Protecting the larger fish: an ecological, economical and evolutionary analysis using a demographic model

Many marine fish stocks are reported as overfished on a global scale. This overfishing not only removes fish biomass, but also causes dramatic changes in the age and size structure of fish stocks. In particular, targeting of the larger individuals truncates the age and size structure of stocks. Recently, there is increasing evidence that this size-selective fishing reduces the chances of maintaining populations at levels sufficient to produce maximum sustainable yields, the chances of recovery/rebuild/drop populations that have been depleted/collapsed and may causes rapid evolutionary changes in life-history traits of exploited fish stocks. The main purpose of the present PhD thesis is to gain an understanding of the role of the larger fish in a population, from three different areas of science specifically, ecology, economics and evolution. An extended classical single species age and size-structured model is used and the whole analysis is focussed on two theoretical stocks with life history traits typical of a large and long-lived species (W¥=20 kg) and of a small and short-lived species (W¥=0.5 kg). Several fish stock-specific studies, both field observations and experimental studies, indicate that not only do the larger and older females spawn more eggs in each spawning event than smaller-younger females, but their eggs are larger and of higher quality in terms of survival than the eggs from smaller-younger females, a phenomenon known as maternal effects. However, most traditional management models assume that all female fish contribute equally per unit biomass to future recruitment. The second chapter of the thesis considers the influence of maternal effects on recruitment and on the commonly used reference points: the fishing mortality rate corresponding to the maximum sustainable yield (FMSY) and the fishing mortality where the population collapses (Fcrash). Our results demonstrate that the incorporation of maternal effects into the recruitment equation will not result in better scientific advice for a stock being managed to achieve maximum sustainable yield (MSY). It may however be important to account properly for maternal effects for collapsing populations.

The third chapter develops an ecological-economic evaluation tool to explore the impact of the choice of a recovery scenario on the time needed to recover the stock and on the net benefit generated by the fishery during the recovery period and beyond. This is achieved by merging a classical age-structured model for a single-species population with an economic cost-evaluation framework. One of the recovery scenarios pay particular attention to the larger individuals. Our results suggest that the larger fish does not matter much neither from an economic nor from an ecological perspective. Only if there is a high fishing pressure during the recovery period can a preservation of the larger individuals reduce recovery time significantly. The fourth and last chapter is focused on fisheries induced evolution and the consequent changes in yield. We attempt to evaluate the capability of the larger fish to mitigate the evolutionary change on life-history traits caused by fishing, while also maintaining a sustainable annual yield. This is achieved by calculating the expected selection response on three life-history traits: size at maturation, growth rate, and reproductive investment under two different fishing scenarios, with and without a maximum-size limit. We find that each life-history trait responds differently to the introduction of size-selective fishing regulations, and that only a reduction in fishing mortality will reduce the magnitude of the selection response on all traits. The consequent changes in fisheries yields are less than 10 % per decade. We conclude that size-based management regulations alone are unable to mitigate fisheries induced evolution on all evolving traits. The main conclusion of this thesis is that in most cases protecting the larger fish does not matter much for the population. High fishing pressure is the primary concern about the sustainability of the fisheries, population recovery and the evolutionary changes in life-history traits.

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