Central Baltic herring stock: What does the assessment of combined stock say about the status of its components?

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ABSTRACT: The local stocks of Baltic herring (Clupea harengus L.) show remarkable geographical variability in morphology and other characteristics. In order to recommend the Total Allowable Catch (TAC), most of the open sea stocks are combined into one Central Baltic Herring (CBH) stock and assessed together in the management process. The study introduces the results from separate assessments of herring in three assessment units within CBH: the Gulf of Finland herring (ICES Sub-division 32), herring in the SD29 & 32 and in SD 28.2, 29 & 32. The results indicate that the fishing mortality can be significantly higher and relative stock biomass lower in local stocks compared to values from the assessment of combined stock. Despite the re-implementation of local assessment and management units on permanent status may not be feasible, at least occasional assessment exercises with the local stocks may give valuable information on the whole Central Baltic herring stock complex.

1 INTRODUCTION

The Baltic fish community of the Baltic Sea is dominated by only a few species like herring (Clupea harengus), sprat (Sprattus sprattus), cod (Gadus morhua) and flounder (Platichthys flesus), which are also prevailing in the commercial catches (Sparholt 1994). The Baltic herring fishery has been practiced for centuries, but it has become particularly important on a commercial scale since the middle of the 1950s, after the wide introduction of pelagic trawls (Ojaveer 1967).

The total landings of the Baltic herring have been fluctuating from 250,000 to 440,000 tons annually since 1978 with Poland, Finland and Sweden being the leading countries in herring fishery (ICES 2015). The majority of herring landings (100,000–300,000 tons annually) have been taken from the Central Baltic herring (CBH) stock in the last three decades. The landings were decreasing until the mid-2000s, stabilizing then at around 100–150,000 t, despite the increase in stock size from the early 2000s. The stabilizing of landings was at least partly caused by the transition to the MSY-based management system since 2011 (Figure 1).

Catch quotas defined on the basis of the Total Allowable Catch (TAC) and effort regulation are the main management tools to enable the sustainable herring fishery. Additionally, a number of other technical measures like gear restrictions and areas and periods closed for fishery have also been implemented in some countries in order to protect the stocks.

In order to take the adequate management decisions, the status of the Baltic herring stocks is annually assessed in ICES (International Council for the Exploration of the Sea) since 1974.

The assessment and management, however have to overcome a number of fundamental problems. The definition of assessment and management units is one of the most crucial, particularly for herring that is characterised by the high intraspecific variety of local populations. So, according to some authors, the number of such populations may reach up to 10 in case of the Baltic herring (Popiel 1958, Ojaveer 1981,
Figure 2. Dobzhansky (1950) defined the population as a reproductive community of individuals sharing a common gene pool. Obviously, a gene flow due to migrations takes place between the neighbouring populations, often not allowing demonstrating the differences on genetic level (Smith & Jamieson 1986). However, a fish stock unit “is a relatively homogeneous and self-contained population, whose losses by emigration and accessions by immigration, if any, are negligible in relation to the growth and mortality” (Parish 1964). Likewise the local herring populations in the Baltic show differences in morphological features, growth rate, fecundity etc (Ojaveer 1981). Therefore, when aiming for adequate management of herring resources, the assessment and management would ideally follow those natural populations (stocks). This would allow better management of the effect of fishery on every particular stock and thus prevent any undesired negative effects.

From 1974 to 1990 Baltic herring stocks were assessed in a number of units mostly corresponding to biological populations (ICES 2002). However, it was found that during their feeding migrations from spawning areas, some of these populations are mixing while sharing the same feeding grounds and they cannot be separated in the catches. Additionally, collecting all biological information needed in assessment process proved to be too costly for all assessment units. In order to overcome this and also to facilitate the assessment process, herring populations in Southern, Central and Northern Baltic proper and the Gulf of Finland were combined to one stock unit in 1990 and a new assessment unit – Central Baltic herring (CBH) was created, merging the herring stocks in the ICES Sub-divisions 25–28.2, 29 and 32; ICES 1990). Since 1991, the herring in the Baltic Sea has been assessed in five assessment units (Figure 3):

- Herring in SD (ICES Sub-Divisions) 22–24 (Western Baltic herring)
- Herring in SD 25–27, 28.2, 29 and 32 (Southern, Central and Northern Baltic proper and Gulf of Finland; also included the Gulf of Riga herring until 2002).
- Gulf of Riga herring (SD 28.1) separate assessment and TAC since 2003.
- Herring in SD 30 (Bothnian Sea).
- Herring in SD 31 (Bothnian Bay).

Consequently, the management decisions taken and also the existing extensive biological information prove that the CBH is not a genuine natural herring population, but a complex of several local populations having their own biological characteristics, and agreed as a compromise to overcome the assessment and management problems. Obviously, such a situation aggravates both the advisory process and the provision of the scientifically sound management decisions.

Since 1991, the information on the fate of the local herring stocks, included in CBH has been scarce and occasional. In order to enlighten the situation, the ad hoc ICES Study Group on Herring Assessment Units in the Baltic (SGHAUB) acted in 2001–2003. The work of the group resulted in a number of trial assessments of herring in several separate assessments for the Central Baltic Sea, which were chosen on the basis of herring population investigations like tagging, migrations and biological parameters (ICES 2002, 2003). The main result of the group was that the results of separate assessments were in rather good accordance with those of the combined CBH stock.

A number of trial assessments of the herring in the Gulf of Finland and the North-eastern Baltic were performed also by Ojaveer et al. (2003), who concluded that the significant differences in the biological parameters and trends between studied local stocks clearly support the need for separate assessment and management of those.

The goal of the present study was to explore if the complex nature itself can be the reason for relative ineffectiveness of management measures. We studied the trends in the estimates of spawning stock biomass (SSB) and fishing mortality (F) in a few separate (conventional) assessment units included in the combined Central Baltic herring stock complex, attempting to reveal the presence of the potential local processes that may not have been surfaced when assessing the combined stock as one stock unit.

2 MATERIAL AND METHODS

Information on landings and biological parameters of stock information (SSB- Spawning Stock Biomass, F-fishing mortality, TAC, SSN- Spawning Stock Abundance) by the Sub-divisions originates from the
reports of the ICES, consolidating the fisheries and biological information reported by its Baltic member countries annually. The data collection of the EU Member states is performed as a part of National data Collection Programmes for stock assessment purposes under the EU Data Collection Framework (EC 2008). The fisheries – independent information used for tuning of analytical assessments was obtained from the results of the Baltic International Acoustic Survey (BIAS) database hosted by the ICES.

Due to the scantiness of reliable information on distribution of historical catch composition between the local populations, the assessment of herring stocks in separate ICES sub-divisions or groups of sub-divisions assuming that no migration takes place between them was carried out as a compromise. The following assessment units were considered in the study:

1. Herring in the Sub-division 28.2
2. Herring in the Subdivision 29
3. Herring in the Subdivision 32
4. Herring in the Sub-divisions 29 + 32
5. Herring in the Sub-divisions 28.2 + 29 + 32.

The conventional virtual population analysis (VPA, Darby & Flatman 1994) methods like Extended Survivors Analysis (XSA, Shepherd 1999) and the State-space Assessment Model (SAM, Buckland et al. 2004, Nielsen 2009), also used by the ICES, were applied in analytical assessment. The similar (default) settings were used in the assessment of all assessment units studied. The diagnostics indicated that the assessments performed reasonably well, so below we concentrate on assessment results only. Two main parameters, spawning stock biomass and average fishing mortality in age groups 3–6, making up the most in catches and SSB, were considered in the analysis.

3 RESULTS AND DISCUSSION

3.1 Trends in Central Baltic herring stock

The history of main parameters like spawning stock biomass (SSB- biomass of the adult part of the stock describing its reproduction potential), fishing mortality (indicates the status of fishing pressure), and catches have shown mixed trends throughout recent decades. The spawning stock decreased steadily till the beginning of this century but is gradually increasing since then. The fishing mortality was lower than \( F_{PA} \) (maximum fishing mortality rate that can be implemented without directly endangering stock reproduction potential, but which should be avoided in accordance with responsible fishing principles), and \( F_{MSY} \) (enables maximum catches to be taken in the long run without endangering stocks), except for the period when the SSB was decreasing (1989–2002, Figure 4). The increase of SSB is evidently connected with appearance of abundant year classes more often in the last 15 years compared to the 1990s. At the same time the fishing mortality increased peaking in 1989–2003. These trends indicate that the management measures applied to that stock complex have been rather ineffective. Additionally, there are indications that realised landings often can differ from those advised (e.g. ICES 2015). Since the TAC advice is fundamentally connected to stock status, the TAC-regulated fishery (catch quotas) should also reflect the stock dynamics. Our previous results have shown, however that different stock structure and herring mean weight may result in different effect of fishery on local stocks across the Central Baltic herring stock complex (Raid et al. 2011, 2014). Obviously, such a situation aggravates both the advisory process and the provision of the scientifically sound management decisions.

3.2 Trends in studied assessment units

3.2.1 Spawning stock biomass

The dynamics of the spawning stock biomass (SSB) of the CBH has shown a declining trend during most of the management history. Thus, the SSB has declined
from almost 1.7 million tons in 1974 to below 0.42 million tons in 2001 (−75%). Since then, the SSB has recovered to around 0.75 million tons. The decrease in SSB, however, was at least partly due to the substantial decrease in mean weight at age of herring observed in 1980–2000. The general dynamics of spawning stock biomass estimates in the smaller assessment units studied show similar trends compared to that of observed in the Central Baltic herring. However, the SSB development found in the Gulf of Finland differed considerably from the respective trends in other assessment units (Figure 5).

The decrease in SSB observed in CBH stock until the 1990s-early 2000s and the following increase can be clearly observed in almost all of the assessment units studied. However, the onset of the following increase in SSB, which started in the CBH in 2002–2003, was delayed in its northern parts with time lag of 2–3 years. Moreover, the increase of the SSB in the Gulf of Finland (S-D 32) remained marginal for the rest of the period (Figure 6).

The dynamics in SSB is driven by several factors, but the effect of stock abundance and the dynamics of individual growth are the crucial ones. The mean weight at age of herring has a variable spatial pattern across the Baltic Sea: the mean weight at age decreases from South-west to North-east (Ojaveer 1981). Differences in environmental and feeding conditions between the saline South-eastern Baltic and the North-eastern Baltic with relatively low salinity and severe winter conditions (Kullenberg 1981) serve as a background for the described growth pattern.

The analysis of the mean weights of herring in the key age groups (ages 3–6) indicate that the observed different growth pattern in studied assessment units may have caused such a delay in SSB recovery. So, the mean weight of herring started to increase later in the northernmost areas (SD 29 + 32), being mostly driven by the Subdivision 32 (Figure 7).

The comparison of the assessment results also showed the high coherence between the estimates from the two assessment methods used. The very close results from both models allow concluding that both models describe the same trends and give close absolute values in SSB estimates for all areas studied (Figure 8).

Figure 5. The correlation between SSB estimates of the Central Baltic herring and the four assessment units.

Figure 6. Dynamics of spawning stock biomass from XSA in the assessment units considered and SGHAUB stock estimates (ICES 2003) on the background of the Central Baltic herring SSB. Please note the different scale for the CBH.

Figure 7. Mean weight of herring in the age groups 3–6 in the assessment units in 1990–2014.

Figure 8. Correlation coefficients between SSB estimates derived from XSA and SAM for the studied assessment units. Comparative trends in the two units are presented as the examples.

### 3.2.2 Fishing mortality

The SSB of the Central Baltic herring has shown a moderate increase since 2002. The landings however kept decreasing in the early 2000s, being restricted
Figure 9. Dynamics of fishing mortality from XSA in the assessment units considered on the background of the Central Baltic herring and SGHAUB estimates. The extremely high estimate of $F_{2002} = 1.3$ in the Sd. 32 was left out from the figure (ICES 2003).

Figure 10. The correlation between estimates of the fishing mortality in the Central Baltic herring and in the four assessment units.

Figure 11. The relationship of the mean weight at age of herring in the age groups 3–5 and the estimated fishing mortality in four assessment units.

Figure 12. Correlation coefficients between fishing mortality estimates derived from XSA and SAM for the studied assessment units. Comparative trends in two units are presented as the examples.

by the TAC constraints. The restrictive TACs were imposed to reduce the fishing mortality, exceeding the estimated $F_{MSY}$ (0.22) for this stock in 1993–2003. The fishing mortality has been particularly high in the period of 1989–2002, peaking at 0.44 in 2000. The implementation of the separate TAC for the CBH since 2003 has remarkably reduced the fishing mortality to below $F_{MSY}$ (Figure 4).

The analysis of fishing mortality estimates in the studied populations/sub-stocks, however, revealed significant deviations from the general pattern observed in the CBH. The results revealed considerably higher level of fishing mortality in the northern part of the CBH during the second half of the 2007–2013. The main contributor to that seems to be the Gulf of Finland (SD 32) herring, showing extremely high values of fishing mortality (Figure 9).

As a result, the coherence of trends in fishing mortality estimates in the Gulf of Finland and the CBH was the lowest (Figure 10).

It has been demonstrated earlier (e.g. Parmann 1990), that herring catches of the Gulf of Finland represent young age groups of a larger population, in which older and large specimens spend most of the year in the more western areas of SD 29 and possibly also more south, in SD 28.2. The older and large herring are found in SD 32 in winter and spawning time in the spring. Additionally, since the fishing mortality implies the stock losses in numbers of individuals as a result of fishing, the immediate conclusion would be that the same quantity of quota in tons taken in the northern Baltic where the mean weight at age of herring is significantly lower than in southern areas, would mean higher fishing mortality compared to southern distribution areas of the Central Baltic herring stock (Figure 11).

Like in the case of spawning stock biomass, the comparison of assessment results showed a high coherence between the estimates from the two assessment methods used: XSA and SAM. The very close results from both models allow concluding that the two different models describe the same trends and give close absolute values in SSB estimates for all areas studied (Figure 12).

According to the results of our study, the assessment of the combined area of subdivisions 28.2, 29 and 32 looks the most reliable and this area may also be
the most inclusive concerning the whole distribution area of the herring that occur in the Gulf of Finland. Our results also suggest that the assessment results of smaller assessment areas may be substantially influenced by unknown rate of migration and mixing of smaller stock units.

4 CONCLUSIONS

The persistent spatial and temporal differences in stock structure and in mean weights in particular could have a significant influence on the effect of the fishery on Central Baltic herring stock. Despite the re-implementation of local assessment and management units on permanent status may not be feasible from the economical point of view, at least occasional assessment exercises aiming at the local populations/stocks may give valuable information on the status of the whole Central Baltic herring stock complex and reduce the present uncertainties in the management of this stock.

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