Reconstructing growth in Norwegian spring-spawning herring: density dependence, environmental drivers and life-history evolution

Marion Claireaux[1], Fabian Zimmermann[1,*], Bruno Ernande[2], Mikko Heino[3,4], Katja Enberg[1,3]

[1]Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway (*fabian.zimmermann@hi.no)

[2]IFREMER, Boulogne-sur-Mer, France - [3]Department of Biological Sciences, Bergen, Norway - [4]IIASA, Laxenburg, Austria

Goals and key findings

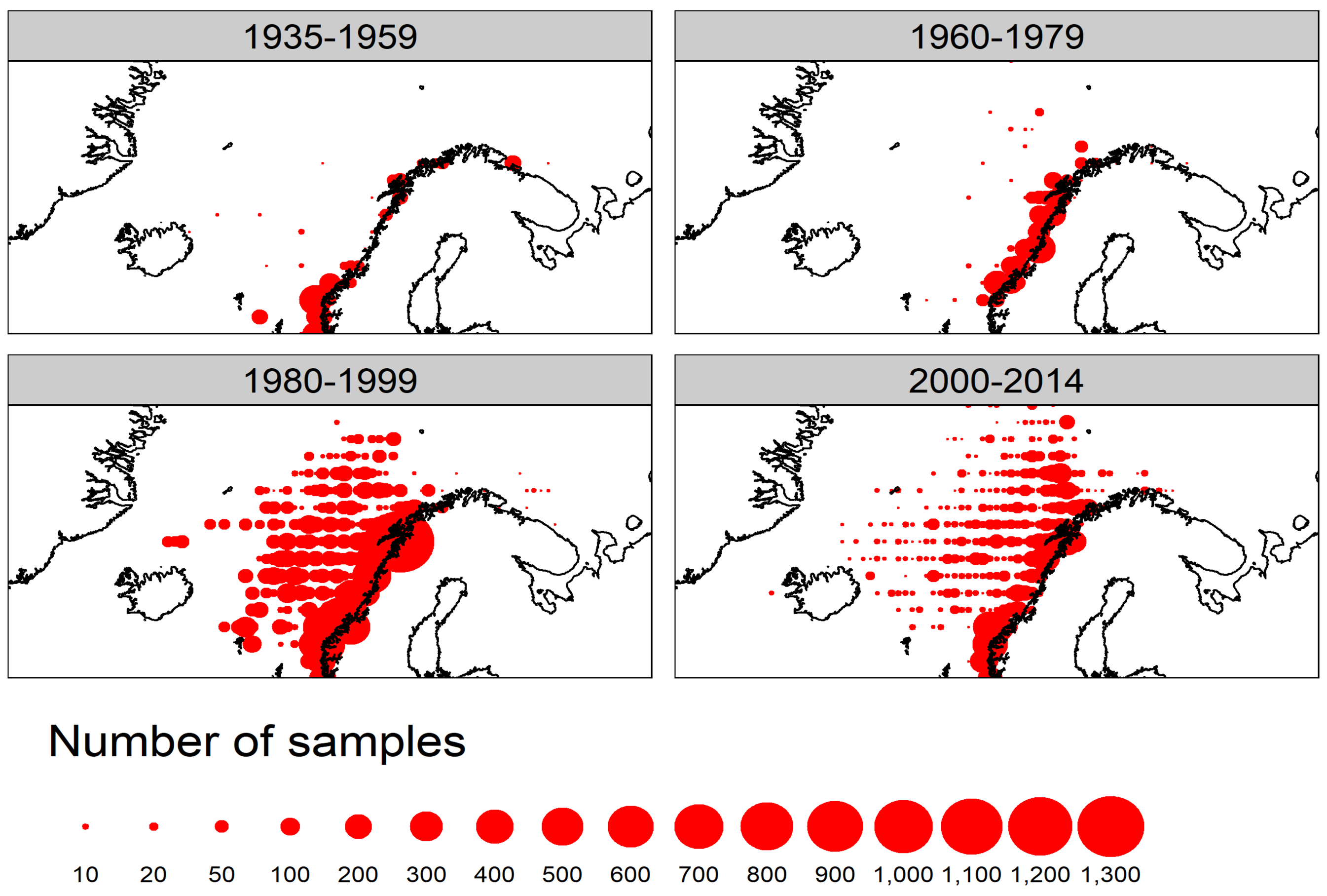
1. Our study analyzed growth dynamics in Norwegian spring-spawning herring based on scale measurements collected within the period of 1935-2014
2. We tested for internal (age, size, catch age, population density) and external (NAO, temperature) predictors of growth using mixed effects models

- Age and size were found to be key determinants of growth but our models also revealed an influence of population density and temperature
- The directionality of density dependence and temperature effects switches from positive to negative when transitioning from juvenile to adult stages

Approach and results

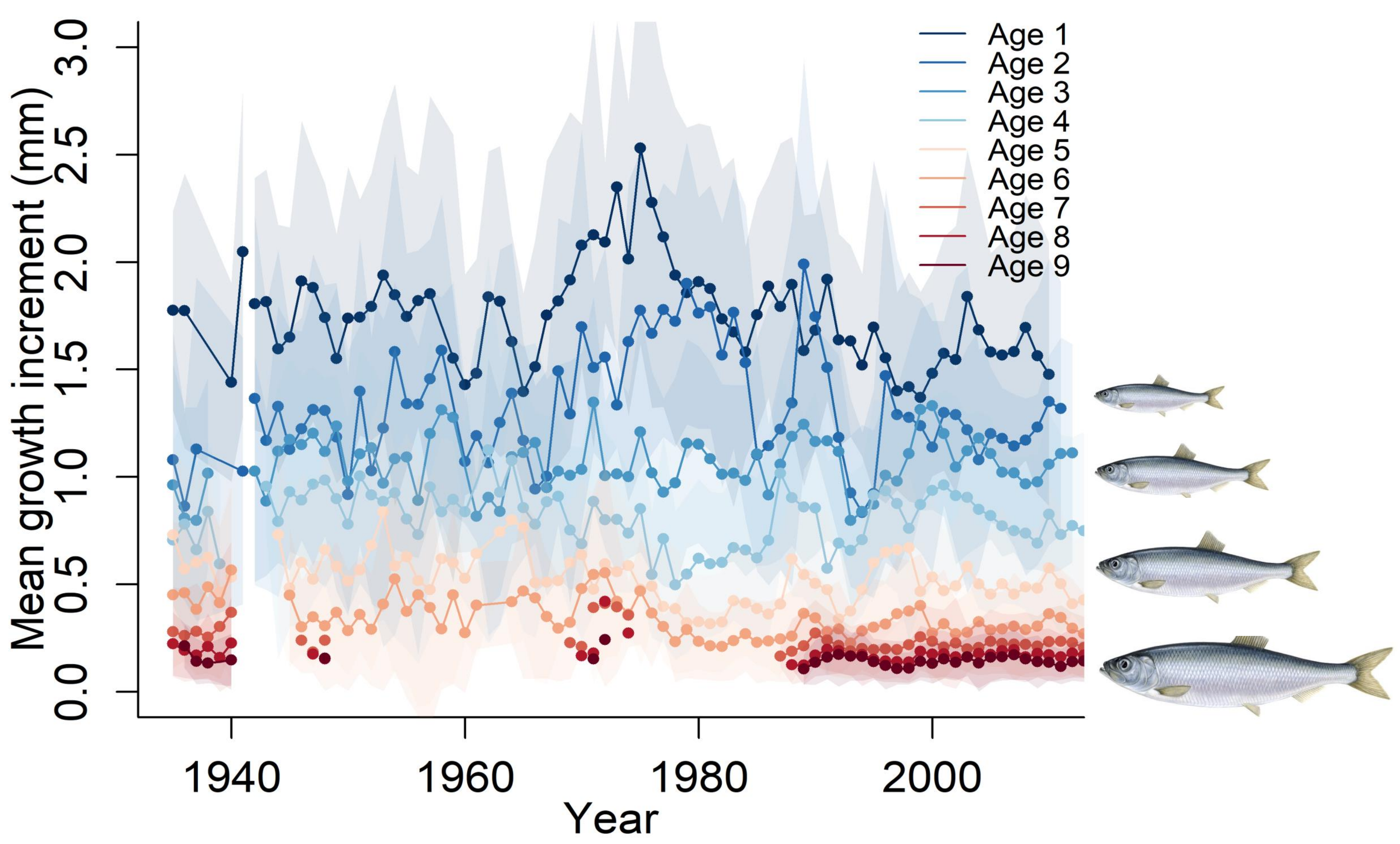
1. Study area

The data encompasses the feeding and spawning areas in the Norwegian Sea and the nursery grounds in the Barents Sea. Variation over time results from changes in stock size, migration patterns and sampling.



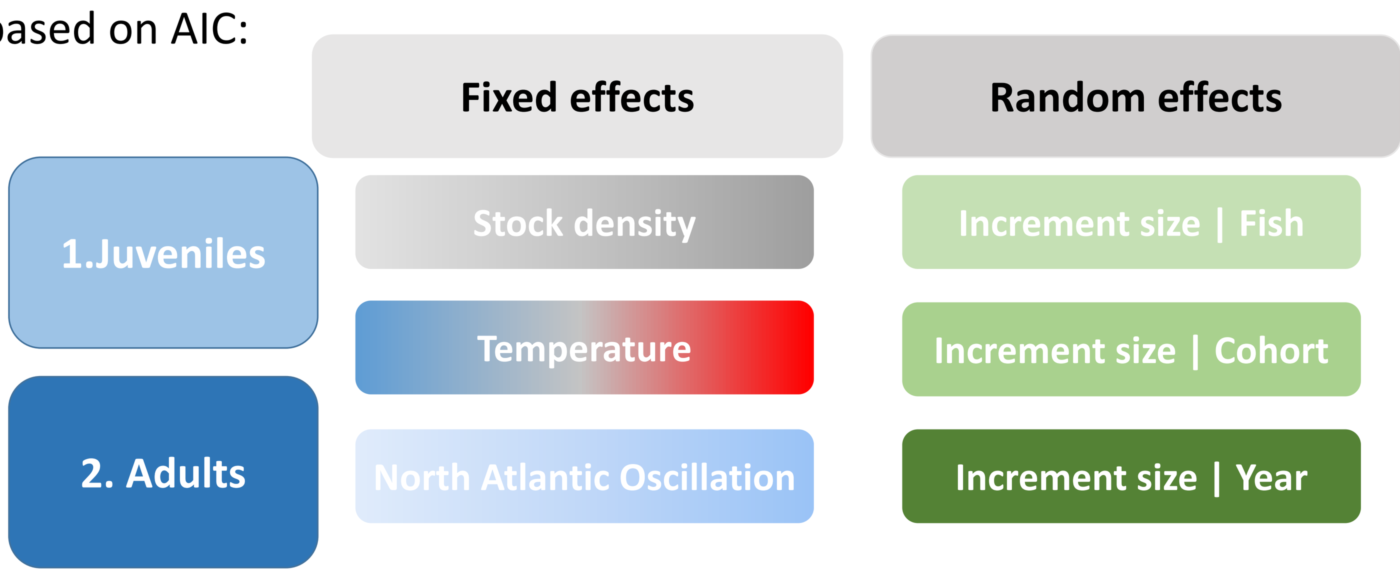
2. Growth dynamics over time

Scale growth increment readings were based on more than 200,000 individuals, covering ages 1-9 and all cohorts between 1935 and 2014.



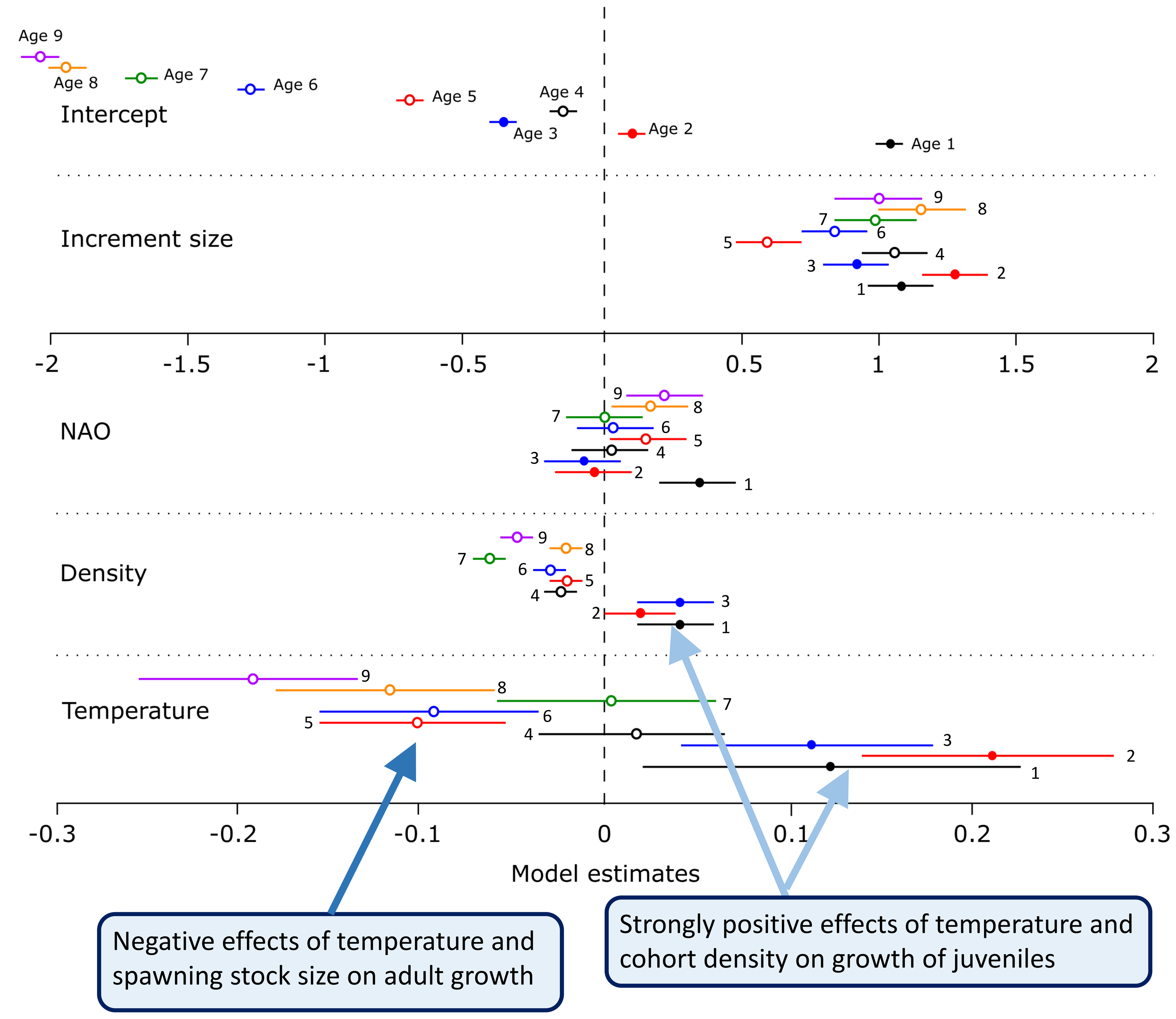
3. Model selection

Mixed effects models of increasing complexity were fitted to juvenile (age 1-3) and adult growth data with a combination of fixed and random effects. The model below was selected for both juveniles and adults based on AIC:



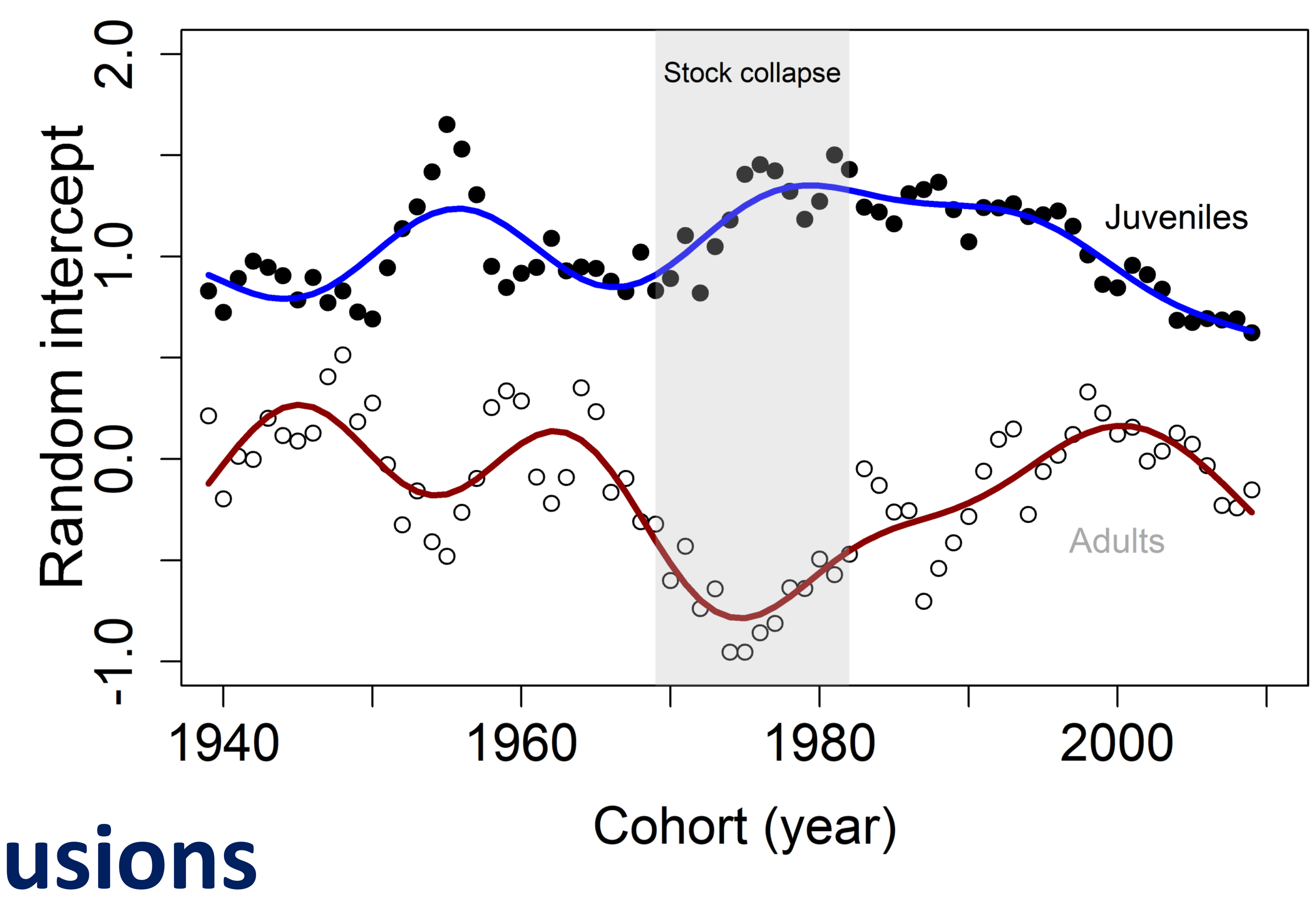
4. Predictors of growth

The fixed effects estimates in the selected models show a strong, statistically significant link of growth with age and total increment size of the scale as well as diverging patterns between juveniles and adults in the effects of stock density and temperature. Shown are the model estimates of each effect for all ages.



5. Temporal trends

Random intercept estimates for cohorts and fitted GAM smoothers, suggesting additional cohort-specific drivers of growth. Trends over time are possibly linked to the stock dynamics: growth in adults mirrors largely the fluctuations in spawning stock size whereas juvenile growth tends to precede these changes.



Conclusions

- The unique dataset of scale increments reconstructs **80 years of fluctuations in growth** dynamics of Norwegian spring-spawning herring
- Age and size of fish are expectedly strong predictors of growth, but there are **statistically significant effects of stock density and temperature**
- **Density dependence changes with life stage**: abundance and growth are positively linked in young ages, competition may lower growth later in life
- **Temperature may also affect growth** directly or indirectly **throughout the life cycle**, enhancing growth in juveniles while reducing it in adults

Key knowledge needs

- Correlation is not causality – **mechanistic links** between environment and growth **remain unclear** and require further investigation
- Are the observed fluctuations in growth over time solely **phenotypic plasticity or** do they also indicate **genetic life-history adaptions**?
- How does growth translate into population dynamics, i.e. **implications for stock productivity, resilience and maximum sustainable yield**?

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