new media, just to get the message out, and so we've hired communication specialists to make people more aware of our science.

Tsunoda:

Thank you very much. Regarding the recent symposium on ocean acidification, there was a representative from the media as a panelist. He said that it's difficult to understand scientific things but although it's difficult subject to understand, it's important for scientists to state what can be understood in a very understandable manner.

Moderator:

The role of media or their responsibility is to communicate difficult topics in a very understandable manner. Regarding how to utilize mass communication to our advantage, Mr. Kikuchi, I think you have many experiences in working with the mass media, both good and bad.

Kikuchi:

For us, JAMSTEC, the end is not that we publish a thesis, but that we use the media to issue a press release on papers. However there is a difference between what we think is scientifically important and what they think is important. Therefore before it goes public, the media may make a judgment about its worth. In this sense they are the first filter about which study to publish or not, and whether the paper will reach the people who need the data or the information. In this respect, I don't know how it should be done but we need a mechanism or scheme by which we can share information.

For example, it has been reported recently that the river ice has been reduced in the Russian Arctic rivers. Rivers in the Arctic are very useful for local people; they use the river for water transportation in summer whereas they use the frozen river like roadway for transportation in winter. However, the breakup of ice creates floods in spring. In either way rivers mean a lot to the local people. Researchers of JAMSTEC issued a press release on this earlier melting of ice but at this point it has rarely been picked up by the media. Maybe sooner or later the data might see the light of day, but even if we are doing something which can contribute to people's life, we cannot be sure if it will go public through the media. Therefore we need to consider the mechanism to exchange information. I think direct communication with recipients of information is better, but we need to think of a way to use mass media to our advantage as well.

Moderator:

How should we handle the mass media? Any experience? Mr. Morishita.

Morishita:

We tends to just sum them up as mass communication, mass media, but there are different types among them. Some of them deal with science information, such as general newspapers and TV. Scientific journals like Nature or Science, specialized journals, also have general readers and in this sense these journals can connect the general readers with experts. Unlike the social media, they have no accountability for the information once it is released but this can be a means to provide information.

Therefore I think it depends on how we use these means. If you take that I' m talking about top journals as the best, it' s misunderstanding, but they have to sell copies, subscriptions, so they go after major discoveries. They tend to pick up very big one, but they don' t like very good news and they have screening as to what to publish. Mass media is not homogeneous in total. We have to be sensitive to their attitude and need, and we have to accordingly adjust the way we use the mass media. I think we have to get to know them well in order to utilize them to our advantage. In this way we can improve the way to release information through the mass media. You can explain your long important paper to famous newspaper but they might spare you only five lines. They can give you just a few lines but if there's a major news going on domestically then your article ends up in the wastebasket. It' s the reality and we cannot help it. We have to understand it and act accordingly.

Moderator:

Thank you very much. Now we have a representative from the Ministry of Land, Infrastructure and Transportation and Tourism. Can I ask you to introduce yourself?

Hayakawa:

I'm from Ministry of Land, Infrastructure, Transport and Tourism, Hokkaido bureau. My name is Hayakawa. Right now we are interested in the Northern Sea Route, because it makes Hokkaido the closest prefecture in Japan to Europe. I' m in charge of port-related things and that is why I'm here. However since we have had a snow storm, the train I was supposed to take was canceled. Before the Northern Sea Route, I have to study about snow first.

Moderator:

Thank you very much for coming to Hakodate, despite the bad weather. Any other – I think we have covered various topics already– one more, Ms. Chi?

Chi:

It's also very important that we let our students and young people know about the Arctic and all the stuff that we talked about today. We should venture to use other types of media like podcast for instance. In my class I use a lot of videos and documentaries and even Youtube as teaching materials. These kind of media attract young people' s attention. For instance when I talk about the Arctic Council in my class, none of my students know what it is. It' s not because they are not interested – it' s just because there is not much coverage at all about the Arctic or the Arctic Council. If we want people to be interested, we need to make that input, especially for younger generation.

Drinkwater:

I think we all agree that we've had a really good discussion here and I certainly want to thank Saitoh-san and his colleagues for putting it together. But one thing, I think we also all agree is that this really should just be the start. At the present time we don't have a mechanism for continuing this, but hopefully, one will be found. But there is something that is a part of this project that we will do. We will develop a stakeholder summary and it will address some of those questions in the perspective. Our idea is not for us to produce this alone, but to do it jointly with the stakeholders. So, I hope that a number of you, or maybe all, will get involved in producing that, so that we really do have a document that is understandable to you, that has the important information that you want; and as I said, we cannot do that as scientists alone, but it needs to be a cooperative effort.

Moderator:

Thank you very much. This workshop, including this meeting, we expect to continue this stakeholders' meeting and we will provide feedback, so we can improve our means of communication. We will not hurry to come to any results, outcomes of this meeting. Lastly before we close, Belmont workshop co-leader, Franz Mueter, do you have any last comments to make?

Mueter:

Thank you for the opportunity to comment. First, I would like to thank all the participants here for your contributions. This is one of the first times I have participated in this kind of forum, and it has been a great learning experience and very informative. I have one quick follow-up on one of the major themes here that has emerged, that is about bridging the gap between industry and academia as somebody put it.

The one point I want to make is that as scientists, we gather a huge amount of data and information, and it's a challenge for me to keep up with the data and the information generated in the narrow field of fisheries. So as scientists, we constantly struggle with how to deliver new information and data to users. I think maybe more important than sharing the information and the data is a sharing of knowledge; we really need more derived products to inform or to share with stakeholders and end users. Maybe the experience of the North Pacific Fishery Management Council could again provide a little bit of a template for how that can be done. As several people here mentioned, the important part is communication. In the council process, there is a constant ongoing dialogue between the stakeholders, industry, and the scientists; people meet at least five times a year or more.

The sharing of information and knowledge at the council is a very intensive process, but it has been very instrumental in figuring out some of the ways in which the huge amount of information that is generated by scientists can be communicated to the end users and to the stakeholders. As one example, we have for a long time now reported on findings from the scientific community on how the ecosystem works, or what we understand about the ecosystem. That has been a process that has been developed over probably 20 years now, through a document that has evolved from throwing in all the information that we gather to something that is a lot more targeted now. Through a very iterative process over many years, we have settled on a number of important things to monitor, and how to summarize those, and how to communicate those to the stakeholders. That's been a very long process, so again, we are just at the beginning here.

And that's just in the fisheries arena. So we are at the beginning here of figuring out some way to make that happen, but clearly communication is the key. Thanks again for all the great ideas.

<u>Moderator:</u>

Thank you very much. We have had a lot of discussion, so finally in the future, in Japan, as Franz said, we would like to have this kind of opportunity at least five times a year, also making use of other funding, to create opportunity for us to meet and work together. We will have a meeting in Alaska next year, but we would like to have this kind of meeting here, step-by-step, with our stakeholder in Japan, we would like to work together with stakeholders in Japan. And if we have this kind of opportunity,

please join us. Now I would like to conclude this stakeholders workshop. Thank you very much for participating today, thank you.

3. RACArctic Science Meeting

3-1. Abstracts

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Mitsutaku Makino: Fisheries adaptation to Climate Change: Case of the Shiretoko World Natural Heritage

Amber Himes-Cornell and Stephen Kasperski (presented by Alan Haynie): Assessing climate change vulnerability in Alaska's fishing communities

Henry Huntington: Vulnerability and Resilience in Alaska Coastal Communities

(1) Climate, Physical Oceanography, Nutrients

Sea ice-ocean modeling analyses of shelf-basin interaction and biological production in western Arctic

Eiji Watanabe

Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokosuka, Japan

Seasonal and interannual variability in biogenic particle flux was revealed by the multi-year bottom-tethered sediment trap moorings in the Northwind Abyssal Plain (Station NAP: 75° N, 162° W, 1975 m water depth) of Chukchi Borderland. The trapped sinking flux of biogenic particles had an obvious peak and the major component of diatom valve flux was sea ice-related species Fossula arctica in August 2011. On the other hand, the observed summer particle flux was considerably smaller in 2012 than those in 2011. In this study, sea ice algae component was newly incorporated into the lower-trophic marine ecosystem model NEMURO, which represented pelagic plankton species (i.e., diatom, flagellate, and copepod). Seasonal experiments with a pan-Arctic sea ice-ocean model COCO demonstrated reasonable spatial distribution and seasonal transition in ice algal productivity during the summer season. The combined observational and modeling analyses indicated that the suppression of sinking materials was attributed to the extension of oligotrophic Beaufort Gyre water toward Station NAP.

Early-winter peaks of biogenic flux were also detected by the sediment trap measurements at Station NAP. In the model simulation, the higher sinking flux was located in the southern Canada Basin, where shelf-break eddies originating in the vicinity of the Barrow Canyon traced along the anti-cyclonic Beaufort Gyre. The primary and secondary production of plankton still continued inside these eddies even after their separation from the Chukchi and Beaufort shelf breaks. Warm eddies generated in late summer had greater contribution to sinking flux compared with cold eddies produced in early summer. Sensitivity experiments suggested that eddy-driven transport of shelf-origin nutrient and biological materials toward the Canada Basin was promoted by the enhancement of shelf bloom and eddy generation in less sea ice condition.

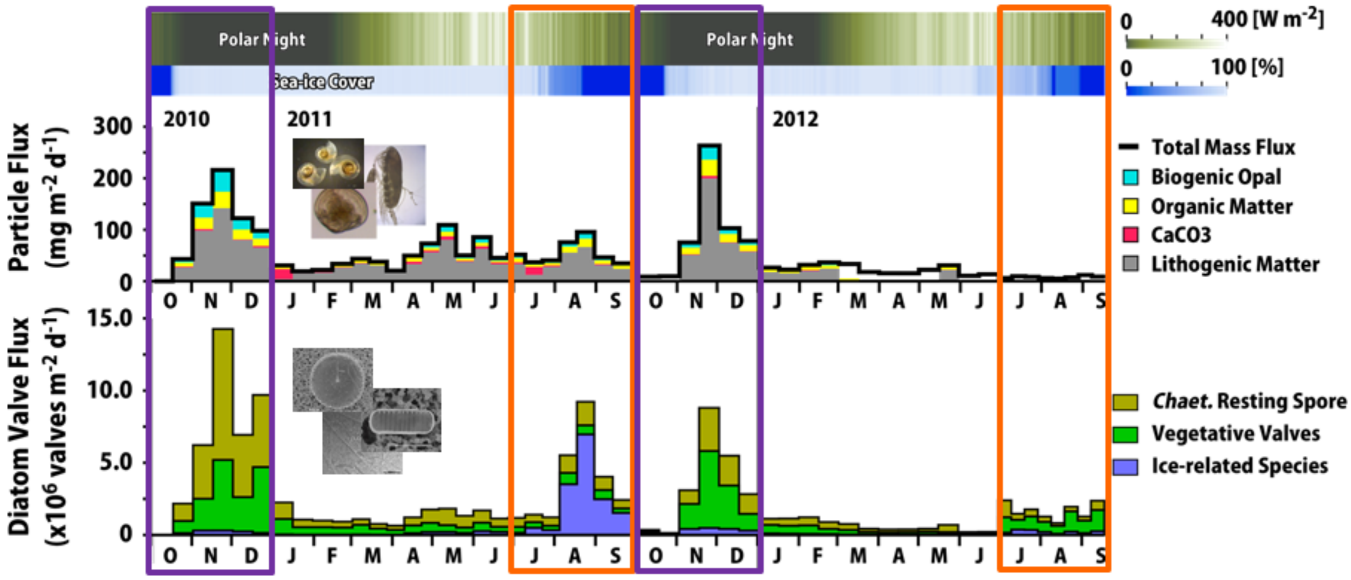

Figure 1. Time series of sinking fluxes of total particle and diatom valve at Station NAP

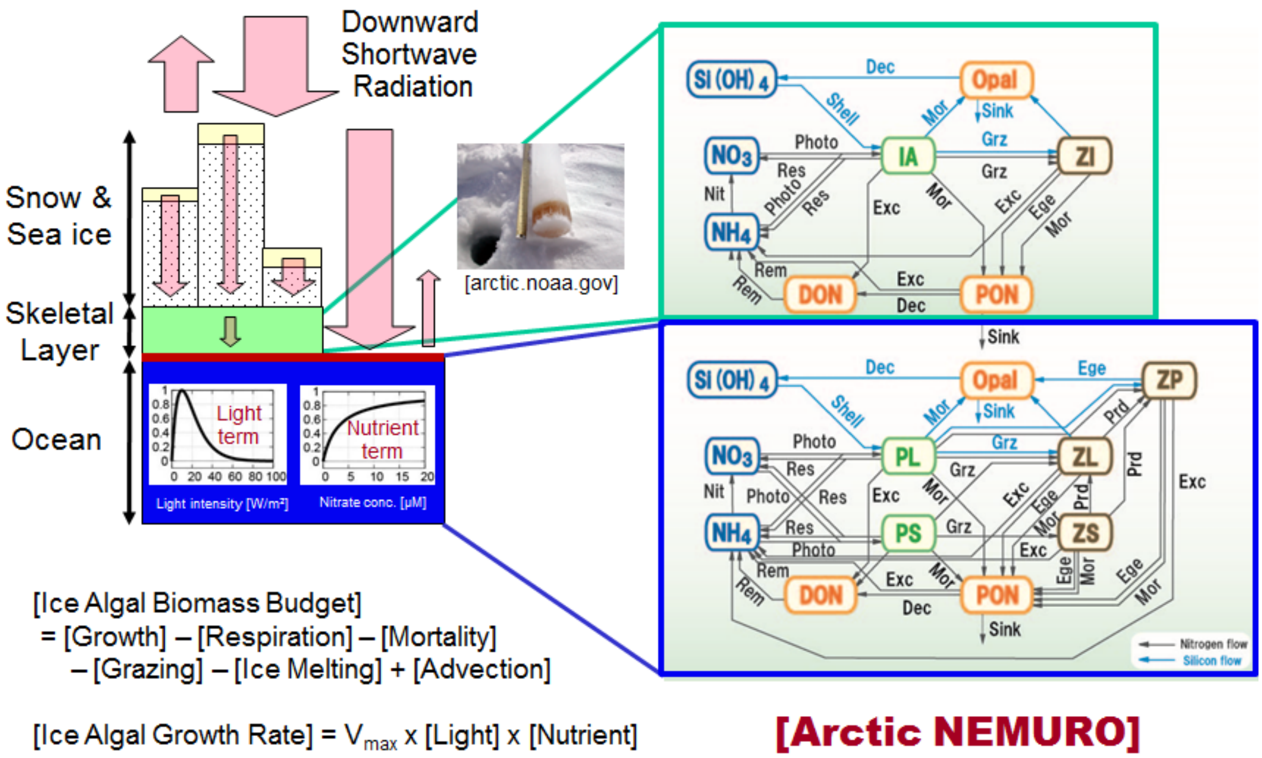

Figure 2. Configuration of Arctic NEMURO model

Oceanography of the North Pacific and Pacific Arctic: A mechanistic view of atmospheric drivers, oceanic pathways & change through time

Seth Danielson
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College of Fisheries and Ocean Sciences
University of Alaska Fairbanks

The Arctic is intimately connected to lower latitudes by atmospheric pressure systems that evolve over synoptic, seasonal, and multi-annual time scales. Seasonally, the synoptic weather patterns manifest as the Aleutian Low, the Beaufort High and the Icelandic Low during the boreal winter and the Azores and North Pacific High Pressure systems during summer. The wind fields and related atmospheric drivers exert dominant control over Arctic and sub-Arctic regions through their influences on storm tracks, wind stress, wind stress curl, air-sea heat fluxes, water column stratification, and terrestrial fresh water runoff. Fundamentally important to the Pacific Arctic sector ecosystem, the steric Pacific-Arctic pressure head drives a large (~1 Sv) and nutrient-rich flow northward through the Gulf of Anadyr to the southern Chukchi Sea via Bering Strait.

Forty-five years of hydrographic monitoring in the Pacific sub-Arctic reveals a depth-dependent increasing temperature trend of 0.5-0.8 °C and opposing trends in salinity near the surface (freshening) and near the seafloor (salinization) [Kelley, 2015]. Together, these observations show that the shelf waters have become more stratified over time and they suggest that the nutrient supply from below the mixed layer into the euphotic zone has decreased.

Coincident with the warming temperatures, Arctic sea ice extent has decreased over recent decades, with seasonally smaller sea ice areal extents and annually fewer days of ice-cover in many locations. In addition to earlier break-up and delayed freeze-up, we also find (Figure 1) that the duration of the ice melt and ice freezup seasons have shortened by 30-40 days each [Danielson et al., 2017]. While we know that the marginal ice zone is important for primary producers and upper trophic level foragers, it is not clear how this multi-decade adjustment in transition rate from 100% spring ice cover to ice-free conditions (and vice-versa in the fall) impacts the ecosystem.

Other observations of the sub-Arctic and Arctic shelf systems show that changes to the system extend far beyond impacts of temperature. For example, we note suggestions of an increased Bering Strait throughflow (and presumably nutrient flux) over 2001-2011 [Woodgate et al., 2012] but it is not clear if previous decades also exhibited similarly elevated transports. The shelf circulation responds strongly to winds on both synoptic and multi-annual time scales [Danielson et al., 2014] and the changes in the Bering Strait throughflow are likely related to alterations in the wind field [Woodgate et al., 2012] that may reflect a transition to a "new normal" or may represent only a temporary shift of this ever-evolving system [Wood et al., 2013]. The observed physical changes can also be traced to bottom-up forced responses of the marine ecosystem (e.g., Coyle et al. [2011]) that are likely consequences of thermal, hydrographic structure, and advective influences.

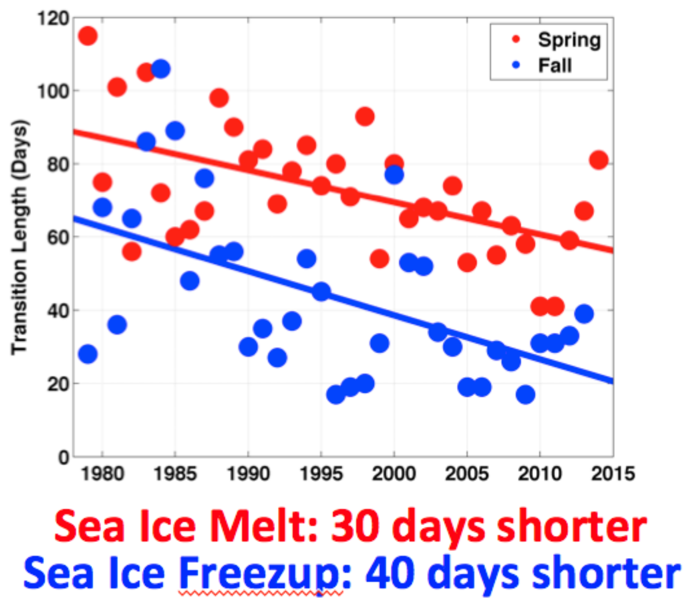

Figure 1: Duration of the seasonal transition from 80% sea ice cover to 20% sea ice cover during the spring-summer melt season (red dots) and the transition from 20% ice cover to 80% ice cover during the fall freezeup season (blue dots) for the northern Bering and Chukchi sea continental shelves. Reproduced from Danielson et al. [2017].

Observations of higher rates of surface temperature increases in the Arctic document the phenomenon of "polar amplification" [Polyakov et al., 2002]. Climate projections suggest that an accelerated hydrological cycle (manifested as increases in precipitation and coastal runoff), continued sea ice retreat, an altered state of ocean acidification, altered wind fields, and altered sea surface elevations and sea level elevation gradients may all play a role in determining the future species composition and abundances of the Arctic and sub-Arctic marine ecosystems. The trajectory of climate change triggers a cascade of complex physical, chemical, and biological interactions. Conceptual models of ecosystem response can help guide our thinking about potential future ecosystem responses, however the unknown and likely non-linear feedback mechanisms and tipping points will quite possibly push us toward a future that today we can not well anticipate. Future Pacific sector productivity in the Arctic depends critically on the volume and nutrient flux through Bering Strait. Identifying sources of vulnerability, resilience, amplifying feedbacks, dampening feedbacks, and tipping points will provide us with tools to better anticipate and prepare for the future.

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Physical and Chemical Oceanography plus Climate, includes Nutrients and Ocean Acidification – Atlantic Arctic side

Randi B. Ingvaldsen and Melissa Chierici

The presentation gave a brief description of the region with focus on large scale patterns and multidecadal variability, changes since the 1970s, processes important for ocean acidification changes, and expected future changes. The region on the Atlantic Arctic side consists of the Norwegian, Greenland and Barents Seas, including Fram Strait. While the Norwegian, Greenland and Fram Strait are deep basins/straits, the Barents Sea is a relatively shallow (average bottom depth 230 m) shelf sea (e.g. Drinkwater et al., 2014). The main water masses in the upper ocean in the study region are Atlantic Water, Arctic Water and coastal water. Below, intermediate, deep water and outflow water from the Arctic Ocean dominate. Advection is an important issue in the regions, as this brings warm, salty, nutrient rich Atlantic Water into the study region. There are Arctic/Polar Fronts separating the Atlantic Water from the Arctic Water both in the Norwegian Sea and the Barents Sea.

Long-term changes in ocean and atmosphere

The Atlantic Multidecadal Oscillation (AMO) is manifested as a long-term variability in SST in the northern north Atlantic (Drinkwater et al., 2014). Represented as anomalies from the mean, it reveals pronounced warm and cold periods in addition to a general warming. AMO show variability with periods 60-80 years and is caused by changes in the Atlantic Meridonal Overturning Circulation (AMOC). It impacts air and sea temperatures (and sea ice cover) in the northern north Atlantic. Paleo proxies indicate this variability has extended back through the Holocene. The North Atlantic Oscillation (NAO) is the dominant mode of atmospheric variability in the north Atlantic. The NAO phases determine (to a large degree) the storm tracks towards the European continent. The NAO is determined by the strength and location of the Icelandic Low and the Azores high. Changes in strength of these causes changes in strength of westerlies in the Norwegian and Barents Seas (high and low NAO) while changes in locations cause's changes in storm tracks.

Observed changes since the 1970s

Focusing on observed changes since the 1970s, there has been a general warming in the 50-200 m depth layer, a substantial decrease in winter sea ice extent, and a northward movement of the Polar Front in the Barents Sea (Johannesen et al., 2012; Ingvaldsen and Gjøsæter, 2013; Smedsrud et al., 2013). In the Barents Sea there has been a general temperature increase of about 1.5oC, most of the area has become completely free of ice during summer, and the area covered by Atlantic Water masses has increased while the area covered by Arctic Water masses has decreased. Changes are also observed in salinity and nutrients, and since the early 1990s silicate has decreased while salinity has increased (Rey, 2012). The salinity/nutrient changes are related to the relative portion of western and eastern source waters of northeastern Atlantic origin, which in turn is related to the Subpolar Gyre, which again is related to the NAO.

Substantial changes are also observed in the ocean CO2 system. Time series data from the Iceland Sea shows an increase pCO2 and decrease in pH and CO32- (i.e. CaCO3 saturation, W) since the early 1980s (Olafsson et al., 2009). The pH in the surface waters in this region has decreased twice as fast as predicted. In the Norwegian and Lofoten Basins the pH is decreasing faster than other areas in the region, and changes are observed much deeper in the water column (Skjelvan et al., 2013). In the Norwegian Basin the pH trend is -0.003/yr in the top 200 m layer, while in the Lofoten Basin similar rates as Iceland Sea are observed (-0.002/yr) for the upper 1000 m water column. Similar decrease in pH (-0.003/yr) are observed in the upper 200 m in Fram Strait (there are however fewer data points in this region), but with less decrease at depth. The deepest waters in Fram Strait show pH increase perhaps linked to change in deep water exchange. The Barents Sea Opening shows a decrease of -0.002/yr.

Focusing on some of the processes important for OA changes

Observations from a summer situation in the Barents Sea were used as an example for some of the processes important for OA changes (Chierici et al., 2013). These show that CO2 uptake by primary production causes high pH and W in surface water. Lowest pH and W was found in bottom waters at Storbanken, probably due to a combination of bacteria respiration of organic matter (which add CO2) and physical processes (mixing and sea-ice processes). Freshwater content is important for the chemical state, and increased freshwater decreases pH and W (Chierici and Fransson, 2009; Yamamoto-Kawai et al., 2010; Azetsu-Scott et al., 2010; Fransson et al., in review). Sea-ice processes impact the carbonate system and the CO2 exchange in the surrounding environment, hence OA, through: 1) CaCO3 formation in sea ice produce CO2, 2) brine pump of CO2 to deeper layers, 3) biological processes in sea ice affects CO2 system, 4) sea ice melt water dilutes thereby decreases OA state, and 5) frost flowers efficient transfer of chemical substances (Fransson et al., 2013). Frost flowers occur on newly formed ice and have high concentration of chemical substances such as CO2. More thin ice formation in a changing Arctic may lead to more frost flowers and thus more CO2 out gassing.

The Barents Sea and area north of Svalbard are especially vulnerable due climate change such as increased freshwater, warming, decreased sea ice cover (summer), increased Atlantic Water inflow containing high CO2 /low pH/low W, changes in biological processes. All of these factors likely contribute to enhance OA, but in different ways: 1) warming decrease CO2 uptake, but higher temperature usually enhance OA effect on organisms, 2) more Atlantic Water inflow carry relatively high CO2, 3) wind-induced upwelling of CO2-rich sub-surface waters might increase when shelves are more "accessible for wind" in less sea ice cover areas, 4) increased freshwater lowers pH and W thereby enhancing OA, 5) more Arctic Water in the termohaline circulation (THC) may affect OA state in Norwegian Sea, 6) sea ice brine CO2 pump strengthen/weakening will cause more/less CO2 sequestered which in turn will affect CO2 uptake, and 7) biological production lowers CO2 which will give increased spring bloom. This will counteract the OA effect. The largest pH change is expected in polar outflow waters (Fram Strait) due to changes within the Arctic Ocean, but also areas influenced by polar water, sea ice and freshwater.

Future changes

Several model studies have been conducted to predict changes in temperature, sea ice, fronts etc on the Atlantic Arctic sides. Regional downscaling of two different global climate models from the CMIP3 runs (GISS and NCAR), from 1998 to 2065 using the AB scenario, reveal differences associated with differences in the global models (Sandø et al., 2014). All predictions show temperature increase and sea ice decrease, but with regional differences as well as differences in salinity changes. Using the regional downscaled products as input to the ecosystem model NORWECOM, projections of modeled change in surface pH from 1998 to 2065 reveal regional differences which corresponds well to the observed trends of -0.002 to -0.003 per/yr in the Norwegian and Barents Sea (Skogen et al., 2014). Largest pH decrease is predicted in the Arctic Ocean basin with changes of -0.3 by 2065. West and north of Svalbard the predicted changes in pH is -0.25, while in the Norwegian and Barents Seas pH values of -0,1 to -0.2 might be excepted. Modeled changes in the location of the Polar Front in the Barents Sea was conducted by Wassmann et al. (2015) using a different model system than above. According to their results the Polar Front by the end of the century (2090-2099) have been pushed all the way north of the Barents Sea. Thus the Polar Front coincides with the slope to the north of the Barents Sea, and the entire Barents Sea will have temperatures above 1oC. However, the uncertainties in the predictions are large. A comparison of Arctic sea ice extent from all global climate models show large spread between models. Thus using only one climate model simulation gives large uncertainties.

Summary

- Air and sea temperatures and sea ice in the northern North Atlantic and the Arctic exhibit multidecadal variability.
- The location of the main atmospheric low and high changes causing altered wind patterns (storm tracks).
- Over the last 40 years the sea temperature has increased by 1.5oC and the (winter) sea ice cover decreased substantially.
- All future predictions reveal higher ocean temperature and less sea ice, but the magnitude of the projected changes is associated with uncertainty given the large spread in the global climate model predictions.
- The Norwegian Sea has already taken up a large part of the anthropogenic CO_2 and this has resulted in decreased saturation state/increased dissolution (W).
- Current aragonite saturation (W=1) is at 2000 meters, shoaling of about 150 m from 1981 (Børsheim and Golmen, 2010; Olsen et al 2006). Further CO_2 uptake will result in undersaturation (W<1) within next 100 years (Olsen et al, 2010).
- Observations show drastic pH decrease in Lofoten and Norwegian Basins of -0.003/yr in top 200 meters. This is larger than what is observed in Iceland Sea.

(2) Plankton

Changes in zooplankton in the Arctic Ocean
Alternation by transported Pacific zooplankton

Atsushi Yamaguchi, Kohei Matsuno and Yoshiyuki Abe
Faculty of Fisheries, Hokkaido University, Hakodate

From viewpoint of alternation of zooplankton community in the Arctic Ocean, we present two topics: year-to-year changes in spatial distribution of zooplankton community in the Chukchi Sea during 1991/92 and 2007/08 and transportation and reproduction success of Pacific copepods in the Arctic Chukchi Sea.

For the first topic, we collected zooplankton samples at 27-34 stations in the Chukchi Sea by T/S Oshoro-Maru cruises during 7 July to 13 August of four years (1991, 1992, 2007 and 2008) (Fig. 1, Matsuno et al. 2011). All the samples were collected from vertical tow of NORPAC net (335 μm mesh), and samples were preserved with borax-buffered formalin (5%) seawater. In the land laboratory, we examined the samples and enumerated with species. Based on log-transformed abundance data, Bray-Curtis similarity connected with UPGMA showed that zooplankton community separated into six groups (Fig. 2). Occurrence of each zooplankton group showed spatial and yearly changing pattern. Thus, only three groups (A, B and E) were observed for 1991 and 1992. For these years, Lisburne Peninsula separated zooplankton community: i.e. group A and B distributed at south and north of the Peninsula, respectively. While in 2007 and 2008, the boundary between zooplankton group A and B were observed further north of the Lisburne Peninsula. Add to such northward shift in boundary, remarkable zooplankton community (group D) was observed at southern end of the Chukchi Sea in 2007. Zooplankton community of group D was only observed for 2007 and was characterized with high abundance and species diversity which caused by the occurrence of the Pacific copepods (Fig. 3). The Pacific copepods: i.e. Eucalanus bungii, Metridia pacifica and Neocalanus spp. may transported to the Chukchi Sea. The highest sea-ice reduction in 2007 may provide high amount of transported Pacific copepods to the Chukchi Sea at that year.

How about the fate of expatriated Pacific copepods in the Chukchi Sea? Since zooplankton fauna of the Pacific and Arctic Ocean is completely different, if transported Pacific copepods succeeded to make repetition of their life cycle in the Arctic Ocean, serious effects may expected for the pelagic food web in the Arctic Ocean. However, ice-coverage in the Arctic Ocean prevent collection of year-round zooplankton samples in this region. To overcome the problem, analysis on zooplankton swimmer collected by year-round moored sediment trap was made in the Chukchi Sea (Matsuno et al. 2014, 2015a). By the moored sediment trap (0.5 m2 in the mouth area) at 180 m depth of St. NAPt during October 2010 to September 2011, zooplankton swimmer was quantified. While the station located further north (ca. 1000 km) from the Bering Strait, Pacific copepods: Neocalanus cristatus C5 stage occurred and formed high abundance in summer (August-September) (Fig. 4). Since summer is characterized by the ice-free season, the amount of the transported Pacific copepods is expected to be the largest at that season. Add to occurrence of the Pacific copepods, more direct evidence on their reproduction success was evaluated by ship-board experiment on their adult females collected in the Chukchi Sea (Matsuno et al. 2015b). Live females of Pacific copepod: Neocalanus flemingeri were collected at station near St. NAPt during September 2013 (Fig. 5). Spawnings were observed for ship-board experiment under field temperature (0°C). While the number of spawning eggs in one clutch (clutch number) is similar for the reported values in Pacific, the observed hatchabiliy was only 7.5% in the Chukchi Sea (>90% in the nursery Pacific). This low hatchability is considered to be caused by the unfertilization of the eggs.

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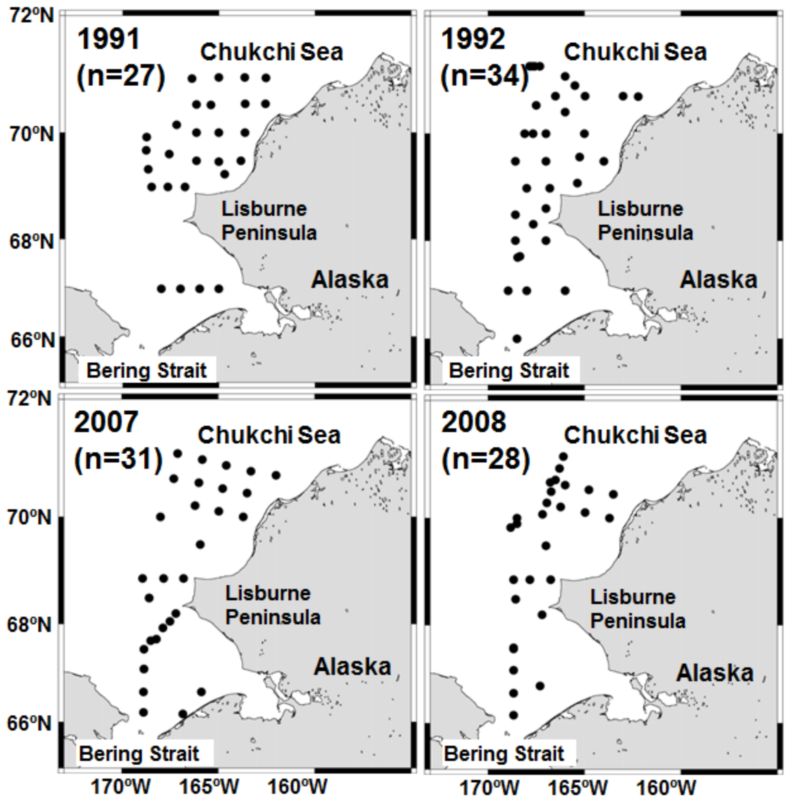

Fig. 1. Zooplankton sampling location in the Chukchi Sea during July-August of 1991, 1992, 2007 and 2008.

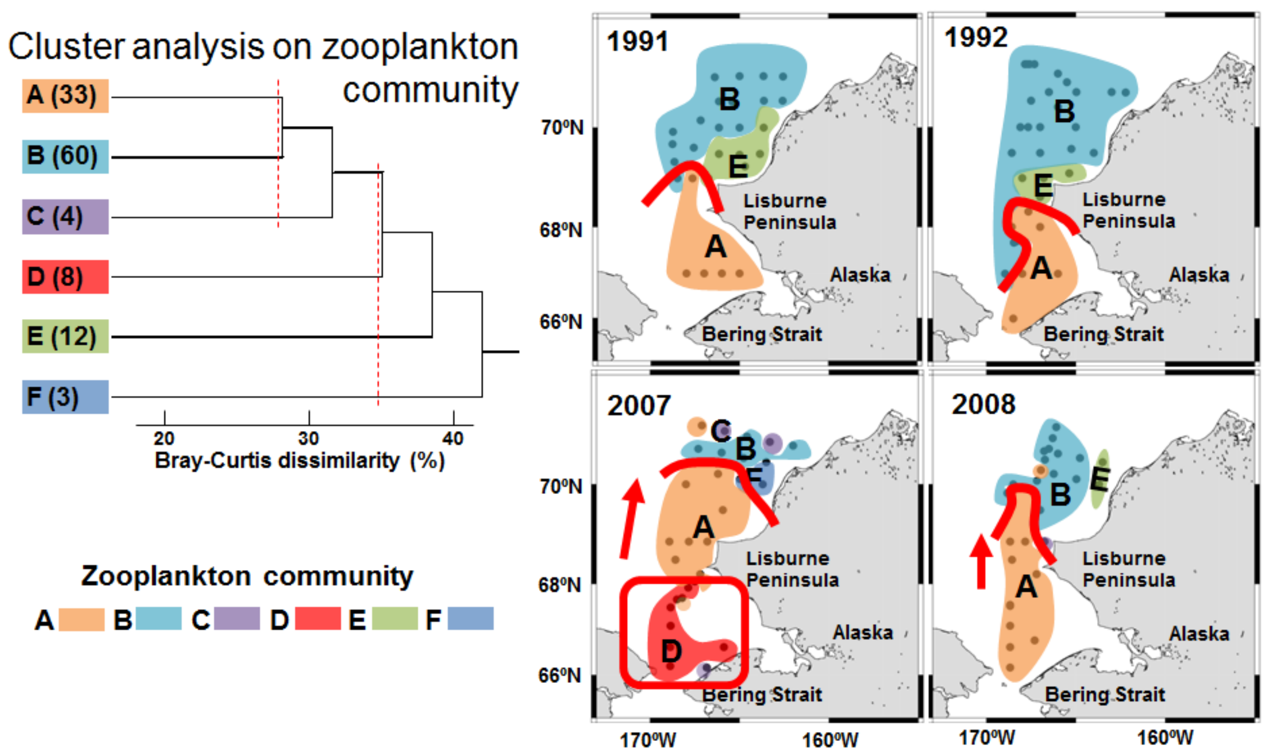

Fig. 2. Result of cluster analysis on zooplankton community (left) and their spatial distribution in each year (right). The boundary between group A and B was shown by red line, and red box in 2007 indicates remarkable group D which only seen in this year.

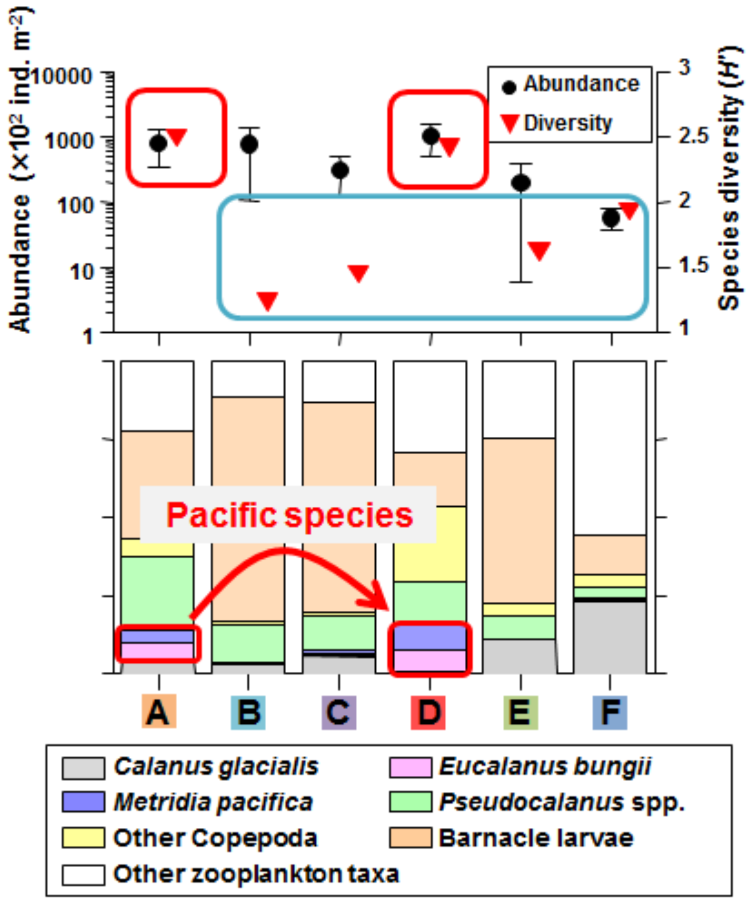

Fig. 3. Abundance and species diversity of each zooplankton community (upper) and their taxonomic composition (lower). Red boxes indicate fraction of the Pacific copepods.

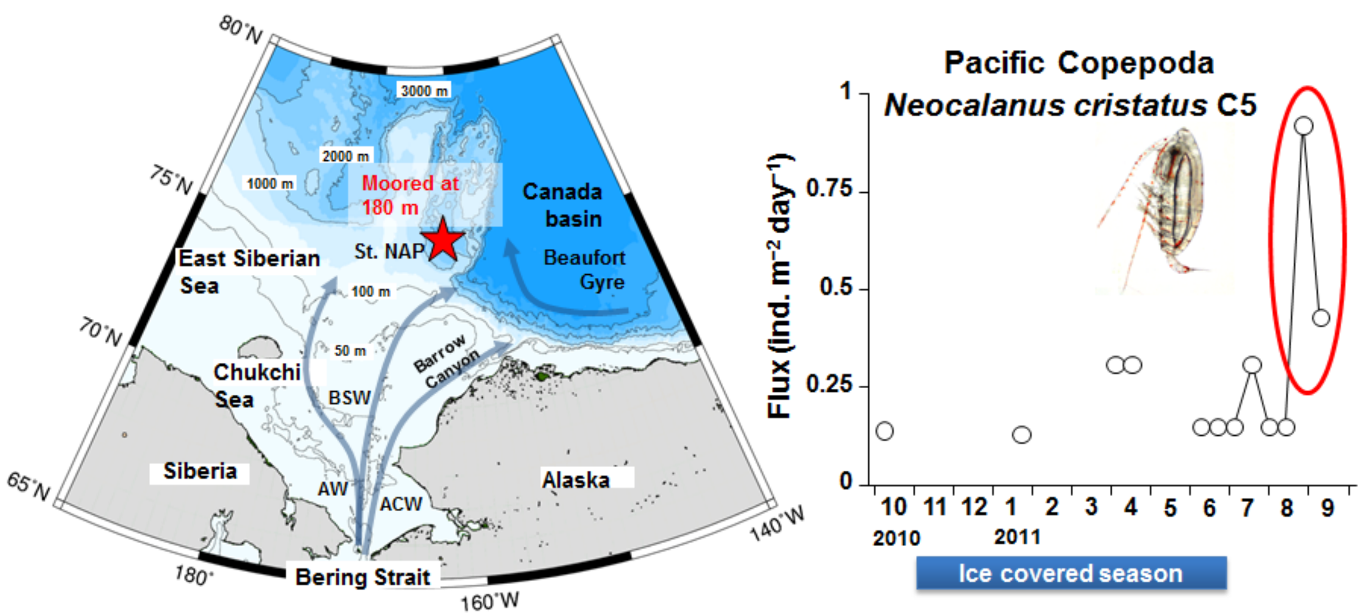

Fig. 4. Sediment trap moored station (St. NAPt) (left) and seasonal occurrence of the Pacific copepods (Neocalanus cristatus C5) as zooplankton swimmer flux (right).

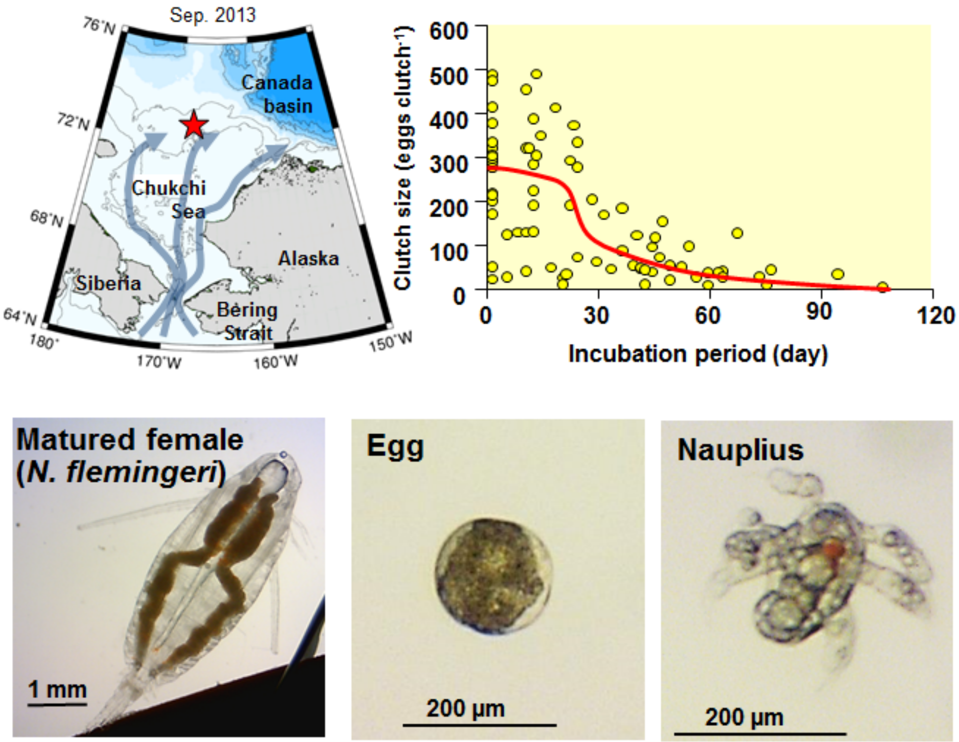

Fig. 5. Location of station which live adult female of Pacific copepod Neocalanus flemingeri was collected (upper left). Their clutch size during incubation period (upper right). Adult female with egg in their body, egg and hatched nauplius (lower pictures).

Response of phytoplankton community structure to recent sea ice decline in the western Arctic

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We have been examined the impact of recent environmental changes on phytoplankton community structure. We found the timing of sea ice retreat plays an important role for the changes. In the case of the northern Chukchi Sea, early sea ice retreat causes higher surface temperature during late summer to autumn. Such higher SST triggered the shift of dominant phytoplankton group: cold adapted prasinophytes to warm adapted haptophytes (Figure 1). The timing of sea ice retreat also has significant impact on phytoplankton size structure on the shelf region of Bering and Chukchi Seas during spring bloom period. We found negative relationship between the proportion of large-sized-phytoplankton and the timing of sea ice retreat (Figure 2). That is, proportion of large-sized-phytoplankton can increase during spring bloom period under the global warming scenario. Thus, we have illustrated that the change of timing of sea ice retreat and subsequent environmental changes have significant impact on phytoplankton community and size composition in the Pacific Side Arctic Ocean. We should also consider about how the changes of phytoplankton community structure, biomass or production affect those of higher trophic level organisms or biogeochemical cycles as the next step.

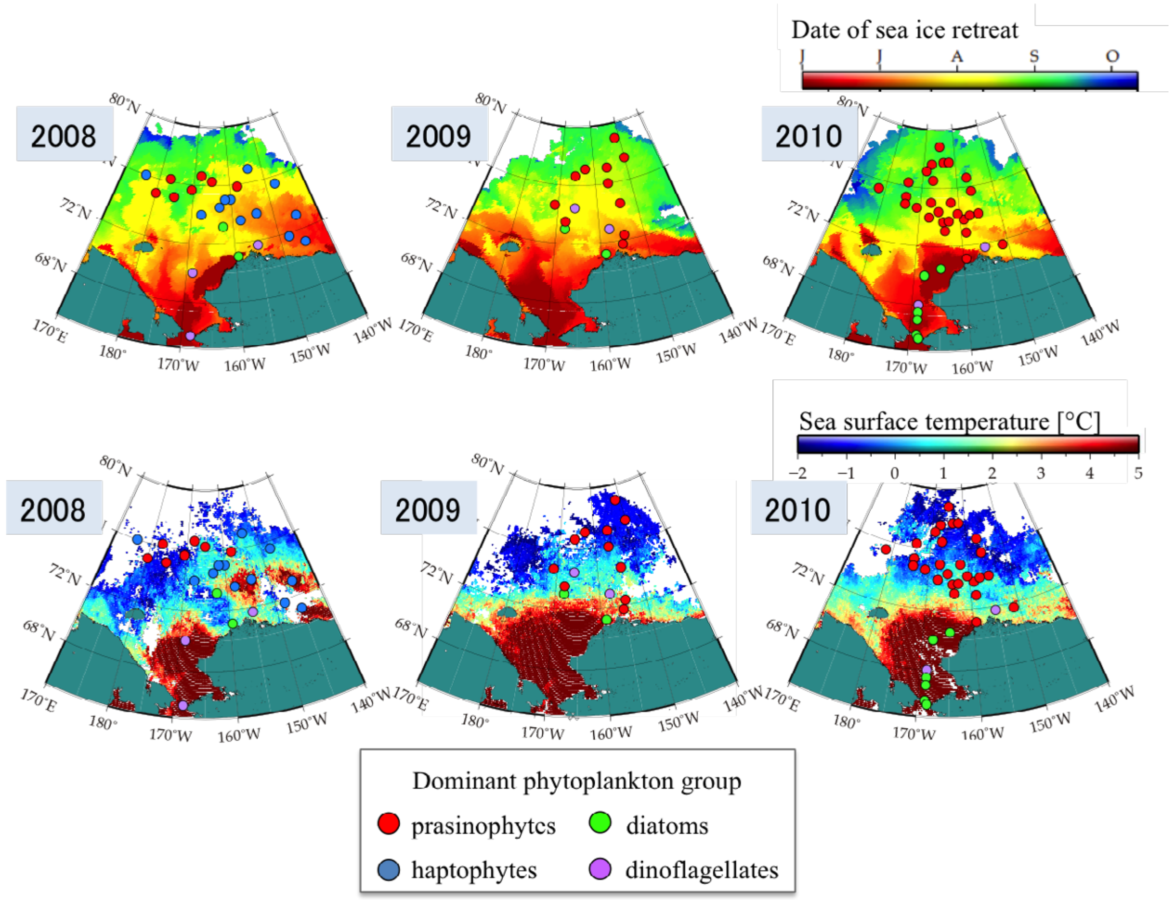

Figure 1. Interannual variability of dominant phytoplankton groups in the northern Chukchi Sea during late summer to autumn at the surface from 2008 to 2010. Top and bottom panels were colored according to the date of sea ice retreat and sea surface temperature, respectively.

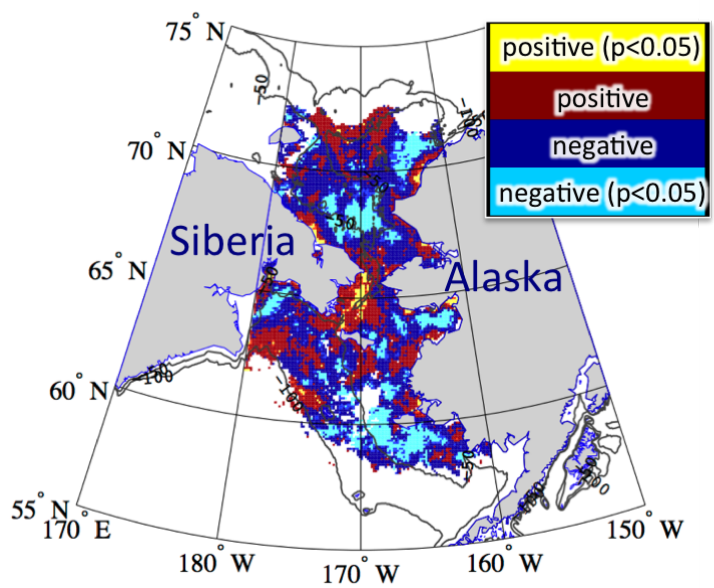

Figure 2. Spatial distributions of Spearman's rank correlation (ρ) between the proportion of large-sized-phytoplankton and the date of sea ice retreat during spring bloom period. Yellow indicates a significantly positive ρ ($p < 0.05$); red, a positive ρ ($p > 0.05$); blue, a negative ρ ($p > 0.05$); and light blue, a significantly negative ρ ($p < 0.05$).

The relationship between phytoplankton and benthic community in the Pacific Arctic region

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The Pacific Arctic region has high biomass, abundance and diversity of benthic organisms, and benthic hotspots provide prey to upper trophic level benthivores. Existing studies have reported that the changes in benthos and benthivores such as their distribution and species composition, but the study about the linkage between phytoplankton and benthic community is relatively scarce, and hence this study focused on this linkage. There is some interesting knowledge about characteristic of benthic community in the polar regions. In the Antarctic, seasonal inputs of phytodetritus to the seafloor are stored and used later by benthic organisms. Therefore, benthic organisms in the Antarctic can be active through long period. On the other hands, Arctic benthic organisms seem to quickly consume those input. These studies suggest that continued food supply during post-bloom period is also important, because strong spike of food input during spring bloom period may be consumed soon, and further food supply is required to keep benthic activity high during post-bloom period.

Average infaunal biomass and centroid of infaunal biomass were calculated through the years 1998-2012. No significant temporal trend ($p < 0.05$) was found in average infaunal biomass, but centroid of infaunal biomass has significantly shifted toward north. This northward shift consisted the changing centroid of phytoplankton size structure during post-bloom period. The relationships between changing centroid of infaunal biomass and other parameters, such as bottom temperature and phytoplankton size structure during spring bloom period, were also investigated and no significant relationship was found. This study found that the distribution of benthic infauna have shifted toward north through the years 1998-2012, and this shift may be affected by the changing food supply during the post-bloom period.

Climate variability and its effects on the southeastern Bering Sea Ecosystem: Timing of sea ice retreat, zooplankton production, and upper-trophic-level responses

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Abstract:

The eastern Bering Sea fishery for walleye pollock (Gadus chalcogramma) is one of the largest single-species food fisheries in the world, and is one of the most valuable in the United States. Year-class strength of the eastern Bering Sea pollock stock is highly variable, and this variability has the potential to impact the fishery negatively. It is thus important for users of pollock to understand the causes of this variability, and how a changing climate may affect the availability of pollock in the future.

The eastern Bering Sea shows marked inter-annual variability in climate, a conspicuous aspect of which is variability in the seasonal extent of sea ice and the timing of its retreat. Sea ice is a defining characteristic of the eastern Bering Sea. Its extent over the southeastern shelf varies by 100s of km and the timing of its retreat by 1 to 2 months, depending on wind patterns and air temperatures. These variations have the potential to affect all levels of the eastern Bering Sea Marine ecosystem.

A considerable body of work supports the hypothesis that variation in the timing of sea-ice retreat affects when ice algae and the phytoplankton bloom will be present, with most workers stressing that an early retreat of sea ice leads to a late open water bloom. More recently, Zach Brown and Kevin Arrigo have suggested, based on satellite imagery, that it is not the timing of the bloom that changes with the early retreat of sea ice, but rather the continuity of availability of algal food eaten by the juvenile forms of large, lipid rich zooplankton, which are a critical food of juvenile pollock as well as of adults (Figure 1).

Over the middle of the southeastern Bering Sea shelf, two species of zooplankton, the copepod Calanus marshallae and the euphausiid Thysanoessa raschii, appear to be critically important agents for the transfer of energy from primary producers (and micro-zooplankton) to a wide variety of fish, seabirds and marine mammals. These two species, in particular, are large and rich in lipids. The abundance of these important transfer agents varies greatly from year to year, and their annual recruitment appears to depend on the availability of algae in spring when they are in early larval and juvenile stages. Papers by Baier and Napp and by Hunt et al. suggested that the timing of sea-ice retreat may determine whether C. marshallae and T. raschii will be abundant or scarce, with early ice retreat leading to low abundances of these zooplankton, while late ice retreat is associated with high abundances.

When abundant, C. marshallae and T. raschii are major constituents of the diets of age-0 and older pollock. Under these circumstances, age-0 pollock grow well and have a high content of lipids by late

summer or fall, when they migrate to depth. In contrast, when these large, lipid-rich zooplankton are scarce, pollock and other fish prey on the small age-0 fish, and the age-0 pollock that are present in late summer have a low content of lipids. Although these lean age-0 fish may be abundant, few recruit to age-1, likely because they have insufficient lipids to survive through their first winter. Thus, those years with low lipid-rich zooplankton abundance produce few age-3 recruits to the fishery (Figure 2).

Although there is considerable evidence linking variation in pollock recruitment to the timing of sea-ice retreat, there is still a need for an examination of the population-level dependency on the availability of sea-ice algae for early life stages of C. marshallae and T. raschii. However, the lack of full information on the mechanisms connecting the timing of sea-ice retreat, the abundance of these zooplankton, and the year-class strength of pollock should not be reason to ignore the correlations that have been documented. In a future with climate warming and the resultant lack of sea ice in the southeastern Bering Sea, we may expect most year classes of pollock to be weak. The result will be a much smaller and less reliable catch of pollock.

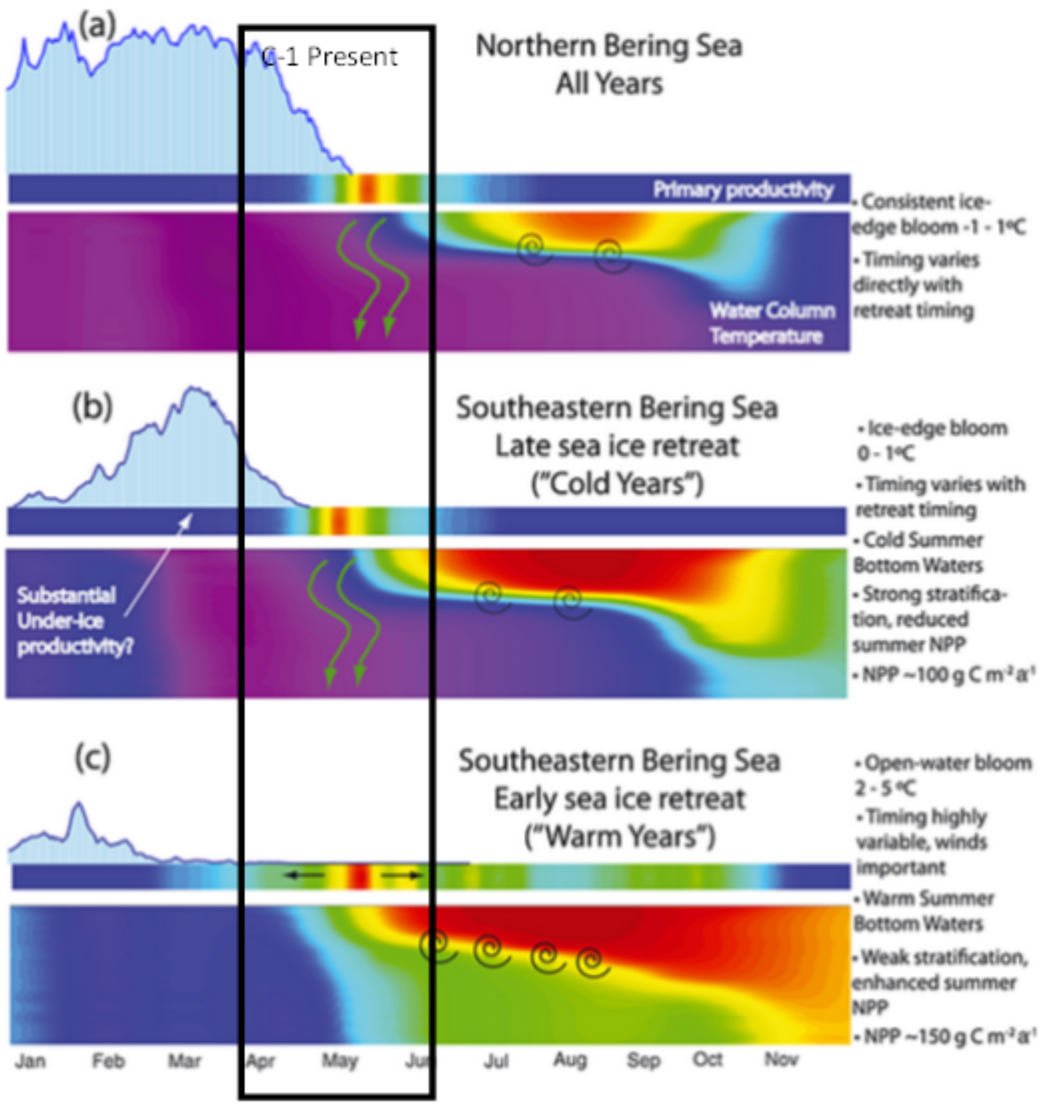

Figure 1. Schematic representation of sea ice impacts on primary producers in (a) all years in the northern Bering Sea, (b) late sea ice retreat years in the southeastern Bering Sea, and (c) early sea ice retreat years in the southeastern Bering Sea. Box represents time when the copepidite 1 stage of Calanus marshallae is present. A steady supply of algae is needed for the successful recruitment of C. marshallae nauplii to the C-1 stage. Note in panel C, there is a gap between when the sea-ice algae would be present (late February- early March) and when the C-1s would recruit (April and May). Green arrows represent strong carbon flux to the benthos. Basic water column temperature pattern in the northern Bering Sea was drawn from M8 mooring data presented in Stabeno et al., 2010. Modified from Brown & Arrigo 2013. Journal of Geophysical Research, Oceans. 118: 43–62.

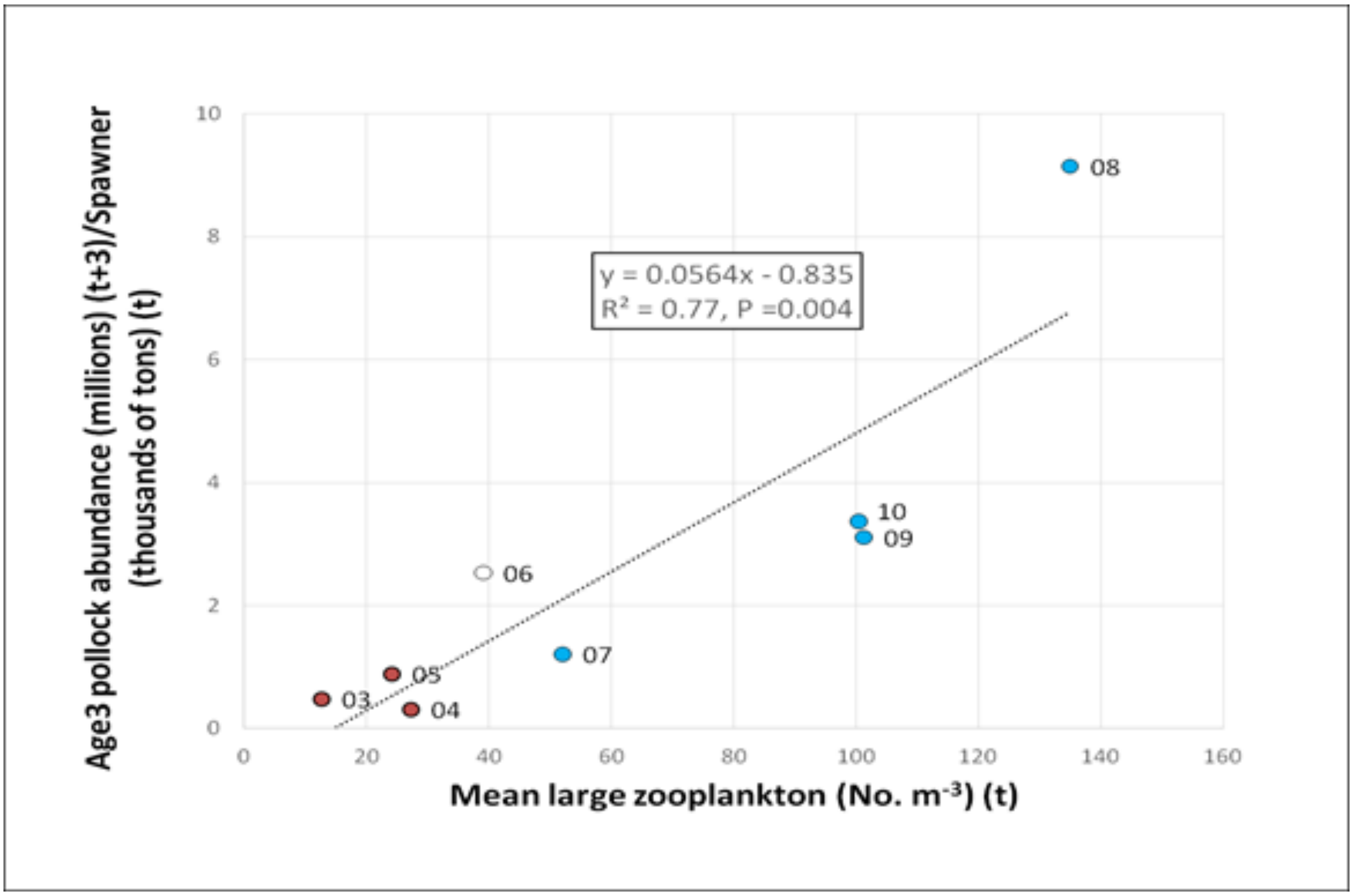

Figure 2. Relationship between average energy content (AEC) of individual young-of the-year walleye pollock (Gadus chalcogramma) and recruitment to age-3 adjusted for the spawning biomass, as a function of the abundance of large, lipid-rich crustacean zooplankton. Blue circles represent years with late sea-ice retreat, red circles years with early sea-ice retreat. Reproduced from: Lisa Eisner & Ellen Yasumiishi, 2015 Large Zooplankton Abundance as an Indicator of Pollock Recruitment to Age-3 in the Southeastern Bering Sea. Pp. 172-175 In: S. Zador,Ed. Ecosystem Considerations 2015, Status of Alaska's Marine Ecosystems. North Pacifc Fishery Management Council, 605 W. 4th Avenue, Suite 306, Anchorage, AK 99301.

Assessing Climate Change and Ocean Acidification Effects on the Lower Trophic Levels in the Atlantic Sector of the Arctic

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In this presentation we focussed on the processes affecting phytoplankton and zooplankton, in particular the role of climate in determining their distribution, abundance and growth. We also briefly presented information on the benthos as well as the effects of ocean acidification.

In the northern subarctic and arctic sectors, primary production depends mainly upon light and nutrient input. Under anthropogenic climate change, we expect that the annual pattern of incoming solar radiation to the water column will increase due to decreased ice coverage, resulting in higher annual primary production. Earlier breakup will mean more light earlier in the season and thus likely earlier phytoplankton blooms (Loeng et al., 2006). A delay in freeze-up will expose the water column to more autumn storms increasing the potential for higher nutrient fluxes into the surface layers, thereby allowing production to continue longer (Loeng et al., 2006). The link between decreased ice coverage and increase primary production, as measured by satellite imagery, has been shown throughout the Arctic shelves (Arrigo and van Dijken, 2011). Using the Norwegian Earth System Model (NorESM), Kristiansen (personal comm.) estimated the changes in light levels for the Barents and Bering seas, with projected increases of 27% and 24%, respectfully, between 2010 and 2090 based on predicted changes in sea-ice concentration, sea-ice thickness, albedo, and snow depth. The increased light levels, in addition to increasing phytoplankton production on the order of 10% or less, are expected to have consequences for time of fish spawning, the availability of prey resources for fish larvae, and general ecosystem biodiversity.

Model projections of phytoplankton production in the Arctic region were published by Slagstad et al. (2011). They increased ocean temperatures in the model by 2, 4, 6 and 8° C and found that in the Barents Sea there was little to no trend in the primary production. In the Arctic Basin and on Eurasian Shelves, however, production increases almost linearly with temperature, typically by a factor of 3-4 between present day conditions and an 8° C increase. Others have projected production changes in the Barents Sea under climate change. Ellingsen et al. (2008) suggested an increase in primary production of about 8% over a 65- year long period, mostly occurring in the eastern and northeastern regions of the Barents. On the other hand, Skaret et al. (2014) projected an increase of 36% by 2046-2064 compared to 1981-1999, again mostly taking place in the northern and eastern regions. The varying results are largely owing to differences in model formulation and the greenhouse gas scenarios used.
In addition to increases in production, models suggest a general loss of large phytoplankton species and

an increase in small phytoplankton throughout much of the North Atlantic, as well as in the Barents Sea and within the Atlantic sector of the Arctic (Kristiansen et al., 2014). Also, phenological changes in timing of the blooms are expected such that initial blooms will be earlier in the year and fall blooms will appear farther north due to longer open water which will allow the autumn storms will break down the summer stratification and provide nutrients to the near surface layers (Loeng et al., 2006; Wassmann et al., 2011).

In the past there has been significant transport of ice out of the Arctic through Fram Strait (Hop and Pavlova, 2008) but as the ice cover is reduced and multi-year ice is lost, ice algal communities will be lost and fewer algae will be transport to the subarctic. Earlier sea ice melt and the subsequent release of ice algal communities to the water column at a time when surface waters are cold and zooplankton growth rates are low could result in reduced grazing, thereby increasing the sinking flux of particulate matter from the sea ice to the sediments (Arrigo et al., 2008). However, reduced sea-ice cover will tend to favour a pelagic-dominated ecosystem over a sea-ice algae to benthos ecosystem (Piepenburg, 2005), which would reduce the vertical export of organic carbon and decrease pelagic-benthic coupling, despite an overall increase in phytoplankton productivity.

The dominant macro-zooplankton and the most important in terms of prey for fish larvae and juveniles in the Atlantic sector of the Arctic are Calanus finmarchicus, C. glacialis, and C. hyperboreous. The former is the smallest and is found in the warmest waters. The latter two are more Arctic species and found in colder waters than C. finmarchicus. Slagstad et al. (2011), in addition to producing projections of phytoplankton (see above), also considered zooplankton. They found that in Barents Sea under increasing temperature C. finmarchicus production increases while that of C. glacialis decreases, mainly due to the latter being pushed out from the northern and eastern regions. On the Arctic shelves the C. glacialis increases substantially over the range of an increase of 2 to 8° C while in the Arctic Basin there is an increase up to a 4 ° C temperature anomaly but under higher temperatures the zooplankton production there declines slightly. Ellingsen et al. (2008) predicted that under climate change Atlantic zooplankton production, primarily of Calanus finmarchicus, would increase by about 20% in the Barents Sea and spread farther eastward. Meanwhile the Arctic zooplankton biomass would decrease significantly (by 50%) resulting in an overall decrease in zooplankton production in the Barents Sea. The increased Atlantic zooplankton is caused by both higher transport into the Barents through greater inflow of warm Atlantic water (Stenevik and Sundby, 2007) and to faster turnover rates due to the higher temperatures, as suggested by Tittensor et al. (2003). On the other hand, there has been a loss of Arctic species observed in the northern Barents Sea during recent years in association with warmer temperatures and reduced ice cover (Dalpadado et al., 2012).

In the seasonal sea ice zone, benthos initially feed on ice algae that sinks to the sea floor and then on pelagic phytoplankton production that sinks. Ice algae tend to be a higher quality food but there tends to be less of it, especially in the more open water regions. While the benthos in Arctic regions are generally considered to be more dependent upon food supplied from the surface layers, primarily sea ice algae, in the Barents Sea the export flux to the benthos is actually higher in Atlantic waters than Arctic waters on an annual basis (Reigstad et al., 20xx). This is because of the much higher pelagic production in the Atlantic waters. However, its quality is considered to be lower than the ice algae and it is supplied more gradually to the benthos over a longer period compared to the ice algae. Under climate change it is expected that there will be higher annual export flux to the seafloor because of increased pelagic primary production, however, the quality of food is likely to be less in regions where seasonal sea ice disappears.

Ocean acidification is occurring in the world's oceans at an alarming rate, with the largest changes in the cold polar waters. The studies of the impact of this on marine organisms have resulted in mixed responses due to different strains or life cycle stages in experiments or short-term experiments. There have been no Arctic studies on viruses and non-Arctic studies show little to no effect. The bacterial community and their abundances do not appear to be strongly affected by pCO2 but elevated pCO2 generally increases bacterial productivity. For phytoplankton there is no consistent affect on growth but it does appear to increase primary production with the effect strongest at low temperatures, i.e. in the Arctic (Holding et al., 2015). Some zooplankton show little to no effect (Calanus spp., benthic foraminifera) while others show measureable to large effects (sea urchins, Psuedocalanus, krill (mortality), bivalvia (Chukchi), and pelagic foraminifera). For those zooplankton with shells such as petropods, the shell weights are often found to be reduced when exposed to acidified water. Cold water corals tend to show little effect but it is difficult to adequately assess because of such slow growth rates.

Some conclusions are drawn from our look at the literature. Many of the mechanisms controlling production, growth and individual size of the phytoplankton and zooplankton are similar in Atlantic and Pacific Sectors of the Arctic (e.g. ice-light-PP; ice-benthos; OA effects). A major difference is related to advection (e.g. fluxes mainly into the Pacific Arctic but 2-way in Atlantic Arctic sector being into and out of the Arctic). Also, the density-Pacific waters results in their being retained in the upper layers of the Arctic Ocean, but the more dense Atlantic waters tend to sink into the subsurface layers. Finally, differences comparing Barents and Bering seas include light (owing to Barents north of Bering), temperature (Barents warmer due to Atlantic water inflow), and nutrients (Pacific source waters have higher concentrations than the Atlantic waters).

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(3) Fish

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

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To understand trophic responses of polar cod Boreogadus saida (a key species in Arctic food webs) to changes in zooplankton and benthic invertebrate communities (prey), we compared its stomach contents and body condition between three regions with different environments: the northern Bering Sea (NB), southern Chukchi Sea (SC), and central Chukchi Sea (CC). Polar cod were sampled using a bottom trawl and their potential prey species in the environment were sampled using a plankton net and a surface sediment sampler. Polar cod fed mainly on appendicularians in the NB and SC where copepods were the most abundant in the environment, while they fed on copepods, euphausiids, and gammariids in the CC where barnacle larvae were the most abundant species in plankton samples on average. The stomach fullness index of polar cod was higher in the NB and SC than CC, while their body condition index did not differ between these regions. The lower lipid content of appendicularians compared to other prey species is the most plausible explanation for this inconsistency.

Potential habitat for chum salmon (Oncorhynchus keta) in the Western Arctic based on a bioenergetics model coupled with a three-dimensional lower trophic ecosystem model

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Chum salmon (Oncorhynchus keta) are predominantly located in the Bering Sea during summer and fall. However, several studies have recently reported a different tendency as follows. Observed densities of chum salmon were higher in the vicinity of the Bering Strait and the Chukchi Sea than the eastern Bering Sea in September 2007, and Japanese chum salmon migrated to northern areas in the Bering Sea during summer 2009. The sea surface temperature (SST) in the Arctic marginal seas has increased since the mid-1960s, and especially since 2000. We speculated that the SST increase directly promoted salmon northing from the Bering Sea to the Western Arctic. In this study, we estimated the potential habitat for chum salmon in the Western Arctic using a bioenergetics model coupled with a three-dimensional lower trophic ecosystem model (3-D NEMURO). "Potential habitat" was defined as "an area where chum salmon could grow (i.e., the growth rate was positive)". In the bioenergetics model, the growth rate of an individual chum salmon was calculated as a function of water temperature, salinity, and prey density, which were obtained from the 3-D NEMURO model results. To evaluate the habitat responses under a global warming scenario, we used the modeled monthly change of water temperature between 2005 (averaged from 2001 to 2010) and 2095 (averaged from 2091 to 2100) under the IPCC SRES-A1B scenario. Our calculations (Figure 1 and 2), following the global warming scenario, suggested that the potential habitat for chum salmon would expand to the north due to the increase in water temperature and prey density. In contrast, south of 71° N during summer, the potential habitat would shrink regionally because the water temperature exceeded the optimal condition.

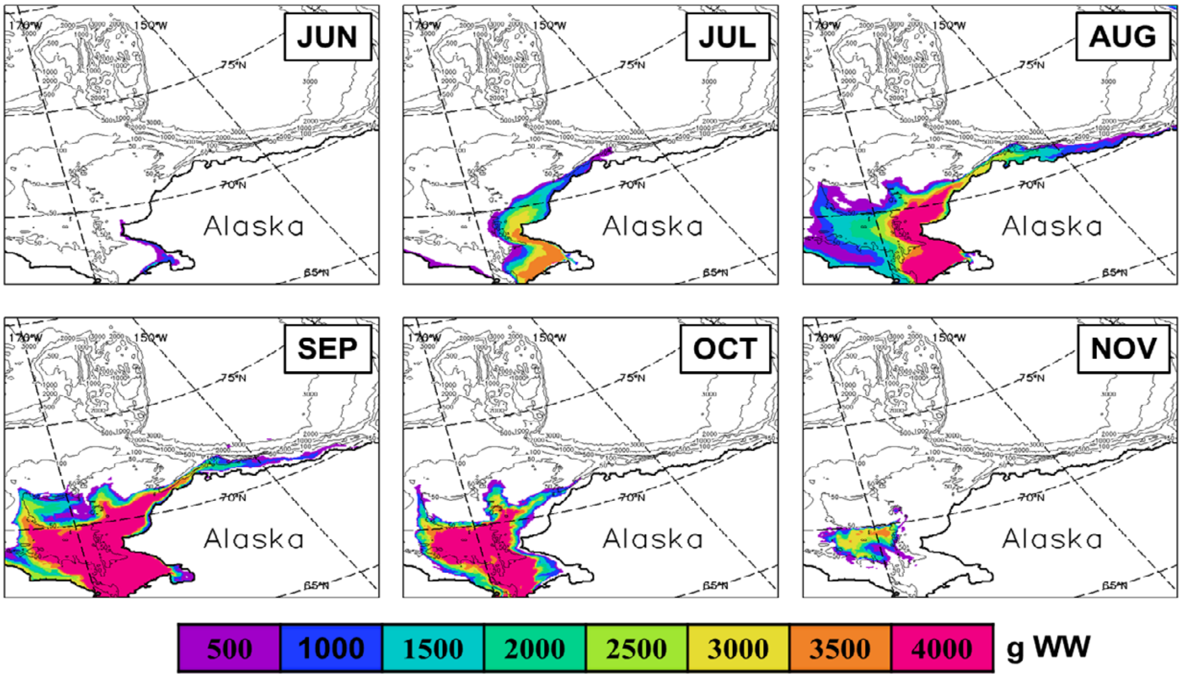

Figure 1: Estimated weight-specific potential habitat for chum salmon at the maximum-growth depth in the Western Arctic from June to November under current climate conditions. The potential habitat of larger chum salmon includes the habitats for smaller salmon: violet-shaded areas indicate the habitats for 100-500 g WW chum salmon and red-shaded areas indicate the habitats for all chum salmon of 100-4000 g WW.

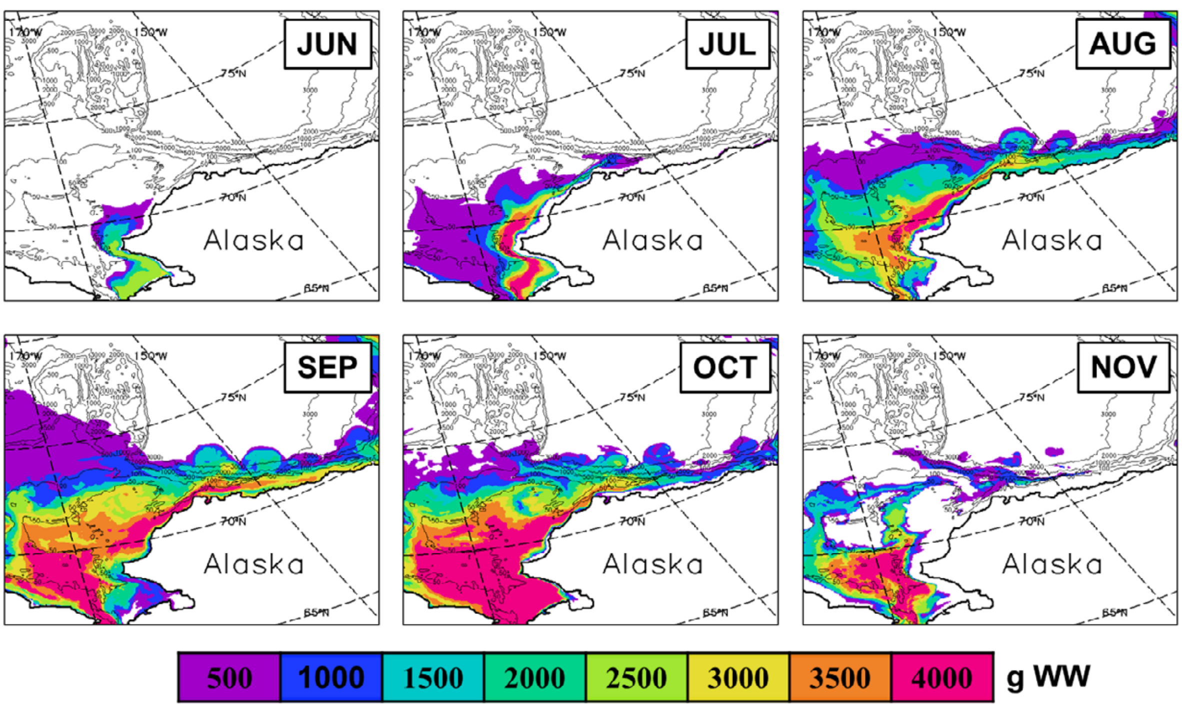

Figure 2: Same as in Figure 1 but for the global warming scenario (SRES A1B).

Responses of Fish and Shellfish to Climate Change in a Changing Arctic

Franz Mueter[1] *and Mike Sigler*[2]

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Increasing levels of CO2 in the atmosphere have resulted in a warming ocean, changing ice conditions, and ocean acidification, with direct and indirect effects on marine organisms (Figure 1). Biological responses of marine communities to changing ocean conditions suggest possible scenarios for future changes to fish and shellfish populations or the ecosystem. Here we provide four possible scenarios of how fish and shellfish populations and communities may change as a result of climate change.

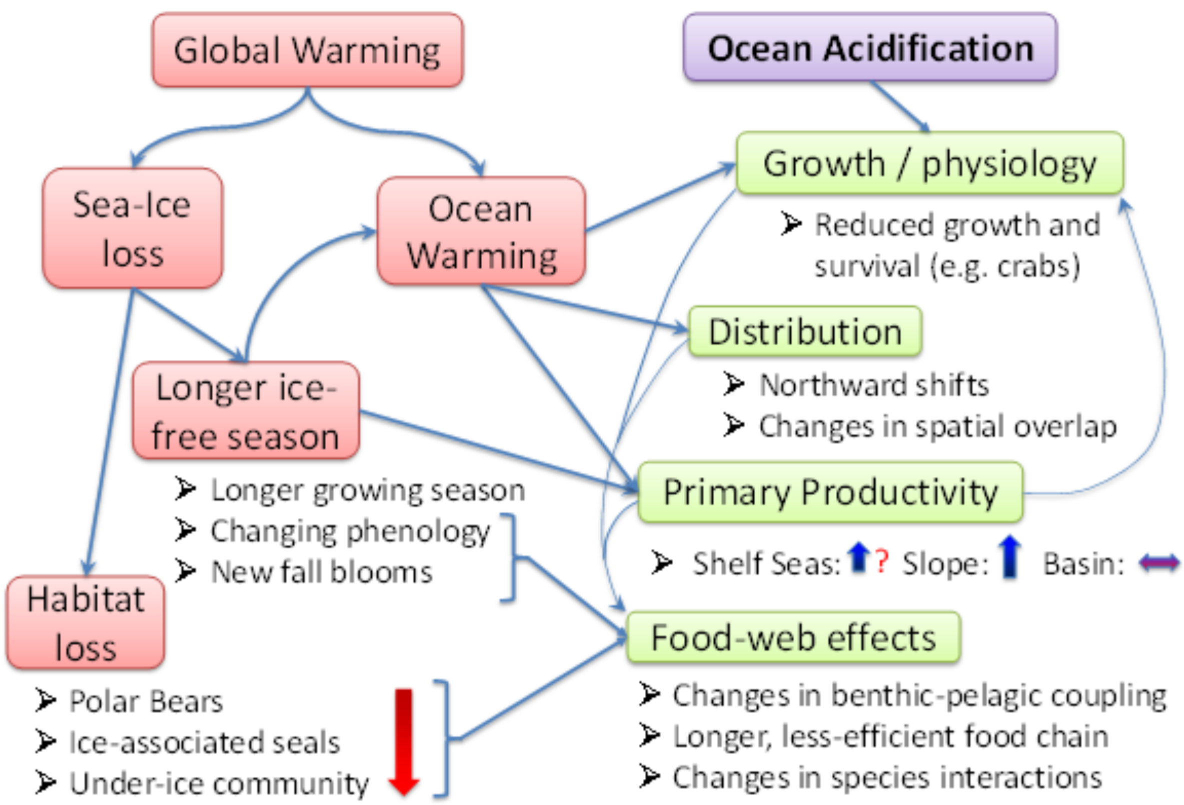

Figure 1: Some anticipated effects of increasing atmospheric CO2 concentrations on marine ecosystems. Effects on the physical environment are in red (global warming and temperature related effects) or blue (ocean acidification) . Biological effects in green. Arrows denote expected increases or decreases in response variables.

1. Walleye pollock (Gadus chalcogrammus) in the eastern Bering Sea support the largest single-species fishery in the US and play a key role as a forage species for other fish, seabirds and marine mammals. Recent work suggests that juvenile pollock are particularly vulnerable to temperature-mediated changes in zooplankton prey composition. Exceptionally warm years in the early 2000s were associated with either an early ice retreat or a complete lack of ice on the southeastern Bering Sea shelf. For reasons not fully understood, these conditions are associated with high abundances of smaller zooplankton, but a relative lack of large, lipid-rich zooplankton on the shelf. The latter are important prey for late larval and early juvenile pollock as they accumulate energy reserves for the winter and the lack of large zooplankton in these warm years was associated with very poor overwinter survival and low abundances of pollock in the following years. In contrast, the abundance of large, lipid-rich zooplankton (such as large copepods and krill) increased during subsequent cold years (2007-2013), providing better feeding conditions for larval and juvenile walleye pollock. This resulted in a much higher energy density of age-0 walleye pollock during late summer, as well as reduced cannibalism and predation on age-0 pollock. As a result, more pollock survived the winter and contributed to a rapid recovery of the population. Therefore it is reasonable to predict that future abundances of pollock are likely to decline if the Bering Sea experiences warm years more frequently in the future as predicted by global climate models. This effect may be further exacerbated if, as predicted, the overlap between juvenile pollock and arrowtooth flounder, a major predator on juvenile pollock, increases in warm years as arrowtooth flounder expand in warmer, shallower areas of the shelf.

2. Snow crab (Chioenocetes opilio) are widely distributed in subarctic and arctic regions, including the northwestern Pacific, Bering Sea, parts of the Arctic, northwest Atlantic south to Maine, and west coast of Greenland. Most recently, they have also been expanding in the northern Barents Sea, where they support a growing fishery. Snow crab are adapted to cold conditions and are expected to decline in a warming climate. Early benthic juveniles prefer temperatures below 2℃, corresponding to conditions within the cold pool of bottom water on the eastern Bering Sea shelf and the number of young snow crab is smaller following warm years. This dependence of the juvenile stages on cold bottom temperatures can result in what has been described as an "environmental ratchet". Following a reduction in the spatial extent of the cold pool, juvenile snow crab are restricted to the colder, northern parts of the shelf. At the same time predatory fish such as Pacific cod expand into areas formerly occupied by the cold pool, inhibiting the southward expansion of snow crab even when intermittent cold conditions return. Moreover, the associated reduction in spawning biomass on the southern parts of the shelf make it more difficult for snow crab to become re-established in the southern area because larvae tend to drift northward with the prevailing currents. Therefore, intermittent warming can result in a pronounced retraction of snow crab to the North that may be difficult to reverse.

3. Red king crab (Paralithodes camtschaticus) are distributed on the continental shelf of the North Pacific Ocean from British Columbia to Japan and into the Bering Sea. The largest stock resides in Bristol Bay, which has a long history of fishing by foreign and domestic fleets and experienced a collapse in the early 1980s but has since recovered in response to reduced harvests and other conservation measures. In addition to fishing effects, several hypotheses have linked red king crab dynamics to climate, including a shift in spawning locations during warm years that may result in larvae being advected towards less favorable nursery areas, with strong recruitment generally occurring when the spawning stock was primarily located in southwestern Bristol Bay. It has also been postulated that, when the PDO is positive, stronger winds associated with the Aleutian Low result in a more mixed water column, which can compromise feeding by king crab larvae. Finally, red king crab are vulnerable to ocean acidification, which is expected to be particularly pronounced in the North Pacific. Waters over large parts of the Bering Sea shelf are already under-saturated with respect to Aragonite during large parts of the year, particularly in the fall. Laboratory studies have shown that the survival of pre-recruit stages that are exposed to elevated CO2 levels (decreased pH) is reduced, suggesting that the population and expected yields are likely to decline over the next decades due to decreasing ocean pH levels over time.

4. A 'borealization' of the Arctic has been observed in both the Pacific and Atlantic Arctic as boreal (subarctic) species expand northward into areas that are covered by cold waters during years with more extensive ice cover. These changes are evident in increasing abundances of boreal species and decreasing abundances of Arctic species in these transition zones during warm periods. As the abundance and distribution of different species changes at different rates, these changes affect trophic interactions and the relative success of different species. However, beyond the prediction that boreal species will increase, it is not yet clear who the primary 'winners' and 'losers' will be.

Fish Distribution and Abundance in the Atlantic Sector

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In this presentation the focus is upon the effects of climate variability and change on fish distributions and abundance, with emphasis in both the Arctic (Barents Sea) and the subarctic (Norwegian Sea). Possible effects of ocean acidification on fish species are also discussed.

The Barents Sea is the largest of the Arctic continental shelves and encompasses both cold Arctic waters as well as warm Atlantic waters. As a result it contains a mixture of both Arctic and boreal species. Andriyashev and Chernova (1995) noted 166 different species of which 107 were regularly occurring. However, 90% of the total fish abundance is contained in 10 species (Stiansen et al., 2009). The main species include Atlantic cod (Gadus morhua), capelin (Mallotus villosus), Atlantic haddock (Melanogrammus aeglefinus), Atlantic herring (Clupea harengus), polar cod (Boreogadus saida), saithe which is a pollock (Pollachius virens) and redfish (Sebastes mantella). The colder water species such as polar cod and capelin tend to be found in higher numbers in the northern and eastern regions of the Barents Sea while the warmer water species such as herring and haddock restricted to the more southern or southeastern areas. Polar cod and capelin spend their entire life history within the Barents Sea, in contrast to herring, haddock, and cod that spawn on the Norwegian Shelf and are transported into the Barents Sea as larvae or young juveniles (see e.g. Vikebø et al., 2011). Herring only spend their first 2 to 3 years in the Barents Sea before leaving for the Norwegian Sea to spend the remaining years of their adult life. On the other hand, haddock and cod remain in the Barents Sea throughout their lifetime, except for annual migrations to the Norwegian coastal regions to spawn. In the warmer Norwegian Sea, pelagic species dominate the fish community with the most abundant being Atlantic herring, Atlantic mackerel (Scomber scombrus) and blue whiting (Micromesistius poutassou). There is high year-to-year variability in species abundances in both regions. Cod, which is the most important commercial species, has varied by a factor of 4-5 between its most and least abundant years over the last more than 100 years. The species with the highest abundance variability are the Barents Sea capelin with changes of a factor of 10-20 and herring in the Norwegian Sea, which varied by a factor of around 20.

Climate can play an important role in producing such abundance variability of fish stocks (Hollowed and Sundby, 2014). Good recruitment of Barents Sea cod, known as the Northeast Arctic cod stock, is dependent on higher than average temperatures (Ottersen and Sundby, 1995; Drinkwater, 2005; Hollowed and Sundby, 2014). Herring and haddock in the Barents Sea also seem to have their best recruitment in warm years. The main reasons for this link between temperature and recruitment in the Barents Sea has been suggested to be due to (i) higher primary production due to a larger ice-free area (Svendsen et al., 2007), (ii) a larger influx of zooplankton carried by the increased inflow of

Atlantic water masses from the southwest (Sundby, 2000) and (iii) higher temperatures promoting higher biological activity at all trophic levels (Sakshaug, 1997).

Climate has also been associated with abundance trends of herring in the Norwegian Sea. Herring levels rose in the 1920s through into the 1950s coincident with increasing temperatures (Toresen and Østvedt, 2000). As temperatures declined, so too did the herring. High fishing intensity coupled with poorer environmental conditions lead to the commercial collapse of the herring stock in the late 1960s. A moratorium on herring fishing was then imposed but it was not until the mid- to late 1980s when temperatures again rose that the herring began to recover (Toresen and Østvedt, 2000).

It is not only abundance that is affected by climate variability. A clear shift in the annual distribution of cod in the Barents Sea with temperature has been observed, being distributed more westward during cold conditions and eastward during warm periods (Fossheim et al., 2015). Cod also moved north during the warm periods of the 1930s and 1940s and retreated farther south, especially off West Spitsbergen during cooler periods in the 1960s (Blacker, 1957). Similar northward movement has been observed during the recent warm period with record northward locations being reported, reaching as far north as the edge of the continental slope of the Barents Sea adjacent to the Arctic Ocean (Kjesbu et al., 2015). Also, proportionately more cod spawn in northern regions of the western Norwegian Coast in warm periods relative to cold periods (Sundby and Nakken, 2008). Haddock has been observed to shift its distribution farther to the northeast during warm conditions (Landa et al., 2015). Capelin also changes its distribution with varying temperature, such that in warm years the feeding area of capelin is extensive and reaches as far north as Franz Josef Land while in cold years the feeding area shrinks and is displaced to the southwest (Vilhjálmsson, 1997). More recently, Ingvaldsen and Gjøsæter (2013) showed that abiotic factors (e.g. temperature and sea ice) set the large-scale limits for capelin distribution area, while stock size (and probably age structure) determines how capelin will use the available area. Huse and Ellingsen (2008) explored what will happen to the capelin distribution under climate change. They showed that capelin would most likely expand their geographic distribution farther to the north and east as water temperatures rose. They noted that this would put stress on the energy reserves of the capelin if they had to return to the present day spawning on the northern coast of Norway. It was likely, under such conditions, that the capelin would seek new spawning sites, perhaps farther east along the Murman coast of northern Russia or even on Novaya Zemlya.

In the Norwegian Sea, Atlantic herring underwent large geographic changes during the last century. As temperatures rose along with the herring abundance, the fish expanded westward occupying habitat in the vicinity of Iceland (Vilhjálmsson, 1997). This led to the rise of the Icelandic herring fishery, which came to dominate the Icelandic economy for several decades. As temperatures and the herring stock declined, the herring distribution retracted and during the minimum abundance levels their distribution was limited to west coast of Norway. When the herring stock increased as temperature rose again, the fish once again spread out into the Norwegian Sea to feed. In the recent warm period, adult herring in the Norwegian Sea have spread east and now farther north than previously observed.

It is not just the distribution of the main commercial species in the Barents Sea that are affected by changes in ocean climate. During the period of Arctic warming from 1930 to 1950, the occurrence of rare Atlantic species greatly increased (Drinkwater, 2006). This is also occurring in recent years, including the capture of a swordfish off northern Norway (S. Sundby, IMR, pers. comm.). It has been predicted that there will be an increasing number of species invasions especially in the Barents Sea (Cheung et al., 2010).

In addition to climate change, the marine environment also has to deal with ocean acidification, which causes the water to become more acidic. Generally, fish show little effect due to ocean acidification. Labratory experiments suggest that the direct effect of high CO2 levels on mortality of adult fish is unlikely. Juvenile and adult fishes have sufficient capacity and flexibility in their acid-base regulation systems to cope with the projected changes in environmental CO2 levels over the this century (Pörtner, 2008; Melzner et al., 2009a,b). Fish eggs and early larval stages might be more sensitive owing to their high surface-to-volume ratios and less developed acid-base regulation systems (Kikkawa et al., 2003; Ishimatsu et al., 2004). Slow moving benthic fish may be more sensitive than fast swimmers (less regulation of intracellular pH). Fish may be mainly affected indirectly through their prey. For example, krill has shown large mortality, some squid are sensitive to high CO2 levels, and decapods and bivalvia show generally negative effects (crabs, lobsters and bivalvia, such as mussels, scallop, and oysters).

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(4) Resilience of ecological communities

Ecosystem Resilience in the Barents Sea - What is it and how can it be measured?

Benjamin Planque

The term resilience is used in different contexts where its definition can vary, but broadly, it is commonly understood as "the ability of a system to absorb disturbance and maintain structure and function". Three features can contribute to the resilience of a system: resistance, flexibility and reorganisation. Resistance implies low sensitivity to external pressures. Flexibility refers to the capacity of a system to return to its original configuration after being exposed to a perturbation. Reorganisation defines the capacity of a system to constantly reconfigure itself in order to maintain its functions in the presence of perturbations.

For marine systems, resilience can be defined at different levels of biological organisation, from individuals to populations, communities or the ecosystem as a whole. High resilience at one level does not necessarily derive from or result into high resilience in other levels. For example, maintenance of ecosystem functions through species turnover (i.e. resilience at ecosystem level) is associated with low resilience at individual population levels.

The BarEcoRe project (2009-2013, http://www.imr.no/filarkiv/2014/03/hi-rapp_16-_2013_barecore.pdf/nb-no) investigated specific features of the resilience of the Barents Sea ecosystem. The analyses were based on data from long term monitoring of the physical and biological properties of the Barents and on over a decade of ecosystem survey in the Barents Sea.

Structural ecosystem properties associated with resilience were investigated by quantifying ecosystem diversity (specific, functional and trophic), redundancy (trophic and functional) and modularity (in food webs). Dynamic properties were investigated by time-series analyses of multivariate-multidecadal patterns in ecosystem structure, e.g. by identifying possible regime shifts or changes in trophic controls. In both analyses (structural and dynamic) a key issue remained the definition of 'reference' states, against which empirical observations may be compared. The development of 'null' ecosystem models in which simple hypotheses are used to generate expected patterns of resilience has been instrumental in the BarEcoRe project. Non Deterministic Network Dynamics (NDND) modelling has been used as a reference model to compare historical patterns of ecosystem variations in the Barents Sea (e.g. regime shifts, decadal shifts in top-down/bottom up controls) against 'null' hypotheses on ecosystem dynamical properties.

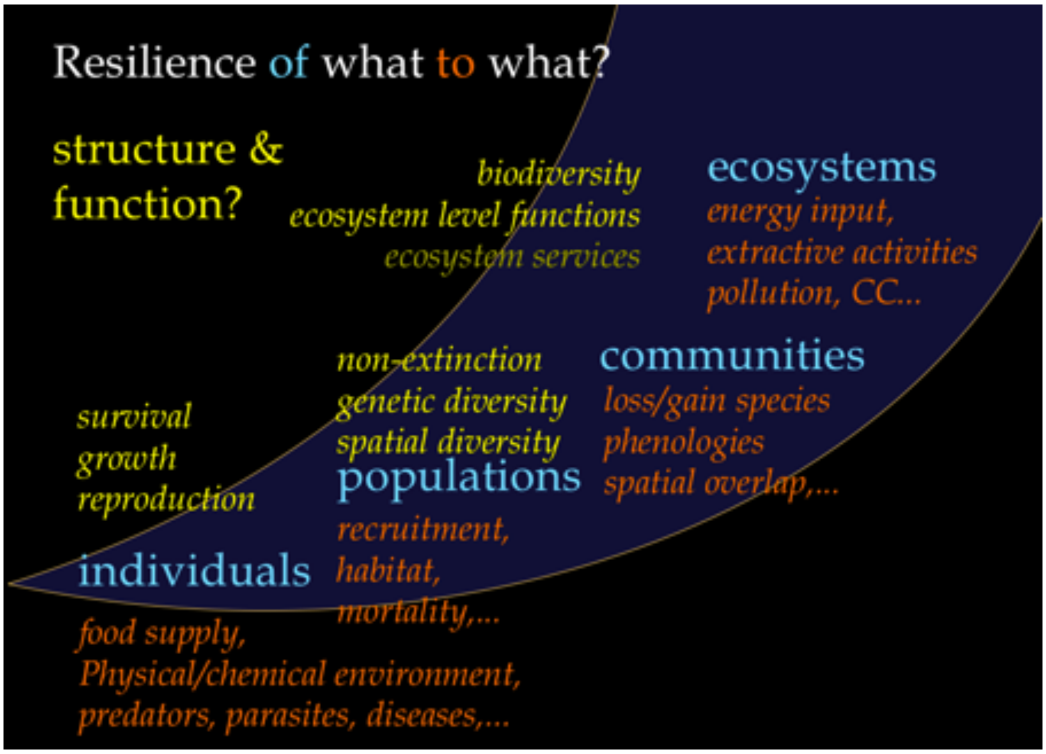

Figure 1: Resilience considered at different levels of biological organisation (in blue), from individuals to ecosystems. Examples of perturbations to the biological systems are provided in orange and examples of key structures and functions are given in yellow.

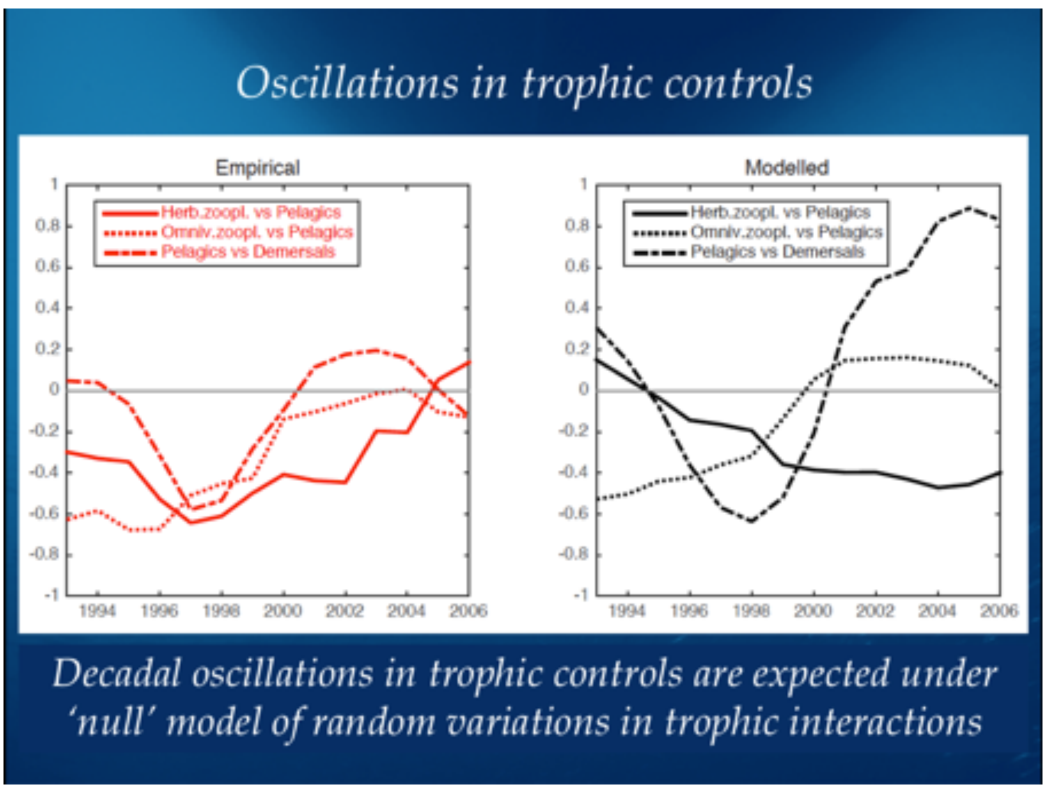

Figure 2: empirical observations (left) and simulated (right) decadal 'swings' between top-down and bottom up controls in the Barents Sea (left). The NDND model used for the simulations suggests that decadal oscillations in trophic controls are expected under 'null' model of random variations in trophic interactions.

(5) Fisheries

Ecosystem-based Fishery Management in the Eastern Bering Sea

Franz Mueter
University of Alaska Fairbanks

Fisheries in federal waters off Alaska are managed by the North Pacific Fishery Management Council, one of 8 regional fishery management councils in the US. Separate Fishery Management Plans have been prepared and are periodically updated for groundfish resources, for crab resources (jointly managed with the State of Alaska), for scallops, and for salmon (managed by the State of Alaska). While harvest levels are largely specified based on a single-species assessment approach, management occurs within an ecosystem context that considers all components of the ecosystem, including the habitat that species depend upon, non-target fish species, seabirds and mammals. One of the strongest ecosystem-based measures is an overall cap on removals of groundfish from the Bering Sea / Aleutian Islands management area, which is set at 2 million metric tons.

Stock assessments use survey and fishery data to estimate current stock status and trends (time series of recruitment and biomass) and biological reference points that are used to specify catch limits. Bottom trawl surveys are conducted annually on the eastern Bering Sea shelf and biannually in the Aleutian Islands. In addition, physical and biological components of the ecosystem are routinely monitored and are annually summarized and presented to stock assessment scientists and to the management council to ensure that information on the status of the broader ecosystem can be considered in the management process in a timely manner. All stock assessments are annually reviewed by teams of scientists including fishery biologists, stock assessment authors, oceanographers, seabird / marine mammal biologists, and economists. Both the assessments and management process are transparent to the public with several levels of review that allow ample opportunity for public input. Permissible catch levels are set at a level below the maximum sustainable yield that is perceived to be precautionary (Figure 1).

This management framework has been successful in limiting catches to sustainable levels and in 2015 none of the stocks in the region were overfished (Biomass > 50% of the biomass corresponding to BMSY) and overfishing was not occurring (2015 catch < MSY for all species). Moreover, discards have been reduced over time to improve utilization, the area disturbed by fishing (bottom-contact gear) has decreased over time, structure-forming benthic invertebrates have increased, and the trophic level of the catch and community size structure have been stable. All monitored indicators suggest that the current harvest policy is sustainable. It is unclear whether current catch levels can be sustained in a changing climate, but models are being developed to evaluate management strategies that are robust to climate change.

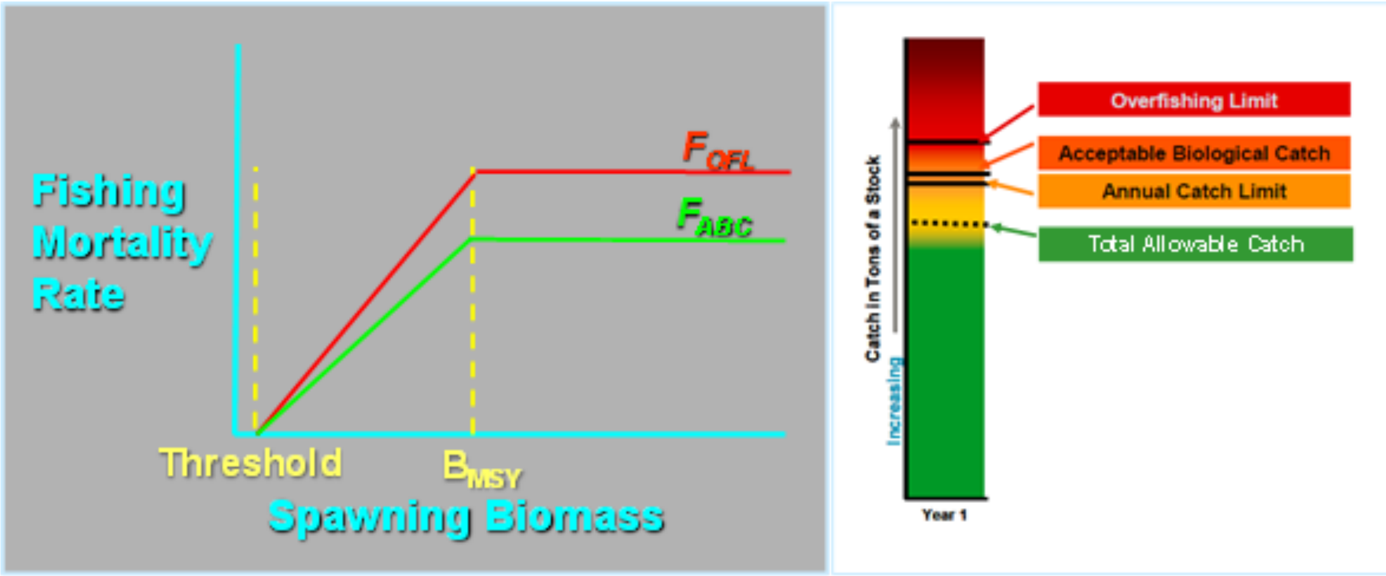

Figure 1: Harvest Control Rule and associated reference points for federally managed stocks off Alaska. The fishing mortality that results in maximum sustainable yield in the long term denotes an overfishing limit (FOFL) that cannot be exceeded. The Acceptable Biological Catch (ABC) is based on a fishing mortality, FABC, set at a level below FOFL that depends on the quality of information available for a given stock. The ABC may be further reduced by uncertainty consideratins to specify the Annual Catch Limit (ACL) as determined by scientists. Managers then specify a total allowable catch that cannot exceed the ACL. Accountability measures prevent the ACL from being exceeded or mitigate overages, if they occur.

Modeling Fisher Behavior under Changing Policies, Economics, and Environmental Conditions

Alan C. Haynie
NOAA Fisheries Alaska Fisheries Science Center

Fisheries management involves managing people as well as developing an understanding of different target and non-target species. This talk provides an overview of several spatial economic analyses conducted at NOAA Fisheries Alaska Fisheries Science Center (AFSC) over the last decade that address how fishers in different Alaska fisheries have been impacted by changing regulations, economics, and environmental conditions. Specifically, we summarized work that was part of the Bering Sea Integrated Ecosystem Research Program (BSIERP), the impacts of the Red King Crab Savings Area and the implementation of cooperatives on the BSAI multispecies trawl fishery, and efforts to reduce salmon bycatch. We also discussed the the spatial economics toolbox for fisheries (FishSET). How do we best utilize this work in fisheries management?

Climate change and Fisheries economics: Management challenges in the Barents Sea cod fishery

Arne Eide

Previous studies indicate that management actions may have a greater impact than climate change on the development of northern fisheries. Many of these studies do however not include the spatial dimension in fisheries. As climate change may alter the spatial distribution of fish and hence fishing activities, it is necessary to include this dimension in the study of climate change impact on fisheries.

Temperature is however only one of many factors influencing the distribution of fish stocks. For benthic species ocean floor and depth are crucial factors affecting fish distribution and densities. The shelf area in the Barents Sea is constrained by the steep slopes in the north and west, while the cold water (e.g. the Kara Sea) largely will remain too cold for cod. Model studies on spatial and temporal distributions based on the SRES A1B scenario (CAb-ABe) suggest that the distribution area of NEA cod will not change significantly the next fifty year period.

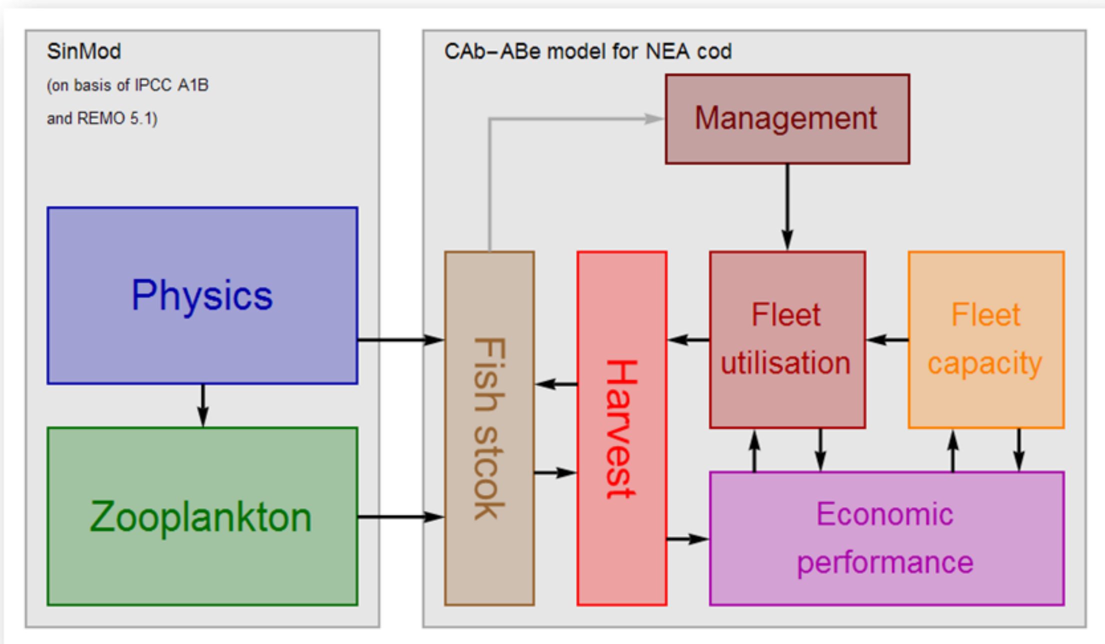

Figure 1. Flow chart of the CAb-ABe model for the NEA cod fishery

The cod stock in the Barents Sea is currently at a historical maximum and is expected to remain in good shape in the coming years. Food availability indicators and increased temperatures may contribute in an increased carrying capacity over the next decades. The utilisation of the stock in the future depends however first of all on how the stock is managed.

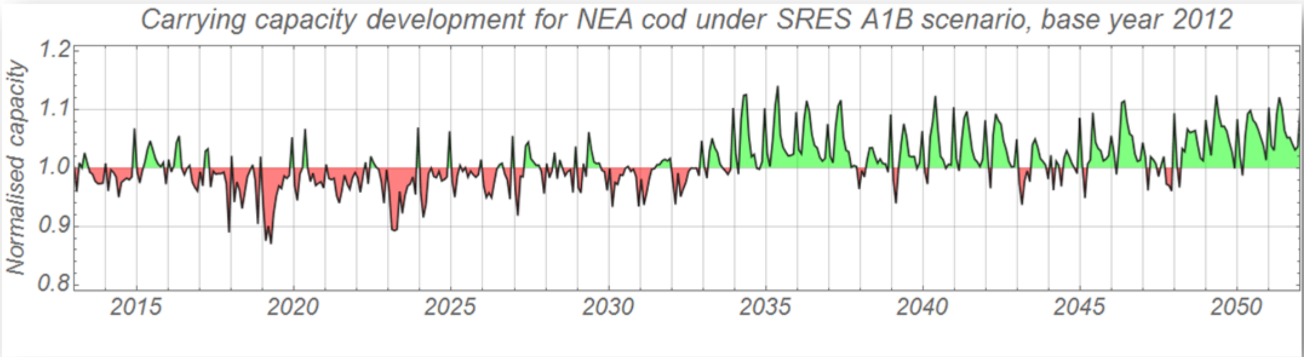

Figure 2. Development of theoretical carrying capacity levels of NEA cod based on the SRES A1B scenario.

(6) Fisheries Management & Governance, Resilience & vulnerability

Fisheries adaptation to Climate Change: Case of the Shiretoko World Natural Heritage

Mitsutaku Makino
Japan Fisheries Research and Education Agency

Japanese archipelago is spreading from the tropical marine ecosystem in Okinawa to the sub-arctic marine ecosystem in the Okhotsk sea. At the coastal area, about 200 thousand small-scale fishers are targeting variety of species using various fishing gears, and landing the catch to more than 2800 fishing ports along the coast line. Shiretoko World Natural Heritage, the very edge of the subarctic area, is a nice case to discuss how local fisheries and communities can adapt to CC.

In Japan, the combination of top-down government measures and bottom-up autonomous measures is introduced to manage local fisheries. It is called the fisheries co-management. In order to adopt to the climate change, Variety of measures are being implemented (e.g., shift of fishing efforts, river improvement, etc.)

Outreach of scientific information to the local fishers and government officers is one of the most important role of academic society, which will improve the quality and efficiency of co-management measures, and indeed strongly needed by the local people. Also, the political will can increase the legitimacy of co-management measures, and facilitate the adaptation to CC.

Photos: Outreach activities to the Shiretoko local fishers from the Shiretoko World Natural Heritage Scientific Council

Assessing climate change vulnerability in Alaska's fishing communities

Amber Himes-Cornell and Stephen Kasperski
(Presented by Alan Haynie)
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Abstract

Alaska's communities are experiencing impacts from unprecedented climate-related changes in the harvests of natural resources. Residents of rural Alaska are reporting heretofore unseen changes in the geographic distribution and abundance of marine resources, increases in the frequency and ferocity of storm surges in the Bering Sea, changes in the distribution and thickness of sea ice, and increases in river and coastal erosion. When combined with ongoing socio-economic change, climate, weather, and changes in the biophysical system interact in a complex web of feedbacks and interactions that make life in rural Alaska challenging.

We present a framework of indicators to assess three basic constituents of community vulnerability:exposure to the bio-physical effects of climate change, dependence on resources that will be affected by climate change, and a community's adaptive capacity to offset negative impacts of climate change.We conduct three principal components analyses, one for each vulnerability constituent, for 315 Alaska communities to assess each community's overall vulnerability to climate change. This research can be used to inform communities about the ways in which their communities are vulnerable to climate change and help develop adaptation strategies. While this study focuses on Alaska communities, the framework is easily adaptable to other regions with different risk factors and sensitivities to climate change.

Vulnerability and Resilience in Alaska Coastal Communities

Henry P. Huntington

Coastal communities in Alaska have long dealt with a variable ecosystem. Animal populations may increase and decrease, and weather conditions may help or hinder hunting. If the communities were unable to deal with variability, they would have vanished long ago. At the same time, variability can have many impacts to communities, and all communities have stories if not living memory of periods of scarcity and even starvation. Today, in a time of rapid environmental change, a big question is how physical, biological, and social factors interact to produce outcomes for a community.

Physical factors can lead to divergent outcomes. The later freeze-up of sea ice in fall in the northern Bering Sea has allowed people from St. Lawrence Island to continue to hunt from boats. This has led to the creation of a fall/winter whaling season which did not exist prior to the early 1990s, and has helped make up for poor spring conditions in some years. By contrast, the poor quality of shorefast ice off Kivalina in the past two decades has made the ice too unreliable and dangerous for travel to the ice edge where the whales are. As a result, Kivalina has not taken a whale since 1995. The changes in ice are all part of a trend towards less sea ice in the Arctic, but for now have produced very different outcomes for whaling on St. Lawrence Island vs. in Kivalina.

Biological change can also be positive or negative. The loss of the opilio crab fishery on St. Paul Island in the Bering Sea in the late 1990s led to population loss in the village. Demographic data strongly suggest that the loss was due to out-migration by non-Native males, who presumably were attracted there for the economic opportunity provided by the crab fishery. On St. Lawrence Island, the hanasaki or brown spiny king crab has recently arrived in the waters of the area, providing a new food source and potentially a marketable species, as the crabs are regarded as being very tasty. Shifts in abundance and distribution of species may produce positive and negative impacts, making it difficult to support sweeping statements about the impact of change for Alaska coastal communities.

Societies change, too. In Shaktoolik, Vice-Mayor Eugene Asicksik described a number of environmental and climate-related changes in his area as a contribution to the Arctic Council's Adaptation Actions for a Changing Arctic report. In addition, though, he noted that regulatory change is perhaps the biggest influence on changing income levels for fishermen, in this case as a result of more permits spreading the fish catch across more fishermen. On St. Paul Island, fur seal harvests have decreased at the same time that the fur seal population has decreased, but this should not be mistaken for an environmental impact on humans. Instead, the fur seals remain accessible and sufficiently abundant to support previous harvest levels. But local tastes and interest in seal harvesting have changed, leading to lower demand and thus lower harvests. Understanding social dynamics is essential to placing environmental changes in the right context for interpretation.

Traditional knowledge can contribute to understanding of ecosystem dynamics, too. An example from a project in southcentral Alaska illustrates this point. Researchers were studying declines in local abundance of Katharina tunicata, the black leather chiton, known locally as the bidarki. This intertidal invertebrate is a local delicacy. Ecological studies found that human gathering and sea otter predation explained much of the local patterns in abundance. Discussions with local residents, however, added decades of time depth to this pattern. Sea otters had been nearly exterminated during the Russian era in Alaska. They began returning in higher numbers to the lower Kenai Peninsula in the 1950s, at which time their favorite foods began to decline. After that, their next favorite prey started declining, and so on through a series of prey declines, of which the bidarki is the latest. Human behavior also changed, with the arrival of electricity and freezers to store bidarkis (among other things) and with an increased number of boats with outboard motors, making it easier to travel to distant beaches to gather bidarkis. Putting the whole story together created a richer understanding of what was happening in the ecosystem and how to interpret the decline of bidarkis.

Many changes are occurring simultaneously, some of them connected (such as sea ice and St. Lawrence Island fall whaling) and others separate (such as declining fur seal harvests on St. Paul and the declining fur seal population). It would be valuable to be able to distinguish the changes that propagate through the system as well as those that appear to be confined to their immediate domain. This idea can be considered in terms of spatial domains in the ecosystem as well as intellectual domains in the way the ecosystem is studied. When do physical changes cause biological changes? When do changes at the bottom of the food web affect the middle and top of the food web, too? How does societal change fit in?

All of these points suggest some questions to consider as RAC-Arctic continues:

- Given the divergent responses to similar changes seen in different villages (and likely by different individuals in the same villages), can we capture essential local details without losing sight of larger trends, and without requiring detailed information about each locale?
- Many examples of change feature innovation, such as the invention of fall whaling on St. Lawrence Island. If innovation is a behavior that has not been seen before, how can we predict when it will happen, and what its effects will be? If we ignore it, we are likely to bias ourselves towards negative impacts. But if we overestimate the potential for innovation, we may underestimate the true impacts of change on the Arctic marine system.
- In a time of change, reducing uncertainty is presumably an advantage. If management and regulatory systems create more uncertainty, they are only exacerbating the situation. If they can reduce uncertainty, for example by greater transparency or predictability, that may help people focus on the many other uncertainties they face. How the regulatory or management system might achieve this is a good question.
- Finally, much emphasis has been placed on providing useful information for a range of stakeholders. At the same time, many stakeholders have made it clear that they would like

information rather than advice. It is not clear, however, what form that information might take or how best to make it available, especially as stakeholders range from individuals living on Arctic coasts to large companies operating worldwide, and from private business to local, national, and international agencies.

3-2. Summary of Science Meeting Discussions

Following two days of science presentations, the RACArctic Principal Investigators, along with several local stakeholders and scientists, met to discuss the next steps towards achieving the project goals and objectives. Ken Drinkwater began the meeting by reviewing project goals and objectives and Franz Mueter facilitated the subsequent discussions, which focused on the stakeholder process, reporting requirements, the structure of future workshops and anticipated products from the project.

Review of project goals and objectives

The overall goal of this project is to review and synthesize available information to assess the resilience and adaptive capacity of arctic marine systems in a changing climate, from both a natural and social science perspective.

Specific objectives include:

(1) Review and synthesize the potential for changes in the physical and chemical oceanography under future climate using results from state-of-the-art models.

(2) Review and synthesize what is known about potential changes at the bottom of the food web, including:

a. the supply of nutrients to surface waters

b. the impact of ocean acidification on calcifying organisms

c. the magnitude and seasonal timing of primary production

d. the distribution, abundance, and species composition of zooplankton; and

e. the role of temperature changes and advection in these processes.

(3) Assess implications of these changes for fish populations and fisheries in the Subarctic to Arctic transition zone: How will the spatial distribution of fish change? What is the likelihood that new fish populations become established in the Arctic? What is the potential for new fisheries to develop outside of historical fishing areas?

(4) Assess the resilience of the Arctic marine ecosystem, in particular fish populations and their zooplankton prey, to changes in physical forcing and primary production.

(5) Identify key challenges, including threats and opportunities, for the fishing industry and for subsistence users arising from these anticipated changes.

(6) Evaluate the ability of scientific and management institutions to adapt to potential threats and opportunities and explore ways in which their resilience can be improved.

Stakeholder involvement

Discussions of the stakeholder process focused on the best approach to involving relevant stakeholders and how to disseminate information and outcomes from the stakeholder meetings and the overall project to stakeholders. There was some concern that the selected group of stakeholders in this and future meetings may be too narrow to adequately summarize stakeholder needs and concerns. For a fuller assessment we could consider more comprehensive surveys following established protocols. However, we recognized that a full social science approach to stakeholder involvement was beyond the scope of the current project, but that there is value in meeting with a small group of stakeholders in this format. This first stakeholder meeting was considered a success as we were already able to learn a number of valuable lessons from the meeting. These include, among others:

- There is a desire for a continuing dialogue between scientists and stakeholders. This may be difficult at the international level, but is likely to happen through existing opportunities for stakeholder involvement within each country.
- We need to "be patient" – this is likely an iterative process as we learn from each other and from experience. Moreover, this is only the beginning of a process that will continue beyond the current project.
- We can learn a great deal from each other through having this dialogue. Rather than a comprehensive assessment of stakeholder concerns, we can contribute to enhancing resilience and adaptive capacity in the Arctic by highlighting what matters most to stakeholders and establishing a process to keep collecting input on the things that matter most.
- Soliciting stakeholder input early and repeatedly is key to incorporating results into ongoing projects, including RACArctic, in a timely and efficient manner.
- Developing good relations between scientists and stakeholders greatly enhances outreach efforts as it allows more effective communication of scientific results to affected stakeholders and communities.

We discussed approaches to disseminating results from the stakeholder process to stakeholders and the public. First, it is important to recognize that, while there is considerable overlap, each meeting has a somewhat different focus with a different mix of stakeholders:

(1) The stakeholder meeting in Japan has a stronger focused on shipping with representatives from the shipping industry, the Ministry of Land and Transport and the Ministry of Economy and Trade. In addition, we had representatives from major fishing industries, seafood supply companies, fisheries management agencies, and NGOs, among others.

(2) The Alaska workshop will have a stronger focus on affected coastal communities that engage in subsistence activities, in addition to the fishing industry, management, government and NGOs.

(3) The Norway workshop will also include representatives from affected coastal communities, as well as from offshore and inshore fishing industries and fisheries management.

Because of the variety of stakeholders at each meeting we discussed having three separate "summaries for stakeholders" by country to reflect the different needs in each country. In addition, we should strive to also produce a summary that integrates across all stakeholder meetings to identify common threads as well as differences. An overall summary will also be useful to develop recommendations for improving communication between stakeholders and scientists.

Finally, we had some discussions about involving stakeholders from each country in each of the workshops by inviting one to a few stakeholders from the other countries to each national workshop. However, the value of selecting one or two stakeholders to represent all stakeholders from a country was questioned. Nevertheless, the strength and perhaps novelty of the RACArctic project is its international scope and we should make every effort to foster international exchanges among key groups of stakeholders and scientists.

Reporting and deliverables

We discussed how best to meet reporting requirements for the project, while simultaneously working towards completing deliverables that meet the overall goals of the project. As a first step, we decided to ask for extended abstracts from each presenter (2-3 paragraphs each, perhaps with one or two figures). These will be shared among participants / PIs, and will form the basis for cross-system comparisons and integrations at the next workshop. It was suggested that we set up a Google workshop docs to post extended abstracts, to provide opportunity for comments / questions (Note: This has been set up and extended abstracts are accessible here).

To work towards the overall project goals and effectively use the time available for scientific syntheses at the workshops in Alaska (2017) and Norway (2018), we agreed on the following approach:

- With the goal of ultimately producing synthetic, comparative papers by topic (following the six focal topics for this workshop, see below), we will strive to produce at least an outline of potential papers prior to the Alaska workshop. We need to identify leads for each topic as soon as possible.
- Initial outlines should include some key statements, ideas and questions, and perhaps a set of draft tables or figures (6-8). These initial drafts can serve as a basis for discussions at the workshop.
- One issue is that we only had a single presentation on ecological resilience based on previously published work and there are whole groups (e.g. Stockholm Resilience Center) that have long focused on ecological resilience. What we can perhaps add is a better approach to quantifying ecological resilience in a marine ecosystem. It was suggested to perhaps consider a single synthesis paper on resilience that encompasses both the ecological and social systems, which could focus on how different countries use the concept of resilience in research & management.
- At the workshop and between the Alaska workshop and the Norway workshop, we will work on integration across disciplines, with a goal of producing at least one overall synthesis paper that integrates across regions and disciplines.
- This 'vertical' integration may not be comprehensive given the limited scope and expertise available within the group, but may focus on specific ideas or questions that investigators are

interested in and excited about. We want to capitalize on existing momentum and enthusiasm of individuals. Example include:

  - o What are the ecosystem consequences, community impacts and management concerns if advection through Bering Strait (and/or into the Barents Sea) changes substantially (increases or decreases) as a consequence of climate change.
  - o How are recruitment mechanisms / dynamics of key fish species in the Subarctic-Arctic transition zone affected by changes in the ecosystem. Focus on case studies / examples.
  - o Other topics focusing on processes (rather than status report).

- The overall product of the scientific syntheses will be a special issue that collects papers for each of the disciplines / topics, case studies that contribute to a broader synthesis, and an overall synthesis. The overall organizing principle for the special issue will be resilience.
- In addition, we will produce summaries of stakeholder discussions specific to each country as well as an overall summary of commonalities and differences across countries.

Follow-up

- E-mail PIs/presenters to ask for an extended abstract (between 1-2 paragraphs, perhaps with 1 or 2 relevant figures), enter in Google document or e-mail to fmueter@alaska.edu
- National-level reporting requirements will be responsibility of lead PI in each country but could draw on summary materials from this workshop, including
- Recorded conversations from stakeholder meeting will be transcribed
- Summarize scientific meeting by compiling extended abstracts and summarizing overall discussions (this document)
- Contact presenters in each group (topic) to ask them to self-organize and choose a lead for a paper within their area of expertise that could contribute to the special issue – maybe provide some guidance on what we envision, but give them latitude to choose a topic that holds their interest and enthusiasm
- Doodle poll to select dates for Alaska workshop

We closed by thanking the local organizers for an excellent meeting.

4. List of Participants

■ Principal Investigators

Name	Affiliation
Sei-Ichi Saitoh	Hokkaido University
Naomi Harada	Japan Agency for Marine-Earth Science and Technology
Takashi Kikuchi	Japan Agency for Marine-Earth Science and Technology
Yutaka Watanuki	Hokkaido University
Mitsutaku Makino	Japan Fisheries Research and Education Agency
Franz Mueter	University of Alaska Fairbanks
George Hunt	University of Washington
Henry Huntington	Huntington Consulting
Alan Haynie	National Oceanic and Atmospheric Administration
Ken Drinkwater	Institute of Marine Research
Arne Eide	University of Tromsø
Randi Ingvaldsen	Institute of Marine Research
Melissa Chierici	Institute of Marine Research
Benjamin Planque	Institute of Marine Research
Jan Erik Stiansen	Institute of Marine Research

■ Stakeholders

Name	Affiliation
Minoru Fujie	Ministry of Economy, Trade and Industry
Yoko Furukawa	Office of Naval Research
Hiroyuki Goda	NYK Group
Svein Grandum	Royal Norwegian Embassy in Tokyo
Tetsuya Hayakawa	Ministry of Land, Infrastructure, Transport and Tourism
Yutaka Ishikawa	Nissui
Takao Kashiwagi	Mitsui O.S.K. Lines
Naoto Matsuo	RALSE (ARCS Group)
Akira Mikami	Hokkaido Government
Joji Morishita	Japan Fisheries Research and Education Agency, (Present: Tokyo University of Marine Science and Technology)
Masashi Nishimura	Japan Fisheries Association
Ryo Omori	Fisheries Agency
Natsuhiko Otsuka	North Japan Port Consultants (Present: Hokkaido University)
Genki Sagawa	Weathernews
Naomi Shimaya	Ministry of Land, Infrastructure, Transport and Tourism
Mineyuki Toyofuku	Hokkaido Federation of Fisheries Cooperative Associations
Tomohiko Tsunoda	The Ocean Policy Research Institute

Presenters and Observers

Name	Affiliation
Irene Alabia	Hokkaido University
Naomi Chi	Hokkaido University
Seth Danielson	University of Alaska Fairbanks
Agneta Fransson	Norwegian Polar Institute
Amane Fujiwara	Japan Agency for Marine-Earth Science and Technology
Jorge Garcia Molinos	Hokkaido University
Kohei Matsuno	National Institute of Polar Research
Jun Nishioka	Hokkaido University
Kari Nordvik	University of Bergen
Fujio Ohnishi	Nihon University (Present: Hokkaido University)
Evgeny Podolskiy	Hokkaido University
Yasunori Sakurai	Hokkaido University
Hiroko Sasaki	Japan Fisheries Research and Education Agency
Hiroshi Suetomi	Hokkaido University
Hiromichi Ueno	Hokkaido University
Hisatomo Waga	Hokkaido University
Eiji Watanabe	Japan Agency for Marine-Earth Science and Technology
Atsushi Yamaguchi	Hokkaido University

▼ Welcome Party