# PICES/ICES WKBCASAS REPORT 2011

SCICOM STEERING GROUP ON HUMAN INTERACTIONS ON ECOSYSTEMS

ICES CM 2011/SSGHIE:14

REF. SCICOM, PICES

# Report of the PICES/ICES Workshop on Biological Consequences of a Decrease in Sea Ice in Arctic and Sub-Arctic Seas (WKBCASAS)

22 May 2011

Seattle, Washington, USA

ICES
International Council for the Exploration of the Sea

CIEM
Conseil International pour l'Exploration de la Mer

PICES

## North Pacific Marine Science Organization

9860 West Saanich Road
PO Box 6000
Sidney, British Columbia
Canada V8L 4B2
Telephone (+1-250) 363 6366
Telefax (+1-250) 363 6827
www.pices.int
secretariat@PICES.int

## International Council for the Exploration of the Sea
## Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk



Recommended format for purposes of citation:

PICES/ICES. 2011. Report of the ICES/PICES Workshop on Biological Consequences of a Decrease in Sea Ice in Arctic and Sub-Arctic Seas (WKBCASAS),22 May 2011 ICES CM 2011/SSGHIE:14. 10 pp.

## Contents

## Executive Summary

ICES/PICES Workshop on Biological Consequences of Decreases in Sea Ice in Arctic and Sub-Arctic Seas (WKBCASAS) met in Seattle, Washington, USA, on 22 May 2011. The objective of this meeting was to assess the biological consequences of decreased sea ice and possible changes in water temperature in Arctic and Sub-Arctic seas. Workshop participants reviewed life-history information and habitat associations of commercial species of fish and shellfish to assess the risk of immigration and settlement of new biological populations in the Arctic Ocean and surrounding shelf seas in response to the retreat of sea ice. Criteria necessary to establish new species in the Arctic Ocean and surrounding areas were developed and compared to expected conditions based on climate scenarios. Opportunities for cooperation in information sharing between groups charged with managing the Arctic was discussed and reported to scientists within ESSAS as well as PICES and ICES.

# 1 Opening of the Workshop

The Co-Chairs Anne Hollowed and Harald Loeng welcomed workshop the participants (Annex 1) to the meeting.

# 2 Overview

The meeting was well attended with 34 participants from 9 countries (Annex 1 and 2). The session consisted of 6 oral presentations and 1 poster, including invited presentations by Trond Kristiansen and Hyunju Seo. Trond Kristiansen used an Individual Based Model (IBM) to evaluate the implications of climate change on four spawning grounds of Atlantic cod. His work revealed the importance of temperature on larval growth and the importance of phenology with respect to matching the emergence of first-feeding larvae with the spring bloom. Projections of future ocean conditions indicated that the small zooplankton will increase and large zooplankton will decrease under future climate conditions. Hyunju Seo predicted future impacts of climate change on chum salmon. Her model incorporated relationships previously identified from a retrospective model of the effect of global warming and density-dependence on Hokkaido chum salmon from the 1940s to the early 2000s. Her results suggest that currently global warming is positively affecting chum salmon by increasing the growth-rate at-age 1+ and survival of Hokkaido chum salmon through the warmer sea surface temperature during summer and fall in the Okhotsk Sea. Over time, population density-dependent effects on the growth rate of chum salmon at age 3+ and expected changes to the maturation schedule changes are predicted because of limited carrying capacity. In future, global warming is expected to negatively affect chum salmon survival by decreasing the carrying capacity and reducing the habitat area in the North Pacific Ocean.

# 3 Key questions

Participants were asked to consider the following questions:

- How will the productivity of Arctic ecosystems change?
- What criteria need to be fulfilled in order to get commercial fishing in the Arctic Ocean and the surrounding shelf seas in future?
- What species are most likely to migrate successfully to the Arctic to establish self-sustaining populations?
- How are successful migrations likely to alter Arctic marine ecosystems?
- What research is needed to understand these ecosystem changes and the impacts of commercial fishing on them?

# 4 Expected Physical and Lower Trophic Level Changes

The morning discussion session focused on the question: *How will climate change impact the productivity of the Arctic and Sub-Arctic seas?* Oceanographers reported that quality of the models and the techniques for assessing the adequacy of IPCC models for use in the Arctic have been improved since the release of the 4th assessment report (AR4) of the Intergovernmental Panel on Climate Change Assessment (IPCC). Further research is needed to model the synergistic effects of decadal to multidecadal variability and climate change to shifts in ocean conditions. The group noted that a fruitful line of research would be to examine ocean/ecosystem responses to the warming trend from the 1930s to 1950s to learn how ocean systems respond to warming. A key observation was that the Arctic has lost much of its old, thick ice that tended to persist through summer. This finding indicates that the pace of sea ice retreat in summer is occurring more quickly than was projected by global climate models. Ice will continue to form in autumn, and is expected to persist until late (mid) spring; this will influence the duration of growing season. The heat content of the Arctic is influenced by solar heating and Atlantic water inflow. A question for the future is whether Atlantic Water will intrude onto the shelf areas in the Arctic Ocean. The influence of large-scale circulation patterns on stratification in the Arctic will also influence the rate of warming in the Atlantic Arctic area. The ability of global climate models to predict subsurface water temperatures in the Arctic and Sub-Arctic is limited.

Lower trophic level species will respond to changing ocean conditions. The Arctic will continue to be dark and cold for several months of the year and these conditions will continue to deter the invasion of new species to the region, and this will continue to limit the total annual production in the region. Reductions in the sea ice extent and thickness in summer in the Arctic Ocean could prolong the growing season and increase stratification. Coupled biophysical models indicate that future ocean conditions will favour the production of small phytoplankton and will reduce the production of large phytoplanktonIce algae will continue to be important in selected regions but this contribution may represent a smaller fraction of the total annual open ocean production in future. Shifts in the timing of ice algal blooms may impact the match of prey with the emergence of zooplankton. It is unclear how future climate conditions will impact advection of zooplankton (copepods and euphausiids) into the region; and whether these conditions will allow overwintering of these species in the region.

# 5 Selection Criteria

The afternoon discussion focused on the question: What criteria need to be fulfilled in order to get commercial fishing in the Arctic Ocean and the surrounding shelf seas in future? The group addressed this question by compiling a list of commercial species and considering the likelihood that these species would extend their range into the Arctic (Table 1). This discussion revealed that fish employed diverse survival strategies, which made them likely or unlikely candidates for the range extensions into the Arctic.

This exercise revealed a suite of key attributes for consideration:

- Species is capable of rapid growth to survive during short growing season;

- Species exhibits physiological characteristics to survive in cold conditions, e.g. blood antifreeze in polar cod and Alaska plaice;
- Species exhibits a broad spawning range, with low site fidelity;
- Species has a diverse prey base.

The group noted that even if a species exhibits several or all of the attributes listed above, the colonization of new regions may not occur unless the thermal windows are suitable for survival at key life stages, and the advective corridors are available for immigration to the new region. Comparison of the advective corridors for colonization in the Atlantic and Pacific sides of the Arctic shows that the flows into the Arctic are much stronger on the Atlantic side. Further comparisons shows that the currents are more favourable to immigration on eastern boundaries. Distances between similar habitat types are relatively small. Topography also appears to influence the probability of immigration. On the Pacific side, the shallow shelves may serve as a barrier to immigration, because of either the presence of cold pools (remnant cold water at depth from winter ice cover) or due to depth preferences of fish and shellfish.

Although fish that exhibit these characteristics may be more likely to immigrate into the Arctic, the processes governing survival are complex spatially and temporally. Considerable uncertainty remains as to whether these species will be able to colonize the Arctic successfully. Many species have evolved temporal patterns of feeding and reproductive behaviour that maximize survival. If climate change shifts the temporal match with key aspects of the life-history, survival may be impacted. Several species exhibit seasonal migrations, if the quality or quantity of habitat is changed, these spawning and feeding migrations may be unsuccessful. Over time, fish often adopt strategies to avoid predation or to partition the limited resources. These strategies result in complex zoogeographic patterns, which allow coexistence. Climate change may influence the effectiveness of these strategies, and species that colonize the Arctic may disrupt the balance of predator and prey.

After considerable discussion the group agreed to attempt applying the criteria identified above to the species in their regions to compile a list of species that would be candidates for colonization of new regions in Arctic and Sub-Arctic seas. Workshop conveners will work with workshop participants to develop a paper that synthesizes this information as a potential contribution to the symposium volume.

## 6 Recommendations for Research

The final session of the workshop was devoted to the question: What research is needed to understand these ecosystem changes and the impacts of commercial fishing on them?

The group identified the following suite of key research activities:

- Study the role of seasonal light and ice on ecosystem production and fish/zooplankton phenology;
- Resolve impacts on Atlantic inflow to Arctic;
- Conduct periodic fish/plankton surveys to monitor shifts in their distributional and abundance patterns;
- Conduct laboratory/field research on tolerance of biota under multiple stressors: acidification, temperature, and fishing;

- Continue studies of zooplankton community dynamics, with special emphasis to the ratio of boreal/arctic and large/small species;
- Conduct food spectra analysis to assess species interactions.

**Table 1. Preliminary assessment of colonization probability of new regions for northern commercial fish and shellfish species.**

| Species | Current northern concentrations | Candidate for movement into the Arctic? | Life-history Characteristics |
|---|---|---|---|
| Atlantic cod (*Gadus morhua*) | N. Atlantic, Barents Sea | Maybe | Dependent on increased zooplankton production, larval stages capable of surviving in cold conditions, species would have to establish new spawning grounds. Evidence of expansion of spawning grounds in NE Arctic cod. Dynamic life history with flexible growth and maturation characteristics. |
| Atlantic mackerel (*Scomber scombrus*) | N. Atlantic | Maybe | Pelagic life history with broad migrations |
| Herring (*Clupea harengus pallasi*) | N. Atlantic and Barents Sea, Bering Sea | Maybe | Prefer water masses with temperature higher than 2o C, but might migrate into frontal areas during the feeding season. Northward migration will depend both on temperature and zooplankton abundance. |
| Red king crab (*Paralithodes camtschaticus*) | Eastern and western Bering Sea & Barents Sea (introduced) | Maybe | Introduced in Barents Sea. Opportunistic feeder. |
| Yellowfin sole (*Limanda aspera*) | Bering Sea | Maybe | Diverse demersal diet, already inhabits shallow shelves in the northern Bering Sea, spawns in summer |
| *Sebastes* spp. | Bering Sea and N. Atlantic | Maybe for Atlantic redfish, unlikely for most Pacific rockfish | Resides in deep water and unlikely to cross Bering Strait, apparent fidelity to spawning sites, larval dispersal less than 100km |
| Arrowtooth flounder (*Atheresthes stomias*) | Bering Sea | Unlikely | Deep-water species less likely to cross Bering Strait, possible prey limitations. |
| Chinook salmon (*Onchorynchus tshawytscha*) | Bering Sea | Unlikely | Extended freshwater life history |
| Coho salmon (*Onchorynchus kisutch*) | Bering Sea | Unlikely | Extended freshwater life history |
| Flathead sole (*Hippoglossoides elassodon*) | Bering Sea, Chukchi Sea | Unlikely | Deeper water species less likely to cross Bering Strait. |

| Species | Current northern concentrations | Candidate for movement into the Arctic? | Life-history Characteristics |
|---|---|---|---|
| Northern rock sole (*Lepidopsetta polyxystra*) | Bering Sea | Unlikely | Reliance on a small group of key prey species. Strong spawning site fidelity |
| Pacific cod (*Gadus macrocephalus*) | Bering Sea | Unlikely | Eclectic prey-base (a positive trait), avoids ice (thermal barrier), would compete as juveniles with arctic cod a cold adapted species. |
| Pacific halibut (*Hippoglossus stenolepis*) | Bering Sea | Unlikely | Deeper water spawner, less likely to cross Bering Strait. |
| Sockeye salmon (*Onchorynchus nerka*) | Bering Sea | Unlikely | Extended freshwater life history |
| Walleye pollock (*Theragra chalcogramma*) | Bering Sea | Unlikely | Avoids ice in winter (thermal barrier), avoids cold pool as age-0 and adult in summer, would compete with polar cod which is cold adapted |
| Alaska plaice (*Pleuronectes quadrituberculatus*) | Arctic Ocean, Chukchi Sea, and Bering Sea | Likely | Demersal diet, 38% of Bering Sea population resides in northern regions, has glycol-protein in blood that acts as anti-freeze |
| Bering flounder | Bering Sea and Chukchi Sea, Arctic Ocean | Likely | Already resides in Arctic Ocean, demersal diet. |
| Capelin (*Mallotus villosus*) | Bering Sea, Barents Sea, Chukchi Sea, Arctic Ocean | Likely | Capable of rapid growth, already resides in Arctic Ocean. |
| Chum salmon (*Onchorynchus keta*) | Bering Sea, Chukchi Sea and Arctic Ocean | Likely | Already spawning in Arctic Ocean |
| Greenland halibut (*Reinhardtius hippoglossoides*) | N. Atlantic, Bering Sea, Arctic Ocean | Likely | Piscivore and could consume polar cod, broad spatial distribution, currently spawn in deep water in northern regions of the Bering Sea and has been observed in the Arctic |
| Kamchatka flounder (*Atheresthes evermanni*) | Bering Sea | Likely | Currently found in northern Bering Sea, Chuckchi Sea and Arctic Ocean |
| Pink salmon (*Onchorynchus gorbuscha*) | Bering Sea, Chukchi Sea and Arctic Ocean | Likely | Already spawning in Arctic Ocean |
| Polar cod (*Boreogadus saida*) | Bering Sea, Chukchi Sea, Arctic Ocean, Barents Sea | Likely | Already inhabits Arctic Ocean, capable of rapid growth, has glycol-protein in blood that acts as anti-freeze. |
| Snow crab (*Chionoectes opilio*) | Arctic Ocean, Bering Sea and Western Canada | Likely | This species is already present in the Arctic |

## Annex 1: List of participants

| | First | Last | E-mail | Organization | Nation |
|---|---|---|---|---|---|
| 1 | Skip | McKinnell | Skip.Mckinnell@pices.int | PICES | Canada |
| 2 | Bill | Montevecchi | Mont@mun.ca | Memorial University, Newfounland | Canada |
| 3 | Adi | Kellermann | Adi@ices.dk | ICES | Denmark |
| 4 | Michael | Klages | Michael.Klages@awi.de | Alfred Wegener Institute for Polar and Marine Research | Germany |
| 5 | Olafur | Astthorsson | osa@hafro.is | Marine Research Institute Iceland | Iceland |
| 6 | Toru | Hirawake | Hirawake@salmon.fish.hokudai.ac.jp | Hokkaido University | Japan |
| 7 | Takahiro | Iida | Iida@nipr.acjp | NIPR | Japan |
| 8 | Kenshi | Kuma | Kuma@fish.hokudai.ac.jp | Hokkaido University | Japan |
| 9 | Kohie | Mizobatat | Mizobata@kaiyodai.ac.jp | Tokyo University of Marine Science and Technology | Japan |
| 10 | Suam | Kim | Suamkim@pknu.ac.kr | Pukyong National University | Korea |
| 11 | HyunJu | Seo | uagiri@hanmail.net | NFRDI | Korea |
| 12 | Trond | Kristiansen | Trond.Kristiansen@imr.no | Institute of Marine Research | Norway |
| 13 | Harald | Loeng | Harald.Loeng@imr.no | Institute of Marine Research | Norway |
| 14 | Margaret | McBride | Margret.Mcbride@imr.no | ESSAS Project Office Institute of Marine Research | Norway |
| 15 | Svein | Sundby | Svein.Sundby@imr.no | Institute of Marine Research | Norway |
| 16 | Sen Tok | Kim | Kimst@sakhniro.ru | Sakhalin Research Institute of Fisheries and Oceanography | Russia |
| 17 | Vladimir | Kulik | Kulik@tinro.ru | TINRO-Center | Russia |
| 18 | Daria | Martynova | daria.martynova@gmail.com | White Sea Biological Station, Zoological Institute, Russian Academy of Sciences | Russia |
| 19 | Michael | Dagg | Mdagg@lumcon.edu | Louisiana Universities Marine Consortium | USA |
| 20 | Matthew | Baker | Matthew.Baker@noaa.gov | University of Washington/NOAA | USA. |
| 21 | Kate | Hedstrom | kshedstrom@alaska.edu | University of Alaska Fairbanks | USA. |
| 22 | Kathy | Kuletz | Kathy_Kuletz@fws.gov | US Fish and Wildlife Service | USA. |

| | First | Last | E-mail | Organization | Nation |
|---|---|---|---|---|---|
| 23 | Paul | Spencer | Paul.Spencer@noaa.gov | NOAA/NMFS/AFSC | USA |
| 24 | Steven | Barbeaux | Steve.Barbeaux@noaa.gov | NOAA/NMFS/AFSC | USA |
| 25 | Nicholas | Bond | Nicholas.Bond@noaa.gov | University of Washington | USA |
| 26 | Enrique | Churchister | Enrique@marine.rutgers.edu | Rutgers University | USA |
| 27 | Anne | Hollowed | Anne.Hollowed@noaa.gov | NOAA/NMFS/AFSC | USA |
| 28 | James | Ianelli | Jim.Ianelli@noaa.gov | NOAA/NMFS/AFSC | USA |
| 29 | William | Karp | Bill.Karp@noaa.gov | NOAA/NMFS/AFSC | USA |
| 30 | Frank | Morado | Frank.Morado@noaa.gov | NOAA/NMFS/AFSC | USA |
| 31 | Kotaro | Ono | Kotarono@uw.edu | University of Washington | USA |
| 32 | James | Overland | Jim.Overland@noaa.gov | NOAA/OAR/PMEL: | USA |
| 33 | Michael | Sigler | Mike.Sigler@noaa.gov | NOAA/NMFS/AFSC | USA |
| 34 | Thomas | Wilderbuer | Tom.Wilderbuer@noaa.gov | NOAA/NMFS/AFSC | USA |

## Annex 2: WKBCASAS Agenda

### Biological consequences of a decrease in sea ice in Arctic and Sub-Arctic seas

9:00 *Introduction by Conveners*

9:10 **Trond Kristiansen (Invited)**

Analysing warm and cold climate phases to understand differences in survival of larval fish: Possible implications of climate variability (W1-7552)

9:30 **Hyunju Seo, Hideaki Kudo and Masahide Kaeriyama (Invited)**

The effect of global warming and density-dependence on Hokkaido chum salmon from the 1940s to the early 2000s (W1-7502)

9:50 **Nicholas A. Bond, Paul D. Spencer and Anne B. Hollowed**

Impacts of climate change on the habitat of Bering Sea arrowtooth flounder (W1-7493)

10:05 **Anne B. Hollowed, Steven Barbeaux, Edward Farley, Edward D. Cokelet, Stan Kotwicki, Patrick Ressler, Cliff Spital and Christopher Wilson**

Forecasting climate change impacts on forage fish distributions in the Bering Sea (W1-7500)

10:20 *Coffee/Tea Break*

10:40 **Michael Klages, Eduard Bauerfeind, Antje Boetius, Melanie Bergmann, Christiane**

**Hasemann, Eva-Maria Nöthig, Ingo Schewe and Thomas Soltwedel**

Rapid shifts of the marine ecosystem at HAUSGARTEN deep-sea observatory (Fram Strait; 79°N, 04°E) observed over the past decade (W1-7513)

10:55 **Daria Martynova and Nikolay Usov**

A life with and without ice in the White Sea: Who will stay tuned? (W1-7401)

11:10 **Group Discussion**

Review information on the life history and habitat associations to assess the risk of immigration and settlement of new biological populations in the Arctic and surrounding shelf seas in response to the retreat of sea ice. Establish the habitat requirements necessary for viable range extensions of major fish stocks.

Develop criteria necessary to establish residency of new species in the Arctic Ocean and surrounding shelf seas.

12:30 *Lunch*

14:00 **Discussion**

Consider climate scenarios for arctic and surrounding shelf seas to evaluate the likelihood of range extensions of selected fish stocks using the criteria.

15:00 *Coffee/Tea Break*

15:20 **Discussion**

Continue

16:40 **Discussion**

Review and report on ongoing relevant activities in the area and suggest ways for cooperation

17:00 **Summary and recommendations**

17:30 **Workshop ends**