

Fisheries-induced evolution in cod

Northeast Arctic cod mature much younger than before. Analysis of individual data strongly suggest that this is partly caused by evolutionary change, probably fisheries-induced. At the same time, also environmentally-induced fluctuations have been important.

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Exploited fish stocks worldwide are maturing at earlier ages and smaller sizes, and northeast Arctic cod are no exception. Traditionally, these ubiquitous trends have been attributed to environmental change or phenotypic plasticity.

Analyzing one of the best long-term data series in marine capture fisheries, we show that variations in growth and survival resulting from environmental and demographic changes have been important for the fluctuations in maturation. Yet, these factors are insufficient to explain the observed maturation trends. This supports the hypothesis that cod have evolutionarily adapted to fishing.

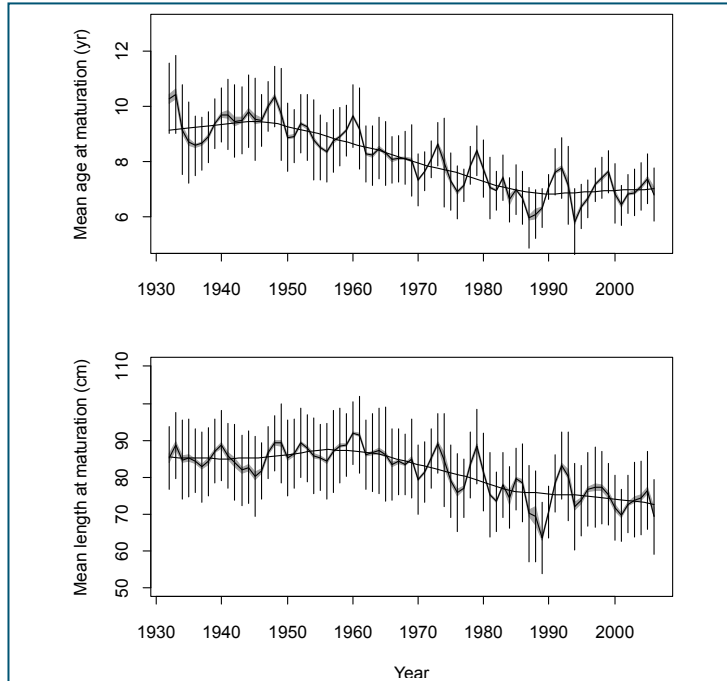


Northeast Arctic cod
Northeast Arctic cod (*Gadus morhua*) is world's largest cod stock, and one of the most valuable fishery resources in Europe. It is also a keystone species in the Barents Sea.

Spawning cod have been exploited near the coast of Norway for centuries, but the nature of fisheries changed when in the early part of 20th century, motorized trawlers enabled fishing in cod's feeding grounds in the Barents Sea. This made delayed maturation a vulnerable life history.

ACKNOWLEDGEMENTS

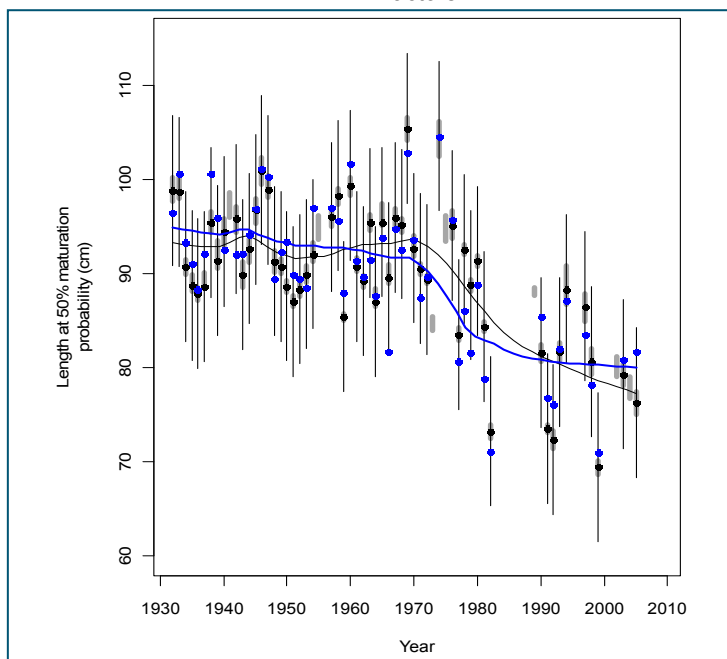
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Cod mature earlier and smaller

Age at first spawning in northeast Arctic cod has declined by about 2.5 years since 1932. They also mature at smaller sizes, and average weight of first-time spawning cod have dropped by 50%. Changing reaction norms for age and

size at maturation (below) suggest that traditional explanations — growth-related plasticity and demographic effects — are insufficient. Yet the conditions cod experience today are different in also many other ways from those in 1930s. Can we strengthen the analysis by considering additional factors?



Could environmental changes explain the trend?

Several factors could facilitate maturation, independently from growth:

High temperature. The Barents Sea is warm today, but it was also relatively warm in the 1930s.

Low stock biomass. The stock declined steadily until 1980s, but has partly recovered thereafter.

High body condition. Condition has steadily increased after WWII.

Capelin biomass. The stock has fluctuated greatly, but has on average declined from 1970s to today (earlier data not available).

Including these factors as explanatory variables, either individually or in combination, shows expected effects on maturation. Yet the significant residual trend remains.

Only the temperature data covers the whole time span of the maturation data. Reaction norms corrected to mean temperature (blue) suggest a more uniform trend in maturation tendency than the uncorrected ones (black).

Accounting for further environmental effects thus strengthens the conclusion arising from the simpler analysis.



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