Potential movement of fish and shellfish stocks from the Subarctic to the Arctic

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## Climate and Shifts in Spatial Distribution

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<th>Publication yr</th>
<th>Region</th>
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<td>Tseng et. al.</td>
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Projecting effects of changes in physical conditions on species distributions and potential catch

Cheung et al. (2009) Fish & Fisheries
Conceptual pathways of direct and indirect effect of climate on marine ecosystems and their implication to adaptation and management
What do we expect in the future?

Photo credit NOAA. (http://marinesciencetoday.com)
Vulnerability Analysis (Daw et al. 2009 FAO)

**FIGURE 1**

Conceptual model of vulnerability

- **Exposure (E)**: The nature and degree to which fisheries production systems are exposed to climate change.
- **Sensitivity (S)**: Degree to which national economies are dependent on fisheries and therefore sensitive to any change in the sector.
- **Potential impacts (PI)**: All impacts that may occur without taking into account planned adaptation.
- **Adaptive capacity (AC)**: Ability or capacity of a system to modify or change to cope with changes in actual or expected climate stress.

\[ V = f(PI, AC) \]

**Source:** adapted from Allison et al., 2005.

**Note:** The word “system” can be interpreted as country, region, community, sector, social group or individual.
Methods

ICES/PICES Workshop May 2011, ESSAS OSM

• Workshop – 34 participants, 9 countries, interdisciplinary team of experts
• Discussed expected changes in sub-arctic and arctic.
• Identified 17 fish or shellfish species
• Discussed key life history characteristics in context of susceptibility and adaptability
• Synthesized outcomes to assess probability of movement to Arctic and probability of fishable concentrations in Arctic.

Exposure: Stronger inflow from Atlantic
Exposure:
Northern and southern regions represent two different domains in the middle shelf and perhaps the coastal domain. Climate change will enhance the differences.

Stabeno et al. 2010, Progr. Oceanogr. 85: 180-196
Beaked Redfish

Figure 3.
Atlantic water in the Arctic Ocean

To day

In the future??
Calanus Marshallae (large copepod) abundance (# per m$^3$), Bongo Tow, 505 μm mesh net

EISNER 2010

Bottom panel: Mean Temperature Below MLD, Cold pool (< 2°C) indicated by dashed black line. 0°C indicted by dashed red line.
Life history considerations?

- Current environmental tolerances
- Distribution shifting zoogeographic boundaries
- Foraging behavior – Range & Diet preferences
- Fidelity to spawning sites
- Changing vital rates (growth, mortality, maturity schedules)
- Phenology (match-mis-match)
- Species interactions (predator-prey, competition)
- Adaptive capacity
• Rapid growth to survive during short growing season;
• Ability to avoid unfavourable conditions (seasonal movement, feeding migration, physiology)
• Access to suitable spawning habitat
• Broad spawning range, with low site fidelity;
• Species has a diverse prey base, prey densities sufficient to support populations

Hollowed et al. in press
Sensitivity: Physiological responses
Denman et al. 2011 ICES J Mar Sci. 1019-1030

- Hypoxia, Acidification, Temperature
- Behavior, growth, survival
Daylength at spawning locations
Fidelity & Plasticity

Important Atlantic cod Spawning Locations

Pacific Cod

Cold pool extent affects location of zoogeographic provinces

Foraging Range and Fidelity to Spawning Locations

Conners and Munro

(P shimada and Kimura, 1994)
Diet Diversity

Pacific cod – Bering Sea
Pollock appear to be pushed to the outer shelf as the spatial extent of the cold pool expands.
Eco-Regions - Pollock
Atlantic and Pacific cod
Low Potential

• Unlikely to spawn in Arctic due to sustained winter sea ice on shelves.
• Fidelity to spawning locations.
• Pelagic larvae may drift from Atlantic. Could result in summer utilization of the Arctic for foraging.
• Atlantic and Pacific cod capable of adapting to different production cycles (both stocks exhibit broad latitudinal range)
• Eclectic diet
• Warm conditions may favor lower quality prey for P. cod.
Walleye Pollock
Low Potential

- Unlikely to spawn in Arctic due to sustained winter sea ice.
- Weaker fidelity to spawning locations.
- Pelagic larvae may drift. Could result in summer utilization of the Arctic for foraging.
- Capable of adapting to different production cycles (broad latitudinal range, apparent shift in spawn timing)
- Ability to shift from pelagic planktivore to pelagic piscivore
- Warm conditions may favor lower quality prey
Movement Assessment

• Six stocks likely to expand in or move to the Arctic: polar cod, snow crab, Bering flounder, Greenland shark, Arctic skate, and beaked redfish.

• Six stocks or stock groups potential to expand in or move to the Arctic: Greenland halibut, capelin, yellowfin sole, Alaska plaice, Atlantic scandic herring, and other elasmobranchs.

• Five stocks have a low potential to expand in or move to the Arctic: Pacific ocean perch, Pacific cod, Atlantic cod, northern rock sole, and walleye pollock.
Summary

• Expert judgment revealed that the potential for fish and shellfish to expand in or move to the Arctic in response to climate change depends on more than distribution of bio-climatic windows.
• The shallow shelf and continued ice formation in the Bering Sea will limit access to the Arctic.
• Greater access to Arctic from Atlantic than Pacific
• Research to quantify this framework is needed.
Next Steps Framework for Assessment of Movement Responses of Fish and Shellfish


Suites of Life History Attributes = Proxies for Sensitivity

Euclidean distance = vulnerability score
Acknowledgements

2011 Workshop Participants

ICES
Conseil International pour l’Exploration de la Mer

NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NSF
National Science Foundation

Lowell Wakefield Symposium