To Migrate or Not?
When may we expect fish species to move poleward?

George Hunt, Franz Mueter, Ken Drinkwater, Harald Loeng, Anne Hollowed

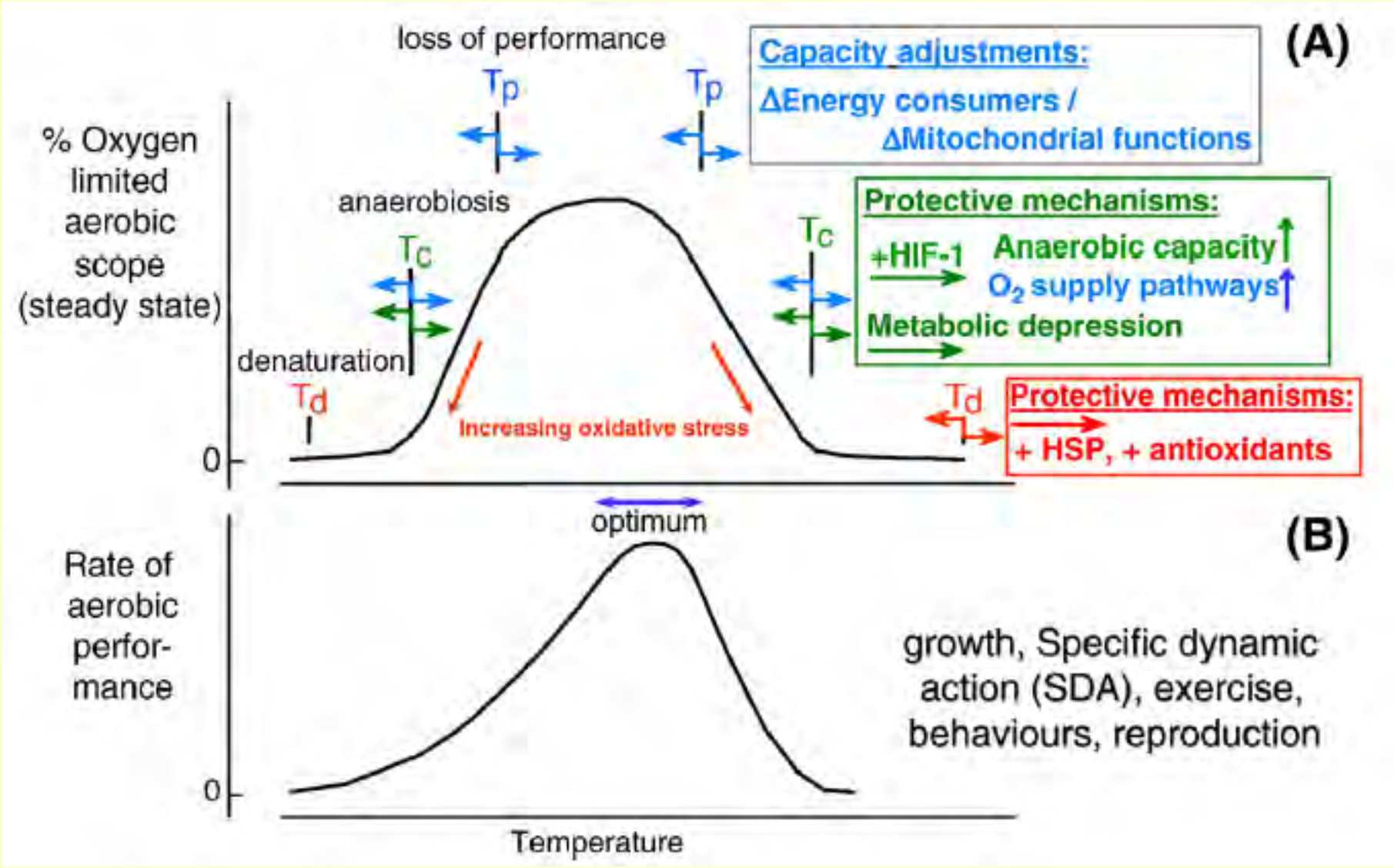
Outline

- **What are the factors that influence shifts in distribution?**
- **What past warming has taught us about changes in fish distributions.**
- **What might we expect fish to do in the future?**

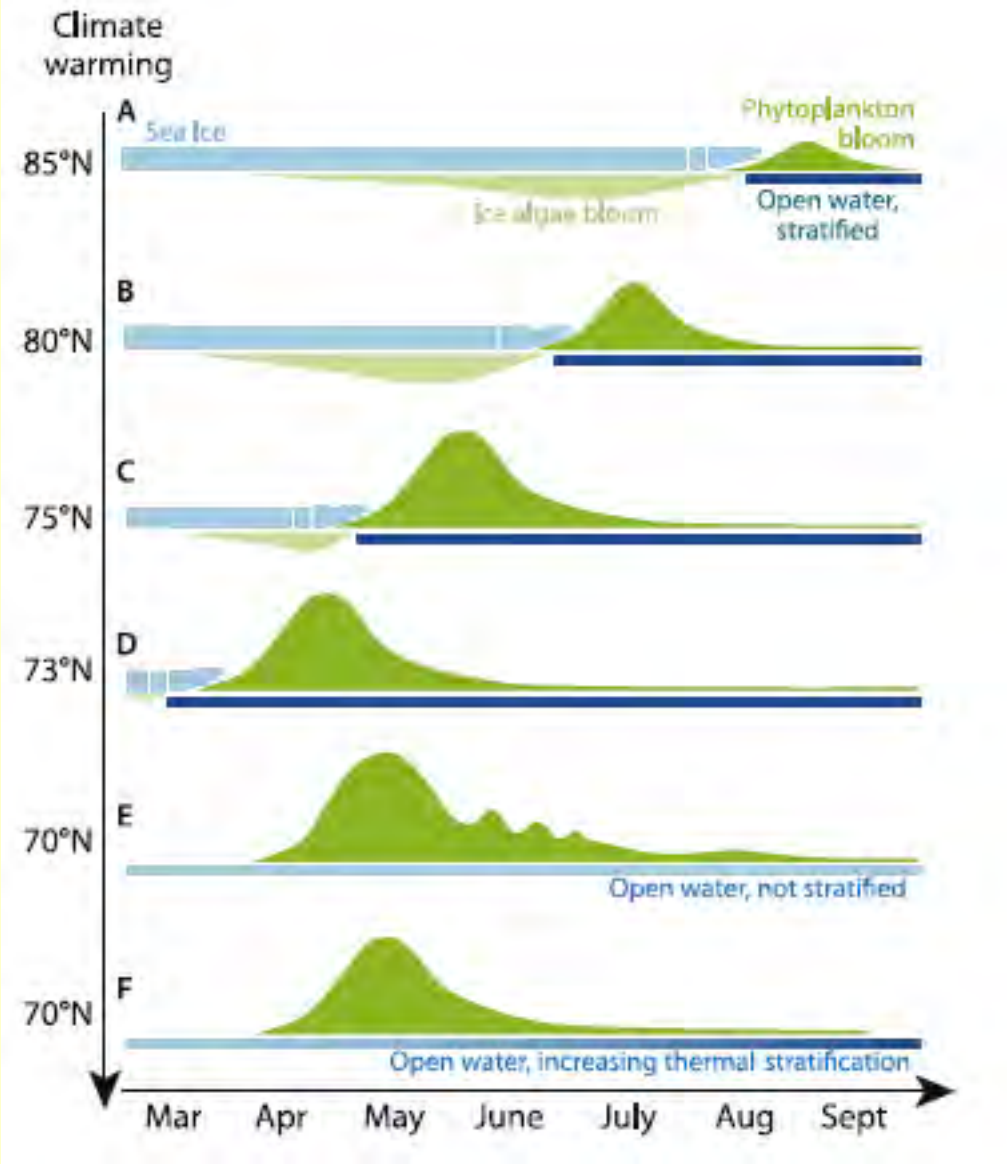
Some Basics

- There must be a need to move
  - Physiological optima and limits
  - Competition (inter- or intra-specific)
- The species must be able to move
  - Flexibility in spawning sites
  - Appropriate prey must be available at right time
  - No new predators in the way

Schematic of Oxygen- and Capacity-limited Thermal Tolerance



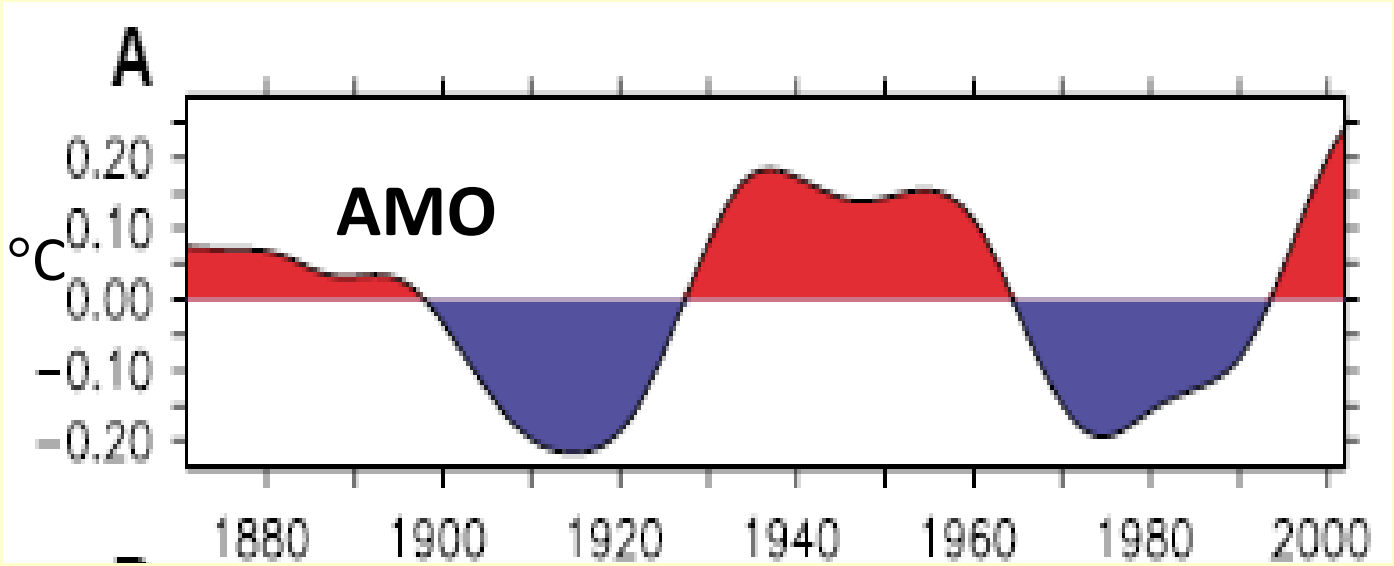
From Drinkwater et al., 2010, J. Mar.



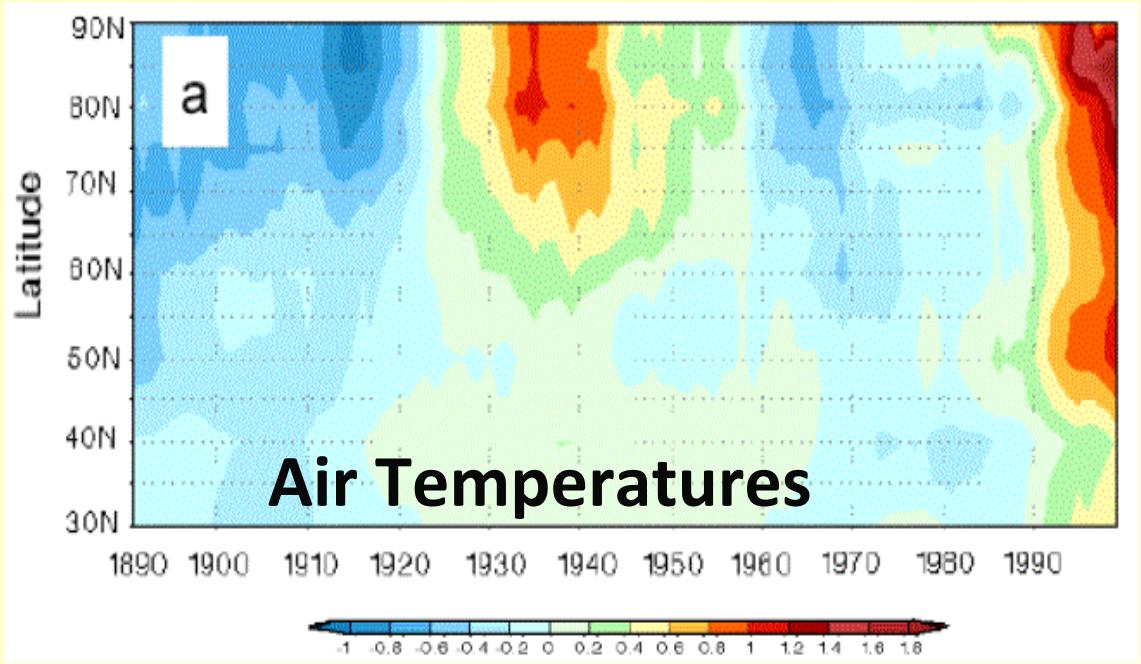
Wassmann 2011, Prog in Oceanogr.

Past Responses to Climate

Atlantic Multi-decadal Oscillation



Sutton & Hodson 2005

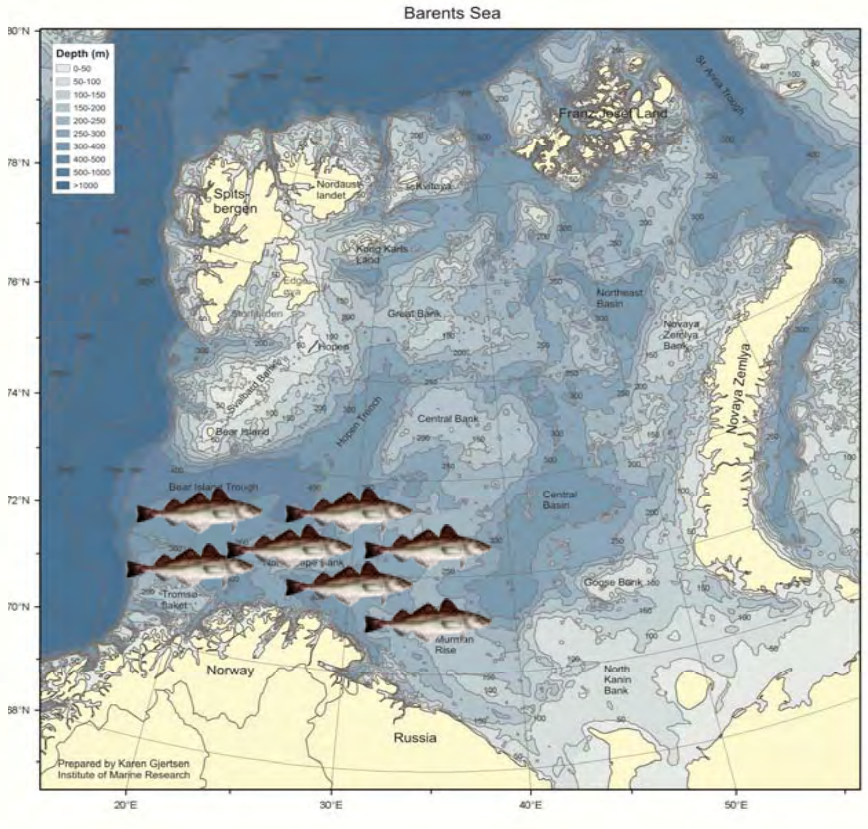


Johannessen et al. 2004

Abundance and Distributional Changes

Warm

Cold

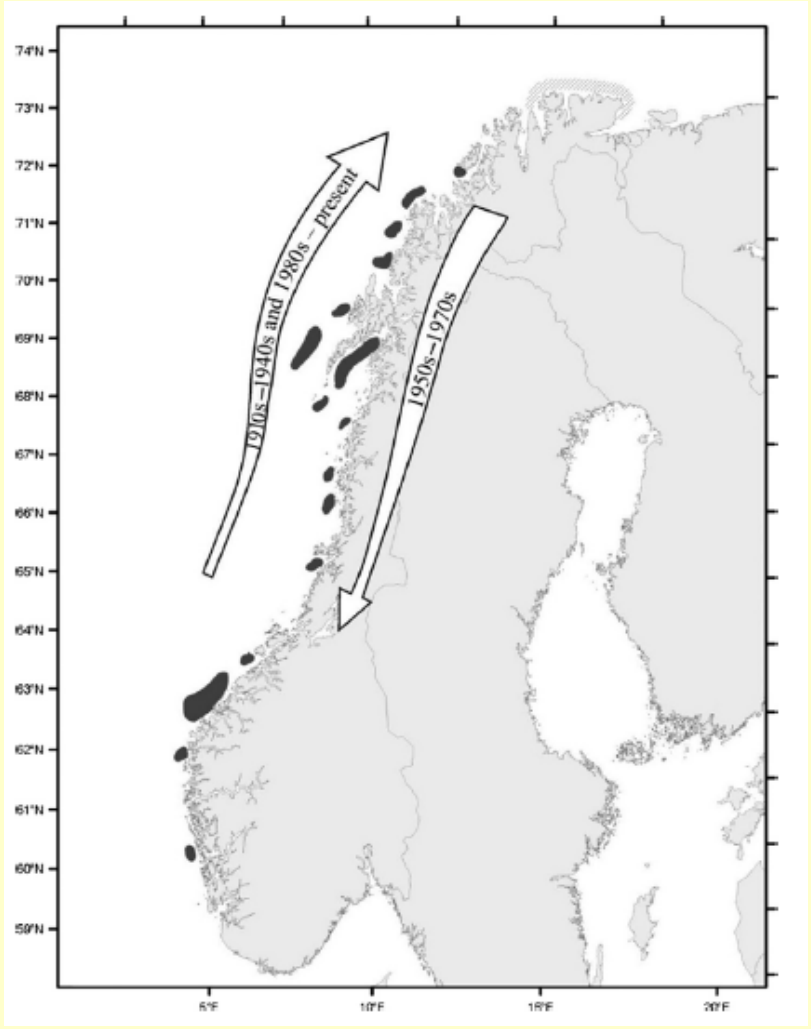


Barents Sea cod tended to spread north and east during warm periods and retreat to SW regions in cold periods.

From Drinkwater 2011, Prog. Oceanogr

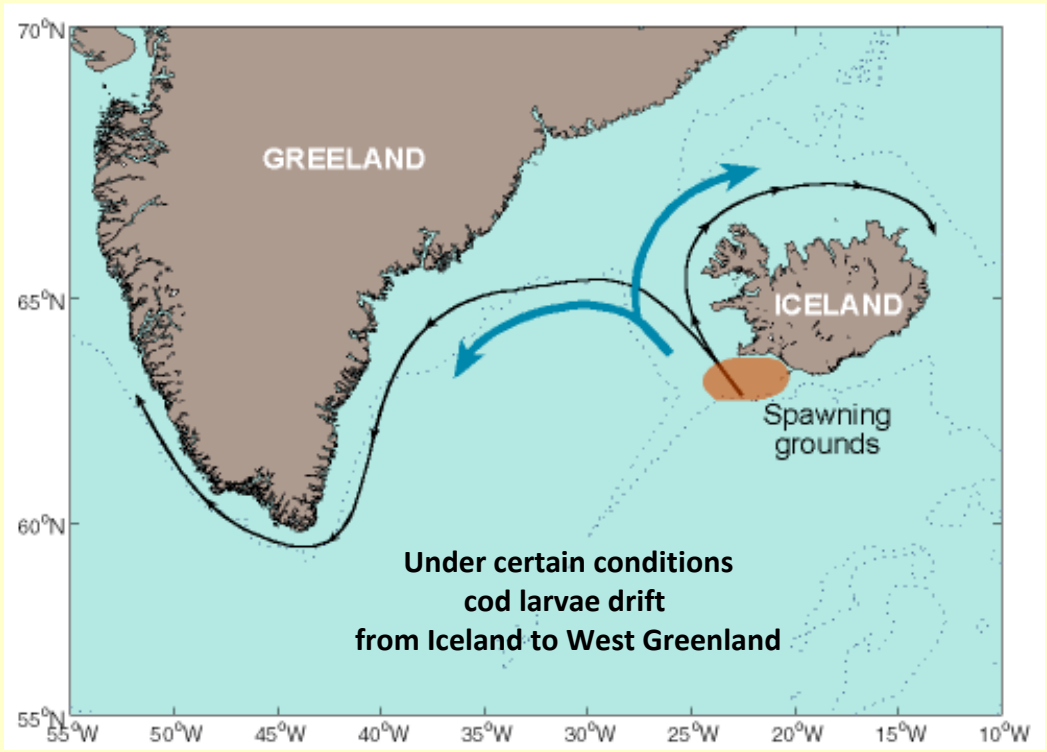
Displacement of Atlantic Cod Spawning Areas on a Multi-decadal Time-scale

Northward shift in the warm 1910-1940s and the 1980s-present



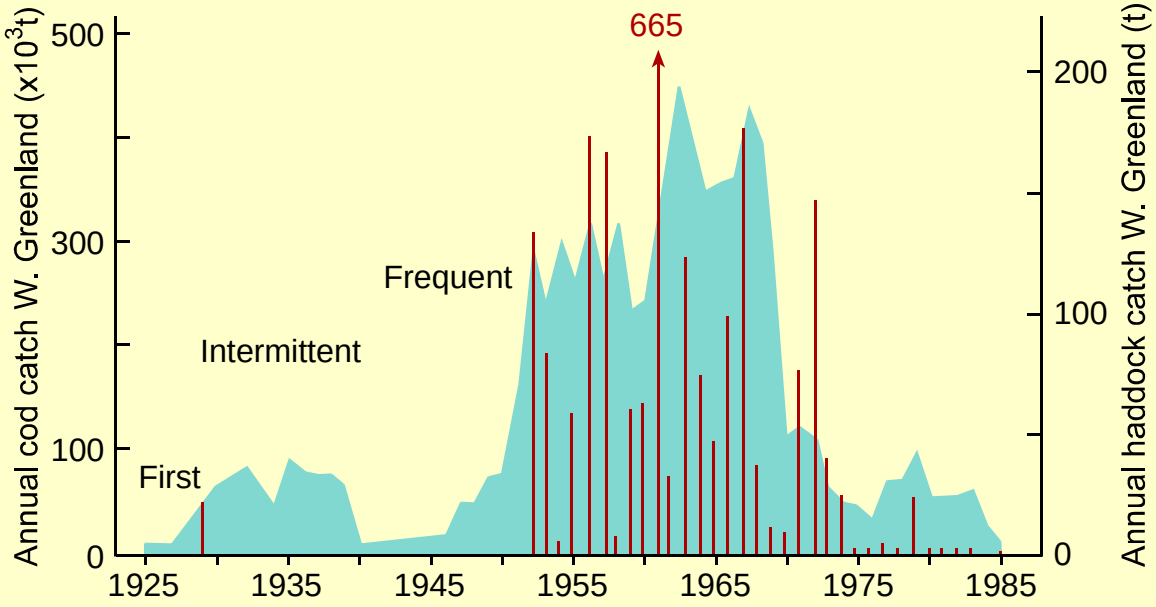
Southward shift in the cold 1950-1970s

From Sundby & Nakken, 2008, ICES J. Mar. Sci.



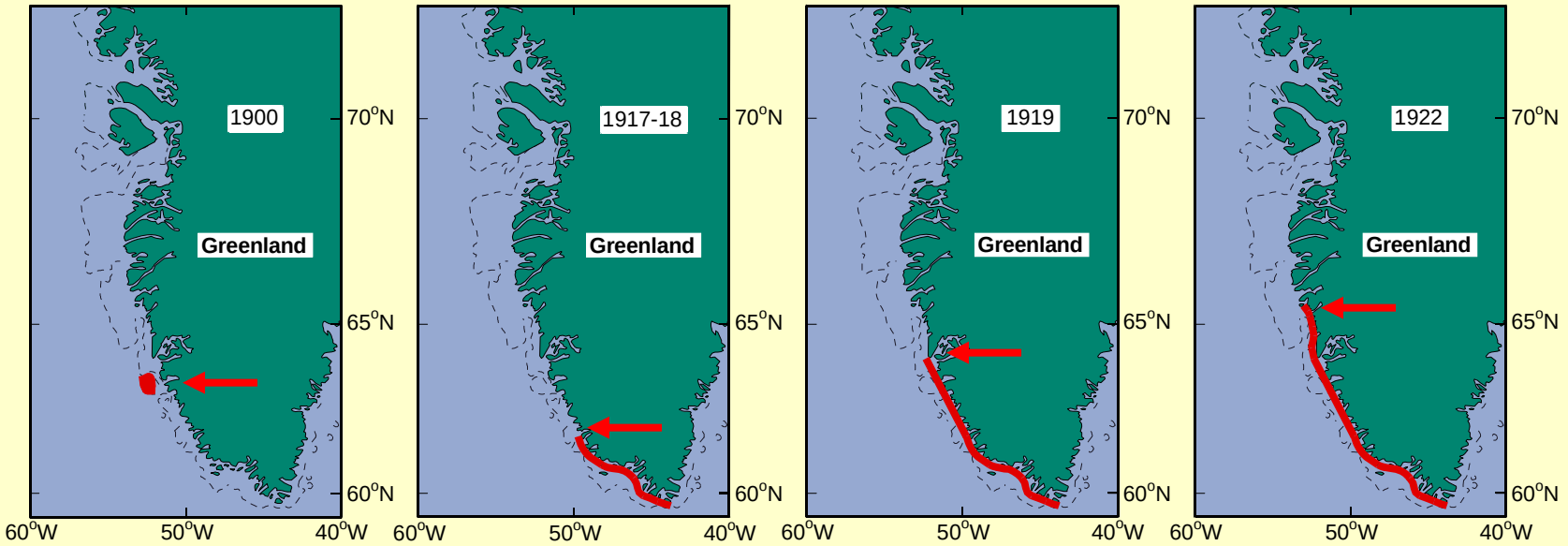
West Greenland-Iceland Connection for Atlantic cod

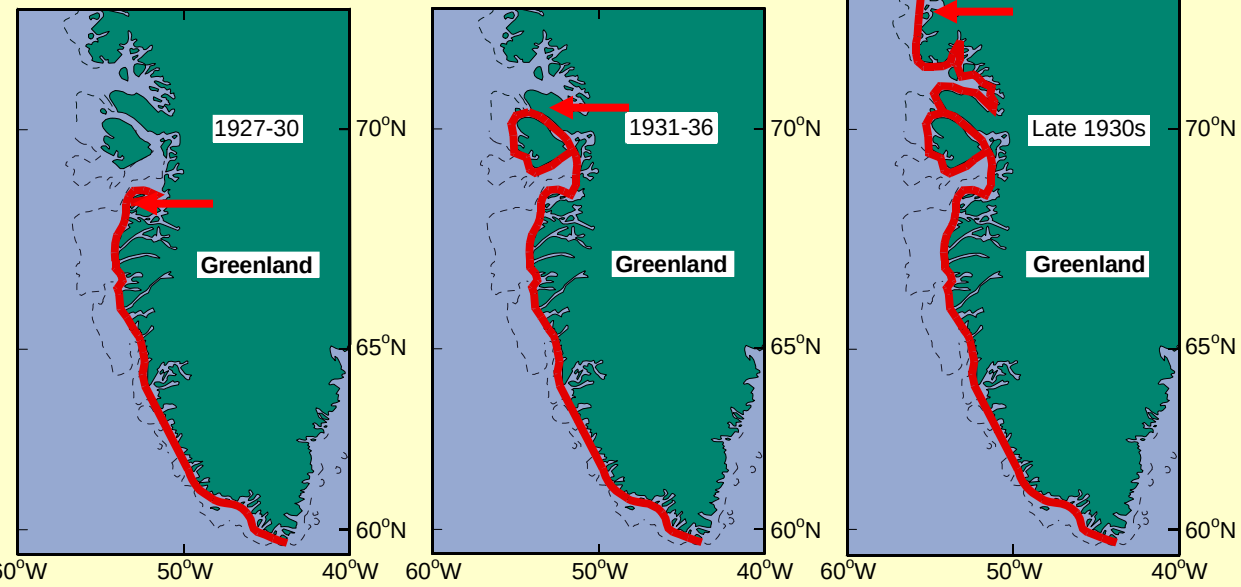
Conditions in 1920s resulted in drift of cod (and haddock) larvae from Iceland to West Greenland and their survival.



West Greenland

Cod gradually spread northward during warm period…





Hansen, 1940

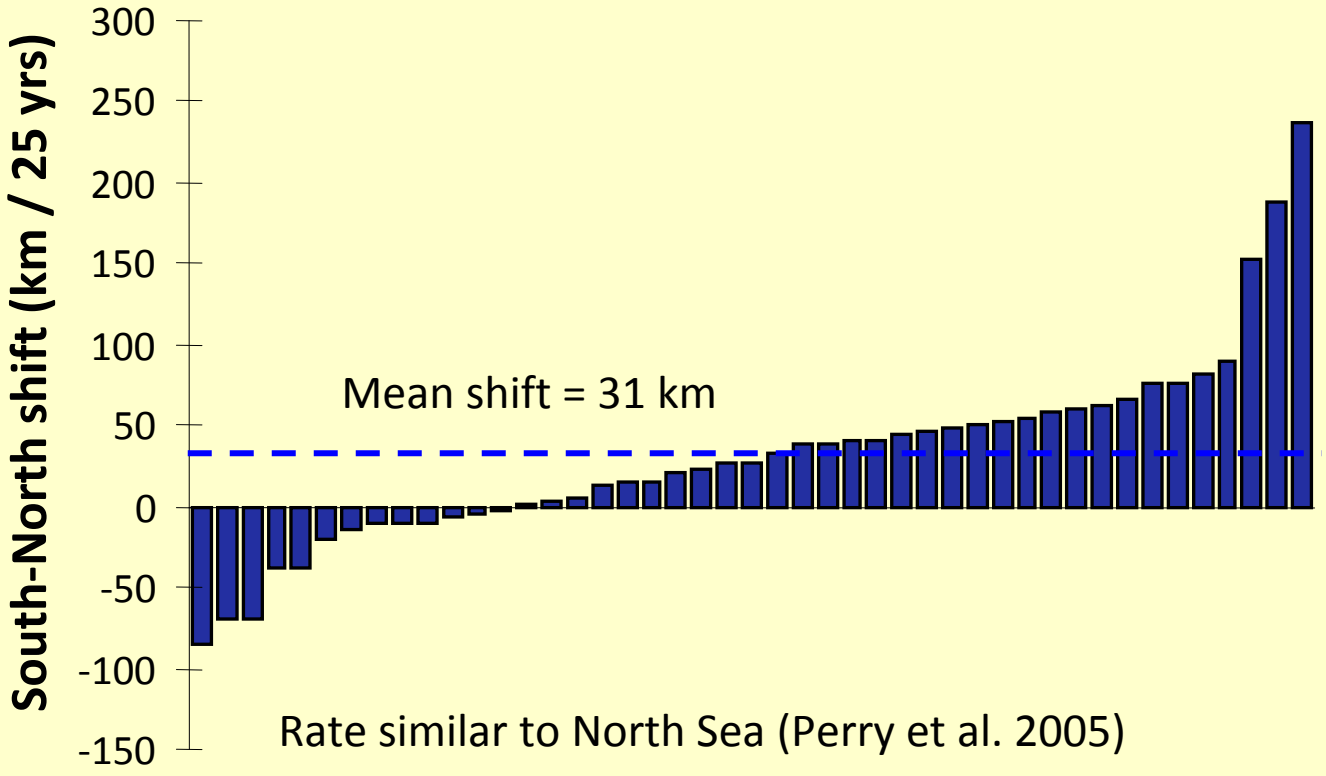
Drinkwater, 2006, Prog. Oceanogr.

and retreated southward in following cool period

Responses to Past Warming Events Eastern Bering Sea

- **Movements northward within the southeastern Bering Sea**
- **Some detections of sub-arctic or boreal fish in Chukchi or Beaufort- mostly juveniles**
- **Shifts farther north in outer shelf and slope than in middle shelf**

Northward Shift, Center of Distribution
45 Species, 1982-2006



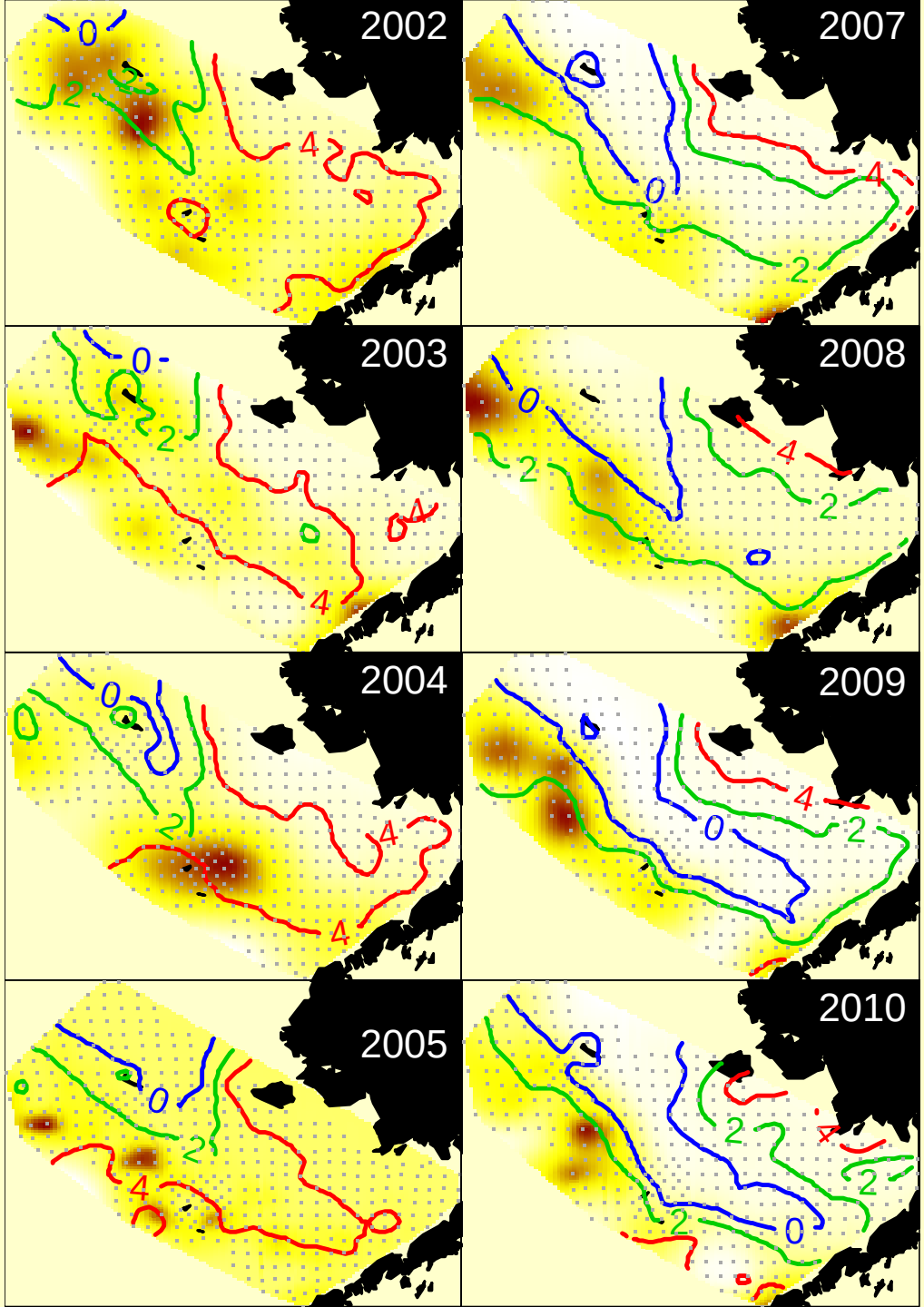
Rate similar to North Sea (Perry et al. 2005)

2-3 times faster than terrestrial mean (Parmesan and Yohe 2003)

Update of Mueter and Liptzow, 2008, Ecological Applications

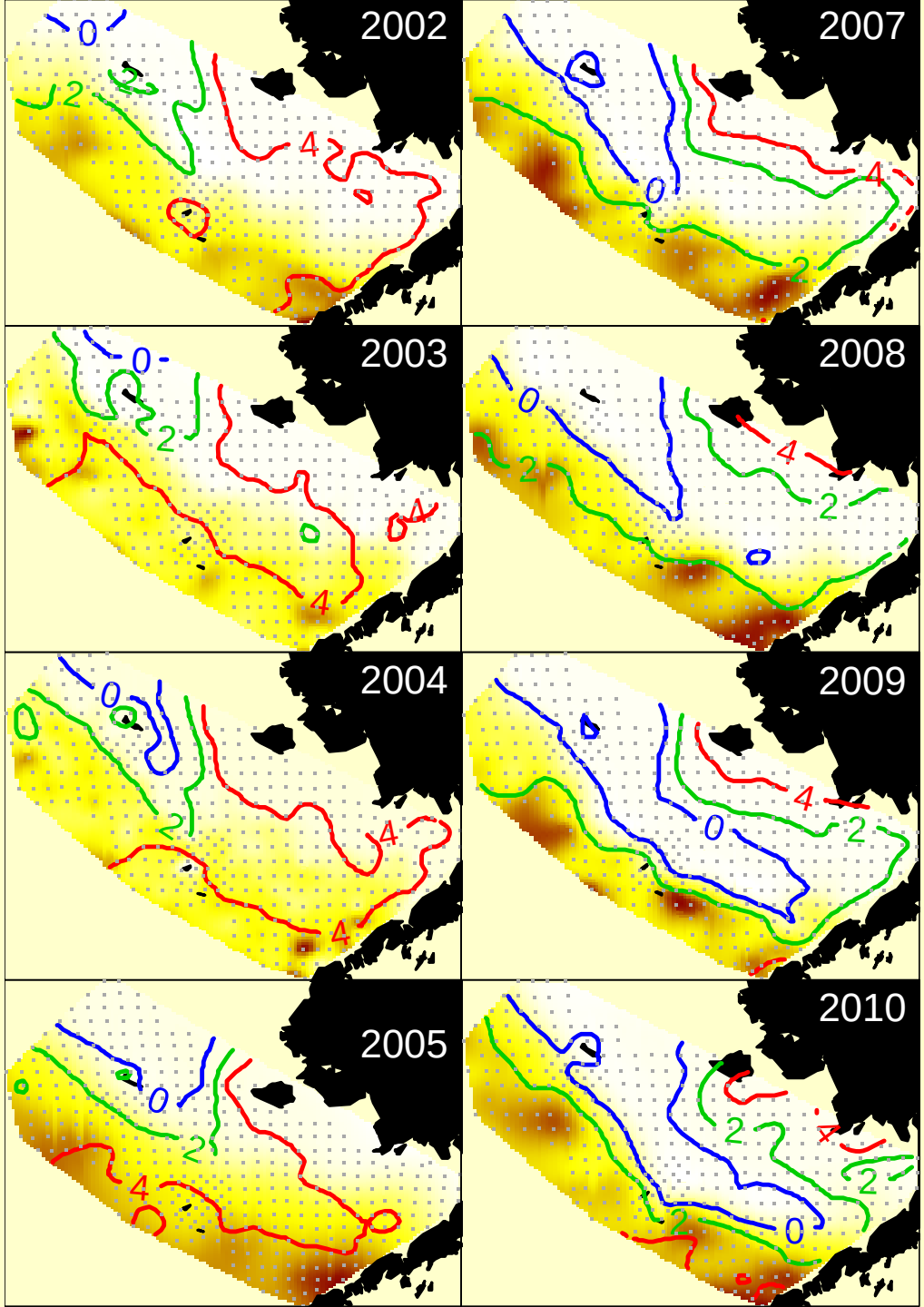
Bering Sea Walleye Pollock

Move onto shelf and north in warm years, off-shelf in cold years



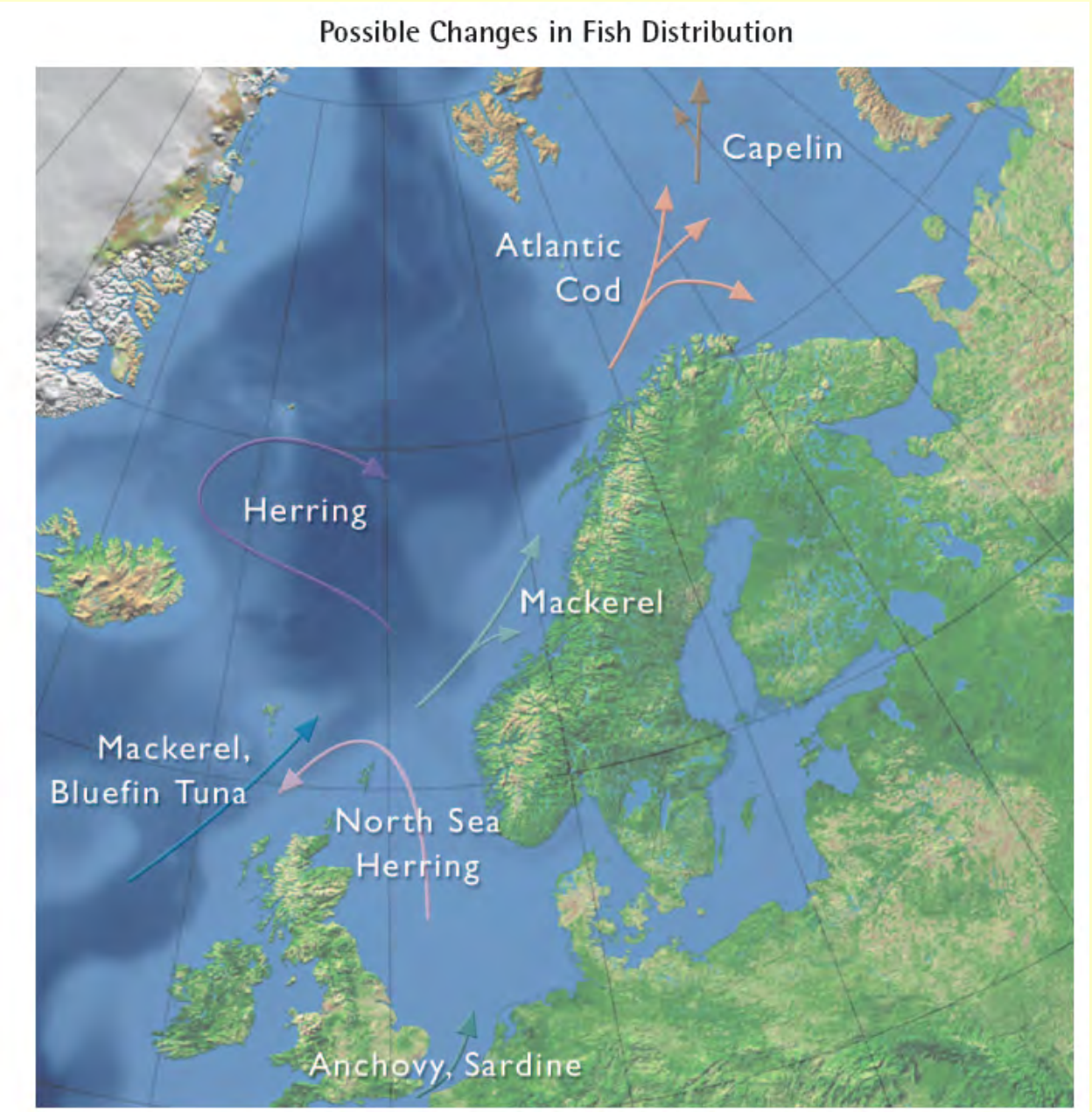
Bering Sea Arrowtooth Flounder

Spread onto shelf from slope in warm years



Future Responses to Climate

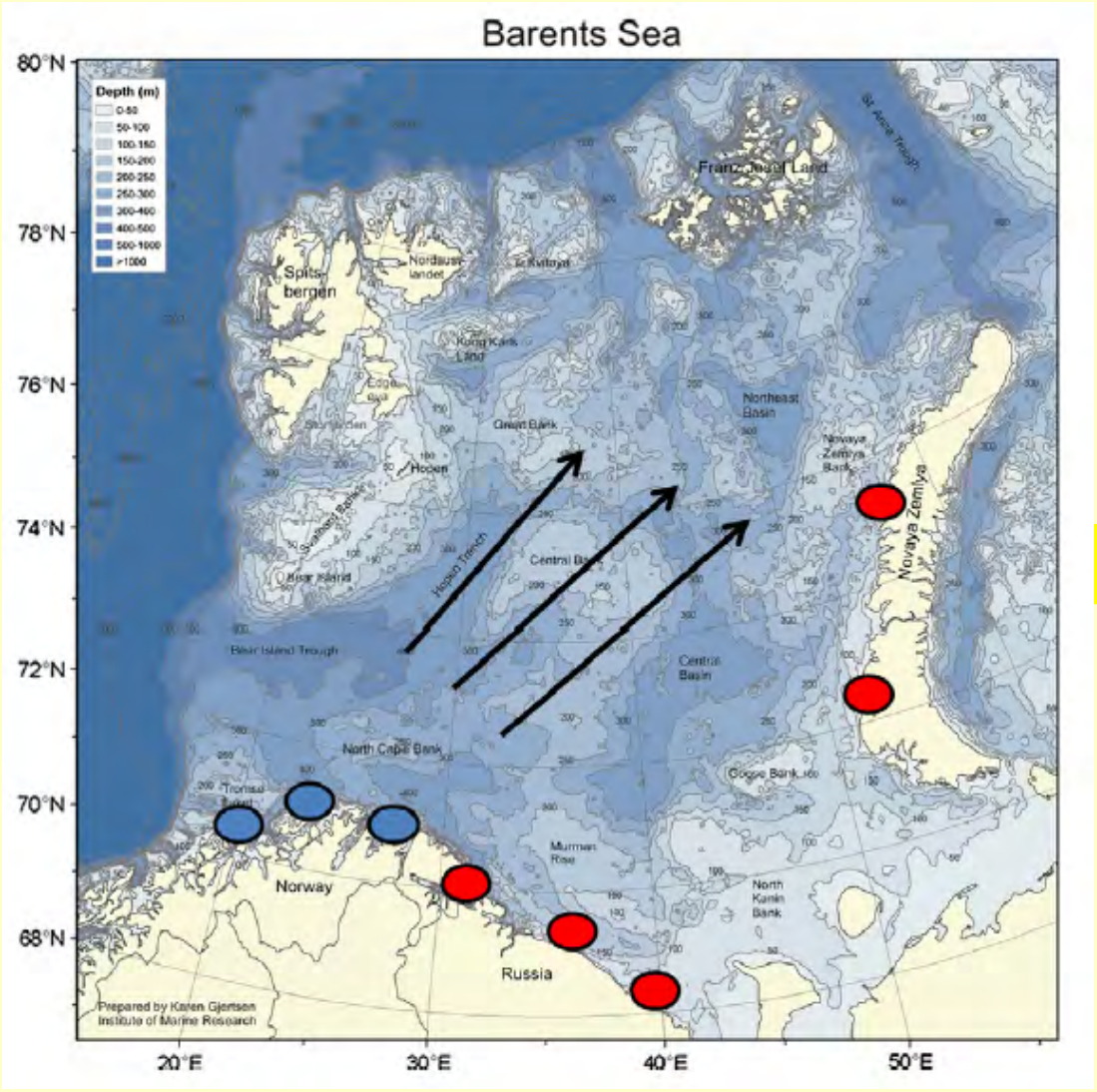
Shifts in Fish Distribution



Likely a northward movement in response to warming (ACIA, 2005)

They are already occurring!

Capelin Spawning in Response to Climate Change



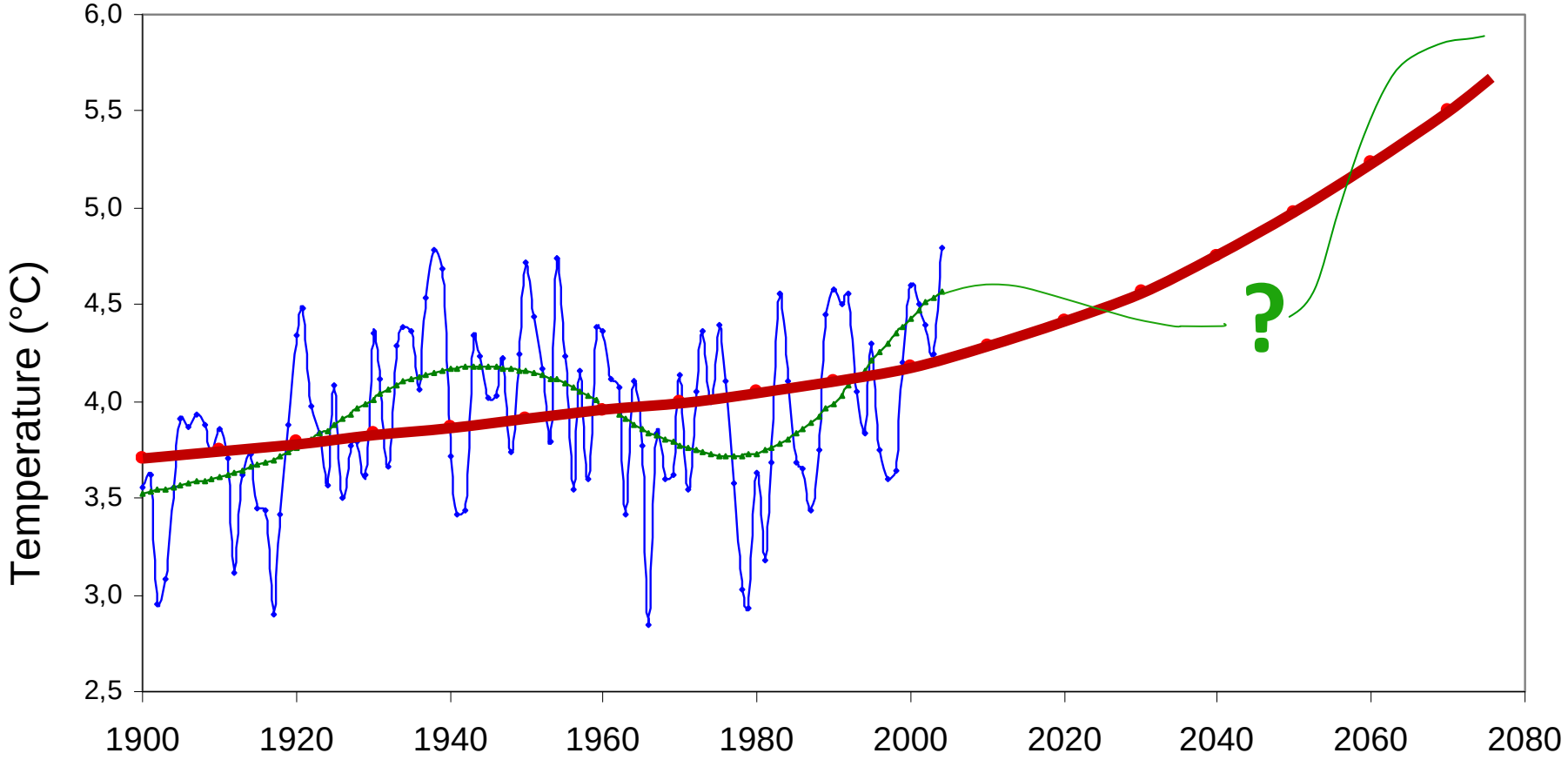
Present Spawning

Future Spawning

Direction of distributional shift of adult feeding migration

Huse and Ellingsen, 2008, Climatic Change

Future Projection(?)



Sundby (2008)

Expected Changes with Climate Warming Eastern Bering Sea Fish Stocks

- Northward shift in both species and biomass to about St. Matthew Island
- Northward shift greater in outer shelf and slope
- Few if any sub-arctic or boreal species will establish stocks north of St. Lawrence Island
- If any make it to the Arctic, they will need to overwinter in warmer layers of water off the shelf

Summary

- During past warming events, fish stocks in the No. Atlantic have moved poleward within warm water
- During past Bering Sea warm events, fish stocks moved poleward, to boundary of cold pool
- Poleward shifts in distributions require year-round favorable conditions
- Water depth may play important role for access to sub-surface warmer layers