Influence of gear selectivity on FIE and yield

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Summary
Size-selective fishing alters the demographic composition of fish stocks, influences population dynamics and may result in evolutionary changes of life-history traits. While mortality through fishing inevitably affects the stock, size selectivity can intensify or mitigate detrimental consequences. In this study we investigate how the interplay of different types of gear selectivity affects maturation evolution in a cod-like stock and the resulting fisheries output. We use a life-history model with maturation age as single evolving trait and study stock dynamics under size-dependent fishing mortality. Total size selectivity is determined by the proportional contribution of gillnet-type and trawl-like selectivity curves to total yield. We vary fishing intensity and selectivity regimes from purely trawl-like via mixed gears to solely gillnet-type selectivity. Results show that shifting harvesting pressure from bigger to smaller size ranges mitigates adverse effects of fishing such as decreasing maturation age, and may increase stock productivity through a protected spawning stock of old, fecund individuals. The positive effects on stock size and yield are partially independent of evolutionary changes. In the long run, targeting mainly individuals below or at the maturation size with dome-shaped selectivity could improve sustainability and output of fisheries, and slow down or reverse evolution towards early maturation.

Introduction

In our study we simulate evolutionary and bioeconomic effects of size-selective fishing gear through population dynamics, life-history evolution and fisheries yield. Our model is parameterized to resemble the Northeast Arctic cod stock. In long-living and slow-maturing stocks like Atlantic cod, maturation age is a key life-history trait since the onset of maturation leads to a shift in energy investment from growth to reproduction. This makes maturation age a determinant for lifetime trajectories of other life-history traits like growth, survival and reproduction, therefore in our model age at maturation is used as single evolving trait that affects growth trajectories. The selection acting on this trait originates from size-selective natural and fishing mortality. We study effects of different selectivity regimes by varying the proportion of total yield harvested by sigmoid and bell-shaped selectivity curves, representing trawl and gillnet selectivity, respectively. This allows us to trace the effects of gradual changes in the gear composition on phenotypic composition, stock size, and yield. Our study assesses the consequences of size-selective fishing by analysing over a wide range of parameter values the combined influence of fishing effort, selectivity curves, and target sizes on the modelled stock of Northeast Arctic cod and its fishery, thus providing insights into how management of size-selective fishing could mitigate the evolutionary impact of fishing and improve the state of stock and sustainable yield.

Methods

The model is based on age-structured population dynamics and life-history evolution with age at maturation as single evolving trait that determines the lifetime trajectories of growth, survival and reproduction. The model assumes that age at maturation is genetically coded and inherited. Natural and fishing mortality represent the source of selection and adaptation over time. For the parameterization, we use information from the Northeast Arctic stock of Atlantic cod, a long-lived and slow-growing species with late maturation, typical for many important commercial stocks. By setting a fishing rate and a range of different size selectivities, defined by target sizes and a mixture between gillnet-type (dome-shaped) and trawl-like (sigmoid) selectivity curves, we can analyse how

the shape and target size of size selectivity influences the development of the stock and its mean age at maturation as well as the resulting yield.

Results

The results of our model show that a gillnet-type fishing selectivity can positively affect maturation age, spawning stock biomass (SSB) and yield in the simulated cod stock. These effects may occur after relatively short time spans and become more pronounced over time, and they depend on the choice of size selectivity and the gillnet proportion as well as fishing pressure. In general, differences accrue for size selectivity at or below 60cm, and they become more pronounced with increasing gillnet proportion and input fishing mortality. Changes in SSB and yield are mainly driven by ecological effects and therefore partially independent of the evolutionary impacts of a specific harvest regime.

Discussion

Our life-history model of stock dynamics in response to fishing shows that dome-shaped selectivity curves targeting low fish sizes could improve sustainability and yield of a cod-like fishery and reverse trends of decreasing age at maturation due to fishing-induced evolution. These outcomes are partially independent but intensify each other. Fishing that selects for small fish creates a size refuge for big, old individuals with high fecundity and therefore allows for a large, robust SSB with high productivity. The same selectivity pattern results in an evolutionary advantage for individuals that grow through the zone of high fishing mortality and mature later, selecting for higher age at maturation. The resulting higher proportion of later maturing fish with higher fecundity adds to the beneficial effects on stock productivity over time. However, shifting size selectivity influences directly stock productivity and yield, and thus not only results in long-term but also immediate benefits for stock and fishery. To adjust size selectivity towards lower sizes and dome-shaped selectivity curves may therefore not only be recommendable to manage fishing-induced evolution, but also as general policy to improve sustainability and yield of stocks with a cod-like life-history.