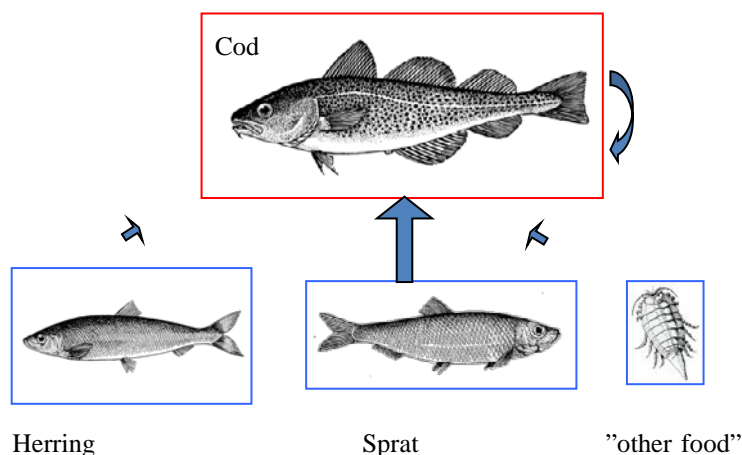


### 8.3.3

### Multispecies considerations for the central Baltic stocks: cod in Subdivisions 25–32, herring in Subdivisions 25–29 and 32, and sprat in Subdivisions 22–32

ICES intends to provide multispecies advice on fisheries for some ecosystems (see Section 1.2) and encourages managers to apply such an approach to the central Baltic Sea. The present section may serve as a starting point for a dialogue between ICES and managers to foster the development of a multispecies management system for the Baltic. This text uses implicit management objectives and risk tolerance that need to be validated by managers. If managers decide to adopt a multispecies management approach a transition period from the present management will be required. As this work is mostly illustrative, ICES focuses on the most obvious interactions between commercially exploited fish stocks in the area and does not attempt to provide a full foodweb model.



**Figure 8.3.3.1** Setup of the Baltic SMS model. Cod is the only predator, and forages on small cod, herring, sprat, and zoobenthos, which is pooled as ‘other food’.

The main result of the present multispecies analysis for the central Baltic is that, compared to the present single-species approach, it could be possible to increase the sum of the sustainable yields in tonnes of the three species combined; the growth of individual fish would be improved if multispecies interactions were taken into account when setting target  $F_s$ . However, cod yields will remain about the same, whereas the probability of low cod spawning-stock biomass (SSB) will increase. Multispecies considerations indicate a multitude of solutions, all being biologically sustainable. The societal choice between these must be based on social and economic considerations and informed by social and economic impact assessments.

These results are derived assuming that there is full spatial overlap for all three stocks. The geographical overlap of cod and clupeid stocks is currently small, with cod found mainly in the south (Subdivision 25) and clupeids in the north (Subdivisions 28–29 and 32) (Figure 8.3.3.6).

The current difference in distribution of cod and clupeids implies that:

- an increase in  $F$  on cod will not necessarily result in increasing Baltic-wide clupeid stock sizes (and hence will not increase clupeid yields);
- a reduction of clupeid  $F$  in Subdivision 25 is likely to improve growth and condition of cod as well as reduce cannibalism;
- an increase in clupeid  $F$  in northern areas (Subdivisions 27–32) is unlikely to negatively affect the major cod stock component distributed in southern areas (Subdivisions 25–26);
- an increase in sprat  $F$  in northern areas (Subdivisions 27–32) is likely to improve the growth rates of the clupeid stocks; and
- an increase in cod  $F$  may imply higher probability of low cod SSB.

The values of presented reference points can change in the near future since there are many process functions in the species dynamics, both in terms of population numbers, spatial distributions, and body growth, which have not been

sufficiently evaluated. The MSY reference points are sensitive to changes in density-dependent effects, cannibalism, and environmental drivers that affect recruitment and body growth.

The single- and multispecies  $F_{MSY}$  are similar, though  $B_{MSY}$  of cod may vary by up to a factor 1.74 (Table 8.3.3.1). This difference is mainly due to cod cannibalism taken into account in the multispecies model.

It should be noted when examining  $F_{MSYS}$  that no value of  $F_{MSY}$  can be considered precautionary until a formal harvest control rule has been evaluated in a management strategy evaluation framework

**Table 8.3.3.1** MSY reference points from the SMS mode and as used in the single species advice. The “~” in front of the MSY values means “around” as no fixed value for the reference points exist in a multispecies context.

	$F_{MSY}$			MSY (yield)			$B_{MSY}$		
	Cod	Herring	Sprat	Cod	Herring	Sprat	Cod	Herring	Sprat
Multispecies advice (SMS)	~0.55	~0.3	~0.3	~77	~178	~225	~200	~730	~1000
Single-stock advice	0.46	0.26	0.29	-	170	180	115	617	655

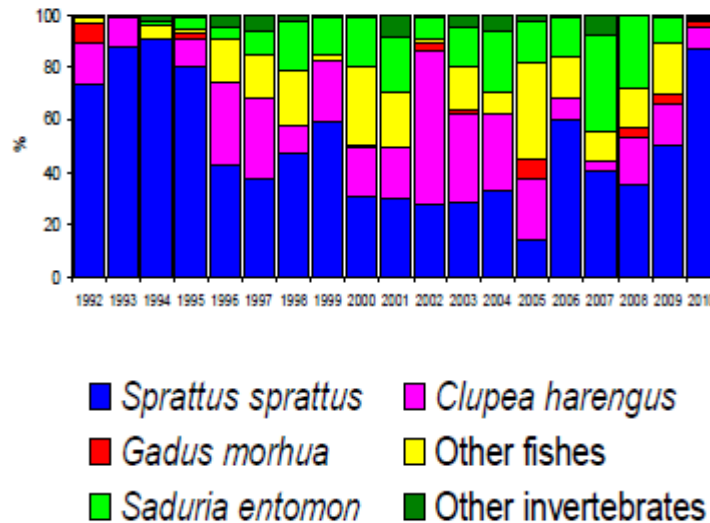
Management of fisheries for cod has an impact on fishing opportunities for sprat and herring, and vice versa; management of the clupeid fisheries influences the food availability for cod, and thereby indirectly cod yield. If the cod stock is large, the yield of herring and sprat will be reduced. Spatial management of the herring and sprat fisheries may influence the growth of individual fish of cod and possibly also on clupeids, and thus the potential yield

## Background

Extensive multispecies and ecosystem research has been performed in the Baltic in the past 30 years. ICES, together with several institutes around the Baltic, has invested substantially in the research on multispecies interactions, ecosystem functioning, and integrated assessment. Currently, several multispecies and ecosystem models exist for the Baltic Sea (for an overview cf. ICES, 2009a). One of them, the stochastic multispecies model (SMS), was chosen for a more detailed scrutiny in 2012 by ICES in cooperation with the EU STECF (ICES, 2012a, 2012b). The MSI-SOM (Holmgren *et al.*, 2012) was also presented during the ICES Benchmark Workshop on Baltic Multispecies (WKBALT 2013) as a complementary model. However, as this model has not yet been benchmarked by ICES, the results are not presented as basis for advice, but model results are available (ICES, 2013).

In 2012 a “Study on stomach content of fish to support the assessment of good environmental status of marine food webs and the prediction of MSY after stock restoration” was funded by EU to run until November 2014. Sampling has been started on BITS surveys.

The three stocks considered are cod in Subdivisions 25–32, herring in Subdivisions 25–29 and 32 (excl. Gulf of Riga), and sprat in Subdivisions 22–32. Cod is a predator on herring, sprat, and juvenile cod (Figure 8.3.3.1). This predation by cod forms the main interactions among these stocks and is the only type of interaction considered in the quantitative analysis (SMS) below.



**Figure 8.3.3.2** Cod stomach content, by prey item, of cod caught in Subdivision 26 in March 1992–2010 (from Patokina *et al.*, 2011).

There are also other aspects of interactions related to these three stocks which are presently not included in the SMS model, the most important being: 1) the variation in spatial overlap between the three stocks, 2) inter- and intraspecific competition for food between and within the two clupeid stocks, 3) cod growth in relation to amount of food available, and 4) herring and sprat predation on cod eggs and clupeid food competition with cod larvae.

### Results of the SMS model

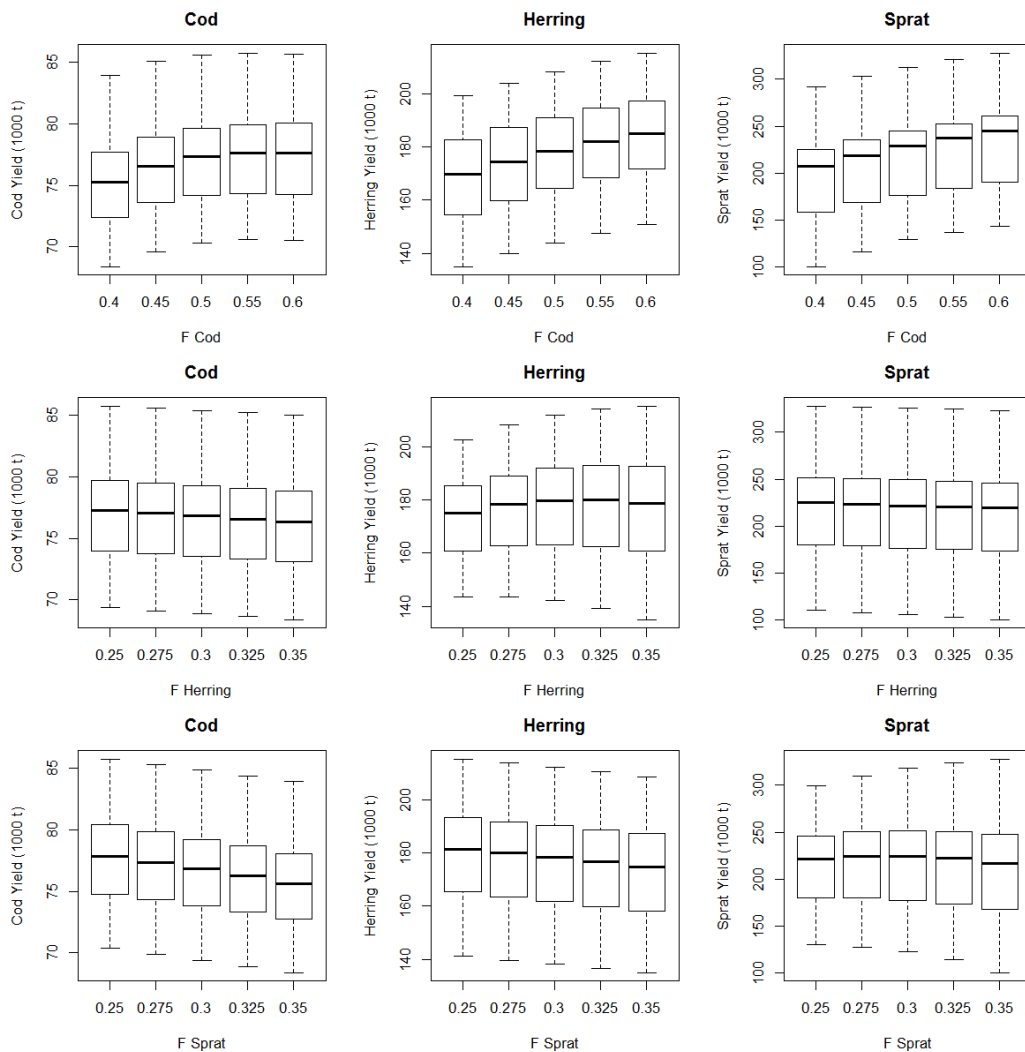
#### *Multispecies $F_{MSY}$*

Figure 8.3.3.2 presents the main results of the SMS model updated and reviewed at the ICES Workshop on Baltic Multispecies (WKMULTBAL) in 2012 (ICES, 2012a) and presented in WKBALT in 2013 with updates of data from the benchmark. For more specific model settings please look at WKBALT 2013 (ICES, 2013).

Each column in Figure 8.3.3.2 represents the effect of varying target fishing mortality on all species in turn on yields of a specific species. Thus, the right column depicts the yield of sprat on the y-axis under different target fishing mortalities on cod (top), herring (middle), and sprat (bottom) on the x-axis. Solid black lines represent the median yield at the given target fishing mortality across all combinations of target F on other species. Boxes represent the range of yields derived when excluding the bottom 25% and the top 25% ranked yields. Whiskers represent the range of yields derived when excluding the bottom 5% and the top 5% ranked yields. A wide box and whiskers implies that the yield of that species is heavily influenced by fishing pressure on species other than the one depicted on the x-axis. In contrast a narrow range suggests that the yield is relatively insensitive to variations in fishing pressure on species other than that on the x-axis.

For example, the median yield at a target fishing mortality of 0.5 for cod across all included combinations of target F for herring and sprat is 77 000 tonnes of cod, 170 000 tonnes of herring, and 225 000 tonnes of sprat. The ranges of yields derived, with the bottom 25% and top 25% ranked yield (the boxes) and selecting a target fishing mortality for cod of 0.5, are 74 000 to 79 000 tonnes for cod, 160 000 to 190 000 tonnes for herring, and 170 000 to 230 000 tonnes for sprat. The narrow range of variation for cod under cod fishing pressure (top left, box covers the median +/-4% at F = 0.5) indicates that cod yield is relatively insensitive to fishing pressure on the other species. Conversely, the wider variation for herring under changes in herring F (centre plot, box covers the median +/-8% at F = 0.25) indicates that yield for this species is sensitive to fishing pressure on the other species.

The elements in the diagonal from the top left corner to the bottom right corner are similar to the way yield as a function of target F is represented in single-species advice. Hence, they represent the change in yield of the specific species that we can obtain by changing the target fishing mortality on that species. Off-diagonal elements represent the effects of species interaction. For example, the change in median yield of herring as cod target fishing mortality is increased shows the effect of the resulting lower cod stock, which then eats less herring, resulting in higher average yields of herring. Furthermore, the change in mean yield of cod as sprat target fishing mortality is increased shows the effect of the resulting lower sprat stock, which leads cod to eating less sprat and more cod, resulting in lower average yields of cod.



**Figure 8.3.3.3** Equilibrium yield simulated in SMS for various levels of fishing mortality for cod (0.4 to 0.6, 0.05 increment), herring F (0.25 to 0.35, 0.025 increment), and sprat F (0.25 to 0.35, 0.025 increment). The graph by species shows the distribution of yields for any given F shown on the X-axis, taking into account the range of Fs for the other species. F values is when recruitment is stochastic. HCR = Fixed F.

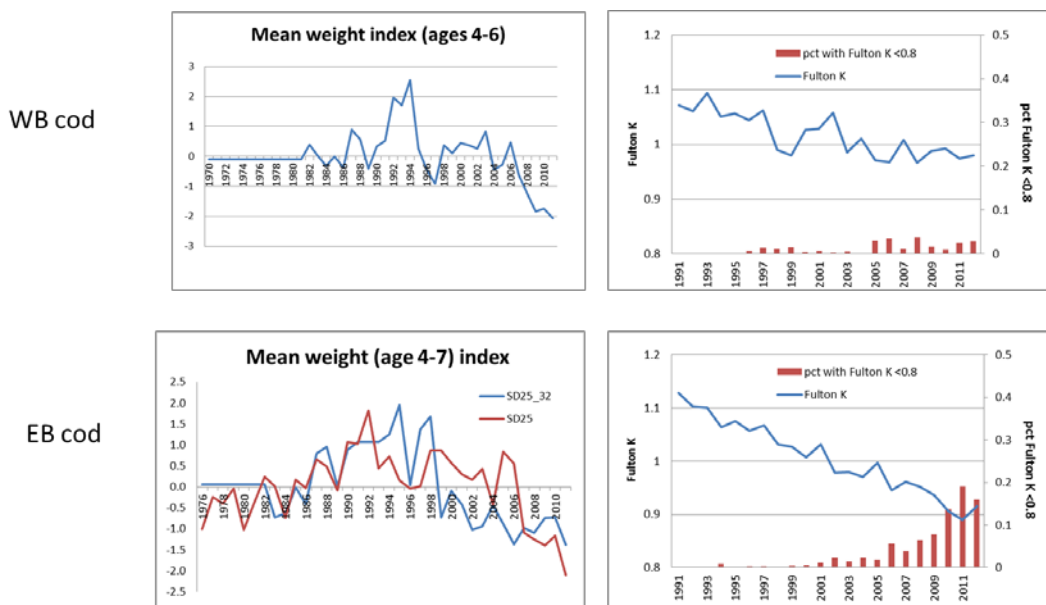
### Additional considerations

#### *Condition and weight at age of assessed species*

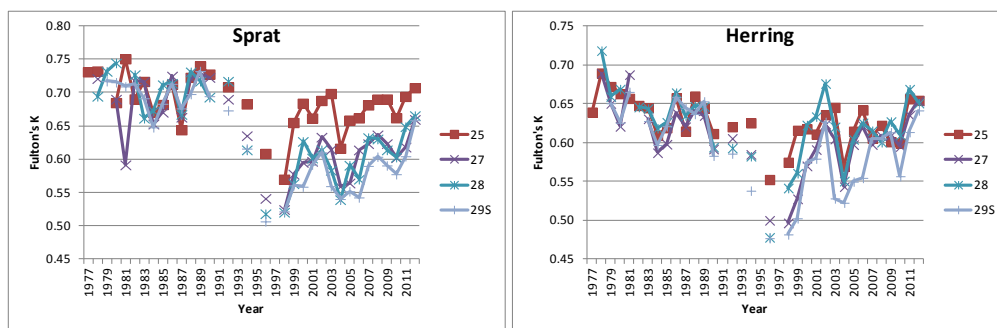
The mean weight for older age groups of cod has drastically declined since 2007 in the western Baltic Sea and in Subdivision 25; i.e. the main distribution area for cod in the eastern Baltic Sea (Fig. 8.3.3.4). In the eastern Baltic Sea, the decline in mean weight is accompanied by a substantial increase in the proportion of cod at poor condition (the Fulton condition index (K) with  $K < 0.8$ ). The decline in condition is less pronounced in the western Baltic cod, despite the larger reduction in mean weight-at-age. The sharp decline in mean weight without a corresponding reduction in condition in the western Baltic Sea may be due to the effect of increased proportion of eastern Baltic cod in the western Baltic Sea, due to density dependence and food limitation of cod in the Bornholm Basin.

Indicators of mean weight-at-age and condition (Fulton's K) were calculated also for sprat and herring, in different subdivisions (Figure 8.3.3.5). Sprat condition was very similar and high in all the subdivisions in the 1970s–1980s. Since the early 1990s, sprat condition has decreased concomitant with an increase in sprat stock size. The decrease was mostly pronounced in the northern subdivisions (Subdivisions 27–29), where the stock increased the most. After the mid-1990s, condition oscillated, with a general increasing tendency. These spatio-temporal patterns in sprat condition are inversely related to the spatio-temporal patterns in the sprat stock, suggesting that density dependence mediated by competition could be the main causes of the variations in condition (Casini *et al.*, 2011). Herring condition showed spatio-temporal patterns similar to sprat, although the decrease began already in the early 1980s. Moreover, for herring, the most evident changes in condition were in Subdivision 29. A combination of inter-specific competition with sprat

and changes in salinity seems to explain the spatio-temporal changes in herring condition (Casini *et al.*, 2011; Holmgren *et al.*, 2012).

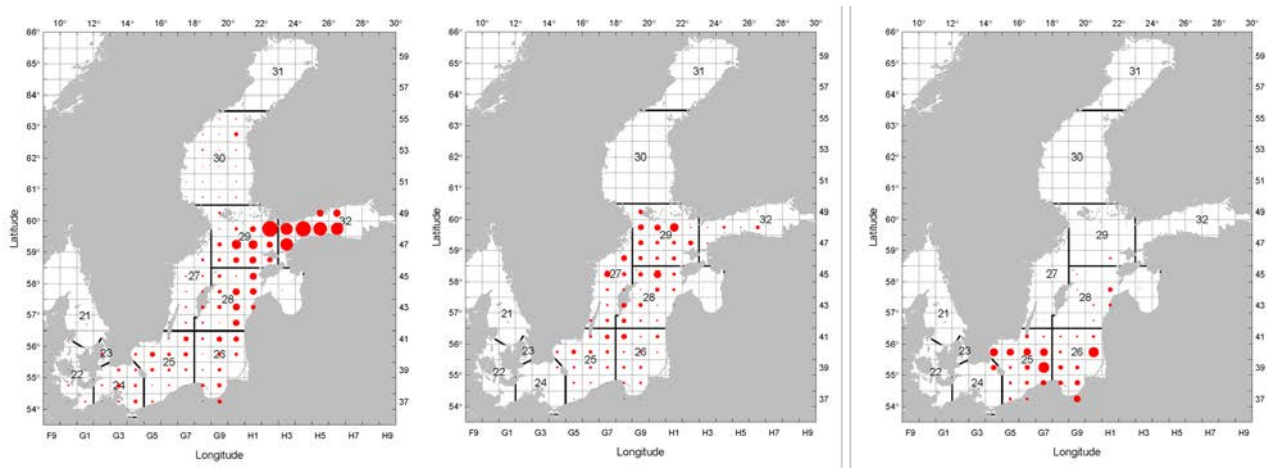


**Figure 8.3.3.4** Mean weight of cod in the western (upper left panel) and eastern (lower left panel) Baltic cod (standardized and combined for ages 4+). For the eastern Baltic cod, the weight is shown separately for Subdivision 25 and for the entire stock area (Subdivisions 25–32). Right panels show mean condition factor (Fulton K) for 40–60 cm cod and the proportion of cod at poor condition (Fulton K < 0.8) for the two stocks.



**Figure 8.3.3.5** Mean condition of sprat (lengths 120–130 mm) and herring (lengths 180–200 mm) by subdivision, from autumn acoustic surveys (BIAS).

### Spatial distributions of cod and clupeids



**Figure 8.3.3.6** Spatial distribution of Baltic sprat from the acoustic survey (BIAS) in the 4th quarter in 2012 (in Subdivisions 22–30; left panel); herring in Subdivisions 25 to 29 and 32, excluding the Gulf of Riga from the BIAS survey (BIAS) in the 4th quarter in 2012 (in Subdivisions 25–29 and 32; middle panel); eastern Baltic Sea cod (Subdivisions 25–32) from the bottom trawl survey (BITS) in the 4th quarter in 2012 (in Subdivisions 25–29 South; right panel).

The combination of an increasing cod stock and low abundance of sprat and herring in Subdivision 25 (in the main distribution area of cod) has resulted in the lowest biomass of clupeids currently available in this area since the 1970s. Consistent with the low biomass of clupeids in the area and thus low amount of food for cod, the mean weight of older cod (age groups 4–7) in Subdivision 25 has sharply declined since 2007 (see advice on cod in Subdivisions 25–32, Section 8.4.3).

Currently, it is assumed in the SMS model that the overlap between cod and clupeids is taken as the mean for the whole area, and that the overlap remains unchanged during the model period. In contrast, at present the overlap between cod and clupeids is limited to Subdivisions 25 and 26, with almost no overlap between cod and clupeids in the northeastern areas (Subdivisions 27–32).

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