Larger mesh-sizes in the North Sea brown shrimp (Crangon crangon) fishery: A win-win situation for the fishermen and the ecosystem

Claudia Günther, Marc Hufnagl, Sebastian Schulz, Juan Santos, Jörg Berkenhagen, Bente Limmer, Tom Neudecker, Daniel Stepputtis and Axel Temming

Summary

Brown shrimp fishery in the North Sea is criticized due to the bottom impact of beam trawling and the use of nets with small mesh sizes generating high by-catch rates of fish and undersized shrimps. Moreover, the decrease in natural mortality due to a decline of predator fish stocks has been replaced by an increase in fishing mortality during the last decades. With a fishery remaining on that level the pressure on the shrimp will increase if fish stocks recover and the stock is currently classified as growth overfished. During the project CRANNET, which was funded by the German government and the fishing industry, we investigated the influence of different mesh sizes on the population dynamics, commercial landings, recruitment and total egg production of brown shrimp. We employed a complex yield-per-recruit model including seasonal stage and length dependent growth and mortality as well as seasonality in recruitment based on a broad data fundament. During a massive field campaign, net selectivity of different mesh sizes and geometries was determined and the results have now been included in the model. Our results indicate that larger mesh sizes than those currently used in the fishery will have substantial benefits for the population without causing a decrease in catch weight on the longer term as by-catch of undersized shrimps is reduced. The fraction of large shrimps will increase and with it egg production, catch weight and economic yield (larger shrimps = higher prices). Additionally, the field data indicate that by-catch of Gobiidae will be reduced.

Introduction

Brown shrimp (Crangon crangon L.) can reach high densities in the Wadden Sea ecosystem of the southern North Sea. It inhabits a key-role in the ecosystem (Kuipers & Dapper 1981) and is a major food resource for various fish species especially cod and whiting (e.g. Welleman & Daan 2001). During the last decades, predation mortality by gadoids has decreased but was replaced by an increase in fishing mortality (Temming & Hufnagl 2015). Brown shrimp is a highly valuable target and is harvested intensively by a fleet of beam trawling vessels. The German fleet catches about 40% of the total North Sea landings and consists mainly of small-scale enterprises which harvest up to 13000 t per year (average 2002-2012, ICES 2013) resulting in 40 Million €/year when assuming an average kilo price of 3 €. The brown shrimp fishery is not managed with quotas or effort management and is highly criticized due to the destruction of the seafloor by beam trawling, fishing in national parks and high by-catch rates of small fishes and undersized shrimps. In order to improve the selectivity for the target species and reducing bycatch, the European Fisheries Fund together with the German federal states Niedersachsen and Schleswig-Holstein and the fishing industry funded the research project CRANNET. The goal of the project was to optimize cod-end mesh-size and geometry, to reduce by-catch rates while simultaneously ensuring sustainable yields for fishermen.
Materials and methods

During a massive field campaign (xxx samples), various cod-ends (n=27) with different mesh-width (18-34 mm) and geometries (diamond mesh, square mesh and 45°-turned diamond mesh) have been tested on a research vessel operating with two beam-trawls. Selectivity of every net-type has been estimated against a reference net with small (xxx mm) mesh size which was employed at the same time (paired-gear method). Results have been analyzed applying a random effect model (Fryer 1991) to estimate the relation between the selection parameters $L_{50}$ (total length when the probability of a shrimp to be retained in the cod-end is 50%) and $SR$ (selection range, range between $L_{25}$ and $L_{75}$), mesh size, geometry and other variables (e.g. catch weight, wind speed) influencing the length distribution of the catch. Afterwards, $L_{50}$ and $SR$ have been applied in a population model for *Crangon crangon* to investigate the long-term effect of different cod-ends on the population dynamics and landings. The population model is a Yield-per-recruit model and has been applied successfully in previous studies (e.g. Temming & Damm 2002, Temming & Hufnagl 2015). It includes seasonal stage and length dependent growth and mortality as well as seasonality in recruitment based on a broad data fundament. The model is able to reproduce the seasonal pattern of landings, 15 mm recruits and egg-production. A selection function was implemented into the model which was defined by $L_{50}$ and $SR$. Population and economic quantities (e.g. egg production and yield) have been calculated for various combinations of $L_{50}$ and $SR$. Finally, three cod-ends have been selected that performed best in the simulation and show the strongest reduction of by-catch (observational data from the field campaign). These three CRANNET cod-ends have been tested on commercial fishing vessels to investigate the “in-situ” performance and selectivity.

Results and discussion

Totally, 321 scientific hauls were used to estimate selection parameters that have been used as input in the random effect model. Selection parameters of the diamond mesh were only influenced by mesh-width while selectivity in other net geometries (square mesh and 45°-turned diamond mesh) was influenced by mesh-width and catch weight. Both, $L_{50}$ and $SR$, increase with increasing mesh size. The application of the population model showed that larger mesh sizes compared to the standard fishing cod-end (diamond mesh with 20 mm mesh size) led to an increase in population biomass and egg-production and a gain in long-term catches of fishermen. Due to larger mesh-width, small shrimps can escape from the net and grow to larger sizes. After a short-term loss in catches - directly after the time where the fleet would change the cod-end from the standard fishermen-cod-end to a cod-end with larger mesh-width - the model predicts an increase of total landings and shrimp sizes in catches. A population of larger shrimp would be considered more healthy as it immediately benefits at once from a higher production of offspring, as fecundity increases with size. According to the model results, any increase in mesh mesh-width has a positive effect on population dynamics and landings in the present ecosystem situation (small natural mortality for shrimp due to a low number of predators). Furthermore, larger mesh sizes in the cod-end will decrease the by-catch of small fishes. In reference catches using a subset of larger meshed cod-ends on commercial trawlers, by-catch of fishes was reduced by up to 20% (e.g. diamond mesh with 26 mm mesh size) in contrast to the standard fishing net (16 mm xxx). Especially the catch of small fish species like gobies (e.g. *Pomatoschistus minutus*) was reduced. Thus, there is a benefit for fishermen (higher catch weight, larger shrimps) and for the ecosystem (less bycatch) when increasing mesh sizes in the shrimps fishery. Fishermen further profit decreasing times of catch processing due to lower by-catches. On the other hand, the ecosystem benefits from lower amounts of small fishes that die and by the increased production of shrimp offspring.