Report of the 2018 DFO Arctic Science Meeting: February 6-8, 2018, Winnipeg, Manitoba

Alain Dupuis (Editor)

Fisheries and Oceans Canada
Ecosystem Science Directorate
National Capital Region
200 Kent Street
Ottawa, Ontario
K1A 0E6

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Canadian Technical Report of
Fisheries and Aquatic Sciences 3292

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

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Ecosystem Science Directorate
National Capital Region
200 Kent Street
Ottawa, Ontario
K1A 0E6
alain.dupuis@dfo-mpo.gc.ca

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Abstract

A. Dupuis (Editor). 2019. Report of the 2018 DFO Arctic Science Meeting: February 6-8, 2018, Winnipeg, Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 3292: viii + 57 p.

The 2018 Fisheries and Oceans Canada (DFO) Arctic Science Meeting was held in Winnipeg, Manitoba from February 6 to 8, 2018. Over the course of the meeting, 80 staff participated from DFO's Science sector from five administrative regions (Central & Arctic, Pacific, Quebec, Maritimes, and Newfoundland & Labrador). The scientific program included: seven topical sessions featuring 36 presentations; six interactive breakout sessions; a presentation to introduce the development of the State of the Arctic Ocean report; and a plenary presentation and guided roundtable discussion on advancing reconciliation with Indigenous Peoples.

This meeting was designed to bring together DFO's science staff that work on Arctic science to present research results, exchange ideas and share knowledge on the implications of climate change, on the status and trends of the Arctic Ocean and on advancing reconciliation with Indigenous Peoples. The meeting included participation by several new staff members and helped to build connections and foster collaboration between individuals working in different DFO Regions and disciplines. The planned deliverables of the meeting include this report, and presenters will participate as chapter leads and expert contributors for the State of the Arctic Ocean report planned for 2019-20. In addition, insights from discussions will help inform activities to advance reconciliation.

Résumé

A. Dupuis (Editor). 2019. Report of the 2018 DFO Arctic Science Meeting: February 6-8, 2018, Winnipeg, Manitoba. Can. Tech. Rep. Fish. Aquat. Sci. 3292: viii + 57 p.

La Réunion scientifique pour l'Arctique de Pêches et Océans Canada (MPO) de 2018 s'est tenue à Winnipeg (Manitoba) du 6 au 8 février 2018. Au cours de la réunion, 80 employés de cinq régions administratives (régions du Centre et de l'Arctique, du Pacifique, du Québec, des Maritimes et de Terre-Neuve-et-Labrador) du Secteur des sciences du MPO ont participé aux discussions. Le programme scientifique comprenait : sept séances particulières avec 36 présentations; six séances interactives en petits groupes; une présentation sur l'élaboration du rapport sur l'état de l'océan Arctique; une séance plénière et une discussion en table ronde animée sur la progression de la réconciliation avec les peuples autochtones.

La réunion visait à rassembler le personnel scientifique du MPO travaillant sur les sciences de l'Arctique afin de présenter les résultats des recherches, d'échanger des idées et de partager des connaissances sur les répercussions du changement climatique, l'état et les tendances de l'océan Arctique et la promotion de la réconciliation avec les peuples autochtones. La réunion regroupait plusieurs nouveaux membres du personnel et visait à créer des liens et à favoriser la collaboration entre les personnes évoluant dans différentes disciplines et régions du MPO. Les produits livrables découlant de la réunion comprennent ce rapport et les présentateurs participeront à titre de responsables et de collaborateurs experts pour le rapport sur l'état de l'océan Arctique planifié pour 2019-2020. En outre, un aperçu des points de discussions permettra d'orienter les activités en vue de faire progresser la réconciliation.

Editor's comments

This report contains presentation abstracts, breakout session reports and a keynote presentation submitted by participants of the 2018 Fisheries and Oceans Canada (DFO) Arctic Science Meeting. The abstracts, presentation and breakout session reports were subject to limited review by the editor and are generally published as submitted by the authors. Comments on any aspects of individual contributions should be directed to the authors.

2018 DFO Arctic Science Meeting – Planning Committee

Meeting Planning Committee:		
Alain Dupuis (Chair)	Science Advisor, Environment & Biodiversity Science	National Capital Region
Andrea Niemi	Research Scientist, Arctic & Aquatic Research Division	Central and Arctic Region
Denise Joy	Manager, Oceans Science	National Capital Region
Emily Smits	Science Advisor, Oceans Science	National Capital Region
Susan Thompson	Science Advisor, Fish Population Science	National Capital Region

Introduction

The 2018 Fisheries and Oceans Canada (DFO) Arctic Science Meeting was held in Winnipeg, Manitoba from February 6 to 8, 2018 at the Canad Inns Destination Centre Fort Garry. The meeting brought together DFO Science staff that conduct research and provide advice related to the Arctic to discuss data and scientific results, and to foster collaboration across administrative regions and disciplines.

The meeting was organized around three overarching themes selected to support national commitments of the Government of Canada (GoC) and DFO and included:

- Research that contributes to our understanding of the implications of climate change on Arctic ecosystems;
- Research that contributes to our understanding of the state of the Arctic Ocean and;
- Advancing reconciliation with Indigenous Peoples;

The meeting was structured to include presentations and breakout discussions that contributed to these themes. The final agenda of the meeting is available in Appendix 1.

The core of the meeting was focused on presenting DFO's research results that contributes to our understanding of a changing Arctic. The meeting also introduced the approach for developing DFO's State of the Arctic Ocean report planned for 2019-20. To address the theme of reconciliation, DFO's Indigenous Affairs and Reconciliation Directorate gave an overview of ongoing activities within the GoC and DFO to advance reconciliation with Indigenous Peoples. This plenary presentation was complemented by a guided roundtable discussion on the integration and inclusion of Indigenous Knowledge with DFO Science.

The meeting was attended by 80 DFO Science staff over the course of the three days (see Appendix 2 for the participant list) and featured 36 scientific presentations and six scientific breakout discussions on topics that benefitted from cross-discipline interaction.

This report gives a summary of the meeting elements and includes the abstracts of the scientific presentations (Appendix 3) and the reports from the breakout discussions (Appendix 4). To assist with locating materials associated with individual presenters, an index is also provided (Appendix 5).

In addition, this summary report includes a list of key outcomes results from a post-meeting survey completed by participants, and planned deliverables.

The French version of this report is also available. Refer to: A. Dupuis (rédacteur). 2019. Le rapport sur la réunion scientifique pour l'Arctique du MPO : le 6 au 8 février, Winnipeg, Manitoba. Rapp. tech. can. sci. halieut. aquat. 3292: ix + 72 p.

Scientific Program

Scientific presentations

Two scientific themes were addressed in the 2018 DFO Arctic Science Meeting: research that contributes to our understanding of the impacts of climate change on Arctic ecosystems, and research that contributes to our understanding of the state of the Arctic Ocean.

To address these overarching themes, participants were invited to contribute presentations that would demonstrate how ecosystem components are changing in magnitude, time and/or space. Additionally, if possible, presenters were encouraged to discuss trends and the inter-relatedness of observed changes.

In total, 36 scientific presentations were given by DFO staff and these were organized into session themes by the meeting's planning committee. See Appendix 3 for the abstracts (names of presenters are underlined).

The session themes were:

- Changing diets and food web
- Implications of climate and warming
- Large-scale patterns and processes
- New approaches to doing science in the Arctic
- Coastal and river linkages
- Changing species distribution
- Habitats and their use

In addition, one presentation was given by Andrea Niemi, Research Scientist, to introduce the approach for developing the State of the Arctic Ocean report planned for 2019-20, a commitment to inform Canadians of the current state of Canada's oceans. The call for abstracts for the 2018 DFO Arctic Science Meeting was designed in part to solicit presentations relevant to the development of the State of the Arctic Ocean report.

Facilitated breakout discussions

Bringing DFO's Arctic science staff together presented a valuable opportunity to have focused discussions on scientific projects and challenges that could benefit from cross-disciplinary ideas and collaboration. Prior to the meeting, participants were invited to submit topic ideas for facilitated breakout discussions to discuss data, programs and/or new opportunities for Arctic science.

In total, six breakout discussions were included in the scientific program. Summary reports of the discussions, including outcomes and next steps, are provided in Appendix 4.

The topics of the six breakout discussions were:

- Arctic Cod – integrating knowledge on a sentinel species for Arctic change
- Integrated Ecosystem Assessment and Monitoring – Pond Inlet as a case study
- Needs for wintertime/ice-covered marine observations in Canada's Arctic
- The Ecosystem story: how to advance the integration of physical oceanography and biological community data to address Arctic change?
- Discussion on the Synoptic Arctic Survey (SAS) program
- Linking climate models, monitoring and laboratory studies with marine ecosystem responses and impacts on subsistence fisheries in the Canadian Arctic

Discussions on advancing reconciliation

The 2018 DFO Arctic Science Meeting included a plenary presentation and a facilitated roundtable discussion on the Department's work towards reconciliation with Indigenous Peoples with a particular emphasis on the role of DFO's Science sector and research in the Arctic.

The plenary presentation was given by Jeff Kennedy, Manager of Reconciliation Policy and Results in DFO's Indigenous Affairs and Reconciliation Directorate. This presentation provided an overview of the federal context for reconciliation and outlined the Department's commitment to build a renewed relationship with Indigenous peoples. An opportunity for questions followed the presentation, during which Arctic science staff discussed implications of reconciliation and approaches for moving forward.

In addition, the meeting included a facilitated roundtable discussion to initiate a conversation, share experiences and gain insights from participants on the integration and inclusion of Indigenous Knowledge with DFO Science. Led by Steven Alexander, a Mitacs Science Policy Fellow and Science Advisor at DFO, the discussion provided an opportunity to learn from participants with experience working with individuals, communities, and co-management partners from Inuit Nunangat. Participants shared experiences and approaches that led to positive and respectful relationship-building with Indigenous communities.

Outcomes and deliverables of the meeting

Outcomes of the meeting

The 2018 DFO Arctic Science Meeting was an initiative to bring together all DFO Science sector staff that conduct research and provide advice related to the Arctic. The meeting achieved several important outcomes as summarized below, including some that were identified through direct participant feedback (online survey and informal).

- DFO staff increased their knowledge of Arctic science research being conducted by the Department in different Regions and disciplines across Canada.
- New connections were created, and existing relationships were strengthened, between individuals across Regions and disciplines that will likely lead to new and continued collaborative work in the Department.
- New opportunities for collaboration and potential synergies on innovative scientific research in the Arctic were identified through the breakout group discussions (see Appendix 4).
- Relevant information, chapter leads and expert contributors were identified for the development of the State of the Arctic Ocean report.
- Knowledge gained from the presentation of research results and exchange of views and ideas will help inform discussions of the DFO Arctic Science Committee regarding future priorities and direction for Arctic Science in the Department.
- DFO staff increased their knowledge of the Department's work to advance reconciliation with Indigenous Peoples, and identified challenges, opportunities and best practices for DFO's Science sector and research in the Arctic with regard to reconciliation and Indigenous Knowledge.
- Key insights from the roundtable discussions will inform the co-development of principles, practices, and policies for bridging Indigenous and science-based knowledge within DFO science activities (e.g., research and monitoring) and science advice processes (lead: Steven Alexander).

Results of the post-meeting online survey

To obtain participant feedback on the meeting, an online survey was issued to all participants during the period of March 22 – April 30, 2018. In total, 30 participants responded to the survey and provided comments that will be valuable for planning future meetings.

All respondents agreed the meeting was a good use of their time and the majority were satisfied with the structure (93%). The meeting benefitted staff in a number of ways as summarized in Table 1. When asked if respondents learned anything new from discussions on reconciliation and the integration and inclusion of Indigenous Knowledge, the results were divided between "yes" (59%) and "no" (41%). The associated comments helped to interpret these results and suggested this could be explained by the fact that many of DFO's Arctic Science staff already have years of on-the-ground experience and good awareness of the concepts of reconciliation and the integration and inclusion of Indigenous Knowledge.

Table 1: Ranked results from: "*How did you benefit from this meeting? (Select all that apply)*".

Answer choices	Response
I learned about research that I was not aware DFO was conducting	97%
I have expanded my professional network	67%
I will be collaborating on projects thanks to new connections made at the meeting	47%
I consider myself a new staff member and this was an important learning experience	37%
Other reasons	33%
I received input from colleagues on my research (presented or otherwise)	33%
I used this meeting as a driver to analyze/interpret data	10%

Deliverables following the meeting

Two key deliverables following the 2018 DFO Arctic Science Meeting are identified as follows:

1) The publication of the 2018 DFO Arctic Science Meeting summary report including the abstracts of the scientific presentations and the reports from the breakout discussions (lead: Alain Dupuis).
2) The development of the State of the Arctic Ocean report will be initiated (to be published 2019-20) and presenters from the 2018 DFO Arctic Science Meeting will participate as chapter leads and expert contributors for the report (lead: Andrea Niemi).

Acknowledgements

Many individuals contributed to this meeting. The meeting would not have been possible without the active participation from staff and particularly those who contributed presentations, facilitated breakout sessions and chaired topical sessions. Thank you to the members of the planning committee who contributed time and expertise to developing the program, and thank you to Bronwyn Keatley who offered guidance and support to make this meeting a success. Finally, thank you to the DFO Arctic Science Committee for proposing the idea for this meeting and to senior management who recognized the value of this undertaking.

Appendix 1 – 2018 DFO Arctic Science Meeting Agenda

Tuesday, February 6

Canad Inns Destination Centre Fort Garry, 1824 Pembina Hwy, Winnipeg, MB

Time	Presenter	Presentation
8:15-9:00	Arrival of participants, loading of presentations	
9:00-9:15	Bronwyn Keatley, Alain Dupuis	Welcome, introductions, and housekeeping
9:15-9:30	Michelle Bielik, Gavin Christie	Welcoming remarks
9:30-10:30	Jeff Kennedy	Advancing Indigenous Reconciliation (followed by Q&A)
10:30-11:00	Health break	
11:00-12:15	Session theme: Changing diets and food web (chair: Alain Dupuis)	
11:00-11:15	Garry Stenson	The impact of climate change on the population dynamics of Northwest Atlantic harp seals
11:15-11:30	David Deslauriers	Improving our understanding of the shrimp fishery in Eastern Canada using an ecosystem-based approach
11:30-11:45	Darcy McNicholl	Coastal Ecological Monitoring Framework
11:45-12:00	Ashley Stasko	Spatial variation in trophic coupling between benthic and pelagic food webs in the offshore Beaufort Sea
12:00-12:15	Lisa Loseto	Knowledge Co-production of Eastern Beaufort Sea Beluga whale diet under a changing environment
12:15-13:00	Lunch (not provided)	
13:00-14:30	** No items scheduled. Session "Large-scale patterns and processes" moved to Wednesday ** (C&A staff to attend Freshwater Institute Town Hall)	
14:30-16:00	Session theme: Implications of climate and warming (chair: Bronwyn Keatley)	
14:30-14:45	Steve Ferguson	How will they die? Changes in distribution and abundance of ringed seals with Arctic warming.
14:45-15:00	Ross Tallman	Climate and the Black Swan in Arctic fish populations
15:00-15:15	Zhenxia Long	Impacts of climate in the Arctic Ocean
15:15-15:30	Nadja Steiner on behalf of Helen Drost	Designing a Database for Physiological Thresholds and Acclimation Potential of Arctic and Subarctic Marine Species in a Multi-Stressor Environment
15:30-15:45	Diane Lavoie	Projected changes in physical and biogeochemical conditions in sub-Arctic waters: How useful are Earth System Model results?
15:45-16:00	Humfrey Melling	Year-round ocean monitoring on the Beaufort shelf: The first quarter century delivers a few surprises
16:00-16:15	Andy Majewski, Kevin Hedges, Bill Williams	Brief introduction to Day 2 breakout sessions (5 min each)
16:15-16:25	Alain Dupuis	Closing remarks

Wednesday, February 7

Canad Inns Destination Centre Fort Garry, 1824 Pembina Hwy, Winnipeg, MB

Time	Presenter	Session/Presentation
8:15-9:00	Arrival of participants, loading of presentations	
9:00-9:05	Alain Dupuis	Welcome, agenda review
9:05-10:20	Session theme: Large-scale patterns and processes (chair: Shannon Nudds)	
9:05-9:20	Nadja Steiner	Development of a Regional Ocean-ice-Ecosystem Model
9:20-9:35	Will Perrie	Springtime North Pacific Oscillation and summer sea ice in the Beaufort Sea
9:35-9:50	Sarah Zimmermann	A 15-year oceanographic time-series of the Beaufort Gyre Region of the Southern Canada Basin: results from Joint Ocean Ice Studies
9:50-10:05	Jane Eert	Features of the trans-Arctic sections of the UNCLOS missions: the Pacific-Atlantic boundary and Eurasian River flow along the Lomonosov Ridge
10:05-10:20	Kumiko Azetsu-Scott	Ocean Acidification in the Eastern Canadian Arctic
10:20-12:00 Health break, as needed	Location: Facilitator: Topic:	**Breakout 1:** Ambassador F Andy Majewski *Arctic Cod – integrating knowledge on a sentinel species for Arctic change* **Breakout 2:** Ambassador F Kevin Hedges *Integrated Ecosystem Assessment and Monitoring – Pond Inlet as a case study* **Breakout 3:** Ambassador E Bill Williams *Needs for wintertime/ ice-covered marine observations in Canada's Arctic*
12:00-13:00	Lunch (not provided)	
13:00-14:15	Session theme: New approaches to doing science in the Arctic (chair: Susan Thompson)	
13:00-13:15	Clark Richards	Our Eyes and Ears on the Northwest Passage: DFO's Monitoring Program and Real-Time Observatory in Barrow Strait
13:15-13:30	Yvan Simard	Observing the Canadian Arctic marine ecosystems through acoustics
13:30-13:45	Mike Hammill	Improving data collection in Arctic areas: Let marine mammals do the work!
13:45-14:00	Xinhua Zhu	Quantitative Monitoring and Assessment of Arctic Fisheries Productivity under Cumulative Impacts
14:00-14:15	Tracey Loewen	Do Arctic Cod have separate spawning aggregations in the Beaufort Sea region?
14:15-14:30	Nadja Steiner, Wojciech Walkusz, Kumiko Azetsu-Scott	Brief introduction to Day 3 breakout sessions (5 min each)
14:30-15:00	Health break	
15:00-16:30	Session theme: Coastal and river linkages (chair: Margaret Treble)	
15:00-15:15	Les Harris	Integrating Telemetry, Population Genetics and Genomics to Understand the Evolutionary Ecology, Life History and Management of Arctic Char, *Salvelinus alpinus*, from the Cambridge Bay Region of Nunavut
15:15-15:30	Christie Morrison	The development of a new otolith back-calculation model to compare early growth patterns in Dolly Varden
15:30-15:45	Zoya Martin	Cumberland Sound Arctic Char Fisheries: Data From Across The Sound.
15:45-16:00	Bill Williams	The Kitikmeot Sea of the southern Canadian Arctic Archipelago.
16:00-16:15	Mike Dempsey	Winter and summer oceanographic observations in Dease Strait,Nunavut
16:15-16:30	Kristina Brown	Where the River Meets the Sea: Investigating Nutrient Dynamics in the Kitikmeot Riverine Coastal Domain
16:30-16:35	Alain Dupuis	Closing remarks
16:35-17:35	Side meeting: Arctic Science Committee meeting, limited to members of the committee	

Thursday, February 8

Canad Inns Destination Centre Fort Garry, 1824 Pembina Hwy, Winnipeg, MB

<table>
<tr><th colspan="2">Time</th><th>Presenter</th><th colspan="3">Session/Presentation</th></tr>
<tr><td colspan="2">8:15-9:00</td><td colspan="4">Arrival of participants, loading of presentations</td></tr>
<tr><td colspan="2">9:00-9:10</td><td>Bronwyn Keatley,
Alain Dupuis</td><td colspan="3">Welcome, message from Patrice Simon, agenda review</td></tr>
<tr><td colspan="2">9:10-10:00</td><td>Steve Alexander,
Jessica Hurtubise</td><td colspan="3">Roundtable Discussion on the Integration and Inclusion of Indigenous Knowledge with DFO Science</td></tr>
<tr><td rowspan="4">10:00-12:00</td><td rowspan="4">Health break, as needed</td><td></td><td>Breakout 1:</td><td>Breakout 2:</td><td>Breakout 3:</td></tr>
<tr><td>Location:</td><td>Ambassador F</td><td>Ambassador F</td><td>Ambassador E</td></tr>
<tr><td>Facilitator:</td><td>Nadja Steiner</td><td>Wojciech Walkusz</td><td>Kumiko Azetsu-Scott</td></tr>
<tr><td>Topic:</td><td>Linking climate models, monitoring and laboratory studies with marine ecosystem responses and impacts on subsistence fisheries in the Canadian Arctic</td><td>The Ecosystem story: how to advance the integration of physical oceanography and biological community data to address Arctic change?</td><td>Discussion on the Synoptic Arctic Survey (SAS) program</td></tr>
<tr><td colspan="2">12:00-13:00</td><td colspan="4">Lunch (not provided)</td></tr>
<tr><td colspan="2">13:00-13:15</td><td>Andrea Niemi</td><td colspan="3">State of the Arctic Ocean report: Integrating and sharing our science</td></tr>
<tr><td colspan="2">13:15-14:30</td><td colspan="4">Session theme: Changing species distribution (chair: Andrea Niemi)</td></tr>
<tr><td colspan="2">13:15-13:30</td><td>Karen Dunmall</td><td colspan="3">Evidence for historic and modern post-glacial colonizations of chum salmon at the northern range edge</td></tr>
<tr><td colspan="2" rowspan="2">13:30-13:45</td><td rowspan="2">Dave Cote</td><td colspan="3">Growth-potential approach to forecasting change in fish communities along the eastern seaboard of Canada</td></tr>
<tr><td colspan="3">Coral diversity in the Canadian Arctic*
*presentation on behalf of Vonda Wareham</td></tr>
<tr><td colspan="2">13:45-14:00</td><td>John Nelson</td><td colspan="3">Further Penetration of Pacific-type Calanus glacialis into the Arctic Ocean</td></tr>
<tr><td colspan="2">14:00-14:15</td><td>Virginie Roy</td><td colspan="3">The Circumpolar Biodiversity Monitoring Program - Benthos Expert Network: Findings and Recommendations from the State of the Arctic Marine Biodiversity Report (SAMBR)</td></tr>
<tr><td colspan="2">14:15-14:30</td><td>Kimberley Howland</td><td colspan="3">Which regions of the Canadian Arctic are most vulnerable to marine invasive species introductions? Insights from habitat suitability modelling under current and projected future climate scenarios.</td></tr>
<tr><td colspan="2">14:30-14:45</td><td colspan="4">Health break</td></tr>
<tr><td colspan="2">14:45-16:00</td><td colspan="4">Session theme: Habitats and their use (chair: Lianne Postma)</td></tr>
<tr><td colspan="2">14:45-15:00</td><td>Christine Michel</td><td colspan="3">Arctic sea ice-associated ecosystems: The good, the bad and the ugly</td></tr>
<tr><td colspan="2">15:00-15:15</td><td>Andy Majewski</td><td colspan="3">Marine fish community structure and habitat associations in the Canadian Beaufort Sea</td></tr>
<tr><td colspan="2">15:15-15:30</td><td>David Yurkowski</td><td colspan="3">Abundance and species diversity hotspots of tracked marine predators across the North American Arctic</td></tr>
<tr><td colspan="2">15:30-15:45</td><td>Claire Hornby</td><td colspan="3">Exploring habitats within the Beaufort Sea ecosystem, have beluga whales become more common in the offshore in recent years?</td></tr>
<tr><td colspan="2">15:45-16:00</td><td>Kevin Hedges</td><td colspan="3">Habitat use, population structure and ecology of Arctic marine fishes</td></tr>
<tr><td colspan="2">16:00-16:10</td><td>Bronwyn Keatley,
Alain Dupuis</td><td colspan="3">Closing remarks</td></tr>
</table>

Appendix 2 – Meeting Participants

Participant	Affiliation
Alain Dupuis	DFO, National Capital Region
Andrea Moore	DFO, Maritimes Region
Andrea Niemi	DFO, Central and Arctic Region
Andy Majewski	DFO, Central and Arctic Region
Ashley Stasko	DFO, Central and Arctic Region
Bill Williams	DFO, Pacific Region
Blair Dunn	DFO, Central and Arctic Region
Brent Young	DFO, Central and Arctic Region
Bronwyn Keatley	DFO, National Capital Region
Bruno Rosenberg	DFO, Central and Arctic Region
Charles Hannah	DFO, Pacific Region
Chelsey Lumb	DFO, Central and Arctic Region
Chris Lewis	DFO, Central and Arctic Region
Christie Morrison	DFO, Central and Arctic Region
Christine Michel	DFO, Central and Arctic Region
Claire Hornby	DFO, Central and Arctic Region
Clark Richards	DFO, Maritimes Region
Cory Matthews	DFO, Central and Arctic Region
Dale Nicholson	DFO, Central and Arctic Region
Darcy McNicholl	DFO, Central and Arctic Region
Dave Cote	DFO, Newfoundland and Labrador Region
Dave Yurkowski	DFO, Central and Arctic Region
David Deslauriers	DFO, Central and Arctic Region
Denise Tenkula	DFO, Central and Arctic Region
Diane Lavoie	DFO, Quebec Region
Doreen Kohlbach	DFO, Central and Arctic Region
Emily Smits	DFO, National Capital Region
Gary Stenson	DFO, Newfoundland and Labrador Region
Gavin Christie	DFO, Central and Arctic Region
Humphrey Melling	DFO, Pacific Region
Jane Eert	DFO, Pacific Region
Jeff Kennedy	DFO, National Capital Region
Jessica Hurtubise	DFO, National Capital Region
Jim Reist	DFO, Central and Arctic Region
Joclyn Paulic	DFO, Central and Arctic Region
John Nelson	DFO, Pacific Region
Karen Dunmall	DFO, Central and Arctic Region
Kevin Hedges	DFO, Central and Arctic Region
Kim Houston	DFO, Pacific Region
Kim Howland	DFO, Central and Arctic Region

Participant	Affiliation
Kristina Brown	DFO, Pacific Region
Kumiko Azetsu-Scott	DFO, Maritimes Region
Laura Murray	DFO, Central and Arctic Region
Les Harris	DFO, Central and Arctic Region
Lianne Postma	DFO, Central and Arctic Region
Lisa Loseto	DFO, Central and Arctic Region
Margaret Treble	DFO, Central and Arctic Region
Marianne Marcoux	DFO, Central and Arctic Region
Michel Gilbert	DFO, Quebec Region
Michelle Bielik	DFO, Central and Arctic Region
Mike Dempsey	DFO, Pacific Region
Mike Hammill	DFO, Quebec Region
Nadja Steiner	DFO, Pacific Region
Neil Mochnacz	DFO, Central and Arctic Region
Oksana Schimonowski	DFO, Central and Arctic Region
Richard Moore	DFO, Central and Arctic Region
Rob Bajno	DFO, Central and Arctic Region
Rob Young	DFO, Central and Arctic Region
Robyn Jamieson	DFO, Newfoundland and Labrador Region
Ross Tallman	DFO, Central and Arctic Region
Samantha Fulton	DFO, Central and Arctic Region
Sarah Zimmerman	DFO, Pacific Region
Shannon MacPhee	DFO, Central and Arctic Region
Shannon Nudds	DFO, Maritimes Region
Sherry Niven	DFO, Maritimes Region
Sileema Angoyuak	DFO, Central and Arctic Region
Stephen Virc	DFO, National Capital Region
Steve Alexander	DFO, National Capital Region
Steve Ferguson	DFO, Central and Arctic Region
Susan Thompson	DFO, National Capital Region
Tiphaine Jeanniard Du Dot	DFO, Quebec Region
Tracey Loewen	DFO, Central and Arctic Region
Virginie Roy	DFO, Quebec Region
Will Perrie	DFO, Maritimes Region
Wojciech Walkusz	DFO, Central and Arctic Region
Xinhua Zhu	DFO, Central and Arctic Region
Muhammad Yamin Janjua	DFO, Central and Arctic Region
Yvan Simard	DFO, Quebec Region
Zhenxia Long	DFO, Maritimes Region
Zoya Martin	DFO, Central and Arctic Region

Appendix 3 – Scientific Presentation Abstracts

Session theme: Changing diets and food web

The impact of climate change on the population dynamics of Northwest Atlantic harp seals

Garry Stenson[1], Alejandro Buren[1] and Mike Hammill[2]

[1] Fisheries and Oceans Canada, St. John's, Newfoundland
[2] Fisheries and Oceans Canada, Mont-Joli, Quebec

Harp seals, *Pagophilus groenlandicus*, are the most abundant marine mammal in the North Atlantic and eastern Canadian Arctic. They are seasonal migrants, wintering in the subarctic waters off Newfoundland and southern Labrador, and summering in eastern Canadian Arctic and Greenland waters. As a high trophic level predator, changes in their environment are reflected in their population dynamics. Harp seals give birth on ice and feed along the southern edge of the seasonal pack ice. As the northern hemisphere continues to warm, declines in sea ice seriously impact all species that rely on ice for reproduction and/or feeding. Harp seals require ice of sufficient quantity and thickness to withstand winter storms until the pups are weaned and capable of feeding on their own. If the ice breaks up before then, the young seals can drown. However, climate change also impacts seals indirectly through changes in prey and subsequent reproductive rates. Estimates of late term pregnancy and abortion rates of Northwest Atlantic harp seals were obtained from samples collected off the coast of Newfoundland, Canada. Since the 1950s, pregnancy rates have declined while inter-annual variability has increased. During the same period, harp seals have increased in abundance from less than 1.5 million seals in the early 1970s to approximately 7.4 million seals today. Using beta regression and GAMM models to explore the importance of biological and environmental conditions, we found that the general decline in fecundity is a reflection of density-dependent processes associated with increased population size, likely operating through changes in body size and energy acquisition. The large inter-annual variability in fecundity is captured by including the late term abortion rates in the model. Changes in the abortion rate is described by a model that incorporates ice cover in late January, body condition, and capelin biomass obtained from the previous fall survey. Capelin is the main prey of harp seals. Without capelin, harp seals are not able to build up the energy they need to continue the pregnancy or nurse their pup and so may spontaneously abort. A previous study has shown that capelin abundance is correlated with ice conditions suggesting that late January ice conditions should be considered a proxy for ecosystem changes in overall prey abundance. These negative impacts of changing climate will likely increase if the general warming trend and associated reduction in ice condition continues.

Improving our understanding of the shrimp fishery in Eastern Canada using an ecosystem-based approach

David Deslauriers[1], Wojciech Walkusz[1] and Sheila Atchison[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba

In Canada, Northern shrimp (*Pandalus borealis*) are harvested in four out of five DFO regions, support a $400 million industry, are important forage species for a wide range of Arctic fishes and marine mammals, and are considered vulnerable to climate change. Despite the economic and ecological value of this species, the main drivers of productivity still remain understudied. In particular, climate change effects such as pH, dissolved oxygen and salinity declines and increases in water temperature will possibly result in the enhancement or compromise of many of these stocks. There is thus an imminent need to understand this fishery using a holistic perspective in order for the appropriate management measures to become implemented. In this presentation, a general overview of the Northern shrimp situation in the Central & Arctic Region will be given with regards to long-term spatial abundance trends, temperature and depth relationships, species interactions, sex dynamics and demographics, and fishery performance under the precautionary approach framework. Remarks will also be provided regarding the stock assessment method, the data it generates, and how this approach compares to other regions that manage Northern shrimp. Finally, research requirements addressing the need for an ecosystem-based monitoring approach for this valuable marine resource will be discussed.

Coastal ecological monitoring framework

Darcy McNicholl[1], Karen Dunmall[1], Chris Lewis[2] and Jim Reist[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba
[2] Fisheries and Oceans Canada, Iqaluit, Nunavut

This study develops a community-based monitoring framework for the Canadian Arctic. Research findings aid in identification of important areas and species, are transferrable among coastal ecosystems and areas, and establish a foundation for community involvement and co-management. This framework is an ecosystem-level approach to monitoring using consistent indicators that encompass multiple trophic levels, thus allowing inferences regarding causation for any observed changes during monitoring. An initial community-based monitoring framework, developed from research conducted in the Anguniaqvia niqiqyuam Marine Protected Area during 2015-2017, was tested in Kugluktuk, Nunavut in 2017. An additional objective of this program is to accomplish field work while working closely with subsistence harvesters, and ultimately developing community-based monitoring programs in respective areas. This approach can include new locations to expand the geographic coverage. The approach also integrates the

variabilities in space and time for coastal ecosystems. Compiled baselines of biodiversity, water chemistry, and benthos serve as valuable indicators for variabilities and changes, in response to cumulative impacts of increased shipping, climate change, coastal erosion, and changing aquatic community composition. The extent of overlap and coupling in the coastal community, and level of sensitivity to change, can also be quantified using biotracers (e.g., stable isotopes which integrate trophic structures and energy flows) in order to assess potential for competition, habitat associations and extent of coupling within coastal and offshore communities These analyses, combined with habitat parameters (biophysical data, benthic samples) can be used to document variabilities and identify if changes are occurring or likely to occur within and at the community-level among multiple sites in the Arctic. A consistent monitoring framework is required to detect change in key indicators in order for effective management, and one that contributes to national initiatives for new protected areas and scientific advancement within Marine Conservation Targets and Ocean Protection Plan objectives, and fisheries management. Identifying probable causation allows for mitigation and/or adaptation actions to be undertaken. The framework establishes critical linkages between freshwater and deeper offshore habitats and is closely tied into research objectives identified by respective Hunters and Trappers Committees. This transferrable community-based monitoring framework is relevant to support consistent monitoring of important areas across the Canadian Arctic, assist in the identification of new areas, and support the collection of baseline data in coastal ecosystems

Spatial variation in trophic coupling between benthic and pelagic food webs in the offshore Beaufort Sea

Ashley Stasko[1], Heidi Swanson[2], Michael Power[2], James Reist[1], Bodil Bluhm[3], Andrew Majewski[1], Carolina Giraldo[1], Wojciech Walkusz[1], Philippe Archambault[4], Christine Michel[1], Jane Eert[5], Sheila Atchison[1] and Shannon MacPhee[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6
[2] University of Waterloo, Waterloo, Ontario, N2L 3G1
[3] UiT – the Arctic University of Norway, Tromsø, Norway
[4] Québec-Océan, Takuvik, Départment de biologie, Université Laval, 1045 avenue de la Médecine, Québec, PQ, G1V 0A6
[5] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia V8L 4B2

Benthic communities strongly influence the broader ecological functioning of marine ecosystems, including carbon storage, nutrient cycling, and the locations of important feeding grounds for migratory marine mammals. Understanding the ecological linkages within and among benthic communities that support higher trophic levels is important to sound ecosystem-based management. To that end, we summarize key findings of the Beaufort Regional Environmental Assessment Marine Fishes Project (BREA-MFP, 2012-2015) that address substantial knowledge gaps regarding spatial variation in benthic fish and invertebrate food web structure in the Canadian Beaufort Sea and Amundsen Gulf. Trophic structure and benthic-pelagic linkages on the continental shelf and slope, from 20 to 1000 m, were examined using stable isotope values ($\delta^{15}N$, $\delta^{13}C$) measured in 113 fish and invertebrate taxa, paired with biomass distributions and biological functional traits. First, pelagic food subsidies actively obtained by large-bodied fishes were important for sustaining fish biomass in deep habitats (> 750 m), and affected community body size distributions. Second, when fish and invertebrates were considered together, indicators of benthic-pelagic coupling based on consumer stable isotope values were linked to spatial patterns in water mass structure (offshore gradient) and organic matter inputs (alongshore gradient). Benthic communities were most decoupled from pelagic production on the upper slope, and became increasingly decoupled alongshore towards the Amundsen Gulf. Third, despite apparent differences in the strength of benthic-pelagic coupling between the Canadian Beaufort Sea and Amundsen Gulf, the trophic diversity of benthic communities based on both stable isotope values and biological feeding traits (e.g., feeding mode, mobility, prey types) did not differ strongly between regions. Together, results provide a baseline understanding of the connection between processes controlling the movement of organic matter and offshore benthic trophic structure in the Beaufort Sea.

Knowledge co-production of Eastern Beaufort Sea Beluga whale diet under a changing environment

Lisa Loseto[1], Shannon MacPhee[1], Sonya Ostertag[1,2], Emily Choy[1,2], Claire Hornby[1], Carie Hoover[2], Kathleen MacMillan[1,2], Elizabeth Worden[1] and Bruno Rosenberg[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6
[2] University of Manitoba

Eastern Beaufort Sea (EBS) beluga whales (*Delphinapterus leucas*) are an important part of a traditional subsistence harvest by the Inupiat in Alaska and the Inuvialuit of the western Canadian Arctic. Beluga harvest monitoring programs have occurred at key harvest locations in the Mackenzie Estuary for 30+ years, and more recently in Darnley Bay (beginning in 1989). Despite access to beluga carcasses and stomachs from harvest-based monitoring, whales rarely contain stomach contents. As with all cetaceans, observing foraging behaviour and defining diet is challenged by access to observations, fecal and stomach samples. To compound this, the Mackenzie Estuary, where the EBS beluga aggregate and are harvested, is turbid, preventing visual observations of belugas below the water surface. As such, we have developed proxies and tools to assist with the identification of beluga diet. Our diet analyses inferred by biomarkers such as fatty acids and stable isotopes (Loseto et al. 2009) as well as habitat use models derived from telemetry and have all pointed to Arctic cod (*Boreogadus saida*) as a key prey species. However, for the first time on record, large numbers of beluga whales were harvested in Ulukhaktok, NT in 2014 and observations, TEK and stomach contents pointed to a diet devoid of

Arctic cod. This event along with recent observations of changing beluga conditions, environmental conditions, and harvest conditions highlight the need to better define beluga-prey interactions in a changing environment. Given that Inuvialuit continue to cope and adapt to changing conditions that effect beluga and their livelihoods there is need to enhance our knowledge of the beluga-prey interactions, associated energetics and to inform on management and action.

With nearly 40 years of monitoring data of the EBS beluga whale population, the Beaufort Sea is home to the world's longest beluga dataset. Beluga whales are an iconic species, representing a key predator in the Beaufort Sea food web and are culturally significant for the Inuvialuit, Western Arctic Inuit. The land claim and co-management framework for the Inuvialuit Settlement Region supported the long term monitoring and management plans for this beluga population. We evaluate knowledge gained from the long term data and ask are beluga ideal indicator species for ecosystem change and are management frameworks in place to respond? Time trends of beluga condition metrics reflected ecosystem changes and demonstrated that impacts are manifested in beluga physiological parameters. Seasonal distribution and relative abundance of beluga were responsiveness to alterations in the physical environment. These observations were supported by changes over space and time of community harvests and traditional ecological knowledge. We conclude that the EBS beluga whales are effective indicators of change, however gaps remain between causation of beluga responses and drivers of change. Beluga management plans were adaptive and responsive to managing human activities; however, newer plans that implement the use of indicators lack critical details required to make firm management decisions. Future research is needed for the interpretation of monitoring trends to advise on management actions. This will require the effective inclusion of Inuvialuit traditional knowledge together with western science, to design research and monitoring programs to directly advise management strategies that will need to be flexible during future climate change uncertainty.

Session theme: Implications of climate and warming

Year-round ocean monitoring on the Beaufort shelf: The first quarter century delivers a few surprises

Humfrey Melling[1] and David A. Riedel[1]

[1] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia

The Institute of Ocean Sciences (IOS) with support from the federal Program on Energy Research and Development established year-round monitoring of sea ice over the Beaufort shelf in April 1990. The initiative was made possible by the development at IOS of the Ice Profiling

Sonar (IPS), which provided capability to measure sea ice from a submerged mooring autonomously for 1-3 years. The suite of instruments required for monitoring ice hazards (large thick features, rapid drift) has provided not only ice thickness every meter across 1000-2500 km of pack ice annually, but also data descriptive of the ocean and of events occurring within it – temperature, salinity, sound scattering from zooplankton, ocean current, upwelling, flaw lead opening and closing, storm waves and surges, ambient sound, etc. for more than a quarter century. These data comprise the longest continuous marine record available anywhere in the Arctic interior.

With a record of this length we are in a position to describe the "ocean climate" of the region of study in relation to the ocean characteristics that have been monitored. Some examples will be presented and discussed. General speaking ocean variability on multi-annual and decadal time scales, which is a part of the Beaufort's ocean climate, has dominated the records. Even with 25 years of data, variability has masked trends so that few calculated values of trend are distinct from zero with much confidence. The trends most likely to be real are those linked to the phenomena at the ocean surface, such as ice clearing and freeze-over dates, net ice drift in autumn and sea state. Pack-ice thickness at mid-shelf (in the seasonal sea ice zone) has thinned by only 9 cm per decade since 1990, in marked contrast to the much discussed thinning of the polar pack that covers the Arctic basins. Moreover the ice-thickness trend is significant at only 50% confidence.

How will they die? Changes in distribution and abundance of ringed seals with Arctic warming

Steve Ferguson[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6

How will the range of Arctic-adapted species retract northward as the ocean warms? To assess whether change will be gradual or punctuated or whether animals will move or die we initiated a research approach to compare (1) patterns in environment (e.g., duration of open water season, sea surface temperature, climatic indices) to (2) vertical and horizontal movements (e.g., satellite telemetry, aerial surveys) and (3) life-history (e.g., reproduction, body condition). First, we contrasted ringed seals (*Pusa hispida*) from Hudson Bay at the southern limit of their range to High Arctic seals. Results indicate that seal body fat cycled seasonally (low in winter) with greater variation but lower amplitude in northern seals relative to the south. Longer migrations occurred in the north possibly due to greater environmental unpredictability. In southern areas, seals grew twice as fast reaching physical maturity at 4.6 years of age for females versus 6.2 in the north but achieving a smaller asymptotic body size (126 cm versus 146). Age of sexual maturity and first reproduction was two years earlier in the south. In the south, ovulation and pregnancy rates were lower resulting in a longer interbirth interval. Overall variation (unpredictability) in demographic rates was lower at the southern limits of ringed seal range which may match the more consistent environment relative to high latitudes.

We assessed the seal population dynamics at the southern limits of their range to try and uncover the mechanism of population decline. Aerial surveys of western Hudson Bay ringed seals (1995-2017) suggest a gradual decline in seal abundance, with a crash in ringed seal numbers between 2010 and 2013. The 2010 open water season in Hudson Bay was one of the warmest on record and resulted in the longest ice-free season and extreme positive North Atlantic Oscillation (NAO) and Arctic oscillation (AO) conditions. Satellite-tagged seals responded by spending less time foraging and making fewer deep dives during the critical open-water season of positive energy balance in 2010. Low foraging activity was also recorded during the following two years possibly due to reduced condition of seals. Following the 2010 warming event, analysis of seal samples provided by Inuit hunters indicated reduced seal reproduction (low ovulation and pregnancy rates), low pup numbers, and increased stress (cortisol levels). Hunters reported sick seals in 2010 suggesting that disease may have resulted in mortality. We conclude that negative demographic responses are occurring both gradually and with episodic declines. Ringed seals prove to be a good study animal in understanding the mechanisms of intraspecific life-history variation and changes in distribution and abundance of Arctic marine mammals.

Climate and the Black Swan in Arctic fish populations

Ross Tallman[1], Kendra Imrie[1,2], Gabrielle Grenier[1,2], Samantha Fulton[1], Zoya Martin[3], Les Harris[1], Simon Wiley[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6
[2] University of Manitoba
[3] Fisheries and Oceans Canada, Iqaluit, Nunavut

Climate change is predicted to be the most pronounced in the Arctic. The dynamics of Arctic fish stocks are already driven by climatic effects in terms of the influence of temperature on vital rates, migration and habitat quality and access. The determining the vulnerability of fish stocks to climate effects will be complicated with information needed on both the sensitivity of species and their likelihood of exposure. We present preliminary results of a fish stock climate vulnerability assessment. We also present direct evidence of climate effects on the biology of Arctic Charr in terms of changes in trophic ecology and early life history. Arctic Charr in Cumberland Sound altered their diet from invertebrates to more fish-oriented consumption concurrent with the invasion and establishment of a temperate species, Capelin. Study of the growth patterns in the early life history using back-calculation techniques suggest that climate effects influence early growth which may result in changes to the dynamics of stocks. Finally, we discuss the problem of "Black Swan" events in natural resource population dynamics.

Impacts of climate in the Arctic Ocean

Zhenxia Long[1] and Will Perrie[1]

[1] Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

Under climate change scenarios, the largest lower tropospheric warming is expected to occur in the Arctic. Here, we investigate how the Arctic Ocean might respond to the surface warming. We performed simulations from 1970 to 2099 with a coupled ice-ocean model (CIOM) implemented for the Arctic Ocean. The surface fields to drive CIOM were provided by the Canadian Regional Climate Model (CRCM), in turn driven by the third-generation Canadian global climate model (CGCM3) outputs following the A1B climate change scenario. Compared to observations, CIOM has a reasonable simulation of sea ice, ocean temperature and salinity in the Arctic Ocean. For example, the CIOM simulation exhibits a warm Atlantic water layer (AWL) in the central Arctic Ocean, captures the observed FWC maximum in the central Beaufort Sea, and the rapid decline of total ice concentration over the last thirty years. Under the A1B scenario, the CIOM simulations suggest an 11% decrease per decade in ice volume, with the Arctic Ocean becoming largely ice free in the summers by about ~ 2060s. Moreover, due to the increased ice melting and Ekman transport, there is an increasing trend in fresh water content (FWC) and sea surface height (SSH) in the Beaufort Sea. The increase is about 2 m for the FWC and 6 cm for the SSH from 1979 to 2069. In terms of the Atlantic water, there is a significant increase in water volume transport into the central Arctic Ocean through Fram Strait, due to the intensified atmospheric low pressure system over the Nordic Seas. However, the AWL temperature tends to decrease from 0.36ºC in the 2010s to 0.26ºC in the 2060s. In the vertical, the warm Atlantic water core slightly expands before the 2030s, significantly shrinks after the 2050s, and essentially disappears by 2070-2099, in the southern Beaufort Sea. Finally, in the Barents Sea, the loss of sea ice significantly increases both the surface solar radiation and the ocean surface heat while the lateral heat transport tends to increase, and the net heat fluxes play an important role in the changes of the ocean temperature associated with the AWL.

Designing a database for physiological thresholds and acclimation potential of Arctic and sub-Arctic marine species in a multi-stressor environment

Nadja Steiner[1], Helen Drost[1,2] and Karen Hunter[3]

[1] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia
[2] Sheluqun Environmental Consulting
[3] Fisheries and Oceans Canada, Nanaimo, British Columbia

To improve our capacity to assess and project climate change adaptation in marine ecosystems and provide locally applicable projections relevant for Arctic communities and governments, higher-resolution basin-scale ocean ecosystem models are required. These models need to be linked to species distribution models to assess a species ability to migrate and survive based on rapidly changing environmental conditions. However, current ecosystem models have a limited capability to predict the response or adaptation of individual species to the expected long-term changes in climate and related variables and cannot answer the key question regarding the response/adaptation of whole ecosystems to multiple stressors. Similarly, species distribution models have a limited capability to reproduce species shifts and extinctions, and do not include a capacity for species adaptation. Our knowledge base of physiological thresholds and acclimation potential needs to be expanded and included into modelling exercises. Thus we have compiled an Aquatic Species Physiological Limits Database for 67 Arctic marine species to date, which includes temperature threshold and acclimation potential estimates. It is important to note that the database includes sub-chronic (upper and lower pejus temperatures) and chronic (critical temperatures) thresholds at different life stages and we have categorized the different depth levels and seasons that the various life stages of a species may occupy. We have found that very little information exists on multi-stressor responses. This is a significant knowledge gap, severely limiting out ability to assess potential climate change impacts on Arctic marine species. We encourage further extension of this database via continued literature research, dedicated laboratory experiments as well as monitoring of species habitat in their natural environment.

Projected changes in physical and biogeochemical conditions in sub-Arctic waters: How useful are Earth System Model results?

Diane Lavoie[1] and Nicolas Lambert[1]

[1] Fisheries and Oceans Canada, Mont-Joli, Quebec

Physical and biogeochemical conditions projected by Earth System Models (ESMs) made available for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change were analyzed in Hudson Bay, Baffin Bay and part of the Labrador Sea. ESMs generally have a coarse resolution and can have difficulties representing the complex oceanographic processes taking place in these regions. We nevertheless looked at the trends for different variables and compared them with observed trends when possible and with trends obtained from regional models when available. In some cases a consistent story emerges. We will present some results of this analysis as well as the probable causes for observed discrepancies.

Session theme: Large-scale patterns and processes

Development of a regional ocean-ice-ecosystem model

Nadja Steiner[1], Jim Christian[1], Amber Holdsworth[1], Tessa Sou[1], Hakase Hayashida[2], Eric Mortenson[2] and Adam Monahan[2]

[1] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia
[2] University of Victoria, Victoria, British Columbia

The presentation summarizes recent progress in coupling sympagic (ice-associated) and pelagic ecosystems using 1-D and 3-D model approaches. The studies highlight processes relevant to adequately represent ice algal growth, as well as carbon and sulfur cycling. The sulfur cycle implementation allows for the simulation of dimethylsulfide (DMS) emission which can form marine aerosols which have been shown to cause new particle formation in the pristine Arctic atmosphere in summer, while the representation of ice algae in the model allows for the assessment of potential habitat changes of ice associated marine species (e.g. Arctic cod) in future scenarios. Model results highlight projections of progressing ocean acidification and changes in primary production in the Canadian Arctic under a high emission scenario.

Springtime North Pacific Oscillation and summer sea ice in the Beaufort Sea

Minghong Zhang[1], William Perrie[1], and Zhenxia Long[1]

[1] Fisheries & Oceans Canada, Bedford Institute of Oceanography, Dartmouth, NS, Canada

We investigate the linkage between the spring (April-June) North Pacific Oscillation (NPO) and the following summer sea ice in the Beaufort Sea. NPO is defined as the third rotated empirical orthogonal function (EOF) mode of seasonal sea level pressure poleward of 20ºN. A positive NPO is characterized by a deepening Aleutian Low and Pacific High. Meanwhile the associated strong East Asian trough steers more cyclones from Siberia to the sub-polar Pacific and thus fewer cyclones into the western Arctic Ocean. Therefore, the Beaufort High tends to be strong. Moreover, Deepening East Asian troughs enhance warm air advection from the Pacific toward the Beaufort Sea. The spring NPO accounts for 16% of interannual variability of the following September sea ice cover in the Beaufort Sea. For example, during a positive NPO, the strong easterly winds over the Beaufort Sea enhance ice advection and reduce ice thickness in the region, while increased solar and longwave radiations accelerate ice melting. Furthermore, the increased solar radiation is caused by reduced cloud cover and water content due to fewer cyclones, and the anomalous warm air offsets the negative cloud effect on longwave radiation.

A 15-year oceanographic time-series of the Beaufort Gyre Region of the Southern Canada Basin: results from Joint Ocean Ice Studies

Sarah Zimmermann[1], Bill Williams[1], Rick Krishfield[2], Andrey Proshutinsky[2] and Michiyo Yamamoto-Kawai[3]

[1] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia
[2] Woods Hole Oceanographic Institution
[3] Tokyo University of Marine Science and Technology

The Joint Ocean Ice Studies (JOIS) is an important contribution from Fisheries and Oceans Canada (DFO) to international Arctic climate research programs. It is a collaboration between DFO and colleagues in the USA from Woods Hole Oceanographic Institution who lead the Beaufort Gyre Exploration Project. The program also includes collaborations with the Japan Agency for Marine-Earth Science and Technology, as part of the Pan-Arctic Climate Investigation (PACI) as well as many Canadian and international scientists.

JOIS is focused on the Beaufort Gyre region of the Arctic Ocean's Canada Basin. The gyre has a mix of waters from rivers (Eurasian and North American), from the Pacific Ocean (via Bering Strait), and from the Atlantic Ocean (via Fram Strait). The program has conducted annual oceanographic surveys since 2003 using conductivity, temperature and depth instruments (CTDs), moorings, zooplankton net tows, and ice observations on a grid extending from the Beaufort Shelf, through the ice, to 79ºN.

Research questions look at the impacts of global change on the physical and geochemical environment of the Beaufort Gyre and the corresponding ecosystem response. We collect data to link patterns in the Arctic atmosphere to basin-scale changes in the ocean, including the freshwater content of the Beaufort Gyre, freshwater sources, ice properties and distribution, water mass properties and distribution, ocean circulation, ocean acidification and biota distribution.

Here we present time-series results of the CTD and water bio-geo-chemistry data, describing the observed changes of water mass properties over the study's 15 years, including this year's recent survey. In the Beaufort Gyre region, physical changes include a persistent clockwise atmospheric forcing, strengthened ocean and ice circulation, and reduction of sea-ice. These in turn serve to increase the total freshwater and stratification, deepen the nutricline, and increase surface water acidification. These climate change effects on the summertime marine ecosystem, now operating with less nutrients, but more solar radiation, include smaller and adapted microbial plankton, greater primary production in the surface mixed-layer and greater recycling of surface nutrients via microzooplankton.

Features of the trans-Arctic sections of the UNCLOS missions: the Pacific-Atlantic boundary and Eurasian River flow along the Lomonosov Ridge

Jane Eert[1], Bill Williams[1] and Celine Gueguen[2]

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, British Columbia
[2] Trent University, Peterborough, Ontario

Conductivity, temperature and depth instrument (CTD), expendable CTD instrument (XCTD) and underway data were collected from the CCGS *Louis S. St Laurent* during the trans-Arctic United Nations Convention on the Law of the Sea (UNCLOS) missions of 2011, 2014, 2015 and 2016. These data are 'rare' as trans-Arctic sections are infrequent, particularly between the North Pole and North America. Of particular interest is the northern extent of the Pacific-origin water in the Arctic Basin. This is the so-called Pacific-Atlantic front and the data show it lying south of the Alpha-Mendeleev Ridge in the Canada Basin each year. We compare the locations of the front with a previous crossing in 2005 by the *Oden* and the original crossing by the CCGS *Louis S. St Laurent* in 1994 and conclude that the location of the front may remained in roughly the same location despite persistent anticyclonic forcing of the Beaufort Gyre region and loss of sea ice. We caution that many crossings of the front would be required each year to plot its path across the Arctic Basin.

In addition, the UNCLOS missions collected data across the Lomonosov Ridge in 2014, 2015 and 2016. Underway chromophoric dissolved organic matter (CDOM) data in the vicinity of the ridge show the signature of Eurasian River water in a narrow flow along the ridge from the Siberian Shelves across the North Pole towards Greenland. While it is understood that Eurasian River water crosses the Arctic Basin, this is the first time it has been so clearly delineated by its CDOM signature and appears to be constrained to follow the underlying ridge.

Ocean Acidification in the Eastern Canadian Arctic

Kumiko Azetsu-Scott[1]

[1] Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, Nova Scotia

Accelerated increase of carbon dioxide (CO_2) concentration in the atmosphere not only causes global warming, but also changes the fundamental chemistry of the ocean. Oceans have sequestered about one quarter of the CO_2 produced by human activities (anthropogenic CO_2), mainly from fossil fuel burning and in much lesser amount from cement production and land use change, since the start of the Industrial Revolution. CO_2 gas dissolves in the surface ocean to form carbonic acid causing a decrease in pH and also carbonate ion concentration, which is a building block of organisms with calcium carbonate shells and skeletons. Consequently, the upper ocean pH has decreased by 0.1 unit (approximately 30% increase in acidity) over the past 200 years and is expected to fall by an additional 0.3 unit by 2100, an approximate 150% increase in acidity. Ocean acidification refers to the decrease in pH and carbonate ion concentration due to the increasing anthropogenic CO_2 in the ocean. Oceans have not experienced such a rapid pH change for at least 66 million years, and possibly 300 million years. Although ocean acidification is a global phenomenon, the Arctic Ocean is especially vulnerable owing to colder and fresher surface water together with rapidly decreasing ice cover, which increase uptake of atmospheric CO_2 and decrease the ocean's buffer capacity.

Our study in the Eastern Canadian Arctic, a key region connecting the high Arctic and the North Atlantic, includes the Canadian Arctic Archipelago (CAA), Baffin Bay, the Hudson Bay System and Davis Strait. The Arctic outflow through the CAA has a high content of Pacific Water with an inherently high CO_2 concentration, and is therefore more acidic, compared to the receiving Atlantic Water. The Pacific inflow to Chukchi Sea is further modified with fluvial input, sea ice meltwater, biological activity and uptake of atmospheric CO_2 during the transit through Beaufort Sea and Canada Basin, further increasing its acidity. These waters can be traced along western Baffin Bay to the south of Davis Strait. Temporal variation of the Arctic outflow along Baffin Island Shelf has shown a steady increase in ocean acidification state for the past 20 years. In contrast to large scale spatial and temporal variations, ocean acidification in fjords and coastal regions is strongly influenced by rivers with diverse watershed characteristics, glacial meltwater and local biological activities, and is more variable in time and space.

Session theme: New approaches to doing science in the Arctic

Our eyes and ears on the Northwest Passage: DFO's monitoring program and real-time observatory in Barrow Strait

Clark Richards[1], Shannon Nudds[1] and Merle Pittman[1]

[1] Bedford Institute of Oceanography, Fisheries and Oceans Canada, Dartmouth, Nova Scotia

Regular monitoring by DFO in Barrow Strait, from 1998 to 2011, provided time-series measures of ocean and ice properties. The measurements quantify the magnitude and inter-annual variability of heat and freshwater flux through this important gateway from the Arctic to the Atlantic. The Icycler, an under-ice profiling system, recorded water properties in the upper 40 m where traditional instruments risk being damaged or lost due to ice. Additionally, a real-time observatory, first deployed in 2011, returns measurements of currents and water properties every two hours throughout the year. The long time series of under-ice measurements of temperature and salinity have led to regression models for the prediction of freeze-up and break-up, a valuable tool in the Northwest Passage, particularly as increased shipping becomes a concern.

This year marks the re-deployment of the monitoring array and the real-time observatory with a wider suite of instruments including real-time ice draft and passive acoustic data. In this talk we give an overview of the past, present and future of this monitoring program, with a focus on the recent success of real-time data and the predictability of environmental variables in the Northwest Passage.

Observing the Canadian Arctic marine ecosystems through acoustics

Yvan Simard[1], Nathalie Roy[1], Florian Aulanier[1], Bazile Kinda[2], Cédric Gervaise[3], Lisa Loseto[4], Marianne Marcoux[4] and Louis Fortier[5]

[1] Fisheries and Oceans Canada, Maurice Lamontagne Institute, Mont-Joli, Québec
[2] SHOM, Brest, France
[3] CHORUS Research Institute, Grenoble, France
[4] Fisheries and Oceans Canada, Freshwater Institute, Winnipeg, Manitoba
[5] Dept. of Biology, Laval University, Québec, Québec, Canada

Active and passive acoustic technologies were used to explore the pelagic ecosystem of the Canadian Arctic and track its seasonal patterns and multiyear changes in the last decade. New knowledge acquired with these technologies on the functioning of this remote marine system is summarized with examples on the time and space distributions of: a) the key forage fish of the Arctic, the polar cod, b) vocal marine mammals, and c) the natural and anthropogenic components of the underwater soundscapes.

Multifrequency (38, 120, and 200 kHz) backscattering from the pelagic organisms, from macrozooplankton to large fish, was acquired with a SIMRAD EK60 scientific echosounder mounted on the CCGS *Amundsen*, within the ArcticNet research framework. The system was operated continuously during the annual surveys since 2003, including the years the ship spent the winter in the Western Arctic. This rich acoustic dataset contributed to several articles unraveling the epi- and meso-pelagic aggregation behaviour of polar cod, the importance of the water masses characteristics and general circulation in determining the location of the aggregations, where fish densities can reach very high values, notably in winter. This 3D pattern of this keystone forage fish is structuring the ecosystem layers up to marine mammal predators.

Passive acoustic monitoring (PAM) was used to track the presence of marine mammals from the specific sounds they regularly emit and which propagate underwater over distances of several tens of km. Autonomous hydrophones were moored at different locations from the Eastern Beaufort Sea to the Hudson Strait, and recorded for durations varying from a few weeks to several years. The frequentation time-series of belugas, narwhals, bowheads, breeding walruses and bearded seals were examined in relation with the ice and water mass characteristics. Clear synchronization of the migration and breeding activity with the ice seasonal time-space pattern

were observed. The Hudson Strait revealed to be an important overwintering area of the marginal ice zone (MIZ) of Canadian Arctic for several marine mammal species. This technology provides an effective mean to monitor the ecosystem change induced by the warming Arctic and to feed predictive models for assessing future scenarios from climate change predictions.

The same PAM time series were used to characterize for the first time the underwater soundscapes of the Canadian Arctic over complete annual cycles. This provides the baseline for different locations along the latitudinal gradient, before more anthropogenic noise is introduced into the ecosystem, notably through increased shipping. The analysis of the natural forcing (wind, wave, ice cover, ice movement) showed the strong correlation of the ambient noise annual series with the presence of an ice cover, the ice thickness, and the large-scale movement of the ice, notably the multi-year ice plume in Eastern Beaufort sea. Decadal change in Amundsen Gulf low-frequency ambient noise indicates up to 7 dB increase in 2016 compared to 2006, likely in response to the increase of ice movement.

The contribution of shipping noise to the underwater soundscape was modeled from shipping traffic during the 2013-2016 navigation seasons for large ecosystems of the Canadian Arctic. The probabilistic modeling approach used for the Gulf of St. Lawrence was applied to these regions. Although the present traffic in the Canadian Arctic is 100 times lower than that of southern Canadian waters, the shipping imprint on the Arctic underwater soundscape is already discernable.

Improving data collection in Arctic areas: Let marine mammals do the work!

Mike Hammill[1], Garry Stenson[2], Fraser Davidson[2] , Jack Lawson[2], Alejandro Buren[2] and Tiphaine Jeanniard du Dot[1]

[1] Fisheries and Oceans Canada, Maurice Lamontagne Institute, Mont-Joli, Québec
[2] Fisheries and Oceans Canada, St. John's, Newfoundland

The northern hemisphere is rapidly warming. Global oceanographic and climate models predict that the most extreme and acute effects of global warming will continue to occur in the Arctic. However, the physical environment and ecosystems of the polar region are poorly sampled and, as a result, relatively poorly understood. Tracking changes in Arctic regions and determining their source will require refinements to current models and their predictions which will require improved data on water temperature and salinity, particularly from crucial areas where important hydrological phenomena occur. Given the large area that needs to be sampled, it is very difficult to obtain adequate data using traditional oceanographic samplers. Fortunately, the development of ocean profiling satellite tags that can be deployed on marine mammals has provided an opportunity to collect the required data to fill in crucial gaps. Over 50,000 temperature and salinity profiles have been obtained by transmitters deployed by DFO on seals and whales in the

North Atlantic and eastern Arctic. The geographical coverage of the animal data fills in large tracts of previously under represented sectors. Animals also have provided data in ice covered areas and during the winter when no other sources were available. Data from these marine mammals have contributed to oceanographic models that have explained patterns of ice melt in Greenland glaciers and identified the interactions of warm, Atlantic-origin water (AW) and colder, polar origin water (PW) in the East Greenland Current (EGC) that influences the heat content of water entering Greenland's outlet glacial fjords. Oceanographic data collected by marine mammals is also contributing to Canadian Government ocean forecasting systems through the CONCEPTS (Canadian Operational Network of Coupled Environmental PredicTion Systems) initiative developed by ECCC, DFO and DND. The CONCEPTS prediction systems assimilate all available data, including marine mammal profiles freely available at the Marine Mammals Exploring the Oceans Pole to Pole (MEOPS) website (http://www.meop.net/database/data-access.html), in real time to provide gridded descriptions of physical oceanographic properties all over the ocean, providing a basis from which ocean forecasts can be initialized as well as constrain long term reconstruction of historic ocean properties. An interface to the CONCEPTS ocean forecast and historical output has been created and named Ocean Navigator (http://navigator.oceansdata.ca). A key component of ocean forecast systems is also verification against observations as well as dissemination. Ocean Navigator allows us to inter-compare and evaluate seal-collected data from conductivity, temperature and depth instruments (CTDs), and temperature and depth instruments (TDs) with the data from the Global Ocean Reanalysis and Simulation (GLORYS) project. Monitoring the movements and diving behaviour of marine mammals also provides us with valuable information on movement patterns, behavior, and habitat use and has contributed to the identification of biologically important areas. Overall, the combination of biological and oceanographic data collection by the animals themselves enhances our understanding of physical oceanography and Arctic ecosystems.

Quantitative monitoring and assessment of Arctic fisheries productivity under cumulative impacts

Xinhua Zhu[1], Ross Tallman[1], Kimberley Howland[1], Ellen Lea[2], Andrew J. Chapelsky[1], Colin Gallagher[1], Muhammad Yamin Janjua[1], and Theresa Carmichael[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6
[2] Fisheries and Oceans Canada, Inuvik, Northwest Territories

The Arctic is the epicenter of climate change, undergoing unprecedented modifications of aquatic environment, vulnerability of biological production potentials and carrying capacity of the ecosystem. Among these cumulative impacts, oil and sand exploration, industrial mining, hydroelectric dam, climate change and exploitation have increasingly deteriorated the habitat quantities and quality, modification of life history strategies for most freshwater, anadromous, and coastal marine animals. To address these cumulative impacts on Arctic fisheries, I used the first example of temporal variation in Dolly Varden in the Rat River system to investigate how climate-induced changes influenced the seasonal upstream migration and how the observatory uncertainty mixed with the nature of Arctic fish population dynamics. A second example is shown using the fish community dynamics in Great Slave Lake (GSL). GSL is a sub-Arctic great lake experiencing tremendous cumulative modification. Our recent field survey data analysis showed that the diversity of fish community in GSL, dominated by cold-water Coregonids, was greatly influenced by variation in the depth-related thermal structure and transparency during summer growing seasons. A third example is shown by demonstrating a pairwise comparison of Lake Erie and GSL ecosystems, in association with biological productivity, ecosystem throughput, ecological transfer efficiency and keystoneness. In Lake Erie, nutrient loading and NIS-based foraging arena were functioned as strong bottom-up driver of food web. Fisheries for cold-water percids significantly controlled the impacts of high trophic-level predators. In GSL, fisheries harvest is relatively limited, but the ecosystem functionality is significantly impacted by its capacity of adaptation and vulnerability of the lower trophic functional groups. The overall ecosystem development largely depended on the balance between two-way anthropogenic impacts, highlighting opportunities for policy response and providing insights on how to conduct cumulative impact research in a comparative framework. The lessons learned from three biological hierarchical case studies have generalized our awareness that many identifiable climate-induced vectors, when viewed as single cause or single effect processes, have being remarkably impacted our Arctic fisheries productivity. The recommendations compliant to DFO's mandate are immediately necessitated to understand how the cumulative effects were dealt with and what appeared to work, including 1) establishment of research programs to identify the key processes that determine the response of biological production systems to stress, their system recovery rate and threshold of resiliency, 2) implementation of area-wide and long-term monitoring programs to support the comprehensive assessment framework, and 3) incorporation of cumulative impacts into DFO integrated fisheries management plan and sustainable fisheries management actions under the amended Fisheries Act.

Do Arctic Cod have separate spawning aggregations in the Beaufort Sea region?

Tracey Loewen[1], Jim Reist[1], Andy Majewski[1], Jane Eert[2], and Christine Michel[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6
[2] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, British Columbia

Arctic Cod are a fundamental part of Arctic marine ecosystems. They are known to be a key component to the food web and higher-level predators in the ecosystem (i.e., beluga, marine fish, Arctic Char). Understanding and delineating population structuring and spawning behaviour is significant for monitoring and management of the Beaufort Sea region fisheries and marine protected areas in the region. Presently it is unknown if Arctic Cod reproduce as a single large aggregation within the region or as structured distinct populations; accordingly, assessing the significance of variations in cod abundance and or local or widespread stressors is impossible. Connecting Arctic Cod to habitat use will provide information to help us address the research question, "Are Arctic Cod spawning as one large aggregate or as structured distinct populations in the Beaufort Sea region?" Otoliths (earbones) in fish have been shown to incorporate environmental signals while forming and thus allow for unique opportunities to connect fish to habitat use during their life span (larval development to adult). We will use Arctic Cod otoliths collected previously from the Beaufort Regional Environmental Assessment – Marine Fishes Project (BREA-MFP) surveys (2012-2014) and the Canadian Beaufort Sea-Marine Ecosystem Assessment (CBS-MEA) to examine potential stock structure and habitat use during spawning. Overall, this study will provide stock delineation and habitat associations of Arctic Cod, a fundamental ecosystem component, to the planning and management of the Beaufort Sea region. This approach provides both knowledge of structuring as well as habitat usage by sub-components of the overall cod population. Additionally, this approach may ultimately provide information regarding habitat usage by cods at different stages of their life cycle, thus further informing regarding habitats of importance to this species.

Session theme: Coastal and river linkages

Integrating telemetry, population genetics and genomics to understand the evolutionary ecology, life history and management of Arctic Char, *Salvelinus alpinus*, from the Cambridge Bay region of Nunavut

Les N. Harris[1], Jean-Sébastien Moore[2], Robert Bajno[1], Ross F. Tallman[1], Aaron T. Fisk[3] and Louis Bernatchez[2]

[1] Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba R3T 2N6, Canada
[2] Institut de Biologie Intégrative et des Systèmes, Université Laval, 1030 Avenue de la Médecine, Québec, Quebec G1V 0A6, Canada
[3] Great Lakes Institute of Environmental Research, University of Windsor, 401 Sunset Ave., Windsor, ON N9B 3P4, Canada.

Anadromous Arctic Char, *Salvelinus alpinus*, are a vitally important subsistence and commercial resource for the Inuit across the Canadian Arctic. Arctic char in the Cambridge Bay region of Nunavut have long provided an important subsistence resource for the community and this species has also been commercially harvested since the 1960s from several local systems under a variety of quotas. For the past 40 years, the management of this fishery has relied primarily on analysis of trends in biological characteristics and life history traits; data that has been collected as part of the long-running commercial plant sampling program. Recently, the integration of acoustic telemetry, population genetics and genomics has significantly advanced our understanding of the evolutionary ecology and life history of this species. In this presentation, I will discuss the integrative approach of combining telemetry, population genetics, and genomics to document dispersal, gene flow, stock mixing and the spatial scale at which stocks of anadromous Arctic Char in the Cambridge Bay region should be managed. Furthermore, I will highlight how our work sheds new light on how migratory behaviour interacts with gene flow to influence the spatial scale at which local adaptation can evolve which will undoubtedly have important implications for population viability and species persistence in the face of a rapidly changing Arctic climate. All told, the results of our overall Arctic Char research program in the Cambridge Bay region will be important for fine-tuning fisheries management strategies and in supporting the conservation of the most significant commercial fishery for this species in Canada.

Decoupling of otolith and somatic growth during migration in Dolly Varden char

Christie Morrison[1], Melodie Kunegel-Lion[2], Colin Gallagher[1], Keith Tierney[2], Kim Howland[1]

[1] Freshwater Institute, Fisheries and Oceans Canada
[2] University of Alberta

Northern-form Dolly Varden (*Salvelinus malma malma*) are migratory salmonids that inhabit the western Arctic. They have been listed as special concern under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Species at Risk Act (SARA) due to their limited distribution, population declines, and concerns over their ability to tolerate climate change. Research is currently being undertaken to reconstruct early life histories of Dolly Varden using otoliths. We examined the otolith size – fish size relationship in three populations of Dolly Varden in order to confirm the assumption of constant proportionality in otolith and fish growth prior to back-calculating size-at-age. Results indicate a decoupling of otolith and somatic growth during first seaward migration, thus leading to an overestimation of size-at-age in the juvenile ontogenetic stage. During first migration, fish are dramatically increasing in body size over a short summer feeding period. We hypothesized that during this period of rapid increase in somatic growth, material is being deposited onto the otolith at a slower rate, thus leading to the subsequent decoupling. This is the first evidence of otolith and somatic decoupling during migration for a migratory salmonid. A modified ontogenetic stage-specific back-calculation equation that accounts for the decoupling of otolith and somatic growth was developed in order to accurately estimate size-at-age for Dolly Varden during early ontogenetic stages.

Cumberland Sound Arctic Char fisheries: Data from across the Sound

Zoya Martin[1], Ross Tallman[2], and Simon Wiley[2]

[1] Fisheries and Oceans Canada, Iqaluit, Nunavut
[2] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba

Arctic Char (*Salvelinus alpinus*) is considered a 'plastic' species showing great variation in biological characteristics between populations across its range. Within Cumberland Sound there are numerous Arctic Char stocks that are harvested under either an exploratory and commercial license. These fisheries have been harvested by the community of Pangnirtung and some have undergone Stock Assessment evaluations. This presentation is a summary of the Stock Assessment research that has been completed over the years in Cumberland Sound. The focus of the Stock Assessment research has been to determine baseline stock status on emerging and commercial fisheries, by collecting biological samples, catch data and harvest information. Although some Stock Assessment Reports have been completed, there have been no comparisons between these reports looking at the variation in biological data of Arctic Char across Cumberland Sound. We are proposing to present the results from completed Stock Assessment reports and look at preliminary comparisons of basic biological features of Arctic Char stocks within Cumberland Sound.

The Kitikmeot Sea of the southern Canadian Arctic Archipelago

Bill Williams[1], Svein Vagle[1], Eddy Carmack[1] and, Kristina Brown[1]

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, British Columbia

The Kitikmeot Sea is unique in the Arctic because of its massive freshwater input relative to its area, and for the shallow bounding sills to the north and west (≤30m deep) that restrict inflow of the nutrient-rich Pacific-origin water. An estuarine-like circulation is maintained in the sea wherein the surface freshwater mixes with the salty oceanic inflow through the straits to produce the surface outflow through the straits. As the straits are shallow, the oceanic inflow has relatively low salinity (29) and also is relatively low in dissolved nutrients. The resulting low annual primary productivity affects the entire food web, and we speculate that this is why the region supports char and seals as top predators instead of the larger polar bears and whales that are found elsewhere.

In addition, summertime stratification generally restricts vertical mixing and the upward fluxes of dissolved nutrients further constraining primary production. However, observations by residents, and high-resolution satellite imagery, suggest that the narrow gaps and straits between the many islands of the Kitikmeot can be prone to early ice break-up, making them dangerous

places for winter travel. We thus hypothesize that these 'winter holes' are caused by upward mixing of subsurface heat, induced as tidal flow accelerates over sills and through narrow passes. Furthermore, the subsurface water is nutrient-rich, so the same upward mixing will also deliver nutrients to the euphotic zone year-round, creating local regions of enhanced biological productivity and a patchwork of nearby benthic 'gardens' that contrast with the region's overall very low productivity. Such biological hotspots may form critical feeding sites for the higher trophic levels.

Winter and summer oceanographic observations in Dease Strait, Nunavut

Mike Dempsey[1], Sarah Zimmermann[1] and Lina Rotermund[1,2]

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, British Columbia
[2] University of Victoria, British Columbia

Dease Strait is the mid- point in the area of the Arctic Archipelago connecting Queen Maud and Coronation Gulfs. The ocean in this region is characterized by low salinity in bottom waters and large seasonal inputs of freshwater from rivers. Conductivity, temperature and depth instrument (CTD) profiles made in winter from sea ice during the Canadian Ranger Ocean Watch (CROW) and in summer from the R/V *Martin Bergmann* are compared.

Where the river meets the sea: Investigating nutrient dynamics in the Kitikmeot riverine coastal domain

Kristina. A. Brown[1], William Williams[1], Sarah Zimmermann[1], Eddy C. Carmack[1], Adrian Schimnowski[2]

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC, Canada
[2] Arctic Research Foundation, Winnipeg, MB, Canada

The Kitikmeot Sea of the southern Canadian Arctic Archipelago is unique in the Pan-Arctic due to its shallow bounding sills and massive freshwater input relative to its size. These conditions maintain an estuarine-like circulation and strong stratification, limiting horizontal exchanges at its gateways and vertical mixing across the pycnocline that would otherwise supply nutrients into the basin's euphotic zone. The end result of these physical constraints is relatively low annual primary productivity in the basin and the potential for enhanced terrestrial influence as the regional climate warms.

Using the R/V *Martin Bergmann* as a platform, the Kitikmeot Sea Science Study has been working since 2014 to quantify the dominant physical, biological, and geochemical processes within this marine region of the Canadian Arctic. As part of this effort, we investigated the river-to-ocean geochemical contributions of three large rivers in the Kitikmeot Region: the Burnside, Ellice, and Coppermine Rivers. We conducted conductivity, temperature and depth instrument (CTD) transects from each river mouth into the marine-dominated portion of the estuary and sampled geochemical constituents along the salinity gradient. Preliminary results illustrate the delivery of N (Nitrate + Nitrite) and reactive silicate into the estuary with river waters, augmenting surface concentrations. However, river inputs were generally P (orthophosphate) deficient, with concentrations increasing as river inputs mixed with marine waters in the estuary. The confluence of terrestrial (N) and marine (P) sourced nutrients in these three estuaries suggests that the riverine coastal domain of the Kitikmeot has an important ecological role in contributing to the productivity of the region and that terrestrial connectivity to the marine system in this region may be more important than previously thought.

Permafrost thaw and precipitation north of the Arctic Circle are anticipated to increase with climate warming, potentially changing the character and magnitude of terrestrial inputs to the Kitikmeot Sea. Understanding the impacts of changing terrestrial nutrient delivery to the Kitikmeot will require dedicated studies that consider the dynamics of each river's annual cycle, physical controls on upwelling and estuarine mixing, and the importance of seasonal transitions during ice formation and break-up.

Session theme: Changing species distribution

Evidence for historic and modern post-glacial colonizations of chum salmon at the northern range edge

Karen M. Dunmall[1,2], Colin J. Garroway[2], Rob Bajno[1], Nicholas Decovich[3], W. Templin[4], Margaret F. Docker[2], Jim D. Reist[1]

[1] Fisheries and Oceans Canada, Freshwater Institute, Winnipeg MB, Canada
[2] Department of Biological Sciences, University of Manitoba, Winnipeg MB, Canada
[3] Alaska Department of Fish and Game, Anchorage AK, United States
[4] Gene Conservation Laboratory, Division of Commercial Fisheries, Alaska Department of Fish and Game, Anchorage AK, United States

Biodiversity change in the Arctic coincides with warming cycles and species' responses can manifest as distributional shifts. Accurate predictions of these biodiversity shifts require understanding of both the capacity of marine species to respond to environmental change and the viability of the Arctic marine environment as habitat to support distributional shifts. Here we use chum salmon, *Oncorhynchus keta*, in the Canadian Arctic to assess viability of the Arctic as habitat since deglaciation, and demonstrate the capacity of this species to adapt to environmental change. Chum salmon are ideal indicators of Arctic marine habitat viability due to their historic persistence in the Arctic, their present increasing abundance and distribution, and expectations of shifts in species compositions and habitats with continued warming. Using population genetic

analyses and by testing colonization scenarios using Approximate Bayesian Computational analyses, we found that chum salmon colonized the Upper Mackenzie River from the Upper Yukon River during early deglaciation, presumably developing anadromous migrations to the Beaufort Sea subsequent to this. Current vagrant occurrences appear to originate from northern Russian populations. This confirms that the current distribution of chum salmon in Arctic Canada extends northward to the Mackenzie River, and identifies a genetically distinct, geographically isolated spawning population of chum salmon that has experienced and perhaps adapted to changing Arctic conditions for thousands of years. This has implications for predicting risks and opportunities associated with biodiversity shifts in a future Arctic, and highlight the need for baseline knowledge of Arctic species and habitats in order to accurately predict future changes.

A growth-potential approach to forecasting change in fish communities along the eastern seaboard of Canada

Dave Cote[1], B.J. Laurel[2], R.S. Gregory[1]

[1] Fisheries and Oceans Canada, Ecological Sciences Section, Northwest Atlantic Fisheries Centre, 80 E. White Hills Road, St. John's, NL A1C 5X1, Canada
[2] Fisheries Behavioral Ecology Program, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, NOAA, Hatfield Marine Science Center, Newport, OR 97365, USA.

Coastal marine ecosystems in subarctic areas are extremely productive and serve as important nursery areas for many commercially important species. The distributions of these species are expected to move north under the ongoing influence of climate change. Comparisons of long term monitoring data from sub-Arctic coastal areas in Bonavista Bay, Newfoundland (since 1996), Kodiak Island, Alaska (since 2006) and Skagerrak, Norway (since 1919) suggest that juvenile gadid recruitment is linked to area-specific growth conditions. While climate is changing in all study areas, the response of resident gadids differed across areas and species in accordance with expectations with growth potential models.

We applied the growth potential models of three gadids (Arctic cod, Greenland cod and Atlantic cod) to 100 year coastal temperature projections to the eastern seaboard of Canada (Newfoundland to Baffin Island) to forecast the geographic distribution of favorable thermal conditions and the rate of northward range expansion for each species.

This physiology-based mechanistic approach is intended to illustrate the expectation that Arctic fish communities will change and that developing fisheries should prepare accordingly.

Further penetration of Pacific-type *Calanus glacialis* into the Arctic Ocean

John Nelson[1], Bill Williams[1], Gina Nickoloff[2], Jessie Ogden[2], Amber Messmer[1]
Moira Galbraith[1] and, Kelly Young[1]

[1] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, British Columbia
[2] University of Victoria, British Columbia

The copepod *Calanus glacialis* is of huge ecological importance in the Northern Pacific and Arctic Oceans. Previous studies have shown that there are two genetically distinct populations of *C. glacialis*, a Bering Sea (Pacific-type) and western Arctic Ocean (Arctic-type). Penetration of Pacific type *C. glacialis* has been observed as far as western Canada Basin, but as yet it doesn't appear to be reproductively established. We used molecular genetics to create a 2002–2013 time-series of Pacific-type *C. glacialis* penetration into the Arctic Ocean. In 2013, we found Pacific type *C. glacialis* further east in the Arctic Ocean than ever before. Both increased transport and a shift towards ocean conditions found in the South, could explain the expansion of the Pacific type deeper into the Arctic Ocean. The ecological effects of the boundary shift in the Pacific genotype are not likely to be large, however it follows that its presence is an indicator of changes in other taxa which may presage Pacification of the Beaufort Sea.

The Circumpolar Biodiversity Monitoring Program - Benthos Expert Network: Findings and recommendations from the State of the Arctic Marine Biodiversity Report (SAMBR)

Virginie Roy[1], Lis Lindal Jørgensen[2], Philippe Archambault[3], Martin Blicher[4], Nina Denisenko[5], Guðmundur Guðmundsson[6], Katrin Iken[7], Jan Sørensen[8], Natalia Anisimova[9], Carolina Behe[10], Stanislav Denisenko[11], Vera Metcalf[12], Steinunn Olafsdóttir[13], Tom Schiøtte[14], Ole Tendal[15], Alexandra M. Ravelo[16], Monika Kędra[17], Dieter Piepenburg[18]

[1] Fisheries and Oceans Canada, Mont-Joli, Quebec
[2] Institute of Marine Research, Norway
[3] Université du Québec à Rimouski, Canada
[4] Greenland Institute of Natural Resources, Greenland
[5] Russian Academy of Sciences, Russia
[6] Icelandic Institute of Natural History, Iceland
[7] University of Alaska Fairbanks, U.S
[8] Faroese Museum of Natural History, Faroe Island
[9] Polar Research Institute of Marine Fisheries and Oceanography, Russia
[10] Inuit Circumpolar Council, Alaska, U.S.
[11] Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia
[12] Inuit Circumpolar Council, Canada
[13] Marine Research Institute, Iceland
[14] Natural History Museum of Denmark, Denmark

[15] Natural History Museum of Denmark, Denmark
[16] University of Alaska Fairbanks, U.S.
[17] Institute of Oceanology, Polish Academy of Sciences, Poland
[18] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

Currently, > 4,000 macro- and mega-benthic invertebrate species are known from Arctic seas, representing the majority of marine faunal diversity in this region. This estimate is expected to increase with future studies. Benthic invertebrates are important ecosystem components as food for fishes, marine mammals, seabirds and humans. The Benthos Expert Network of the Circumpolar Biodiversity Monitoring Program (CBMP) aggregated and reviewed information on the population status and trends of macro- and mega-benthic invertebrates across eight Arctic Marine Areas as well as the state of current monitoring efforts for these communities. Drivers are affecting benthic communities on a variety of scales, ranging from pan-Arctic (related to climate change, such as warming, ice decline and acidification) to regional or local scales (such as trawling, river/glacier discharge, and invasive species). Long-term benthic monitoring efforts have largely focused on macro- and mega-benthic communities of the Chukchi and Barents Seas. Recently, they are increasing in waters off Greenland and Iceland, as well as in the Canadian Arctic and the Norwegian Sea. All other Arctic Marine Areas are lacking long-term monitoring. The presentation will summarize current level of knowledge and monitoring across the Arctic, drivers of observed trends, and knowledge and monitoring gaps.

Which regions of the Canadian Arctic are most vulnerable to marine invasive species introductions? Insights from habitat suitability modelling under current and projected future climate scenarios

Kimberly Howland[1], Jesica Goldsmit[2], Philippe Archambault[3], David Barber[4], Guillem Chust[5], George Liu[4], Jennifer Lukovich[4], Chris McKindsey[2], Ernesto Villarino[5]

[1] Freshwater Institute, Fisheries and Oceans Canada
[2] Maurice Lamontagne Institute, Fisheries and Oceans Canada
[3] Département de biologie, Université Laval
[4] Faculty of Environment, Earth, and Resources, University of Manitoba
[5] Marine Research Division, AZTI-Tecnalia

In recent years, high-latitude areas have shown a disproportionate increase in temperature, and their coasts are highly susceptible to climate change impacts. These projected impacts together with increased shipping activity are expected to increase the risk for establishment of ship-mediated marine invasive species. Within this context, potential for establishment was evaluated for a suite of eight potential benthic invertebrate invaders by projecting habitat suitability in the Canadian Arctic under current environmental conditions and future climate change scenarios.

Species were selected based on known dispersal pathways/donor regions, biological attributes and invasion history. Habitat suitability modelling was conducted using MaxEnt based on global native and non-native occurrence records and environmental ranges. Results showed that under current environmental conditions the habitat is suitable in the Hudson Complex and Beaufort Sea for three of the modelled species. Under a future climate change scenario, all species showed poleward gains in habitat suitability with at least some regions of the Canadian Arctic projected to be suitable for the complete suite of species modelled. These results are being used to focus research and monitoring efforts in high risk geographic regions. Ongoing efforts include evaluating risk in a larger pool of potential invaders using rapid screening tools and modelling suitable habitat for additional taxa including marine plankton and macro algae.

Session theme: Habitats and their use

Arctic sea ice-associated ecosystems: The good, the bad and the ugly

Christine Michel[1]

[1] Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6

This paper discusses on-going changes in sea ice and sea ice-associated ecosystems in the Arctic, identifying pivotal elements for the productivity, biodiversity, and architecture of marine food webs. We present an integrated perspective based on results obtained during various field campaigns in the Canadian Arctic, including recent results from the Canadian Arctic Archipelago and the productive region of Lancaster Sound, and a compilation of pan-Arctic sea ice biomass data from a variety of sources (published and unpublished). These results unambiguously show that the highest sea ice algal biomasses are found in the Canadian Arctic Archipelago. Our analysis shows that sea ice productivity and biodiversity compares with, and at times surpasses that in open waters, playing an important role in Arctic marine food webs. Changes in sea ice dynamics (e.g. timing, extent, and type of sea ice cover) impact the abundance, composition, and phenology of primary producers, with cascading effects on trophic interactions and higher trophic levels including harvestable resources. In particular, shorter ice covered periods impact the seasonality of ice algal and phytoplankton production, shifting ecological pathways towards pelagic producers. We also discuss the role of sea ice microbial communities in the cycling of organic materials including their potential to degrade hydrocarbons. Experimental results showing the capability of sea ice and under-ice microbial communities to degrade hydrocarbons suggest that they can play a role in mitigating potential accidental hydrocarbon release in the Canadian Arctic.

Environmental drivers of inter-annual variability in Beaufort Sea marine fish community structure

Andrew Majewski[1], Sheila Atchison[1], Jane Eert[2], Mike Dempsey[2], Shannon MacPhee[1], Christine Michel[1] and Jim Reist[1]

[1] Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba R3T 2N6
[2] Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, British Columbia V8L 4B2

The Beaufort Sea is a complex and dynamic system influenced by a wide suite of oceanic and riverine inputs that affect the ecosystem. Interactions within the resulting water masses are largely driven by factors such as precipitation, wind, and ice cover. Thus, the Beaufort Sea environment is highly variable in both space and time, and this variability is reflected in the habitats of biota. Inherent system variability must be factored into baselines designed to detect changes resulting from anthropogenic stressors and natural drivers. Between 2012 and 2014, Fisheries and Oceans Canada conducted the first baseline survey of offshore marine fishes, their habitats, and ecological relationships in the Canadian Beaufort Sea. In 2012, benthic trawling was conducted at 28 stations spanning 20-1000 m depths across shelf and slope habitats, and selected stations were re-sampled in 2013 and 2014. Concurrent sampling of oceanographic parameters and sediment composition was conducted at each station. We examine the stability of marine fish assemblages over a three-year period, and compare results for shelf stations to previous research to develop longer-term perspectives. Oceanographic (e.g., salinity), physical (e.g., depth and sediment grain size) and geographic (e.g., distance from shore) parameters, and proxies for local productivity (i.e., water-column and benthic chlorophyll) are explored as explanatory variables affecting fish community structure among years. Establishing knowledge baselines and understanding variability in the community structure and habitat associations of Beaufort Sea marine fishes will support mitigation and conservation efforts by enhancing our ability to predict, detect and monitor the effects of hydrocarbon development and climate change on this pivotal ecosystem component.

Abundance and species diversity hotspots of tracked marine predators across the North American Arctic

David J. Yurkowski[1], M. Auger-Méthé[2], M. L. Mallory[3], S. N. P. Wong[3], H. G. Gilchrist[4], A. E. Derocher[5], E. Richardson[6], N. J. Lunn[6], N. E. Hussey[7], M. Marcoux[8], R. Togunov[2], A.T. Fisk[7], L. A. Harwood[9], M. P. Heide-Jørgensen[10], R. Dietz[11], A. Rosing-Asvid[10], E. W. Born[10], A. Mosbech[11], J. Fort[12], D. Grémillet[12], L. Loseto[9], P. R. Richard[9], J. Iacozza[1], F. Jean-Gagnon[13], T. M. Brown[14], K. H. Westdal[15], J. Orr[8], B. LeBlanc[8], K. J. Hedges[8], M. A. Treble[8], S. T. Kessel[16], P. J. Blanchfield[8], S. Davis[16], M. Maftei[17], N. Spencer[17], C. L. McFarlane-Tranquilla[14], W. A. Montevecchi[14], B. Bartzen[18], C. Anderson[3] and S. H. Ferguson[8]

[1] University of Manitoba, Winnipeg, Manitoba, Canada;

[2] University of British Columbia, Vancouver, Canada;
[3] Acadia University, Wolfville, Nova Scotia, Canada;
[4] Environment and Climate Change Canada, Ottawa, Ontario, Canada;
[5] University of Alberta, Edmonton, Alberta, Canada;
[6] Environment and Climate Change Canada, Edmonton, Alberta, Canada;
[7] University of Windsor, Windsor, Ontario, Canada;
[8] Fisheries and Oceans Canada, Winnipeg, Manitoba, Canada;
[9] Fisheries and Oceans Canada, Yellowknife, Northwest Territories, Canada;
[10] Greenland Institute of Natural Resources, Nuuk, Greenland;
[11] Aarhus University, Roskilde, Denmark;
[12] Centre National de la Recherche Scientifique;
[13] Carleton University, Ottawa, Ontario, Canada;
[14] Memorial University, St. John's, Newfoundland, Canada;
[15] Oceans North Canada, Winnipeg, Manitoba, Canada;
[16] Daniel P. Haerther Center for Conservation and Research, John G. Shedd Aquarium, Chicago IL, USA;
[17] High Arctic Gull Research Group, Victoria, British Columbia, Canada;
[18] Environment and Climate Change Canada, Saskatoon, Saskatchewan, Canada

Aim: The distribution, abundance and diversity of highly mobile marine predators influence the ecological structuring and functioning of ecosystems. Climate change is causing altering marine ecosystems and is most pronounced in the Arctic, with significant physical changes to water temperature and the phenology of sea ice formation and breakup. Economic development has been quickly expanding leading to increased disturbances and pressures on Arctic wildlife. Identifying areas that sustain higher levels of predator abundance and biodiversity is important for the implementation of targeted conservation measures across the Arctic.

Location: Primarily Arctic marine waters of Canada but also including parts of United States, Greenland and Russia.

Methods: We compiled the largest dataset of existing telemetry data for Arctic marine predators consisting of 1298 individuals from 21 species. Data were arranged into four Arctic species groups: 1) cetaceans and pinnipeds, 2) seabirds, 3) polar bears *Ursus maritimus*, and 4) fishes to address the following objectives: 1) identify abundance hotspots for each species group in the summer-autumn and winter-spring periods; 2) identify species diversity hotspots across all species groups by period; and 3) assess the extent of overlap of species diversity hotspots with designated protected areas

Results: Abundance and species diversity hotpots during summer-autumn and winter-spring were identified in Baffin Bay, Davis Strait, Hudson Bay, Hudson Strait, Amundsen Gulf, and the Beaufort, Chukchi and Bering seas both within and across species groups. Abundance and species diversity hotpots generally occurred nearshore and within the continental shelf and slope

in summer-autumn and offshore in areas of moving pack-ice in winter-spring – both areas with oceanographic features that enhance productivity and foraging opportunities. The current level of conservation protection that overlapped species diversity hotspots was low covering only 3% (42,707 km^2) in summer-autumn and <1% (3,061 km^2) in winter-spring.

Main conclusions: We identified several areas of potential importance for Arctic marine predators that could provide policy makers with a starting point for expanding conservation measures given the multitude of threats facing the Arctic. These results are relevant to multinational governance to protect this vulnerable ecosystem in our rapidly changing world.

Exploring habitats within the Beaufort Sea ecosystem, have beluga whales become more common in the offshore in recent years?

Claire A. Hornby[1], John Iacozza[2], Carie Hoover[2], David G. Barber[2], Lisa L. Loseto[1,2]

[1] Freshwater Institute, Department of Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba R3T 2N6, Canada
[2] Centre for Earth Observation Science (CEOS), Department of Environment and Geography, University of Manitoba, 125 Dysart Rd., Winnipeg, Manitoba R3T 2N2, Canada

The eastern Beaufort Sea beluga whale, *Delphinapterus leucas*, population aggregates in the Mackenzie Estuary every summer, and moves toward the continental shelf and offshore waters in the late summer. From 2007 to 2009, systematic aerial surveys recorded beluga whale locations beyond the estuary, over the Mackenzie Shelf and offshore waters, where distributions were observed to occur widely. It is thought that beluga use of the offshore is primarily driven by feeding opportunities, and historical abundance trends suggest that the offshore may have become more attractive to beluga in response to prey availability. To determine drivers of beluga late summer habitat use, a resource selection function (RSF) model was used to measure se lection of 4 key environmental variables: (1) chlorophyll *a*, (2) sea surface temperature, (3) bathymetry and (4) distance from shore. Results revealed that all 4 variables contributed significantly to the individual 2007, 2008 and 2009 best-fit habitat models. Beluga preferred warmer sea surface temperatures (>2°C) and mid-to-high chlorophyll a concentrations (0.01−10 mg m^{-3}), conditions that are indicative of enhanced local productivity and/or upwelling. Beluga distributions varied slightly between years, although high-use areas were identified in nearshore waters (0−50 m) offshore of the Tuktoyaktuk Peninsula, and along the continental shelf-slope (100−500 m), a region known to support a principal prey species, Arctic cod, *Boreogadus saida*. This study improved knowledge of beluga habitat use in the offshore and revealed that selection of late summer oceanographic variables may provide support for foraging habitats, as these dynamic conditions are important to structuring forage fish ecosystems.

Habitat use, population structure and ecology of Arctic marine fishes

Kevin Hedges[1] and Nigel Hussey[2]

[1] Fisheries and Oceans Canada, Arctic Aquatic Research Division, Winnipeg, Manitoba
[2] University of Windsor

Fisheries represent one of the very few economic opportunities in Canadian Arctic communities. A commercial Greenland Halibut fishery has existed in Cumberland Sound since 1987 and is harvested exclusively by the community of Pangnirtung. Development of this fishery relied heavily on extrapolation of information on Greenland Halibut from habitats with significant environmental conditions. The fishery has now provided 30 years of fishery-dependent data and is flourishing. The success of the Cumberland Sound fishery has spurred interest in fishery development in other Nunavut communities, but efforts have generally been slowed by a lack of information on species distributions, abundances, population productivity and trophic interactions. To support fishery development within Nunavut, multi-species exploratory bottom trawl and longline surveys have been conducted near Clyde River, Coral Harbour, Pond Inlet and Qikiqtarjuaq. All captured fishes and invertebrates are enumerated and potential commercial species are individually measured. These surveys provide an important complement to community-based test fisheries that are typified by short operating seasons and irregular catches as harvesters begin to collect fisher knowledge. DFO surveys provide a wider spatial coverage and greater replication of sets within potential fishing grounds. Surveys are also important opportunities for training new fishers and imparting the importance of collecting and reporting catch data, particularly regarding bycatch species. To move beyond simple assessments of species distributions, the movement patterns of Greenland Halibut, as a key potential commercial species, Greenland Shark and Arctic Skate, frequent commercial bycatch species, have been examined using a combination of archival pop-off satellite tags, mark-report satellite tags, acoustic tags and floy tags. The resulting data are being used to assess stock structure and connectivity patterns to better understand the implications of new fisheries on currently harvested stocks. Tissue samples have also been taken from all species for population genetic and trophic analyses. Altogether, the research program is assessing the marine benthic community and linkages across a wide latitudinal gradient in the Eastern Canadian Arctic and identifying opportunities for sustainable commercial fishery development within an ecosystem context.

Appendix 4 – Breakout reports

Session topic: Arctic Cod – integrating knowledge on a sentinel species for Arctic change

Date of session: February 7, 2018
Facilitator: Andrew Majewski
Note taker: Tracey Loewen
Participants: Andy Majewski, Tracey Loewen, Nadja Steiner, John Nelson, Lisa Loseto, Wojciech Walkusz, Steve Ferguson, David Deslauriers and, Jim Reist

Objectives:

1) Assess the state of knowledge of Arctic Cod (*Boreogadus saida*) ecology in different areas of the Canadian Arctic.
2) Identify local- and regional-scale knowledge gaps that need to be addressed to understand Arctic Cod life-history, ecosystem roles, and related dependencies and vulnerabilities.
3) Identify integrative research themes and potential collaborations to address local- and regional-scale knowledge gaps.
   - Consider emerging technologies and interdisciplinary approaches.
   - Identify opportunities to integrate existing knowledge and data.
   - Identify opportunities to leverage existing expertise and resources through collaboration.

Summary of discussions:

Participants described their research interests relating to Arctic Cod. Interests ranged from understanding distribution and population variability to ecosystem linkages including predator-prey interactions, bioenergetics, vulnerabilities to stressors, population structure and adaptability to climate change scenarios.

Eastern Arctic research is primarily focused on stock assessment, but knowledge of the ecosystem interactions of Arctic Cod, and how they support subsistence and commercial stocks are important considerations.

In the western Arctic, knowledge of Arctic Cod is an important component of providing ecosystem based science advice to co-management bodies, Oceans Management, and to inform risk assessments.

Knowledge gaps identified by participants:

- Foodweb and trophic ecology (both regions).
- Relationship with sea-ice and adaptation to changing habitats.
- Differences in habitat associations (e.g., dependency on sea-ice), relative abundances (regional), trophic dynamics, and energy content between *B. saida* and *Arctogadus glacialis* (Polar Cod).
- Genetic and genomic aspects of *B. saida* and *A. glacialis* species to understand population structure and functionality, and adaptability to changing environments.
- General knowledge of the, structure, timing, and location of spawning aggregations in the Canadian Arctic.

Emerging programs and technologies were discussed, including:

- Application of Acoustic Zooplankton and Fish Profilers (AZFP by ASL) in the western Arctic (Nelson, Majewski), for inter-seasonal and inter-annual observations of Arctic Cod presence, relative biomass, and water-column habitat associations.
- Glider mounted acoustics systems.
- Can collect associated oceanographic information (e.g., temperature, salinity).
- Fully developed glider program exists with DFO on the east coast.
- Potentially cheaper method of data collection?
- Otolith Microchemistry as a tool for studying habitat associations across life history stages (Loewen). Inter-species comparison between *B. saida* and *A. glacialis*?

Outcomes:

Information exchange amongst researchers and regions:

- Identified current research interests and programs among regions that include Arctic Cod as a central component.
- Identified knowledge gaps that are priorities 1) within regions/areas, and 2) that are shared in common across regions.
- Identified and discussed emerging methods and technologies to help address knowledge gaps.

Proposed next steps:

- Consider follow-on workshops on *B. saida*, or development of a working group.
    - Would assist with leveraging expertise and resources for research proposals.
- Breakout group facilitator will send an email to breakout participants with discussion summary and contact information of participants.

Session topic: Integrated Ecosystem Assessment and Monitoring – Pond Inlet as a case study

Date of session: February 7, 2018
Facilitator: Kevin Hedges
Note taker: Les Harris
Participants: Kevin Hedges, Les Harris, Virginie Roy, Andrea Moore, Humphrey Melling, Charles Hannah, Garry Stenson, Dave Cote, Robyn Jamieson, Alain Dupuis, Susan Thompson, Emily Smits, Jessica Hurtubise, Lianne Postma, Kim Howland, Chelsey Lumb, Christie Morrison, Ross Tallman, Samantha Fulton, Zoya Martin, Sileema Angoyuak, Xinhua Zhu, Marianne Marcoux, David Yurkowski, Blair Dunn, Brent Young, Cory Matthews and, Ashley Stasko

Purpose/Issue/Question:

- Describe overall needs for assessment and monitoring in protected areas or sentinel areas.
- Need for multi-disciplinary research and monitoring, both within DFO and among Federal partners (e.g. ECCC, CIRNA, ISED, NRCan, PCA, Polar Knowledge Canada, TC)
- Past experiences and suggested strategies in developing and managing similar collaborations.
    - Data management and sharing.
    - Publications and reporting.
    - Financing

Summary of discussions:

The discussions started with a presentation that provided an overview of the DFO research near Pond Inlet, including marine surveys and the Ecosystem Approach to Tremblay Sound program. Participants asked various questions about the programs, how they got started and how they were being funded. The best approaches to developing new ecosystem level programs were discussed. The general opinion was that these types of programs can be generated by funding that is targeted at a particular area, at the direction of DFO management and usually in response to an urgent issue, or they build up over time by researchers collaborating on projects or reducing costs by sharing logistic burdens for programs that can be conducted in more than one location. Maintaining ecosystem level projects was identified as an issue. Regardless of how an ecosystem level project gets started they always run into funding constraints that require them to be down scaled in space and or time. Creating projects in areas that are likely to be areas of concern, in some cases for reasons related to economic interest, provide the best opportunity for long term sustainability of the program.

Outcomes:

General principles of how to develop and maintain ecosystem level projects were shared among discussion members. Participants briefly mentioned various ecosystem projects in which they had been involved; people were made more aware of the experiences and interests of their DFO colleagues.

Proposed next steps:

The discussion did not lead to any proposed next steps. The discussion was a venue for sharing information and lessons learned. Connections were made among participants regarding possible collaborations with DFO colleagues, both for projects occurring near Pond Inlet and in other locations.

Session topic: Needs for wintertime/ice-covered marine observations in Canada's Arctic

Date of session: February 7, 2018
Facilitator: Bill Williams
Note taker: Bill Williams and Bronwyn Keatley
Participants: Bill Williams, Bronwyn Keatley, Mike Hammill, Yvan Simard, Tiphaine Jeanniard Du Dot, Clark Richards, Shannon Nudds, Will Perrie, Kumiko Azetsu-Scott, Zhenxia Long, Jane Eert, Kristina Brown, Mike Dempsey, Andrea Niemi, Karen Dunmall and, Darcy McNicholl

Purpose/Issue/Question:

Fieldwork for oceanography in the Arctic marine environment is almost entirely conducted during the ice-free season. While it has been common practice to use moored instruments for year-round observations, field work is difficult and uncommon in the winter and ice-covered months.

The purpose of the session was to focus on:

- Techniques for winter sampling, looking at existing practices and ideas for improvements,
- Techniques, logistics & specialized equipment for wintertime deployment/recovery of oceanographic moorings where heavy ice precludes ship-based operations in summer.
- Discussion of results from recent studies, and
- Identification of needs for future work.

Summary of discussions:

Collaboration and Integration:

Arctic oceanography benefits from research conducted in DFO laboratories across Canada. Participants discussed and highlighted opportunities for greater integration, including:

- An Arctic Canadian Integrated Ocean Observing System (ACIOOS).
- Greater integration of data
- An online data portal, searchable by map, date, data types, project and laboratory.
- Greater collaboration with researchers in Canadian universities, with ArcticNet and the international Arctic science community.
- Uniformity of data collection protocols and calibration of instruments.
- An online place to work, webex teleconferencing to improve collaboration and communication within DFO.

Near surface, under ice measurements:

Moorings deployed under sea ice usually require their top float to be deep enough to reduce the probability of contact with the thickest expected ice. In the mobile pack ice, this depth is approximately 30m, in the fast ice of the Canadian Arctic Archipelago this depth is approximately 12m. Dependable ways to measure environmental conditions between the top float and the sea ice are required to observe freshwater content and stratification, seasonal cycles of surface nutrients and carbon geochemistry and the Arctic under-ice spring bloom. There are several ways to do this, all of which are problematic and, with limited budgets, often not attempted.

Several techniques were identified and characterized as follows:

1. Instruments above top float:

- A string of instruments can be suspended above the top float and the data collected transmitted via inductive modem to a data logger in the top float.
- If the instruments or their floatation are caught in the ice, their line will break at a weak link with possible loss of instrumentation.
- Cost of instrument replacement needs to be factored into this approach.
- This technique is unsuitable for deployment of a suite of biological and geochemical sensors owing to the cost of possible loss.

2. Profiler above top float:

- BIO makes the Icycler, which profiles, via an efficient winch mechanism, from the top float to just under the sea ice. But an Icycler is ~$100K, and difficult to successfully use.
- The Arctic oceanography community is in need of a less expensive (max $30K) and more robust profiler.
- The Build in Canada Innovation Program may be able to encourage development of a new design of profiler. This is not trivial, we would be asking for a compact, battery powered, underwater winch, powerful enough to work against the buoyancy and drag of a large instrument package, endurance to profile once a day for a year and with technology to avoid hitting the ice above.
- Such a profiler, if it existed, could be a primary platform for an Arctic ocean observing system.

3. Gliders:

- It has been recently demonstrated that gliders can navigate under sea ice using acoustic sources for location (gliders are unable to surface in ice covered water to obtain GPS fixes).

- We expect the endurance and capabilities of gliders to further improve so they continue to become more useful for collecting data over Arctic continental shelves, which are shallow and have large density stratification.

4. Ice buoys:

- In winter, during stable ice conditions (e.g. after freeze-up and before melt) instruments can be hung from the ice.

5. Cabled observatories:

- Cabled observatories bring power to moored instrumentation and return real-time data. Thus, power hungry instrumentation and profilers can be used and rapid change observed in real-time. Cabled observatories are currently installed in western Lancaster Sound (DFO-BIO) and near the dock in Cambridge Bay (Ocean Networks Canada (ONC)).

6. Community-Based Monitoring (CBM):

- Community-based monitoring requires good relationships, communication, and contacts within each community.
- Examples of programs/organizations that collect oceanographic data include the Canadian Ranger Ocean Watch (CROW) program and the Arctic Eider Society. Both of these examples collect wintertime conductivity, temperature and depth (CTD) profiles.
- There is potential for a coordinated program of community-based monitoring across Canada's Arctic, with current support and interest from northern communities, internet connectivity and training provided by CBM programs, by the Environmental Technology Program in Iqaluit and by ONC.

7. Marine mammals:

- Environmental sensors (such as temperature, salinity and pressure) can be tagged onto marine mammals and result in unique and useful datasets, difficult to obtain otherwise.
- Permitting may be difficult
- Sensors are disposable
- Salinity is $5K to add to a tag.

8. Plane-based winter sampling:

- To some extent we are losing expertise in utilizing Twin Otters on skis to conduct wintertime oceanography.
- We now have fewer pilots with long experience of landing on sea ice and more restrictive flying regulations.
- We may be using Twin Otters less for oceanographic sampling.

- Suggest an annual Twin Otter expedition for CTD profiles and water sampling to complement other work. This would require dedicated kitting-out and use of a Twin Otter over a number of weeks.

Overarching comments and challenges on instrumentation:

- Compass issues. We are near the magnetic north pole and the inclination of the earth's magnetic field is over 82 degrees in most of the Canadian Arctic. Thus the magnetic field is pointing nearly strait down, so there is little horizontal field strength for a compass to use. Typically compasses that work well at lower latitudes do not work well in the Canadian Arctic and more sensitive, expensive, better designed compasses are required or an independent direction reference. Compasses of note are made by Watson and KVH. Recent advances in Inertial Motion Units, combining compass, gyro, and accelerometer may be useful for ocean observations.
- Underwater pH and pCO_2 sensors are power hungry, requiring large battery packs or external power. DFO is exploring ideas to potentially use small underwater turbines to power instruments from current flowing past the mooring.

Proposed next steps:

The discussion did not lead to any proposed next steps. The discussion was a venue for sharing information and lessons learned. Connections were made among participants regarding possible collaborations with DFO colleagues.

Session topic: The Ecosystem story: how to advance the integration of physical oceanography and biological community data to address Arctic change?

Date of session: February 8, 2017
Facilitator: Wojciech Walkusz
Note taker: Tracey Loewen
Participants: Wojciech Walkusz, Tracey Loewen, Robyn Jamieson, Darcy McNicholl, Brent Young, Andrea Moore, Andrea Niemi, Margaret Treble, Les Harris, Steve Ferguson, David Cote, Garry Stenson, Clark Richards, Zhenxia Long, Sileema Angoyuak, John Nelson, Zoya Martin, Mike Dempsey, Chelsey Lumb, Yvan Simard and, Tiphaine Jeanniard du Dor.

Purpose/Issue/Question:

Discussion in regards as to how the biological data could be better integrated with oceanographic information to address Arctic change. Is there a better way to collect, analyze and jointly use the information on physical and biological oceanography?

Summary of discussions:

Overarching issue:

Combining biological and oceanographic data is challenging at times. While there are examples of positive outcomes from such collaborative efforts, often biological and physical oceanographers have a hard time to find a common ground. That seems true at both the project planning stage and the data analysis.

Issue of accessibility of the oceanographic data:

While there are regional repositories of the oceanographic data, individuals located in other regions have limited awareness/access to these holdings. Also individual researchers often work in isolation (e.g. small coastal projects) and the data are not disseminated to a broader audience.

Issue of incompatibility of collected data vs. data required/desired:

Discussion need to be held before the project is executed, for example at the planning/proposal stage, in order to design a joint approach to data collection that would benefit all parties involved. Particularly biologist often collect the data with no input from oceanographers, while expect the oceanographers to analyze the collected information.

Issue of usability/compatibility of particular instruments:

Some of the instruments used in data collection may not be regarded as reliable/standard for oceanographic work. A synthesis/list of ‘’approved’’ oceanographic instruments would help in standardization of data collected. This could be done centrally with regional input.

External sources of data:

While DFO staff often rely on their own data, there are other agencies and institutions that collect data that can be widely used e.g. ArcticNet, Canadian Ice Service. Collaborations are desired in order to fill the data gap.

Issue of lack of sea-ice data:

While biologically significant, sea-ice is relatively little monitored by the DFO-based efforts. These data can be found outside of DFO however, it is sometimes troublesome to gain and access. There is lack of capacity within DFO to analyze large data sets related to sea ice. There are also a current lack of synergies between physical oceanographers and biologists in regards to the approaches in sea-ice research.

Issue of lack of focal areas or research in the Arctic:

Since we cannot study everything and everywhere in the Arctic, there should be localized effort made in a number of focal areas (e.g. Beaufort Sea, Canadian Archipelago, Davis Strait) to create a long term data sets and inform future science needs.

Well known issue of the data management:

There are multiple and variable issues with historical data accessibility (different formats and data basis), accessibility issues related to location and administration of datasets and lack of training for metadata.

Outcomes:

- Meetings such as the 2018 DFO Arctic Science Meeting:
    - Help generate awareness of issues and brings together staff across DFO Regions and disciplines to create collaborations and provides a platform for integration.
    - Help inform initiatives such as State of the Ocean.
- Having similar meetings in the future is highly recommended and desirable.

Proposed/suggested next steps:

- Create a summary of oceanographic instruments regarded as standard/approved to help biologist with data collection and subsequently help oceanographers with data analysis.
- Improve collaboration between sea-ice oceanographers and biological oceanographers as these two domains are heavily coupled.

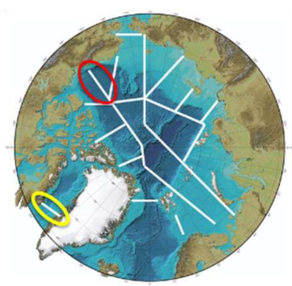
Session topic: Discussion on the Synoptic Arctic Survey (SAS) program

Date of session: February 8, 2018
Facilitator: Kumiko Azetsu-Scott
Note taker: Sherry Niven
Participants: Kumiko Azetsu-Scott, Sherry Niven, Will Perrie, Shannon Nudds, Humphrey Melling, Bill Williams, Jane Eert, Kristina Brown, Sarah Zimmermann, Stephen Virc, Christine Michel, Kevin Hedges and, Ashley Stasko

Purpose/Issue/Question:

The purpose of this breakout session is to inform the progress of SAS international program and to discuss issues regarding Canada's participation.

Two proposed transects for the SAS could potentially be surveyed by programs with existing or recent Canadian involvement (also note, these transects also correspond to GO-SHIP's lines):



- Canada Basin line (shown in red in the figure) – Joint Ocean Ice Studies (JOIS) currently surveys part of this transect but there may be a need to extend further offshore to meet another transect. Current indications are that this cruise will likely occur in 2020.
- Davis Strait line (shown in yellow in the figure) – This section survey has been in a hiatus since 2015. This cruise would require support of ship time.

SAS-International has also requested Canadian large icebreaker(s) to assist smaller research icebreakers of other countries.

Summary of discussions:

Logistics:

- Ships – The CCGS *Louis S. St-Laurent* is expected to be used for JOIS 2020. Is it reasonable to use the ship for Davis Strait as well? The cruises could be combined with the CCGS *Louis S. St-Laurent* either sailing from St. John's NFLD through Davis Strait to the JOIS site, or Davis Strait could be conducted on the way back to St. John's from the JOIS line. Considerations include: timing regarding ice conditions and day light length at JOIS, the duration of combined cruises versus separate cruises, including crew change issues. The Davis Strait line doesn't require an icebreaker. It may be cheaper and easier to use other non-icebreaker ship (a ship designed for offshore open water) for Davis Strait.

- Can we mobilize large Canadian icebreaker(s) to assist research icebreakers for other country?
- Cost estimates need to be done under different scenarios
- We will contact academic colleagues in ArcticNet and Geotrace to discuss the survey plans, collaboration, and mobilization of Amundsen.
- A first SAS-Canada meeting including outside DFO colleagues should be held in early spring of 2018.
- Arctic fishery survey which is planned in 2020 should be coordinated with SAS-2020.
- How do we secure funding?

Scientific considerations:

- Coastal/shelf regions should be included to understand the boundary conditions for freshwater, nutrients, carbon and tracers. Higher temporal and spatial variability in these regions require different sampling schemes including high frequency temporal sampling with covering larger area using smaller boats. Existing coastal programs can be coordinated to extend JOIS section to the shore. Indigenous community involvement for seasonal sampling along Baffin Bay/Davis Strait regions should be developed.
- Surface 20m of water column is important for atmosphere-ocean interaction for heat and carbon flux, and salinity structure modified by addition of freshwater from sea ice meltwater and river runoff. However, it is difficult to sample surface 20m by icebreaker due to mixing of the water column which is caused by an icebreaker itself. Sampling from ice/ice floe in selected area can be an option, but feasible?
- Satellite studies need to be incorporated in SAS. To provide ground-truthing, additional measurements such as high-performance liquid chromatography (HPLC) pigment analyses should be considered. Bring this idea to SAS-International to discuss whether HPLC analyses are included in level 1 measures.

Outcomes:

- DFO scientists are eager to participate in SAS 2020 and form a core of SAS-Canada.

Proposed next steps:

- Budget estimates for different scenario (using the CCGS *Louis S. St. Laurent* for both JOIS and Davis Strait cruise, separate ships, including the second icebreaker to assist smaller research icebreakers of other countries)
- Cost estimates for various proposed measurements (Barium, HPLC)
- Contact Keith Levesque on potential ship time coordination
- SAS-Canada workshop to be held in early spring 2018, inviting academic colleagues.
- Kumiko to share SAS Science and Implementation Plans when available.

Session topic: Linking climate models, monitoring and laboratory studies with marine ecosystem responses and impacts on subsistence fisheries in the Canadian Arctic

Date of session: February 8th 2018
Facilitator: Nadja Steiner
Note taker: Diane Lavoie, Alain Dupuis
Participants: Nadja Steiner, Diane Lavoie, Alain Dupuis, Mike Hammill, Kim Houston, Lisa Loseto, Neil Mochnacz, Andy Majewski, Muhammad Yamin Janjua, Christie Morrison, Ross Tallman, Samantha Fulton, Blair Dunn and, David Deslauriers

Purpose/Issue/Question:

Within the Arctic Monitoring and Assessment Programme's (AMAP) Arctic Ocean Acidification Assessment Case Study #5 we have been starting to combine tools to assess Climate Change impacts on subsistence fisheries in a multi-stressor environment in the changing Canadian Arctic. This initial effort has a lot of potential to be expanded and applied to different areas of the Canadian Arctic.

- How can we link the various DFO tools and expertise to provide useful projections and impacts assessments for Arctic communities and policy makers?
- How can this be used to support Marine Spatial Planning including Marine Protected Area Network Planning?
- How can this be used to assess locations and areas of potential climate refugia?

Summary of discussions:

A summary based on the AMAP report showed an example linking different modelling tools, including regional climate models, species distribution and Ecopath models and economic models, with observed environmental conditions, fish distributions and current fisheries activities and measured physiological responses to eventually assess climate change impacts on subsistence fisheries in the Inuvialuit Settlement Region.

Participant introductions showed that all work on one or more components of this tool set and work on linking components with an aim to perform vulnerability analyses.

Comments were made on the high uncertainty of Ecopath models and the need to validate them. It was also noted these models can be difficult to make work. The link to stock assessment was made indicating the need to identify the trophic pathways to improve Ecopath model parameters. However, this type of data is very limited in the Arctic. The uncertainty range (for all model tools) needs to be communicated (to managers) to allow adequate assessment of the tool (confidence versus dismissal; attitude towards models is often negative so we need to communicate more and listen and demonstrate the model capacities). Also, the limited ability of (all) models to accurately represent the near-shore environment was highlighted, which is important for some of the species.

Models are important for spatial questions such as spatial-based conservation measures. There will be a need to understand that change outside of a conservation area may actually be driving changes inside that conservation area. For example, ice movement outside of conservation areas and potential relationships with beluga habitat usage.

It is often difficult to get to the advice stage using models; there will always be a need for traditional approaches for validation etc.

Section heads can/should support the intra-departmental/cross-region linkages among people which are necessary to combine all the tools and identify the need for and deliver interim as well as final end products. It was also commented that this DFO Arctic Science Meeting was very useful to get an overview of DFO capacity and to build linkages. It was noted that efforts to create more occasions for the scientists to get together would be valuable.

Several challenges were noted including:

- Very little expertise with respect to Ecopath modelling exists within DFO, particularly with respect to linking them with climate models.
- Need for quality data to validate Ecopath models. Many assumptions are made in these models and interpretation needs to be careful.
- It was recognized that to date, these kinds of ecosystem models can only show trends and species linkages and cannot be relied upon for biomass estimates. It will be important to educate clients and management on usage and uncertainties.
- Some sectors (like Fisheries management) tend to have a single-species focus and ecosystem approaches has not been fully implemented. The importance of demonstrating successes has been highlighted.
- Models take a long time to develop (several years) which doesn't allow quick results and/or answer.
- Capturing seasonality of biological events and patchy environmental characteristics are difficult.
- There are challenges creating a link with the appropriate expertise and with the clients.
- There is a real need for easier access to computing capacities, disk space, technical support, data management.

Outcomes:

Overall, there was agreement that the combination of measurement, modelling and interpretation tools with an example presented for the Inuvialuit Settlement Region was a good approach to assess ecosystem changes and vulnerability. The information obtained could be useful for marine spatial planning and generating other policy advice. Participant all worked on one or more components of this tool set, but with limited linkages. In the development towards the end product, it was highlighted that interim products are often relevant to clients and leads should strive to work with clients to promote awareness and their usage. This highlights the need for client involvement early on.

Overall, there was agreement for the need and value of improved and enhanced collaboration facilitated by regional managers and focused cross-regional workshops.

Proposed next steps:

- Provide clear communication about what "these" models can and cannot do. (e.g., capacities of and differences between biogeochemical models, Ecopath type models and species distribution models)
- It may take time to develop a full end to end system: Highlight steps along the way which can and should be considered as important interim deliverables
- Identify and work with main clients/novel clients on how to best deliver these interim products. Bring clients into the discussion earlier rather than later (e.g., ask what the clients need a model to do, what timescales the clients interested in).
- Recognize multiple uses of models, for example, they could help direct future work but also inform conservation area development and marine spatial planning.
- Need to be clear about the end-product and end-goal of this work. While a broader initiative may involve socio-economics, for DFO, the focus are steps that involve understanding environmental impacts (past trends, physiological responses, future projections) and fisheries and species distribution (Ecopath/Ecosim, species distribution and habitat suitability models).
- Clearly report on the uncertainties of the models along the development.
- Gather a small expert working group for a week long workshop to work on some details.

Appendix 5 – Presenter Index

Presenter Index