

Oxygen minimum zone induced rapid temporal fluctuations of Eastern Baltic cod genetic diversity

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Summary

Oxygen minimum zones are increasing, yet the effects of these zones on the genetic composition of marine fish stocks has been neglected. We assessed the combined effects of stock size and structure, and the prevailing oxygen situation, on Eastern Baltic cod (ICES SD25) genetic diversity. For this purpose, we used an integrative long-term otolith sample and data series (1995-2013) to (1) calculate the approximate number of females with surviving eggs in a given year, i.e., contributing to reproduction (n_F), and (2) the annually resolved cohort mean allelic richness as proxy of genetic diversity, based on 12 microsatellite markers. Cohort mean allelic richness showed strong year-to-year fluctuations though no permanent decline. Importantly, it was highly correlated with n_F , but with an unexpected 1.5 year time lag that may be an artefact of Eastern Baltic cod ageing problems. Our findings indicated that environmental pressure can effect rapid alterations in exploited fish stock genetic composition, and pointed to the importance of large females for Eastern Baltic cod reproduction during stagnation periods. Considering the importance of standing genetic variation for the evolutionary potential of populations, this is relevant for projections of the future state of cod stocks under global change.

Introduction

Both globally and locally in the Baltic Sea, oxygen minimum zones are increasing, with important ecological repercussions (Diaz & Rosenberg 2008, Carstensen et al. 2014). However, the effects of these zones on the genetic composition of marine fish stocks has been neglected to date. Recent work suggests that despite the large population size of most marine fishes, their genetic diversity is affected by population declines due to overfishing (Pinsky & Palumbi 2014). Here, we took a step further and assessed the combined effects of stock size and structure, and the prevailing oxygen situation, on Eastern Baltic cod (ICES SD25) genetic diversity.

Material and Methods

To assess whether and how temporal fluctuations in Eastern Baltic cod genetic diversity are related to fluctuations in the number of females with eggs that are able to survive under the prevailing environmental conditions, we:

(1) calculated a time series of genetic diversity from cod samples from ICES SD25 from the years 1995 – 2013, based on microsatellite analysis of DNA from historic otolith collections ($n = 542$). Since age data for these individuals were not directly available, we backcalculated age from fish length based on ICES DATRAS age-length tables, and then assigned all individuals to cohorts. We used mean allelic richness as measure of genetic diversity, and ran the analysis on the cohort level for the years 1991 – 2011.

(2) calculated a time series of the number of females spawning eggs with the potential to survive under the conditions in a given year for the period 1966-2011. This number was based on ICES stock assessment data, horizontally and vertically resolved oxygen concentration data from own cruises

with RV Alkor and the ICES OC database, density layers of neutral egg buoyancy following age-egg buoyancy relationships described by Vallin and Nissling (2000) and O₂-egg survival dependencies after Köster et al (2001).

(3) graphically and statistically assessed the association of genetic diversity with the number of females with surviving eggs based on (1) and (2).

Results and Discussion

Cohort mean allelic richness showed strong year-to-year fluctuations though no permanent decline (Figure 1 top panel). Moreover, it was highly significantly correlated with the number of cod females with surviving eggs in a given year (Figure 1 bottom panel) ($r^2 = 0.51$, $p = 0.001$), but with a 1.5 year time lag for which we have no biological explanation and which may be an artefact of the Eastern Baltic cod ageing problems (Figure 1).

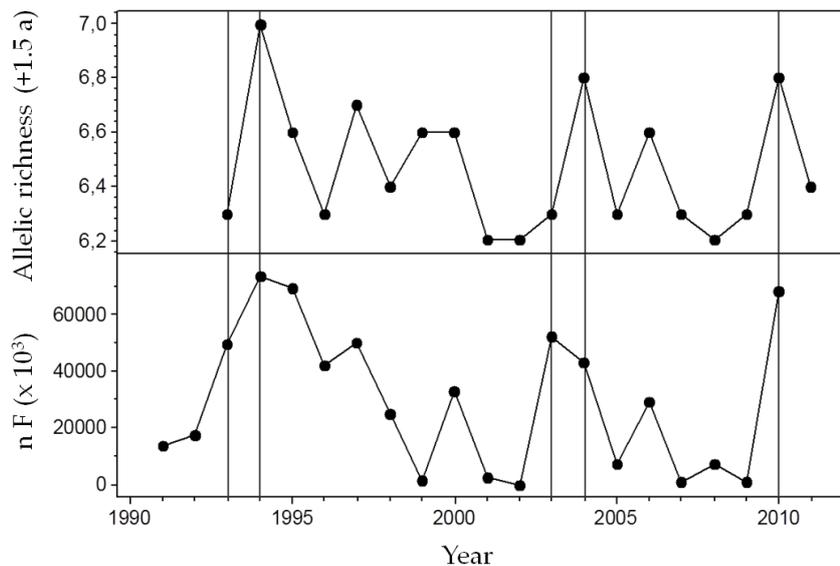


Figure 1. Time series of the predicted number of cod females with surviving eggs (n F) in ICES SD25 (bottom panel), and the mean allelic richness as measure of genetic diversity in this stock (top panel). Vertical lines designate periods with inflow conditions (i.e., improved oxygen concentrations in deep water).

Our findings provide one of the first indications that environmental pressure can effect rapid alterations in exploited fish stock genetic composition, and point to the importance of large females for Eastern Baltic cod reproduction during stagnation periods.

Considering the correlation of standing genetic variation and the evolutionary potential of populations, this is relevant for projections of the future state of cod stocks in the Baltic Sea under global change.

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