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Stock diversity of herring in the Northern Baltic: is the separate assessment of herring natural stock units possible?

Tiit Raid, Georgs Kornilovs and Heli Shpilev

Besides to the long- term sustainable management of fish recourses, the maintaining of the biological diversity on inrfa-specific level is one of the main goals of sustainable management of exploited fish stocks. Therefore, the assessment and management on the basis of natural populations would be the best solution. However, lack of methods allowing fast and reliable discrimination between fishes belonging to different stocks (populations) and temporal and spatial variability of migrations are the general problems, leading in most cases to different compromises between natural and assessment/management units.
The Baltic herring (*Clupea harengus membras* L.) follow the suit of ocean herrings, showing remarkable geographical variability. The local stocks (up to 10-12) showing differences in morphology, growth pattern and stock dynamics, can be divided as gulf stocks and open sea stocks. Three gulf stocks (Gulf of Riga herring, Gulf of Finland herring and Gulf of Bothnia herring) and the stock of Northern Baltic proper inhabit the Northern Baltic. The discrimination between gulf and open sea stocks is based on differences in otolith shape and growth pattern. The Gulf of Riga herring and the Gulf of Bothnia herring are assessed and managed as a separate units whereas the rest two as parts of Central Baltic herring stock complex (Sub-divisions 25- 29S&32). Long-term decrease in the biomass of the Central Baltic observed since early 1990s contrasts to the opposite dynamics in Gulf stocks (Gulf of Riga and Gulf of Bothnia).

Differences in the growth pattern, and stock structure and dynamics between the stocks are discussed in the paper. The successful management of the Gulf of Riga and the Bothnian Sea herring in the recent period indicate that the assessment and management of natural stock units of the Baltic herring can be achievable.

Keywords: Baltic herring, stock diversity, growth, sprat, assessment, management

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1. Introduction

Besides to the long- term sustainable management of fish recourses, maintaining the infra-specific diversity should be one of the main goals in the sustainable management of fish species, forming many local stocks (populations), (Stephenson et al., 2001). Therefore, following the pattern of natural stock units (populations) should be desirable in sustainable assessment and management

The Baltic herring (*Clupea harengus membras* L.) follow the suit of ocean herrings, showing remarkable geographical variability. The local stocks (up to 10-12 (Ojaveer, 1988)) showing differences in morphology, growth pattern and stock dynamics. The results of historical tagging experiments catch structure observations and international acoustic surveys are the main source of information on spatial and temporal distribution pattern of herring in the Baltic (e.g. Otterlind, 1961, Aro, 1989.and others). The results have indicated a considerable amount of spatial and temporal mixing of herring of herring particularly during the feeding period in the open sea area. However, the rate of mixing is mostly not clearly known. That makes separation of different stocks in assessment and management purposes problematic. Evan if the mixing rate were known, there

is no agreement considering the mixing rate limits in order to define separate assessment units. The lack of a comprehensive and simple working methodology for routine discrimination of herring from different populations has been another serious obstacle.

The international assessment and management of herring in the Baltic Sea started in early 1970s, when in its first report the Working Group on Assessment of Pelagic Stocks in the Baltic (ICES, 1974) considered the state of Baltic herring and sprat stocks by various areas or subdivisions, and proposed in its 1975 report (ICES, 1975,2001) four management units of the Baltic herring:

- Sd 22, 23, 24, 25 and 26
- Sd 27, 28 and 29S
- Sd 30, 31 and 29N
- Sd 32.

Later, both assessment and management units have been changed in several occasions, reflecting developments in compromises between the desire to follow the "natural" stock units and various practical considerations in assessment and management process. However, the assessment and management units matched in a few cases only. On the background of methodological difficulties described above, most of the former assessment units were combined into one big Central Baltic herring (Sd. 25-29&32) in 1990 (ICES, 1990).
In most recent period, the herring in the Baltic Sea has been assessed in 5 assessment units:

- Sd 22-24
- Sd 25-29&32 excl. Gulf of Riga
- Gulf of Riga
- Sd 30
- Sd 31

while, the management considered three management units:

- Sd 22–29S and 32 (excl. Gulf of Riga),
- Gulf of Riga,
- Sd 29N, 30 and 31

The management units were changed for four in 2005, resulting in spatial matching of three assessment and management units (Sd 22-24, Sd 25-29, 32 (excl. Gulf of Riga), and the Gulf of Riga herring) (Figure 1):

- Sd 22-24,
- Sd 25-29, 32 (excl. Gulf of Riga),
- Gulf of Riga
- Sd 30, 31.

The successful assessment and management of several local stocks in recent years have served as a background for those changes.
Below an overview of developments in gulf and open sea stocks during the recent decades is presented with special emphasize on the Gulf of Riga herring. The most of data used in the paper were derived from the reports of the ICES.

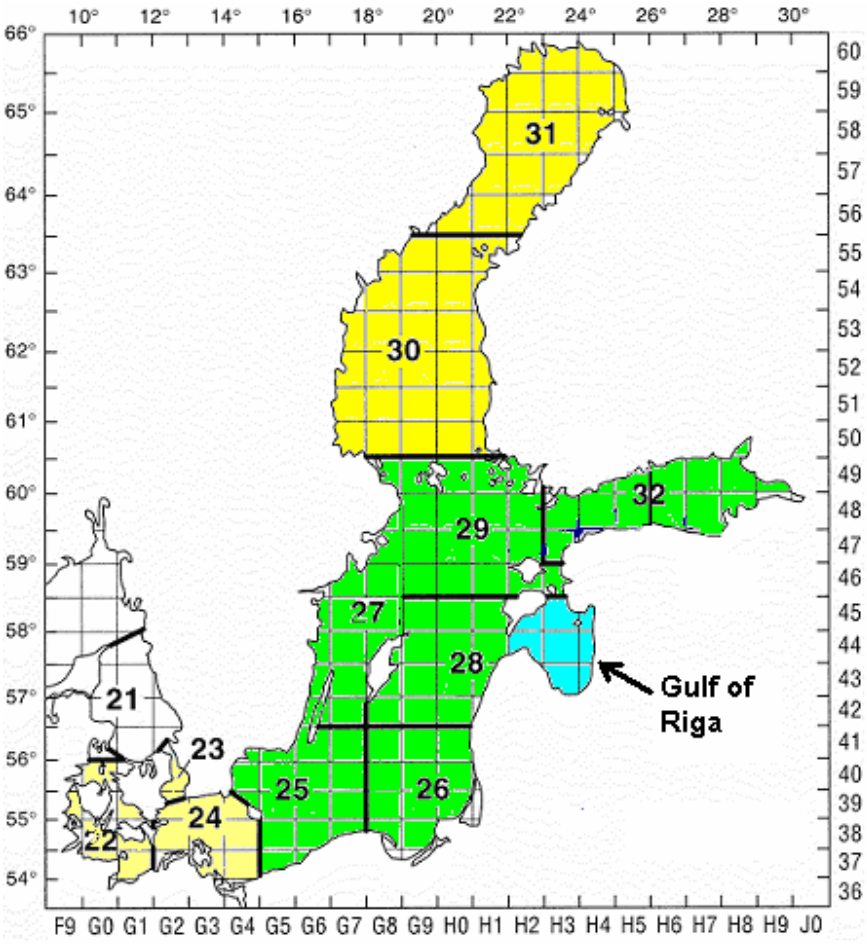


Figure 1. Management units of the Baltic herring.

2. Baltic herring: gulf stocks and the open sea stocks

In broader scale, all local herring populations inhabiting the Baltic Sea can be divided as open sea herrings and the gulf herrings (Gulf of Riga herring, Gulf of Finland herring and the Bothnian Sea and Bothnian Bay herring). The gulf herrings spend all year in the big gulfs, while open sea stocks perform annual migrations between spawning grounds often located in then same gulfs and feeding/wintering areas, located in the Baltic Proper. Such a migrations have been well documented by the tagging experiments; catch structure and results of morphometric analyses (e.g. Aro, 1989, Aro et al., 1990, Ojaveer, 1988, Parmanne, 1990, Parmanne et al., 1997).
The Gulf of Riga herring, the Gulf of Bothnia herring and the Bothnian Sea herring are treated as separate assessment units at present, while the Gulf of Finland stock, also assessed separately in former years, was merged with the rest of open sea herrings as a Central Baltic herring (Sd. 25-29&32incl.) stock since 1990. However, the information collected on the biology of the Gulf of Riga herring allowed to start its treating again as a separate assessment unit in the 1990s.

The open sea and gulf stocks are affected by different environmental conditions both in terms of non-biotic and biotic factors. The resulting morphological differences provide tools for discrimination between the gulf and open sea stocks.

3. The Gulf of Riga herring – a good example for separate assessment of natural population.
Gulf of Riga herring is a local population of the Baltic herring inhabiting in the Gulf of Riga (Sub-division 28). It is a slow-growing herring with one of the smallest mean length and weight at age

in the Baltic and thus considerably differing from the neighboring herring stock in the Baltic Proper (Subdivisions 25-29). The stock does not perform migrations into the Baltic Proper; only minor part of the older herring leaves the gulf after spawning season in summer –autumn period but afterwards returns to the gulf. The extent of this migration depends on the stock size and the feeding conditions in the Gulf of Riga. In 1970s and 1980s when the stock was on a low level the amount of migrating fishes was considered negligible.
Herring fishery in the Gulf of Riga has been performed by Estonia and Latvia, using both trawls and trap-nets.
The stock was assessed as separate assessment unit up to 1990 and then (like the Gulf of Finland herring), included to the Central Baltic herring stock. However, the obvious differences between the gulf stock and the open sea stock encouraged to start separate analytical assessments of that stock again in 1994.

3.1. Method used for discrimination between the Gulf of Riga and open sea herrings.

Otoliths (*sagitta*) have been widely used not only age determination, but also as a tool for discrimination of different herring groups (e.g. Kompowski, 1969, Ojaveer et al., 1981) Discrimination between open sea herring and Gulf of Riga herring is also based on the different otolith structure due to different feeding conditions in the open sea and in the gulf. In the Gulf of Riga the feeding season is usually shorter due to longer ice cover and lower water temperatures in spring and autumn. After severe winters the feeding conditions in the Gulf of Riga are especially unfavorable that reflects in the formation of transition zones on otoliths. Transition zones in are narrower and darker than usual annual growth in zones.The dark pattern of the of the annual zone of the bad feeding year is usually continued in the next years. The differences in annual growth zone pattern can be seen in the Figure 2, showing otoliths of gulf and open sea herring at age 5, both sampled in the spring 2005. The last transition zone in the otoliths of the Gulf of Riga herring was formed in 2003 (left panel).), while in the otoliths of open sea herring no transition zone is visible in 2003 (right panel).

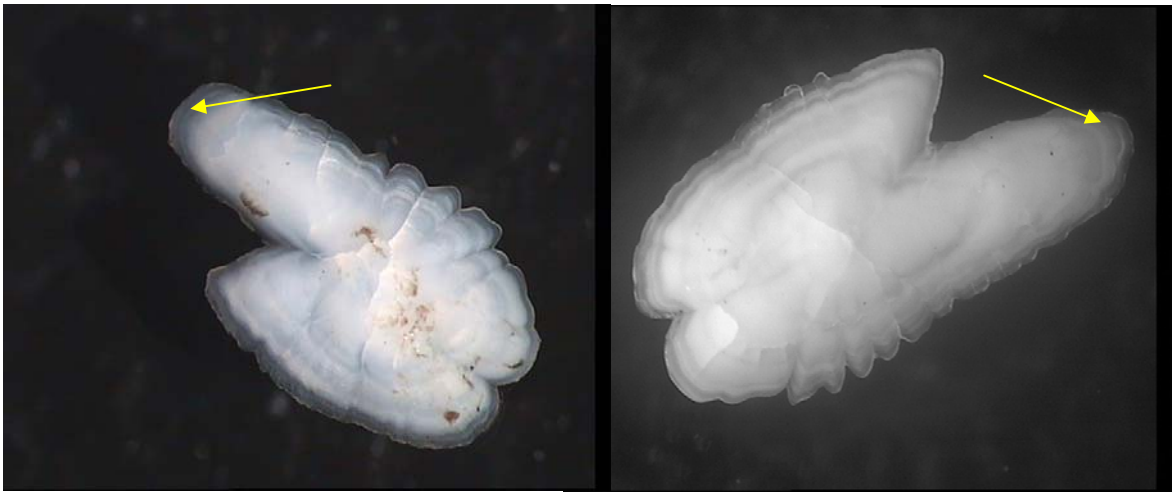


Figure 2.Otoliths of the gulf herring (left) and open sea herring (right), both age 5, sampled in spring 2005. Arrows show the growth zone of 2003.

Since the differences in growth pattern can be easily detected during the routine ageing. The method allows fast discrimination between the gulf and open sea populations and their separate assessment.

3.2. Data and the assessments of the Gulf of Riga herring.

Data from the quarterly catches of Gulf herring from Estonian and Latvian trawl and trap-net fishery is compiled to get the annual catch in numbers as well as catch/stock weights and other input parameters for XSA.

Two **tuning fleets** are available for XSA: from trap-net fishery (1984-2004) which was used for tuning XSA in the previous years and from joint Estonian-Latvian hydro-acoustic survey in the Gulf of Riga which is carried out in the end of July-beginning of August since 1999. The limited area ang good configuration of the Gulf of Riga allow fast and complete coverage of the Gulf by the acoustic surveys (Figure 3) what therefore

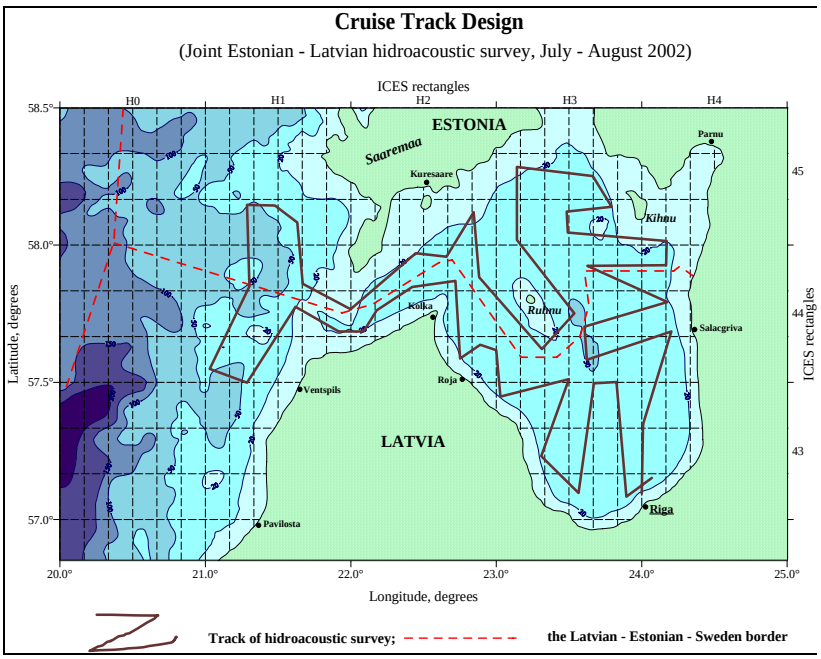
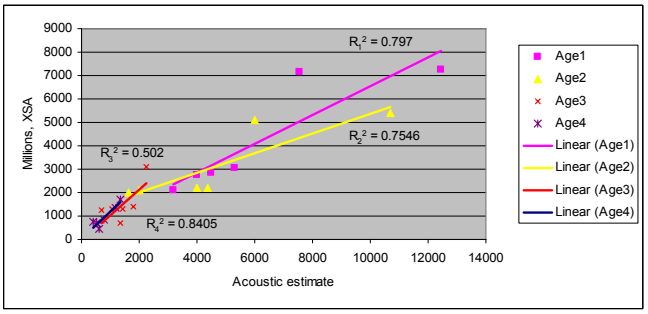


Figure 3. Cruise track of Estonian-Latvian acoustic survey in the Gulf of Riga (July, 2002)

have proved to be very efficient source of catch-independent abundance estimates, showing satisfactory coherence with the XSA estimates, particularly in the younger age groups (Figure 4).



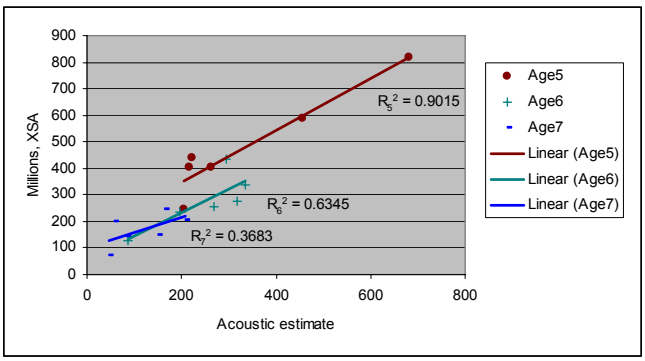


Figure 4. Gulf of Riga herring: abundance estimates in age groups 1-7 from acoustic survey and XSA.

The **recruitment estimates** for short-term predictions are obtained using the temperature and zooplankton data. It has been found, that the values of mean water temperature in April and abundance of zooplankton in May significantly influence the year -class abundance of gulf herring (Figure 5). It is considered that year-class strength of the Gulf of Riga herring is strongly influenced by the severity of winter, which determines the water temperature, and abundance of zooplankton in spring. A series of mild winters since 1989 has been favorable for the reproduction of Gulf herring and resulted in a row of rich year classes for the period 1989-2003, only the year classes 1996 and 2003 were below the average level. One could expect the similar relations also in case of other gulf stocks, particularly in the Northern Baltic. The described relations are used in order to obtain the Gulf of Riga herring recruitment estimates for short-term forecast.

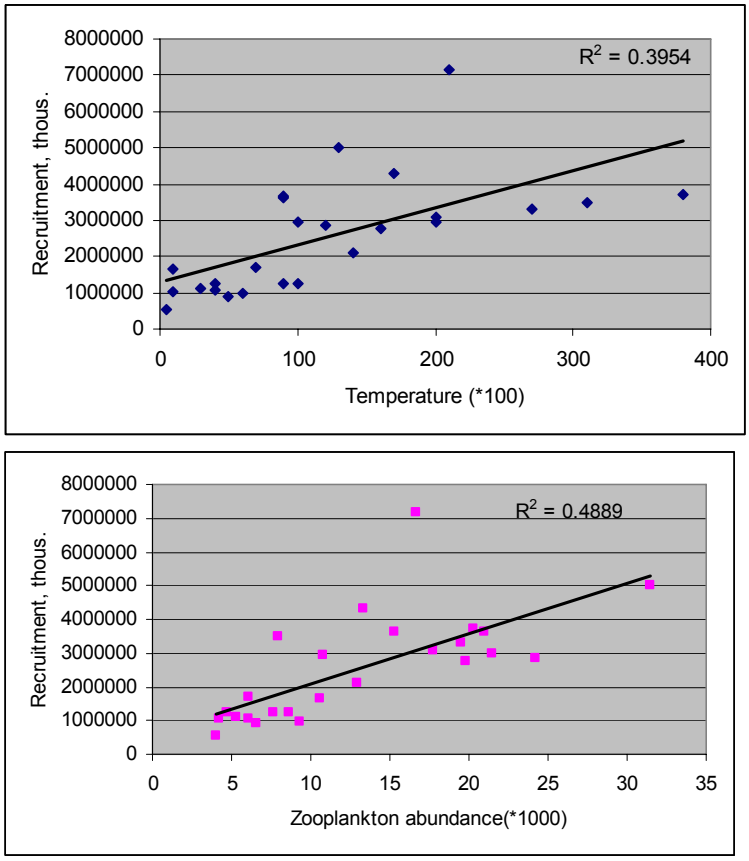


Figure 5. Recruitment of the Gulf of Riga herring, plotted against mean water temperature in April and zooplankton abundance in May (1977-2001)

The **assessment results of the Gulf of Riga herring have been** rather stable and consistent with previous assessments (differences <5% in recent years, ICES, 2005).

Besides to the TAC regulation, the Estonian and Latvian Authorities have enforced a number of **regulatory measures** in the Gulf of Riga herring fishery in order to protect the stock (1- month ban for trawl fishery in the beginning of spawning season, 3-month summer ban for trawl fishery (Estonia), maximum allowed engine power etc.)

The quality of input data and the successful trial assessments from 1994-1998 have allowed re-establishing the Gulf of Riga herring as an assessment unit from 1999 and as a management unit since 2005. Moreover, information obtained from the separate assessments of the gulf populations in

the Northern Baltic have allowed to reveal a few different trends in the Baltic herring populations during the recent decades.

4. General developments in main Central and Northern Baltic herring stocks in the 1980- 2000s.

4.1. Dynamics of biological parameters

The results of separate assessment have shown quite a different dynamics in basic biological stock parameters between the combined open sea stock and the gulf stocks of the Northern Baltic during the past decades, indicating probably different response to the environmental factors and possibly also to the different assessment/management problems.

The spawning stock biomass (SSB) of **Central Baltic herring** (ICES Sub-divisions 25-29&32 excl. Gulf of Riga), decreased almost continuously (by app. 70%) since 1980s up to the most recent years, while the SSB of the **Bothnian Sea and the Gulf of Riga herring** more than doubled during the same period (Figure 6). The less pronounced decrease in the open sea herring abundance may indicate that the drop in mean weights at age, observed all over the Baltic during the same period, and being particularly abrupt in case of the open sea stocks can probably explain part of that dramatic decrease (Figure 7)
However, the conflicting dynamics in gulf and open sea stocks has been obvious.

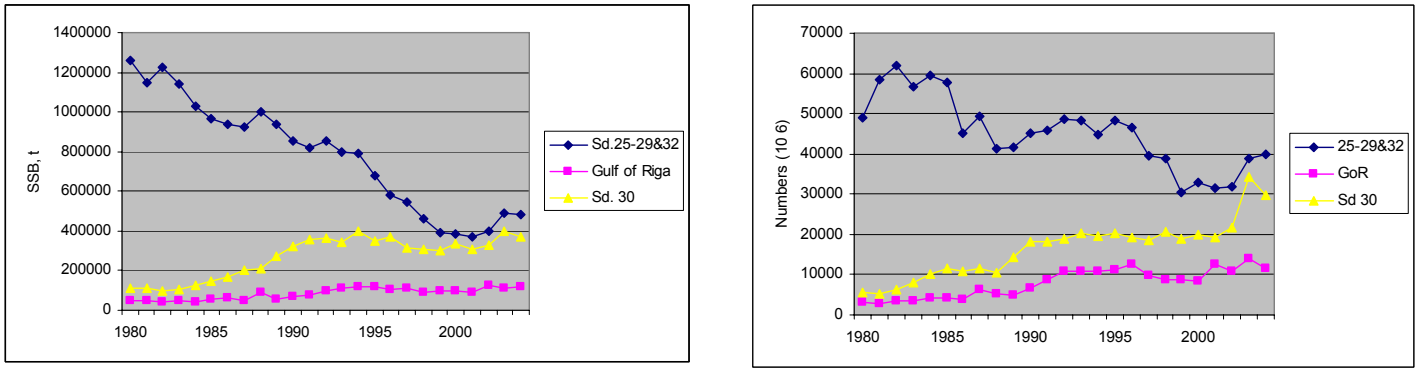


Figure 6. Developments in SSB (left panel) and abundance (right panel) of herring in Sd. 25-29&32 (excl. Gulf of Riga), the Gulf of Riga herring and the Bothnian Sea herring (Sd. 30) in 1980-2004 (ICES, 2005).

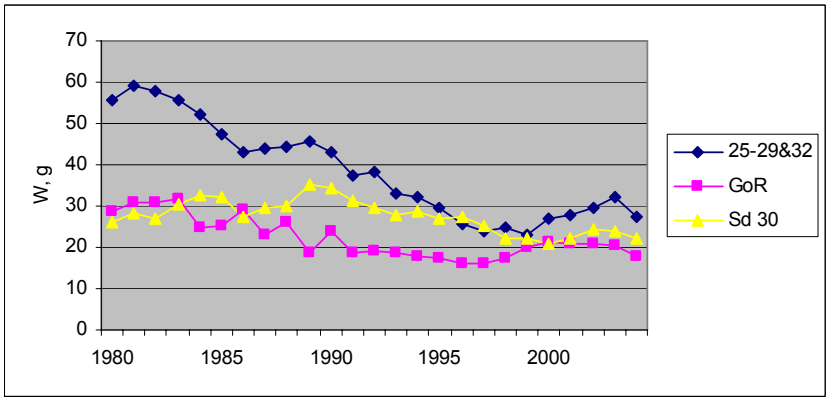


Figure 7. Dynamics in mean weight in age groups 2-5 of herring in Sd. 25-29&32 (excl. Gulf of Riga), the Gulf of Riga herring and the Bothnian Sea herring (Sd. 30) in 1980-2004 (ICES, 2005).

The fishing mortality has generally shown similar pattern in all stocks (higher values in mid-1980s and in late 1990s, however, the level has been different. So the fishing mortality rate fluctuated on relatively low level (between 0.1-0.2 while the Central Baltic herring and the Gulf of Riga herring, in particular, have sustained clearly higher values (Figure 8). The above indicates that main background for different dynamics in the gulf and open sea stocks might be in the different conditions, necessary for formation of the abundant year-class.
It has been stated that in the open sea herring populations abundant generations appear in the periods of higher salinity and intense water exchange between the Baltic and the North Sea favouring vertical mixing of water layers and up-mixing of nutrients to support high biological production and abundant stock of copepods. In the populations of gulf herrings, (e.g. the Gulf of Riga herring), spawning in the gulfs, strong year-classes are formed mainly in warm springs after mild or moderate winters with dominating westerly winds promoting rich biological production in the period of larval development and favouring their high survival (Rannak, 1971; Ojaveer, 1988; Raid, 1997; Grygiel, 1999).

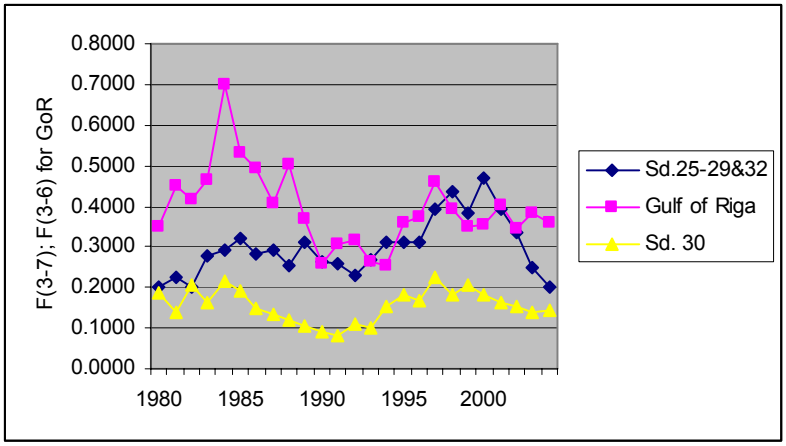


Figure 8. Dynamics of fishing mortality estimates for herring in Sd. 25-29&32 (excl. Gulf of Riga), the Gulf of Riga herring and the Bothnian Sea herring (Sd. 30) in 1980-2004 (ICES, 2005).

The Baltic Sea has been facing with extended stagnation period since the major inflows of the late 1970s. The altered salinity conditions, significantly affecting the structure of zooplankton communities, together with a series of mild winters in the Northern Baltic have favored to the year-class formation of gulf herring populations in the 1990s and 2000s. (Ojaveer, 1991, Ojaveer & Järvik, 1997).

The comparison of recruitment estimates between the Central Baltic herring and the gulf herring stocks also indicate different pattern in recruitment dynamics between the gulf and open sea stocks over the period, while the gulf stocks show relatively similar pattern. (Figure 9).

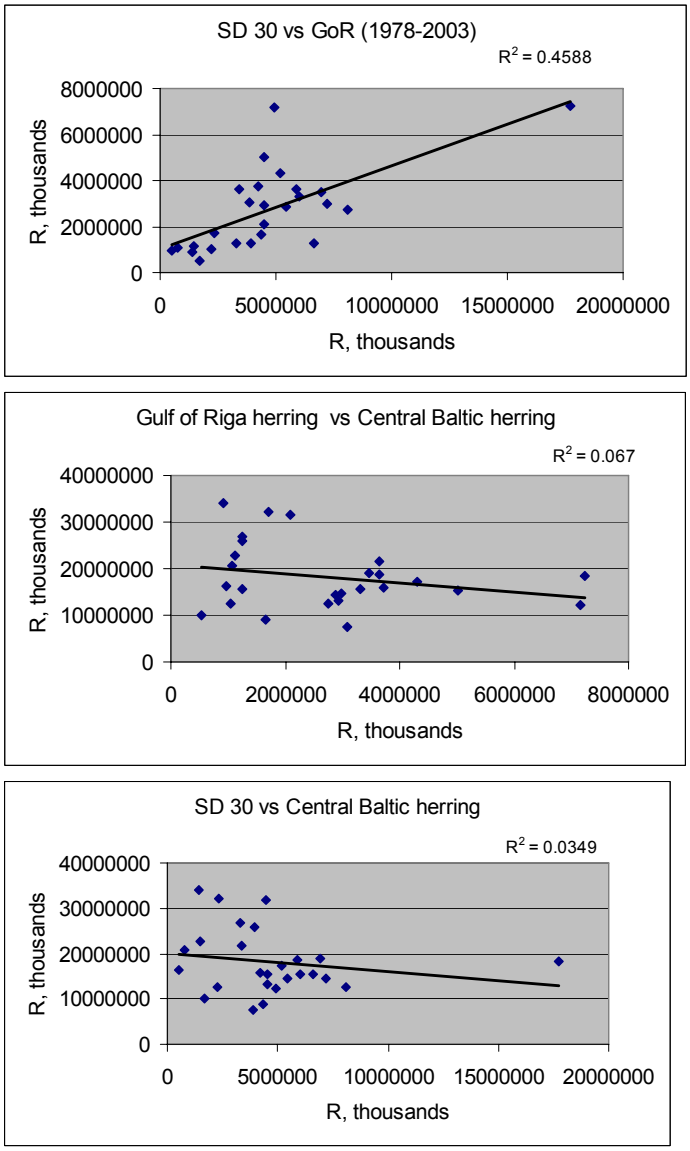


Figure 9. Comparison of recruitment estimates for herring in Sd. 25-29&32 (excl. Gulf of Riga), the Gulf of Riga herring and the Bothnian Sea herring (Sd. 30) in 1980-2004 (ICES, 2005).

4.2. Following to the fishery advice in assessment units

The following on scientific advice should be one of the basic prerequisites for sustainable management of fisheries. However, comparison of catch statistics and the catch advice show remarkably different pattern in different stock units. While the catches follow the advice rather well in the Gulf of Riga herring (1989-2004) where the differences have been less than 20%. The differences increase in case of the Bothnian Sea herring (1991-2004) mostly less than 30%. However, the differences reached almost 200 000 t or 50% in the Central Baltic herring (Figures 10). Such a differences between catch and advice clearly demonstrate that managing of fisheries according to the scientific advice could be easier in case of smaller management units.

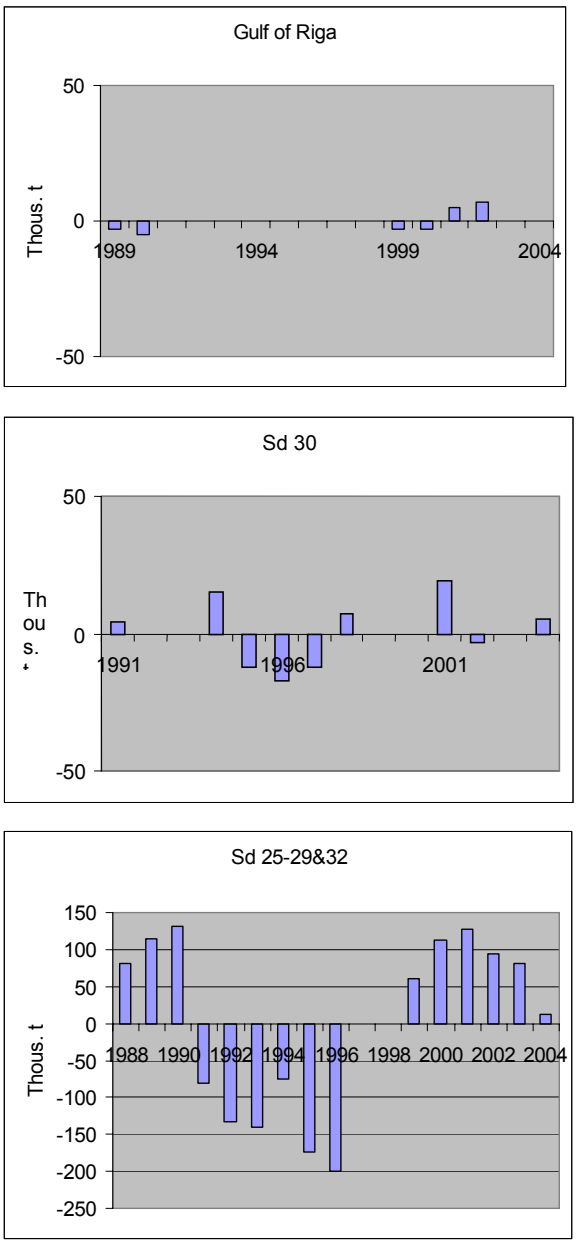


Figure 10. Differences between catch advice and the resulting catch (ICES 2005a).

Conclusion.

A successful re-establishment of the Gulf of Riga herring as a separate assessment unit has shown that following as much as possible the pattern of natural populations as a basis for assessment (and management) units of Baltic herring allows not only proper monitoring and providing forecast options of the state of the population, but enhance the effect of management measures as well.
That also suggests that further elaboration of assessment and management scheme of the Baltic herring would be most relevant.

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