Stereology as a tool to assess reproduction strategy and fecundity of teleost fishes: Integrated studies in Central Baltic herring (Clupea harengus L.)

In fish stock assessment, spawning stock biomass (SSB) is used as an index of stock reproductive potential (SRP), and proportionality is assumed between SSB and recruitment, i.e. offspring production. SSB is calculated as the sum of biomass proportions of sexually mature individuals per age group. However, evidence that SSB is not a reliable SRP indicator has accumulated over the past decades. The SSB estimation does not consider individual differences in fecundity, skipped spawning, timing of spawning or differences in reproductive traits between sexes, which may all fluctuate significantly, influenced by individual physiological condition. The Central Baltic herring has experienced a radical decline in SSB over the past decades. This is mainly due to overfishing. However, significant changes in Baltic Sea salinity and temperature have also altered herring prey composition and abundance, while reduction in the number of cod has caused sprat numbers and thereby food competition to increase. Together, this has resulted in a significant drop in Central Baltic herring physiological condition. The influence which this lowered condition may have on herring SRP, in terms of increased down-regulation and thereby lowered fecundity, skipped spawning and timing of spawning, has not been investigated and is not considered in assessment of the stock.

The objective of the study was two-fold. Firstly, improve methods for quantification of oocyte recruitment dynamics by adapting and applying modern stereological methods to assess fecundity and reproductive strategies. The strength of the stereological method being that, in combination with conventional histological analysis, quantification of all oocyte categories is possible, as well as registration of qualitative characteristics relating to spawning history of individuals, and further that statistical evaluation of estimates and method is possible. Secondly, apply the stereological methods to fill in gaps in knowledge about Baltic Sea herring reproductive strategy under current environmental conditions, including oocyte recruitment pattern, fecundity determination and down-regulation, skipped spawning and spawning fidelity, and to understand how factors like condition may influence individual decision making and fitness regarding these reproductive traits. The stereological methods applied in this project constituted a powerful set of tools for quantification of oocyte dynamics in fish and were successfully implemented in herring ovaries for quantification of both oocyte numbers and sizes as well as total volume fraction of atretic oocytes, introducing a negligible error to the total variance of estimates. The histological nature of the stereological methods facilitated a ready validation of maturity data, distinguishing first time spawners from repeat spawners, as well as a ready recognition of ongoing oocyte recruitment in early maturity stages, early stage atresia, POFs and residual eggs.

Analyzing a sample of females all collected during a short time frame in March 2008 covering various stages of maturation progression, we saw that oocyte recruitment followed the characteristic pattern of an iteroparous total spawner with determinate fecundity and group synchronous oocyte development. However, a significant fecundity down-regulation was apparent, which followed a three-step mechanism, resulting in low potential fecundity, but high relative potential fecundity compared to other herring stocks. Individual maturation progression revealed a substantial number of specimens with early developing ovaries, thereby being skipped or delayed spawners in accordance to the spring spawning season. Individual condition generally did not appear to influence fecundity regulation, but showed a strong correlation with degree of maturation progression, skipped or delayed spawners having significantly poorer condition than specimens expected to spawn during the spring spawning season. Results further indicated, that spawning occurs throughout the year in the Central Baltic herring population and that spawning time appears to be independent of individual hatch type, but rather relying on especially condition, but also size and age. Bioenergetic modeling showed that an individual condition factor threshold may control timing of spawning. These results may all influence Central Baltic herring SRP.