Supplementary material and methods

Sampling protocol

The acoustic survey has been carried out annually since 1972, and was mainly a capelin survey, gradually developed into a survey including all pelagic fish in the area (Eriksen et al. 2018). Since capelin is the main target species, the survey is designed to cover the total area of capelin in the Barents Sea. Some years, polar cod may be found also north and east of the Barents Sea so that the survey may have failed to cover the complete distribution area of polar cod and have resulted in underestimation of stock abundance e.g. 1995 or 2003. Acoustic data at 38 KHz (nautical area scattering coefficients NASC $m^2.nmi^{-2}$ Maclennan et al. 2002) were integrated continuously along the survey tracks. Mean values of acoustic backscattering per nautical mile are recorded for calculations of fish abundance. The echosounders were monitored continuously, and trawl hauls with a "Harstad trawl" (Godø et al. 1993) were carried out whenever the recordings change their characteristics and/or the need for biological data makes it necessary. These hauls were used for identifying the acoustic recordings to species and to obtain biological information (length, weight, maturity stage, age, stomach content etc.). This information was used to convert the acoustic abundance estimates to biomass, and to divide the estimate on age groups (Eriksen et al. 2017). Data for young of the year originates from the same survey, however data about abundance were estimated from pelagic trawls hauls covering the upper water column on a layer from 0 to 60 m depth. Trawls consisted of 7 panels of decreasing mesh size from 100mm to 30mm ending in a codend with meshsize of 8mm.

Raw spatio-temporal data for amphipod were collected using the same trawl type as for age 0 polar cod sampling. Biomass was reported as kg wet weight per nautical mile trawled (kg $WW.nm^{-1}$). Data for copepod biomass originated from vertical hauls on the whole water column using a 180µm mesh plankton net. Biomass was reported as g of dry weight per sampled squared meter (g $DW.m^{-2}$). Harp seal (*Pagophilus groenlandicus*) abundance was predicted using a deterministic age structured population model (Øigård et al. 2014) and takes into account mortality rates of pup and older individuals as well as age-class annual seal catch.

Temperature

Temperature profiles were extracted from the ICES website as CTD water column profiles for the Barents Sea northern region (74–80°N and 20–50°E). First, profiles were restricted to the August-September period to ensure a satisfying spatial and temporal distribution of sampling. Second, profiles were further selected based on bottom depth (deeper than 150 m) and on the profile including at least 90% of the total water column. Mean values of water column temperature below 150 m were computed for each selected profile (n=4623). To take into account differences in stations location and date, we fitted a generalized additive model (GAM) using the following equation:

$$T_{(Lat,Long,DoY),Year} = \alpha_{Year} + f(Lat, Long, DoY) + \varepsilon_{(Lat,Long,DoY),Year}$$

with the response variable $T_{(Lat,Long,DoY),Year}$ representing mean water column temperature below 150 m for each CTD station at latitude *Lat*, longitude *Long*, day of year *DoY*, and year *Year*. The coefficients α_{Year} are year-specific intercepts, $f(Lat, Long, DoY)$ is a 3-dimensional tensor-product smooth function with a mean of zero and a maximum of 5 knots

per dimension for latitude, longitude, and day of the year, and $\varepsilon_{(Lat,Long,DoY),Year}$ is a normal distributed error term with a mean equal to 0. The mean annual temperature index below 150 m was constructed by extracting the year-specific intercepts (α_{Year}) from the model results.

Predation index

The biomass of polar cod consumed by harp seal was reported depending on the availability of capelin (*Mallotus villosus*) in the Barents Sea, with low capelin stock period 1993-1996 showing an increased consumption of polar cod compared to high capelin biomass period 1990-1992 (Nilssen et al. 2000). The consumption of polar cod by the NorthEast Arctic Atlantic cod (NEA cod, *Gadus morhua*) was as well suggested to vary depending on capelin stock with a higher consumption of polar cod in year with low capelin stock (Orlova et al. 2009).

Based on reported values for the period 1990-1996, we evaluated the consumption rate of polar cod for each predator for both low and high capelin stock biomass period following the equations:

$$m_{NEAcod} = \frac{\sum_i^Y \left(Wpolar\_cod_{NEAcod,i}/NEAcod_i\right)}{Y}$$

and

$$m_{seal} = \frac{Wpolar\_cod_{seal}}{\sum_i^Y (Seal_i)/Y}$$

Here, $Wpolar\_cod_{NEAcod,i}$ is the yearly polar cod consumption by cod for year i in the period of Y years of either low (1993-1996) or high (1990-1992) annual capelin biomass stock condition (Prozorkevich et al. 2018) and $NEAcod_i$ is the cod biomass during the same years (annual biomass of Northeast Arctic stock of Atlantic cod aged of 3 years and older ICES 2018). $Wpolar\_cod_{seal}$ is originally reported as an average estimation of consumed biomass of polar cod by harp seals for either low or high annual capelin biomass condition (Nilssen et al. 2000). We divided it by the average value of $Seal_i$, the abundance of harp seals for year i in the period of Y years of either low or high annual capelin biomass stock condition (abundance of harp seal aged of 1 year and older ICES 2016).

Ignored observation data

Year 1995 presented an abnormally low observed abundance value for age 0 (three orders of magnitude lower than the other years). The coverage of the eastern part of the Barents Sea was incomplete that year, and too few age 0 individuals were found in the sampled area to calculate an abundance index for the eastern component (Anonymous 2004). This indicates that although that year class was probably a weak one, its size could not be determined, and our coverage index could not correct this incomplete coverage. As the variable ($N_{0,t}$) is predicted dynamically in the process model, the observed value $Nobs_{0,1995}$ was not replaced as for the missing amphipod biomass in 1988. It was simply excluded from our analysis to prevent it to influence environmental parameter estimation through the observation model.

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Supplementary figures

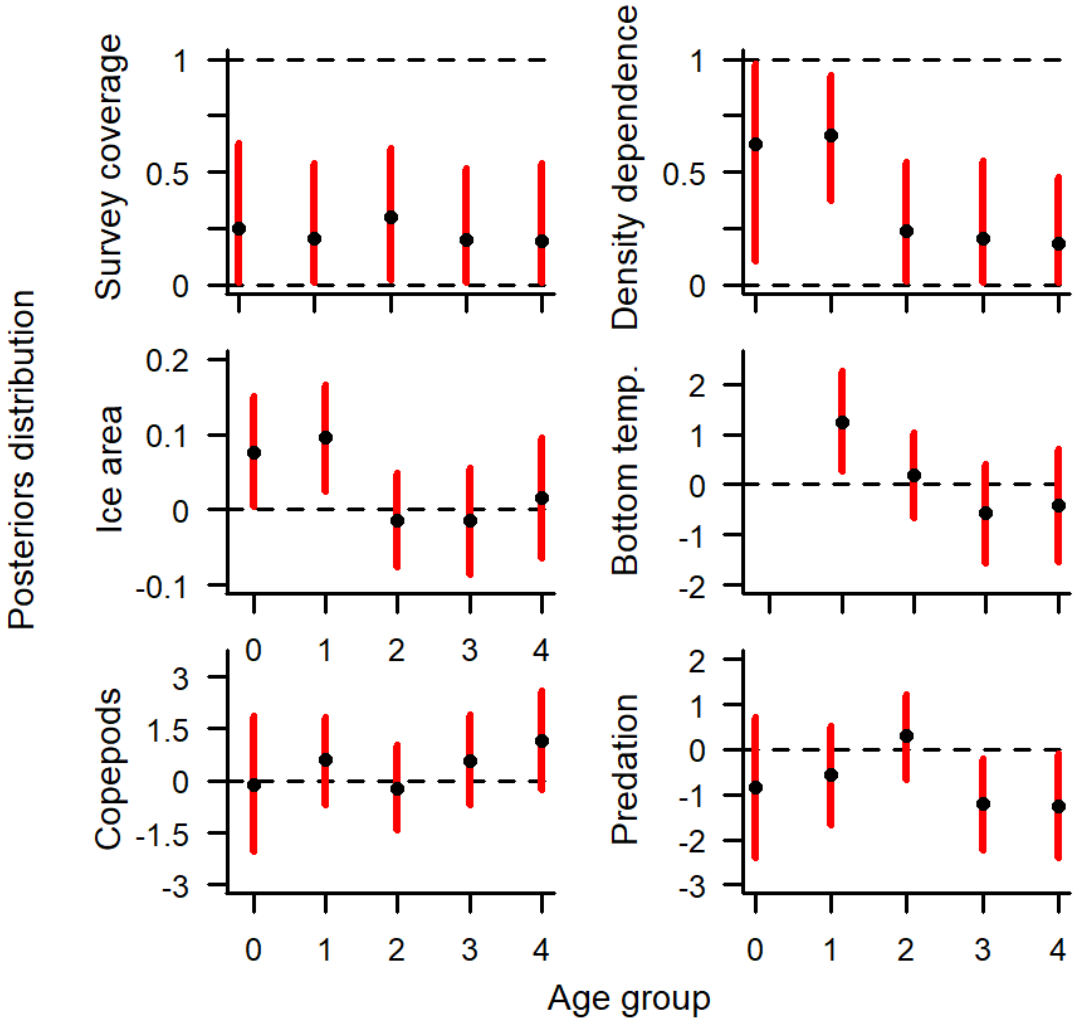

Fig. S1: Posterior distribution of the environmental parameters in the restricted model depending on age group

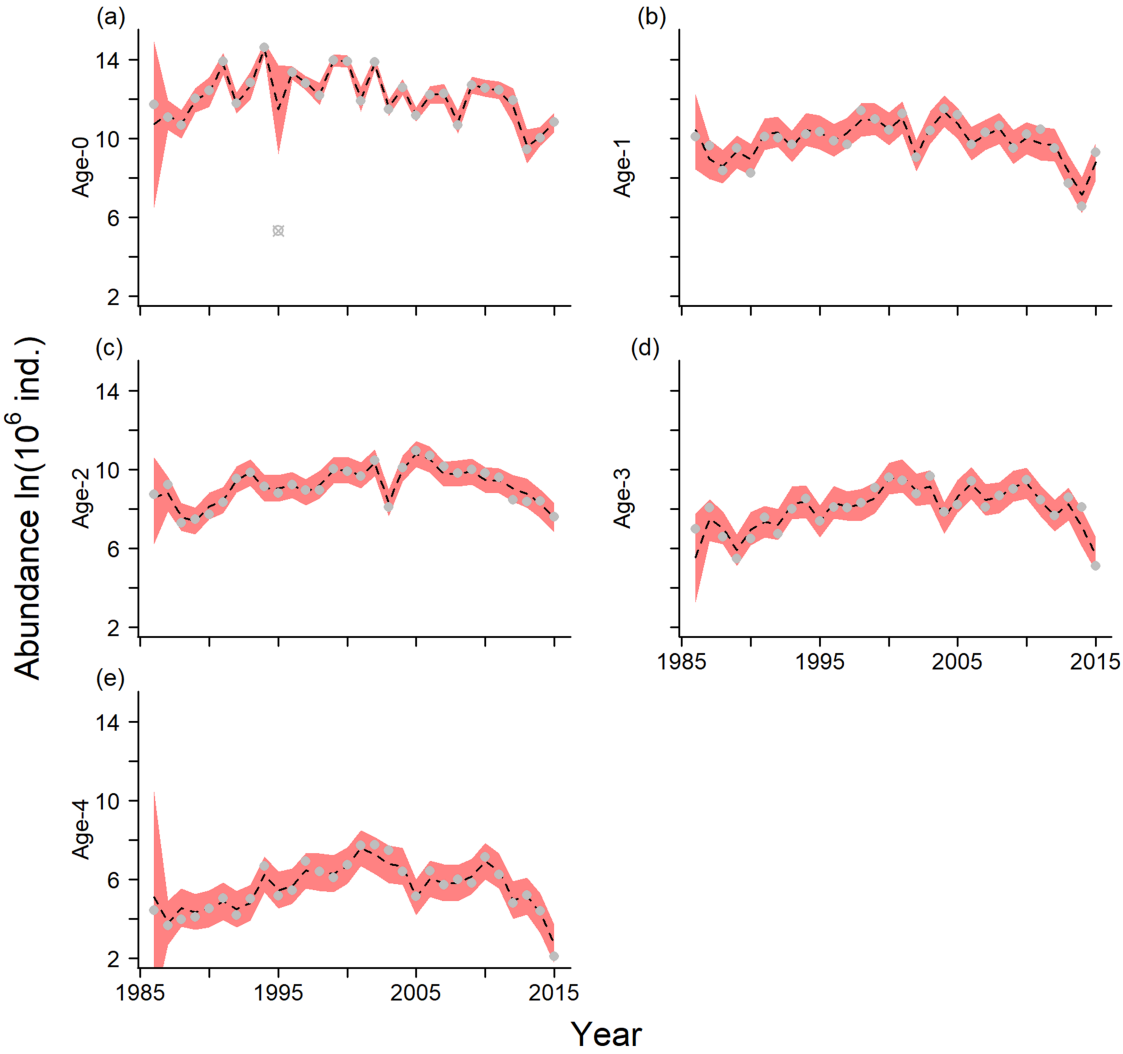

Fig. S2: Time series of the corresponding state variables in the restricted model with posterior median values (black dotted line) and 95% credibility intervals in blue: (a) age 0, (b) age 1, (c) age 2, (d) age 3, (e) age 4. Points (grey) show data on abundance-at-age of polar cod for ages 0 to 4. Due to unrealistically low age 0 abundance value in 1995, this data point was ignored in the observation model (see SI for more details).

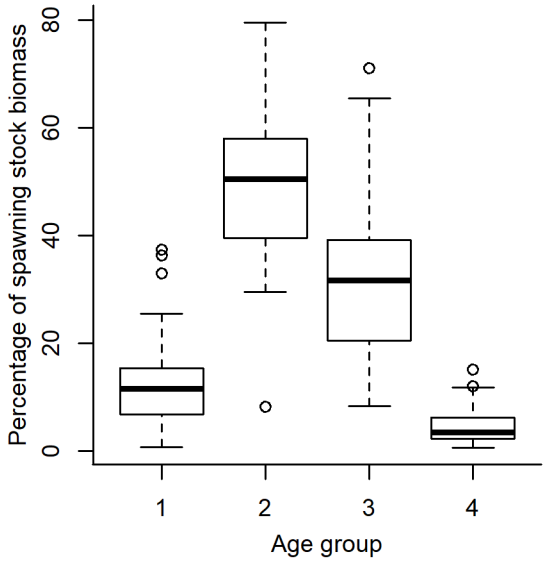

Fig S3: Contribution in percentage to the total spawning stock biomass from observed abundance values, maturation at length distribution and weight-at-age, depending on age groups