Presentation based on:

ORIGINAL ARTICLE **Kjesbu et al.**

2023 FISH and FISHERIES WILEY

Latitudinally distinct stocks of Atlantic cod face fundamentally different biophysical challenges under on-going climate change

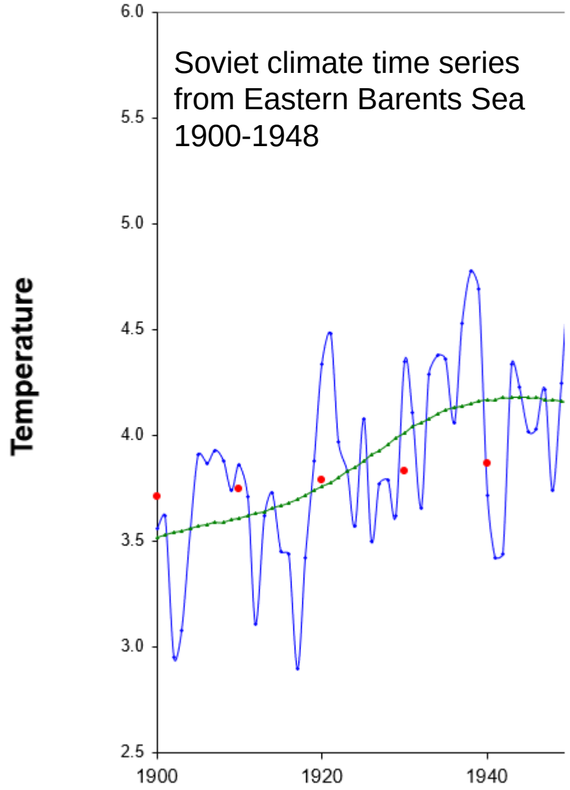
and supported by related articles

presented by Svein Sundby

NWWAC Webinar Dublin, 12 June 2024

Impacts of climate change in marine ecosystem was already in the focus of ICES before 1950

1948: ICES Special scientific meeting on
«Climatic changes in the Arctic in relation to plants and animals»



CONSEIL PERMANENT INTERNATIONAL POUR
L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT — DANEMARK

RAPPORTS
ET
PROCÈS-VERBAUX DES RÉUNIONS
VOLUME CXXV

CONTRIBUTIONS
TO
SPECIAL SCIENTIFIC MEETINGS
1948

”Climatic changes in the Arctic in relation to plants and animals”

Preface by *Gunnar Rollefsen* with Appendix: Enquiry into the Problem of Climate and Ecological Changes in Northern Waters

Introductory address by *Hans W:son Ahlmann*

A. Contribution to Physical Changes

Recent Climatic Fluctuations *by Leo Lysgaard*

The increase in the Sea Temperature in Northern Waters during Recent Years *by Jens Smed*

B. Contributions on Biological changes

On Changes in the Marine Fauna on the North- Western Atlantic Area, with special reference to Greenland by *Å. Vedel Tåning*

Boreo-tended Changes in the Marine Vertebrate Fauna of Iceland during the last 25 years *by Arni Fredriksson*

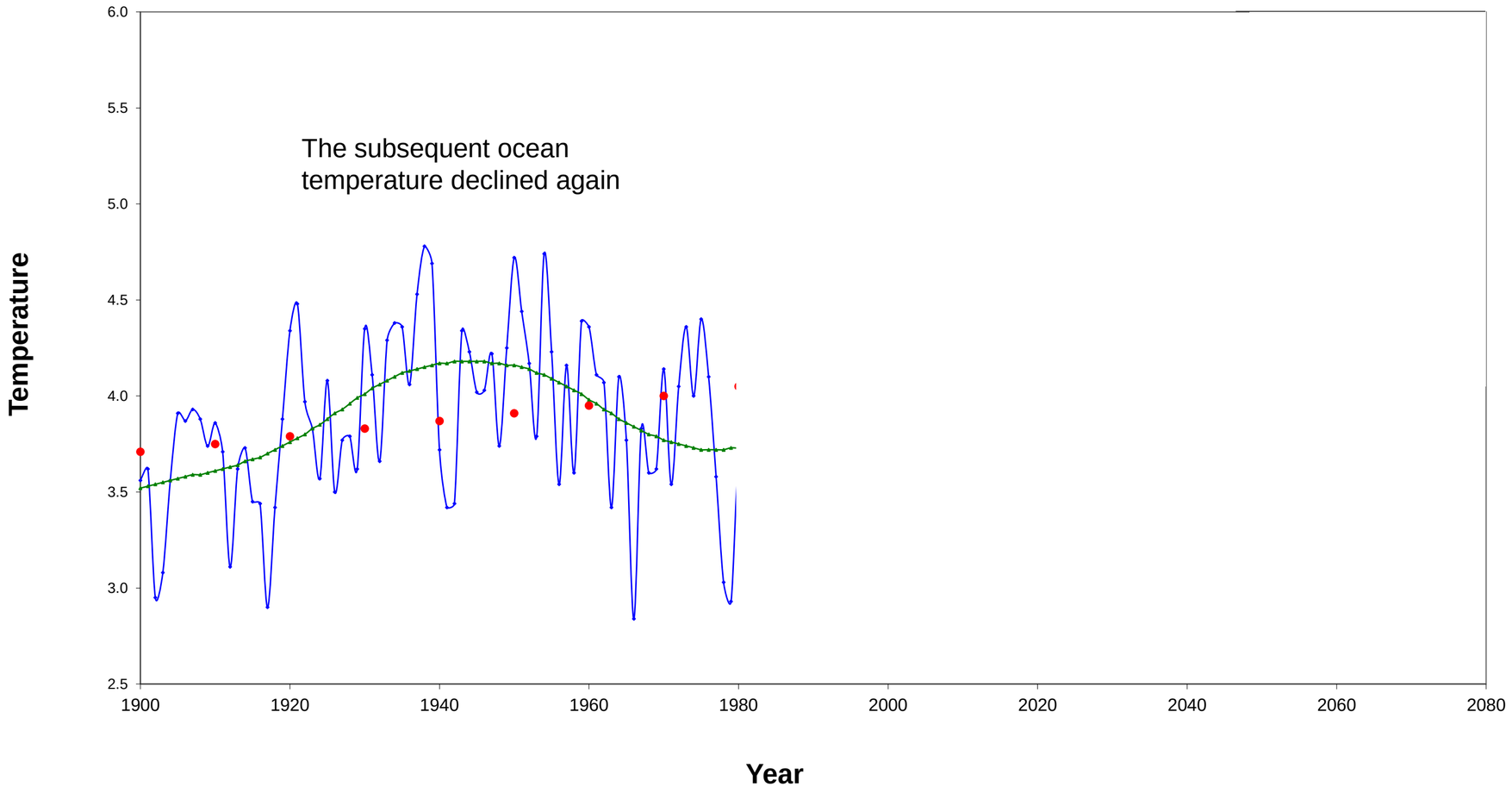
Fluctuations in the two most important Stocks of Fish in Northern Waters, the Cod and the Herring
by Gunnar Rollefsen

On Changes inthe Distribution of Terrestrial Animals in Relation to Climatic Changes *by Poul Jespersen*

The Forecasting of Climatic Fluctuations and Its Importance to the Arctic Fisheries *by Arthur Lee*

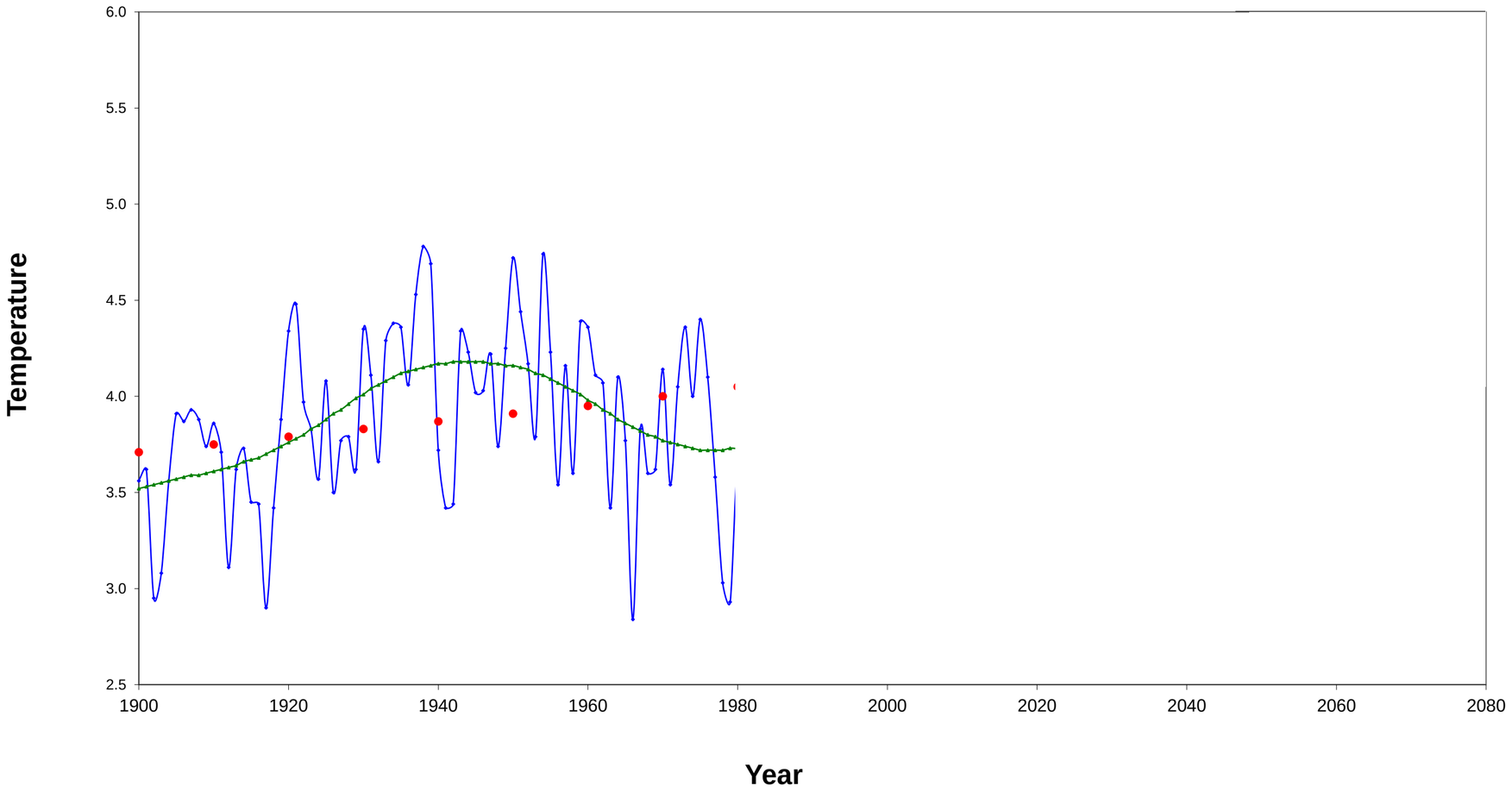
Development of Barents Sea temperature

observations, **30-yr low-pass filter of observations**



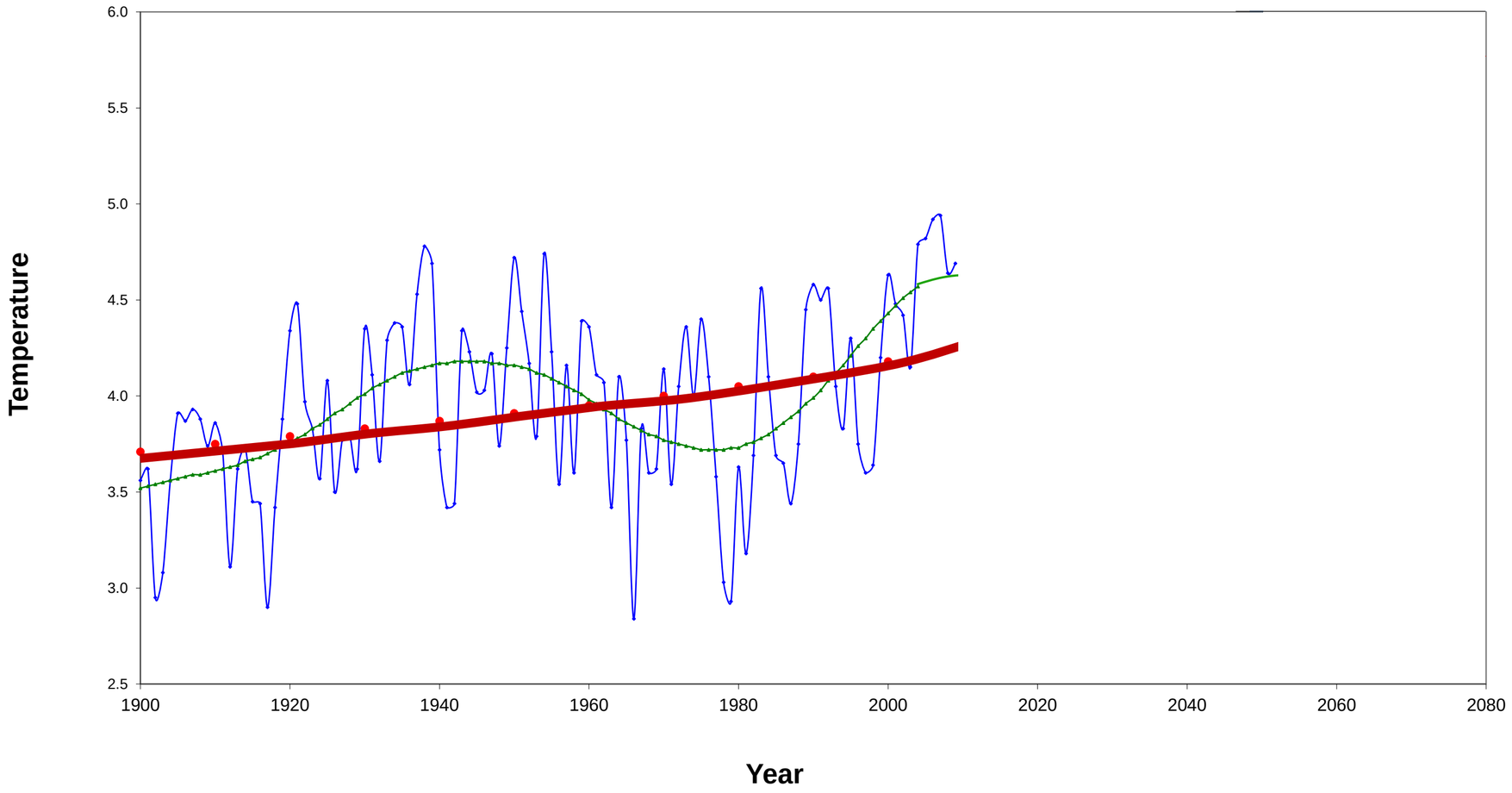
Development of Barents Sea temperature

observations, **30-yr low-pass filter of observations**



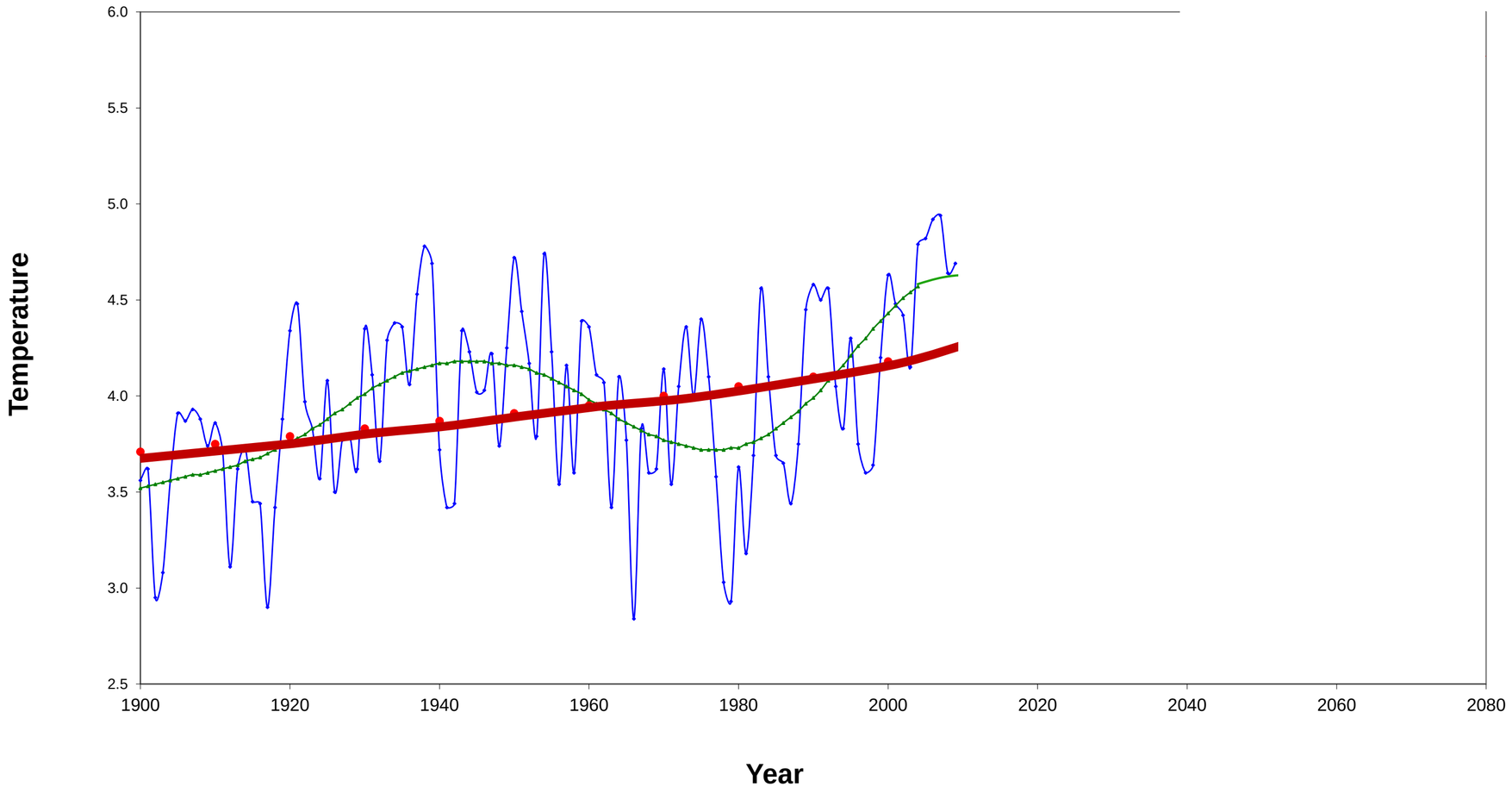
Development of Barents Sea temperature

observations, **30-yr low-pass filter of observations**, and **modelled anthropogenic component**



Development of Barents Sea temperature

observations, **30-yr low-pass filter of observations**, and **modelled anthropogenic component**

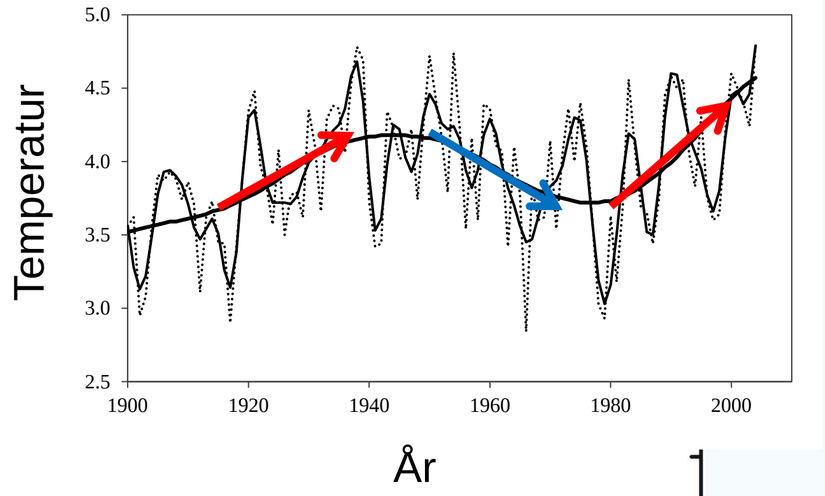


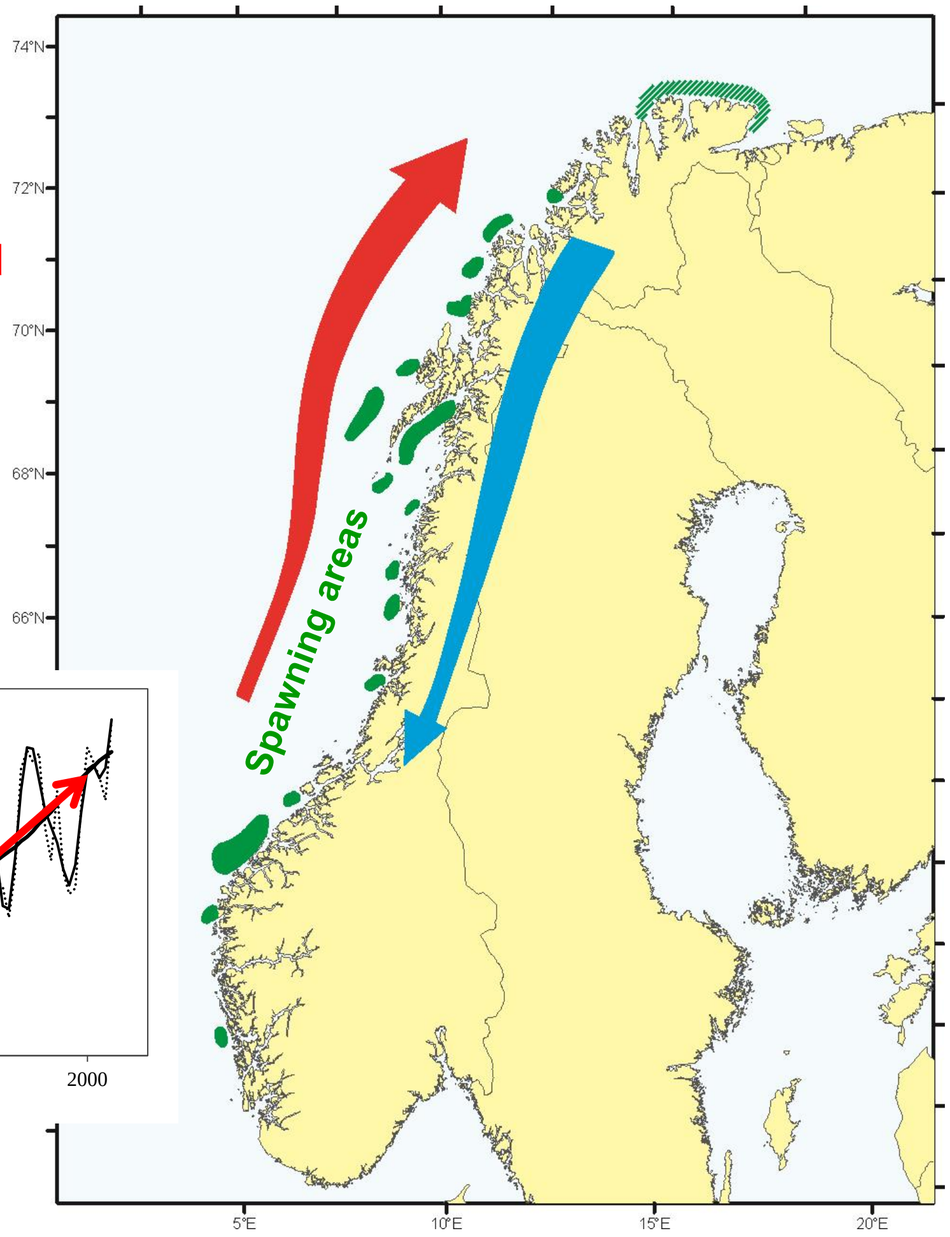
Climate response from Northeast-Arctic cod

In warming phases:

- Spawning sites displaced northward

- Increasing spawning stock





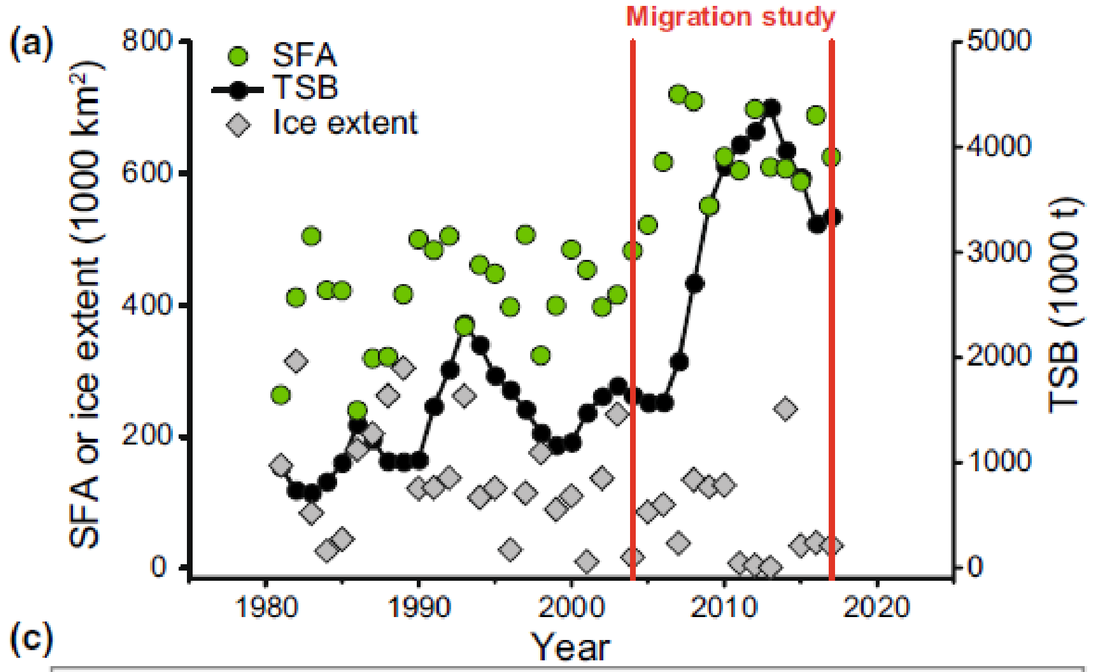
In cooling phases:

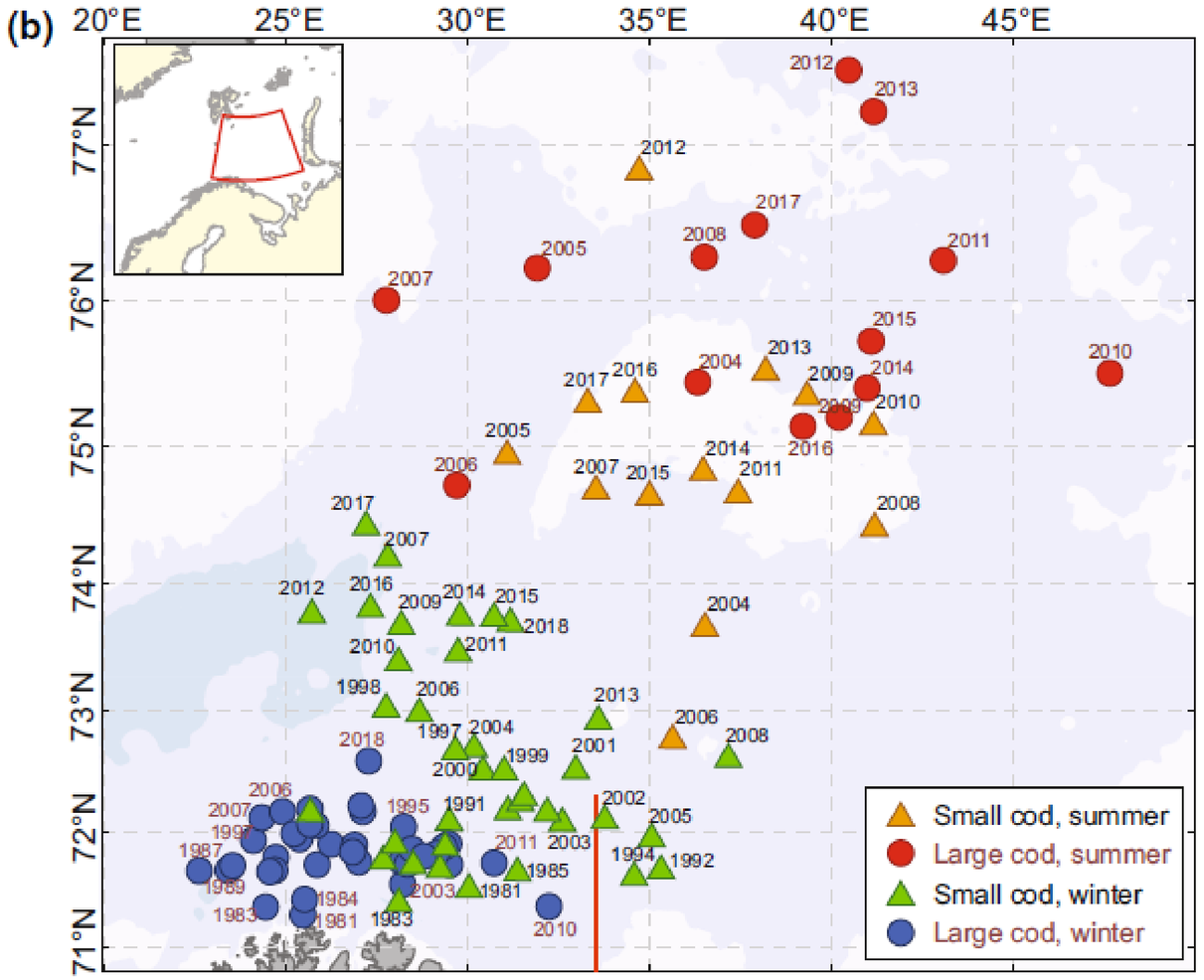
- Spawning sites displaced southward

- decreasing spawning stock

Sundby and Nakken (2008) IJMS

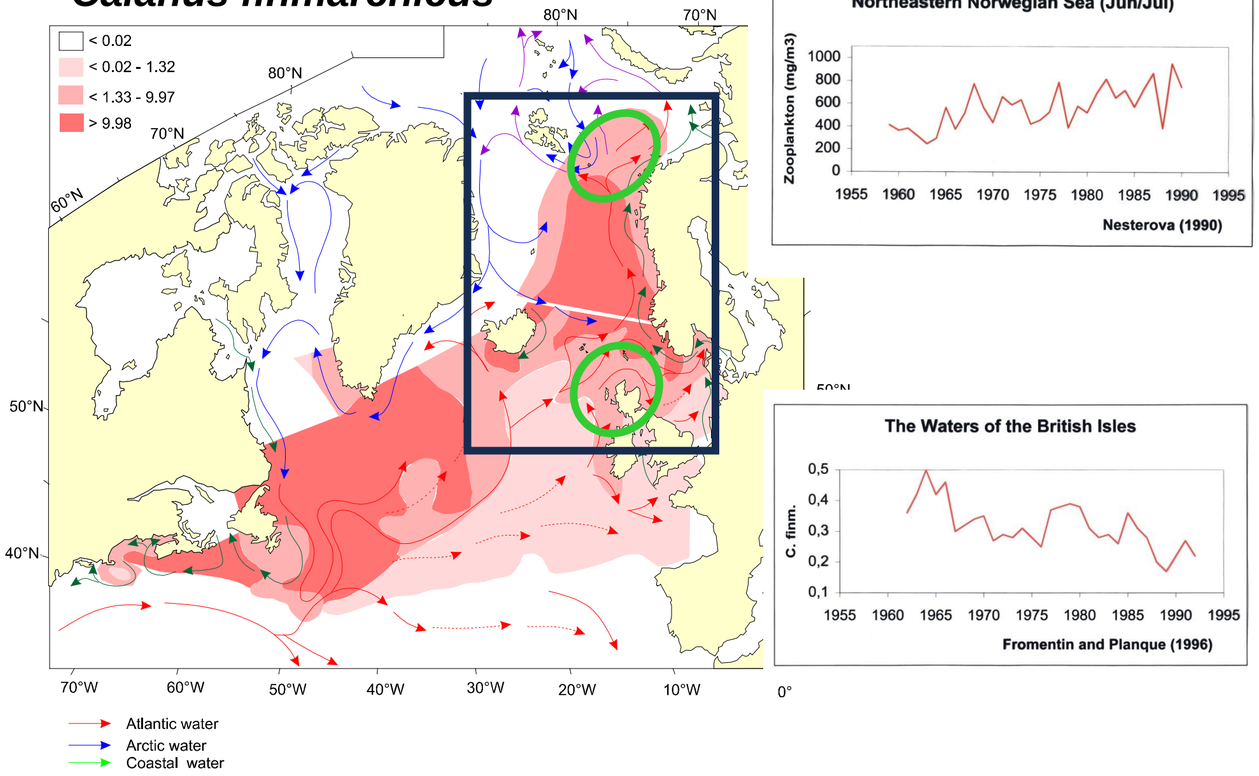
Cod migration dynamics in the Barents Sea

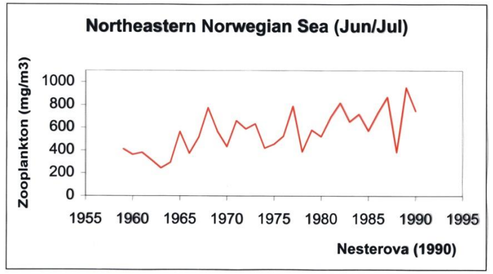


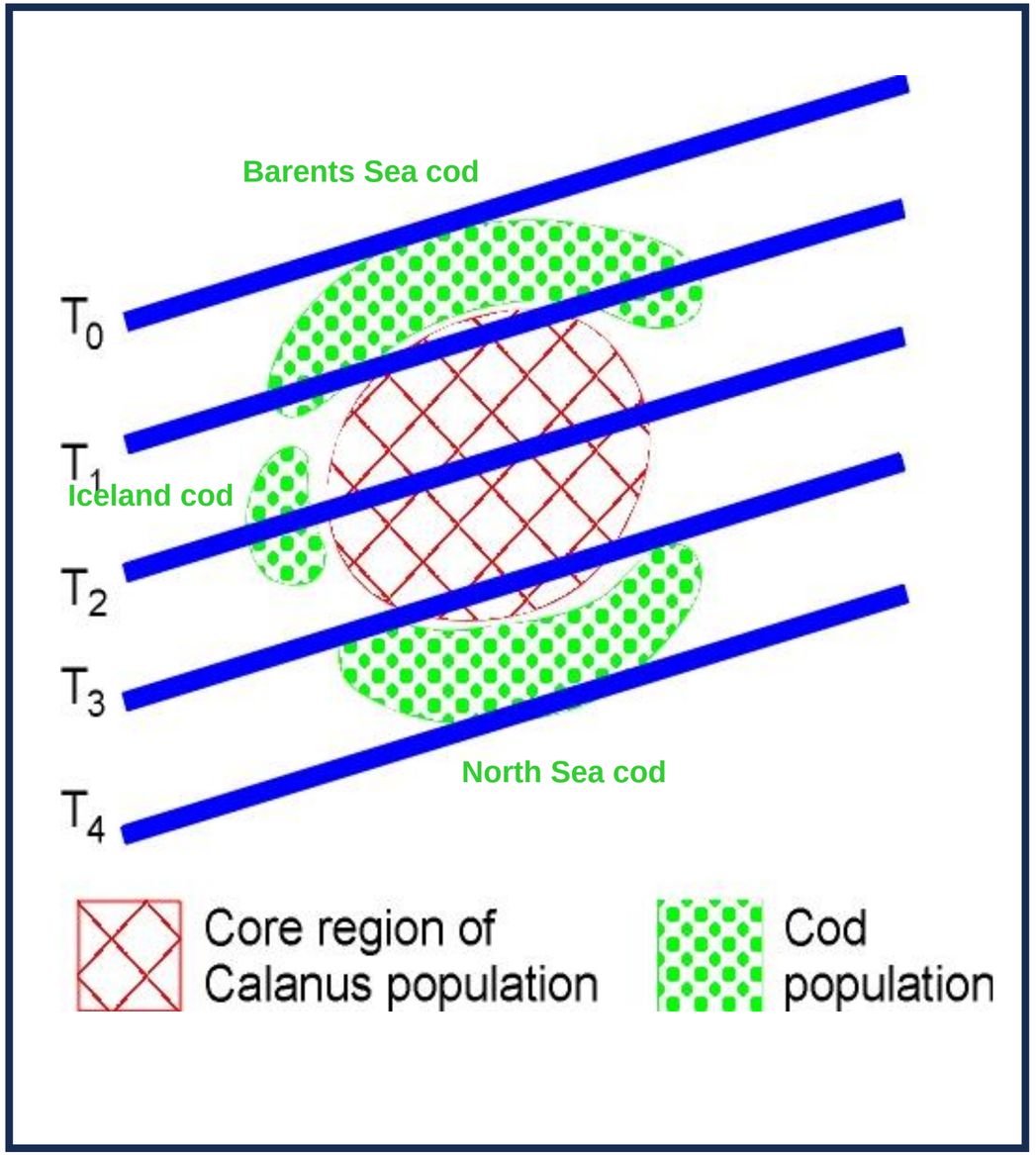


Kjesbu et al. (2023) F&F

Key prey species for early-life Atlantic cod: *Calanus finmarchicus*

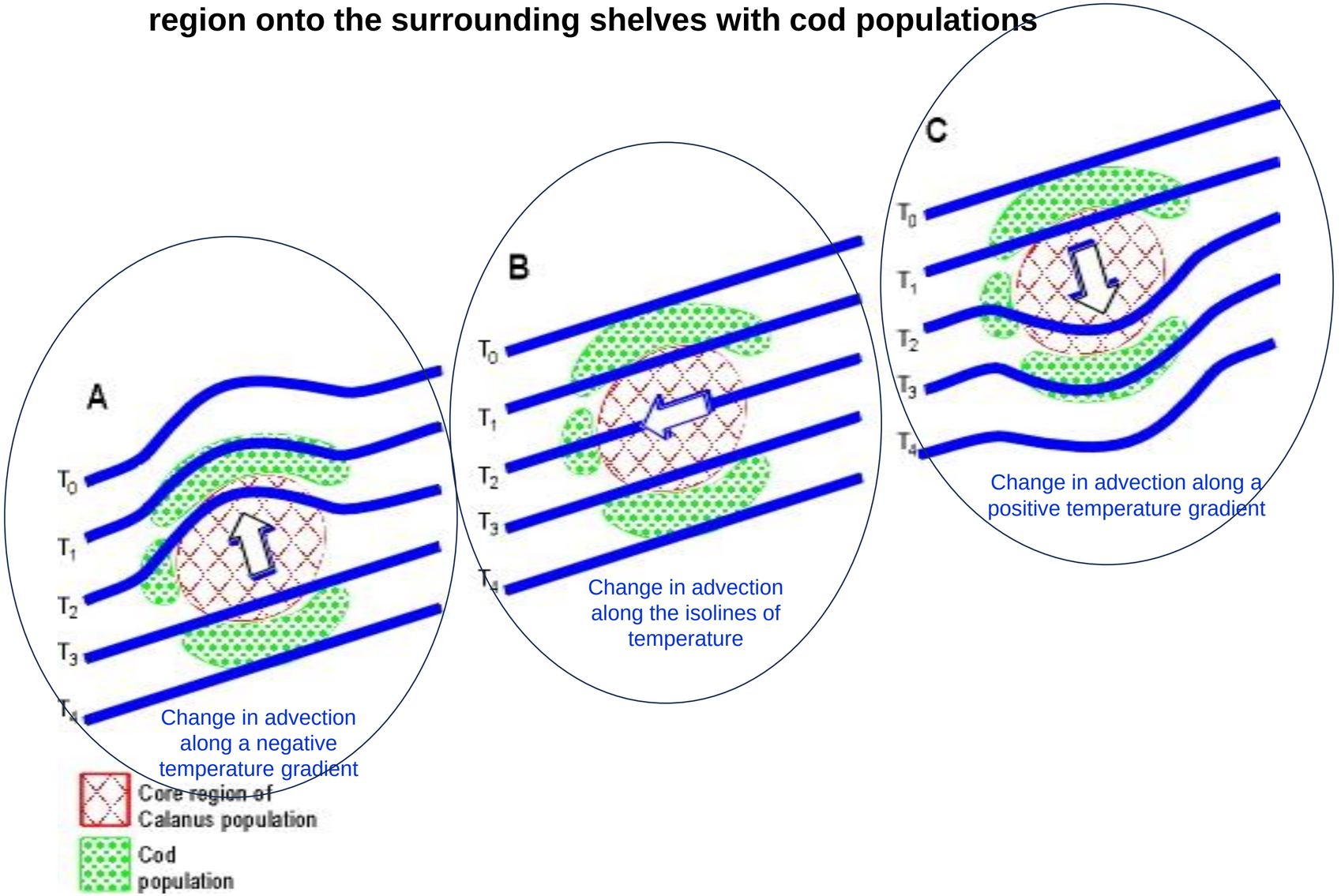




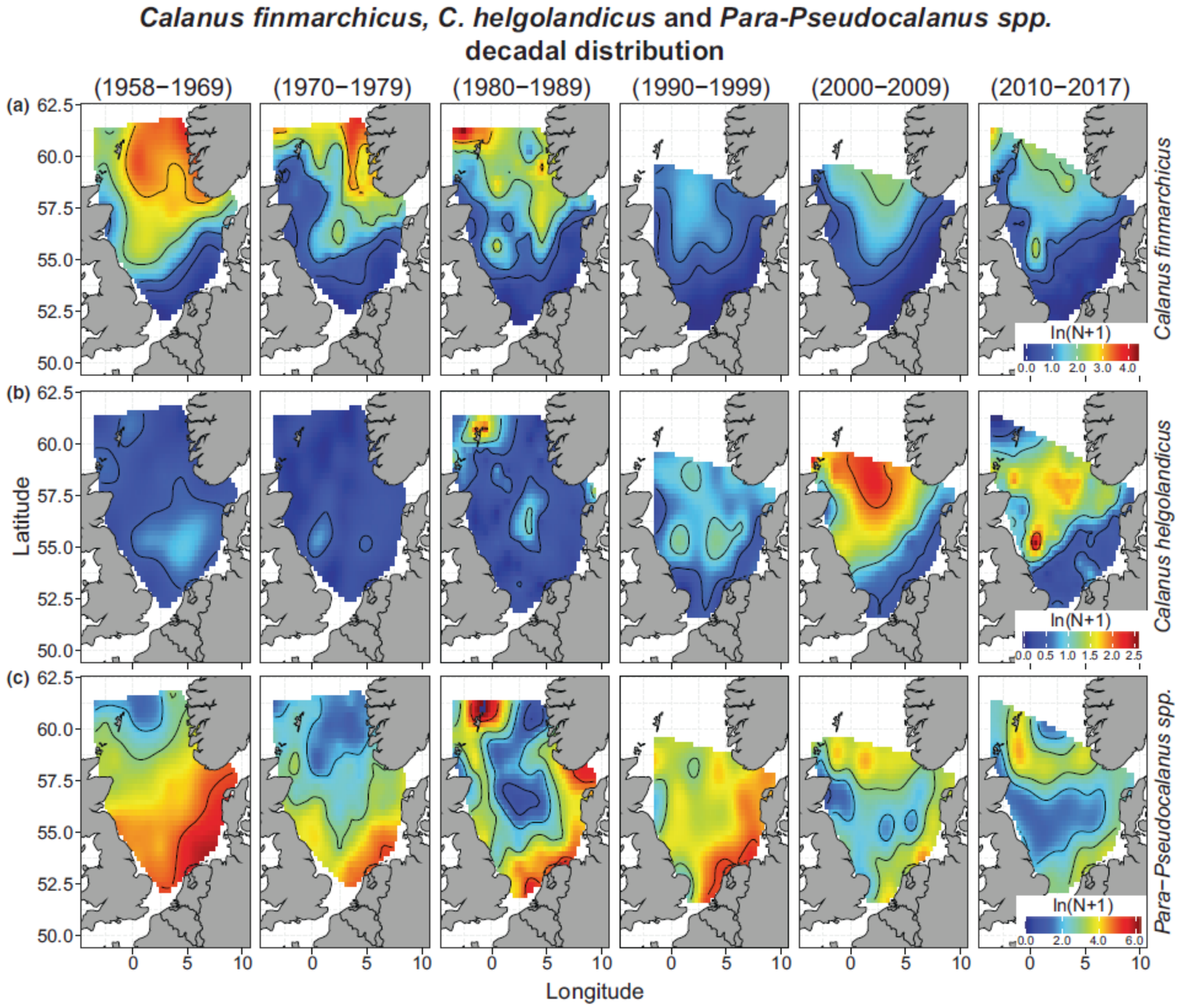


Sundby (2000)

Conceptual model for the combined advection of heat and *Calanus finmarchicus* from the deep-sea core production region onto the surrounding shelves with cod populations

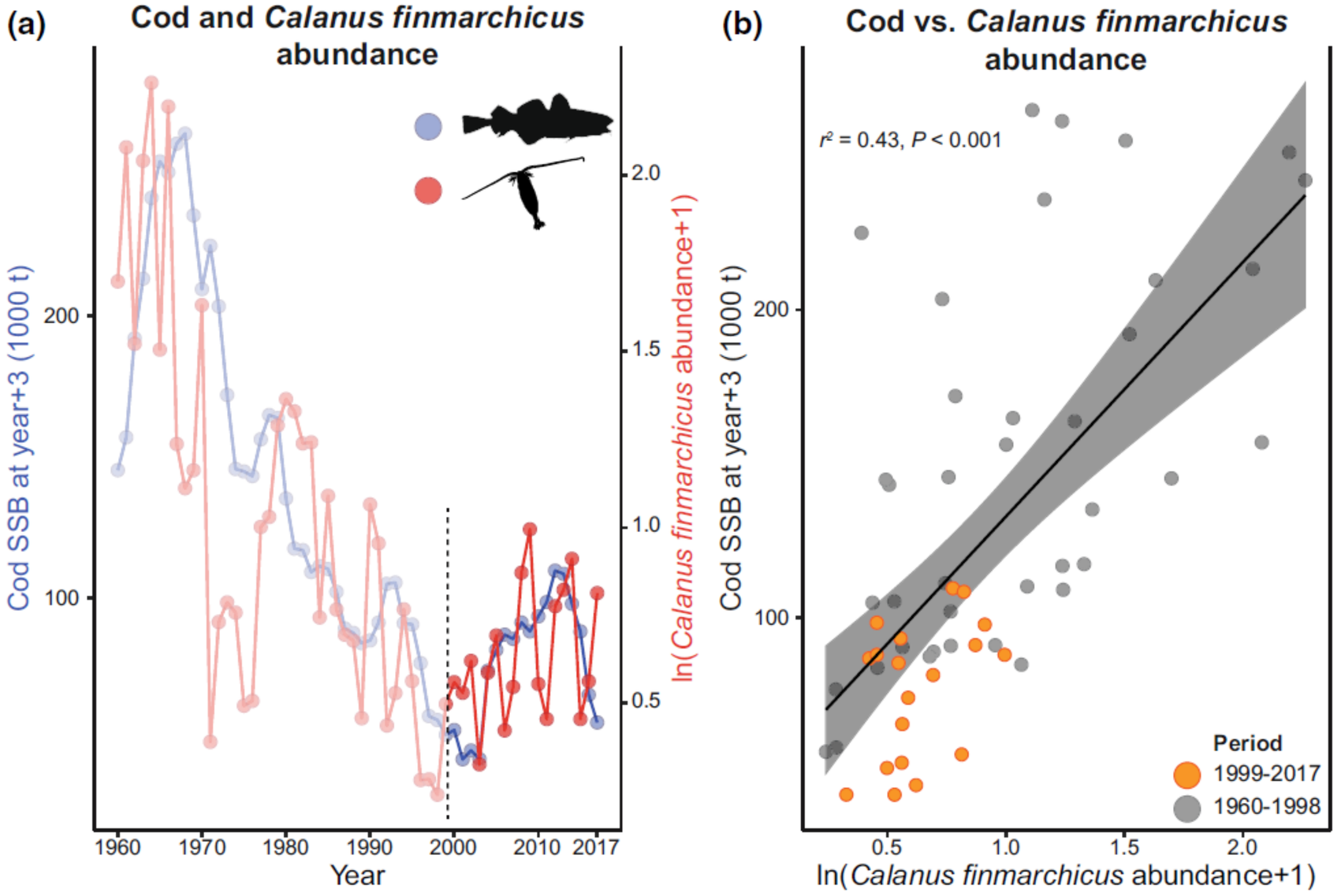


Sundby (2000)



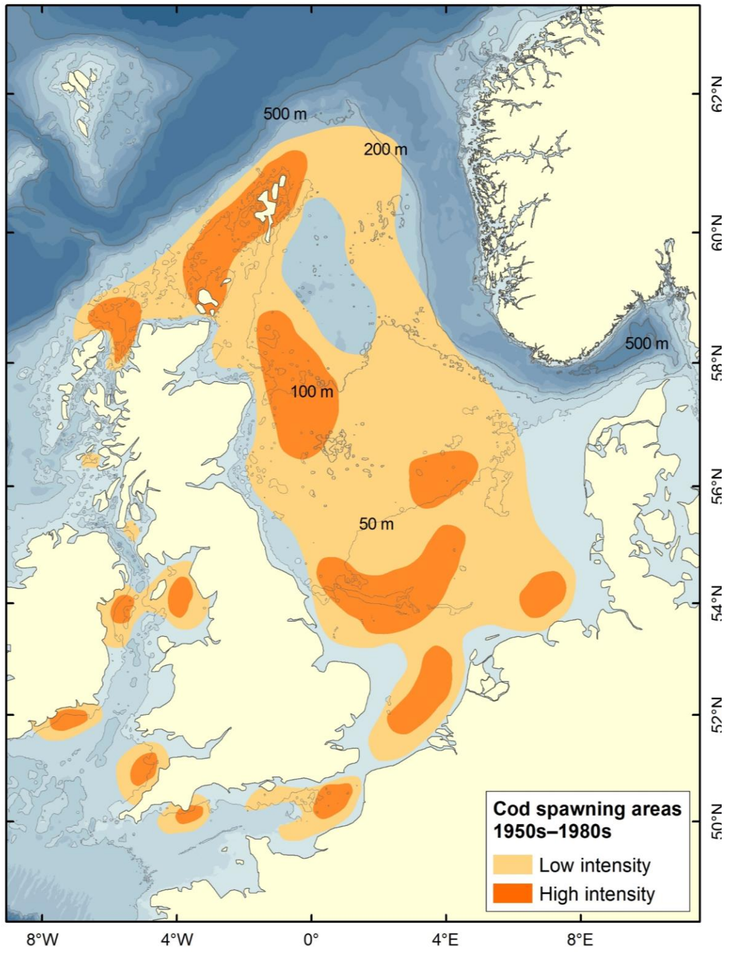
Kjesbu et al. (2023) F&F

North Sea cod and *Calanus finmarchicus*

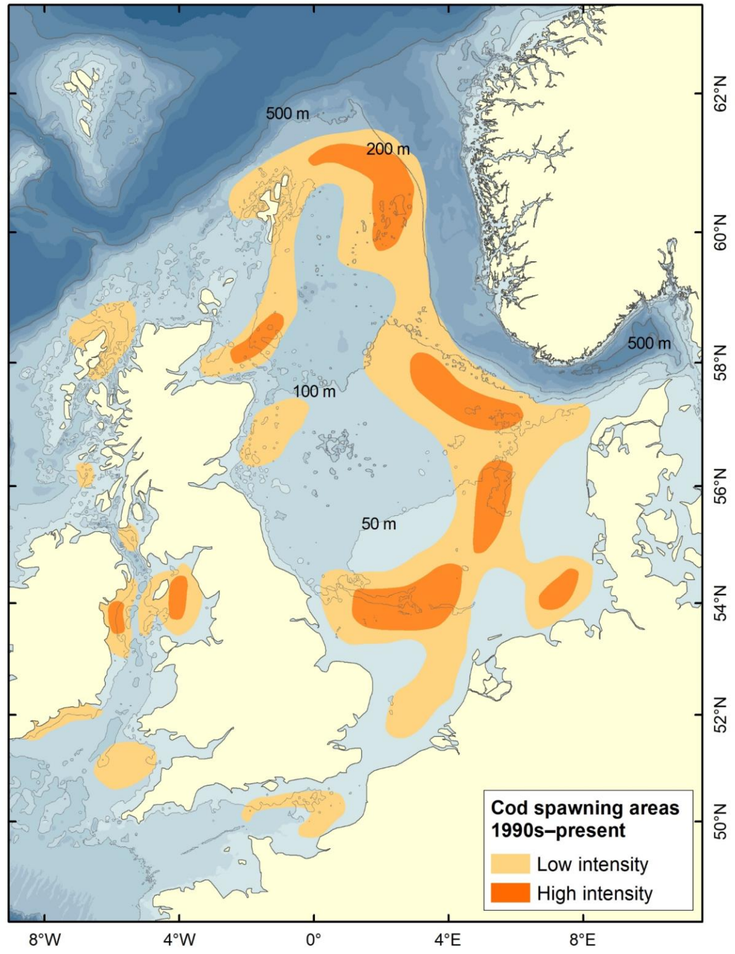


Kjesbu et al. (2023) F&F

Cod spawning areas 1950s -1980s



Cod spawning areas 1980s - present



Sundby et al. (2017) KINO Report

SYNTHESIS BASED ON LITERTURE 1994-2016:

Brander, K.M. 1994. The location and timing of cod spawning around the British Isles. *ICES Journal of Marine Science*, 51: 71-89.

Rogers, S., and Stocks, R. 2001. North Sea fish and fisheries. Technical Report TR_003. Strategic Environmental Assessment – SEA. CEFAS, Lowestoft.72 pp.

Wright, P.J., Gibb, F.M., Gibb, I.M., Heath, M.R., and McLay, H.A. 2003. North Sea cod spawning grounds. Fisheries Research Services Internal Report No 17/03. Fisheries Research, Services Marine Laboratory, Aberdeen. 13pp.

Gibb, I.M., Wright, P.J., and Campbell, R. 2008. Identifying critical spawning and nursery areas for North Sea cod; improving the basis for cod management. Scottish Industry / Science Partnership (SISP) Report No 03/08. Fisheries Research Services. 18pp.

Fox, C.J., Taylor, M., Dickey-Collas, M., Fossum, P., Kraus, G., Rohlf, N., Munk, P., van Damme, C.J.G., Bolle, L.J., Maxwell, D.L., and Wright, P.J. 2008. Mapping the spawning grounds of North Sea cod (*Gadus morhua*) by direct and indirect means. *The Royal Society. Proceedings: Biological Sciences* 275(1642): 1543-1548.

Munk, P., Fox, C.J., Bolle, L.J., van Damme, C.J. G., Fossum, P., and Kraus, G. 2009. Spawning of North Sea fishes linked to hydrographic features. *Fisheries Oceanography* 18(6): 458–469.

ICES. 2010. Report of the Working Group on North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS), 9–11 November 2010, ICES Headquarters, Copenhagen. ICES CM 2010/SSGESST:23. 29 pp.

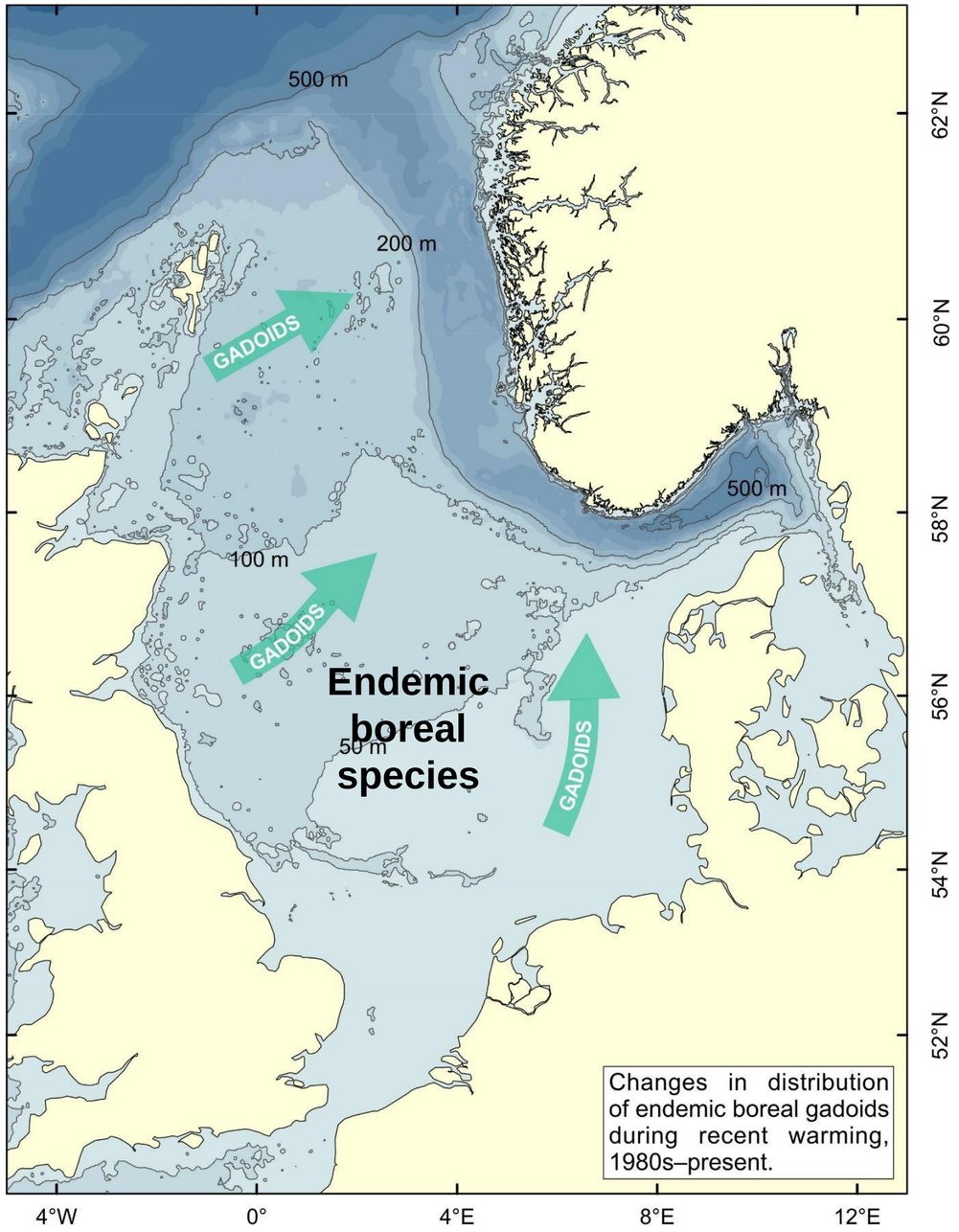
ICES. 2011. Report of the Working Group on North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS), 25–27 October 2011, Sète, France. ICES CM 2011/SSGESST:19. 14 pp.

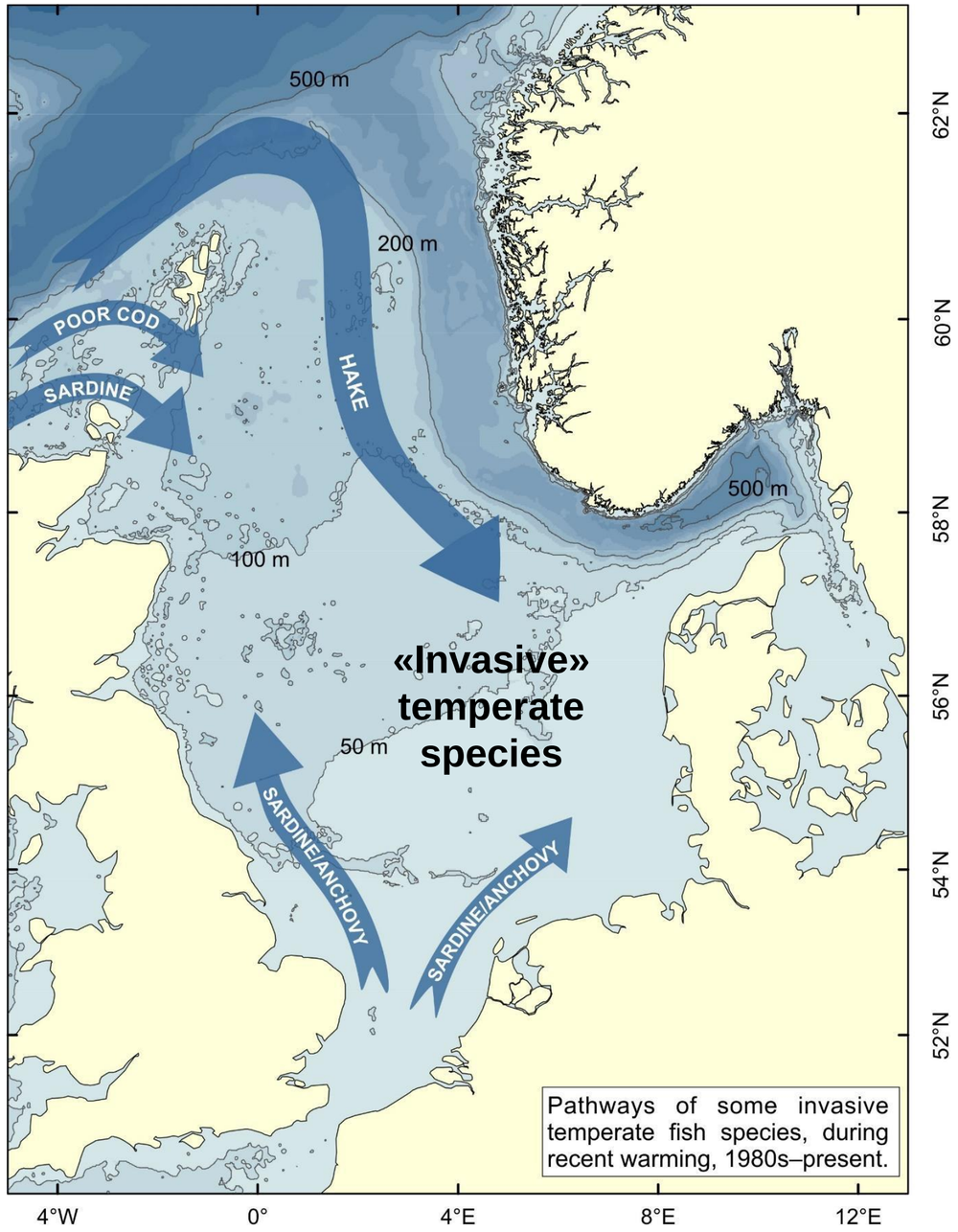
Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. 2012. Spawning and nursery grounds of selected fish species in UK waters. CEFAS Science Series Technical Report no. 147.

Hislop, J. Bergstad, O.A., Jakobsen, T., Sparholt, H., Blasdale, Wright, P., Kloppmann, M., Hillgruber, N., and Heessen, H. 2015. Cod – *Gadus morhua* Linnaeus, 1758. *In*: H.J.L. Heessen, N. Daan, and J.R.Ellis, editors. Fish Atlas of the Celtic Sea, North Sea, and Baltic Sea. Pp. 189-194. Wageningen Academic Publishers and KNNV Publishing, Wageningen, Netherlands (572 pp). ISBN: 978-90-8686-266-5.

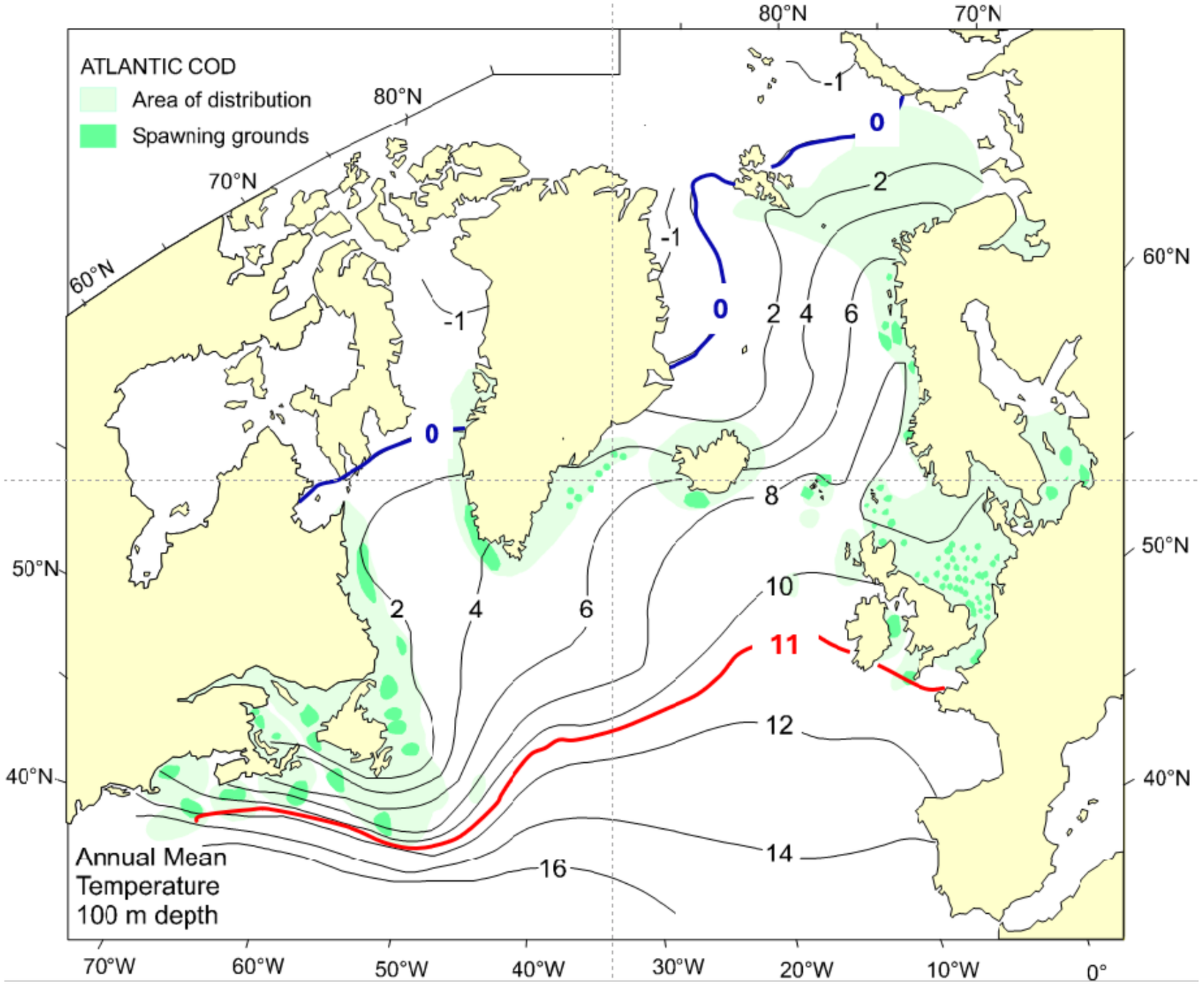
González-Irusta, J. M., and Wright, P. J. 2016. Spawning grounds of Atlantic cod (*Gadus morhua*) in the North Sea. *ICES Journal of Marine Science*, 73: 304–315.

North Sea shifts in species distributions since 1980s

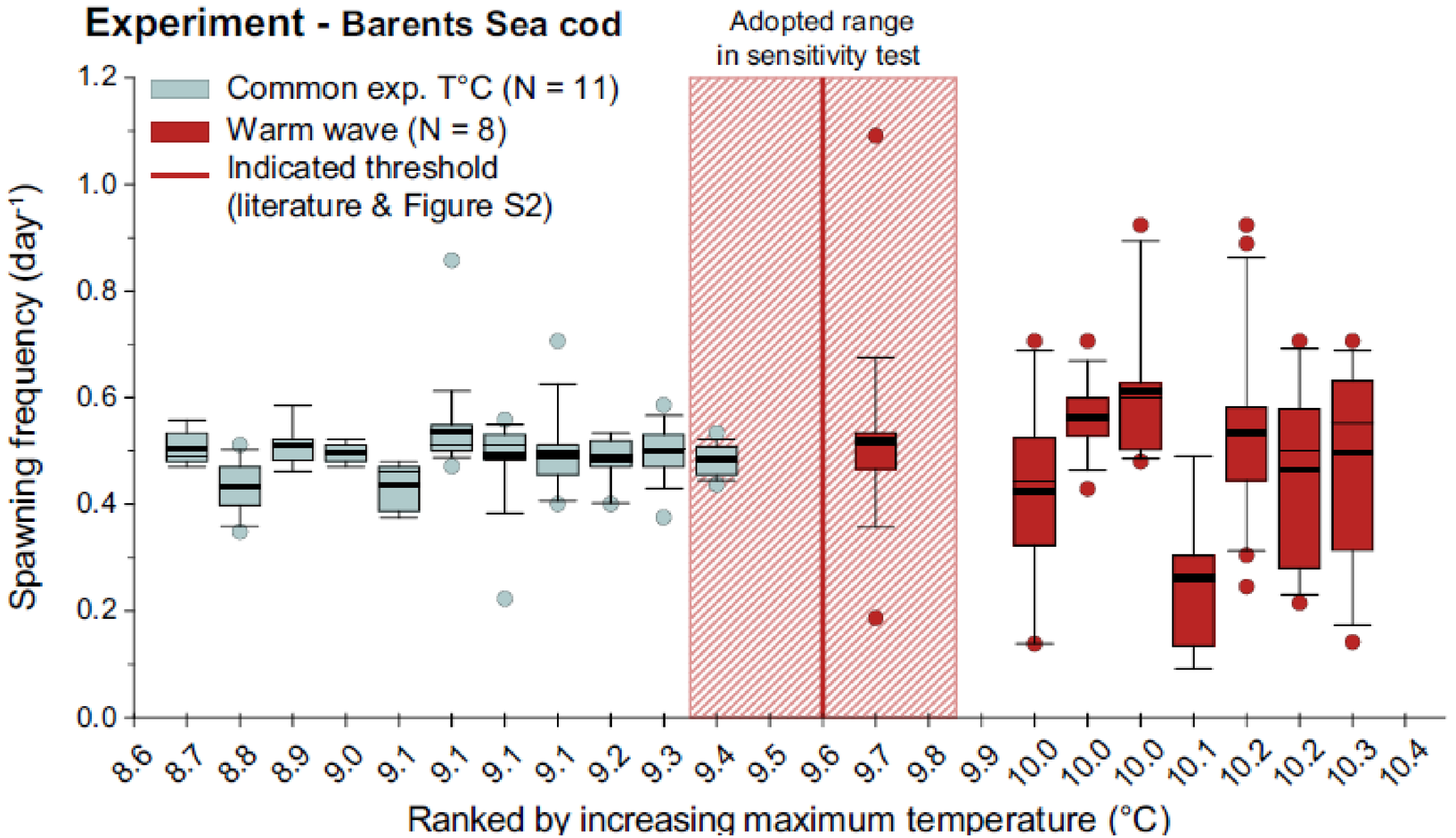




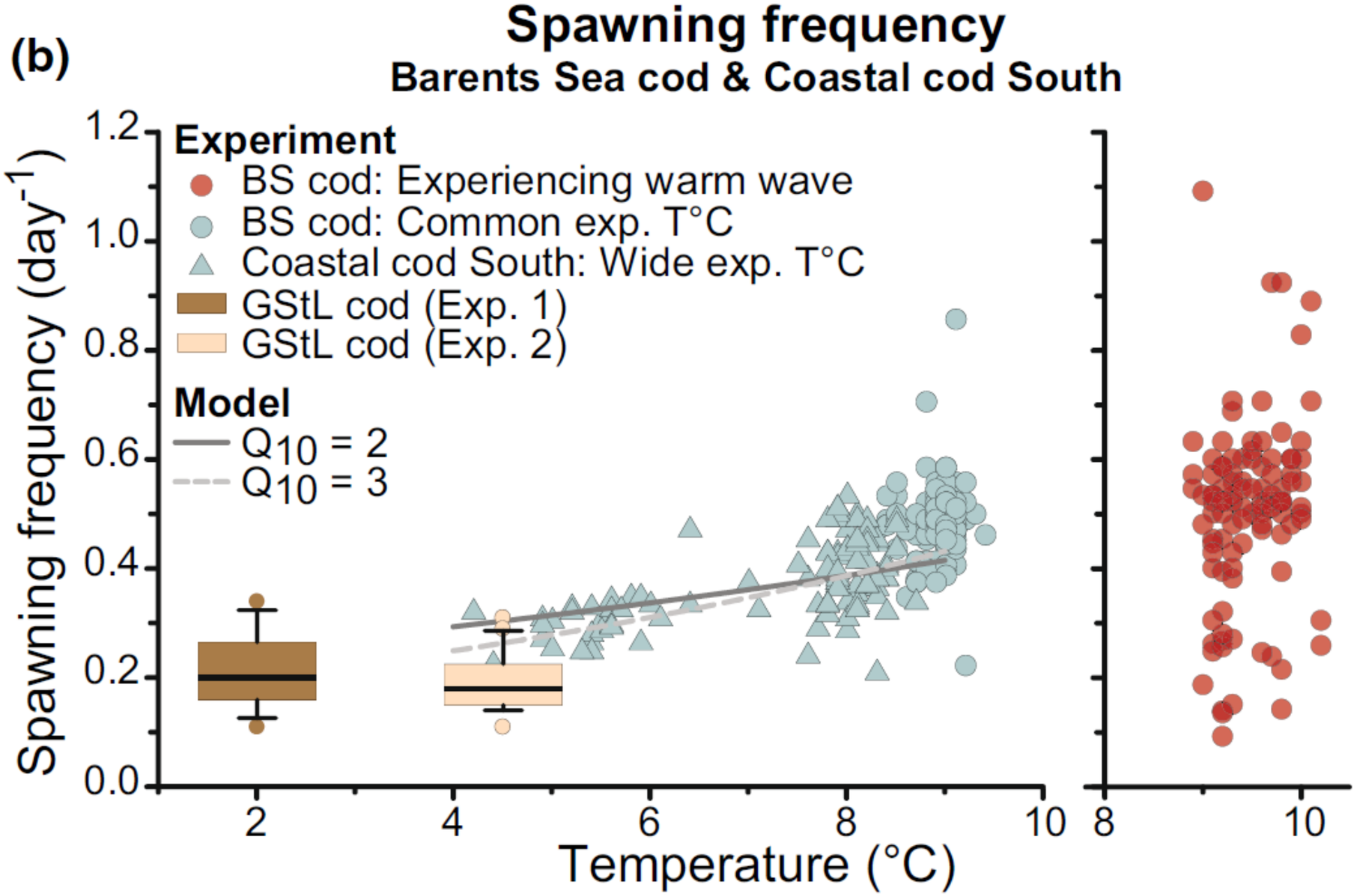
Sundby et al. (2017) KINO Report


ATLANTIC COD
Area of distribution
Spawning grounds
Annual Mean
Temperature
100 m depth
80°N
70°N
60°N
50°N
40°N
70°W
60°W
50°W
40°W
30°W
20°W
10°W
0°
-1
0
2
4
6
8
10
11
12
14
16

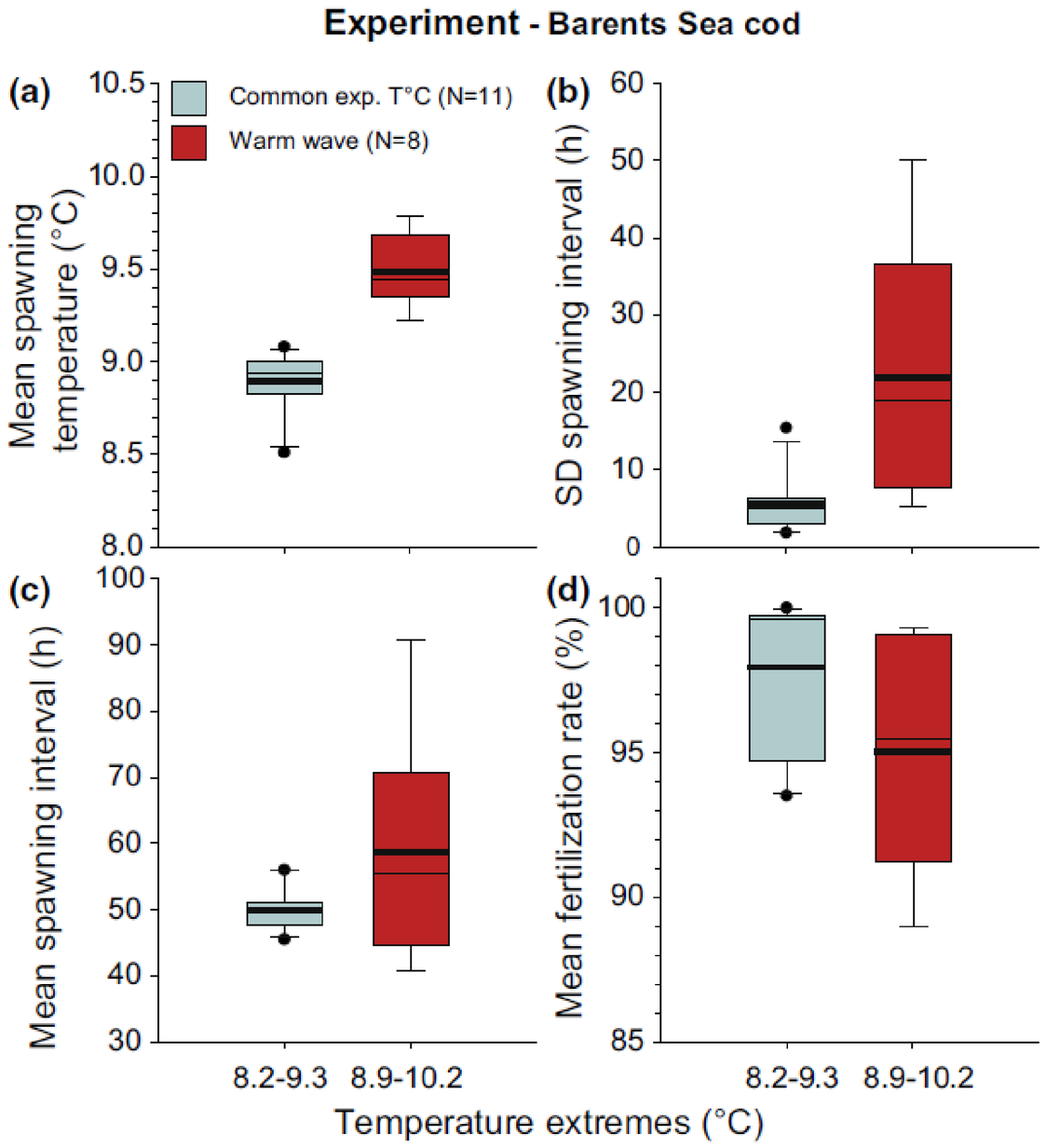
Sundby (2000)



Kjesbu et al. (2023) F&F

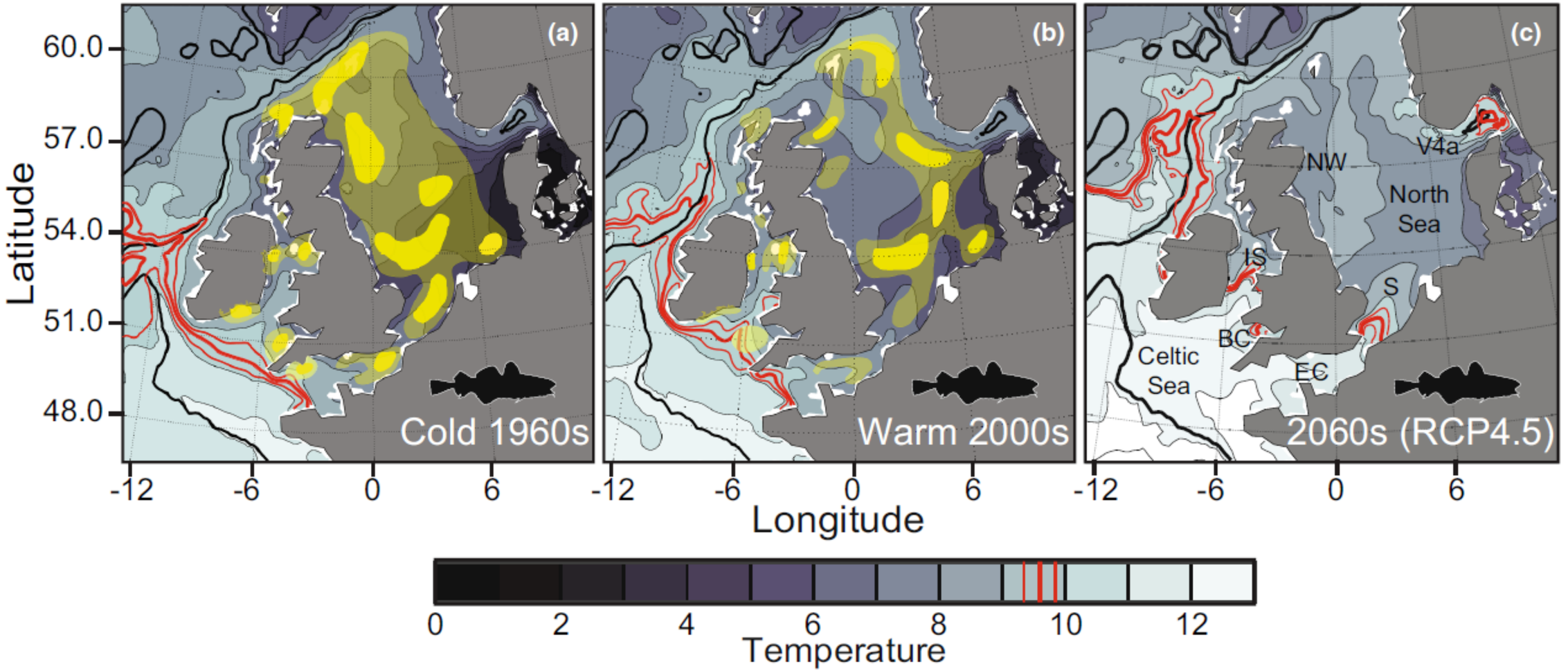


Kjesbu et al. (2023) F&F



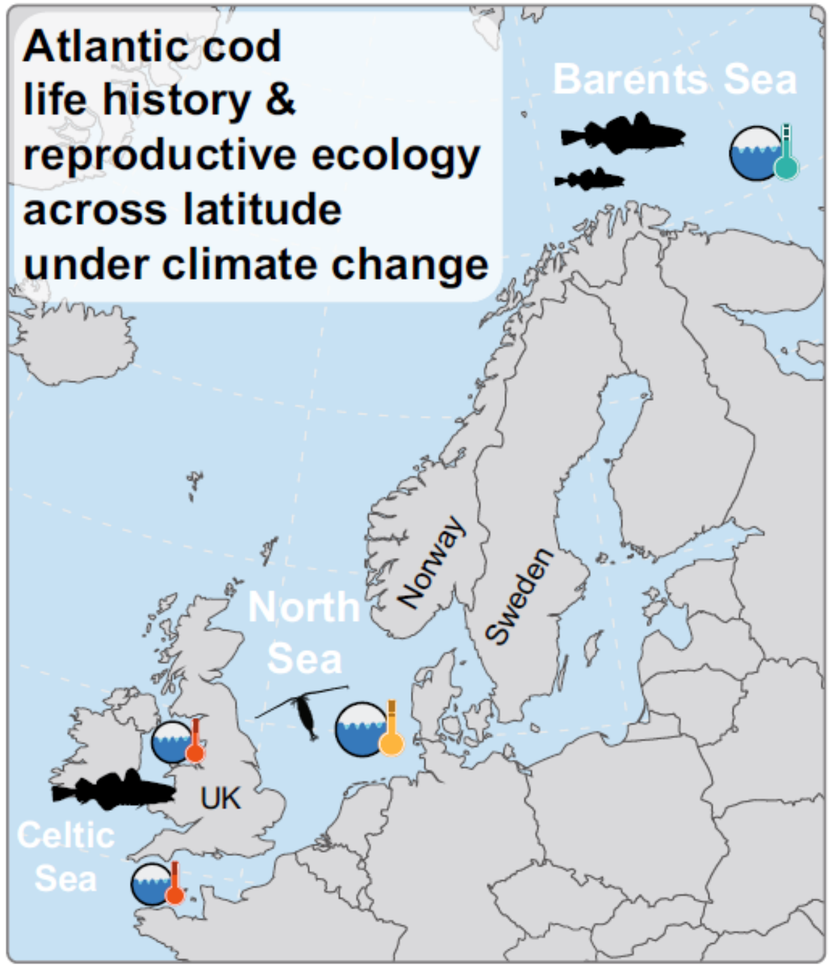
Kjesbu et al. (2023) F&F

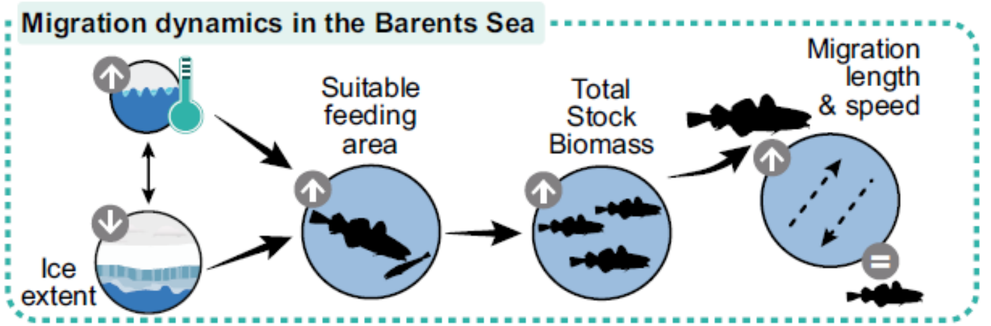
Cod spawning grounds displacement

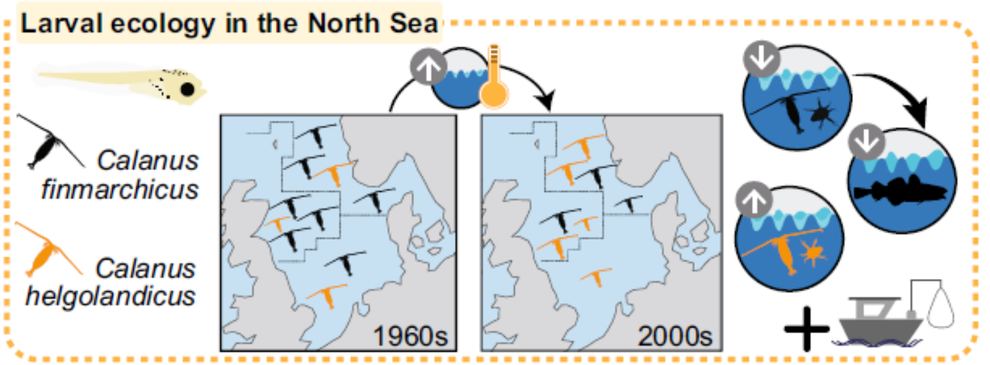


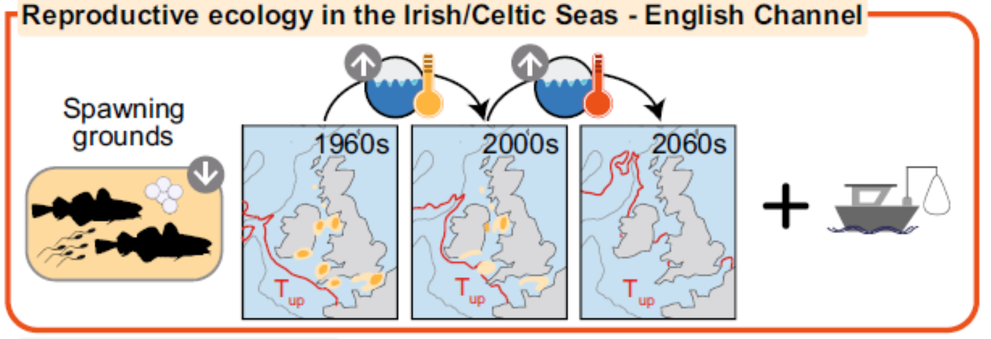
Kjesbu et al. (2023) F&F

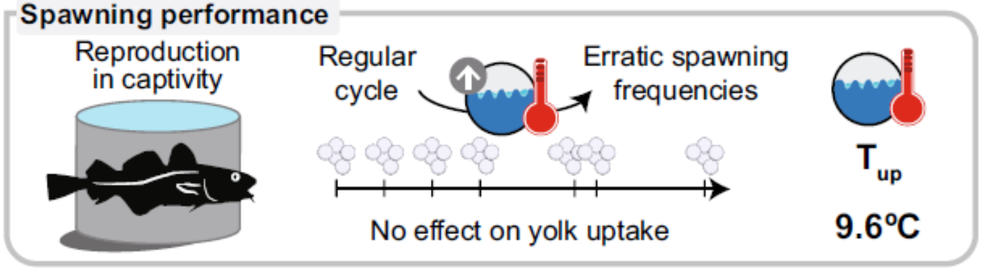
All three northeast Atlantic cod stocks have displaced their spawning areas northeastward during the recent 40 years of ocean warming

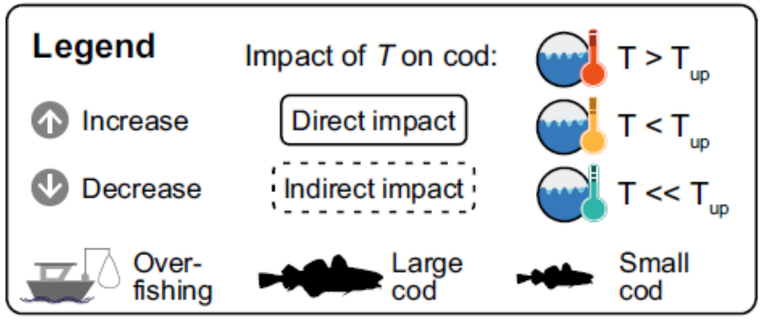










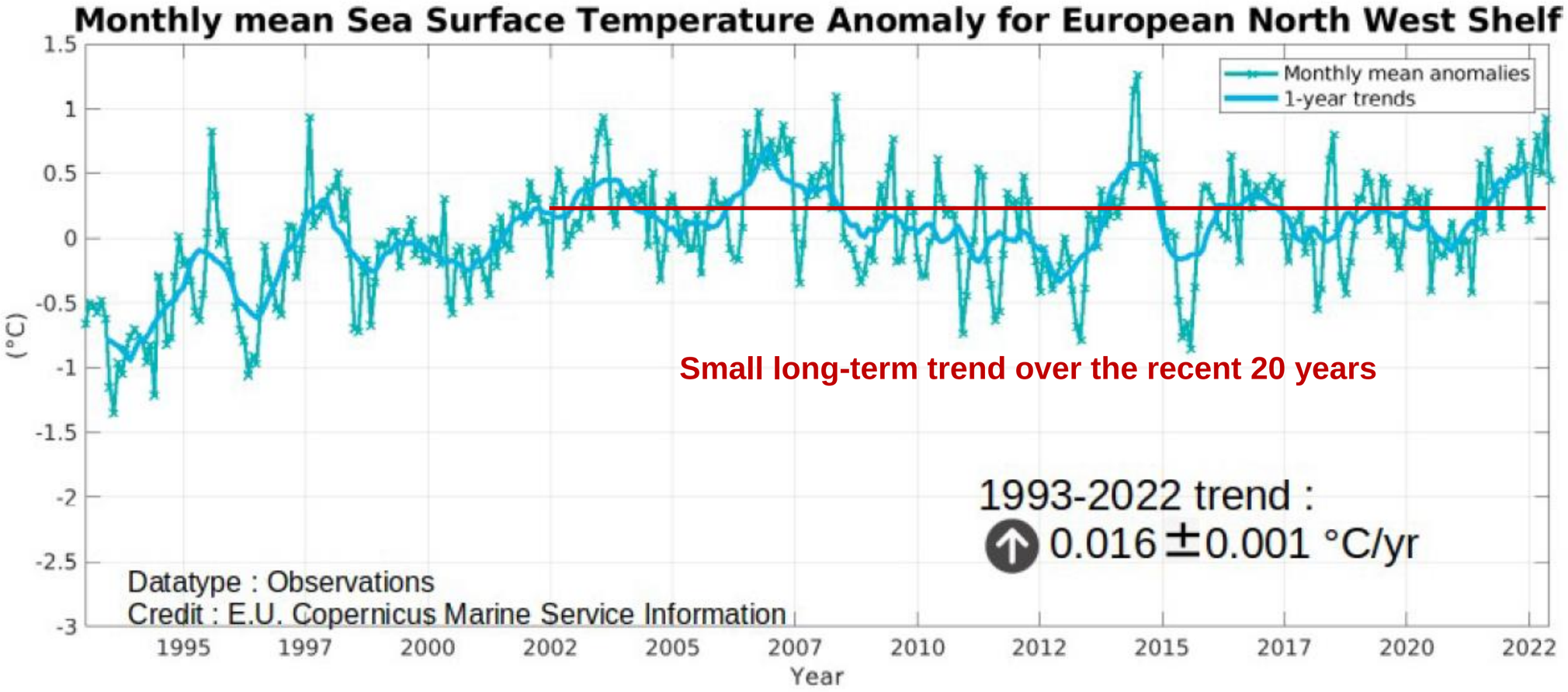


Supercritical spawning migration length due to improved feeding condition in the northern Barents Sea

Northward displacement of key spring-spawning prey species for the cod offspring

Supercritical tempeature for maturation and spawning of SSB

Kjesbu et al. (2023) F&F



Copernicus Marine Service

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Conclusions for the Celtic Seas cod

* Climate-induced decline/northward displacement of cod populations associated with the Celtic Seas are probably linked to multiple causes:

1) Most importantly, in the southernmost part of the habitat, ambient temperature for the maturing and spawning cod are on the limit of being supercritical resulting in unsuccessful spawning.
2) In central to northern regions, change in suitable prey species (e.g. spring-spawning copepods like *Calanus finmarchicus*) may have contributed to reduced offspring survival.