Environmental and demographic controls on the distribution of North East Arctic cod spawning around the Lofoten Islands

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Summary

Constructing statistical models for the distribution of recently spawned eggs of North East Arctic cod (*Gadus morhua*) we attempted to elucidate the influence of environmental, temporal, demographic and spatial factors, of local up to habitat-wide relevance, on variations in the distribution of spawning gadoid fishes. Statistical models explained between 23 and 42 % of deviation from the mean. The explained variation for observations on the inshore side of the Lofoten Islands (Vestfjord) was primarily related to environmental variables, while on the Outer Shelf spatial dependency appeared more important. Similarly shaped spline smooths for large scale variables and different shapes in relation to local variables indicate a primarily local control on the proportions between the regions.

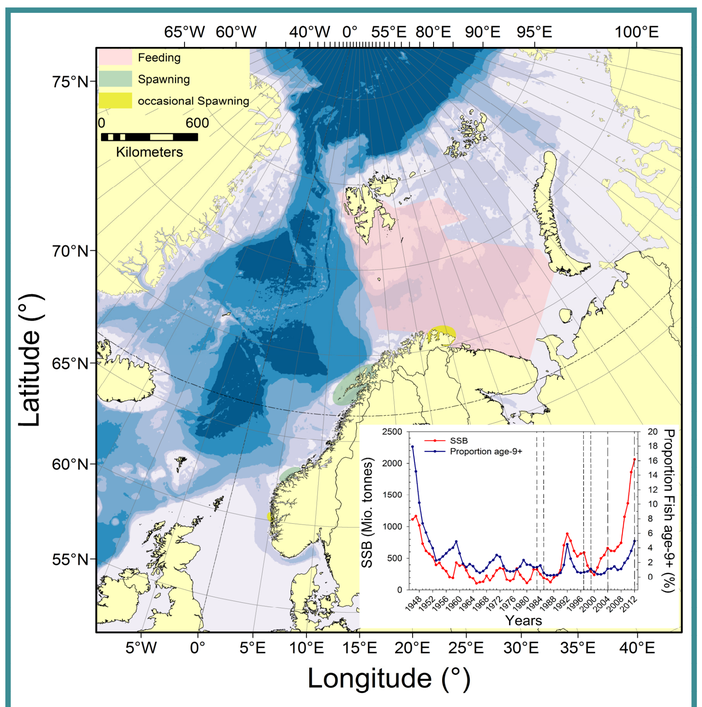

Figure 1: North East Arctic cod feed in the Barents Sea and migrate south to spawn. The inset diagram depicts the development of SSB and proportion of old fish (age-9+) from 1946 onwards.

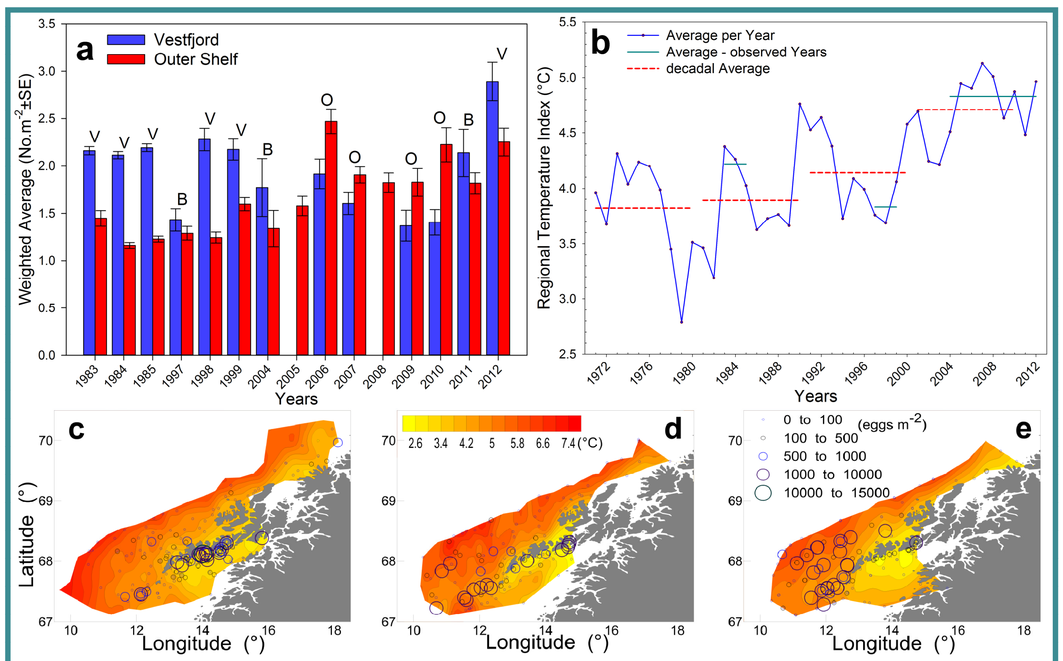

Figure 2: Panel **a** shows the grouping of years into periods of higher egg densities in Vestfjord (V), balanced distribution (B) and higher densities on the Outer Shelf (O). Panel **b** depicts the development of the Regional Temperature Index (Kola-Transect) over the last four decades. Panels **c** to **e** depict the local hydrography for the groups of years defined in Panel **a**, represented as temperature at a depth of 30 m, and density of eggs (all stages combined) as dot-plots.

Materials and Methods

We grouped data from egg surveys in 1983-1985, 1997-1999 and 2004-2012 into periods with higher egg density on the inshore or the offshore side of the archipelago. These data sets were then mapped out for single stages and we constructed Generalized Additive Models (GAMs) for non-zero abundance and presence/absence of stage 1 (following Friðgeirsson 1978) eggs in the two areas. Independent variables were environmental, temporal, demographic and spatial dependency constructed with Moran's Eigenvector Maps (MEMs). The statistical models were optimized by stepwise regression within the groups of variables and by testing all possible combinations between them.

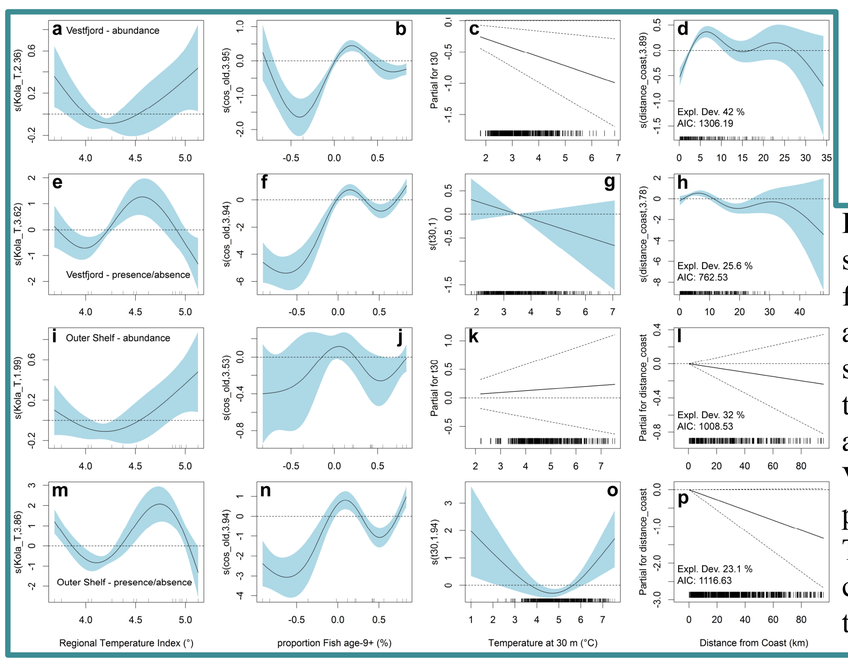

Figure 3: Representative smooths of GAM models for non-zero abundance and presence/absence of stage 1 cod eggs. Panels **a** to **d** depict the model for abundance of eggs in Vestfjord, **e** to **h** show the presence/absence model. The lower rows depict the corresponding models for the Outer Shelf.

Results

When cod eggs were more abundant in Vestfjord, patches of high egg densities were small and dispersed over time, while a dominant Outer Shelf meant aggregation into a single, relatively stable, patch. Relation of stage 1 distribution to variables affecting the entire stock (Regional Temperature Index, proportion fish age-9+, Day of the Year) was similar in both regions, while the relation to local conditions (temperature, distance from coast, bottom depth) differed to some extent. Spatial dependency played a greater role on the Outer Shelf than in Vestfjord.

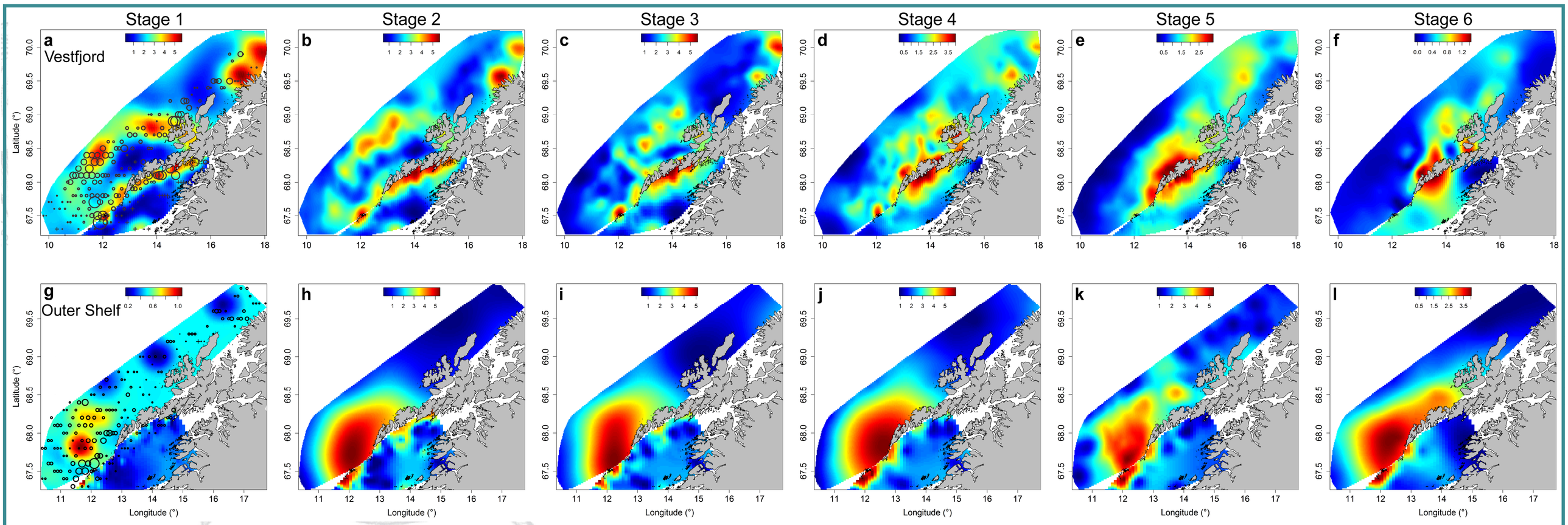

Figure 4: Average egg density (eggs m^{-2}) for single development stages. Panels **a** to **f** depict the progression through the stages for the group of years with higher abundance in the Vestfjord area while the lower row of panels (**g** to **l**) show the development in the period with higher abundance on the Outer Shelf. Black circles represent acoustic observations of adult fish (crosses indicate zero-observations).

References

Friðgeirsson, E. (1978) Embryonic development of five species of gadoid fishes in Icelandic waters. Reykjavík, Hafrannsóknastofnunin.

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