

Phenological responses to climate and fishing – changes in maturation cycles and spawning time in a depleted cod population

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Abstract

Eastern Baltic cod (*Gadus morhua callarias*) is a prime example for the combined effects of climate change and overfishing on a commercially important fish population. In addition to collapse, both environmental change and size-selective fishing have resulted in a population that is now skewed towards young ages with a largely lacking component of larger and older individuals. These changes in population structure have made the population vulnerable and less resilient to external pressures, making it a real challenge for scientific fisheries advice and management. Here we show phenological changes in two important and interrelated life-history traits of marine fish populations, i.e. maturation and spawning time. We investigated these changes for the Gotland Basin cod population, a sub-component of Eastern Baltic cod that has suffered the most from environmental change and overfishing. Using a unique set of long-term biotic and abiotic time-series we present a statistical analysis that revealed two pathways of direct and indirect effects of environmental change and fishing. First, deoxygenation of benthic habitat due to the cumulative effects of reduced inflow activity into the Central Baltic and eutrophication leads to food shortage and hence slower growth and lower condition of individuals eventually affecting cod maturation timing. Additionally size-selective removal of individuals may have induced earlier maturation schemes. Eventually we combine both pathways of change to explain the observed phenological changes in maturation and spawning time, knowledge that is important for a better and more reliable assessment and advice of the Eastern Baltic cod stock.

Keywords: Condition, Eastern Baltic cod, environmental change, growth, maturation, phenology spawning time, size-selective fishing

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