Multispecies reference points for a three species system with a predator and two prey species in the Baltic Sea

Norrström Niclas (1), Casini Michele (2), Holmgren Noél (1)
(1) The systems biology Research Centre, University of Skövde; Skövde Sweden; (2) Institute of Marine Research, Swedish University of Agricultural Sciences, Department of Aquatic Resources; Lysekil Sweden.
Presenter contact details: niclas.norrstrom@his.se, Phone +46 500 448653

Summary

Studies have shown that maximizing the total yield in a multispecies system isn't desirable since it will enforce fishing solely on the lowest trophic levels (Gislason, 1999). An economic maximal yield can benefit the inclusion of top predatory species in the catches, but is with variable fish market values difficult to analyze . An alternative approach is of the aggregate surplus production models in mixed fisheries (Fogarty et al. 2012). We have developed a method to calculate the integrated reference points for three species via an analysis of the spawning stock biomasses at maximum sustainable yields (BMSY). The model is parameterized to describe the Baltic Sea with only three species constituting the main resources for the fisheries; cod *Gadus morhua*, herring *Clupea harengus* and sprat *Sprattus sprattus*. By analyzing how the BMSYs vary for different abundances of prey and predator we find a point where each species produces maximum sustainable yields (MSY) given the spawning stock biomass (BMSY) of the other species. This approach maintains the productivity on both trophic levels.

Introduction

An ecosystem-based fishery management (EBFM) and a restoration to maximum sustainable yields is now the current directive from the European Commission to the ICES (ICES 2009). The problem is that multiple single-stock MSYs may be in conflict with each-other and it is likely that although single stocks are harvested sustainably, the environment is not (Pikitch et al. 2004).

The case of the Baltic Sea involves few species compared to other marine systems, and this fact allows us to study the effects of both competition between related species and predator-prey interactions. We have developed a MSY-analysis concept based on a stochastic operative model of the stocks (SOM-MSY). The SOM-MSY returns targets and reference points for the different species in relation to ecological and environmental drivers and has been used for the advice of Baltic sea main basin herring and Baltic sea sprat 2011 (ICES, 2011). We have further developed the SOM-MSY to a Multi Species Interaction-SOM (MSI-SOM) model which includes all the three commercial species and their interactions.

Materials and Methods

The model consists of three stochastic operative models (SOMs) for cod, sprat and herring stocks, respectively (Holmgren et al. 2012). Each SOM has numbers-at-age and weight-at-age as dynamic variables. The changes in the dynamic variables are defined by a set of four functions: (i) a recruitment function, (ii) a weight-of-recruits function, (iii) a natural mortality function, and (iv) a body-growth function. The joint MSY-analysis is conducted by solving SSB at MSY (BMSY) for one species while stepping through a range of constant BMSYs of the other species. Herring and sprat turn out to have additive impact on cod growth, herring having an effect 3.4 times stronger than sprat. This enabled the use of a weighed SSB sum of the clupeids, here measured in herring SSB equivalents. The joint MSY is presented as the intersection between MSY-isolegs plotted in the phase portrait of SSB for clupeids and cod (Figure 1). The intersection of the MSY-isolegs represents the situation where the cod FMSY results in cod BMSY that allow the herring equivalents to be fished at FMSY and where the resulting herring equivalent BMSY simultaneously can support the cod BMSY.

Results and Discussion

The result points out the state of the three dominating species in the Baltic Sea at which they simultaneously produce maximum sustainable yields (Figure 1). The corresponding FMSYs, associated yields, SSBs and trigger points only apply to the system being in the MSY state and the analysis is based on equilibrium based targets. To apply the proposed FMSY on the current stocks without the use of a harvest control rule to decrease F at low population densities will most likely prevent the populations from recovery to BMSY. The analysis provides target FMSYs for all the species but does not provide a strategy for how to move the stocks to the state where they are capable of producing MSYs. The analysis is also based on the assumption that the effects of the two prey species on the predator are additive and constant in relation to each other.

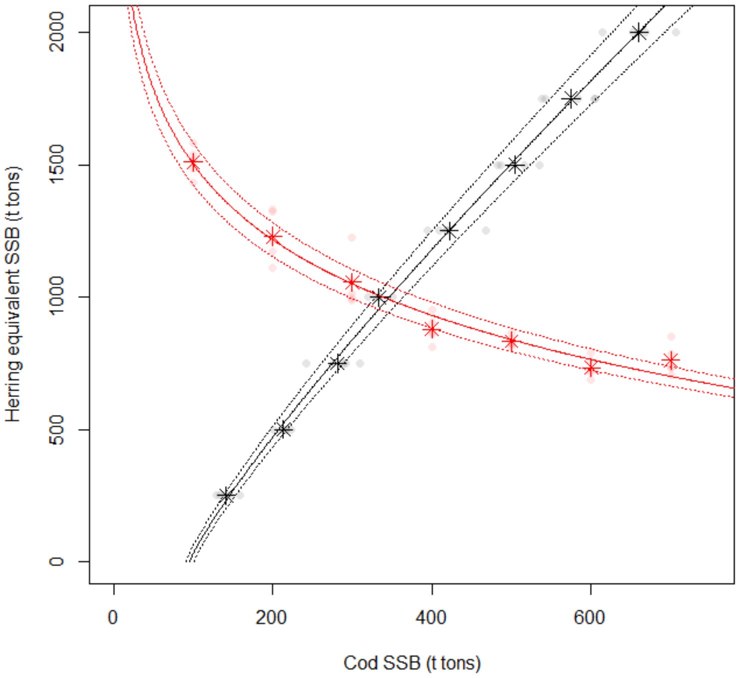

Figure 1. BMSY-isolegs for cod (black line) and clupeids (red line) in terms of herring SSB equivalents (sprat SSB weighed by its impact on cod in relation to herring). The asterisks represent average SSBs from the five simulations of each biomass with the underlying data points represented with slightly transparent red and black points. The intersection of the isolegs indicates the SSBs at which joint MSY for cod and clupeids are defined. The dotted lines are 95 % confidence intervals of the means.

It should be noted that with the proposed multi-species MSY all stocks can co-exist at MSY given that all other stocks are at MSY. This differs from the alternative MSY-objective to maximize total MSY of all species, which leads to eradication of all stocks except the ones on the lowest trophic level when based on biological considerations only (Gislason, 1999). Also, our analysis provides ecologically based recommendations in contrast to economically based recommendations which have to incorporate erratic fluctuations of the values of different fish species. Mixed fisheries can undercut potential catches by adhering to the most sensitive population whereas our analysis maximizes the sustainable yield in all three populations.

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