ICES WKBALTCOD REPORT 2015

ICES ADVISORY COMMITTEE

ICES CM 2015/ACOM:35

REF. ACOM

Report of the Benchmark Workshop on Baltic Cod Stocks (WKBALTCOD)

2–6 March 2015

Rostock, Germany

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2015. Report of the Benchmark Workshop on Baltic Cod Stocks (WKBALTCOD), 2–6 March 2015, Rostock, Germany. ICES CM 2015/ACOM:35. 172 pp.

Contents

Executive summary

The ICES Benchmark Workshop on Baltic Cod Stocks (WKBALTCOD), chaired by External Chair Jean-Jacques Maguire, Canada and ICES Chair Marie Storr-Paulsen, Denmark, and attended by two invited external experts Verena Trenkel, France and Meaghan Bryan, USA met in Rostock, Germany, 2–6 March 2015 with 39 participants and six countries represented. The objective of WKBALTCOD was to evaluate the appropriateness of data and methods to determine stock status and investigate methods appropriate to use in the single-stock assessment for the cod stock in SD 22–24 and cod in SD 25–32 in the Baltic. Participants in the workshop were a large group with diverse backgrounds representing the industry, fisheries, NGOs, managers and scientists.

The single-stock analytic assessment of the eastern Baltic stock was not accepted by the assessment working group (WGBFAS) in 2014 due to severe problems with the input data. The advice for the eastern Baltic cod was, therefore, based on the ICES approach for data-limited stocks. As an outcome ICES decided to establish a benchmark for both cod stocks and to scope an integrated assessment for the Baltic cod stocks. The first meeting (WKSIBCA) was therefore meant to introduce the intercessional work conducted since the assessment working group in April 2014, and to reach some conclusions on how to proceed both in the short term (Benchmark in March 2015) and longer term (2–3 years) and was seen as a data compilation workshop, there is produced a separate report from this workshop. The WKBALTCOD was the 2nd meeting in the benchmark process and was intended to come up with a final stock assessment method, stock annex and input data for both stocks. As it was not possible to reach conclusive decision on the final model to be used for the east Baltic cod stock during the benchmark meeting and as more work on the preferable models was needed, it was decided by the ACOM leadership to prolong the benchmark process until the assessment working group meeting in April 2015. This decision has led to a relatively long process partly mixed with the assessment working group WGBFAS.

It became clear during the benchmark process that although large effort has been put into explaining the underlying processes leading to the changes in the Baltic ecosystem, there is still some lack of understanding of the present situation in the eastern Baltic cod stock. Therefore, it was not possible to reach firm conclusions on the final model to be used and therefore not possible to set reference points. It was decided to continue to explore the most promising models and to continue to improve the input data until the assessment working group started in April.

The main challenges still to be solved for the Eastern Baltic cod stock is the quantification of increased natural mortality and decrease in growth. Through several presentations during the workshop (both WKSIBCA and WKBALTCOD) it became clear that natural mortality very likely has increased in later years, due to decreased condition and increased parasite infection. A decrease in growth also seems plausible duo to a decrease in condition and/or selectivity-induced mortality of the largest individuals. However, as none of these parameters are easily estimated, especially with the severe ageing problems, different model assumptions made the output very shaky.

For the western Baltic cod, stock identification issues were examined in area SD 24, the intermediate area: based on otolith characteristics and genetics. Due to the results showing a large proportion of east cod in this area, it was decided to split the catch

and survey from SD 24 into either the western or eastern Baltic cod stock. It was possible to derive proportions of eastern and western cod in SD 24 back to the mid-1990s.

For the western Baltic cod stock a modelled survey indices was included in the assessment covering the western part of SD 24 and Area 22+23 and based on a smoothed ALK.

Both cod stocks have in the past used commercial tuning fleet to have a better covered of older age groups. It was decided to abound this time-series duo quality issues such as a limited coverage and problems with technical creeping.

WKBALTCOD was not able to explore and define reference points for the Western Baltic cod stock during the meeting due to time constraints, but these were calculated and decided by correspondence after the meeting. The recent protocols on estimation procedures developed by WKMSYREF3 for stocks with a full analytical assessment and for data-limited stocks served as objective guidelines to obtain reference point estimates.

1 Benchmark process

The meeting was opened March 2nd at 10 am by Director Dr Christopher Zimmermann from the Thünen Institute of Baltic Sea Fisheries (OF) in Rostock, Germany. Participants were hereafter introduced. The chairs went through the ToRs, explained the role of the participants and the expected outcome of the meeting. The agenda was adopted and the list of participants and the agenda are presented in Annexes 1 and 2, respectively.

The single-stock analytic assessment of the eastern Baltic stock was not accepted in the 2014 assessment working group (WGBFAS) due to severe problems with the input data. The advice for the eastern Baltic cod was, therefore, based on the ICES approach for data-limited stocks. As an outcome ICES decided to establish a benchmark for both cod stocks and to scope an integrated assessment for the Baltic cod stocks. WKSIBCA was therefore conducted in October 2014 to introduce the intercessional work conducted since the assessment working group in April 2014 and to reach some conclusions on how to proceed both in the short term, Benchmark in March 2015, and longer term (2–3 years). WKSIBCA was also perceived as a data compilation workshop before the benchmark and a separate report is available from this workshop.

The age of Baltic cod is at present determined by the traditional method of annual ring interpretation. It is well known that this method is not an optimal method for the Eastern Baltic cod stock since no clear annual rings are deposited. Severe inconsistencies in age readings between readers and institutes have existed since the beginning of age determination for this stock. A wide range of less subjective methods has been evaluated. Although some attempts do look promising, it has been impossible to implement these without proper validation with an appropriate "known-age" sample. During the WGBFAS (2014) it was realized that the ageing problems had increased and that there were more severe differences between countries in the length-at-age data than previously. The problem was reviewed and presented in WKSIBCA (2014) based on new otolith exchanges. The result from these exchanges suggested that there was a large bias in the age reading and that none of the participating countries were precise, although Sweden was the country with less bias in the readings, although only for young fish as no known age fish above age 3 were available.

Main outputs from the data compilation WKSIBCA workshop were;

1) Analysis of an otolith exchange showed that traditional age reading of the eastern cod stock is subject to substantial bias leading to low accuracy and precision (SD 24–32). A review process was recommended and should take place before the benchmark to draw conclusions if the current age reading should be abandoned.

2) Analysis for alternative assessment independent of age readings should be carried out simultaneously. A data call on historic length-based data (2000–2013) was recommended to be sent out before the benchmark, and as soon as possible after WKSIBCA, to be able to compare length and age-based assessment outputs.

3) In SD 24 a large part of the stock is currently belonging to the eastern Baltic cod. It was decided to split the catches and survey data in SD 24 according to the proportion on eastern and western cod found in the area. Different methods for splitting were suggested.

4) Infection of cod with the seal associated cod worm and liver worm has been increasing in later years. Analyses were needed to quantify the potential parasite-related mortality and the effects on cod growth (by length class/group) and performance.

5) The grey seal population has increased since the beginning of the 2000s. This has likely increased the predation mortality on cod but should be quantified by size.

6) Discards has apparently increased in the last years. Further investigation of the effect of gear selection on cod discards is needed.

7) Body condition of cod has declined during the last decade. However, the mortality caused by the decrease in condition has to be quantified. The reasons for the decline in condition are currently not fully understood, but is likely a combination of several factors such as density-dependent effects, food availability, anoxic areas and parasites.

8) Since the middle of the 2000s the recruitment of eastern Baltic cod has increased. However, the most recent ichthyoplankton surveys indicate a low larval abundance. Until the benchmark in March 2015 an egg production estimates from ichthyoplankton surveys in 2011–2014 should be prepared. On a longer time-scale, a study relating growth and condition with fecundity and viability of offspring is needed.

9) There is a need for additional data time-series to explain and understand the development in growth and mortality. These dataset should be spatially disaggregated and include biomass and abundance of species (macrobenthos, marine mammals, fish-eating birds) and consumption rates (marine mammals and birds).

10) For short-term prediction a feasibility of an ecosystem-based recruitment model should be investigated, thereby giving indications on new year classes at a much earlier stage than at present.

11) For defining reference points in an ecosystem context, regime shift and managements objectives should be considered.

12) In the longer term a development of assessment methods ensemble modelling approach (many models are used together) need to investigate ways to integrate ecological knowledge into advisory process need to be tested.

In the 2nd meeting in the benchmark process the WKBALTCOD many of the highlighted issues were presented, however, none of the participant from the integrated assessment participated in this workshop and therefore no further process was made on these issues. However, several of the above mentioned points were addressed in the intermediate period before the WKBALTCOD and presented during the meeting. 1) A review process on the age exchange was conducted in late 2014 and the final review presented during WKBALTCOD and assessable on SharePoint. The conclusions are to be found in this report in Section 2.1. 2) A data call on length-based data was conducted and a feedback on this process can be found in Section 4.8. 3) Addressing the splitting of the stocks in SD 24 was incorporated in the assessment and is further addressed in Section 3.1. 4) Although new updated information was available on seal parasites and presented during the meeting, it was at present state not possible to quantify the direct effect on the natural mortality caused by the parasites (Section 4.4.1), although different exploratory runs were conducted. However, the indirect effect caused by a decrease in condition from the parasite infection has been

taken into account. 5) There was an attempt to quantify the amount of cod predated by grey seals in the Baltic, however these values are encumbered with high uncertainty, see Section 4.4.1. 7) Condition was linked to the natural mortality and recalculated back in time, however only the method was agreed upon during the meeting and final values were agreed by correspondence.

For the western Baltic cod stock the main part was conducted during the WKBALTCOD meeting however the reference points were agreed upon by correspondence and the survey indices was also agreed upon at a WebEx meeting after the WKBALTCOD. As no final conclusion was reached on the east Baltic cod the benchmark process was prolonged to the start of WGBFAS.

2 ToRs

2.1 WKBALTCOD–Benchmark Workshop on Baltic Cod Stocks

a) Evaluate the appropriateness of data and methods to determine stock status and investigate methods for short-term outlook taking agreed or proposed management plans into account for the stocks listed in the text table below. The evaluation shall include consideration of:

  i) Conclusions s and recommendations from WKSIBCA 2014;

  ii) Stock identity and migration issues;

  iii) Life-history data;

  iv) Fishery-dependent and fishery-independent data;

  v) Further inclusion of environmental drivers, multispecies information, and ecosystem impacts for stock dynamics in the assessments and outlook.

b) Agree and document the preferred method for evaluating stock status and (where applicable) short-term forecast and update the stock annex as appropriate. Knowledge of environmental drivers, including multispecies interactions, and ecosystem impacts should be integrated in the methodology

c) Evaluate the possible implications for biological reference points, when new standard analyses methods are proposed. Propose new MSY reference points taking into account the WKFRAME2 results, the introduction to the ICES advice (section 1.2), and WKMSYREF3.

d) Develop recommendations for future improving of the assessment methodology and data collection;

e) Compile and review available fleet and fisheries data for fisheries in the Baltic Sea.

STOCKS	STOCK LEADER
cod-2224	Margit Eero
cod-25–32	Joakim Hjelm

The Benchmark Workshop will report by 1 April 2015 for the attention of ACOM.

2.2 Recommendations from WKSIBCA

RECOMMENDATION	ADRESSED TO
1. To establish a workshop under WGBIOP to look into age estimating of Baltic cod	WGBIOP (see proposal)
2. To review the presented data on WKSIBCA on age quality. To detemine if present age data can be used in stock assessment. Two reviewers with the knowledge of; age readings, stock assessment and data quality assurance should be contacted	ICES Secretariat
3. Spatial abundance information on grey seal population in the Baltic Sea, with consumption information (species, amount and size). Information on target distance.	HELCOM seal group
4. Time-series on benthic data in the Baltic?	BEWG

2.2.1 Review of age determination of Baltic Cod

The second recommendation from WKSIBCA was arranged by the ICES secretariat and on the 17th of November 2014, ICES invited Steven Campana (Bedford Institute of Oceanography) and Mike Armstrong (Cefas) to work by correspondence to review the work on age readings presented at the ICES Workshop on Scoping for Integrated Baltic Cod Assessment (WKSIBCA). The terms of reference for the review were:

a) Review the results of the otolith image exchange (prepared in WebGR);

b) Review the results of studies on daily increments;

c) Review the results of studies on otolith microchemistry and possible age interpretation based on microchemistry techniques;

d) Advise on possible methods applicable for using otoliths for age determination of the two Baltic Sea cod stocks;

e) Advise on the reliability of historical Baltic cod age data based on otolith age reading and its use for stock assessment.

A WebEx meeting was held on the 11th of December, involving the reviewers, ICES secretariat and the scientists involved in Baltic cod ageing and stock assessment, to obtain clarification on information provided for the review.

Each of the terms of reference was addressed in a separate document available on SharePoint for all participants in the workshop.

Their main conclusions were:

1) Set up a historical reference collection of Baltic cod otoliths, consisting of a range of ages, sizes, regions and collection years, and carry out double-blind age readings of subsamples of reference or historic collections to detect long-term drift in age interpretations within or across age readers.

2) Develop a reference collection of known-age otoliths based on some combination of otolith micro-increments, bomb radiocarbon, a chemical tag marking/recapture programme, and age sampling of length–frequency modes. This collection will be used for testing the accuracy and precision of the available age readers. Known-age otoliths should be obtained across the entire age range.

3) Identify the subset of age readers who can provide unbiased (accurate) age readings for Baltic cod, and have them do all of the ageing for the Baltic, rather than try to combine age readings from all countries.

4) Investigate utility of stable oxygen isotope ratios to age fish using an ion microprobe to scan entire otolith sections to determine oxygen isotope cycles. Possible confounding of the temperature cycle by salinity variation would need to be evaluated.

5) Produce plots like those of Figure 14 in the Decode document, but colour-coded by age, and for only one year/quarter at a time.

6) Obtain time-series of length-at-age distributions and mean lengths-at-age from each country, for fishery sampling and surveys in the eastern Baltic, so that apparent changes in growth can be compared between countries.

7) Consider the use of simple two-stage assessment models such as Catch-Survey Analysis, if robust recruitment indices and catch data could be developed for young cod based on age readings and/or length–frequency decomposition in BITS surveys, and used with age-aggregated data for older cod. Ideally, harvest control rules based around simple assessment models should be developed using management strategy evaluation methods applied to operating models that represent plausible ranges of population dynamics and errors in data. More complex assessment models can be used to explore the data and set up parameters of the operating model.

3 Western Baltic cod stock

3.1 Stock ID and substock structure

Cod in the Baltic Sea is assessed and managed as two separate stocks, i.e. eastern and western Baltic cod, located in ICES Subdivisions (SD) 25–32 and 22–24, respectively. There is ample evidence supporting the difference between the two populations, based on taggings (Berner, 1967, 1974; Bagge, 1969; Otterlind, 1985; Berner and Borrmann, 1985), phenotypic differences (Birjukov, 1969; Berner and Vaske, 1985; Müller, 2002) and genetics (Nielsen *et al*., 2003; Nielsen *et al*., 2005). However, the tagging programmes also provide documentation that eastern and western Baltic cod stocks co-occur in the Arkona Basin (SD 24) (Aro, 1989; Nielsen *et al*., 2013). In recent years, the abundance of adult cod in SD 24 has increased, and genetic analyses of 2011 data revealed that a large part of the cod found in SD 24 is genetically eastern Baltic cod (Eero *et al*., 2014). This was confirmed by otolith form analyses (WD 2 by Hüssy *et al*. on Stock mixing of eastern and western Baltic cod in SD 24, see Annex 3 for further details) and new genetic analyses from 2014 (Hemmer-Hansen *et al*., unpublished), presented at WKBALTCOD. The presence of eastern cod in SD 24 has resulted in large spatial differences in cod abundance and biological parameters in the western Baltic management unit, i.e. in SD 22–24 (Eero *et al*., 2014). This poses a number of challenges for fisheries management, related to potential depletion of the true western Baltic cod population, and misinterpretation of exploitation status of the cod found in this area (Eero *et al*., 2014). WKSIBCA (ICES, 2014) considered different options for dealing with SD 24 in stock assessment, and concluded that splitting the assessment input data according to the proportions of eastern and western Baltic cod in SD 24 would be appropriate. This option was followed by WKBALTCOD.

Different methods that potentially could allow separating eastern and western cod in SD 24 using otoliths were presented at WKBALTCOD (see Oeberst *et al*., 2015 WD 5 on Evaluation of different methods to assign individual Baltic cod to the Western or Eastern stock, Appendix 3). Otolith shape method was the only approach presented that currently has been applied on otoliths from several years and enables to derive a time-series of eastern and western cod proportions in SD 24, essential to stock assessment. In recent years otolith shape analysis has developed into a useful tool for stock identification purposes (Campana and Cassleman, 1993; Bolles and Begg, 2000; Cardinale *et al*., 2004; Mérigot *et al*., 2007). Stock-specific otolith shape description based on Eliptic Fourier Analysis provides a means for classifying individuals caught in a mixed-stock area to their respective natal stocks. In Baltic cod, this approach has recently been documented as a potential tool to separate individuals belonging to the eastern and western stock (Paul *et al*., 2013). This approach has been further developed and tested using genetically validated fish (Mosegaard *et al*., in prep). Applied to archived otoliths, this technique provides an opportunity to estimate spatio-temporal trends in stock mixing within SD 24. The details of the method are described by Hüssy *et al*. in WD on Stock mixing of eastern and western Baltic cod in SD 24. This method was adopted by WKBALTCOD to derive proportions of eastern and western cod in SD 24 back to the mid-1990s.

3.2 Issue list

The main issue with previous assessment of cod in SD 22–24 was retrospective bias, especially in the estimates of fishing mortality. This was considered to be potentially related to mixing of eastern and western cod in SD 24. In addition to blurring the

picture of stock status of the western Baltic cod population, large proportion of eastern cod within the management area of the western stock brings along the issue of age reading which has become relatively more uncertain for the eastern Baltic cod in later years. Thus, the main issue with the western Baltic cod addressed at WKBALTCOD was mixing with the eastern stock in SD 24 and associated data challenges.

A detailed issue list was produced at the data compilation workshop WKSIBCA, with deliverables, persons responsible to follow up and deadlines.

Table 3.2.1. Work-plan for the age-reading issues.

Area	Challenge	Solution	Comments	Responsible	Timeline to application
24–32	Consensus on abandoning traditional age reading	Daily increment method review: Send around literature and method description		Karin Hüssy	1/11/2014
	Age reading	WebGR: Include Russians, LV		Karin Hüssy	1/11/2014
		External review of applicability of traditional age readings of Eastern Baltic cod	Relevant only if consensus on abandoning traditional ageing not reached	Cristina Morgado	
		Length–frequency analysis	Restricted to <3 years old -> Not applicable to solve assessment in 2015	Rainer Oeberst	Case study
1/02/2015					
		Microchemistry:			
Case study to evaluate present otoliths					
Validation of element signals via tagging					
Application to catch data		Karin Hüssy	After April 2015		
>2 years					
>2–3 years					
		Tagging (fish + otolith)			
(GER experiment starting in 2014 SD22/24)					
Provide Call for tender text to EU	Input as validation for elemental signals	MSP/KH *et al*.	>3 years		
7/11/2014					

Area	Challenge	Solution	Comments	Responsible	Timeline to application
		Approach evaluation to derive age from length: Back-calculation of fish size at hyaline zone formation to identify sizes with higher frequency → alternative age estimate	Not applicable to solve assessment in 2015	Rainer Oeberst	Case study
1/02/2015					
	Data	Data call on Length data in catch (2000–2013)		Marie Storr-Paulsen	15/10/2014
	Assessment methods	Stock-production models		Jan Horbowy	1/02/2015
		Length-based SAM?	Uncertain outcome	Anders Nielsen	1/02/2015
		Exploration of age-reading uncertainty in SAM	Uncertain outcome	Noél Holmgren	
		SS3	Uncertain outcome	Max Cardinale	1/02/2015
		Exploration of different ALK: Is it possible to apply only the most consistent country's ALK			
Cohort analysis: If cohorts can be followed (BUT: Need to borrow data; ALK from one country not necessarily applicable to others)	Relevant only if consensus on abandoning traditional ageing not reached	Joachim Hjelm	1/02/2015		
22, 23	Age				
reading	Compare length distributions of catch:				
DK sends data to GER and vice versa		Marie Storr-Paulsen /Uwe Krumme	1/11/2014		
		Compare mean age at length between countries for survey and submit methodology description to other countries		Rainer Oeberst	15/10/2014

Area	Challenge	Solution	Comments	Responsible	Timeline to application
		Application of Rainers mean-length-at –age-methodology to catch data		Margit Eero (DK data)	1/11/2014
		(Compare otolith size distribution of a cohort from age 0 to 1 (Q1) with identified otolith structure)	Different trends in otolith exchange, age structures survey and catch	Uwe Krumme	1/11/2014

Table 3.2.2. Workplan for stock ID and splitting for Baltic cod.

Challenge	Solution	Comments	Responsible	Timeline to application
Method validation	Correlate genetic/shape/readability	KH sends selection of genotyped otoliths to Uwe	Karin/Uwe	30/11/2014
Approach	- Plan A: 2007-2013, split derived from otolith readability. Split provided by GER and DK. - Plan B: 2007, 2010, 2013, split derived from otolith shape. Split provided by GER, DK. By 1/02/2015 - Plan C: Keep 24 separate			
Proceeding	1. Step: initiation of splitting process with available methods 2. Step: Validation exercise using 300 otoliths 3. Step: Stock split of catch using quality flags for 2007-2013 4. Step: Set up sampling protocol for 2015 involving also genetic samples (starting with catches Q1 and Q4) – timeline before 1/01/2015			
Catch and survey splitting	1) Apply constant stock mix until 2006 2) Otolith readability based stock mix 2007-2013 3) Otolith shape based stock mix 2007, 2010, 2013 (starting with 2013, moving back in time)		Rainer (survey) Uwe (catch)	1) 1/02/2015 2) After 1/02/2015
	Historic stock mixing: Tagging database			After April 2015

Table 3.2.3. Workplan for growth and mortality for Baltic cod.

Challenge	Solution	Comment	Responsible	Timeline
Mortality of larger cod from recreational fishery	Length distributions to be compared from trawl and recreational catches			Long term
Mortality which may be induced by parasitic infection	Model work		Jan Horbowy	01-03-2015
	Experimental work in tanks	Will depend on funing	**Jane Behrens**	Long term
Mortality by direct seal predation	Seal abundance from HELCOM and stomach papers		Marie Storr-Paulsen Jane Behrens	01-03-2015
Mortality through increased discard	Possible effects of different codends on size selection and hence on discards		Uwe Krumme / Joakim Hjelm	01-03-2015
Mortality caused by decreased condition	Litterature study on the effect of condition on mortality		**Michele Casini**	01-03-2015
	Investigate length distribution from BITS survey	Do we really have marked decline in growth?	**Rainer** Oeberst	01-03-2015
Parasite effect on cod condition	Investigate the effect of the parasite		Jan Horbowy	01-03-2015

This work should be further explored and available for the benchmark (March 2015).

Table 3.2.4. Recruitment related actions suggested.

Estimate egg production of stock (at least SD 25) per egg stage from ichthyoplankton surveys (data from May and August 2011–2014 need to be analysed).	Indication whether individual egg production has been reduced over time Whether mortality in egg stage has changed since 1986	Short term (until benchmark)
Recruitment estimate for 2015 and 2016, based on:	Larval abundance March–November 2014 (November survey to be 2014 included) BITS survey in Q4 (age 0 and 1 separated by length compared to 2001–2013)	
Predation on cod eggs by clupeids in SD 25	Quantification of predation 2004–2008 compared to 1990s	
Estimating spawning–stock size via egg production, requires	Above total egg production from ichthyoplankton surveys Individual fecundity (TI has recent data from SD 24 and 25 needs analysis also with respect to point1.) Sex ratios and sex specific maturity ogives (need updates)	Within 2015
Cannibalism (results from stomach tender, data from AtlantNiro)?	Demo and MS WG?	
Study on impact of condition/growth on individual egg production and survival of offspring (BIO-C3 project). Quantifying egg production, survival and fate in SD 24 based on:	Egg production based on distribution of adults during spawning time (problem: covering trawl surveys only outside spawning area available, ichthyoplankton surveys not regularly conducted) Buoyancy of eggs and oxygen related egg survival (available) Analysis of drift model output (runs conducted)	Longer term
Predation on cod eggs by clupeids in SD 24	Importance in SD 24 (not quantified, but observed), however, sampling of stomachs too limited, rather analysis of hydroacoustic survey	

Table 3.2.5. Table is showing the work-plan for the further work to be conducted in respect to the integrated assessment.

Challenge	Solution	Comment	Responsible	Timeline
Availability of benthic food components	Develop a database with benthos data	Ask WGBENTHOS to prepare the data call Data call for benthos data member countries (national programmes)	Jörn Schmidt	25/10/2014
	Incorporate the data in the ICES DataCenter	Communication with DataCenter	Jörn Schmidt	15/11/2014
Analyse changes in growth and mortality	Use existing environmental data to analyse the effect		DEMO2, Anna Gårdmark and Michele Casini	30/11/2014
Effect of changes in distribution of sprat, herring on cod growth	Analyse existing datasets		SGSPATIAL, Michele Casini	30/11/2014
	Spatially explicit SMS		Stefan Neuenfeldt	?
Are the reference points still valid? (see also objective setting in a multispecies or even ecosystem context)	Evaluation of existing reference points (ensemble modelling approach??)	Multispecies models	Noel Holmgren, Niclas Norrström	01/03/2015
			Morten Vinther, Stefan Neuenfeldt	
			Rudi Voss, Jörn Schmidt	
		Production models	Jan Horbowy	
Effect of environment on recruitment	Environmental sensitive stock–recruit relationships		Based on literature and DEMO1 results - Piotr Margonski	March 2015
	Dynamic stock modelling		DEMO3, March 2015, and Martin Lindegren	April 2015
Consumption of Marine mammals and birds	Calculate consumption rates	Request to WGMME, WGSE	Cristina Morgado	08/10/2014
Effect of contaminants on mortality, recruitment and growth	Calculate rates for different contaminants	Thünen Institute for Fish Ecology? Propose Baltic workshop on this topic?		

Challenge	Solution	Comment	Responsible	Timeline
Effect of environmental indicators on TAC level	Using Ecosystem Indicators to inform the advice	Provide information on ecosystem indicator that could be use in the 2016 advice (advice for 2017)	DEMO4, August 2015, Maciej Tomczak and Christian Möllmann	September 2015
		Expert Group to continue DEMO activities - Create WG DEMOnstration of Integrated Ecosystem Assessment and Advice of Baltic Sea fish stocks.	Maciej T. Tomczak and Christian Möllmann WGIAB 2015/DEMO 2015	After DEMO and WGIAB 2015 long term To disscuss within WGIAB not to overlap.
Valuable information from fisherfolk and other sources is not taken into account	Include fisherfolks knowledge; include them in the observing framework	Example of Norwegian reference fleets draft a proposal for Baltic	Staffan Larsson and Henrik Loveby	15/11/2014
Data for the science groups is distributed and difficult to assemble; often only available in excel sheets	Incorporate the data in the ICES DataCenter and formalize the data stream → request to PGDATA and the data center	Prepared and update consistant dataset of enviromental and fisheries data for SCICOM EG (i.e WGIAB)	Jörn Schmidt	15/11/2014
The objectives in a multispecies or even ecosystem context are not clear	Define a process of defining objectives with advice recipients		WKRISCO, November 2014, Mark Dickey-Collas, Jörn Schmidt	15/12/2014
Integration of the socio-economic perspective into the advisory framework	Explore options		WGIMM, March 2015, Rasmus Nielsen, Eric Thunberg, Jörn Schmidt WGMARS, December 2014, Dorothy Dankel	Long Term

3.3 Scorecard on data quality

ICES did not request countries to complete any type of scorecard and no diagnostics on spatio-temporal sampling coverage and sampling intensity were produced. Data quality issues are given in the sections below.

3.4 Fisheries, multispecies and mixed fisheries issues

The main part of western Baltic cod is taken by trawls and gillnets. The landings by trawl have declined since late 2000s, while the landings by gillnets have been relatively stable since 2003 (Figure 1). About 60% of the cod in SD2224 is landed by trawl, 40% by passive gear (mostly gillnetters). The majority of the landings in SD 22–23 are taken in Q1 and this pattern has not changed since 2003 (Figure 2). The fishing effort (kw-days) of otter trawls has substantially declined in later years, while the effort development for gillnetters is more variable (Figure 3).

Given the relative shallowness, cod in the Western Baltic area feed on benthic and pelagic prey, neither of which can be considered a limiting factor for cod diet. The trawl fisheries is a mixed fisheries, involving cod and flatfishes, mainly founder, plaice and dab. Hauls with larger amounts of flatfish in the codend can be clogged/papered which alters the selectivity characteristics of the gear. This may lead to different overall size selection features when compared to the Eastern Baltic cod where ca. 80% of the cod are removed by trawls, and flatfish bycatch in the trawl fishery for Eastern Baltic cod is restricted to flounder during the spawning season in quarter 1.

3.5 Ecosystem drivers

The hydrodynamic conditions within the Baltic Sea are extremely variable, particularly in the narrow Belt Sea, the Sound, and the Fehmarn Belt, through which all water passes in and out of the eastern Baltic Sea (Matthäus and Franck, 1992; Schinke and Matthäus, 1998). The hydrography of the Arkona Basin resembles the condition in the Bornholm Basin more than those of the Danish Straights and the Belt Sea in SD 22 (Matthäus and Franck, 1992; Lass and Mohrholz, 2003), with pronounced thermohaline stratification and stagnation in the deepest areas of the basin. Spawning areas of western Baltic cod are in the deep, saline waters below 20–40 m, depending on area topography (Hüssy, 2011). The highly variable hydrodynamic conditions and the fact that cod eggs float in the water column cause their entrainment by currents, and their destination is determined by the prevailing winds and currents. Salinity limits the east–west exchange of eggs as a consequence of the stocks' differential requirement for neutral buoyancy. Superimposed on this, oxygen content and temperature have a significant effect on fertilization, egg/larva development, and survival (Hüssy, 2011). The long-term resolution of environmental conditions allowing survival of western Baltic cod eggs indicates that favourable conditions predominantly occur during the late spawning season in April/May, while minimum survival rates could be expected from January to March. Unsuitable time periods and habitats exhibiting the highest mortality rates are exclusively characterized by ambient water temperatures below the critical survival threshold. Despite the strong influence of water temperature on habitat suitability, the impact of habitat suitability on recruitment was not clearly defined, suggesting that other mechanisms regulate year-class strength (Hüssy *et al.*, 2012).

3.6 Stock assessment

3.6.1 Quality of catch data

The coverage of landings of large cod by national catch and port sampling programmes in Western Baltic cod was raised at WKBALTCOD as a potential concern. An example was given in the WD 4 of Krumme and Storr-Paulsen. When large cod contribute significant proportions to the landings from certain strata, especially if these landings are large (as was consistently the case for Danish landings from SD22 in quarter 1 in the last years and occurred also in German landings in some years), the uncertainty or bias of the data may be high. WGBFAS may consider to request (1) additional information on landings by size sorting category, country, quarter, gear type and rectangle to produce a useful diagnostics for assessing possible bias; (2) that countries with port sampling should not only report the total number of boxes sampled per stratum, but the total number of boxes per size sorting category per stratum. This would also allow a better evaluation of the data quality provided for stock assessment.

No evidence of misreporting was presented at the benchmark.

Discards: the discard estimates are considered relatively reliable. Denmark does not sample discards from passive gear fisheries (derogation by the EU commission). This could be accounted for by borrowing data from passive gear discard sampling programmes of Germany and Sweden.

Recreational fishery: Only German recreational fisheries catches are included in the assessment. A potential nonresponse bias of the effort estimates used in the final estimation procedure was addressed issuing a nation-wide CATI Bus telephone screener (50 000 households) in 2014, followed by a one-year-telephone-diary-survey and quarterly follow-up. Preliminary findings from a twelve-month recall survey after first contact of sea angling households revealed that the estimated number of Baltic Sea anglers (German) and total number of fishing days were relatively similar to the estimated figures used so far (163 000 vs. 153 000 sea anglers and 860 000 vs. 1.1 million fishing days in 2013). However, new catch and effort estimates will only be applied in WGBFAS 2016. WGRFS 2015 will compile Danish and Swedish recreational fishery data for future inclusion in the assessment.

3.6.2 Age information

Validated age is the most urgently needed information of Baltic cod. Germany has started a cod tagging programme in Fehmarn (centre of SD22) in autumn 2014 (http://www.ti.bund.de/tagging). Juvenile cod are marked internally (intraperitoneal injection of tetracyclin) and externally (individually marked t-bar tag). So far, seven cod out of ca. 1500 released cod were recaptured. This project will be continued in 2015 to produce age-validated material of Western Baltic cod. In addition, there are national plans to initiate a similar age validation study for SD24 cod in Rügen/Germany in autumn 2015. Recent findings of clearly visible tetracyclin rings in Baltic cod otoliths marked 40 years ago highlight the fact that tetracyclin is an appropriate long-term marker for age validation studies in Baltic cod (Krumme and Bingel, in preparation).

WKSIBCA identified a shift in age readings in SD 22 by one year for commercial data of one country since 2010. These data were corrected before WKBALTCOD. WKBALCOD considered age information from otolith readings for western Baltic cod (SD 22–23) to be of sufficient quality to be used in stock assessment. Age structure

from SD 24 was not used because i) large part of the stock in SD 24 in later years has been identified as eastern Baltic cod (see below) with possibly different age structure than the western population; ii) due to a large proportion of eastern cod found in SD 24, the age information for this area is uncertain given the age-reading problems in later years identified for the eastern Baltic cod.

3.6.3 Relative proportions of eastern and western cod in SD 24

Time-series of estimated proportions of eastern and western Baltic cod within SD 24 were available for the years shown in Table 1, based on otolith shape analyses (see WD on Stock mixing of eastern and western Baltic cod in SD 24 by K. Hüssy *et al*. for description of the method). The possibly different proportions of mixing by quarter and size of the fish were explored; however consistent patterns could not be demonstrated. Thus, to derive keys for population splitting, the data for different length groups and quarters were pooled. Systematic differences in the proportion of mixing were found by subareas within SD 24, with a larger proportion of eastern cod closer to SD 25 (Figure 4.). The proportions of mixing in the easternmost rectangles in SD 24 and those in the middle of SD 24 were relatively similar (Figure 4). Thus, these data were also merged. The final keys for splitting populations in SD 24 were estimated separately for two subareas, marked as Area 1 and Area 2 in Figure 5.

Relatively frequent annual estimates for population splitting were available from otolith form analyses for the second half of 1990s (1996, 1998, 2000) and since 2008 (2008, 2010, 2011, 2013). The missing information for single years in both periods, when the data for adjacent years were available, was filled by averaging the data from neighbouring years. To fill the gap in the data from 2000 to 2008, the population splitting keys were derived assuming a linear increase in the proportion of eastern cod in the period from 1996 to 2013, both in Area 1 and in Area 2, the regression being based on the years for which data were available. WKBALTCOD considered the stock mixing in SD 24 to be related to hydrographic regime of the Baltic Sea, e.g. in relation to utilization of Arkona basin (in SD 24) vs. the eastern Basins (Gdańsk and Gotland) for spawning by the eastern cod. Before 1993 (when one of the last major inflows in recent decades took place), the Baltic Sea was characterized by relatively frequent inflows from the North Sea, and the eastern Baltic cod was distributed in a larger area in SD 25–32. Thus, expansion of the eastern stock to SD 24 may have been of a lesser issue before the 1990s; that is in line with former assessment working groups in ICES that have not identified stock mixing in SD 24 as a major issue. Consequently, the proportions of stock mixing available for 1996 were gradually reduced to derive estimates for 1994–1995, with the assumption of zero proportion of eastern cod in SD 24 in 1993. However, historical tagging and other studies have shown that stock mixing also in former years has occurred (see the Stock ID section above), thus assuming no mixing for years before 1994 may not be correct. Exploratory assessment analyses (not shown in the report) revealed that historical catches had an impact on assessment results for recent years. Also, the historical catches could have a substantial influence on reference points. Thus, it was decided to omit the years before 1994 from the final assessment, until data on population mixing for the historical period can be provided (e.g. from otolith form analyses of archived otoliths), as the proportion of stock mixing in the years before 1994 is currently unknown.

The resulting proportions of western cod in SD 24, by year and subarea for 1994–2013 are shown in Figure 6.

Table 1. Percent of western Baltic cod in SD 24 by two subareas, westernmost part of SD 24 (Area 1 and middle and easternmost part of SD 24 (Area 2) (Areas 1 and 2 are shown in Figure 5).

	SD24–West	SD24–East
year	Area 1	Area 2
1996	66	49
1998	72	71
2000	71	49
2005	no samples	48
2008	46	20
2010	55	21
2011	51	15
2013	53	23

3.6.4 Catch data preparation

Landings in tons

Landings in tons by SD for 1994–2013 were obtained from WGBFAS reports. Total landings in SD 24 were adjusted to include only those representing the WB cod population. To do this, weighted average of the proportions of WB cod in SD 24 in the two subareas (Area 1 and Area 2) was applied. The weightings represented relative proportions of Danish and German (main part of fisheries in SD 24) commercial cod landings taken in Areas 1 and 2, respectively. The landings in rectangles 39G2, 38G2 and 37G2 were used as representing Area 1 and landings in rectangles 39G3, 38G3, 37G3, 39G4, 38G4 and 37G4 were used as representing Area 2. The landings by rectangle from 2003 onwards were available from STECF database (http://datacollection.jrc.ec.europa.eu/dd/effort/graphs). Danish landings by rectangle back to 1994 were derived from national database. Relative distribution of German landings between Areas 1 and 2 in 1994-2002 was set to the average of that in the years 2003–2013. The total landings of Germany and Denmark in SD 24 (derived from earlier ICES WGBFAS reports) were used as weighting factors to derive average distribution of landings between Areas 1 and 2 for the two countries combined. These average proportions of landings between Areas 1 and 2 were then used as weighting factors to derive an average splitting key for landings in SD 24 (from the two separate stock-splitting keys for Areas 1 and 2). The resulting landings of WB cod population by SD are shown in Figure 7.

Landings at-age

Landings at-age for SD 22 for 1994–1995 were derived from the multispecies assessment databases for the Baltic Sea, and from 1996 onwards the landings at-age by SD were available from WGBFAS reports. For SD 23, landings at-age for 1997–2013 were derived from WGBFAS reports (Lindegren *et al.*, 2013). For 1994–1996, the landings at-age in SD 22 were upscaled by the landings taken in SD 23 compared to SD 22, to obtain landings at-age for SD 22–23. Thus, the age structure of landings in SD 23 in 1994–1996 was assumed to be equal to that in SD 22.

Landings at-age for the entire western cod population (i.e. including landings in SD 24) were obtained by upscaling the landings at-age in SD 22 by the ratio of landings of WB cod taken in SD 24 compared to SD 22. Landings at-age in SD 23 were subse-

quently added, to get the landings at-age of WB population for SD 22–24. Thus, the age structure of the landings in SD 24 was assumed similar to that in SD 22. The age structure from SD 23 was not included in distributing landings from SD 24 to ages, due to different fishing patterns in SD 23 (trawling ban) and presumably separate spawning aggregations in SD 23 (Lindegren *et al*., 2013).

Commercial catch–at–age

Discards at-age separately for 22 and SD 24 were available for 1996–2010 from earlier WGBFAS reports. The average relative distribution of total discards (SD 22+24) between SD 22 and 24 in 2008-2010 was applied to derive discards at-age separately for SD 22 for 2011–2012 (from the discards at-age for the entire WB Sea). Average ratio between discards and landings in 1997–2003 and in 2011–2012, by age, was used to derive discard estimates for 1994–1995 and for 2013, respectively. No discards were included for SD 23. Similarly to landings, the obtained commercial catch-at-age for SD 22 (landings plus discards) was upscaled by the ratio of landings of WB cod taken in SD 24 compared to SD 22. Thus, the discards in relation to landings of WB cod in SD 24 were assumed to be the same as in SD 22.

Recreational catch–at–age

German marine recreational fisheries data for western Baltic cod were provided for SD 22 and 24 (see WKBALT 2013). German recreational fisheries data for cod are available from 2005 until 2014. The estimates for earlier years are based on assumptions (see WKBALTCOD 2013 for further information).

All recreational cod catches taken in SD 22 and 24 by Germany were considered western Baltic cod and included in the assessment. Spatial analysis revealed that recreational catches (charter boat) in SD 24 around the Island of Ruegen were taken close to shore in area 38G3. All catch-at-age data from 2009 onward is estimated using the recreational length distribution from SD 24 and the ALK from German commercial data from SD22. For a further description of the compilation method see WKBALT 2013. Only German recreational catches are included in the assessment.

3.6.5 Mean weight, growth, maturity ogive

Mean weight–at–age in the catch

Average annual mean weight-at-age in commercial landings in SD 22 was available from earlier WGBFAS reports. For SD 23, the data were available from 1997 onwards, the weights for 1994–1996 were set equal to the average values from 1997–1999. Weight-at-age in landings in SD22–23 was calculated as a weighted average of SD 22 and SD 23 data, weighted by respective landing numbers-at-age. Weight-at-age in recreational fisheries was provided for the entire time-series from 1994 onwards (based on weight information from surveys and German commercial landings). Discard weights for SD 22–23 were not available. Thus, mean weight-at-age in total catch was calculated as a weighted average of mean weights-at-age in commercial landings and in recreational catches, weighted by respective catch numbers. For assessment update in 2015, discards weights at least for 2014 should be made available, to be able to appropriately separate between landings and discards in the forecast.

Mean weight–at–age in the stock

Weight-at-age in the stock for ages 1–3 were calculated from BITS Q1 data for SD 22–23, following the same calculation procedures as previously used for cod in SD 22–24

(see stock annex from 2014). For ages 4+, mean weight in the stock was set equal to the mean weight in the catch.

Additional information on growth

Analyses of length–frequency data from German surveys indicated a stable mean length and stable growth patterns for cod smaller than 40 cm for the last 40 years. The estimated growth parameters (VBGF) from length–frequency analyses were supported by estimates of mean daily growth rates using mark-release–recaptured cod from a tagging programme conducted since 2007 (see WD 5 on Growth of western Baltic cod - Estimated based length–frequency distribution of smaller cod by Oeberst *et al*. for further information).

Maturity ogive

Maturity and spawning probability were estimated from BITS Q1 data for SD 22–23. Spawning probability separates between the gonad development stages where the fish is likely to spawn or skip spawning, while proportion mature includes all the fish that are mature. Especially for younger ages, there are large differences between spawning probability and proportion mature, thus spawning probability was chosen to use for ages 1–4. Due to very few older fish in samples, maturity/spawning probability was set to 1 for ages 5+. Due to large interannual fluctuations in spawning probability, smoothed values applying running mean over three years were used.

3.6.6 Surveys

Different options for calculating survey indices for WB cod, while taking into account stock mixing, were explored. Cpue by age and by length for SD 22, 23 and 24 are available from ICES DATRAS database. To account for mixing with the eastern Baltic cod in SD 24, different options were considered:

i) Include SD 22–23 and the cpue in SD 24 should be split according to the proportions of EB cod found in the area.

ii) Include only SD 22–23.

iii) Include SD 22–23 and the westernmost part of SD 24 where proportions of EB cod are lower compared to the eastern part.

To derive survey indices corresponding to option (i), the data from SD 24 were divided using the population splitting keys for Area 1 and Area 2 described above. The procedure was the following:

1) Cpue-at-length per haul from DATRAS for SD 24 was used to derive relative proportions of fish in Areas 1 and 2 within SD 24.

2) The population splitting keys for Area 1 and Area 2 were combined as a weighted average, using the proportion of fish in each subarea as weightings, separately for Q1 and Q4.

3) The original cpue-at-length values (cpue-per-length-per-area from DATRAS) for SD 24 were multiplied with the proportion of cod belonging to the western population, separately for Q1 and Q4.

4) Age–length-key (ALK) for SD 22 was derived from DATRAS database, by year and separately for Q1 and Q4.

5) ALK from SD 22 was applied on cpue-at-length in SD 24 (adjusted for proportion of WB cod), by year and quarter.

6) For length groups for which matching age data from ALK for a given year were not found, an average ALK overall years in a given quarter was applied.

7) Cpue at-age for SD 24 was calculated by summing the cpue-at-length values (now distributed between ages) in a given year and quarter.

8) Indices for WB cod were calculated as a weighted average of SD specific cpues. The weighting factors represent areas sampled for SD 22–23 (available from DATRAS). For SD 24, the size of the entire sampling area was adjusted with the population splitting key, by year and quarter. Different options for weighting the SDs in combining the indices were discussed at WKBALTCOD. An option with giving full weight to SD 24 was considered as well, which has the advantage that the weighting of an area would not be too variable from year to year. On the other hand, giving full weight to SD 24, especially in cases where only a relatively small fraction of SD 24 belongs to WB cod population, the indices from SD 24 may become too dominant compared to the core area of the WB cod stock (i.e. SD 22). The effect of both weighting options on survey indices was explored.

Survey indices for option (i) compared to option (ii) are shown in Figures 8 and 9. The main trends and fluctuations in the survey time-series generally were similar regardless of whether a fraction of the SD 24 data was included or the survey index was only based on SD 22–23. Similarly, the internal consistency of survey indices in terms of following year-class strength was not remarkably affected by inclusion or exclusion of SD 24 data (Figure 10, 11). Generally, very large interannual variability between survey indices was noted (more than factor 400 in some cases). Especially for older ages (above age 2) the cpue values in SD 22–23 are generally much higher than in SD 24, which explains the relatively little impact of including or excluding a fraction of SD 24 data on overall survey trends. The data for age groups above 4 were considered not informative, being based on very few individuals (in many cases less than one fish per hour and showing no consistency with younger age groups in earlier years). The conclusions regarding trends and internal consistency where similar also regardless of whether SD 24 was given full weight when combining cpue indices by SDs as a weighted average, or the area of SD 24 was reduced according to the proportion of western cod found in the area (results not shown).

WKBALTCOD was concerned about the extensive data treatment procedures and assumptions involved in including a fraction of the SD 24 data in the survey indices. Thus, among the two options: (i) include SD 22–23 and the cpue SD 24 data should be split according to the proportions of EB cod found in the area, and (ii) include indices from SD 22–23 only, the option (ii) was preferred.

Additional concerns regarding the survey data were raised in relation to differences in stock trends between the two surveys in Q1 and Q4 in the core area of the western Baltic cod (SD 22). Q4 data indicated a decline in larger cod in recent years, while no clear trend was visible in Q1 data (Figure 12). This might be due to seasonal differences in catchability of larger cod, i.e. larger cod may be less likely to use the deeper areas during the Q4 BITS.

WKBALTCOD also recognized that part of the western population is found in SD 24, especially in the westernmost part of it. The western part of SD 24 is also linking SDs

22 and 23, that otherwise are geographically disconnected. Thus, it was considered appropriate to include the westernmost part of SD 24 (Area 1 in Figure 5) to the survey index. This is however currently not possible when using standard outputs from DATRAS.

Survey indices using Delta–GAM approach

Alternative method for calculating survey indices based on the approach described in Berg *et al*., 2014, was presented to WKBALTCOD. This method is using spatially varying age–length keys, estimated using the methodology described in Berg and Kristensen (2012). Numbers-at-age are then calculated using the observed numbers-at-length and the estimated ALKs. This methodology avoids *ad hoc* borrowing of samples from neighbour areas or quarters, when certain age groups are missing, and it provides an objective fill-in procedure for missing length groups. The methodology has been implemented in the DATRAS package with full source code available (Kristensen and Berg, 2012).

This method allows easily adjusting the area wished to be included in the survey index, and was used to calculate survey indices for SD 22–24W (Area 1). The indices for SD 22–23 from DATRAS and the indices for SD 22–24W using Delta-GAM approach are presented in Figure 13. The indices calculated using Delta-GAM approach showed higher internal consistency (Figure 14) compared to the indices from DATRAS (Figure 10, 11). Indices from Delta-GAM approach showed a reasonable consistency up to age 5 in Q1, while the DATRAS indices were considered not useful for ages above 4. Also, the indices using Delta-GAM approach showed lower variances in SAM assessment model (see section on Exploratory Assessment Analyses). The indices from Delta-GAM approach use only the time period from 2001 onwards due to a large number of different gears used in earlier period with too few hauls with each gear to be able to standardize for this properly within the model.

The Delta-GAM approach was generally approved by WKBALTCOD as a method (being already previously adopted in ICES for North Sea cod). However, due to limited time in WKBALTCOD to scrutinize the calculations for Western Baltic cod, an intersessional procedure between WKBALTCOD and WGBFAS 2015 was requested to refine and document the calculation of modelled survey indices for western Baltic cod. Thus, the new method was conditionally accepted by WKBALTCOD, and if the additional work conducted intersessionally will be approved, the new survey calculation approach (Delta-GAM) should be applied at WGBFAS 2015.

Do to time limitation during the WKBALTCOD a final decision on the survey indices to be used was not reached and some further investigations were requested. It was decided to have a final decision at a WebEx before the WGBFAS where a working document should be distributed before the meeting. The WebEx meeting concluded:

1) To use the model approach;

2) To use a time-series starting at 2001;

3) Include the small western area of SD 24 (area 1)Figure 5;

4) To take into account the vessel effect.

3.6.7 Assessment model

State–space stock assessment model (SAM) was used as in previous years. No other stock assessment model was applied.

3.6.8 Exploratory assessment analyses

Correlated vs. uncorrelated fishing mortalities by age

SAM settings include options for fishing mortalities by age to i) follow a random walk, separately for each age class, ii) fishing mortalities for all ages are correlated; iii) fishing mortalities of neighbouring age classes are more correlated than those further apart.

In former assessments for cod in SD 22–24, option (i) had been used. This is because it has been recognized in later years that mixing with eastern cod takes place in SD 24 that possibly can results in different fishing mortalities by age. In WKBALTCOD, the eastern stock component was removed from the assessment data for the western Baltic cod. Due to relatively larger uncertainties for older ages in catch data and poor survey information for older ages, WKBALTCOD considered the option (iii) (i.e. fishing mortalities for neighbouring age classes are more correlated than those further apart) as most appropriate. Comparison of F at-age for option (i) and option (iii) is shown in Figure 15. Applying option (iii) significantly improved the model fit compared to option (i) ($p = 0.0182$).

Age range for F_{BAR}

Due to generally poor information for older ages from surveys, possibilities for age range in F_{bar} were discussed. Age 2 is a substantial part of catches in the time-series (Figure 16). However, age 2 appears not to be fully selected by the fisheries (Figure 17). Thus, the age range 3–5 was maintained as F_{bar}.

Commercial catch per unit of effort

The assessment for cod in SD 22–24 in previous years used commercial cpue from Danish trawlers for tuning. These indices were abandoned at WKBALTCOD as the tuning fleet previously used operated mainly in SD 24, in the areas close to the border of SD 25. Thus, the commerical cpue previously used was likely more reflecting the abundance of eastern Baltic cod in the area rather than that of the western Baltic cod. Preliminary catch per unit of effort series for SD 22 from Danish trawlers and gillnetters was presented at WKBALTCOD. However, these were not included in the final assessment due to general issues with using commercial cpue, such as changes in gear selectivity, etc.

DATRAS vs. Delta GAM survey indices

Figure 18 compares the outputs for SSB, F and R from the run using DATRAS survey indices for SD 22–23 and from the run using survey indices from Delta-GAM approach for SD 22–24W. The largest difference is detectable for recruitment, where the values for latest years are somewhat higher and much more uncertain in the run using DATRAS indices compared to the run using the indices from Delta-GAM approach. Further, the observations variances were estimates lower in SAM in the run using survey indices from Delta-GAM approach, compared to DATRAS indices (Figure 19). This implies that in the run using survey indices from Delta-GAM approach, the survey data are getting more "weight" in the model than in the run with DATRAS indices, where the model is to a larger degree driven by catch information.

Key run

In this section, full key runs for both options, i.e. using DATRAS survey indices for SD 22–23 and using Delta-GAM indices for SD 22–24W are presented. The final deci-

sion on which survey indices to use will be taken based on the intersessional work conducted in between WKBALTCOD and WGBFAS 2015.

The run with DATRAS indices for SD 22–23

Figure 20 shows spawning–stock biomass, fishing mortality, and recruitment, including residuals from the run using survey indices from DATRAS for SD 22–23. Catchability estimates (Figure 21) indicate a higher catchability for ages 0 and 1 compared to older ages in Q4, and an opposite pattern in Q1, where the catchability is estimated higher for older ages compared to age 1.

Leave-one-put runs do not indicate a substantial change in the perception of the stock status based on Q1 or Q4 survey information, and the estimates using only one survey series are within the confidence intervals of the combined estimates. The low effects of individuals surveys (despite the different trends in survey time-series (Figure 12) is probably because both surveys are getting relatively little weight in the assessment that is mainly driven by catches (Figure 19).

Retrospective analyses do not indicate systematic bias and the estimates are generally within the confidence intervals (Figure 23).

The run with Delta–GAM indices for SD 22–24W

Figures 24 shows spawning–stock biomass, fishing mortality, and recruitment, including residuals from the run using survey indices from Delta-GAM approach for SD 22–24W. Relative catchability estimates (Figure 25) for Q4 were similar to those from the run with DATRAS indices for SD 22–23 in terms of estimating a higher catchability for ages 0–1 compared to ages 2+. For Q1, a high catchability is estimated for age 2 compared to both age 1 and older ages (3+), which is different from the run with DATRAS indices that estimated a relatively higher catchability for all ages above age 2.

Similarly to the run with DATRAS survey indices, leave-one-out runs did not indicate a substantial change in the perception of the stock status based on Q1 or Q4 survey information, and the estimates using only one survey series were within the confidence intervals of the combined estimates (Figure 26).

Similarly to the run with DATRAS survey indices, retrospective analyses did not indicate systematic bias and the estimates were generally within the confidence intervals of the final estimates (Figure 27).

Do to time limitation during the WKBALTCOD a final decision on the survey indices to be used was not reached and some further investigations were requested. It was decided to have a final decision at a WebEx before the WGBFAS where a working document should be distributed before the meeting. The WebEx meeting concluded:

1) To use the model approach;

2) To use a time-series starting at 2001;

3) Include the small western area of SD 24 (Area 1, Figure 5);

4) To take into account the vessel effect.

3.6.9 Short–term projections

Short-term forecast was not specifically discussed at WKBALTCOD. Standard options in SAM forecast, as used in previous years, were considered to apply.

3.6.10 Appropriate Reference Points (MSY)

B_{lim}

The classification of S–R relationship was considered to correspond to type 5 in the ICES guidelines (ICES 2003). The trends in fishing mortality and stock size indicated that a continuously rising S–R function seems unlikely to be supported and B_{lim} should lie within the observed SSB.

One suggestion was to use the single high R value at around SSB of 20 000 t as a basis for B_{lim}, below which only low recruitments have occurred. However, a careful examination of the values suggested that it is was hard to find good support for such mechanism, as there are seven lower R values at immediately higher biomasses. This R at SSB=20 000 t looks more like an outlier than an indicator of a change in dynamics due to SSB, i.e. historically there has still been a high probability of low recruitment between 20 000 and 27 000.

The HS fitted value of 27 421 t gives a slope to the origin that seemed to be a good representation of recruitment for the residuals against estimated recruitment (Figure 28). Although the R residuals do become more positive above 27 000 t there is no strong information to support a breakpoint above ca 27 000 t.

In conclusion based particularly three aspects: a) the fact that F has been high which is expected to have contributed to the depletion of the stock; b) there is still a high probability of low recruitment above 20 000 t and c) the probability of recruitment above ca 27 000 has a symmetrical distribution, the breakpoint fitted from Hockey-Stock analyses, i.e. 27 421 t was agreed to be set as B_{lim}.

F_{MSY}

F_{MSY} calculations were performed according to the methodology recommended by WKMSYREF3. In the calculations, breakpoint in S–R relationship was forced to the middle of observed values, i.e. 25 000 t. Tables 2 and 3 show the estimates with or without applying $B_{trigger}$ in the calculations. The values suggested to be used were: F_{MSY}=0.26 (F_{lower} =0.15 and F_{upper} = 0.45). The outputs from calculation are illustrated in Figures 29-31.

Table 2. F_{MSY} estimates applying $B_{trigger}$.

	Flim	Flim10	Flim50	medianM	meanMSY	Medlowe	Meanlow	Meduppe	Meanupper
catF	0.658	0.786	1.452	NA	0.316	NA	NA	NA	NA
lanF	NA	NA	NA	0.258	0.316	0.156	0.177	0.438	0.462
catch	27596.27	26217.48	19722.49	NA	32046.53	NA	NA	NA	NA
landings	NA	NA	NA	32344.04	32046.53	30515.08	34013.6	30458.68	33935.68
catB	54416.28	45477.14	26992	NA	116037.6	NA	NA	NA	NA
lanB	NA	NA	NA	138456	116037.6	202218.4	NA	83110.22	NA
bio.years=c(2004,2013), sel.years=c(2004,2013),Fscan = seq(0,									
2, len = 20),Fcv=0.25, Fphi=0.30									

Table 3. FMSY estimates applying no $B_{trigger}$.

	Flim	Flim10	Flim50	medianM	meanMSY	Medlowe	Meanlow	Meduppe	Meanupper
catF	0.574	0.658	0.975	NA	0.316	NA	NA	NA	NA
lanF	NA	NA	NA	0.252	0.316	0.152	0.177	0.45	0.46
catch	28262.93	26838.2	18718.13	NA	31868.39	NA	NA	NA	NA
landings	NA	NA	NA	32237.78	31868.39	30321.69	33946.27	30304.07	33899.48
catB	62189.58	52678.87	26821.7	NA	115659.4	NA	NA	NA	NA
lanB	NA	NA	NA	141109.7	115659.4	205344.6	NA	80578.53	NA
bio.years=c(2004,2013), sel.years=c(2004,2013),Fscan = seq(0,									
2, len = 20),Fcv=0.25, Fphi=0.30									

3.7 Future research and data requirements

Surveys

It was recognized that the quality of survey data for SD 22–23 needs to be improved in future as it is the core area of western Baltic cod distribution. Currently the number of survey stations in SD 22–23 is relatively low and some areas are not properly covered. Thus, it was recommended to shift part of the survey effort in SD 24 (that is currently considerably better covered than SD 22) over to SD 22. Further, the age–length keys available in DATRAS for SD 22–23 currently contain very few fish above age 3 (4) per year. This should also be improved in future.

During the spawning season in quarter 1, the fishery is targeting (pre-)spawning aggregations and larger-sized cod (EU size sorting categories 2 (4–7 kg) and 1 (7–20 kg weight per individual)). These areas are not well covered by the survey in quarter 1. A better coverage of these areas by the survey is needed in future.

Cod abundance in BITS surveys in Q4 is low. This is because cod avoid the deeper areas of the Kiel and Mecklenburg Bay (>20 m) in summer and the early autumn when they rather stay at the shallower "slopes" (ca. 5–15 m) where there is enough oxygen (which is not the case in the deeper waters in SD22) and where water temperatures are low enough (which is not the case in very shallow water) (personal communication with German fishers). Only when water temperatures remarkably decrease, e.g. from December onwards (i.e. after the BITS Q4), cod start leaving the shallower slopes towards the deeper basin and have improved catchability by trawls (personal communication with German fishers). The shallower areas are poorly covered by BITS and hence, survey indices of Q4 provide limited information on stock status. National laboratories in Germany and Denmark are called on exploring whether there are national surveys that can provide additional information on cod abundance in SD 22 in future.

Stock mixing

Regular updates on mixing proportions of eastern and western Baltic cod in SD 24 are required. Continued improvements of the otolith form analyses currently used for stock separation, and to the genetic baseline are expected. Further, the genetic information currently available should be used to validate potential alternative approaches (e.g. the analyses of ring structures (WD 5 Oeberst) or microchemistry.) A method that could equally well assign individual cod to either the Western or Eastern cod stock as genetic information (but would be cheaper providing a greater sample size) would facilitate and improve the spatio-temporal coverage and quantification of the mixing between stocks.

Also, the possible differences in proportions of eastern and western cod by size and season should be further explored. Further, improved historical information on population mixing in SD 24 is required (e.g. to be derived from archived otoliths).

Tagging experiments to resolve the movement patterns of western Baltic cod would be valuable.

Commercial data

WGBFAS may consider to request (1) information on landings by size sorting category, country, quarter, gear type and rectangle to produce a useful diagnostics for assessing possible bias in sampling data used for assessment; (2) that countries with port sampling should not only report the total number of boxes sampled per stratum, but the total number of boxes per size sorting category per stratum. This would also allow a better evaluation of the data quality provided for stock assessment.

Assessment model

Stock assessment models that can account for population mixing within the model rather that mechanically splitting the assessment input data should be developed and tested.

The possibilities of accounting for age-reading errors (that to some extent may exist also for the western Baltic cod) within the assessment model should be explored, if information on these errors is available for the entire age range of cod. This requires data on “true” ages, i.e. from age-validation studies.

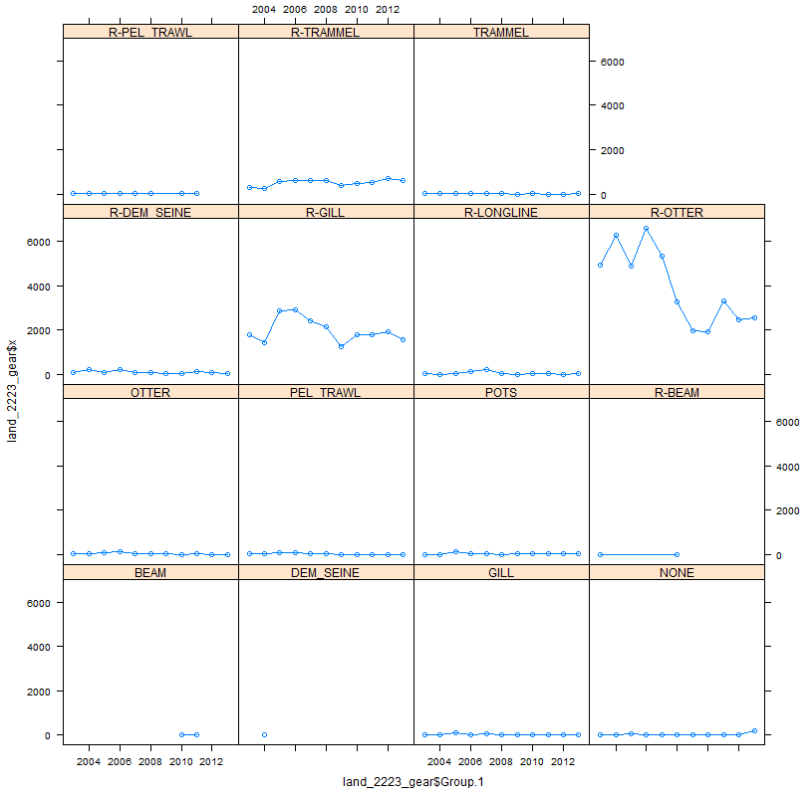


Figure 1. Western Baltic cod. Landings by gear categories in SD 22–23 (data from EU STECF database).

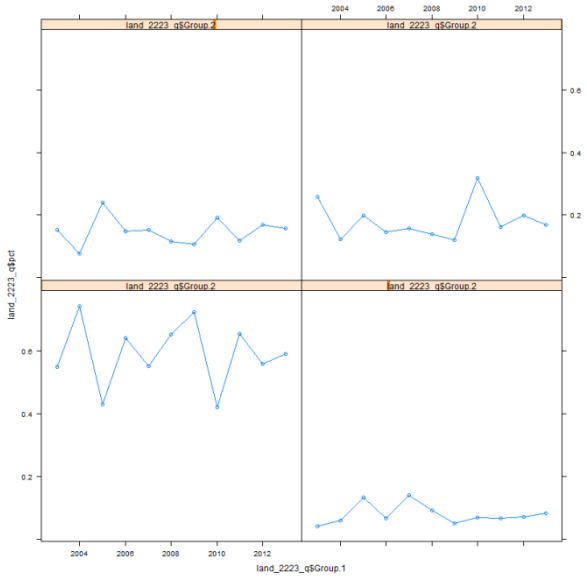


Figure 2. Western Baltic cod. Proportion of landings in SD 22–23 by quarter (from bottom left to top right) (data from EU STECF Database).

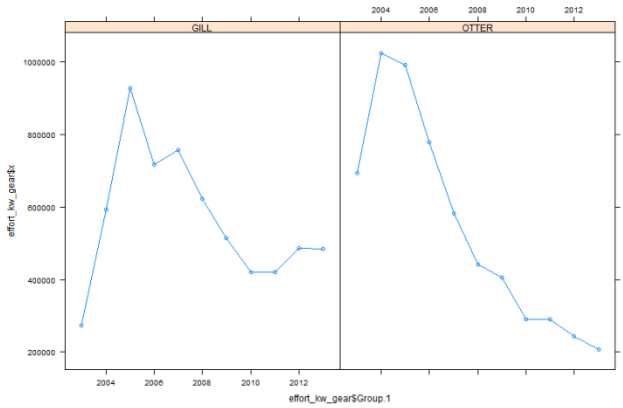


Figure 3. Western Baltic cod. Effort (kw-days) of gillnetters and otter trawlers in the western Baltic Sea (Area A, i.e. SD 22–24) (data from EU STECF Database).

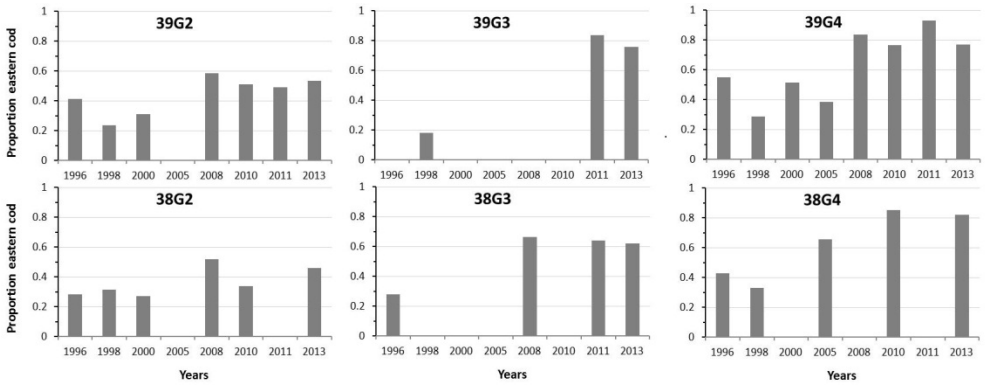


Figure 4. Western Baltic cod. Proportion of eastern Baltic cod (>20 cm) per year in the six ICES rectangles within the Arkona Basin. Only years with >10 fish per rectangle and year were used. Years without bars indicate lack of data. Rectangles are arranged to match their relative positions within SD 24 from west to east.

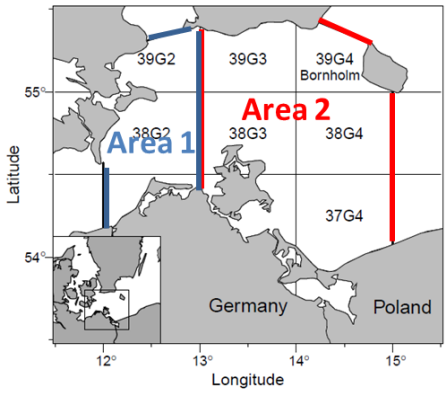


Figure 5. Western Baltic cod. Map of SD 24 (mixing area of western and eastern cod) and subareas (Area 1 and Area 2) for which separate mixing proportions were estimated.

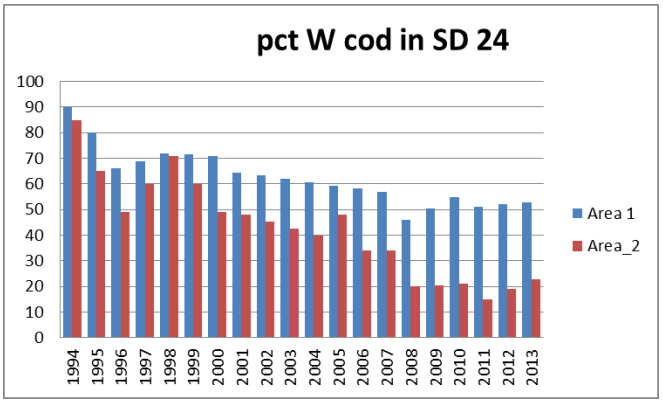


Figure 6. Western Baltic cod. Time-series of proportion of western Baltic cod in SD 24, by subareas (Area 1 and Area 2, see Figure 5 for location of the subareas), used in the assessment.

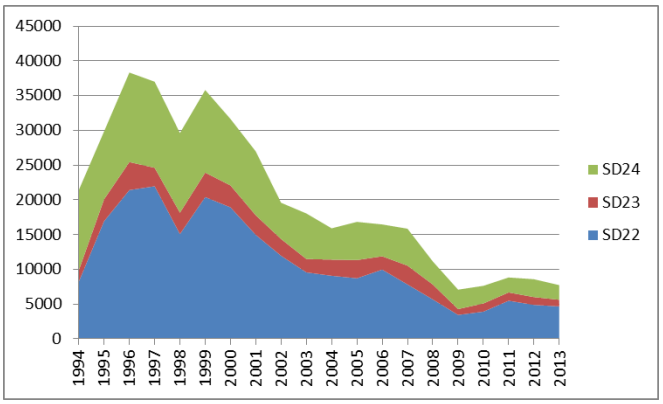


Figure 7. Western Baltic cod. Landings of WB cod population by SD (adjusted for stock mixing in SD 24).

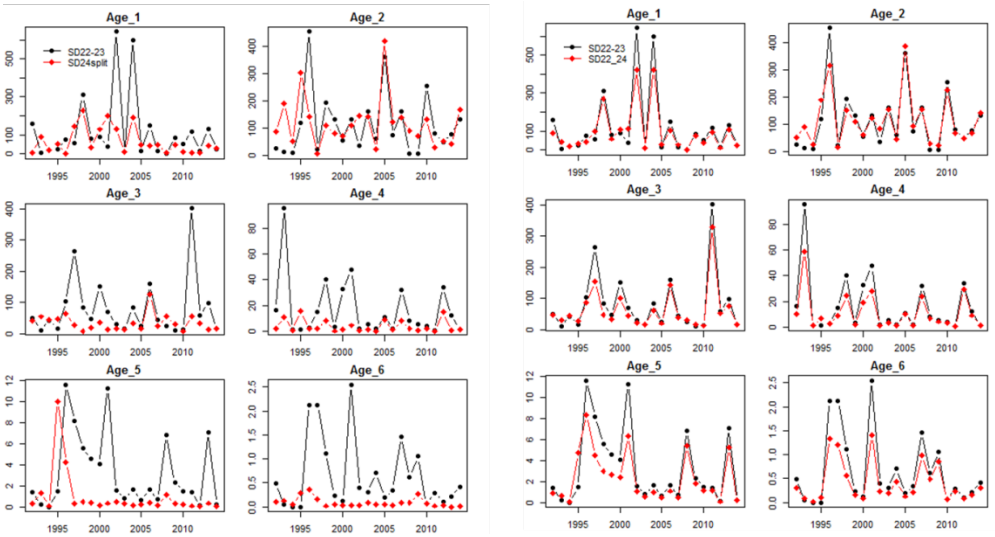


Figure. 8. Western Baltic cod. Left panels: survey cpue for SD 22–23 compared to SD 24, where the values for SD 24 are adjusted to take into account the proportion of eastern Baltic cod in the area (Q1 data). Right panel: survey cpue for SD 22–23 compared to SD 22–24, where the cpue values for SD 24 and the weighting of SD 24 in the procedure of combining the cpues by SDs (SD 22,23,24) are adjusted to take into account the proportion of eastern Baltic cod in the area (Q1 data).

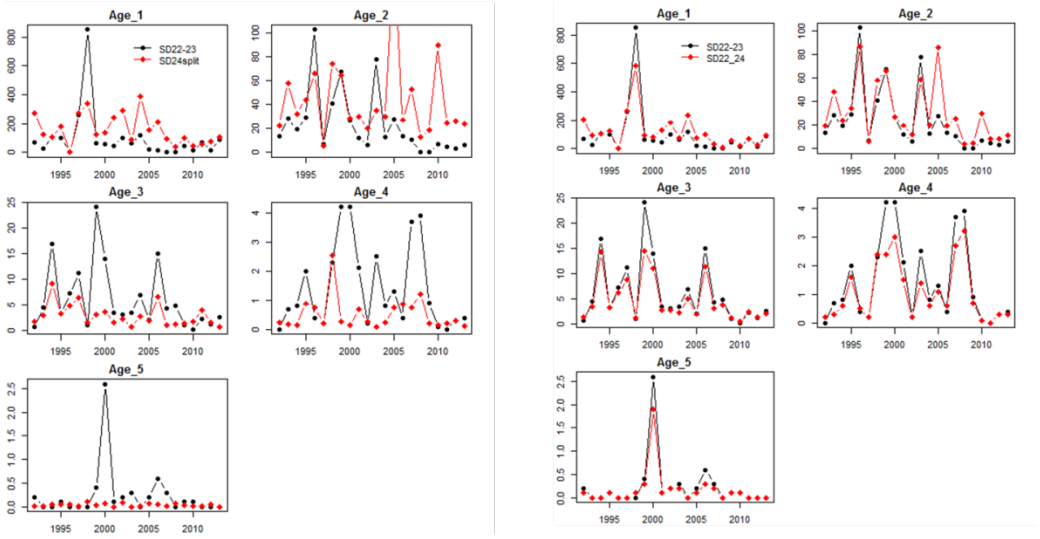


Figure. 9. Western Baltic cod. Left panels: survey cpue for SD 22–23 compared to SD 24, where the values for SD 24 are adjusted to take into account the proportion of eastern Baltic cod in the area (Q4 data). Right panel: survey cpue for SD 22–23 compared to SD 22–24, where the cpue values for SD 24 and the weighting of SD 24 in the procedure of combining the cpues by SDs (SD 22,23,24) are adjusted to take into account the proportion of eastern Baltic cod in the area (Q4 data).

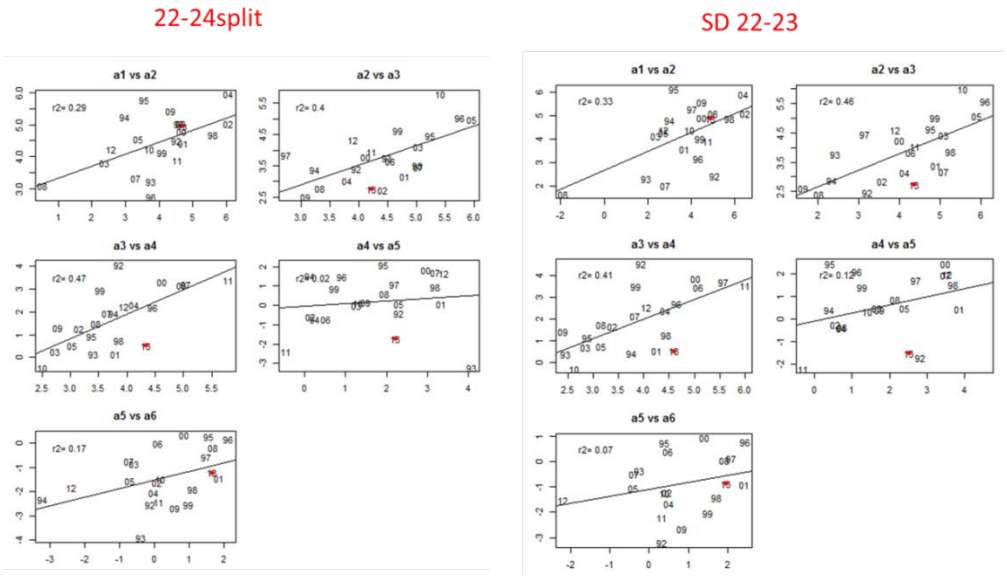


Figure 10. Western Baltic cod. Internal consistency of cpue for SD 22–23 (right panels) compared to SD 22–24, where the cpue values for SD 24 and the weighting of SD 24 in the procedure of combining the cpues by SDs (SD 22,23,24) are adjusted to take into account the proportion of eastern Baltic cod in the area (Q1 data).

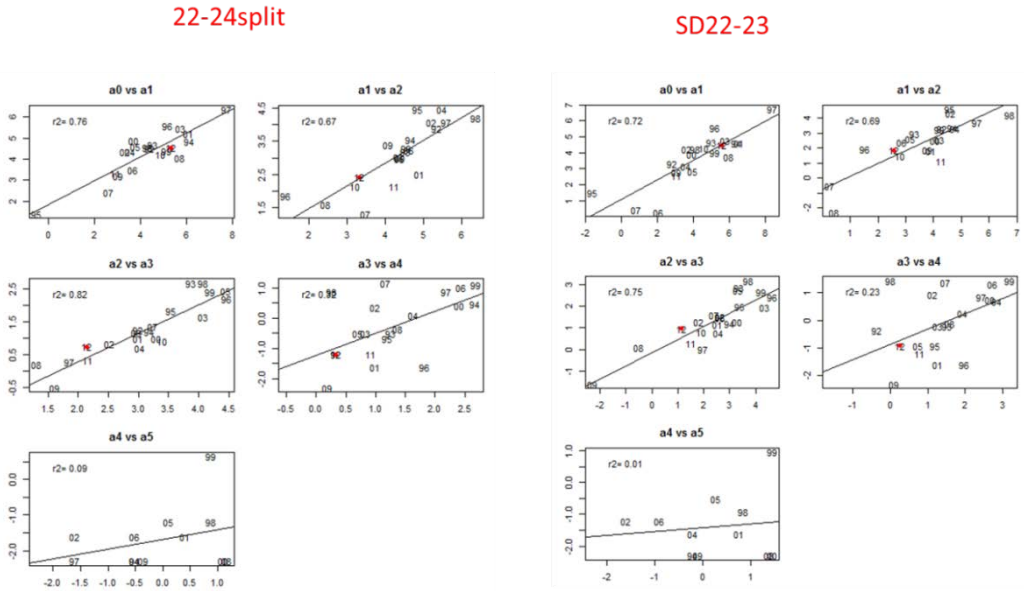


Figure 11. Western Baltic cod. Internal consistency of cpue for SD 22–23 (right panels) compared to SD 22–24, where the cpue values for SD 24 and the weighting of SD 24 in the procedure of combining the cpues by SDs (SD 22, 23, 24) are adjusted to take into account the proportion of eastern Baltic cod in the area (Q4 data).

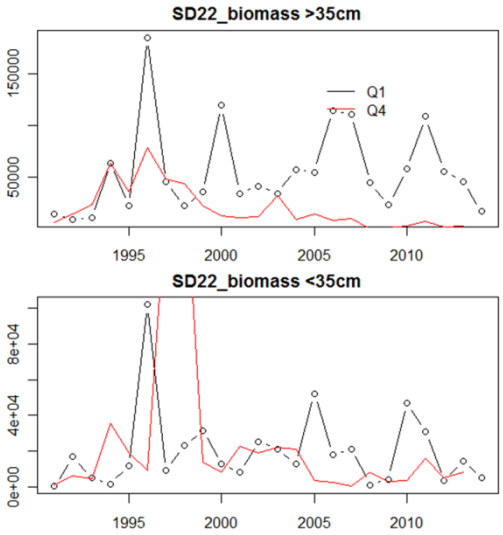


Figure 12. Western Baltic cod. Relative biomass index from surveys for >35 cm and <35 cm cod, respectively, in Q1 and Q4 in SD 22.

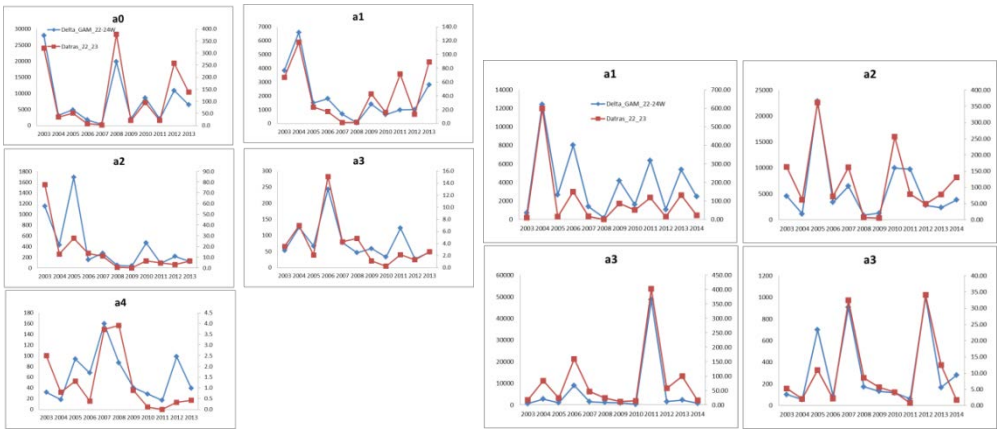


Figure 13. Western Baltic cod. Cpue indices for SD 22–23 from DATRAS compared to indices for SD 22–24W calculated using Delta-GAM approach. Left panels: Q1; right panels: Q4.

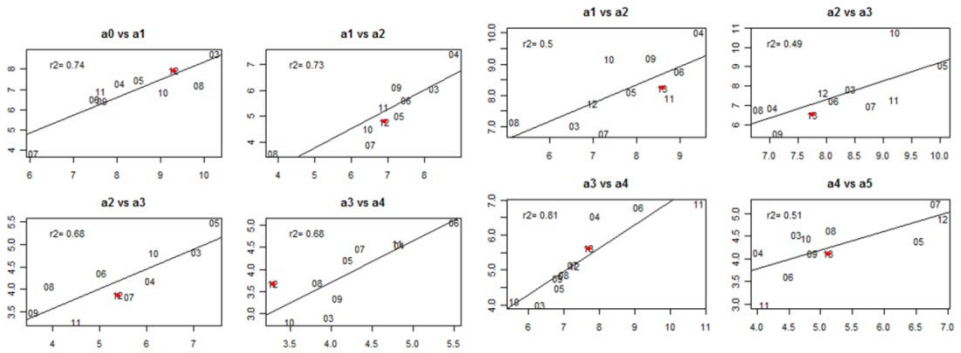


Figure 14. Western Baltic cod. Internal consistency of survey indices calculated using Delta-GAM approach. Left panels: Q1; right panels: Q4.

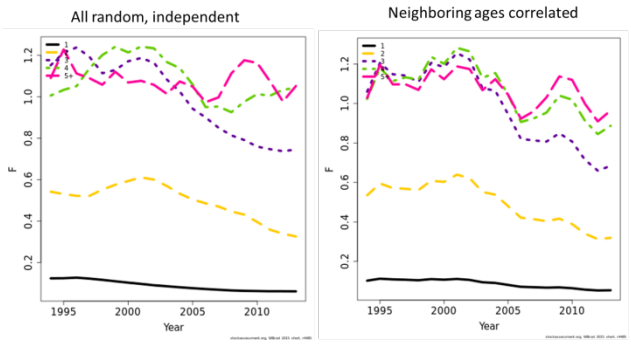


Figure 15. Western Baltic cod. Fishing mortalities at-age applying the SAM option where F for each age follows a random walk independent of other ages (left panel); Neighbouring age groups are more correlated than the ones further apart (right panel).

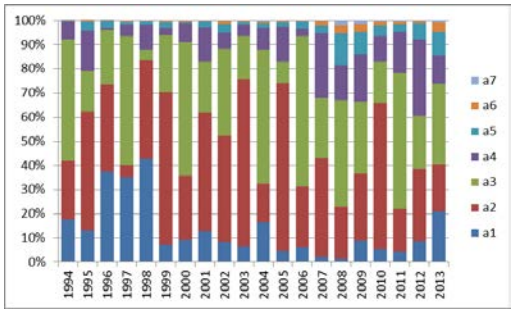


Figure 16. Western Baltic cod. Relative age structure of total catch.

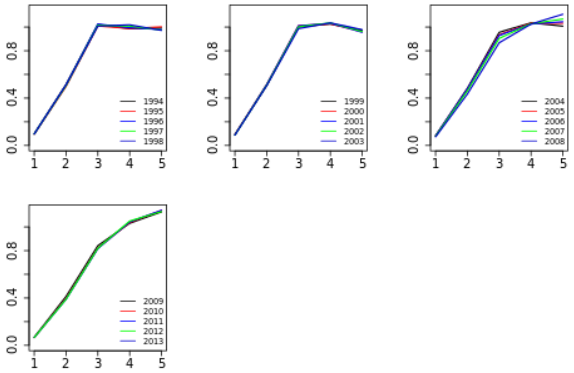


Figure 17. Western Baltic cod. F at-age in different years from SAM run with DATRAS survey indices for SD 22–23 and applying the option where F for neighbouring age groups is correlated.

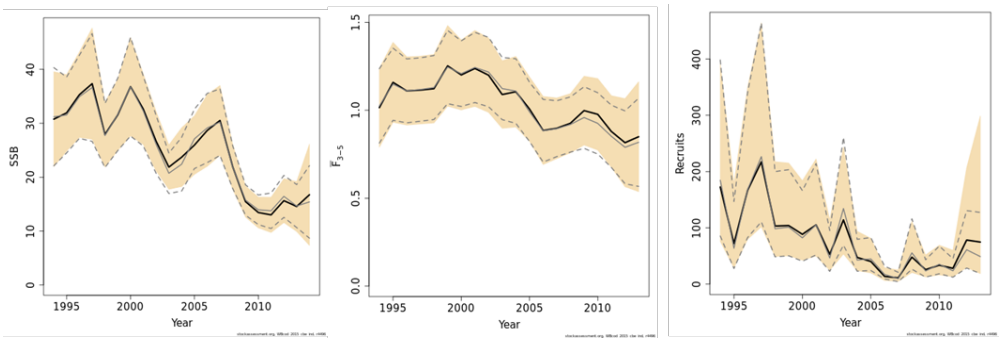


Figure 18. Western Baltic cod. Comparison of SSB, F and recruitment from the run using survey indices for SD 22–23 from DATRAS (black solid line with shaded areas showing confidence intervals) or from using survey indices from Delta-GAM approach (grey line with stippled lines showing confidence intervals).

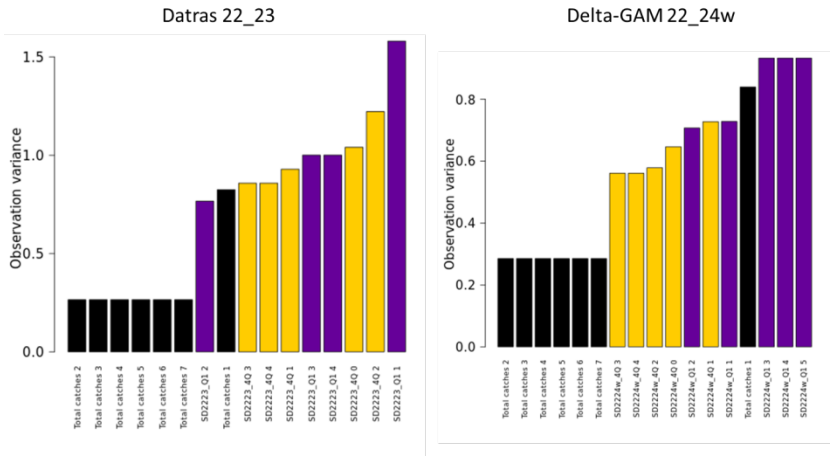


Figure 19. Western Baltic cod. Variances for catch and survey data for difference age groups, estimated in SAM model. Left panel: survey indices from DATRAS for SD 22–23. Right panel: survey indices from Delta-GAM approach for SD 22–24W.

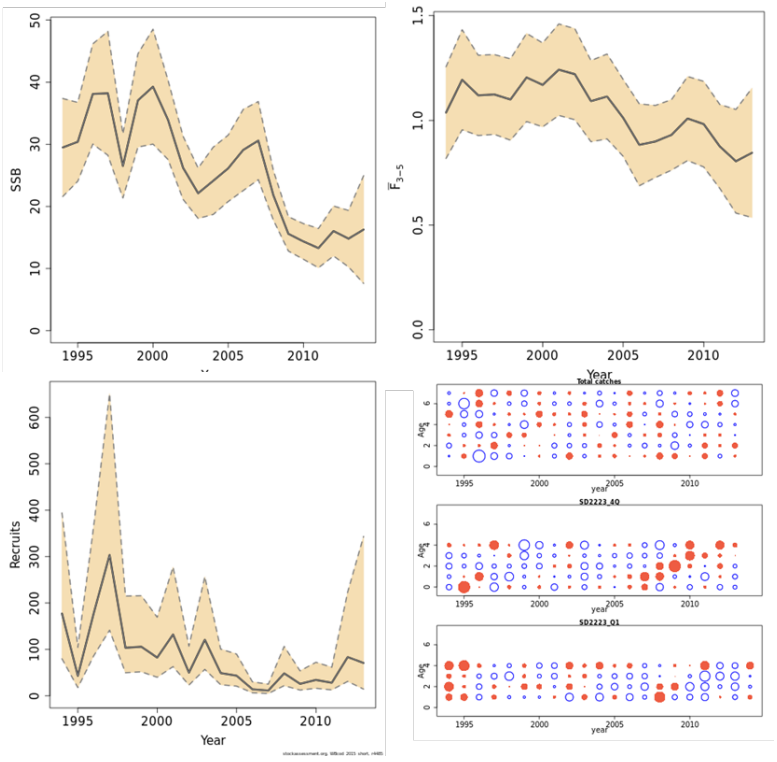


Figure 20. Western Baltic cod. Spawning–stock biomass (SSB), $F_{(3–5)}$, recruitment and residuals from the run using DATRAS survey indices for SD 22–23.

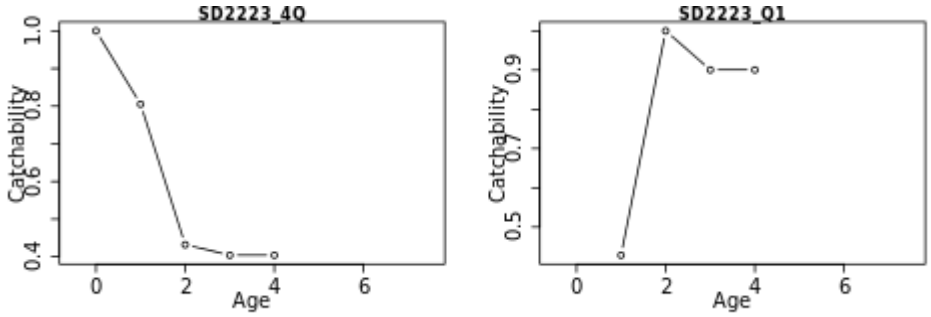


Figure 21. Western Baltic cod. Catchability estimates by age for surveys from the run using DATRAS survey indices for SD 22–23.

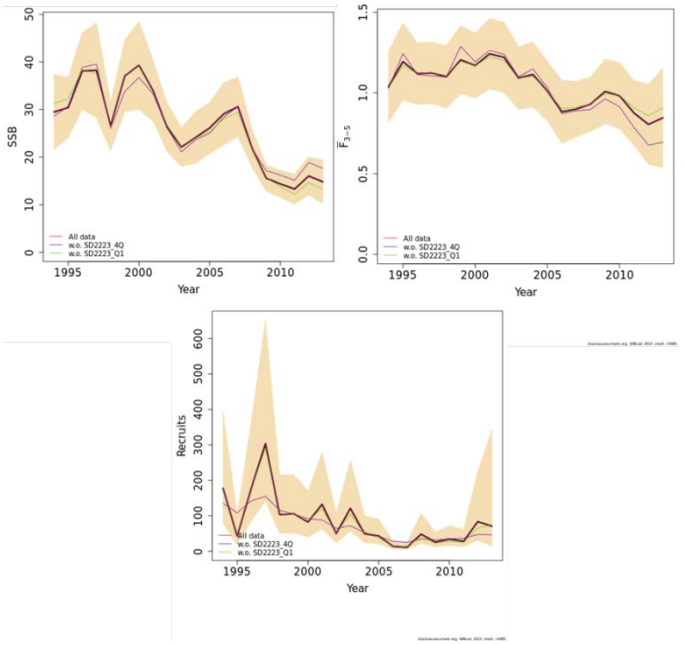


Figure 22. Western Baltic cod. Leave-one-out analyses (excluding one survey at a time) for spawning–stock biomass (SSB), $F_{(3–5)}$, recruitment from the run using DATRAS survey indices for SD 22–23.

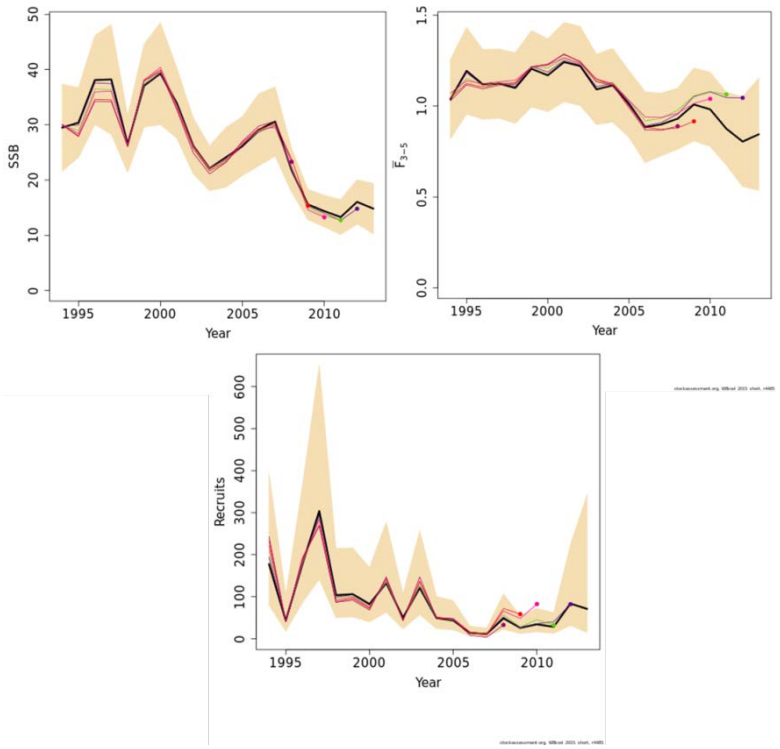


Figure 23. Western Baltic cod. Retrospective analyses for spawning–stock biomass (SSB), $F_{(3-5)}$, recruitment from the run using DATRAS survey indices for SD 22–23.

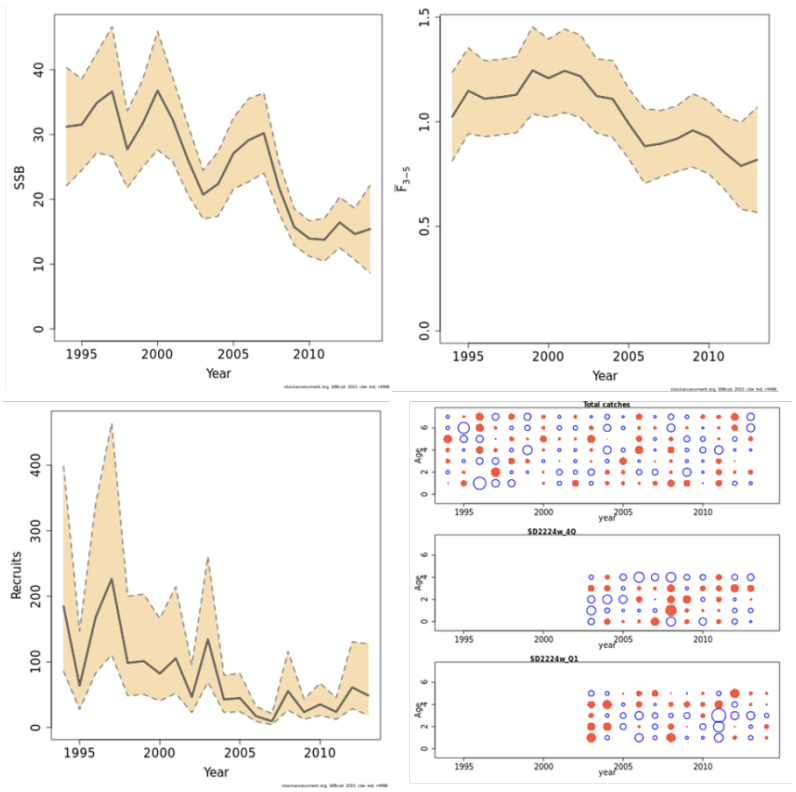


Figure 24. Western Baltic cod. Spawning–stock biomass (SSB), $F_{(3-5)}$, recruitment and residuals from the run using survey indices for SD 22–24W from Delta-GAM approach.

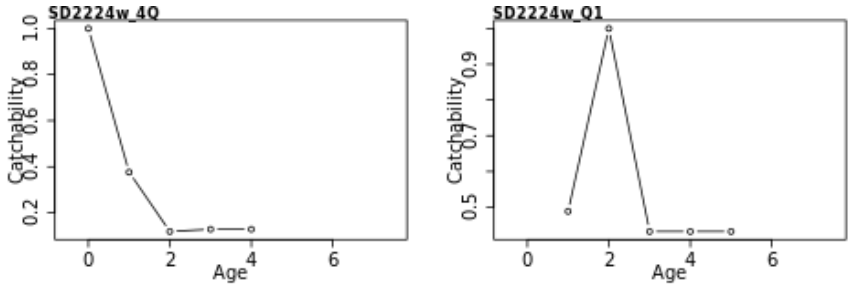


Figure 25. Western Baltic cod. Catchability estimates by age for surveys from the run using survey indices for SD 22–24W from Delta-GAM approach.

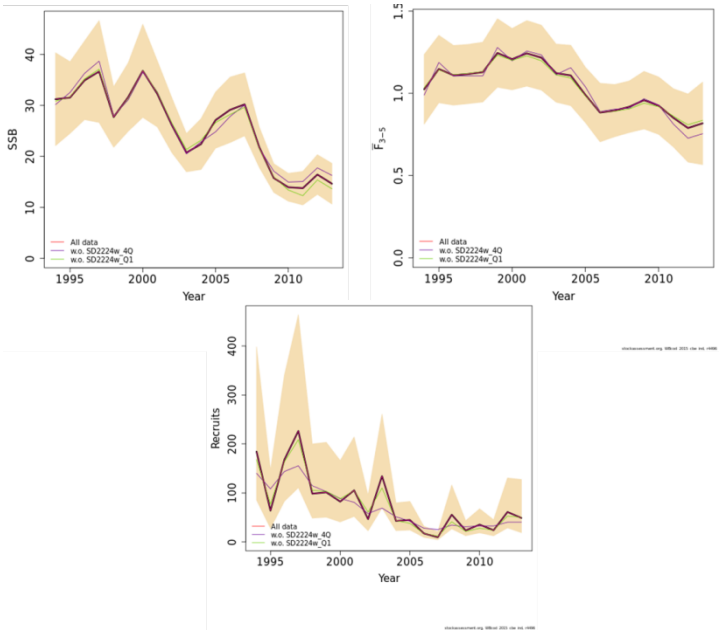


Figure 26. Western Baltic cod. Leave-one-out analyses (excluding one survey at a time) for spawning–stock biomass (SSB), $F_{(3–5)}$, recruitment from the run using survey indices for SD 22–24W from Delta-GAM approach.

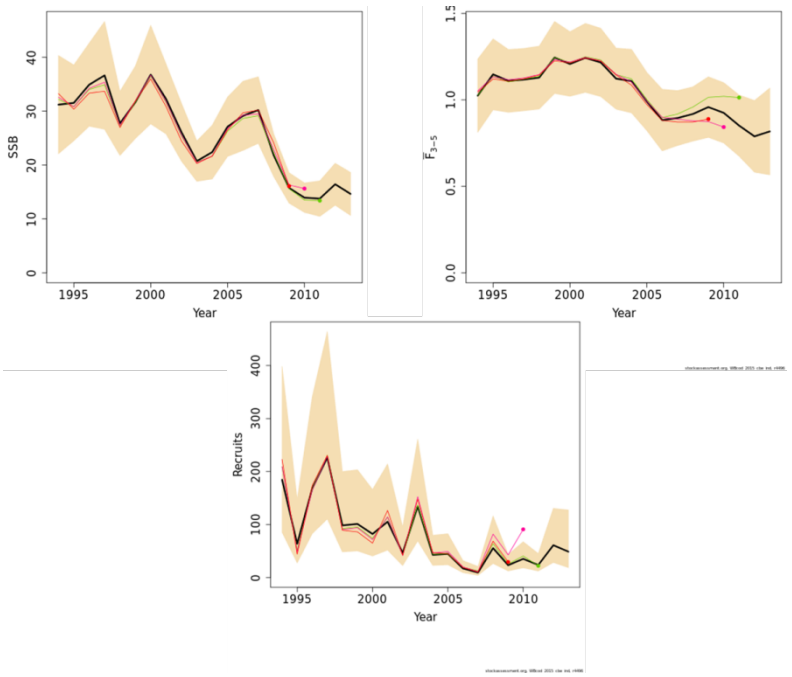


Figure 27. Western Baltic cod. Retrospective analyses for spawning–stock biomass (SSB), $F_{(3-5)}$, recruitment from the run using survey indices for SD 22–24W from Delta-GAM approach.

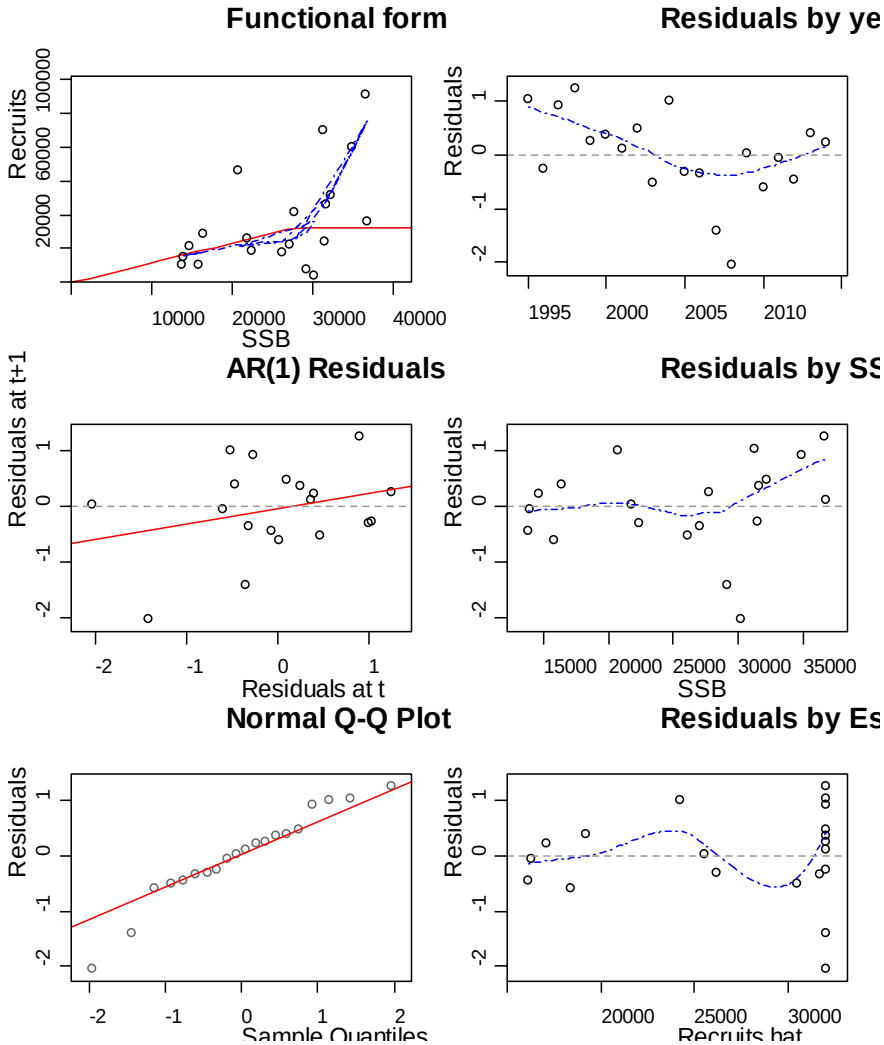


Figure 28. Western Baltic cod. Hockey-Stock fit and diagnostics for S–R relationship estimated using FLR package (FLSR).

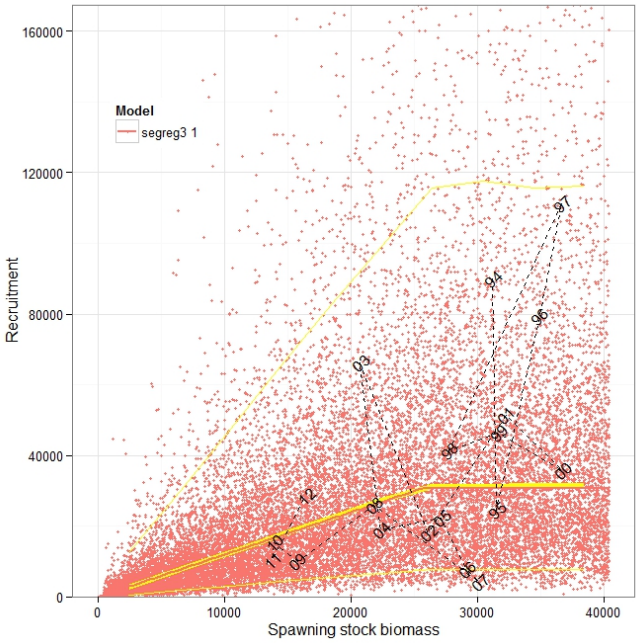


Figure 29. Western Baltic cod. S–R relationship with forced breakpoint in the middle of observed values.

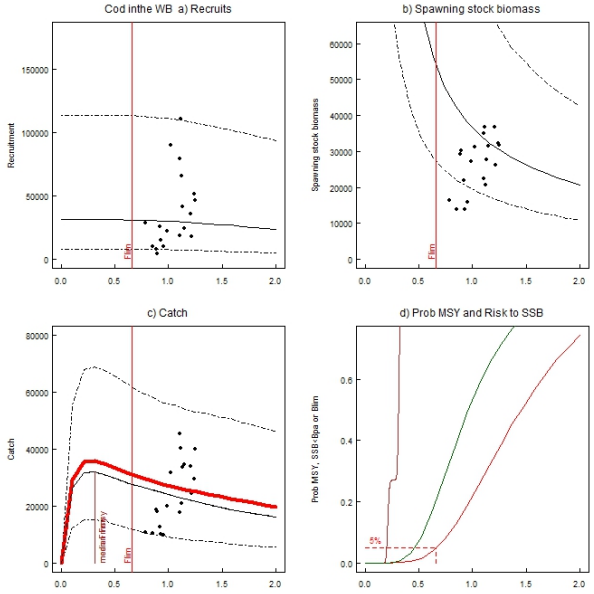


Figure 30. Western Baltic cod. F_{MSY} estimation outputs for the option applying $B_{MSY\ trigger}$ in the calculations.

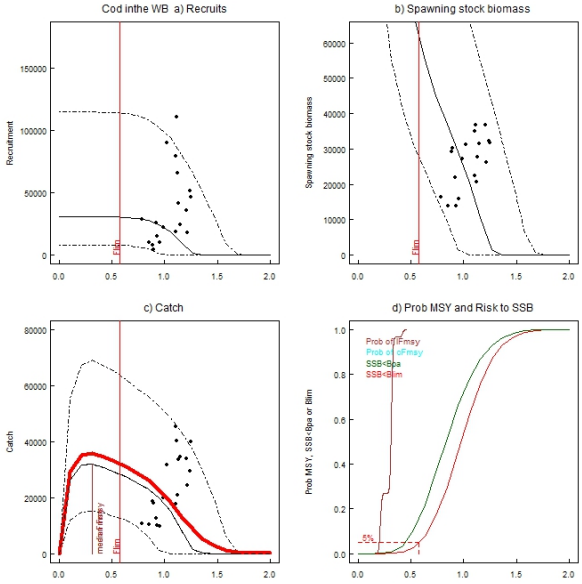


Figure.31. Western Baltic cod. F_{MSY} estimation outputs for the option applying no $B_{MSY\ trigger}$ in the calculations.

4 Eastern Baltic cod

4.1 Issue list

The main issues with previous assessment of cod in SD 25–32 were large retrospective bias for both fishing mortality and spawning biomass. Since 2011 the abundance of large cod has decreased very fast. This was considered to be potentially related to lack of growth or increased mortality of older fish or a mix of both. However, to answer these questions, it is important to have good age estimates to see if the cod are small and old or just thin and young. It was, however, realised during the WGBFAS 2014 that the age estimation particularly in eastern Baltic cod had become even more biased than before. Thus, the main issue with the eastern Baltic cod addressed at WKBALTCOD was age-reading problems, growth and mortality and associated data challenges.

- Absence of large cod, despite a lot of recruits;
- Age-reading problems;
- Reduced condition / changed growth?
- Changed catchability?
- Unaccounted mortality (Natural / Fishing)?
- Lack of ecosystem understanding.

4.2 Scorecard on data quality

ICES did not request countries to complete any type of scorecard and no diagnostics on spatio-temporal sampling coverage and sampling intensity were produced. Data quality issues are given in the Section 3.9.

4.3 Multispecies and mixed fisheries issues

4.3.1 Fisheries dynamics (change in selectivity/ fleet structure)

The TAC of EBC has not been utilized since 2009 due to a combination of several factors, involving low market prices of cod, low condition of Eastern Baltic cod, increasing discards, difficulties to encounter larger cod and increased mesh size since 2010, increased fuel prices and therefore low profitability. Hence, the quotas did not restrict fishing activities for the last five years. This happened in a situation where the majority of EBC was concentrated in the SD25 and SD26 and therefore the fishing effort was very concentrated in a smaller area.

Approximately 80% of Eastern Baltic cod is removed by active gear. There is strong evidence that the change in codend mesh size in trawl gears from 110 mm to 120 mm (i.e. BACOMA 110 mm to BACOMA 120 mm and T90 110 mm to T90 120 mm) in 2010 had a strong and rapid influence on changes in population structure of Eastern Baltic cod (WD Stepputtis *et al*. see Annex 3). There are basic effects of right-shifted selectivity curves, in this case: decreased catchability, increased (relative) fishing pressure on larger cod, unforeseen effects on discard rates. An additional problem with the BACOMA 120 mm-codend when compared to the BACOMA 110 mm is an unbalanced selectivity, i.e. the two netting materials in the BACOMA 120 mm-codend result in a selectivity curve that is not only moved to the right, but also flattened (Figure 4.3.1.1). This results in increased discards and decreased landings per unit of effort.

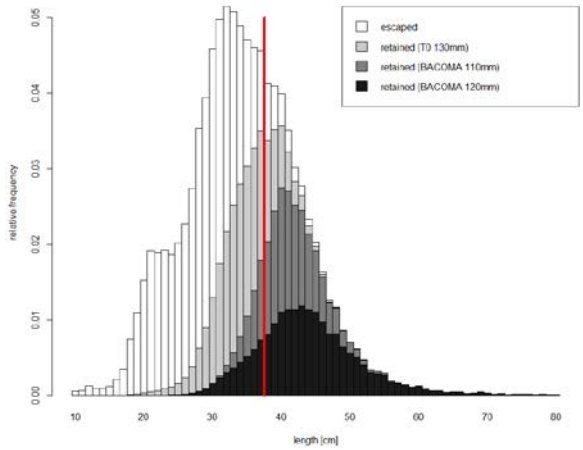


Figure 4.3.1.1. Examples of population structures from SD25 quarter 1 (white) and theoretical catch profiles (greyish colours) when using three different codends in 2010.

This change and the possible effects were communicated to the EU commission in 2010 (STECF 2010, Appendix D) but did not lead to an adaptation in the management measures. An important finding of this exercise was that the catchability changed significantly for length classes within the range ca. 30–50 cm. This implies that the use of commercial tuning fleets without reliable correction factors is not advisable.

Moreover, the change in codend selectivity due to an increase in the legal mesh size in 2010 may help to explain three major changes observed in Eastern Baltic cod in recent years: (1) TAC were not fished since 2010, (2) increasing discards in the national discard sampling programmes since 2011/12 and evidence from the fisheries for even higher discards (>50%), (3) decrease of larger cod in recent years.

4.4 Ecosystem drivers

4.4.1 Natural mortality

4.4.1.1 Condition

Low condition can increase natural mortality in cod (Dutil and Lambert, 2000). We used the paper Dutil and Lambert (2000) to estimate the changes in natural mortality of Baltic cod between 1991 and 2014. The potential reasons for the changes in cod condition and growth are presented in Section 4.4.2 "Growth and condition" below.

Method to estimate condition

We used the paper by Dutil and Lambert (2000) that measured in controlled experiments the condition (Fulton's K) of cod from the Gulf of St Lorenz (Canada) that were dead, starving and in good condition after feeding them at different rates for 100 days (cod within the length range 30–55 cm). Dutil and Lambert (2000) used gutted weights (GW) and fork length (FL) in their K estimates. Therefore, to make their study applicable to the Baltic Sea cod, the total lengths (TL) and total weights (TW) from the DATRAS database were converted into GW and FL for each fish, by using length- and quarter-specific conversions equations from Danish and Swedish biological samples collected in SDs 25 and 26 in the period 2006–2014. No annual differences in the conversions were noticed during this time period.

After conversion, the condition for each fish in the DATRAS database was estimated as K = GW / (FL^3) * 100.

Approach to estimate natural mortality (IBIS)

Dutil and Lambert (2000) observed that cods with K in the range 0.36–0.56 deceased, cod with K = 0.42–0.67 were starving and cods with K = 0.83–0.98 were considered to be in good condition. Many starving fish had however biological properties resembling very much those of dead fish, so they were expected by the authors to decease shortly. Moreover, fish in the wild suffer from harsher environment conditions than in a controlled experimental conditions, this probably being especially true for the Baltic Sea (varying temperature, low salinity, hypoxia), likely making wild EB cods with low condition (K <67) more prone to decease.

The following steps were taken:

1) The EB cods with K <0.65 were considered as deceasing. The proportion of fish with K <0.65 was estimated for BITS Q1 and BITS Q4 surveys between 1991–2014. The estimation was done by length classes (30–39, 40–49, 50–59 and 60–69 cm).

2) The proportions of fish with K <0.65, by quarter and year, were translated into mortality rates ($M_{condition}$).

3) The estimated mortality rates were added on the top of the 0.2 used so far (ICES, WGBFAS 2014). By doing this, the assumption is that the mortality = 0.2 is due to everything but condition. New M = 0.2 + $M_{condition}$.

The results of this analysis are shown in Figure 4.4.1.1 for cod 30–39 cm length group, and Figure 4.4.1.2 for cod 50–59 cm length group.

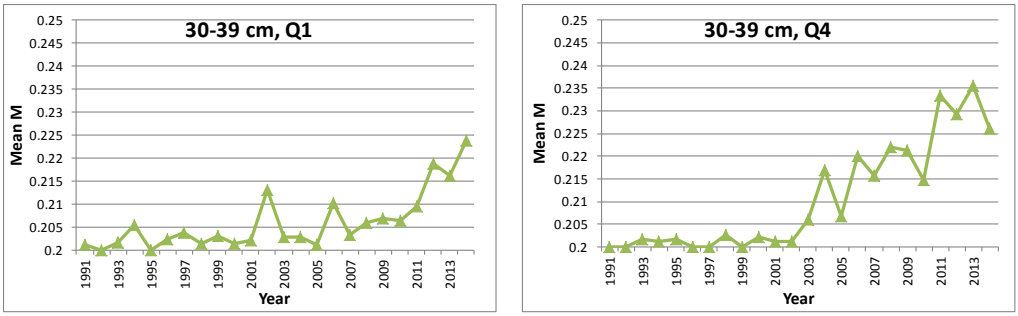


Figure 4.4.1.1. Time-series of natural mortality for cod 30–39 cm in which mortality due to condition is included.

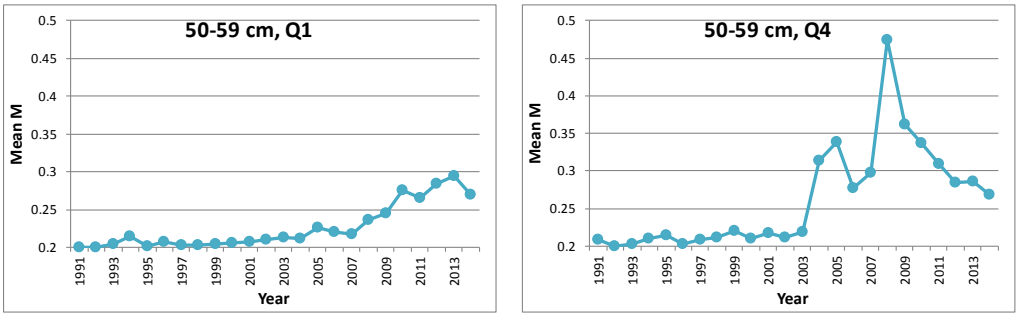


Figure 4.4.1.2. Time-series of natural mortality for cod 50–59 cm in which mortality due to condition is included. Note the different scale of the Y-axes compared to the previous figure.

4.4.1.1.1 Historically used natural mortality values

Condition and natural mortality has been fluctuated in the Baltic for many years. Thurow (1974) estimated the natural mortality to be 0.4. He estimated Z as a function of the total yield by a single regression and as the dataset was from a time period with varying effort he used the intercept (with very low yield) as a proxy for the natural mortality. The calculation was done in the Bornholm Deep and in Gdańsk/ Gotland area. The results were similar to a slightly higher M in the Bornholm Deep. The argument for higher M compared to the North Sea cod was that feeding condition was less satisfactory in the Baltic and frequently occurring oxygen deficits may also diminish survival, same picture as we are experiencing currently. The value from Thurow was adopted by the assessment working group as basis for the natural mortality. However, one year later in 1974 the working group felt that the natural mortality was higher than in the North Sea but not as high as estimated by Thurow and as an average of M=0.3 was chosen in 1975. It was realized by the assessment working group that the condition improved in the mid and late 1970s due to inflow events and even in the early 1980s with large cod stock abundance the condition was estimated to be very good (ICES 1986).

4.4.1.2 Parasite

Parasite studies conducted later years showed that the infection level of Baltic cod with nematode larvae increased with fish length. A major proportion of Eastern Baltic cod >47 cm were infected by nematode larvae (Figure 4.4.1.3.3) while in Western Baltic cod this occurred for fish approximately >84 cm (SD2224). Data of Thomas Lang (WD Lang *et al*.) showed that the condition factor of cod in SD252628 decreased with fish length. The decrease of the condition factor was stronger in infected cod than in non-infected cod. However, it was also showed that the condition of uninfected cod in SD2224 cod was higher than in uninfected cod in SD252628, suggesting that more factors than infestation with nematode larvae are involved in the lower condition factor of Eastern Baltic cod.

Poland collected data for parasitological examinations of cod in 2011–2014. Fish were caught in February and March in the Polish waters of the Baltic. In total, ca. 1200 individuals were examined, and the whole liver of each fish was inspected visually for the presence of Anisakidae nematodes (the number and systematic position of each individual parasite were noted). In addition, standard biological characters of examined fish were recorded (length, weight, sex, gonads stage, age).

First, data on prevalence of infection were analysed statistically, using GLMs. Prevalence was modelled as dependent on area and year of sampling, sex, and length or age of fish with logit link function and binomial distribution of dependent variable. It appeared that the prevalence of infection showed a parabolic shape, so finally the model including quadratic terms of length or age was fitted. Considered variables were highly significant and models explained ca. 70–75% of the prevalence deviance.

The dependence of prevalence on length increased up to ca. 60 cm (or age 6) and declined next (Figures 4.4.1.3.3–4.4.1.3.4). Such decline may be effect of two possibilities:

a) cod starts to loose parasites at some length with rate higher than the rate of accumulation of new ones;

b) infected cod exhibit higher natural mortality than fish free of parasites.

It is known that the proportion of herring (largely infected with A. simplex) in the diet of cod increases with cod length, the option b) seems to be more likely. It was assumed that the decline of prevalence at length above 60 cm (or age 6) was an effect of increasing natural mortality of infected cod.

The formulae for additional mortality due to parasitic infections (MI) were developed (Working Document by Horbowy and Podolska) and such mortality was evaluated. The estimates of MI increased from 0.15 to 1.3 for ages 6–9. However, the estimates for older age are very uncertain, as these ages were not well represented in the prevalence samples and, of course, the age determination is also uncertain.

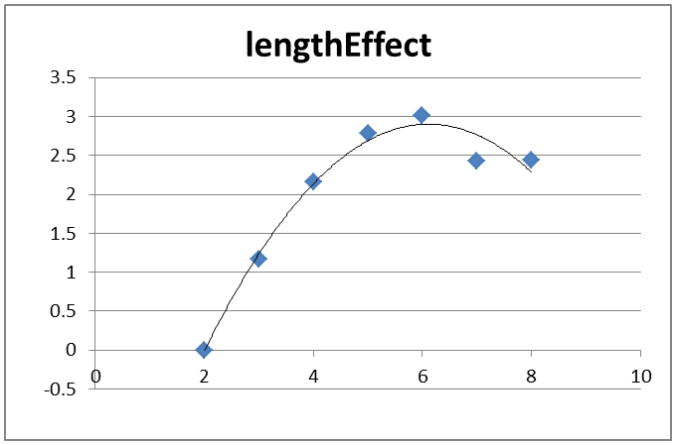


Figure 4.4.1.3.3. The length effect of the prevalence model (10 cm length classes, 2 means 20–29 cm, etc.) with length fitted as factor.

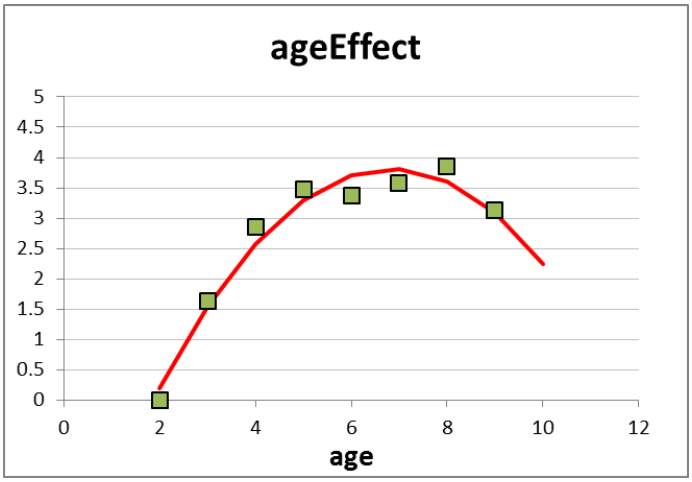


Figure 4.4.1.3.4. The age effect of the prevalence model with age fitted as factor.

4.4.1.3 Seal predation

The increasing grey seal population in the Baltic has lately been causing debate among the fishing community. At the beginning of the 20th century, the grey seal population in the Baltic Sea was much larger, estimated to be around 90 000 animals, but hunting and high contaminant loads decreased the level to a few thousand animals, a level from which the population started to recover during the 1980s (Harding *et al.*, 2007; Harding and Härkönen, 1999). In 2000, approximately 10 000 animals

were counted on land during the moulting period, in 2006 this had increased to 20 000 and in 2014 the count of grey seals was 32 000 (Härkönen *et al*., in press). In the abundance estimate conducted by HELCOM they state that close to 30% of the grey seals are in the water during the counting implying that the current population size is approximately 40 000 animals. The fishermen have been concerned about the increasing abundance as grey seals consume fish and there have been theories that seals may be involved in the decline of the Baltic cod stocks. It was estimated that the grey seal population in 2014 consumed 4 kg fish a day in average and that the total grey seals population was consuming 5% cod in their diet (Anders Galatius, personal communication), indicating that the total consumed level is just below 3000 t cod. However, if only the grey seal population in the southern area is considered (3575 individuals) but with a higher percentage of cod in the diet (50%) the level is close to 2600 t, both estimations are considered uncertain.

Other unpublished analyses, using diet information (from stomachs and faeces) of grey seals sampled in SD 27 and 28 and estimates of seal population in the southern Baltic (SDs 24 and 25), showed an annual consumption of cod between 800–5500 t in the southern Baltic. The data however, are very uncertain. For comparison the total landings of cod in 2013 were 31 400 t and the discard estimated to be close to 5000 t, indicating that seals are taking less than 8% of the total catch (seals+ landings +discards).

4.4.1.4 Cod cannibalism

Cod cannibalism appears to have increased rapidly during the latest years. While practically absent during the late 1990s and early 2000s, the frequency of occurrence increased in the late 2000s, and especially since 2010. Interestingly, the decreasing rate visible for the 1980s, and the sharp increase in 1992 and 1993 is confirmed by independent data not used in this analysis (Neuenfeldt, pers. comm.).

Whether or not cannibalism has increased the mortality cannot be judged based on the stomach data only. For example, if the very high frequencies of smaller cod observed after 2010 correspond to very high abundance of cod inside the predation length range for cod (about 5 cm to 35 cm total length, Neuenfeldt, pers. comm.), then the actual mortality rate, caused by cannibalism, exerted on the small cod by conspecifics might not be above average, but only reflect the increased abundance.

Further analyses and the estimation of cannibalism rates depend, hence, on the availability of relative abundance estimates, such as survey catch rates, both for the small prey cod, and the predatory large cod. On the other hand, the estimation can be conducted in the absence of age estimates, using exclusively predator and prey length data:

$$N_{35} = N_5 \times e^{\int_{x=5}^{x=35} -\frac{\mu(x)}{g(x)} dx}$$

N35 is the number of 35 cm TL cod. This is the product of the Number of 5 cm cod and the integral of hazard rate μ(x) over growth rate g(x) over the size/time/space window where small cod are matter to predation by large cod. Considering μ(x) to be due to cannibalism only, it can be described based on stomach content data and relative abundances of predator and prey. Other possibly important effects such as oxygen or spatial overlap can be included.

Although cannibalism has increased significantly since the mid-2000 it is not likely that cannibalism is the main reason for the present lack of large cod in the east Baltic

cod stock. The main size distribution of cod exposed for cannibalism is below 25 cm (Neuenfeldt and Köster, 2000) and currently these size groups are very abundant. The challenge in the east Baltic is the lack of the larger cod (>45 cm) and it is very unlikely that these larger cod have been exposed to cannibalism.

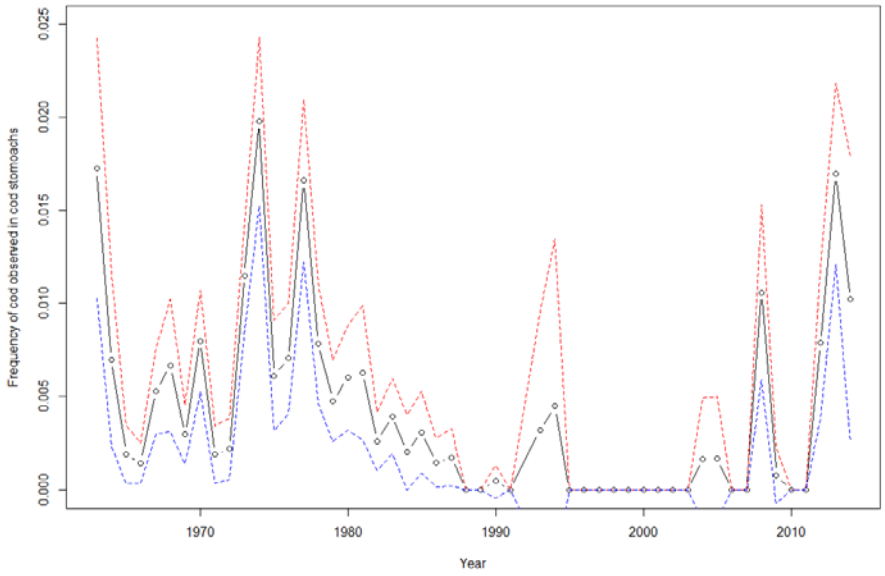


Figure 4.4.1.4.1 Time-series of the frequency of occurrence of cod in cod stomachs. Data from the recent EU tender on stomach sampling. Dashed line indicate +/- 2 standard deviations of the frequencies, assuming independence of other prey types found in the stomachs (binomial distribution).

4.4.2 Growth and condition

Nutritional condition of adult cod has been continuously declining since the early 1990s. However, since the mid-2000s, when cod abundance started to increase, the proportion of cod with very low condition index (Fulton K <0.8) rapidly increased, reaching 20% in recent years in the Bornholm Basin, where cod densities are highest (Eero *et al*., 2012b; Eero *et al*., 2015). The decline in cod condition is evident in all offshore areas of the central Baltic Sea. It has been suggested that the growth of cod in terms of length-at-age has also declined (Svedäng and Hornborg, 2014). Hypothesized reasons for deteriorating nutritional condition include: 1) increased extent of low oxygen areas that could affect cod growth directly via altering metabolism (Plambech *et al*., 2013) and reducing food intake (ICES, 2015, WD Krumme *et al*., WD Casini *et al*.); 2) low availability of fish prey in the main distribution area of cod (Eero *et al*., 2012, WD Casini *et al*.); 3) shortage of benthic prey given the stagnation period and frequent oxygen depletion at the bottom; 4) increased infestation with parasites (see Section 4.4.1.2; 5) size selectivity in commercial fisheries, which may have contributed to a larger proportion of small-sized fish in the stock that may have led to density-dependent effects (Svedäng and Hornborg, 2014).

Hypoxia-induced reduction of growth of Eastern Baltic cod would suggest that the productivity of the stock is low because of an environmental factor that can only be influenced by unpredictable inflows. Food limitation would suggest that stock productivity can be increased by decreased removal of pelagic prey in the main area of cod distribution (Eero *et al*., 2012; ICES Advices 2013, 2014, 2015). Density-

dependence would suggest that stock productivity can be increased by increased removal of cod individuals. Although there are currently several hypothesis on the reason to the reduced condition they are not mutually exclusive, the theories can be linked as a reduced suitable area for the cod will lead to a higher cod density in the areas with higher oxygen.

There are currently no reliable estimates available of the current growth rates of Eastern Baltic cod. This is mainly due to the problems in ring interpretation (age-reading problems) and lack of age-validated otoliths, lack of age-validation studies or tagging experiments. However, decreased condition factor of EBC suggest that growth has decreased in recent times.

4.4.2.1 Oxygen

Laboratory experiments have shown that cod growth can decrease under conditions of chronic hypoxia (e.g. Chabot and Dutil, 1999). This applies both for growth in length and weight. Growth is, however, not stopped but growth rates are reduced. Other parameters such as condition factor, hepatosomatic index, food uptake and swimming activity also went down under chronic hypoxia (Chabot and Claireaux, 2008). It is important to note that in the experiments food uptake was reduced despite *ad libitum* feeding, i.e. cod under hypoxia reduced feeding despite presence of food. These adverse effects are all due to metabolic constraints of cod living under low oxygen saturation levels. In the laboratory experiments these effects started at oxygen saturation levels of 70%. In conclusion, hypoxia reduces the energy reserves of individual cod and, if major parts of the population are affected, of the entire stock (WD Krumme *et al*.). In addition, metabolic theory predicts that larger cod should be stronger affected by hypoxia than smaller cod because the relationship between gill size and body weight decreases with increasing body size, due to declining oxygen supply per unit of weight.

Generalised Additive Models (GAMs) were used to investigate the relative importance of density-dependence, food availability, risk of seal parasite infection and extent of hypoxic areas, on cod condition (WD Casini *et al*.). The extent of hypoxic areas was the most important explanatory variable, followed by sprat abundance (i.e. food limitation) and as last cod density (i.e. density-dependence). Seal abundance and herring abundance were not found important in explaining changes in cod condition.

The extent of hypoxic areas could affect cod condition in multiple ways, such as 1) direct physiological effects (e.g. reduced digestion and feeding rate), 2) reduced benthic prey abundance, 3) change in behaviour, with larger proportion of the population dwelling in the pelagic, more oxygenated waters, but also 4) reduced suitable area which would result in increasing competition and density-dependence.

Support for the hypothesis on hypoxic areas was provided by analyses performed by the ICES SGSPATIAL 2014 (ICES, SGSPATIAL 2014b) that investigated the stomach content of cod from 2007–2014 BITS survey Quarter 4. This analysis showed that cod caught in areas with high extent of hypoxic areas had a lower frequency of occurrence of both pelagic and benthic prey in the stomach and a higher amount of cod did not have food in the stomach. This indicates that in hypoxic conditions a smaller proportion of the cod population is feeding.

4.4.2.2 Size selectivity in commercial fisheries

In support for the density-dependence hypothesis a case study showed that increasing selectivity may have been one of the mechanisms producing crowding and therefore decrease in growth via density-dependence (Svedäng and Hornborg, 2014).

In this growth model (based on BITS data from DATRAS), the length (or weight) asymptote of a fish stock, L_∞, reflects the growth potential of the stock. According to Beverton and Holt (1957), L_∞ varies with feeding conditions. Incidence of density-dependent growth in combination with management actions intended to increase selectivity towards larger size classes was early on predicted to be a potentially malicious combination, which may give considerably lower yields than anticipated. Raising length at first catch (L_c), measured as the 50% point of the selectivity ogive (i.e. the curve of a cumulative distribution function), results in increases in intraspecific competition in size groups left unexploited as population density becomes higher, and, consequently, in decreases in L_∞. Lower growth potential at sustained levels of recruitment also leads to crowding, as the number of fish will inevitably increase in non-fishable size groups as growth drops. Consequently, fewer fish will reach fishable sizes; further increases in selectivity might even result in a Lc above L_∞, which means few fish will reach fishable size.

In the study, it was found that growth measured as L_∞, have continuously declined over the last 20 twenty years as gear selectivity has been increased. It was also found that increased selectivity in the Eastern Baltic cod fishery was correlated to higher abundance in non-fishable size groups. With new recruits entering the population, the lower growth induces crowding in smaller, non-fishable size groups, further decreasing growth potential.

4.4.2.3 Prey availability

The focus of SGSPATIAL 2014 was to make the first analyses on the cod stomach content from the EU tender "Study on stomach content of fish to support the assessment of good environmental status of marine foodwebs and the prediction of MSY after stock restoration". The Baltic cod has suffered from a drastic reduction in growth and body condition since the early 1990s, creating large problems for the fishery and also likely increasing the discard rate from the fishery. One of the explanations that have been put forward to explain the drop in condition is the decline in the availability of pelagic prey (sprat and herring) (Eero *et al*., 2012). Another explanation could be related to the increase in the area of hypoxic and anoxic bottoms (Hansson and Andersson, 2013) with potential consequences on the amount of benthic prey for cod and cod behaviour. Therefore, SGSPATIAL 2014 especially focused on making the first analyses of the cod stomach content in relation to oxygen condition and cod body condition. Overall, the following analyses were made:

1) Length-frequencies of prey in the cod stomachs in different areas.

2) Food composition and frequency of cod empty stomachs in different areas. Are there hot spots in the frequency of occurrence of different prey types? What is the proportion of the cod population that is actually feeding in the Baltic seascape?

3) Food composition of cod in good/bad body condition. Do fat vs. lean cod feed in different habitats (pelagic vs. benthic)?

4) Food composition of cod in anoxic environment and good oxygen condition. Do cod eat more pelagic vs. benthic organisms under different oxygen conditions on the seabed?

The analyses are described detailed in the SGSPATIAL report (ICES CM 2014/SSGRSP:08)

Results

Cod in ICES Subdivision 25 have shown a considerable decrease in weight-at-length since 2007. We used newly available data from an EU financed stomach-sampling scheme to investigate, if cod between 30 cm and 40 cm total length consuming less food nowadays, and if yes, the difference a possible cause for decreased condition. Using first a stochastic stomach content model, we found that average meal intensity (number of meal per day if searching for food) increased, but that average daily food consumption decreased by about 35%. The ratio of fish compared to benthos in the stomachs decreased since 2009, but is on the same level as in the 1980s, when there was no poor condition observed in cod of the investigated size group. Second, we applied a bioenergetic model to investigate if the cod between 30 cm and 40 cm total length consumed enough energy to support somatic growth. The alternative estimate of daily consumption was considerably lower than the one derived by the stochastic mode, implying that the assumption of lognormally distributed meal sizes in the stochastic model has probably been misleading. Daily consumption, estimated based on food intake of benthos and fish with different energy densities, ranged in the new collected stomachs between 10.7 kJ/day in 2012, and 18.6 kJ/d in 2008. These values are in line with literature values, but at the lower end of consumption rates supporting somatic growth. Accounting for the food conversion, and cost of activity, the excess energy was about 20%, i.e. the consumed energy was ca. 20% than the estimated standard metabolic rate. This energy excess has to be distributed over somatic growth and maturation, and is possibly compromised by the increasing degree of infection with parasites.

The cod caught during surveys that showed a Fulton's k above 1 had a larger proportion of pelagic (sprat, herring, stickle-back, juvenile cod) prey in their stomachs. Furthermore, in this fraction of the cod the proportion of empty stomachs was lower (Figure 4.4.2.3.1 and 4.4.2.3.2).

The very much discussed decrease in weight-at-length (or condition) starts (during life history) between 30 cm and 35 cm total length, and stops again at length >55 cm (in the first plot only visible part of the changes in the variance band). From the available time-series back to 2002 it is not identifiable, when this phenomenon started. There are some, yet untested, implications that the decrease in condition for cod between 30 cm and 55 cm started sometimes in the late 1980s, when the inflow stagnation really had kicked in (last inflow then 1983, no one until 1992). However, there were plenty of sprat available at that period (Figure 4.4.2.3.3).

The range above 55 cm with no decrease in weight-at-length is easily identifiable here. Full range of food items in the diet, very flexible, able to go for benthic fish, too.

The range between 30 cm and 50 cm is characterized by the successive change from demersal to pelagic (herring and sprat) feeding. If the decrease in weight-at-length started at times when there were enough herring and sprat, it is probably caused by too low condition to initiate pelagic foraging, or no overlap between cod and sprat

(primarily, because it is sprat they start foraging on, herring comes later in their life, because it is bigger) (Figure 4.4.2.3.4).

Further analyses

- Extend the cod weight-at-length data backwards in time as far as possible; when did the decrease in weight-at-length start, and have the small cod also experienced decreasing condition? Are the cod taking the condition deficit over from their period of life foraging on benthos, or does the decrease first start at length where they forage on sprat?
- Investigate the stomach data to see, if there is support for the hypothesis that decrease in weight-at-length is due to decreased sprat in the transitional period between demersal and pelagic foraging.
- In case, analyze if this can be explained by change in the benthos diet, simply less or worse quality in terms of energy content.

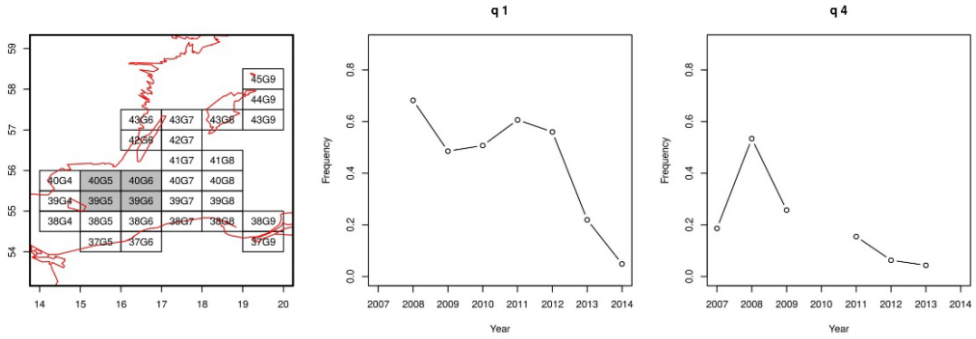


Figure 4.4.2.3.1. The occurrence of sprat in cod stomach during the time period 2007–2014 in the 1st and 4th quarter BITS survey.

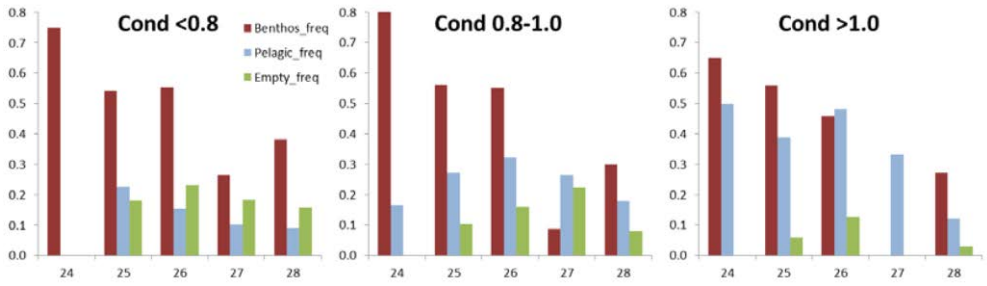


Figure 4.4.2.2.2. The proportion of cod stomachs with zoobenthic and pelagic (sprat, herring, stickle-back, juvenile cod) prey and the proportion of empty stomachs per SD in 2011–2014. The samples have been grouped based on condition of the cod, into predators in poor (<0.8; left), intermediate (0.8–1.0; middle) and good (>1.0; right) condition.

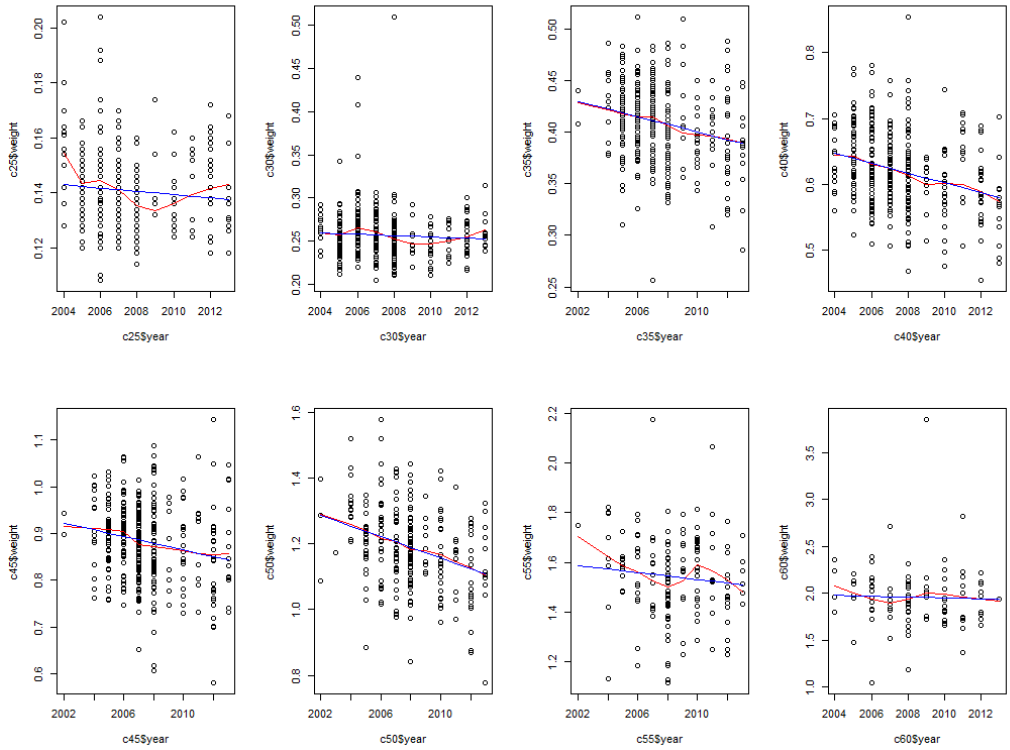


Figure 4.4.2.3.3. Length in a given cm group in a given year vs. weight.

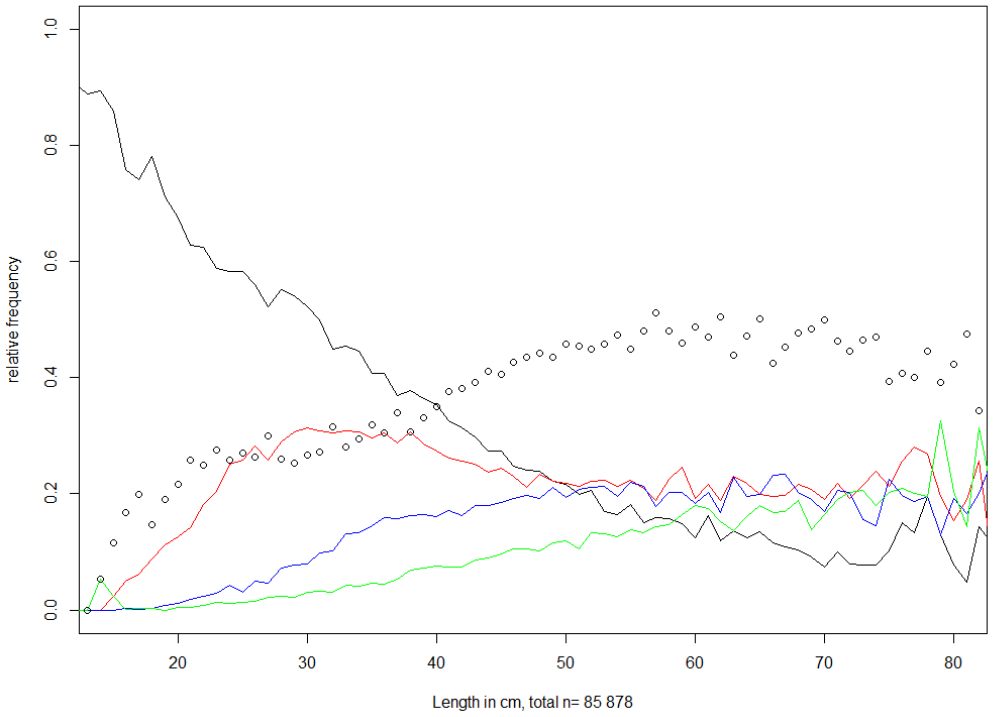


Figure 4.4.2.3.4. Cod diet composition, here expressed as frequency of occurrence of different prey types over cod length.

Black dots: frequency of empty stomachs. Note that there are two plateaus, one between c. 25 cm and 40 cm, and another above 50 cm.

Black line: Benthos except for Saduria entomon.

Red line: Saduria, always in the stomachs at constant frequency above 15 cm length (mouth too small before).

Blue line: Sprat; coming in slowly between 20 cm and 40 cm.

Green line: Herring; coming in later than sprat (they are on average bigger).

4.4.2.4 Apparent growth change

Length-based assessment models require information on growth. Several parameter estimates of von Bertalanffy growth function (VBGF) were available from the literature. $L\infty$ varied between 67.7 cm (Bagge, 1974 for western Baltic cod) and 126.0 cm (Pauly, 1978). Estimated k values varied between 0.1 (Pauly, 1978) and 0.37 (Bagge, 1974). Two recent studies with somewhat contradictory results were presented at WKBALCOD.

Svedäng and Hornborg (2014) estimated new parameters of the VBGF by year class based on raised numbers-at-age-per-unit-of-effort of cod captured in SD 25–28 during Baltic International Trawl Surveys (BITS) between 1991 and 2013. Only Swedish age–length keys were used and the data were not weighted to account for the number of individuals aged (Svedäng, pers. information). Estimates of $L\infty$ decreased from a maximum of around 130 cm to around 40 cm with partly strong fluctuations from year class to year class. However, an $L\infty$ at 40 cm at present state seems rather low even for the eastern Baltic cod stock. In addition to the published results, decreasing mean length-at-age of year classes was shown during the working group meeting

(Figure 4.4.2.2.1 upper). However, the explanation for this decrease is uncertain. The scatterplot of the raised age–length data of cod sampled in 2014 in quarter 4 showed that the spread and maximum lengths of age groups 5 and 6 were generally smaller than those for age 4 and 3 (Figure 4.4.2.2.1 lower). This could indicate that there is a high mortality for ages 5 and older or that there is a sampling bias towards smaller individuals or that age reading is biased for older individuals. In all cases this raises doubts regarding the suitable of the data for ages 5 years and older for estimating growth parameters.

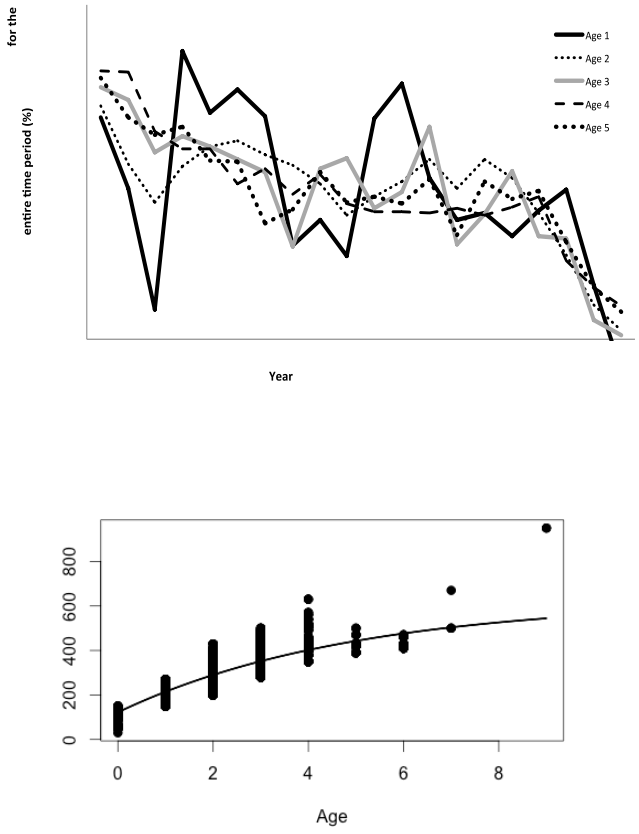


Figure 4.4.2.2.1. Mean annual length as percentage of mean value for the entire time period [%] (upper). Age–length data of cod sampled in quarter 4 in 2014 (lower) - presented during WKBALTCOD 2015 by H. Svedäng.

Oeberst and Krumme (2015) used age–length data of Denmark, Poland, Russia and Sweden to estimate VBGF parameters by country for the year classes 1995 to 2010. The observed decrease in $L\infty$ and was correlated with an increase in k for all countries. However, the mean length-at-age by cohort derived from the country-specific VBGF parameters estimates did not show much decrease except for older ages (4 and older) in recent cohorts (see results for Polish and Swedish data in Figure 4.4.2.4.2. top row). Mean length-at-age was also estimates based on the combination of country-specific age–length-keys and the sampled length frequencies of the cod stock in SD 25 during 2002 to 2013 (Figure 4.4.2.2.2 bottom row) using the estimation procedure given in the BITS manual. Again some decrease was found for certain older ages but not younger ones, with differences between countries.

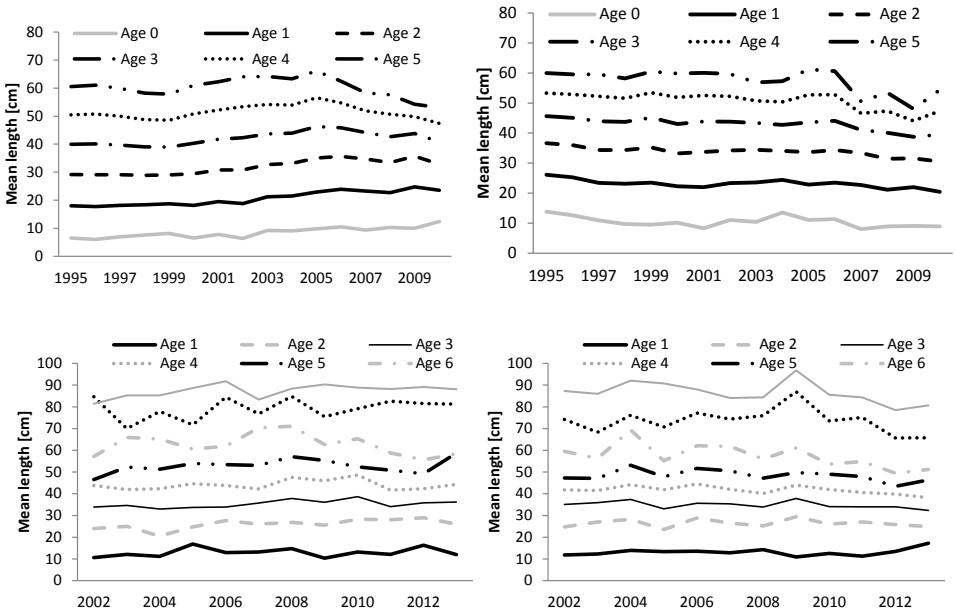


Figure 4.4.2.2.2. Mean length-at-age using Polish (left column) and Swedish (right column) data. Top row: Estimates by cohort based on fitted VBGF. Bottom row: estimates by year based on the combination of age–length keys and length–frequency data.

Finally, VBGF parameters were estimated based on Polish and Swedish age–length data sampled in periods where cod larger than 38 cm were abundant (Table 4.4.2.2.1). Using this approach VBGF parameters by period did not indicate a significant decrease of growth in length.

Table 4.4.2.2.1. Estimated VBGF parameters for eastern Baltic cod estimated based on Polish and Swedish age data sampled in SD 25 and SD 26. SD: standard deviation of residuals; N: number of fish aged.

Period	L_∞	k	t_0 in month	SD	N
1995–1998	124.2	0.118	2.2	7.5	11390
1999–2002	204.6	0.062	1.0	5.9	5755
2008–2011	183.7	0.072	1.2	6.5	7583

In conclusion, the different analyses indicated that estimates of VBGF parameters for Eastern Baltic cod were rather sensitive to methodological choices (which ALK used, range of ages and lengths sampled, sample size weighting, etc.). Furthermore, the uncertainty in the age estimation will have a large influence on the results. Thus care has to be taken when using any of the presented VBFS parameter values in the stock assessment models. Despite this, all studies agree that Eastern Baltic cod growth has varied over time with indications of a decrease in recent years, but the extent of it is not known.

4.4.2.5 Blocks in condition factors

Time blocks in cod condition factor were identified as structural changes in ordinary least-squares regression relationships using the R package 'strucchange' (Zeileis *et al.*, 2002). Time-series (Q1 and Q4) of condition factor were modelled as empirical pro-

cesses to capture the fluctuation in standardized residuals. Significant structural changes were measured using *F* statistics for all potential change points in the time-series. We identified significant structural changes for Q1 during 1997 and 2004 ($p<0.001$) and for Q4 during 1997 and 2007 ($p <0.001$, Figure 4.4.2.3.1).

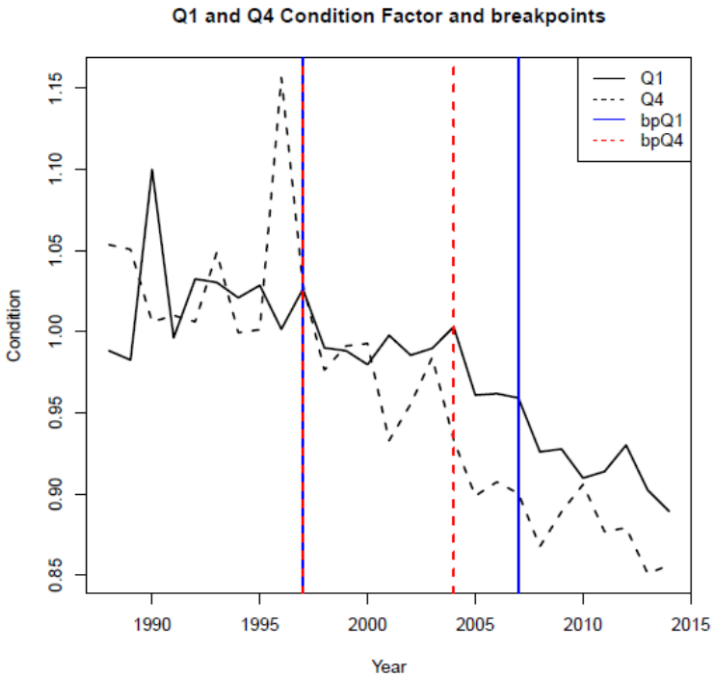


Figure 4.4.2.3.1. Condition factor and breakpoints in the timeline.

4.4.3 Environment

4.4.3.1 Inflow events

The health of the Eastern Baltic Sea ecosystem is highly dependent on inflow events from the North Sea through Kattegat. The frequency of inflow events has decreased since the 1990. The last major Baltic inflows took place in 2003, and a smaller one in early 2014. The 3rd largest inflow event since the beginning of the time-series in 1880 took place in December 2014 (Mohrholz *et al.*, 2015). Hence, since 2003 the Eastern Baltic Sea was characterized by a stagnation period with spreading dead zones. However, minor inflows may have occurred since 2003, especially from 2009/2010 onwards, but where not recognized because the detection threshold that defines an inflow event was apparently not chosen adequately. The time-series is now being revised (Mohrholz *et al.*, 2015).

The first inflows after a stagnation period, especially if of minor magnitude, may lead to the formation of a cap or tunnel effect (WD Krumme et al.). Denser, more saline and oxygenated water uplifts older water. Pelagic cod which regularly dive to the bottom (Neuenfeldt *et al.*, 2009) may return to their demersal habitat. These "first re-colonizers" may, however, suffer from an environment poor in benthos, crowding, variable oxygen conditions due to hydrographic dynamics and reduced incentive to conduct vertical movements. Thus, there might be a paradox on of what Good Environmental Status (GES) means for the environment and for certain components of the environment. It is hypothesized that the first inflows may improve the overall environmental status but initially deteriorate the conditions of cod that, due to their af-

finity to demersal habitat, become trapped in the new, unstable body of inflow water, with a number of adverse changes, e.g. greater catchability, increased hypoxia-effects on cod metabolism, reduced food intake, and even increased natural mortality, especially after the spawning period (WD Krumme *et al.*). However, with increased oxygen the area suitable for cod will expand at it is likely that the cod will spread over a larger area and this will reduce the risk of density-dependent growth.

4.4.3.2 Recruitment

Increased reproductive success of the eastern Baltic cod stock in the 2nd half of the 2000s can be explained by:

- The stock uses successfully the Arkona Basin as spawning ground with enhanced hydrographic conditions allowing increasing egg survival since 1999, while the Gotland and Gdańsk Basin still do not contribute substantially to recruitment of the stock;
- minor inflows enhanced egg survival in the Bornholm Basin since 2007;
- egg production in the Bornholm Basin increased from 2003 to 2008/2009 several fold, with egg production being higher in July/August compared to May/June, but egg production in early spawning month 2006–2010 reaching similar high levels;
- egg survival during July/August being relatively high since 2000, with a peak in the inflow year 2003, and high egg survival also in May/June 2006–2008;
- egg predation by sprat and herring was consistently lower in 2004–2008 than in the 1990s, caused by a combination of reduced predator abundance (most pronounced sprat, but also herring) and lower daily rations by each individual predator (especially sprat in spring and herring in summer);
- larval abundances do not follow egg production and egg survival indicating that other mortality processes act showing both seasonal and interannual variability;
- larval prey availability in spring has improved and sprat as competitor for zooplankton prey has declined in mid-2000s and larval growth performance has increased in 2007 compared to mid-1990s;
- highest larval survival in summer originating from hatch positions on the fringes of the basin, sustaining sufficient growth even in the absence of *P. acuspes*, however, high survival also in other month, with the extended spawning season (April to November) spreading risks.

In summary, evidence from recent hydrographic and ichthyoplankton surveys and related modelling suggest a series of processes explaining enhanced reproductive success of the stock since the mid-2000s, despite an overall continuation of hydrographic stagnation in the central Baltic. However, the relative contribution of these processes to recruitment is not yet quantified and processes affecting juvenile survival, e.g. settling time and success as well as cannibalism, need to be considered.

While there is evidence that prey quality for adults, specifically limited availability of essential fatty acid impact on individual egg production, fertilization and hatching success as well as post-hatch survival, the full consequences of declining growth and reduced condition on stock recruitment is not clear. It may in fact have resulted in declining egg production and survival as observed in ichthyoplankton surveys since

2010 and failing reproductive success in 2013 and 2014 as indicated by the sharply declining larval abundances encountered in all surveys. Apart from using this type of information in stock projections, application of the egg production method to estimate the spawning–stock biomass (Kraus *et al*., 2012) is suggested.

4.5 Stock assessment

4.5.1 Catch-quality, misreporting, discards

There was evidence provided by the fishery and recorded in some national observer programmes that the discards of Eastern Baltic cod in the last two or three years might have been much higher than the reported estimates (WKSIBCA 2014). However, the data compilation in InterCatch used the reported estimates only and no attempts were made to account for a possible underestimation of the discards in the data used for the assessment.

Misreporting: No evidence of misreporting was presented at the benchmark.

4.5.2 Surveys

During quarter **4**th **BITS in 2014**, the level of realized valid hauls represented 100% of the planned stations. This level of valid hauls was considered by WGBIFS as appropriate to tuning-series and is recommended for the assessment of Baltic cod stocks. In Subdivision 27 the coverage was significantly lower than planned because the Swedish military denies access to some areas in SD 27 and SD 28. Few replacements hauls were possible given the strata allocation. The coverage by depth stratum was (depth stratum, coverage,) (1, 96), (2, 97), (3, 87), (4, 102), (5, 71), (6, 138). The low coverage in depth stratum 5 and high coverage in stratum 6 was because of incorrect depth information in the Trawl database. This has now been corrected. The general coverage is on the same level as in previous years. Russia did not participate in the survey.

In general, the coverage 1st **quarter 2015** was god. Only in SD 27, the number of hauls carried out is significant lower than the number of hauls planned. In SD 27 this was due to the Swedish military. The coverage by depth stratum is (depth stratum, coverage,) (1, 100), (2, 98), (3, 93), (4, 96), (5, 113), (6, 90). The deeper strata (5 and 6) have significant higher and lower coverage respectively and are coursed by the Swedish fishing access in Swedish military areas and incorrect depth information in the Trawl database. New depth information is reported. Preliminary results suggest that cpue per length has decrease in Q1 compared to Q1 2014.

During WKBALTCOD (2015) there was a discussion to analyse and develop the survey design for both BITS surveys. This exercise should take place before the next benchmark.

4.5.3 Weights, maturities, growth

During WKBALTCOD 2015 it was decided to use weights-at-length instead of weights-at-age. The reason was that there is large variation in age reading between countries and true age is not known (ICES 2014). Weights-at-length in the catch was estimated from national data using the same procedure as for catch numbers-at-age. The mean weights-at-age in the catch matrix were corrected taking into account the mean weights in the discards by weighting to the number in landing and discards. The weights-at-length are only available from 2002 and onwards.

In previous assessments, and used in the SAM 2015 assessment using the Swedish ALK only, weights-at-age in the catch was estimated from national data using the same procedure as for catch numbers-at-age. The mean weights-at-age in the catch matrix were corrected taking into account the mean weights in the discards by weighting to the number in landing and discards (previously used mean weight-at-age in landings alone caused SOP deviations). The trends of mean weight-at-age in catch (WGBFAS 2014) reveals a strong decreasing trend since mid-2000s for the older age groups. In 2012 a slight increase in mean weights has been observed for the older age groups. Until 2013 assessment, mean weight-at-age in the stock from 1995 onwards were taken from the BITS Quarter 1 using calculations provided in DATRAS. In the WKBALT benchmark (2013) it was decided to use mean weights for ages 2 and 3 from the BITS Quarter 1 survey. The weights for ages 4+ were instead taken from commercial catches (therefore equal to the mean weights in the catches).

Estimates of growth and maturity have been executed in different ways depending on the particular assessment model.

4.5.4 Assessment models

4.5.4.1 Production model CSA State space PM

A. Stock–production/difference models–"standard approach"

The approach was presented in WD by Horbowy and Luzeńczyk Annex 4.

Serious inconsistencies in cod age determination have been observed for years, and such inconsistencies even increased recently. Thus, the attempts were undertaken to assess eastern cod with stock-production models, in which age structure of the stock is not needed or age information used in the models is limited.

Three models were attempted:

1) Schaefer (1954) stock-production model

$$dB/dt = rB(B_{\infty} - B) - qfB$$

2) CSA model (Collie and Sissenwine, 1983)

$$N_{t+1} = (N_t - C_t + R_t)\, exp(-M)$$

3) Difference model of Horbowy (1992)

$$B_{t+1} = B_t\, exp\left(Hw^{-1/3} - k - qf - M\right) + R_t$$

where

B – biomass,
N – abundance,
C – catch in numbers,
r – intrinsic rate of increase,
Binf – carrying capacity,
q – catchability,
H & k – growth parameters (anabolism & catabolism coefficients), Winf=(H/k)3,

f – fishing effort,
R – recruitment index or submodel,
w – mean weight in the modelled part of the stock,
t – time, year.

The Schaefer model was implemented using ASPIC software (Prager, 1994) and the model was fitted to BITS survey index of biomass-at-age 3 and older while catches were considered as exact.

The Collie-Sissenwine Analysis (CSA) (Collie and Sissenwine, 1983) was implemented from NOAA toolbox (http://nft.nefsc.noaa.gov/Download.html). The model was fitted using 1991–2013 data on total catches and BITS estimates of stock size. In the CSA to convert numbers into biomasses, time-series of mean weight in the recruit and post-recruit part of the stock as well as in the catches were used.

Two approaches of CSA model were considered; first based on age, second on length distribution. In the first approach the recruits were assumed at-age 3, while post-recruits were assumed at-age 4 and older.

In the length-based approach, the recruits were assumed at length 28–37 cm as it was approximately related to fish at-age 3 (based on von Bertalanffy relationship) and post-recruits at 38 cm and more. Input data were estimated from Datras and Inter-Catch databases and were available for years 2000–2013.

The different models were implemented in a spreadsheet and for stock–recruitment relationship both Ricker and Beverton and Holt stock–recruitment equations were applied. Fishing effort was approximated as the ratio of catches to biomass index, both at-age 3+. In addition, the model required mean weight in the stock (as CSA) and growth parameters. Growth parameters were fitted outside the model from weight-at-age data used by WGBFAS for stock assessment. The model was fitted to catches and recruitment-at-age 3 from BITS survey. Two options for natural mortality were considered: (a) constant M of 0.2 and (b) M increasing from 2007 by constant level estimated by the model; up to 2006 the M was assumed constant as in option (a).

In all models BITS data were separated into two series: 1991–2000 and 2001–2013 (both for Q1 and Q4) as in 2001 change of survey gear and survey design took place.

Results

BITS indices used to fit the models, catches and mean weights in adult components are presented in Figures 4.5.4.1.1–2.

Schaefer model estimates indicate increase of stock biomass in recent years to the stable level of about 150 Kt which is in contrast to decline in biomass indices shown by BITS (Figure 4.5.4.1.3). Fishing mortality is estimated to decline to low values of 0.2–0.3. The estimate of MSY and F_{MSY} are 87 Kt and 0.97, respectively. The retrospective analysis shows strong pattern in biomass estimates (Figure 4.5.4.1.4). However, retrospective estimates of the MSY parameters are relatively stable (Figure 4.5.4.1.5).

CSA based on age shows increasing trend of the biomass in the last ten years, which reached about 180 Kt in 2013 (Figure 4.5.4.1.6). Fishing mortality is estimated relatively low and stable from 2008 onwards and decline slightly in the last year (less than 0.3; Figure 4.5.4.1.7). The retrospective analyses show strong pattern in both biomass (overestimation; Figure 4.5.4.1.8) and fishing mortality (underestimation; Figure 4.5.4.1.9).

CSA based on length estimated biomass decline from 60 Kt to about 40 Kt in 2010–2013 (Figure 4.5.4.1.10). Fishing mortality was increasing in recent years but dropped to 0.6 in 2013 (Figure 4.5.4.1.11). The retrospective analyses is not very informative as dataseries is short, but the same strong pattern as in case of analysis based on age is visible (Figure 4.5.4.1.12–13).

The difference model applied with Ricker stock–recruitment relationship and constant M values estimated biomass at 120 Kt in recent years and did not show biomass decline as observed in survey index. On the contrary, the difference model with M gradually increasing since 2007 was able to reproduce partly stock decline showed in the survey (Figure 4.5.4.1.14). The estimated yearly increase in M was 0.076. Distribution of residuals is presented in Figure 4.5.4.1.15. The attempts to fit the model with Beverton and Holt stock–recruitment relationship led to estimate of recruitment at constant value and were considered less realistic than approach with Ricker S–R.

The retrospective analysis shows tendency to overestimate biomass with moderate spread of values, except 2010 estimates (Figure 4.5.4.1.16).

Comparison of estimates

The estimated with production model biomasses and fishing mortalities are compared in Figure 4.5.4.1.17. All models show similar trends until 2010–2011. However, only difference model with option allowing increase in natural mortality or CSA with low survey CV reproduced observed in survey decline of biomass in recent years.

Figure 4.5.4.1.1a,b. BITS indices of stock size (biomass-at-age 3+, recruits at-age 3) , catches (age 3+) and mean weight (age 3+).

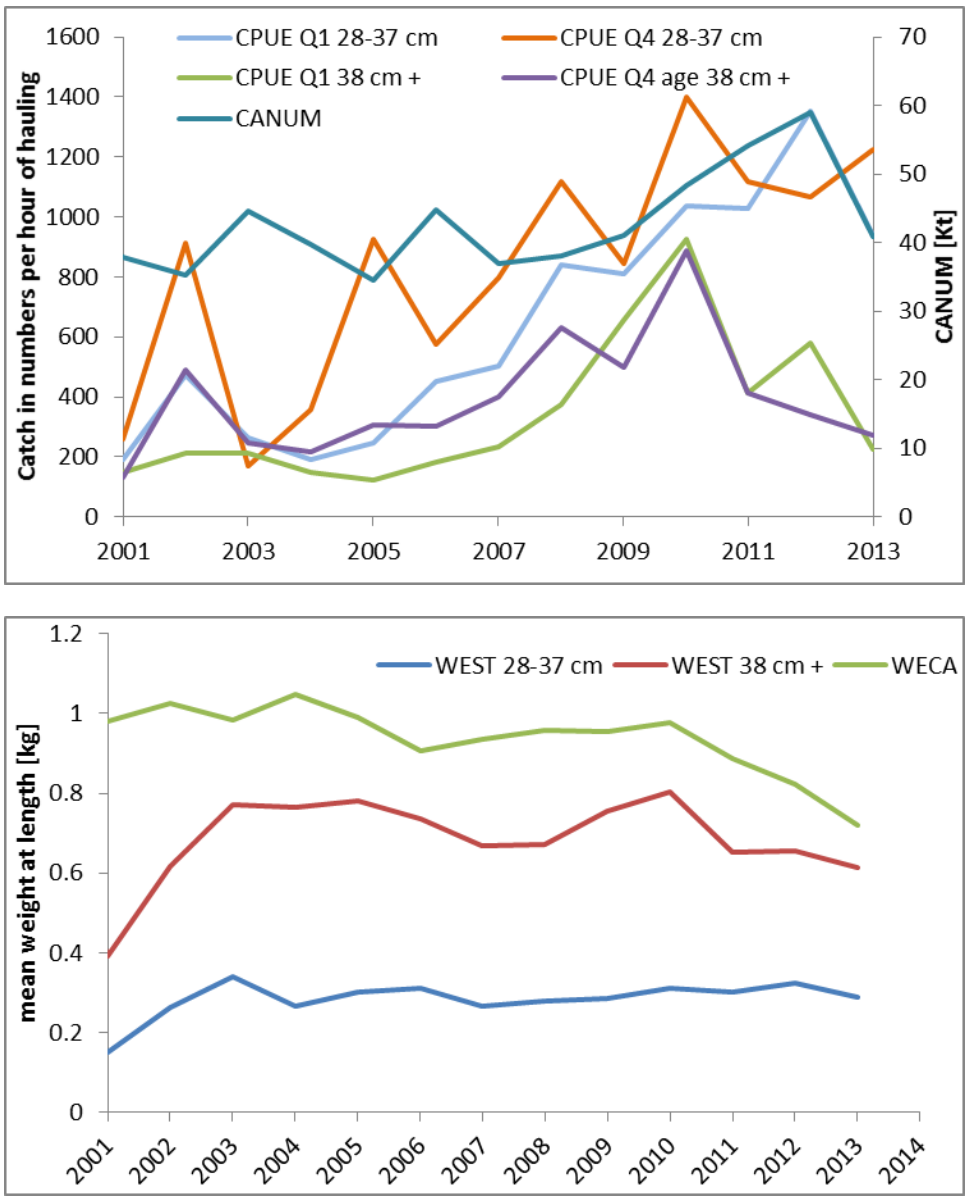


Figure 4.5.4.1.2a,b. Cpue from the 1st and 4th quarters, from the BITS in SDs 25–28, divided into two groups 28–37 cm and 38 cm+ (from ICES DATRAS database), catch data 38 cm + (from InterCatch), and mean weight-at-length in the survey and in the catch.

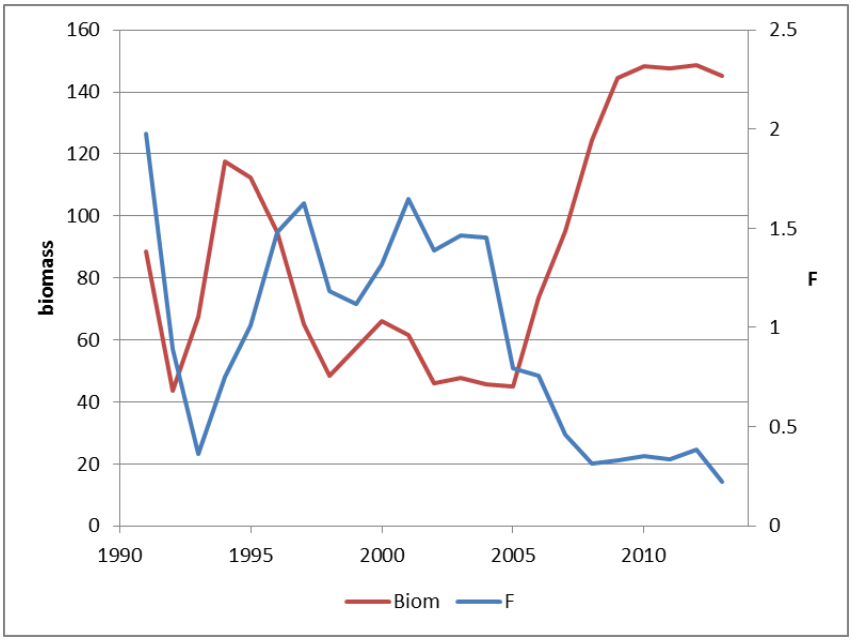


Figure 4.5.4.1.3. Estimates of biomass (age 3+) and fishing mortality from Schaefer model (ASPIC).

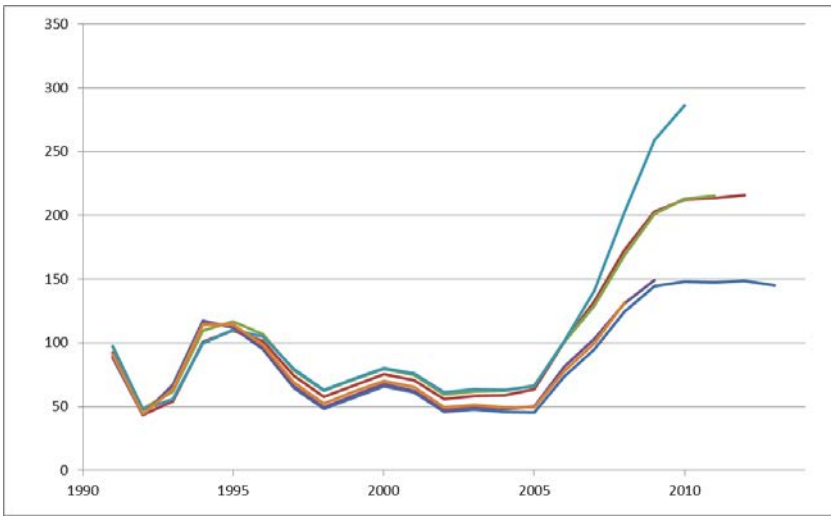


Figure 4.5.4.1.4. Retrospective estimates of biomass from Schaefer model (ASPIC).

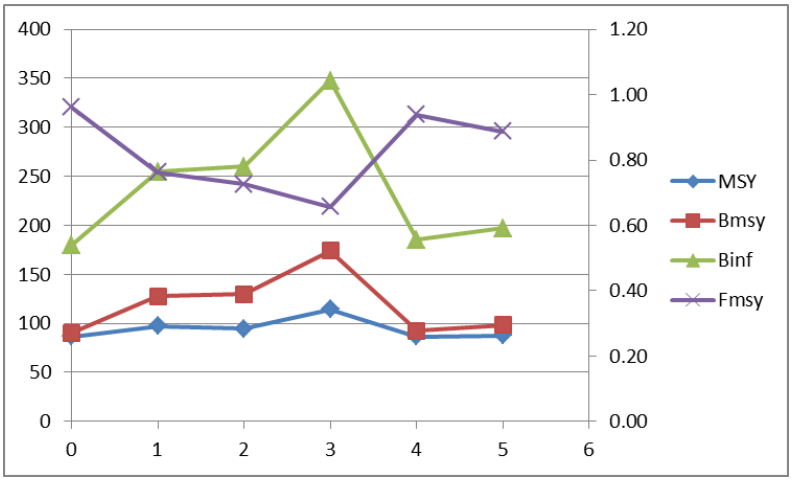


Figure 4.5.4.1.5. Retrospective estimates of MSY and Schaefer model parameters (ASPIC).

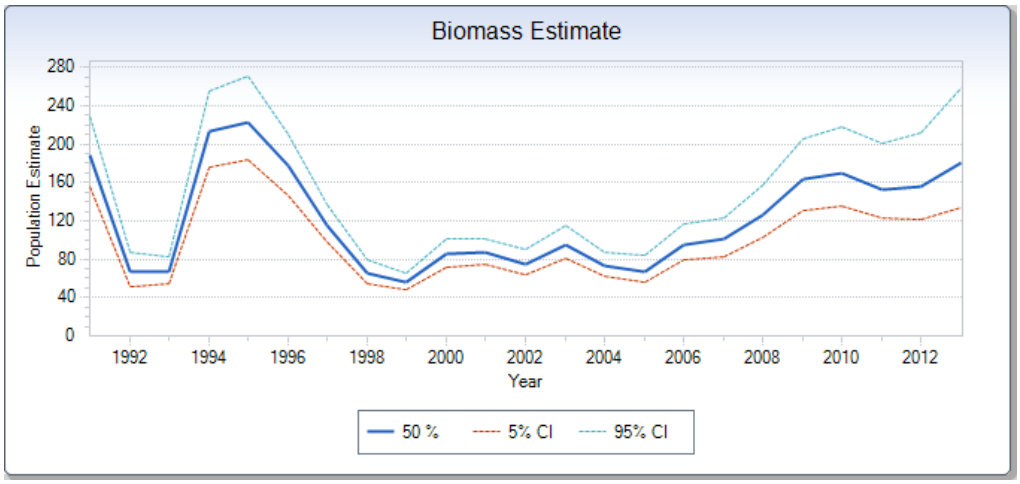


Figure 4.5.4.1.6. Estimates of biomass (age 3+) and fishing mortality in CSA.

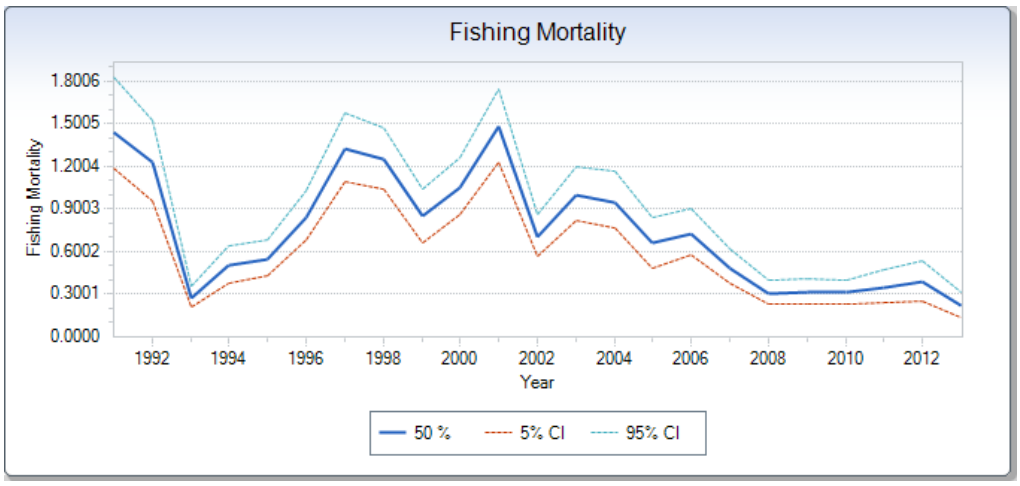


Figure 4.5.4.1.7. Estimates of fishing mortality in CSA.

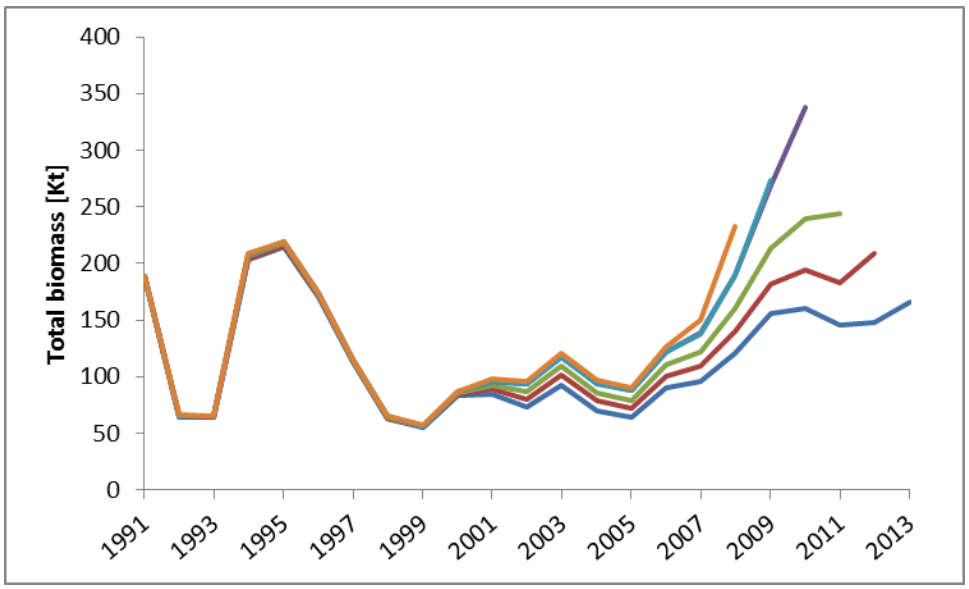


Figure 4.5.4.1.8. Retrospective estimates of biomass (age 3+) from CSA.

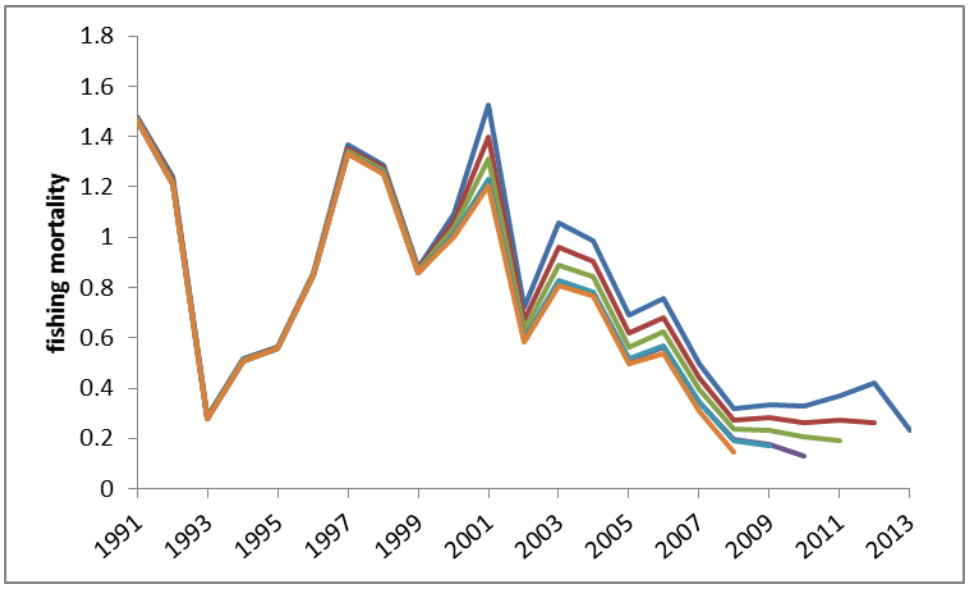


Figure 4.5.4.1.9. Retrospective estimates of fishing mortality from CSA.

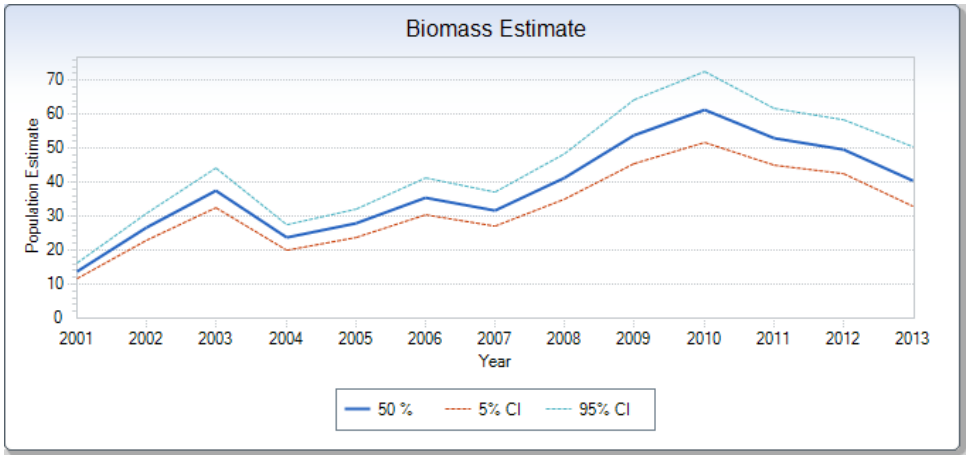


Figure 4.5.4.1.10. Estimates of biomass (38 cm +) from CSA.

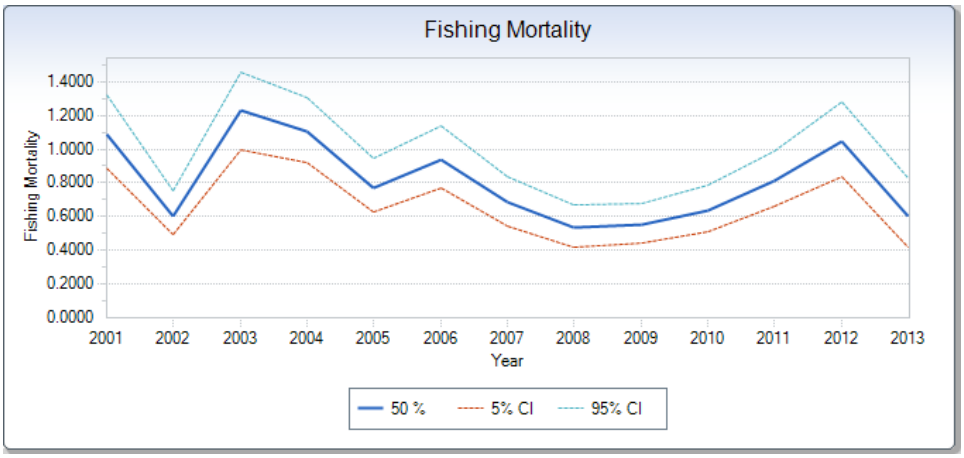


Figure 4.5.4.1.11. Estimates of fishing mortality (38 cm +) from CSA.

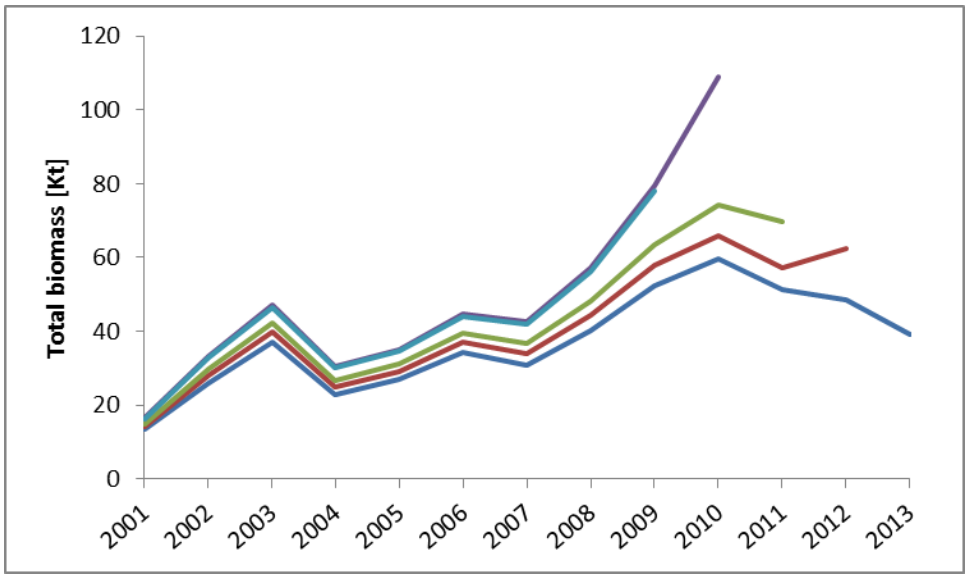


Figure 4.5.4.1.12. Retrospective estimates of biomass (38 cm+) from CSA.

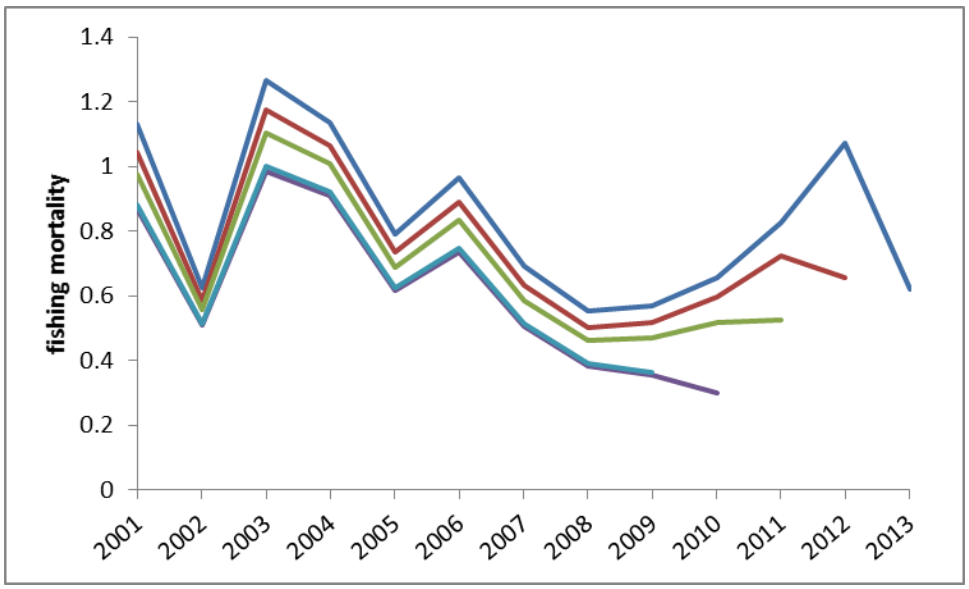


Figure 4.5.4.1.13. Retrospective estimates of fishing mortality from CSA.

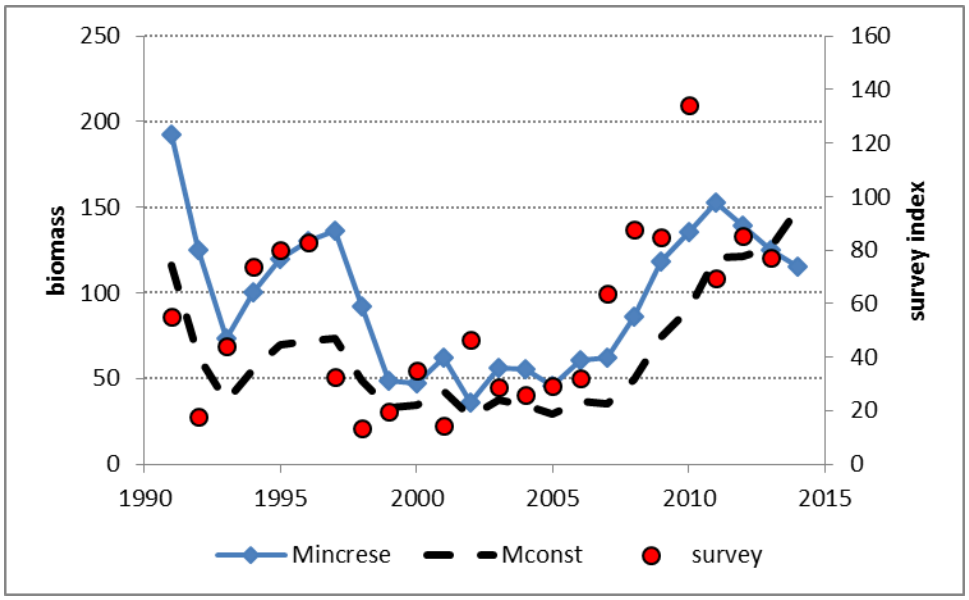


Figure 4.5.4.1.14. Biomass (age3+) estimates from difference model, survey index is shown for comparison.

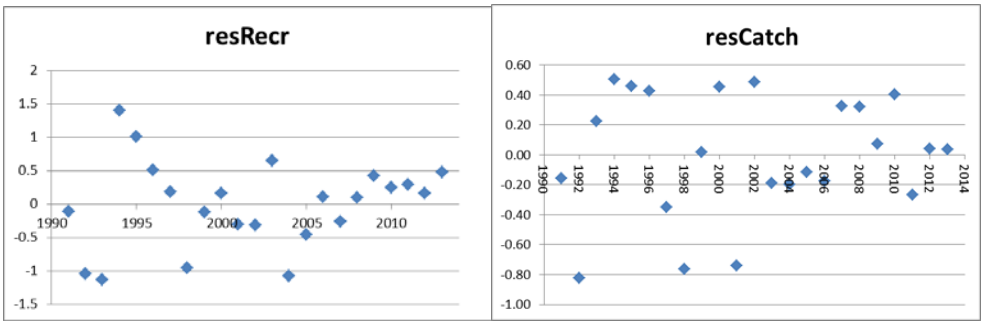


Figure 4.5.4.1.15. Residuals in recruitment and catch from difference model fit.

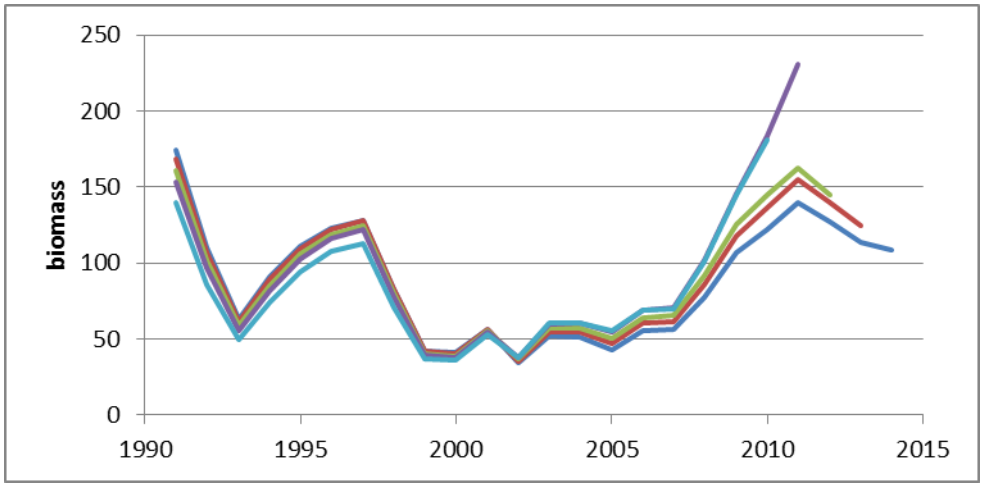


Figure 4.5.4.1.16. Retrospective estimates of biomass in difference model, Ricker S–R relationship.

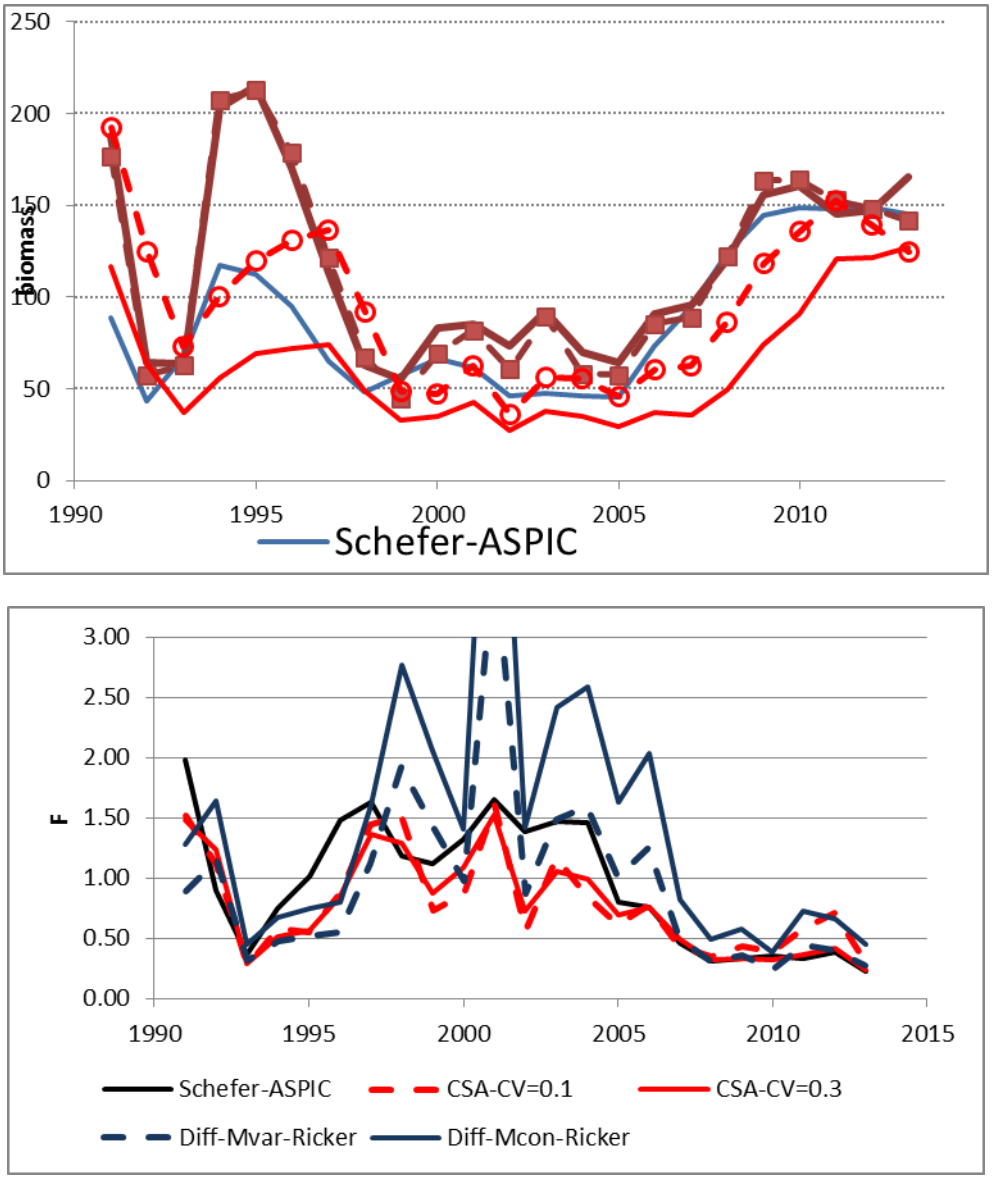


Figure 4.5.4.1.17. Comparison of biomass and fishing mortality estimates from different production models.

CSA mod conducted post WKBALTCOD meeting

After the benchmark meeting further work was ongoing on developing the model and some of this work was presented at the WGBFAS meeting in April.

Three approaches of the CSA model based on length distribution were implemented. In the age-based assessment performed by WGBFAS in the previous years, age 2 was assumed as recruits. To distinguish between recruits and post-recruits in the CSA the age–length relationship from the SS3 model was applied. The two values for each age were provided: the beginning and the middle of length range. For the age 2 the beginning size was 26 and middle 29, whereas for age 3–33 and 36 cm, respectively. In addition, based on the knowledge of growth rate of the cod, the 10 cm length range for recruits was assumed, while post-recruits were presumed as equal and longer than 38 cm.

Thus, three options for length range of recruits and post-recruits were used;

Option	recruits [cm]	Post-recruits [cm]
1	26–32	33+
2	29–35	36+
3	28–37	38+

For all three options, the effects of different natural mortalities were investigated; first included corrections of M due to low cod condition, and in the second M corrections for both fish condition and mortality caused by parasites infection (in the last four years) were implemented. In CSA M for both recruits and post-recruits must be the same, so to obtain one value per year mean M was estimated as weighted by cpue for each length range.

During the WGBFAS meeting six runs of the model were provided:

- Option 1 (26–32 cm recruits 33 cm + post-recruits) with M corrected for condition (negative log likelihood of BITS_Q1_from_2001 = -16.775 and for BITS_Q4_from_2001 = -17.4859)

Figure 4.5.4.1.18. Biomass and fishing mortality for recruits 26–32 cm and post-recruits equal and longer than 33 cm for M including condition corrections.

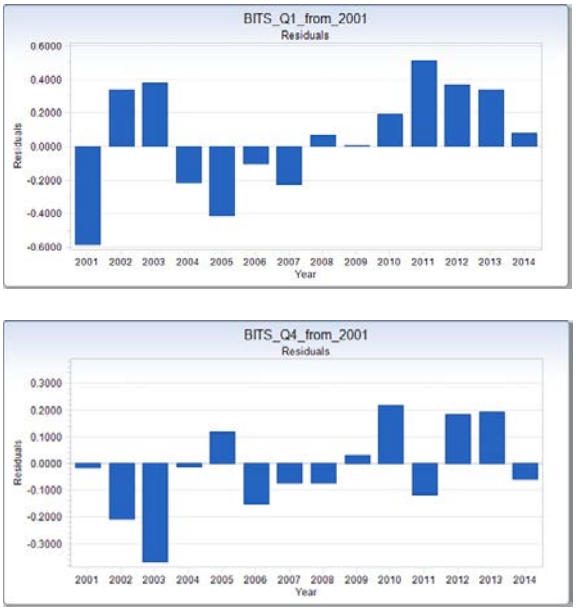


Figure 4.5.4.1.19. Residuals for recruits (26–32 cm) for 1st and 4th quarter for M including condition corrections.

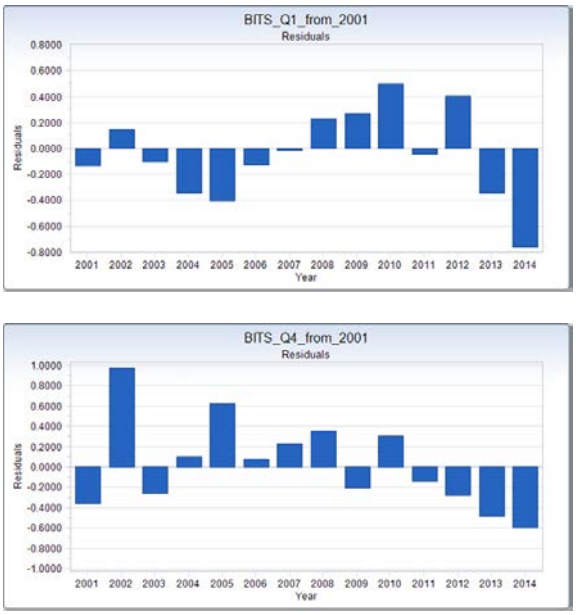


Figure 4.5.4.1.20. Residuals for post-recruits (33+ cm) for 1st and 4th quarter for M including condition corrections.

- Option 1 (26–32 cm recruits, 33 cm + post-recruits) with M condition + M parasites (negative log likelihood of BITS_Q1_from_2001 = -18.8012 and for BITS_Q4_from_2001 = -19.488)

Figure 4.5.4.1.21. Biomass and fishing mortality for recruits 26–32 cm and post-recruits (33+ cm) for M including both condition corrections and mortality caused by parasites infection implement for 2011–2014.

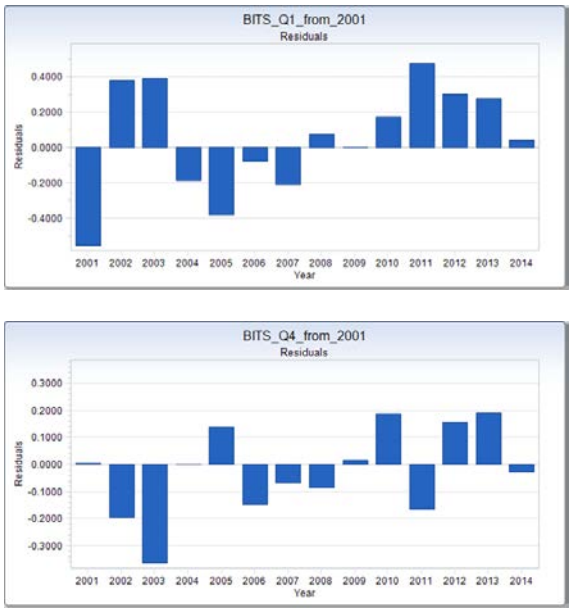


Figure 4.5.4.1.22. Residuals for recruits (26–32cm) for 1st and 4th quarter for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

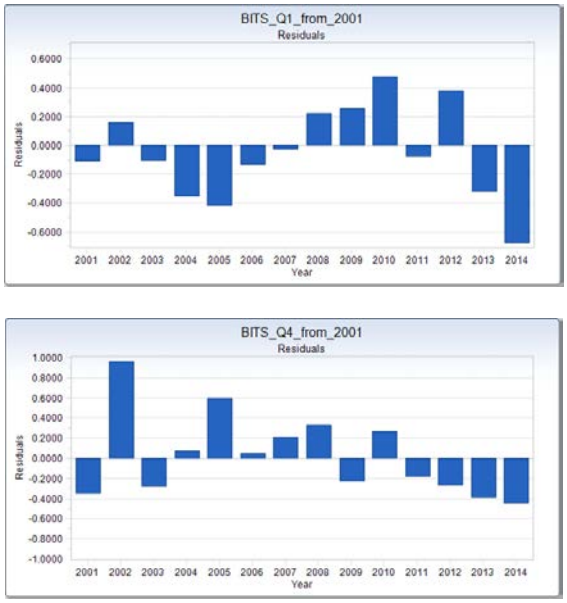


Figure 4.5.4.1.23. Residuals for post-recruits (33+ cm) for 1st and 4th quarter for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

- Option 2 (29–35 cm recruits, 36 cm + post-recruits) with M condition (negative log likelihood of BITS_Q1_from_2001 = -0.963126 and for BITS_Q4_from_2001 = -13.2113)

Figure 4.5.4.1.24. Biomass and fishing mortality for recruits 29–35 cm and post-recruits equal and longer than 36 cm for M including condition corrections.

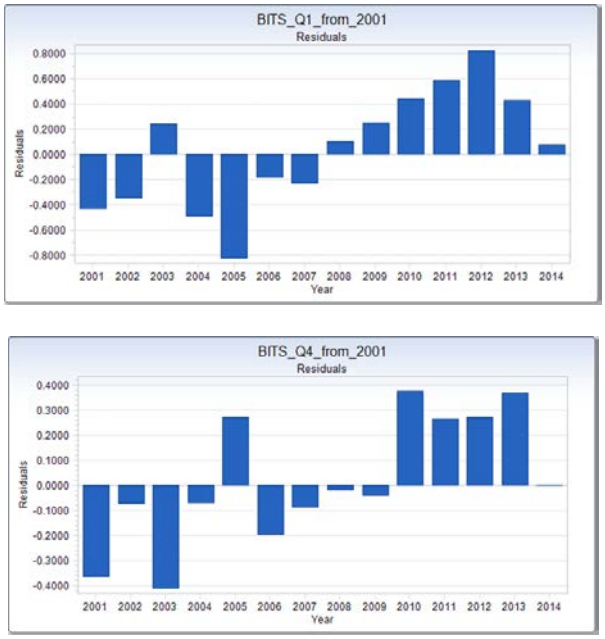


Figure 4.5.4.1.25. Residuals for recruits (29–35 cm) for 1st and 4th quarter for M including condition corrections.

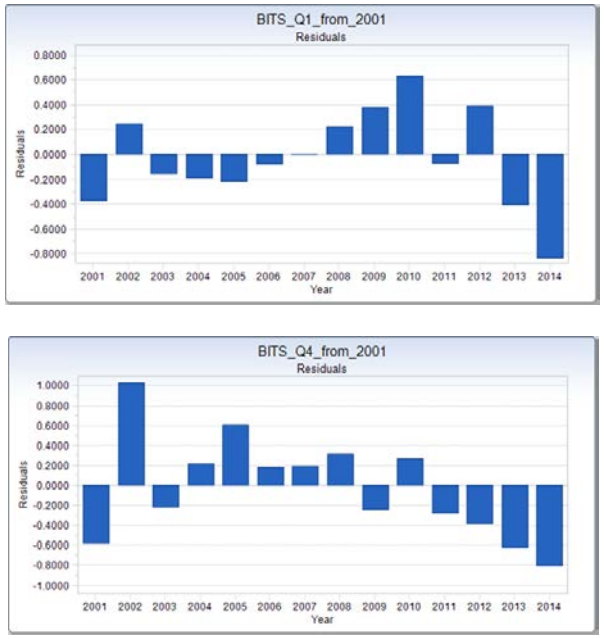


Figure 4.5.4.1.26. Residuals for post-recruits (36+ cm) for 1st and 4th quarter for M including condition corrections.

- Option 2 (29–35 cm recruits, 36 cm + post-recruits) with M condition+ M parasites (negative log likelihood of BITS_Q1_from_2001 = -2.68307 and for BITS_Q4_from_2001 = -14.1981)

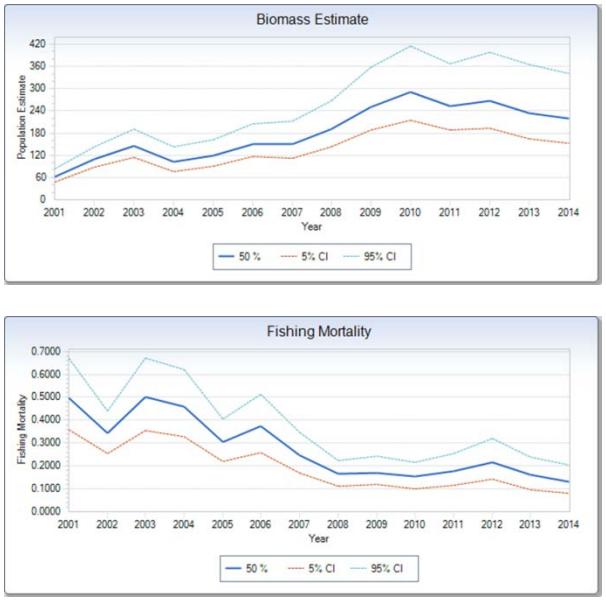


Figure 4.5.4.1.27. Biomass and fishing mortality for recruits 29–35 cm and post-recruits equal and longer than 36 cm for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

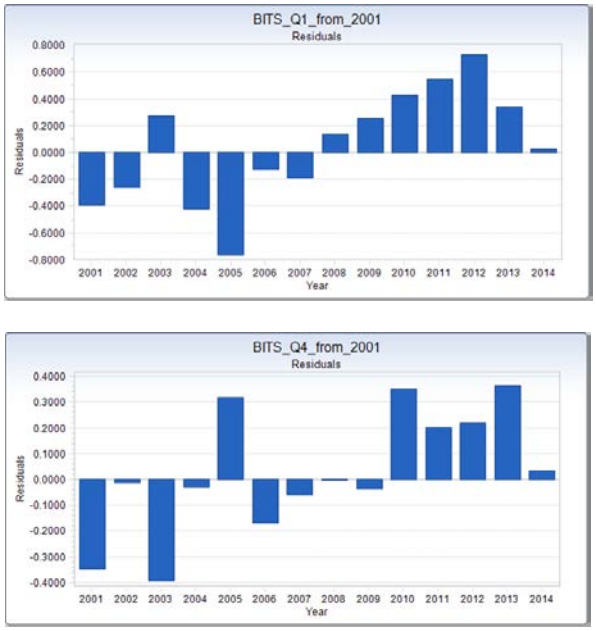


Figure 4.5.4.1.28. Residuals for recruits (29–35 cm) for 1st and 4th quarter for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

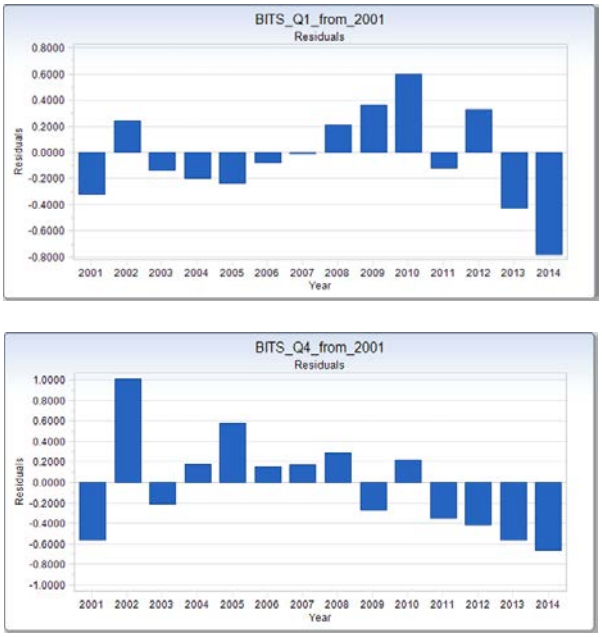


Figure 4.5.4.1.29. Residuals for post-recruits (equal and longer 36 cm) for 1st and 4th quarter for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

- Option 3 (28–37 cm recruits, 38 cm + post-recruits) with M condition (negative log likelihood of BITS_Q1_from_2001 = -0.963126 and for BITS_Q4_from_2001 = -13.2113)

Figure 4.5.4.1.30. Biomass and fishing mortality for recruits 28–37 cm and post-recruits equal and longer than 38 cm for M including condition corrections.

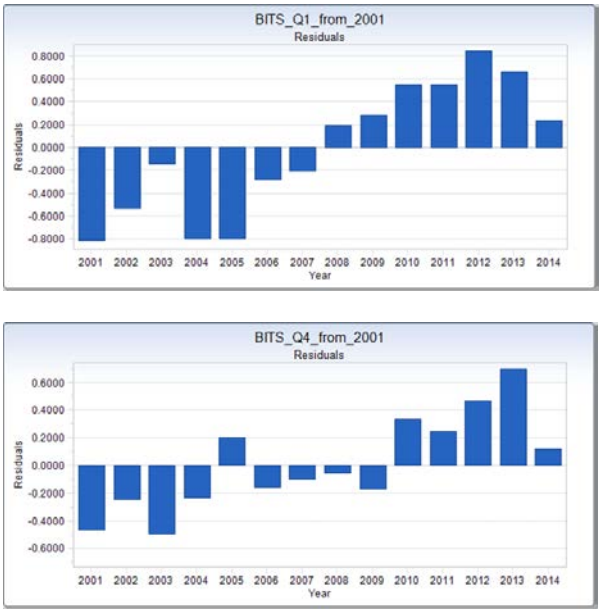


Figure 4.5.4.1.31. Residuals for recruits (28–37 cm) for 1st and 4th quarter for M including condition corrections.

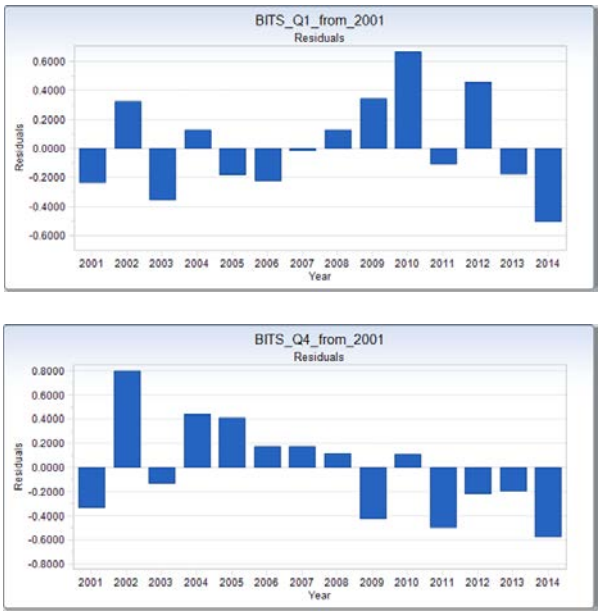


Figure 4.5.4.1.32. Residuals for post-recruits (equal and longer than 38 cm) for 1st and 4th quarter for M including condition corrections.

- Option 3 (28–37 cm recruits, 38 cm + post-recruits) with M condition+ M parasites (negative log likelihood of BITS_Q1_from_2001 = -2.68307 and for BITS_Q4_from_2001 = -14.1981)

Figure 4.5.4.1.33. Biomass and fishing mortality for recruits 28–37 cm and post-recruits equal and longer than 38 cm for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

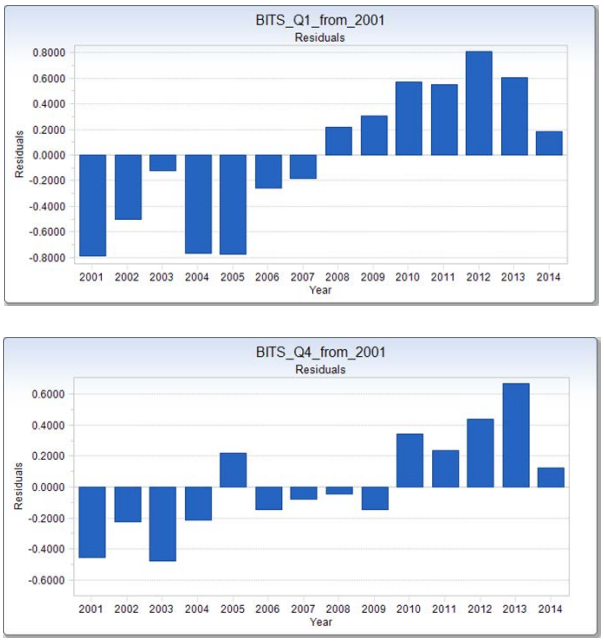


Figure 4.5.4.1.34. Residuals for recruits (28–37 cm) for 1st and 4th quarter for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

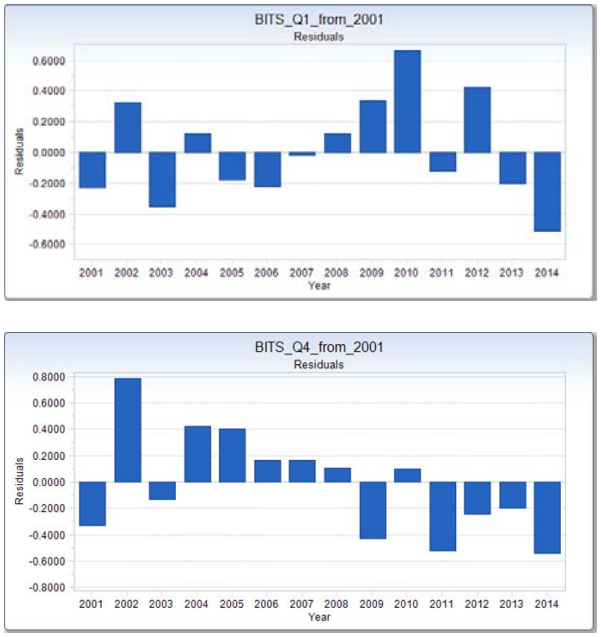


Figure 4.5.4.1.35. Residuals for post-recruits (equal and longer 38 cm) for 1st and 4th quarter for M including both condition corrections and mortality caused by parasites infection implement only for the last four years.

The method is very sensitive to the assumption of length range for recruits and post-recruits. We could get biomass from 60 to 400 thousand tons, depending on these assumptions. The runs including M due to parasite infection in 2011–2014 were always slightly better fitted to the data (lower negative log likelihood and smaller residuals) than the runs without this corrections. The best fitted run (26–32 cm recruits, 33 cm + post-recruits with M condition + M parasites) gave the broadest confidence ranges, which was not expected. Even if some of the assumed length ranges differed only by a few cm, the respective BITS stock numbers and catches were quite different as most cod are now in smaller length classes.

4.5.4.2 Stochastic surplus production model in continuous-time (SPiCT)

SPiCT is a traditional surplus production model with some refinements. It is formulated as a state–space model and therefore incorporates dynamics related to the biomass in the form of Pella and Tomlinson (1969) and to the fisheries. These two latent processes are then related to the observed data (catches and biomass survey indices) via observation equations, which include observation error.

The SPiCT formulation is a generalisation of previous surplus production models in that it includes the dynamics of the fishery and the uncertainty of the observed catches, which are commonly omitted in these models. The continuous-time formulation of SpiCT, as opposed to constant fixed time-steps, enables the model to accommodate arbitrary and irregular data sampling without a need for catch and index observations to match temporally. It is therefore straightforward to fit SPiCT to data containing a mix of annual, biannual and quarterly data.

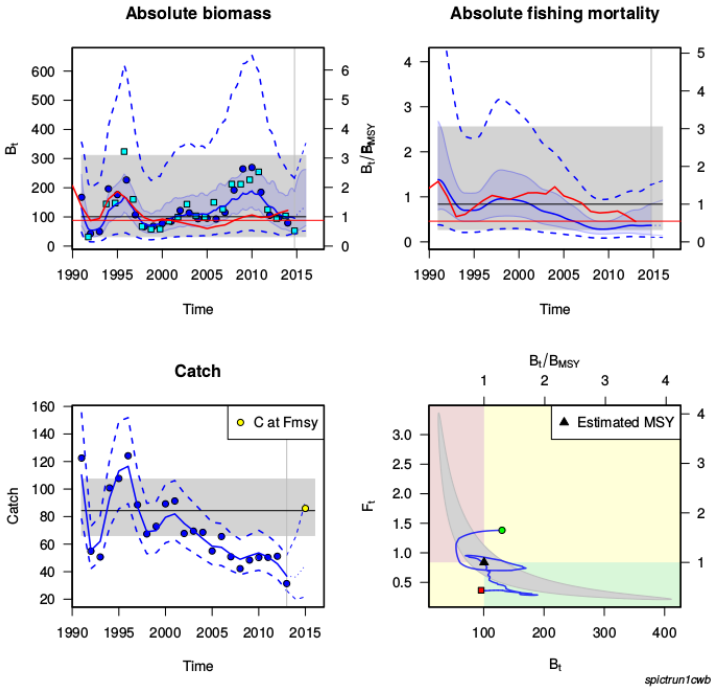
The ability to accommodate irregular data sampling was relevant to the eastern Baltic cod stock as survey data were available from quarter one and four while observations of catches aggregated annually were available. Survey index data were available calculated according to the traditional ICES standards, and an alternative survey index

calculated by Casper W. Berg (CWB). Both datasets were analysed using SPiCT, however only results using CWB data are presented.

In addition to the base run (run1) described above, an extended model containing a regime shift in the biomass growth rate was fit. The timing of the switch point between regimes was estimated by selecting time point that yielded the lowest AIC values. Two years emerged as candidates for the timing of the regime shift: 2011 (run7) and 2003 (run8). Results of run1, run7 and run8 are shown in Figure 4.5.4.2.1.

```
SPiCT run1cwb

MSY type: d
AIC: 68.9065
             est    ll     ul
Bmsyd     100.63 32.59 310.68
Fmsyd       0.84  0.28   2.55
MSYd       84.32 66.31 107.22
C15@Fmsy   85.97 47.68 155.02
r           1.68  0.55   5.11
K         201.26 65.19 621.37
sdb         0.33  0.24   0.44
sdf         0.19  0.12   0.29
sdi         0.33  0.24   0.44
sdc         0.19  0.12   0.29
```



The base model (run1) provided a reasonable fit to the catch observations, however the model had problems fitting to the index observations in the time periods containing large values of the survey indices (1994–1996, 2008–2011). The reason for this lack of fit is probably related to the time period 2011–2015 where the index observations indicate a decrease in biomass without any sign of change in the catches. Production models in their simplest form do not contain an explicit recruitment component and therefore only allows decreases in biomass resulting from catches. Thus, the model struggles to fit to the pattern observed in 2011–2015 where the catches remain constant while the indices drop substantially. The result is inflated confidence bounds on all parameters.

The extended model containing a shift in growth conditions was implemented to account for the apparent change of dynamics. Both models including a switch point in either 2011 (run7) or 2003 (run8) resulted in notable improvements in AIC. Both models furthermore estimated a decrease in growth rate after the switch point suggesting that growth conditions for the stock has shifted to the worse. As a direct consequence of this shift, the level of F_{MSY} drops below the current fishing mortality indicating that the stock is currently more likely to be overfished than underfished.

```
SPiCT run7cwb

MSY type: d
AIC: 43.5468
             est    ll     ul
Bmsyd      40.15 21.93  73.51
Bmsyd      40.15 21.93  73.51
Fmsyd       2.24  1.26   3.98
Fmsyd       0.79  0.31   2.02
MSYd       89.75 78.33 102.84
MSYd       31.89 19.20  52.95
C15@Fmsy   14.27  6.64  30.67
r           4.47  2.51   7.96
r2011       1.59  0.62   4.04
K          80.30 43.86 147.02
sdb         0.17  0.13   0.24
sdf         0.27  0.20   0.36
sdi         0.17  0.13   0.24
sdc         0.27  0.20   0.36
```

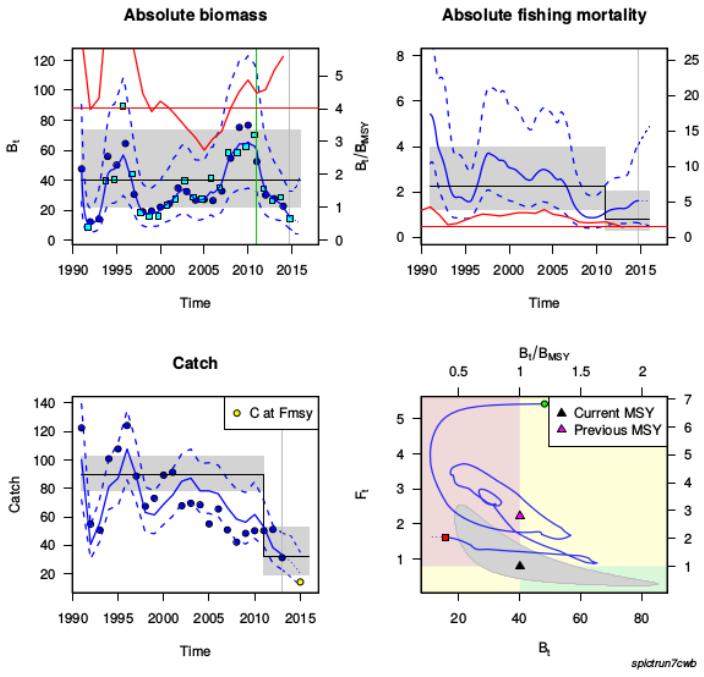


Figure 4.5.4.2.1. Run 1, no shit in growth condition. Left panels contain parameter estimates with lower (ll) and upper (ul) 95% confidence bounds, right panels show estimated biomass, fishing mortality and catch with estimated MSY values indicated by black horizontal lines (ICES estimates in red colour), 95% confidence intervals are indicated by dashed lines. Estimated MSY values are also presented in the left panel together with a catch prediction for 2015 under F_{MSY} (C15@Fmsy), r is growth rate, K is carrying capacity, sd* are standard deviations of the noise levels of the biomass (b), fishing (f), survey index observations (i), and catch observations (c).

The results presented here are quite preliminary in that they are outputs from a newly developed model, which has yet to be tested in a range of scenarios. Furthermore, one could think of potentially more realistic alternatives to modelling the change in growth conditions as a step function such as gradual shift in conditions modelled by a regression line or a spline. The confidence bounds on model parameters, reference points, and estimated biomass and fishing mortality are relatively wide. This is a consequence of fitting to only 25 years of data generated by a complex and apparently temporally heterogeneous system.

```
SPiCT run8cwb

MSY type: d
AIC: 44.4452
             est     ll      ul
Bmsyd      38.24 21.36   68.47
Bmsyd      38.24 21.36   68.47
Fmsyd       2.80  1.64    4.79
Fmsyd       1.57  0.86    2.85
MSYd      107.10 89.97  127.49
MSYd       59.88 50.39   71.17
C15@Fmsy   27.66 16.87   45.33
r           5.60  3.27    9.58
r2003       3.13  1.72    5.70
K          76.49 42.72  136.95
sdb         0.16  0.12    0.23
sdf         0.26  0.19    0.34
sdi         0.16  0.12    0.23
sdc         0.26  0.19    0.34
```

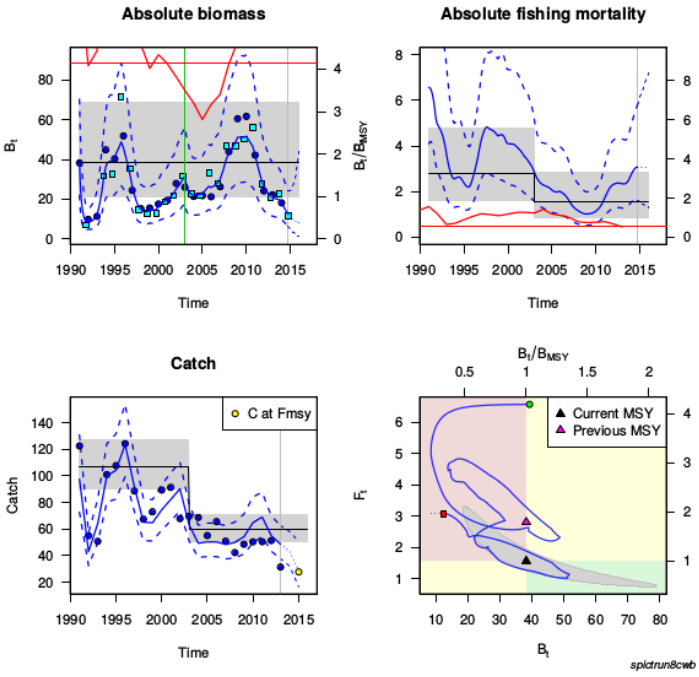


Figure 4.5.4.2.1. Left panels contain parameter estimates with lower (ll) and upper (ul) 95% confidence bounds, right panels show estimated biomass, fishing mortality and catch with estimated MSY values indicated by black horizontal lines (ICES estimates in red colour), 95% confidence intervals are indicated by dashed lines. Estimated MSY values are also presented in the left panel together with a catch prediction for 2015 under F_{MSY} (C15@F_{MSY}), r is growth rate, K is carrying capacity, sd* are standard deviations of the noise levels of the biomass (b), fishing (f), survey index observations (i), and catch observations (c).

4.5.4.3 SAM SW– ALK with error matrix after 2007

We applied the Swedish age–length key on all data since it was shown to have a lower bias for age 1 and 2, compared to the other nations. However, to be able to compare the effect of an age error to the SPALY assessment we first constructed an age matrix based on Swedish age–length data. This was suggested by the reviewers of the otolith evaluation, based upon similar ALKs from each country or identify clusters of similar national ALKs in recent years (WKSIBCA 2014). Based on that, we carry out a series of age-based assessments in which total international catches-at-age and survey indices are derived from the ALKs from only one of the clusters of countries. This approach will have some bias due to loss of linkage between length compositions and age sampling, particularly if national fisheries occur in different areas. Hence, we applied a Swedish ALK on the total catch and a survey index was conducted based on a Swedish ALK only.

Landings: the ALK and mean weight estimates used to calculate CANUM and WECA for the eastern Baltic stock was based on samples obtained through the Swedish port sampling programme for cod. The national programme samples directly for ages, i.e. no age–length key is used, instead samples are used directly to estimate proportion age-at-length and mean weights. Catches are sorted before landing, and only available for sampling in commercial sale categories, sampling and estimation was therefore stratified by sale category. Separate ALKs for each sale category was created and merged into a single ALK, weighted by the total landings (in relation to sample size) in respective sale category. The same was done for the mean weight estimates. The sampling was not stratified by gear, under the assumption that the relation between fish size and age is the same regardless of gear, and that the selec-

tion of different gears is reflected in the commercial size categories. Only data from Subdivision 25 and 26 were included in the ALK, the vast majority of samples from Subdivision 25.

Since the Swedish sampling design is not originally designed for creating and use of age–length keys, there was a need to estimate missing values when producing the ALKs requested by ICES for the benchmark 2015. Empty cells in the ALK (i.e. proportion age-at-length) were estimated from the available data using multinomial modelling as described by Gerritsen *et al*., 2006. For the landed part of the catch we used linear log-log regression to estimate missing mean weights from the available sample data. Age was entered as a fixed factor in the modelling and estimation.

Missing data, landings: 2007, quarter 3: no sampling of landings. Data from quarter 4 the same year was used instead.

Discards: ALK and mean weight estimates were based on samples obtained through the Swedish on-board sampling programme. A fixed number of discarded cod is sampled by length class, with the intention of creating an ALK, which minimizes the number of missing cells in the ALK. However, since length distributions from all countries were used, there was still a need for estimation missing values for lengths that were not covered by the Swedish discard sampling. For fish <25 cm in length, data from Swedish BITS surveys were used, combined with data from the discard sampling program. BITS quarter 1 was used for both quarter 1 and 2 and data from BITS quarter 4 was used for quarter 3 and 4. Empty cells in the ALK (i.e. proportion age-at-length) were estimated from the available data using multinomial modelling as described by Gerritsen *et al*., 2006. Missing mean weights in the discard was estimated from the available data using non-linear estimation. A 3-parameter logistic regression was fitted to the data to account for discarded fish in poor condition. Fish around the minimum legal size (38 cm) make up the bulk of the discard and it was considered important to optimize the weight estimation for these length classes. Due to the limited sample size, age was not included in this estimation.

Missing data, discards: Due to difficulties to obtain discard trips some quarters, data from neighbouring quarters, and in some cases neighbouring years, were used in a few cases.

Quarters missing in ALK:

Target quarter (missing quarter)	Source quarter
2003_Q1	2003_Q2
2007_Q3	2006_Q3
2007_Q4	2006_Q4
2008_Q1	2008_Q2

In addition, in 2002, the Swedish on-board sampling programme did not include individual weights of discarded fish, i.e. only length and age were recorded. Mean weights from 2003 were used for estimation of discard mean weights in 2002.

Results and discussion

For comparison, we based the runs on the latest assessment (2014). Based on the standard settings we performed a set of different runs with the Swedish ALK. Generally, the fishing mortality is higher and SSB lower compared the standard assessment (Figure 4.5.4.2.1). The confidence interval and the retrospective patterns are also

somewhat better but not perfect. Changes in catchability, natural mortality and correlated mortality made only minor improvement to the model diagnostics. The conclusion is that by using a Swedish ALK you will have better residuals but with a completely different trend in F and collaborated by the analysis made by WKSIBCA (2014).

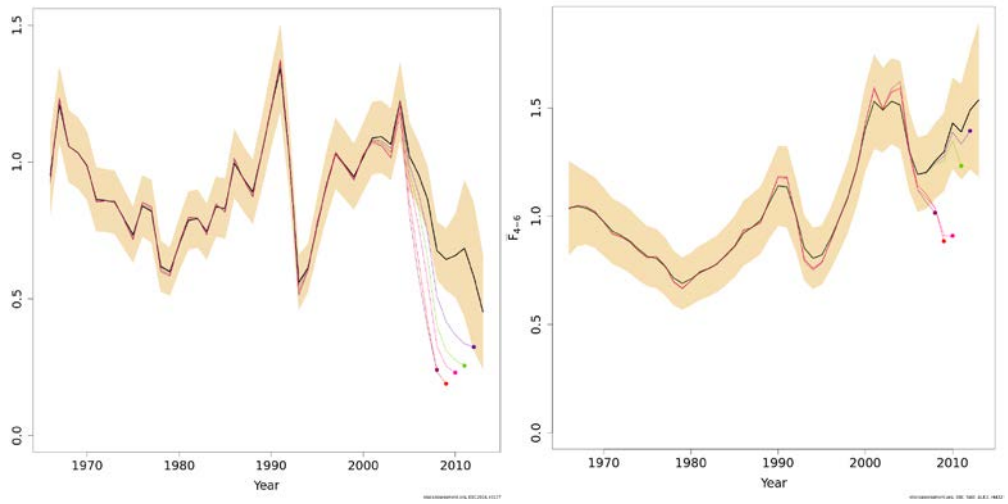


Figure 4.5.4.2.1. Fishing mortality with retrospective pattern from the SPALY run (left) and from the SPALY with Swedish ALK (right).

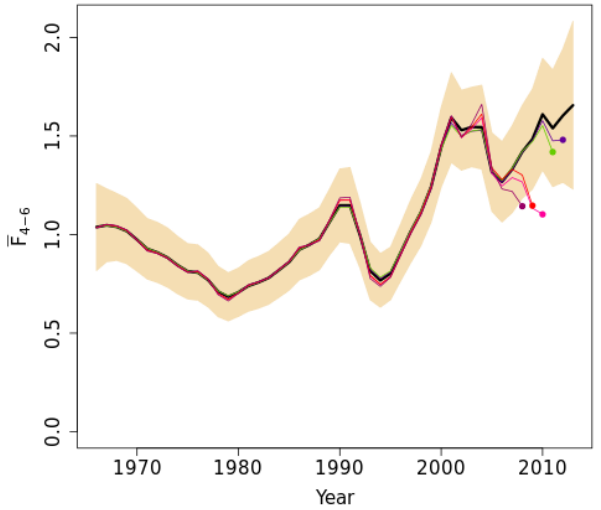


Figure 4.5.4.2.2. Fishing mortality with retrospective pattern with SPALY settings but with Swedish ALK and ageing error since 2007.

When applying the SAM model with the ageing error since 2007, the results are fairly similar but with a slightly better retrospective pattern (Figure 4.5.4.2.2). The residuals showed the same trends. Another difference was that the estimated numbers-at-age was slightly different between the SPALY run and the SAM with the ageing error. Mostly observed in older ages (Figure 4.5.4.2.3).

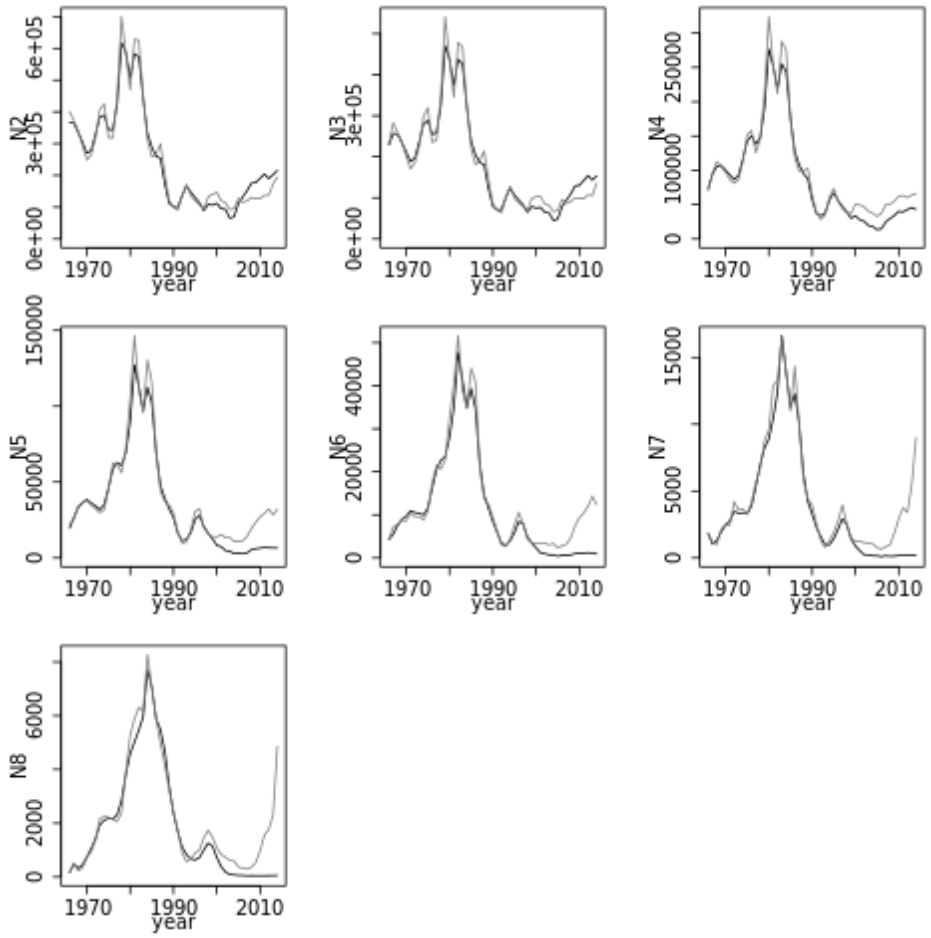


Figure 4.5.4.2.3. Numbers-at-age when comparing the calculated (black line) to the estimated numbers-at-age (grey line) in the SAM with ageing error. SPALY settings but with Swedish ALK.

Due to ageing errors in the Baltic Sea cod we adjusted the SAM, which is currently the assessment model used for Baltic Sea cod. To match the observations of catches and survey indices, an age-error matrix was applied with its parameters estimated by SAM. We tried a single-probability model, a double-probability model and a binomial model. All of them were tried with ageing error over the entire assessment period and from 2007 an onwards. The most likely model in this set was the double probability model applied for the entire assessment period (98%). It showed the least variation and bias in the retrospective patterns of number of recruits, SSB and F4–6 of the models tested, and lesser than the uncorrected assessment. The assessed probability to identify true year-band is 0.71 and the probability to misidentify a false band is 0.16, which leads to 55%–52% correct ageing for 4–6 year-olds. These error rates are similar to those observed in controlled studies of otolith ageing.

The ageing error in cod is influenced by the uncertainties of the first age rings due to differences in the formation of the rings (Rehberg-Haas *et al*., 2012). The first ring is formed in response to a settlement process in which the cod choses demersal habitats whereas the second ring is a seasonally induced process which may be the first annulus. If the settlement occurs at a similar time to the formation of the second ring only one ring will be observed and consequently rings will have different meanings depending on when during the year the fish was born or when it settled. Hüssy *et al*. (1997) show that the age rings that are seen on otoliths of Baltic cod are a function of a

range of factors that in combination create the opacity patterns that can be observed. Hüssy *et al*. (2010) shows that it is possible to estimate the daily growth rings in Baltic cod by using temperature data to estimate growth in periods with low water temperature. The daily growth increments on otoliths reveals that true age rings can be all four combinations of present, not present, visible and not visible.

In this study we incorporate assumptions about the age reading problems in the current assessment method of the eastern Baltic cod to evaluate if this can improve the retrospective patterns and better represent the stock. The currently used assessment method for the eastern Baltic cod is the state space model SAM (Nielsen and Berg, 2014).

The probability of errors in ageing

Data on errors in the age readings of the Baltic Sea cod shows that the proportion of correctly aged fish ranges from 42% to 67% depending on age (Hüssy, unpublished; Table 1). The underlying process generating the errors is not completely understood and we therefore tried three different approaches, (i) a single probability model (SP), (ii) a double probability model (DP), and (iii) a double binomial model (DB).

Table 1. Proportions of observed ages in relation to true ages of Baltic Sea cod. The sample size is 25 for each true age, except for age 3 where some samples were excluded because there was some uncertainty in the true ageing. Data provided by Karin Hüssy.

	Observed age					
True age	0	1	2	3	4	5
0	0.42	0.33	0.25	0	0	0
1	0.25	0.5	0.19	0.04	0.01	0
2	0.04	0.22	0.51	0.21	0.03	0
3	0	0	0.33	0.67	0	0

The age-reading data do not disagree with the notion that the errors are symmetrical and can be used as an assumption for an age-reading error matrix. Hence, we produced an SP-matrix with the structure.

The matrix is used to generate observations in the model which are compared to catches and survey data. The parameter p denotes the probability for correct ageing for those ages when the error can be ± 1 year. For the minimum and maximum age, the error is unilateral and the probability of correct ageing has a corresponding increase (with (1-p)/2). The probability (p) is estimated in the stock assessment model, SAM, which is a state–space model based on maximum-likelihood estimation.

Rehberg-Haas *et al*. (Rehberg-Haas *et al*., 2012) show that errors in ageing of cod based on the otoliths are not primarily due to the lack of visibility of translucent rings but are produced by both failure to identify true year-bands, and the incorrect assignment of false bands as being year bands. We assume that the process can be described by a double binomial process. In this case we defined p as the probability of correctly identifying a true year-band, and hence (1-p) is the probability to overlook the same band. The second parameter q is the probability of assigning a false year band as being true, and hence (1-q) is the probability of correctly identifying a false band as being false. Here we have to make an assumption about the presence of false bands that can be interpreted as age bands. We assume that the number of false

bands is equal to the number of true bands. The probability to observe the age o when the true age is a.

The ranges for summing the probabilities differ depending on the relationship between the number of observed bands and the number of true bands. If the number of observed bands are less than the true one, all or none of the true bands can be counted as year bands. If the number of observed bands is larger than the number of true bands, at least one (o-a) has to be a true band. This gives the probability matrix.

The last model tried against the data is the double probability process. It builds on the assumption that identifying true and false bands as age bands is not an independent process. The study of individual otolith readers also shows that only one band is counted as a year band when the true and false bands are close. We therefore defined the double probability model as a modification of the double binomial model with binomial coefficients removed.

4.5.4.4 SAM – age/ length based after 2007 change between age and length

To avoid the most problematic age-reading periods a model was constructed where catch-at-age are used before year 2006, and length data only are used after (and in) year 2006.

Method

The model developed is based on the existing SAM state–space stock assessment model (Nielsen and Berg, 2014). The internal age dynamics of the model is preserved, but the model is extended to allow catch-at-length observations. The challenge of using length observations in an age-based assessment is that the observations are more indirect. Especially for larger ages the difference in length is very small, and can disappear in the observation uncertainty.

A von Bertalanffy growth model $L(age) = L_\infty - (L_\infty - L_0) \exp(-k * age)$ is assumed in the model, which allow predictions of the length distribution for set of numbers caught-at-age. For this initial implementation the prediction of the catches from 2006 were simply approximated as:

$$C_{l_i,y} = \sum_{\text{ages}} \left(\Phi\left(\frac{\text{up}(l_i) - L_\theta(a+0.5)}{\sigma_L} \right) - \Phi\left(\frac{\text{lo}(l_i) - L_\theta(a+0.5)}{\sigma_L} \right) \right) \cdot \widehat{C}_{ay} + \varepsilon_{l_i y}$$

Here the model first predict the numbers caught per age group (C_{ay}), then these are divided into length groups ($[\text{lo}(l_i);\text{up}(l_i)]$) by assuming that the lengths are normally distributed (c.d.f Φ) around the von Bertalanffy growth curve (L_0). This conversion is done mid-year, and all age groups are added.

The age-determination problem is similar for the survey catches, so survey indices are converted similarly:

$$I_{s,l_i,y} = \sum_{\text{ages}} \left(\Phi\left(\frac{\text{up}(l_i) - L_\theta(a+\tau_s)}{\sigma_L} \right) - \Phi\left(\frac{\text{lo}(l_i) - L_\theta(a+\tau_s)}{\sigma_L} \right) \right) \cdot \widehat{I}_{say} + \varepsilon_{sl_i y}$$

where the only difference is that the conversion is done at the time of year where the survey is actually taken (ts).

One complicating factor is that the minimum age of the age-based assessment is age=2, so when predicting lengths only, lengths from ages 2 and above are included.

For commercial catch observations this is less problematic as only a very small fraction of the catch is expected to be 0 and one year old. For the survey catches it is more problematic, as they are designed to select the younger fish. As a first approximation all only lengths above 25 cm were used for the survey.

Results

Many scenarios were run, but only two are outlined here. In the first run age observations were used before 2006 and length data for 2006 and after. No surveys were used after 2006. The parameters of the growth parameters were estimated, but sat constant in the period 2006–2013. The results show that the model is able to predict the observation (Figure 4.5.4.3.2), but also that the estimated fishing mortalities for the older age groups are very large (Figure 4.5.4.3.1).

In the second scenario the surveys were included, and the growth parameter k was allowed to vary over time. Results still showed greatly increased fishing mortalities for the older ages (Figure 4.5.4.3.3), but less than for the constant growth scenario. The model again predicted catches well (not showed). The main features of the survey were also captured (Figure 4.5.4.3.4), but length distributions did not match as closely as for the catches.

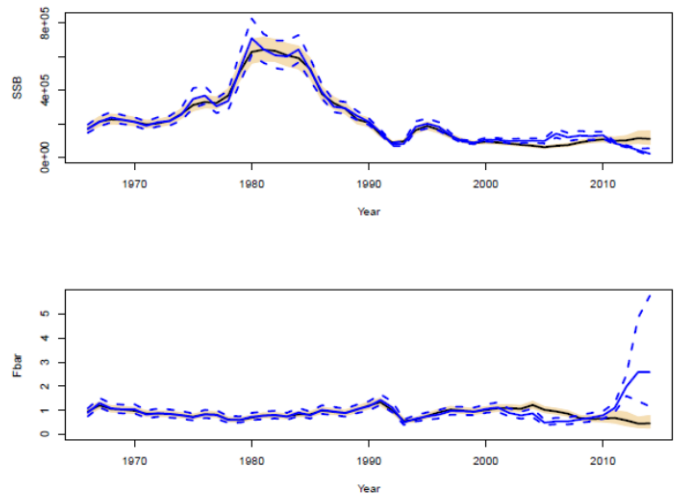


Figure 4.5.4.3.1. Scenario one (without surveys). Spawning–stock biomass and average fishing mortalities (ages 4–6). The black line and the yellow shaded area correspond to the purely age-based assessment. The age-, then length-based assessment correspond to the blue lines.

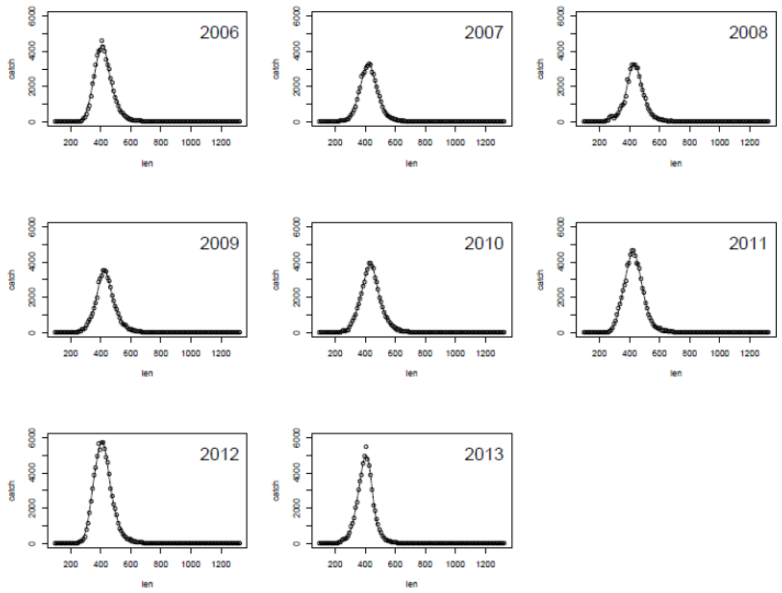


Figure 4.5.4.3.2.: Scenario one. Observed and predicted for the length based catches.

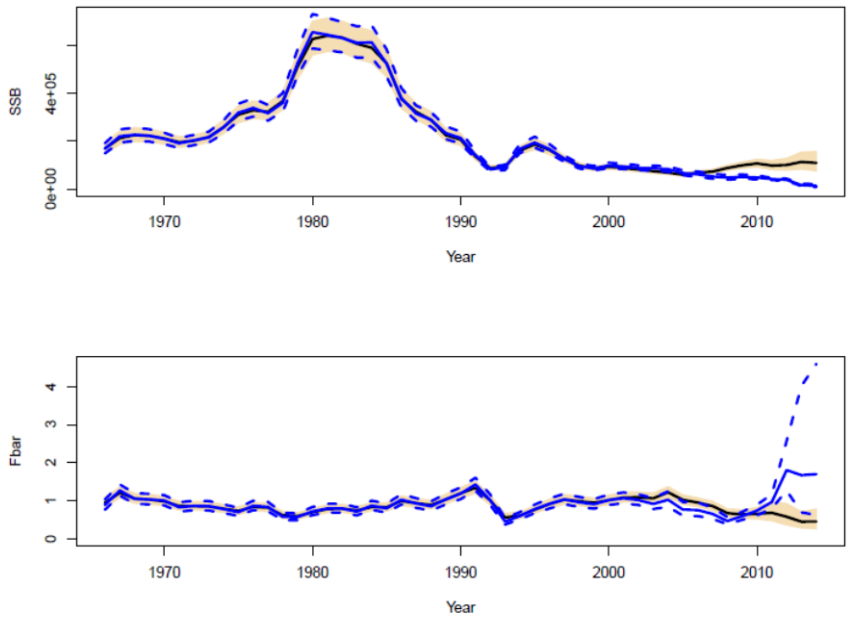


Figure 4.5.4.3.3. Scenario two (including survey data length >25 cm). Spawning–stock biomass and average fishing mortalities (ages 4–6). The black line and the yellow shaded area correspond to the purely age-based assessment. The age-, then length-based assessment correspond to the blue lines.

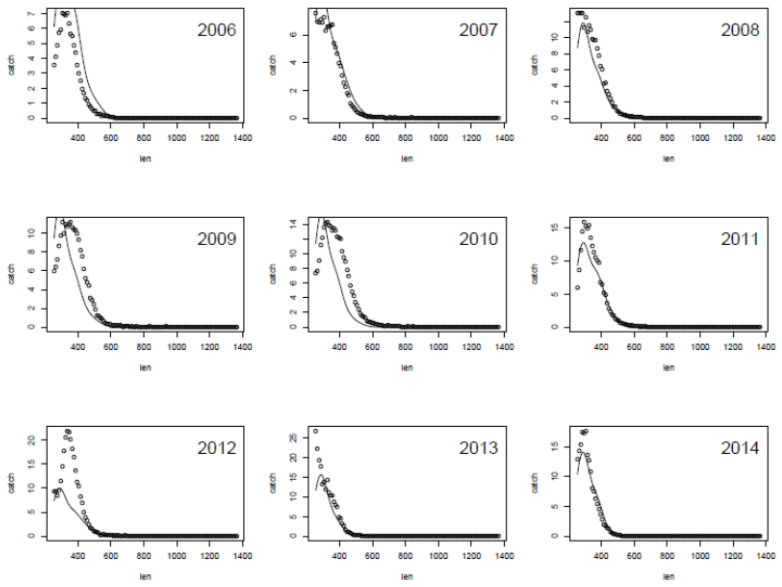


Figure 4.5.4.3.4. Observed and predicted for the length-based quarter 1 survey.

4.5.4.5 SS3

Stock Synthesis (SS3) (Methot and Wetzel, 2013) provides a statistical framework for the calibration of a population dynamics model using fishery and survey data. SS3 is a state-of-the-art statistical catch-at-age framework for conducting stock assessments for marine fisheries management using fishery and survey data. Fishery and survey selectivity can be represented as age-specific or size-specific, with the ability to capture the major effects of size-specific survivorship. It is designed to accommodate both population age and size structure data, and also multiple stock subareas, fleets, populations and gender can be analysed. It uses forward projection of a population in the "statistical catch-at-age" (hereafter SCAA) approach. SS3 estimates initial abundance-at-age, recruitments, fishing mortality, selectivity but also biological parameters can be estimated within the model. Differently from VPA based approaches (e.g. XSA) and similarly to SAM, SCAA calculates abundance forward in time and allows for errors in the catch-at-age matrices. SS3 model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various data components, and quantify the magnitude of differences between observed and expected data. Some of the SS3 features (not all where used in the model developed here) include ageing error, growth estimation, spawner–recruitment relationship, movement between areas and uncertainty estimate around the survey estimates. The ADMB C++ software in which SS3 is written searches for the set of parameter values that maximizes the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian methods or using MCMC (Markov Chain Monte Carlo) estimation.

We developed a length-based model using Stock synthesis (SS3) and conducted an assessment of the Eastern Baltic cod stock (EBC). We modelled the effect of changing M, growth and conditions over time on the estimates of stock–spawning biomass, recruitment and fishing mortality. The EBC dynamics was modelled as a single area stock harvested by a single fleet over the entire area of the stock distribution (i.e. the Eastern Baltic (SD25–32). The modelled time period includes the years 1965–2013 (last year of available data). The variance of the estimated parameters was calculated using the inverse Hessian method.

Input data

Catch, surveys and biological data

Catch data in metric tonnes were assembled from 1965 to 2013 using official ICES sources, including transferred catches from SD 24. Survey data (BITSQ1 is carried out in 1st quarter (March) and BITSQ4 in 4th quarter (November)) were obtained from official ICES sources. Number at length of Eastern Baltic cod for the catches (2000–2013) and for the surveys (BITSQ1 and BITSQ4, 2000–2013) were assembled using official ICES sources. Numbers-at-age in the catches for the period 1966–2005 were taken from official ICES sources.

Weight-at-length parameters (i.e. *a* and *b*) were estimated for each year (1988–2013) using a length–weight relationship derived from BITS survey data in Q1. Time blocks of the weight-at-length parameters were estimated using the method from Section 4.4.2.4 and set for periods 1966–1997, 1998–2004 and 2005–2013.

Survey age-specific catch rates from ICES official survey data for Subdivisions 25–29 were used for parameterizing von the Bertalanffy's growth model, i.e. using all BITS surveys available and the ALKs coming from Swedish age readings. Length increase as a function of time: Lt=L∞(1-e-K(t-t0)), where Lt is the expected or average length-at-time (or age) t, Linf is the asymptotic average length of year class i, K is the Brody growth-rate coefficient (units are per year) and t0 is a modelling artefact that represents the time or age when the average length was zero. Modelling of the von Bertalanffy growth equation was performed using fisheries stock assessment software (FSA fishR; http://www.rforge. net/FSA/). The number of iterations for convergence was set to 50 and different initial values of Linf and K were tested. Linf can be estimated as year class or by year. Annual means for Linf, and t0 were estimated for the two separate BITS surveys in the first and fourth quarter of the year. Estimated time blocks of Linf and k were set for periods 2000–2004, 2005–2010 and 2011–2013. For the period 1966 to 1999, Linf was estimated to be 89.3 (derived from Bagge *et al.*, 1994) while k for the same period was estimated by the model.

Maturity-at-length was derived from the BITS survey data in Q4 Estimated time blocks of L50 were set for periods 1965–1990, 1991–2002 and 2003–2013. A time invariant vector of natural mortality (M) by age groups (1.13, 0.52, 0.40, 0.35, 0.32, 0.30, 0.29, 0.28, 0.27, 0.27, 0.26, 0.26, 0.25, for age 1 to 12+ respectively) was estimated for the period between 1966 and 1990 using the Prodbiom model (Abella *et al.*, 1997), which is based on the von Bertalanffy growth and length–weight parameters and the assumed maximum age in the population (Linf = 89.3 cm; k=0.187; t0=0; maximum age=15 years). Natural mortality for the period 1991 to 2013 was instead coupled with condition using method developed by Casini, Lövgren and Köster (see Section 4.4.1.1). Estimated time blocks of M were set for periods 1991–2003, 2004–2007 and 2008–2013. The time blocks were used to reduce number of parameters in the model. The basic biological data are summarized in Table 4.5.4.5.1 and Figure 4.5.4.4.1, and the reason for that we use different time blocks for different biological parameters are related to the different methods used to calculate them and on the underlying assumptions.

Table 4.5.4.5.1. Eastern Baltic cod. Biological parameters used for the SS3 model.

Parameter	Value												
Linf	89.3												
k	0.187												
a	0.000006												
b	3.1503												
L50	28												
M (0-12+)	1.13, 0.52, 0.40, 0.35, 0.32, 0.30, 0.29, 0.28, 0.27, 0.27, 0.26, 0.26, 0.25												
Blocks	2000-2004	2005-2010	2011-2013										
Linf	81.5	63.6	51.5										
k	0.242	0.290	0.279										
Blocks	1998-2004	2005-2013											
a	0.00001	0.00001											
b	2.9701	2.9767											
M (0-12+)													
1991-2003	1.13, 0.52, 0.40, 0.35, 0.32, 0.31, 0.33, 0.32, 0.31, 0.31, 0.30, 0.30, 0.30												
2004-2007	1.13, 0.52, 0.40, 0.36, 0.35, 0.36, 0.44, 0.43, 0.42, 0.42, 0.41, 0.41, 0.41												
2008-2013	1.13, 0.52, 0.40, 0.37, 0.39, 0.39, 0.40, 0.39, 0.38, 0.37, 0.37, 0.37, 0.36												
Blocks	1991-2002	2003-2013											
L50	26	24											
Steepness	0.8	Rose 2001											
Sigma R	0.6	SAM 2013											

SS3 model settings

The SS3 model allows specifying the different source of data, providing different uncertainties estimates for each dataset. As the information on the standard deviation of the catches and survey estimates were lacking, we assumed that the catches were known with a standard error of 0.01 and the survey indices had a standard deviation of the estimates equal to 0.20, which are usually used as rule of thumb when estimates are not available. Selectivity-at-age was estimated for all fleets and surveys assuming no variation over time (i.e. time invariant selectivity) (Table 4.5.4.5.2 for details of estimated parameters).

Table 4.5.4.5.2. Eastern Baltic cod. Parameters estimated for the SS3 model.

Parameter	Value	Period
k	Estimated	1965-1999
L at age 1	Estimated	1965-2013
CV young	Estimated	1965-2013
CV old	Estimated	1965-2013
R_0	Estimated	1965-2013
Selectivity	Estimated	1965-2013
Recruitment deviations	Estimated	1960-2013

The underlying SS3 model contained a total of twelve age classes. The stock–recruitment function was a Beverton–Holt parameterization, with the log of the mean unexploited recruitment freely estimated and the steepness, the recruitment variabil-

ity and the autocorrelation between year classes assumed to be fixed (Table 1). Year-specific recruitment deviations were estimated from 1960–2013. It was not possible to reconstruct the sample size for survey data as data are not systematically collated by ICES and thus a 100 sample was assumed for all surveys, while sample sizes were available for the landings-at-age fleet-specific data (1966–1999) but not for the landings-at-length fleet-specific data (2000–2013), which were thus set at 100. The complete model structure, including parameter specifications, bounds and prior distributions (where applicable) and the input data used are available in Appendix 4.

Results

We ran a series of SS models based on catch data (in tonnes) from 1965 to 2013, length composition data from 2001 to 2013 for BITS Q1 and BITS Q4 surveys, length composition data from 2000 to 2013 for the catches and number-at-age in the catches from 1966 to 2005.

The basic model did converge but the results were sensitive to the starting parameters, especially the assumed growth parameters. In particular, the basic model is unable to fit the data, converge and produce reasonable results if the model does not assume that growth has declined in the recent years. The basic model was tested for sensitivity to the starting values using a jitter functions where the starting values of the parameters are jitter by a given fraction (i.e. a small quantity is added randomly to the initial parameters; in this case 0.001) and the model was run 50 times. For ten of the 50 runs, the model did not converge, while for the remaining 40 runs the model results are reasonably stable for stock–spawning biomass (SSB), recruitment and fishing mortality (Figure 4.5.4.4.2). The median estimates of stock–spawning biomass (SSB), recruitment and fishing mortality for the 40 converging jitter runs are very similar to those obtained by the basic model (data not shown).

Retrospective analysis of the basic run (i.e. five years retrospective was run) showed a rather good pattern for all years (Figure 4.5.4.4.3). The aggregated fit of the age and length compositions is good, although the model estimates a larger number of 50+ cm fish for the length compositions of the fisheries (Figures 4.5.4.4.4–4.5.4.4.5) compared to the observed data. The model fit of the yearly age composition is also good (Figure 4.5.4.4.6). However, rather large yearly positive residuals were estimated for fish measuring 70 cm and larger, while it was satisfactory for smaller individuals (Figure 4.5.4.4.7.) without apparent year or cohort effects. This was a characteristics of all models run and likely indicates that the disappearance of the large individuals cannot be explained solely in terms of declining growth and natural mortality only as assumed here. The residuals pattern of the length compositions improves considerably only when we assume that growth has declined even more than currently estimated (e.g. Linf less than 50 cm) or/and that natural mortality has increased to very high values (e.g. M around 0.6.–0.8) (data not shown).

The model fit is good for BITSQ4 and good to moderate for BITSQ1 (Figure 4.5.4.4.8). The selectivity pattern of the survey is shown in Figure 4.5.4.4.9–4.5.4.4.10 and does not show particular issues. Finally, stock–spawning biomass (SSB), recruitment and fishing mortality are estimated with very small uncertainty (Figure 4.5.4.4.11.).

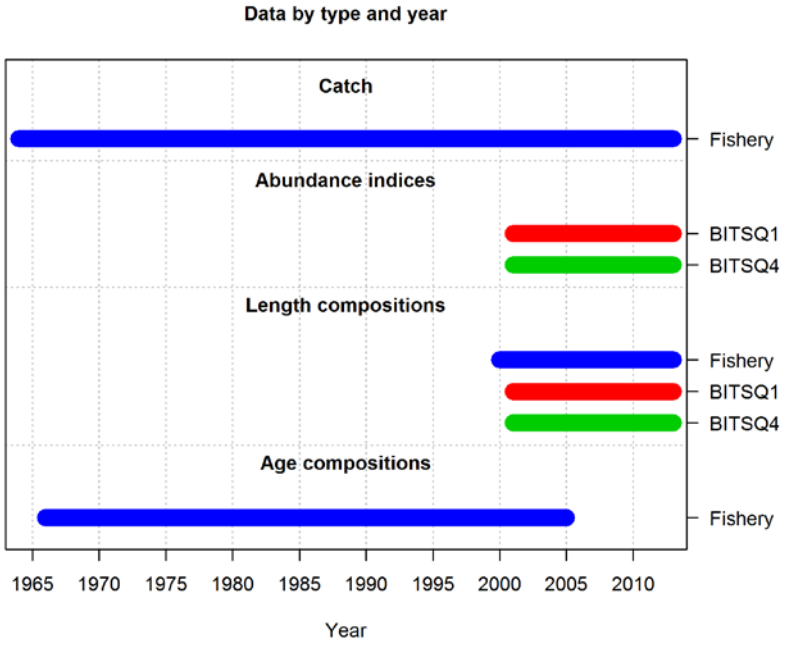


Figure 4.5.4.4.1. Input data in the model.

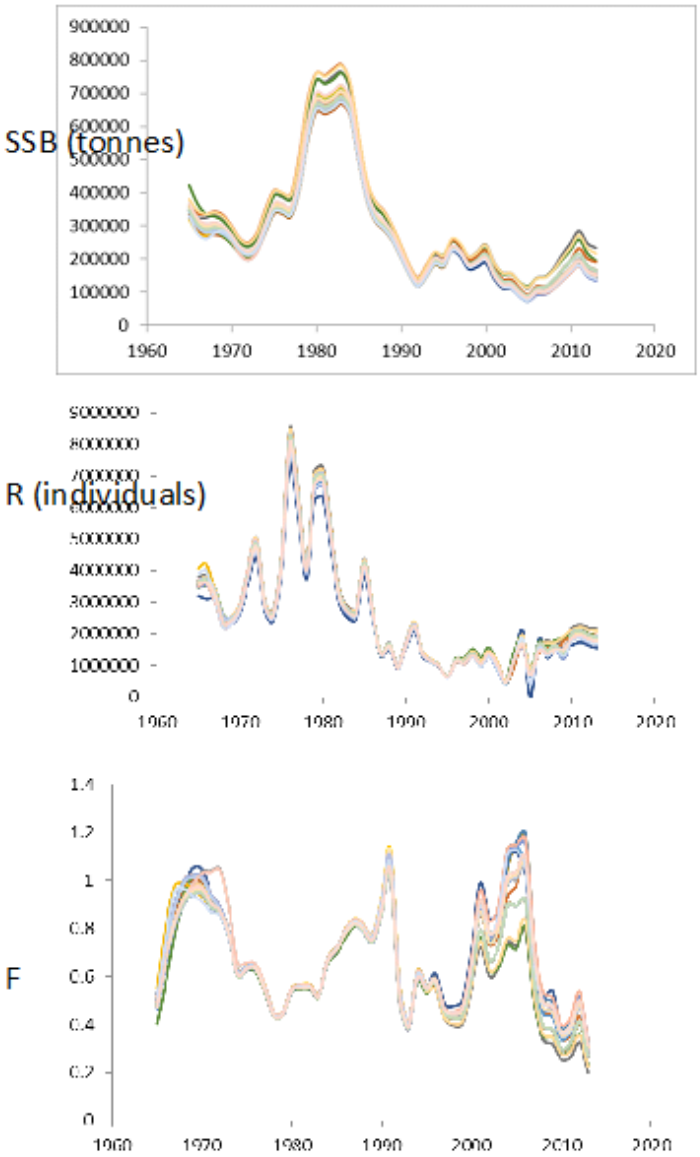


Figure 4.5.4.4.2. Spawning-stock biomass (SSB), recruitment R) and Fishing mortality (F) in 40 runs with different starting settings.

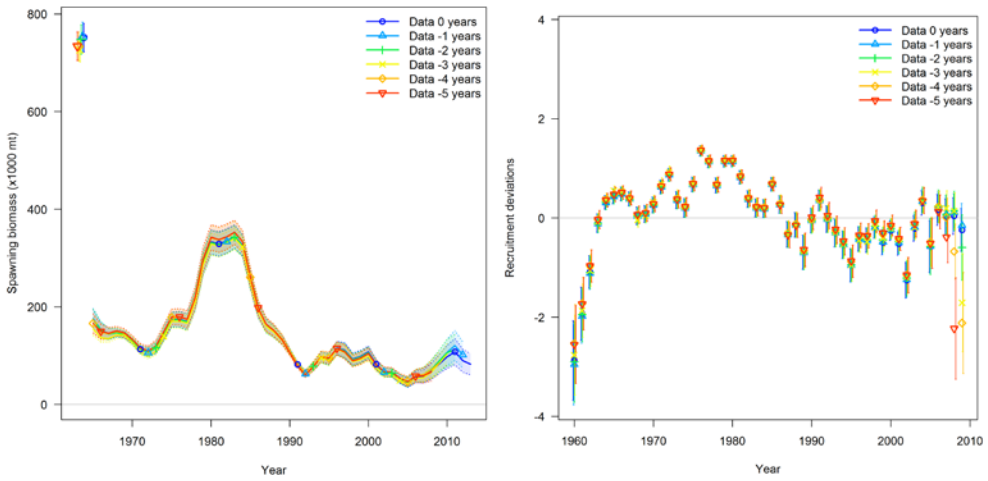


Figure 4.5.4.4.3. Retrospective runs five years back in time for SSB and recruitment.

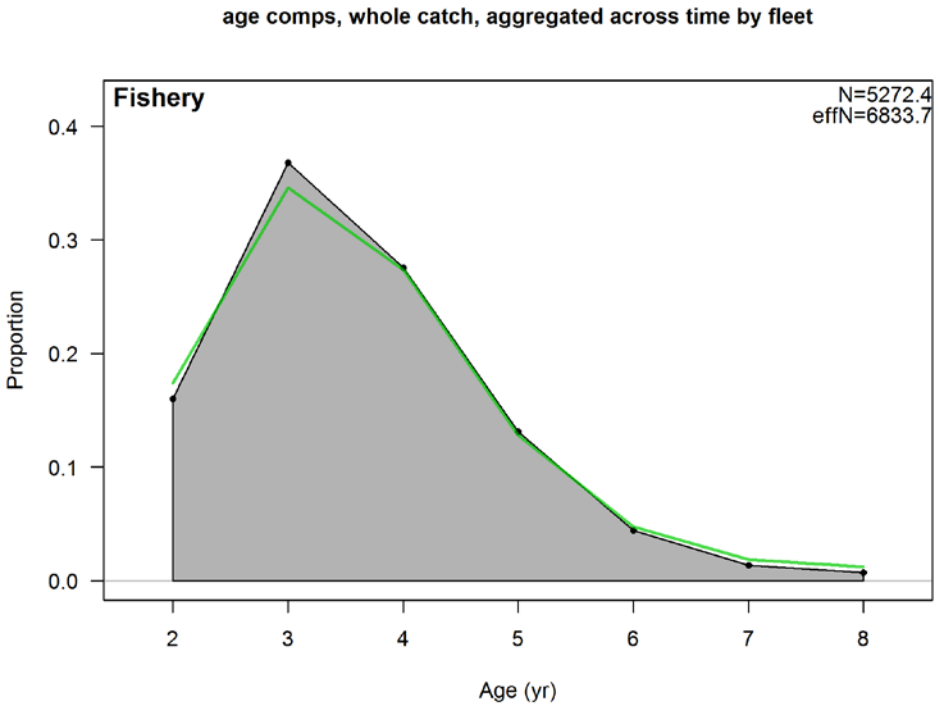


Figure 4.5.4.4.4. Model fit to commercial catch data on age.

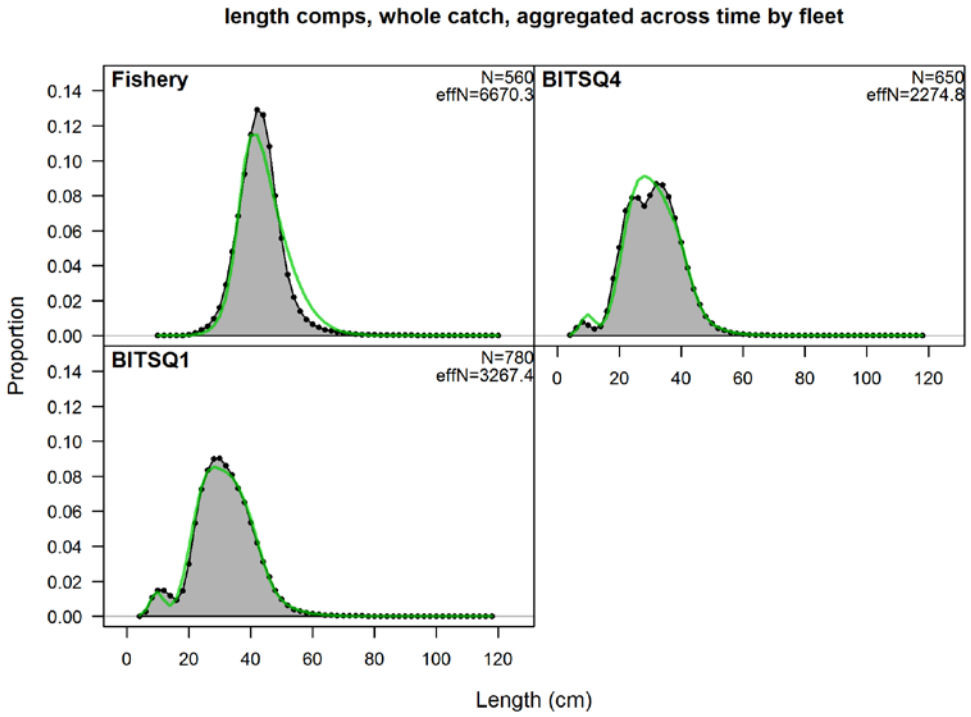


Figure 4.5.4.4.5. Model fit to survey and catch data on length.

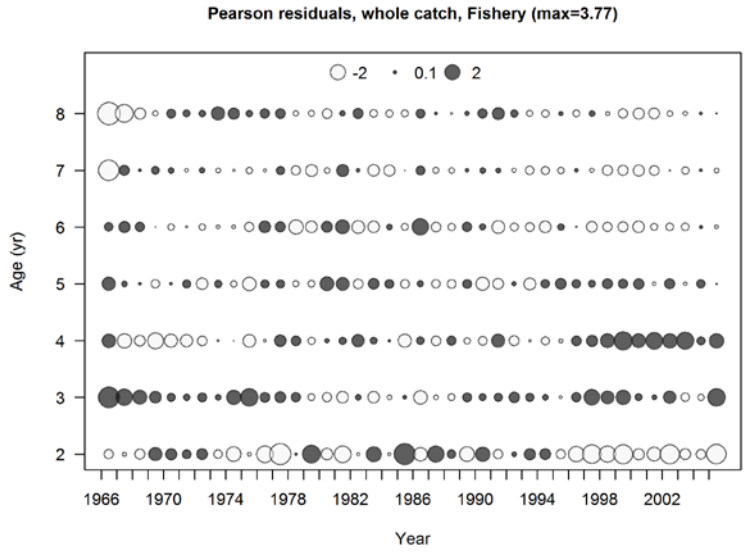


Figure 4.5.4.4.6. Residuals based on age.

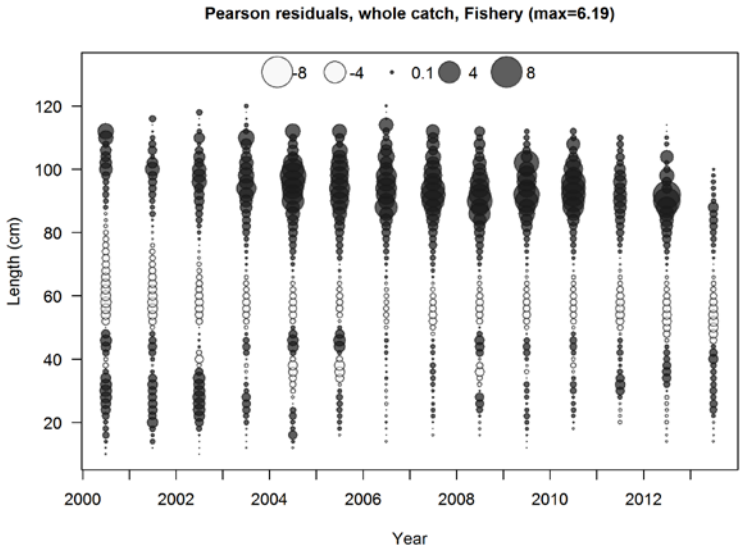


Figure 4.5.4.4.7. Residuals on length.

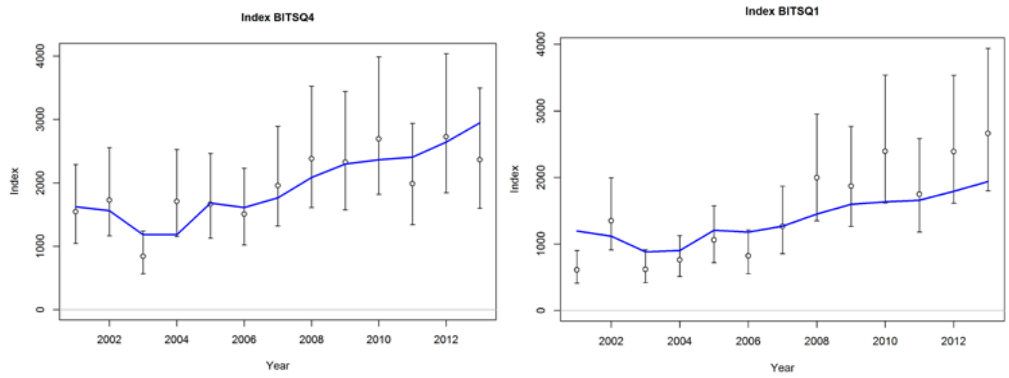


Figure 4.5.4.4.8. BITS 4th and 1st quarter from 2001–2013 compared to the model fit.

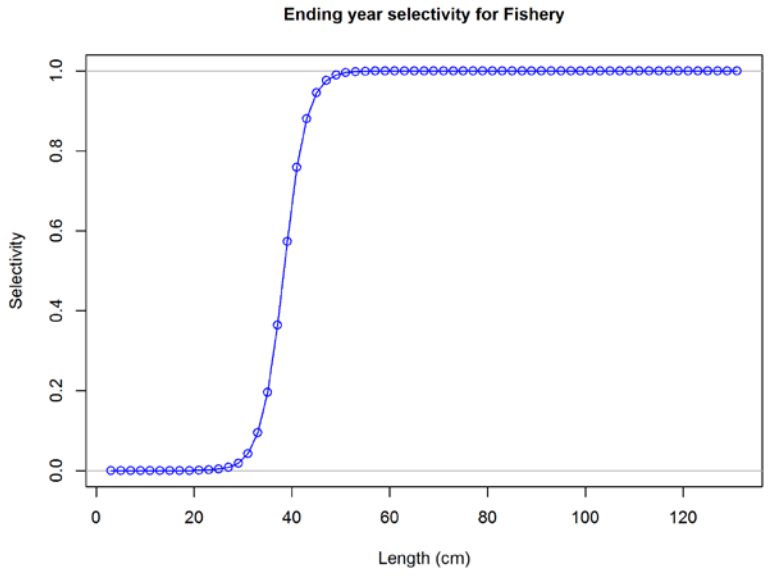


Figure 4.5.4.4.9. Selectivity curve for the fishery.

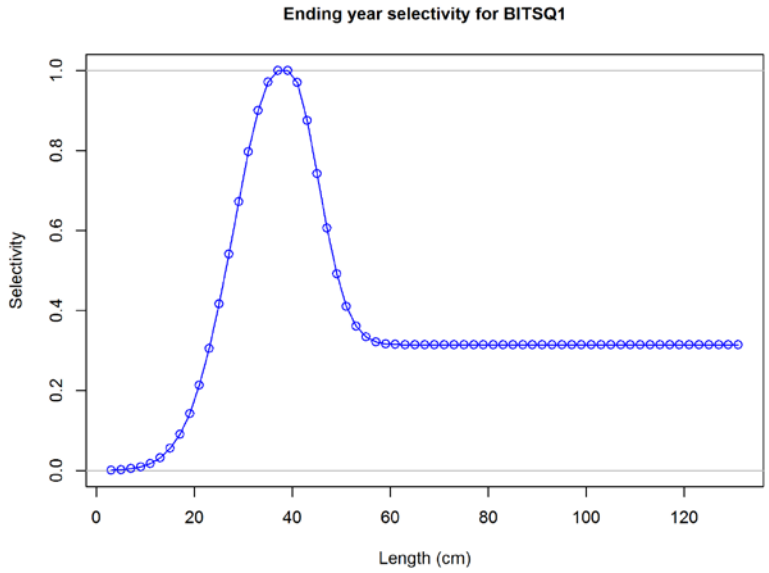


Figure 4.5.4.4.10. Selectivity curve for the BITS survey (1st and 4th quarter are very similar).

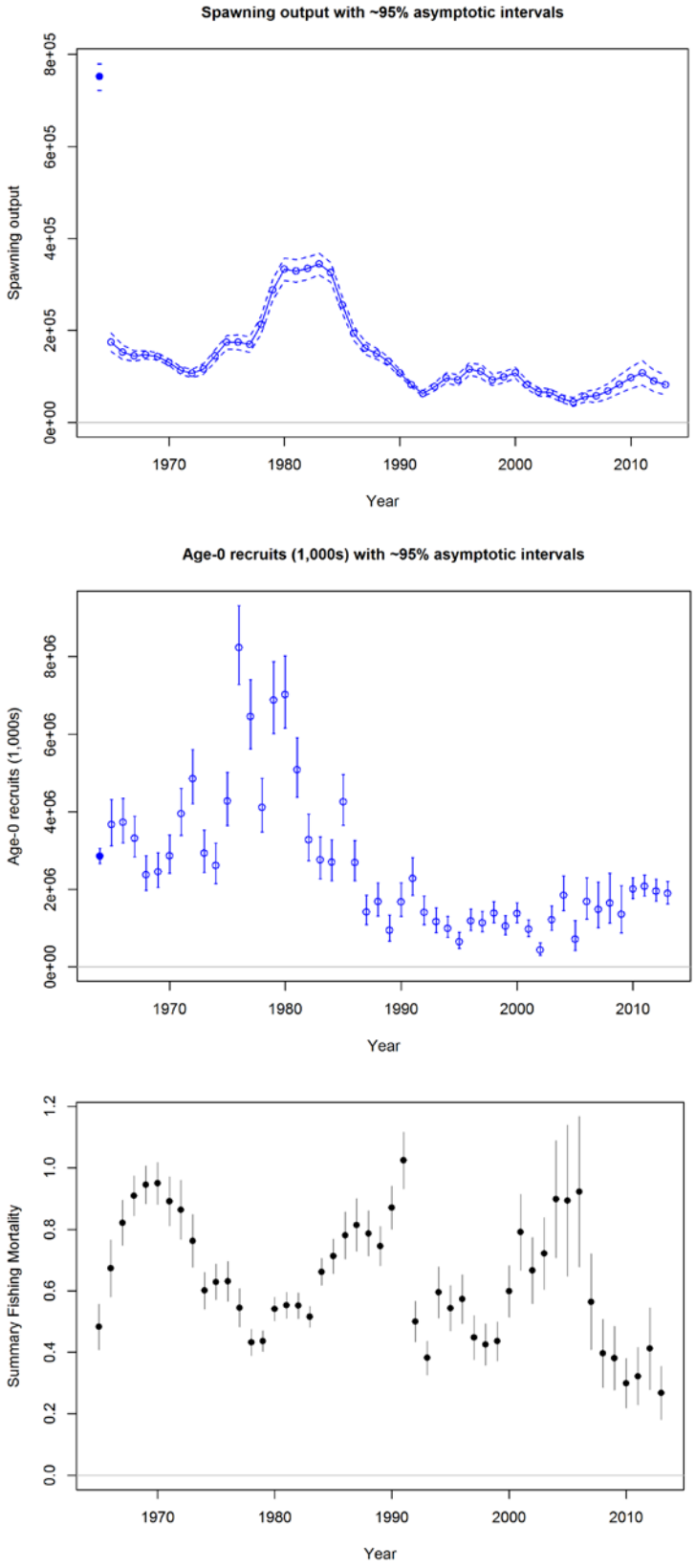


Figure 4.5.4.4.11. Summary plots of SSB, recruitments (age 0) and F.

4.5.5 SS3 Additional results, conducted after the benchmark meeting

After the benchmark, different alternative SS runs was explored to further investigate the possibilities of the SS model. In these extra model runs, 2015 data for landings, discards and survey index information were added. The three models were based on the same input information as the model presented above (Table 4.5.4.5.1). The different of models that were tested was based on the discussions during the benchmark including estimates of growth and the rate of natural mortality. Hence, three different sets of model variations were developed:

- New estimates of the development of natural mortality over time (without parasites), called median mortality;
- New estimates of the development of natural mortality over time, but including increased mortality due to parasites, called high mortality;
- Alternative estimates of development in growth (steeper decline), called different growth.

All these models produced similar results in terms of estimated SSB and F (Figures 4.5.4.4.12 and 4.5.4.4.13), but the difference was mainly in the diagnostics. The model with the steeper decline in growth (different growth) was the model with the lowest residual pattern and the model, which predicted overall catch and surveys best.

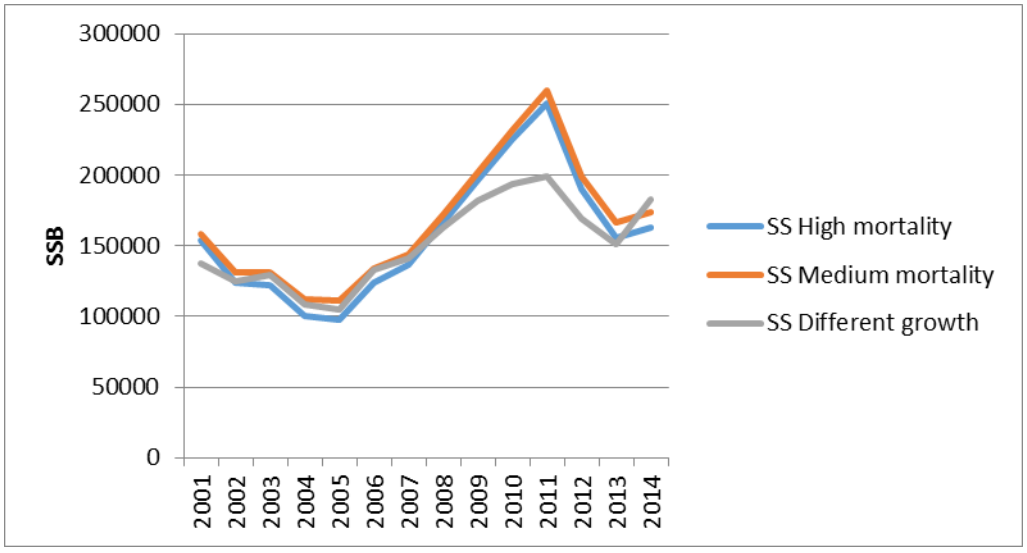


Figure 4.5.4.4.12. Summary plots of SSB for the different model runs.

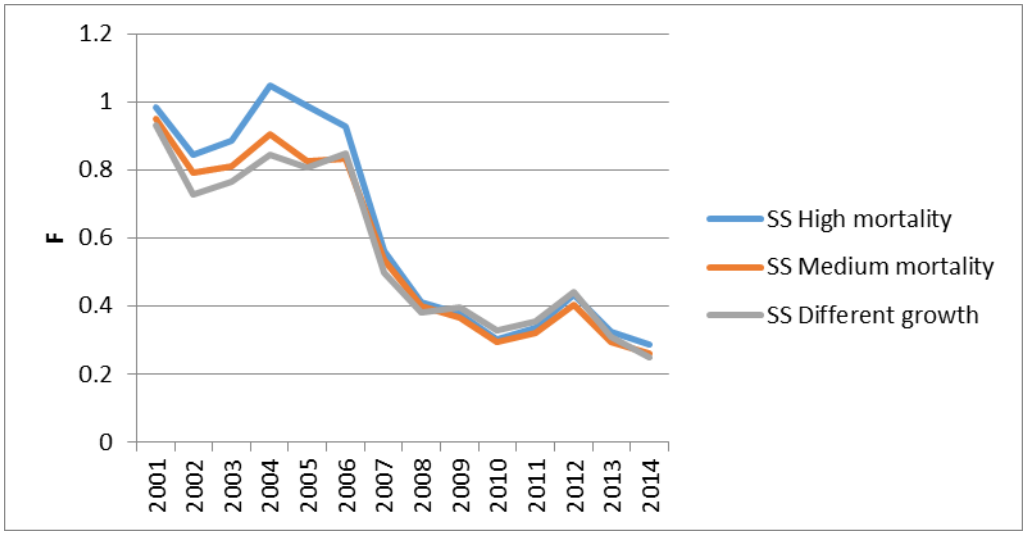


Figure 4.5.4.4.13. Summary plots of F for the different model runs.

To develop the SS model further it is suggested that estimates of growth is confirmed and that the length information from each country is checked thoroughly.

4.6 Appropriate reference points (MSY)

As no final assessment has been accepted by the group at the present time no reference points could be calculated.

4.7 Future research and data requirements

An alternative to age-based assessment models would be to use a length-based approach. These types of models are available and commonly used mainly in USA. These models include some of the models explored at WKBALTCOD (2015). The advantage with length-based models is that they do not include age reading of otoliths, where we currently have very uncertain data and it also makes them more cost-effective compared to traditional method of annual ring interpretation. However, all length-based models have to divide the population length structure into cohorts and that includes an in-depth understanding of growth, which we lack in the present situation. This basically means that if we do not know age or growth via the age of the fish, we cannot use length-based models without possibly unrealistic assumptions. There are also other assessment models available, for example production models, but they rely on constant growth over time, which we do not assume in the Baltic at present. The only way to solve the present problem concerning age and growth is to use "known-age" samples, which we can get by tagging cod or with expansive otolith micro-chemistry analysis. If age and growth are known it is important to analyse both age-based and length-based models, or models that can use both age and length to get a firm understanding of the pros and cons with the different model types. It should be noted that length-based models can possibly incorporate information from a large-scale tagging programme at an earlier stage compared to age-based models because growth information will be available before we have full information of age-based cohort growth.

Brief description of a large-scale tagging program

The objective of a large-scale tagging programme is to validate age structure in the Baltic cod, but at the same time get information of size-specific growth. This is agreed by the age-reading experts to be the best option to improve the quality of the assessment. The tagging programme must cover all Baltic cod stock components and cover several years and could be performed during the coordinated surveys in the Baltic (BITS). External marking of fish has proven to be a cost efficient method. Coupling this external marking with chemical marking of the otolith in a release/recapture programme provides the most reliable method to validate fish age and at the same time quantify the extent of migrations. A large-scale tagging programme has also the advantage of resolving other problems observed in the Baltic. Tagging has been used worldwide to evaluate migration patterns (i.e. between the eastern and western component but also between the western, the Sound and Kattegat component), independent mortality rates estimates and validate otolith structures in a wide range of species, including cod. Tagging experiments could also be used to evaluate the potential of closed areas/seasons. All this information would be important for a trustworthy stock assessment.

4.8 Feedback on the data call

A number of minor and major problems were associated with this data call requesting length-based data:

Currently, there are limitations in the setup of InterCatch to work and hold datasets representing differing strata in the same year (i.e. different types of fleets or CANUM values irrespective of whether length or age data were uploaded). These limitations of Inter Catch were not tested before the data call and not made clear to the data uploaders when sending out the data call. This lead, especially in the case of Eastern Baltic cod, to a situation, where datasets uploaded to InterCatch were similar to already existent datasets causing that wrong results occurred when extracting data from InterCatch. These errors were detected by the stock coordinators because their routine checks outside InterCatch showed that landing values were often twice as high as in WGBFAS time-series. These problems had to be fixed after the data submission, which led to an unnecessary delay in the data workup of almost two months and cost disproportionate additional time of scientists at several national laboratories. After some discussions, the InterCatch team developed a routine to delete the double datasets. However, by doing this, some datasets from some countries disappeared (which again had to be discovered and reported by stock coordinators). Furthermore, few countries did not upload data for all years, but due to all the other problems with InterCatch, these issues were detected at a very late stage.

It was also not possible to retrieve weight-at-length of length-based data in the correct format from InterCatch, so that these tables had to be produced manually by an *ad hoc* work-around provided by the InterCatch team.

Adding to the delay, the answers from the InterCatch experts to questions from national laboratories that wanted to submit their data as well as from stock coordinators often took long time (while acknowledging that some queries could also be rapidly solved). In consequence, the final achievement of length-based catch data was delayed by several weeks and still showed large discrepancies compared to the landings figures of WGBFAS. To give stock assessors at least some data prior to WKBALTCOD, the length-based data for the years 2000 to 2009 had to be extrapolat-

ed (using the factor between total annual landings of the ICES advice from 2014 and the data call).

For future exercises like this one, a thorough analysis should be carried out beforehand how InterCatch could be enhanced so that the following tasks could be fulfilled:

- Estimation of landings data on a rectangle basis which would be required for more detailed analyses of length or age distributions in SD24.
- Simple, simultaneous storage and use of age and length data for a given year in InterCatch. Presently, in InterCatch the latest upload will overwrite the previous for the same stratum, i.e. for the same stratum catch with length data will overwrite a previous imported catch with age data (and vice versa). This contradicts the aim of InterCatch to store and document national datasets.
- Holding and merging of more than one dataset (stratum) per year, together with the possibility to select the needed strata when extracting data. This possibility would be required for sensitivity analyses, e.g. alternative datasets with discards twice or three times those reported, age information raised by data from only one country, landings raised by data from one country.

Either IC needs to be developed further or ICES should decide to invest the energy in the RDB which is able to do a lot of the required exercises but is currently not able to handle all countries sampling strategies.

4.9 References

A. Zeileis, F. Leisch, K. Hornik, and C. Kleiber. strucchange: An R package for testing for structural change in linear regression models. Journal of Statistical Software, 7(2):1–38, 2002. URL http://www.jstatsoft.org/v07/i02/.

Abella A., J.F. Caddy and F. Serena. 1997. Do natural mortality and availability decline with age? An alternative yield paradigm for juvenile fisheries, illustrated by the hake *Merluccius merluccius* fishery in the Mediterranean. Aquat. Living Resour., 10: 257–269.

Aro, E. 1989. A review of fish migration patterns in the Baltic. Rap. Proc. Verb. Réun. Cons. Int. Explor. Mer 190, 72–96.

Eero, M., Vinther, M., Haslob, H., Huwer, B., Casini, M., Storr-Paulsen, M., and Köster, F.W. 2012. Spatial management of marine resources can enhance the recovery of predators and avoid local depletion of forage fish. Conservation Letters, 5: 486–492.

Eero, M, Hjelm, J., Behrens, J., Buchmann, K., Cardinale, M., Casini, M., Gasyukov, P., Holmgren, N., Horbowy, J., Hüssy, K., Kirkegaard, E., Kornilovs, G., Krumme, U., Köster, F.W, Oeberst, R., Plikshs, M., Radtke, R., Raid, T., Schmidt, J., Tomczak, M.T., Vinther, M., Zimmermann, C., Storr-Paulsen, M. 2015. Eastern Baltic cod in distress: biological changes and challenges for stock assessment ICES journal of Marin Science. Doi: 10.1093/icesms/fsc09.

Bagge, O. 1969. Preliminary results of the cod tagging experiments in the western Baltic. ICES Document CM 1969/F: 29.

Bagge, O. 1974. The Danish cod fishery in the Baltic 1957–1970. Rapp. P.-V. Réun. CIEM 166:103–105.

Bagge, O., Thurow, F., Steffensen, E., Bay, J. 1994. The Baltic cod. Dana, vol. 10, pp. 1–28, 1994.

Bedford, B.C, Woolner, L. E and Jones. B.W. 1986. Length–weight relationships for commercial fish species and conversion factors for various presentations: -Fisheries Research data report no.10. Lowestoft.

Berg, Casper W., Anders Nielsen, and Kasper Kristensen. 2014. Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models. Fisheries Research, 151:91–99.

Berg, Casper W. and Kasper Kristensen. 2012. Spatial age–length key modelling using continuation ratio logits. Fisheries Research, 129:119–126.

Berner, M. 1967. Results of cod taggings in the western and central Baltic in the period 1962–1965. ICES Doc. CM 1967/F: 05.

Berner, M. 1974. Some results of cod tagging experiments of the GDR in the Baltic 1968–1971. ICES Document CM 1974/F:32.

Berner, M., Borrmann, U. 1985. Zum saisonalen Längenwachstum des Dorsches der Mecklenburger Bucht nach Wiederfangdaten von Markierungsexperimenten und Bestandsvergleichen. Fisch. Forsch. Wissenschaftl. Schriftenr. 23, 63–69.

Berner, M., and Vaske, B. 1985. Morphometric and meristic characters of cod stocks in the Baltic Sea. ICES Document CM 1985/J: 11.

Birjukov, N. P. 1969. Spawning communities of Baltic cod and the extent of their mixing. ICES Document CM 1969/F: 7.

Bolles, K.L., Begg, G.A. 2000. Distinctions between silver hake (*Merluccius bilinearis*) stocks in US waters of the Northwest Atlantic based on whole otolith morphometric. Fish. Bull. 98, 451–462.

Campana, S.E., Casselman, J.M. 1993. Stock discrimination using otolith shape analysis. Can. J. Fish. Aquat. Sci. 50, 1062–1083.

Cardinale, M., Doering-Arjes, P., Kastowsky, M., Mosegaard, H. 2004. Effects of sex, stock, and environment on the shape of known-age Atlantic cod (*Gadus morhua*) otoliths. Can. J. Fish. Aquat. Sci. 61, 158–167.

Collie, J. S. and M. P. Sissenwine. 1983. Estimating population size from relative abundance data measured with error. Can. J. Fish. Aquat. Sci., 40: 1871–1879.

Dutil, J.-D., and Lambert Y. 2000. Natural mortality from poor condition in Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci., Vol. 57.

Eero, M., Hemmer-Hansen, J., Hüssy, K. 2014. Implications of stock recovery for a neighbouring management unit: experience from the Baltic cod. ICES J. Mar. Sci. 71, 1458–1466.

Gerritsen, H.D., McGrath, D., Lordon, C. 2006. A simple method for comparing age–length keys reveals significant regional differences within a single stock of haddock, *Melanogrammus aeglefinus*. ICES J. Mar. Sci. 63, 1096–1100.

Harding KC, Harkonen T, Helander B, Karlsson O. 2007. Status of Baltic grey seals: population assessment and extinction risk. NAMMCO Scientific Publications 6, 33–56.

Harding K.C., Härkönen T.J. 1999. Development in the Baltic grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) populations during the 20th century. Ambio 28, 619–627.

Härkönen, T., Galatius, A., Hårding, K., Karlsson, O., Ahola, M. 2015. Population trends and Abundance of seals. HELCOM core indicator report. In press.

Horbowy, J. 1992. The differential alternative to the Deriso difference production model. - ICES J. mar. Sci., 49: 167–174.

ICES. 2000. Report of the study group on Baltic Cod age reading. Karlskrona, Sweden. 27–31 March 2000. ICES CM 2000/H:01.

ICES. 2003. Report of the Study Group on Precautionary Reference Points For Advice on Fishery Management ICES CM 2003/ACFM:15.

ICES. 2014. Report of the Workshop on Scoping for Integrated Baltic Cod Assessment (WKSIBCA). ICES CM 2014/ACOM:62.

ICES. 2014b. Report of the Study Group on Spatial Analysis for the Baltic Sea (SGSPATIAL), 4–6 November 2014, Gothenburg, Sweden. ICES CM 2014/SSGRSP:08. 49 pp.

Hüssy, K. 2011. Review of western Baltic cod (*Gadus morhua*) recruitment dynamics. ICES Journal of Marine Science, 68: 1459–1471.

Hüssy K., St John M. A., and Böttcher U. 1997**.** Food resource utilization by juvenile Baltic cod *Gadus morhua*: a mechanism potentially influencing recruitment success at the demersal juvenile stage? Marine Ecology Progress Series, 155: 199–208.

Hüssy, K., Hinrichsen, H.-H., and Huwer, B. 2012. Hydrographic influence on the spawning habitat suitability of western Baltic cod (*Gadus morhua*). ICES Journal of Marine Science, 69: 1736–1743.

Kristensen, K. and Casper W. Berg. 2012. Datras package for r.http://rforge.net/DATRAS/,2012

Lass, H.U., Mohrholz, V. 2003. On dynamics and mixing of inflowing salt water in the Arkona Sea. J. Geophys. Res. 108(C2), 3042, doi:10.1029/2002JC001465.

Lindegren, M., Waldo, S., Nilsson, P.A., Svedäng, H. and Persson, A. 2013. Towards sustainable fisheries of the Öresund cod (*Gadus morhua*) through sub-stock-specific assessment and management recommendations. ICES Journal of Marine Science, doi.10.1093/icesjms/fst042.

Matthäus, W., and Franck, H. 1992. Characteristics of major Baltic inflows – a statistical analysis. Continental Shelf Research, 12: 1375–1400.

Mérigot, B., Letourneur, Y., Lecomte-Finiger, R. 2007. Characterization of local populations of the common sole *Solea solea* (Pisces, Soleidae) in the NW Mediterranean through otolith morphometrics and shape analysis. Mar. Biol. 151, 997–1008.

Methot R. D. Jr., Wetzela, C. R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142 (2013) 86–99.

Mohrholz, V., Naumann, M., Nausch, G., Krüger, S. and Gräwe, U. 2015. Fresh oxygen for the Baltic Sea — An exceptional saline inflow after a decade of stagnation Journal of Marine Systems 148 (2015) 152–166 http: //dx.doi.org/ 10.1016 /j.jmarsys.2015.03.005.

Müller, H. 2002. The distribution of "Belt Sea cod" and "Baltic cod" in the Baltic Sea from 1995 to 2001 estimated by discriminant analysis of the number of dorsal fin rays. ICES Document CM 2002/L:16.

Nielsen, A. and Berg, C. W. 2014. Estimation of time-varying selectivity in stock assessments using state–space models. Fisheries Research. 158.

Nielsen, E.E., Grønkjær, P., Meldrup, D. and Paulsen, H. 2005. Retention of juveniles within a hybrid zone between North Sea and Baltic Sea Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 62, 2219–2225.

Nielsen, E.E., Hansen, M.M., Ruzzante, D.E., Meldrup, D. and Grønkjær, P. 2003. Evidence of a hybrid-zone in Atlantic cod (*Gadus morhua*) in the Baltic and the Danish Belt Sea revealed by individual admixture analysis. Mol. Ecol. 12, 1497–1508.

Nielsen, B., Hüssy, K., Neuenfeldt, S. Tomkiewicz, J., Behrens, J.W., Andersen, K.H. 2013. Individual behaviour of Baltic cod *Gadus morhua* in relation to sex and reproductive state. Aquat. Biol. 1, 197–207.

Oeberst and Krumme. 2015. Evaluation of factors influencing growth estimates of eastern Baltic cod, WD of WKBALTCOD, 2015.

Otterlind, G. 1985. Cod migration and transplantation experiments in the Baltic. J. Appl. Ichthyol. 1, 3–16.

Pauly, D. 1978. A preliminary compilation of fish length growth parameters. Ber. Inst. Meereskd. Christian-Albrechts-Univ. Kiel (55):1–200.

Paul, K., Oeberst, R., Hammer, C. 2013. Evaluation of otolith shape analysis as a tool for discriminating adults of Baltic cod stocks. J. Appl. Ichthyol. 29, 743-750.

Pella, J. J. and Tomlinson, P. K. 1969. A generalized stock production model. Bulletin of the Inter-American Tropical Tuna Commission, 13, 421–458.

Pinhorn, A.T. 1969. Cod length conversions factors for Flemish Cap. ICNAF Res-doc. 69/38.

Prager, M. H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fish. Bull. (US) 92: 374–389.

Schinke, H., and Matthäus, W. 1998. On the causes of major Baltic inflows – an analysis of long time-series. Continental Shelf Research, 18: 67–97.

Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bull. Inter-Am. Trop. Tuna Comm., 1:25–56.

Svedäng, H. and Hornborg, S. 2014 Selective fishing induces density-dependent growth. Nature Com. DOI: 10.1038/ncomms5152.

4.10 External Reviewers report (both stocks)

1. The external experts are members of the benchmark workshop. One among the external experts will chair the Benchmark workshop. Although, the external experts are members of the meeting, they should report on the peer review process.

Jean-Jacques Maguire served as co-chair of WKBALTCOD 2015 along with ICES chair Marie Storr-Paulsen. All reviewers were involved in all aspects of the review of the two cod assessments. Meaghan Bryan was involved more closely in verifying that the SS3 set up and results for Eastern Baltic cod were consistent with best practices before the detailed results were presented to the Workshop and Verena Trenkel provided detailed input to the Western Baltic cod assessment and more general for the Eastern Baltic cod assessment.

The external experts would like to recognize all of the participants for their contributions to the benchmark workshop. Over the week many presentations about various data collection programs, research projects, and assessment models were presented. They provided ample context about this complex fisheries system.

2. External experts have special responsibility to focus on the quality of the work. In that context it is hoped that the external experts will be consulted on the assessment approaches well in advance of the benchmark workshop. The actual assessment work should be done by the leading assessment expert and co-workers, coordinated by the ICES chair.

A conference call was organised on January 28, 2015 to brief the external experts on the issues in the assessments, particularly for the Eastern Baltic cod. Problems identified were i) increasing discrepancies in the age-reading between countries, ii) retrospective patterns in the SAM assessment which led to rejecting that method as a basis for advice, iii) decrease in growth and condition factors, iv) possible increase in natural mortality, and v) difference in stock trends in the survey between small fish (increasing) and large fish (decreasing). External experts were informed that methods expected to be considered included Stock Synthesis 3, SAM including ageing errors, SAM using lengths-at-age, and production models. External experts suggested that

the Collie-Sissenwine-Analysis should be considered and warned that, considering the different trends by sizes, this should be taken into account in fitting production models.

3. The external experts are recruited outside the ICES system (or at least outside the region under discussion) and therefore have a special responsibility to feed other approaches to fish stock assessment and advice than those favoured by ICES. They are independent and therefore in no way involved with the political details of management of the stocks.

None of the scientific participants in the workshop gave signs of being involved in the political details of the management of the fisheries for these stocks. The observers also behaved reasonably neutrally and provided useful information on changes in the fisheries and the environment. Input on alternate stock assessment approaches was provided during the conference call. ICES scientists were already planning to consider Stock Synthesis 3, modifications of SAM to include ageing error and modification of SAM to include using length frequencies instead of age frequencies for recent years. The CSA approach was applied.

4. The external experts would need to report on:

a) The issues raised by the reviewers throughout the process (i.e. during the preparatory work before the workshop and during the workshop).

There were few opportunities to raise issues and make suggestions prior to the workshop as data were received late and assessment models / results were not made available until the first day of the meeting.

b) Statement confirming that the outcomes of the benchmark (i.e. the stocks annex) are appropriate to provide scientific advice:

External experts agreed that the updated SAM for Western Baltic cod was an appropriate basis to provide. The experts were of the opinion that the different assessment approaches should be continued to be developed for the Eastern Baltic cod. All agreed that the apparent decreases in growth, the possible increase in natural mortality, whatever the causes, and the poor larval production in 2014 were causes for great caution in fishery management for 2015 and 2016 until sustained positive signs are detected. There was insufficient time during the workshop to agree a basis for advice for Eastern Baltic cod. The ACOM leadership agreed that Workshop would continue to work on SS3 and other assessment models by correspondence. Worked continued and a stable SS3 configuration with no retrospective pattern was found. However, the external experts did not feel confident in suggesting to use that model configuration as a basis for advice without extensive testing and closer examination of the model results. The external experts suggest that suggests that in the absence of substantial progress with data and modelling, the Difference production model of Horbowy and the Collie-Sissenwine Analysis (CSA), with updated survey indices and natural mortality estimates, would likely be an improvement over the approach taken in 2014 to provide advice.

c) Recommendations for future work. This item is facultative and can be incorporated as a separate annex as a generic recommendation for future work from all workshop participants.

The external experts were surprised that getting the data for the assessment required so much effort from the stock coordinator. They expected that submission of data to the ICES Secretariat would be automatic but this does not seem to be the case and

there continues to be substantial human input at several stages of the process to put the assessment together. Ideally, all data and data decisions should be finalized and the data made available on SharePoint prior to the benchmark workshop. If data decisions require the advice or opinion from external experts this should be addressed through webinars prior to the workshop. This will not always be possible, but it would improve the efficiency of this process. It would also be helpful to ensure that any new software developments are finalised before the Benchmark meeting and ideally validated by the Methods working group.

Data and software files should be shared on the SharePoint so that external experts can examine the data and make calculations if they are inclined to do so. The ICES Benchmark process, unlike other such processes e.g. in the USA, welcomes analyses from external experts. It would be easier to contribute analyses if data and models were routinely available on the SharePoint site prior to and throughout the benchmark workshop. Working documents explaining each assessment model, clearly defining the model assumptions, and summarizing the available data and the data inputs should be made available prior to the workshop. This would also facilitate external expert contributions and review.

Although many scientists are involved in research and assessment of Eastern Baltic cod, the external experts felt that the stock was an orphan with no single scientist / Institute taking responsibility for compiling the information and taking charge for the assessment. The collective nature of the stock assessment making process in ICES is often a strength of ICES but it can also become a weakness when no single institute or consortium of institutes is taking responsibility for the delivery of the assessment.

External experts have no doubt that some of the recommendations above have been made previously.

The stock synthesis model (SS3) presented for Eastern Baltic cod took advantage of some of the flexible features this modelling platform offers. More specifically, changes in natural mortality and growth were modelled using time blocks. Prior to and during the benchmark workshop issues including, changes in growth and natural mortality due to changing body condition were discussed. Due to time constraints other features that could potentially improve the Eastern Baltic cod SS3 model and account for changes in natural mortality and growth were not investigated. Future iterations of this model could estimate natural mortality internally in the model and use body condition as an environmental link to reflect the suspected changes in natural mortality. This should also be investigated for changes in growth. Another parameterization of this model could use the full time-series of age composition data and account for ageing-error. If one set of age estimates from a particular lab can be considered the "gold standard", then estimates from other labs can be compared to estimate age error and be incorporated in the model so as not to lose the information of the most recent ageing data.

Annex 1: List of participants

NAME	ADDRESS	PHONE/FAX	E-MAIL
Gustaf Almqvist	University of Stockholm Universitetsvägen 10A 106 91 Stockholm Sweden	Phone +46 Fax +46	gustaf.almqvist@su.se
Michael Andersen	Danish Fishermen's Association Fredericia Nordensvej 3 Taulov 7000 Fredericia Denmark	Phone +45 70 10 9645 Cell: +45 4026 5040	ma@dkfisk.dk
Casper Willestofte Berg	DTU Aqua – National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 2920 Charlottenlund Denmark	Phone +45 35 88 34 33 Fax +45	cbe@aqua.dtu.dk
Wendy Broadgate	The Fisheries Secretariat (FISH) Prästgatan 9 11129 Stockholm Sweden	Phone +46 8 25 07 90 Cell +46 707 14 17 99	Wendy.broadgate@fishsec.org
Meaghan Bryan Invited Expert	National Oceanic and Atmospheric Administration Southeast Fisheries Science Center 4301 Rickenbacker Causeway Miami FL 33149 United States	Phone +1 Fax +1	Meaghan.bryan@noaa.gov
Steven Campana Reviewer of ageing	Fisheries and Oceans Canada Bedford Institute of Oceanography PO Box 1006 Dartmouth NS B2Y 4A2 Canada		Steven.Campana@dfo-mpo.gc.ca
Max Cardinale	Swedish University of Agricultural Sciences Institute of Marine Research Turistgatan 5 453 30 Lysekil Sweden	Phone +46 523 18 750 / 700 Fax +46 523 13977	massimiliano.cardinale@slu.se

NAME	ADDRESS	PHONE/FAX	E-MAIL
Michele Casini	Swedish University of Agricultural Sciences Institute of Marine Research Turistgatan 5 453 30 Lysekil Sweden	Phone +46 10 478 4016 Fax +46 523 13977	michele.casini@slu.se
Jan Dierking	Leibniz-Institut für Meereswissenschaften Düsternbrooker Weg 20 24105 Kiel Germany	Phone +49-431-600-4580 Fax +49-431-600-4553	jdierking@geomar.de
Christian von Dorrien	Thünen Institute Baltic Sea Fisheries Alter Hafen Süd 2 18069 Rostock Germany		christian.dorrien@ti.bund.de
Margit Eero	DTU Aqua – National Institute of Aquatic Resources Charlottenlund Slot Jægersborg Alle 1 2920 Charlottenlund Denmark	Phone +45 21314880/35 88 33 18 Fax +45 33963333	mee@aqua.dtu.dk
Yuri Efimov	Russian Federal Research Institute of Fisheries & Oceanography (VNIRO) 17 Verkhne Krasnoselskaya 107140 Moscow Russian Federation	Phone +7 499 264 9129 Fax +7 499 264 9129	efimov@vniro.ru
Pavel Gasyukov	AtlantNIRO 5 Dmitry Donskogo Street 236000 Kaliningrad Russian Federation	Phone +7 4012 225 257 Fax +7 4012 219 997	pg@atlant.baltnet.ru
Jakob Hemmer-Hansen	DTU Aqua – National Institute of Aquatic Resources Department of Inland Fisheries Vejlsøvej 39 DK-8600 Silkeborg Denmark	Phone 33963129	jhh@aqua.dtu.dk
Joakim Hjelm	Swedish University of Agricultural Sciences Institute of Marine Research PO Box 4 453 21 Lysekil Sweden	Phone +46 523 18751 Fax +46 523 13977	joakim.hjelm@slu.se

NAME	ADDRESS	PHONE/FAX	E-MAIL
Noél Holmgren	University of Skövde School of Life Sciences PO Box 408 541 28 Skövde Sweden	Phone +46 500 448607 Fax +46	noel.holmgren@his.se
Jan Horbowy	National Marine Fisheries Research Institute ul. Kollataja 1 81-332 Gdynia Poland	Phone +48 587-356-267 Fax +48 587-356-110	horbowy@mir.gdynia.pl
Karin Hüssy	DTU Aqua – National Institute of Aquatic Resources Jægersborg Allé 1 2920 Charlottenlund Denmark	Phone +45 35 88 34 58 Fax +45	kh@aqua.dtu.dk
Reine Johansson	Baltic Sea Advisory Council PO 5105 471 15 Dyrön Sweden	Phone +46 70 812 4591 Fax +46	rj.j@pelagic.se
Stanislovas Jonusas	DGMare 200 rue de la Loi 1049 Brussels Belgium	+32 2 298 01 55	Stanislovas.jonusas@ec.europa.eu
George Kornelius	Institute of Food Safety, Animal Health and Environment (BIOR) 8 Daugavgrivas Str. Fish Resources Research Department 1048 Riga Latvia	Phone +371 676 76 027 Fax +371 6761 6946	georgs.kornilovs@bior.gov.lv
Fritz Köster	DTU Aqua – National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 2920 Charlottenlund Denmark	Phone 45 35 88 30 00 Fax 45 33 96 33 33	fwk@aqua.dtu.dk
Sarah Kraak	Thünen Institute Bundesallee 50 38116 Braunschweig Germany		sarah.kraak@ti.bund.de
Uwe Krumme	Thünen Institute Baltic Sea Fisheries Alter Hafen Süd 2 18069 Rostock Germany	Phone +49 381 8116-148 Fax +49 381 8116-199	uwe.krumme@ti.bund.de

Name	Address	Phone/Fax	E-mail
Scott Large	International Council for the Exploration of the Sea H. C. Andersens Boulevard 44–46 1553 Copenhagen V Denmark	Phone +45 33 38 67 86 Fax +45	scott.large@ices.dk
Staffan Larsson	Swedish Cod Fishermen's Producer Organisation Tofta Sörhagen 10 442 75 Lycke Sweden	Phone +46 703 64 04 11 Fax +46	staffan.larsson@stpo.se
Anna Luzenczyk	National Marine Fisheries Research Institute ul. Kollataja 1 81-332 Gdynia Poland	Phone +48 58 735 62 74 Fax +48 58 735 6110	aluzenczyk@mir.gdynia.pl
Johan Lövgren	Swedish University of Agricultural Sciences Institute of Marine Research PO Box 4 453 21 Lysekil Sweden		johan.lovgren@slu.se
Jean-Jacques Maguire External Chair	1450 Godefroy Quebec Quebec GIT 2E4 Canada	Phone +1 418 688 3027	jeanjacquesmaguire@gmail.com
Henrik Mosegaard	Aqua DTU Charlottenlund Castle Jægersborg Allé 1 2920 Charlottenlund Denmark		hm@aqua.dtu.dk
Anders Nielsen	DTU Aqua – National Institute of Aquatic Resources Jægersborg Allé 1 2920 Charlottenlund Denmark	Phone +45 35 88 34 54 Fax +45	an@aqua.dtu.dk
Niclas Norrström	University of Skövde PO Box 408 541 28 Skövde Sweden	Phone +46 500 448653 Fax +46	niclas.norrstrom@his.se
Rainer Oeberst	Thünen Institute Baltic Sea Fisheries Alter Hafen Süd 2 18069 Rostock Germany	Phone +49 381 811 6125 Fax +49 381 811 6199	rainer.oeberst@ti.bund.de
Daniel Stepputtis	Thünen Institute Baltic Sea Fisheries Alter Hafen Süd 2 18069 Rostock Germany	Phone +49 381 8116 136 Fax +49 381 8116 199	daniel.stepputtis@ti.bund.de

NAME	ADDRESS	PHONE/FAX	E-MAIL
Edward Stern	The Fisheries Secretariat (FISH) Prästgatan 9 11129 Stockholm Sweden	Phone +46 (0)8 25 07 90	Edward.stern@fishsec.org
Marie Storr-Paulsen ICES Chair	DTU Aqua – National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 2920 Charlottenlund Denmark	Phone +45 35 88 34 41 Fax +45 3396 3333	msp@aqua.dtu.dk
Harry Vincent Strehlow	Thünen Institute Baltic Sea Fisheries Alter Hafen Süd 2 18069 Rostock Germany		harry.strehlow@ti.bund.de
Henrik Svedäng	Swedish University of Agricultural Sciences Institute of Marine Research Turistgatan 5 453 30 Lysekil Sweden	Phone +46 52318723 Fax +46 523 13977	henrik.svedang@slu.se
Verena Trenkel Invited Expert	Ifremer Nantes Centre PO Box 21105 44311 Nantes Cédex 03 France	Phone +33 240 374157	verena.trenkel@ifremer.fr
Martin Wæver Pedersen	DTU Aqua – National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 2920 Charlottenlund Denmark		map@aqua.dtu.dk
Christopher Zimmermann	Thünen Institute Baltic Sea Fisheries Alter Hafen Süd 2 18069 Rostock Germany	Phone +49 (0) 381 8116-101 / mobile (0) 1712777464 Fax +49 (0) 381 8116-199	christopher.zimmermann@ti.bund.de

Annex 2: Agenda

Agenda

Benchmark for the Baltic cod stocks

Purpose of the meeting: see TORs

Use of the results of the meeting: assessment of cod 25-32 and 22-24 at WGBFAS

Information on the meeting:

Date: 2-6 March, 2015

Location: Thünen Institute of Baltic Sea Fisheries, Rostock, Germany (see info in the SharePoint under 01.tors and general information)

To prepare: Working papers to be uploaded latest the 23rd of February at the share point

To bring along: Data to be used in assessment for cod

Agenda item:	Process and outcome:	Responsible:	Duration
March 2nd START: 10 am	**SETTING THE SCENE:**		
Welcome	Welcoming words And house keeping	Dir. Christopher Zimmermann	10 min
Introduction	Presentation of participants. Chairs orientate on general background of the meeting, and what is the expected outcome of the meeting	External Chair Jean-Jacques Maguire	15 min
Summary and outcome of WKSIBCA	Orientate on the main issues encountered in EB and WB cod assessments, to have a common understanding of the issues and outcome of WKSIBCA	Marie Storr-Paulsen	30 min
Adjusting agenda	Go through agenda, add if needed	Marie Storr-Paulsen All	10 min

GENERAL **11 am**	**Input data for stock assessment** **Cod 25-32 and 22-24:**		
AGE READING:			
Outcome of age reading review	Summary of results from otolith exchange and outcome of the external review and follow up (both **EB and WB cod**)	Karin Hüssy	30 min
Options to continue with age based assessment	**EB cod**: Presentation of assessment analyses, testing sensitivity of the results with only Swedish age readings	Joachim Hjelm	20 min
	WB cod: differences in G and DK length distribution in SD 22 implications for data collection, allocation and management	Uwe Krumme	20 min
Discussion	Discussion and conclusion on whether or not to continue with age based assessment until next benchmark (**EB** and **WB** cod).	All	45 min
LUNCH 13.00-14.00	**Input data for stock assessment 25-32 cod**		
GROWTH/ NATURAL MORTALITY:			
Catch data	Quality of catch data	Christian von Dorrien	15 min.
Parasites	Presentations on the developments in seals, parasites and related potential effects on cod condition/growth and mortality.	Jan Horbowy	15 min.
	Larval Anisakidae in Baltic cod: Results from fish disease surveys 2011-2014	Thomas Lang/ Lina Weirup	20 min
	Is cod condition affecting mortality?	Johan Lövgren	10 min
Predation by seals	How large is the seal population and can seal predation have an effect on natural mortality	Marie Storr-Paulsen	10 min
	Discussion and conclusion on i) mortality has/has not changed? Different growth parameters to be used/tested in assessments	All	30 min

	Input data for stock assessment 22-24 cod		
Stock mixing			
Methods for stock splitting	New genetic results	Jakob Hemmer-Hansen	20 min
	Different methods for splitting the east and west cod	Rainer Oberst	20 min
	Otolith shape method	Henrik Mosegaard	20 min.
Discussion	Discussion and conclusion on the method to go forward with/identify the assessment analyses to be conducted during WKBALTCOD, in relation to stock splitting	All	45 min.
End of day at 18.00			
3rd of March 9 am.	**Summing up data input for cod 22-24 (west)**		
Implications for assessment input data	Presentation of assessment input data after applying splitting based on otolith form analyses.	Margit Eero	20 min.
Feed – back	Suggestions for alternative inputs - runs	All	30 min
MODELS:	**Models for cod 25-32 (east)**		
ES-SR model	Environmentally-Sensitive Stock-Recruitment model	Michele Casini/ Piotr Margoński	20 min
Production models	Presentation of production models with preliminary application for EB cod	Jan Horbowy/ Anna Luzeńczyk	20 min

	Stated based production model	Martin Væver	20 min
Length based models	Presentation of SS3 with preliminary application for EB cod	Max Cardinale	20 min
	Presentation of length-based SAM with preliminary application for EB cod	Anders Nielsen	20 min
Age-based model	SAM model estimating age-reading errors	Noel Holmgren/ Niclas Norrström	10 min
Survey	Standardization of survey indices	Casper	1 hour
Discussion	Discussion and identification of further work with the models to be carried out during WKBALTCOD	All	
LUNCH 13.00-14.00	**Sub- group work: parallel groups for assessment analyses; and for presentations on ecosystem processes/other issues relevant for advice**		
Ecosystem process understanding			
Environment /ecosystem	Presentation of outcome of DEMO2/SGSPATIAL	Michele Casini	15 min
Food base	Presentation of the new stomach analyses to elucidate potential changes in food base (cannibalism, pelagic fish/ benthic food)	Karin Hüssy	15 min
Environment	Potential explanations for the change in condition/growth (prey composition, oxygen, seals)	Michele Casini	20 min
Genetic	Baltic cod genetic diversity in	Jan Dierking	20 min

Growth	SD25 predicted by stock structure and oxygen situation – a different perspective on the cod ageing problem		
	Growth on eastern Baltic cod based on survey data	Rainer Oberst	20 min
	Effect of selectivity on discards and populations structure of Baltic cod (EB, WB)	Daniel Stepputtis/Voss/ Schmidt/Krumme	20 min
	Why are the eastern Baltic cod so thin? Possible mechanism and implications	Uwe Krumme/ Rainer Oeberst/ Martina Bleil/ Christopher Zimmermann	20 min
End of day at 18.00			
March 4th Start 9 am.	**Sub-group work continues**		
Con. understanding of processes in the ecosystem/other issues			
Fisheries catch	Selectivity induced mortality	Henrik S.	20 min
	Recreational fishery – mark recapture. Migration and growth rates	Harry/Simon	20 min
Recruitment	Presentation of processes/variables affecting recruitment	Bastian Huwer/ Fritz Köster	20 min
Summing op sub-group work	**PLENARY**		
	Major points from ecosystem process understanding group	Chair of the sub-group	20 min
Discussions	Discussion and identification of further work on the most important processes and how to incorporate it in advice	All	1 hour
LUNCH 13.00-14.00			

	Preliminary assessment results		
Stock assessment WB cod	Presentation of suggested key-run for stock assessment of WB cod	Margit Eero	30 min
Discussion	Discussion and decision on which model/approach to use for WGBFAS and identifying any remaining issues to look into	All	45 min
Stock assessment EB cod	Presentation of suggested key-run(s) for stock assessment of EB cod (potentially from different models)	Joakim Hjelm	30 min
Discussion	Discussion and decision on setup to use for WGBFAS and identifying any remaining issues to look into	All	45 min
March 5th START: 9 am			
Forecast (both stocks)	Settings for forecast, if applicable	All	
Reference points (both stocks)	Discussion and estimation of new reference points, if applicable	Noel Holmgren/ Niclas Norrström	15 min
Stock annexes	Writing stock annexes		
March 6th START: 9 am			
Final assessments	Presentation of final assessment for EB cod	Joakim Hjelm	
	Presentation of final assessment for WB cod	Margit Eero	
Stock annexes	Presentation of stock annexes	Joakim Hjelm, Margit Eero	
Summing up/ Discussion	Discussion on long-term work needs, pending issues until WGBFAS etc.	All	

Report/Annexes	Data problems IC ? Finalizing stock annexes, report writing	Uwe / Christian - All	
15.00 END OF WKBALCOD			

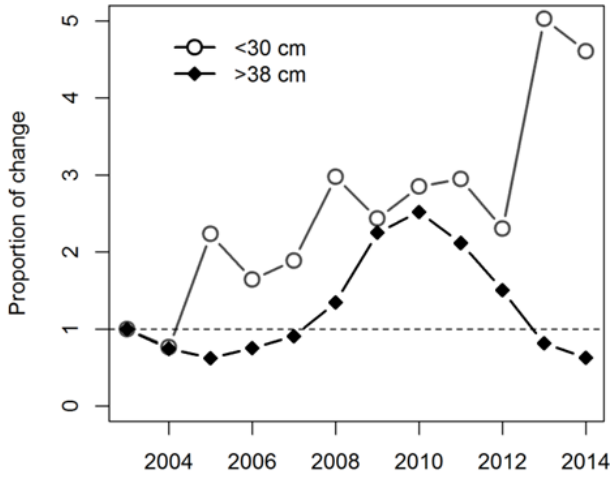
Annex 3: Abstracts of presentations

WD1) Introduction to the issues with cod assessments by Marie Storr-Paulsen (DTU Aqua, Denmark)

The age-based analytic assessment of the eastern Baltic cod stock was not accepted by ICES last year (2014). There were several factors that have changed the prerequisite of the former assessment with the most important being the decrease of larger cod the latter years despite a historic high level of recruits. This resulted in an advice in 2014 based on ICES data-limited approach.

The reasons for the distrust of the present assessment can be found in several different challenges with the data.

- Absence of large cod, despite a lot of recruits;
- Age-reading problems;
- Reduced condition / changed growth?
- Changed catchability?
- Unaccounted mortality (Natural / Fishing)?
- Lack of ecosystem understanding.



The proportion of change in cod larger than 38 cm and smaller than 30 cm. from the combined survey.

It was during the WGBAS realized that there were severe differences between countries in the length-at-age data. This was analysed and presented in WKSIBCA by Karin Hüssy who conducted new otolith exchanges. The result from these exchanges were that there was a large bias in the age reading and that none of the participating countries were precise although Sweden were the countries with less bias in the readings. Furthermore, it is evident that condition has decreased and mortality increased although the main reason for the changes is yet to be found. Several hypothesis have been suggested during the WKSIBCA among others changes in food availability, changed hydrography condition, seals parasite and predation, fishery induced mortality, etc. It seems clear that although much new information has been looked on and a large amount of work conducted since WGBFAS 2014, there is still a lack of understanding of the recent processes in the Baltic Sea.

WD2) External Review of Age Reading problems in Baltic cod by Karin Hüssy (DTU Aqua, Denmark)

After WGBFAS (2014) observed a strong divergence in age structure of catches and survey data suggesting an increase in ageing inconsistencies, an extensive age-reading exchange including all countries contributing to the Age–Length-Key of Baltic cod was carried out in 2014. The objectives of that exchange were to 1) Examine the extent of the problems 2) Identify where the problems are (i.e. first winter ring and/or subsequent rings), and 3) To provide a validation through daily increment analysis. The results of the exchange were presented at WKSIBCA (Gdynia, October 2014) showed extensive inconsistencies between countries and within readers, suggesting that age reading based on traditional methods is not sufficiently accurate and precise to justify the use of age data in stock assessment. Two external reviewers were asked to review existing information on the ageing problem (study and working group reports, published papers, project reports) and the results of the 2014 exchange.

The compiled material is available at the WKBALTCOD SharePoint under "Ageing review"

Reviewer contact information

1) Steven Campana: Bedford Institute of Oceanography, Canada. Steve.Campana@dfo-mpo.gc.ca

2) Mike Armstrong: Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, UK. Mike.armstrong@cefas.co.uk

Summary of review by ToR

a) Review the results of the otolith image exchange (prepared in WebGR)

- In the validation exercise with true ages available Sweden and Poland had unbiased age estimates for ages 1 and 2 but not for 0. The CV of all countries, including Sweden and Poland ranged from 46–100%.
- Only age readings of readers with unbiased age estimates and with a Coefficient of Variation (CV) <20% should be used. None of the countries complied with these guidelines.
- Extrapolation from ages 0–2 to the entire age range would be a rather big assumption.
- Nothing in the Age Reading Exchange document definitively identified the cause of age-reading difficulties in Baltic cod, nor identified who (if anyone) might be ageing correctly.
- There seems to be little advantage to conducting further age calibration exercises until some known-age otoliths are available.
- Future attempts to "correct" or calibrate age readings from Baltic cod are doomed to failure unless additional known-age otoliths become available.

b) Review the results of studies on daily increments

- Daily increment patterns yield accurate ages but are only applicable to ages <3 years.

c) Review the results of studies on otolith microchemistry and possible age interpretation based on microchemistry techniques

- No substantive results to review.

d) Advise on possible methods applicable for using otoliths for age determination of the two Baltic Sea cod stocks

- Two issues are mandatory for any age information to be used in assessment of eastern Baltic cod: The establishment of a known age sample and a reference collection of historic otoliths to monitor trends in age interpretations.
- **Known-age fish otoliths:** These could be obtained through methods like Bomb radiocarbon (samples from late 1970s), Isotope and elemental composition, Tag/recapture experiments, age sampling of length–frequency modes (only applicable if sufficiently clear length modes).
- **Reference collection of historic otoliths:** This collection should cover all regions, seasons, and fisheries, a broad range of sampling years and should be used in annual monitoring of bias between/within readers.

e) Advise on the reliability of historical Baltic cod age data based on otolith age reading and its use for stock assessment

- National allocation of trawl stations differs between SDs cause substantial effects in that differences in ageing affect BITS indices differently in each SD. This allocation prevents the use of one nations ALK to all catch data. Also, shift in geographic distribution will cause varying bias in age composition.
- There is no clear evidence in the surveys and the combined international age structures for the last 15–20 years that the age composition data are consistently tracking year classes.
- Test if year-class signals become discernible using separate national fishery age composition is advisable.

Stock mixing of eastern and western Baltic cod in SD 24

Background: Cod in SD 24 are, together with SD 22-23, managed as a single stock: The Western Baltic cod stock. Since 2006, conspicuous changes have been observed in SD 24, both with respect to abundance and biological parameters (size and weight at age, maturation and spawning), suggesting an immigration of cod from the neighbouring eastern Baltic cod stock. Denmark examined the stock mixing issue in a national project funded by the Ministry for Food, Agriculture and Fisheries and the European Fisheries Fund.

Materials and methods: Baseline samples of the true eastern and western cod stocks were collected during the peak spawning time in SD 22 and 25. Additionally mixed-stock samples of mature and immature individuals were collected in SD 24 covering the spawning season of both stocks. From each individual standard biological data was recorded together with catch location and time. Genetic samples were collected as well as otoliths. The genotype of each individual was identified based on single-nucleotide polymorphism (SNPs). Stock-specific discriminant functions were obtained from the otolith contours. These discriminant functions were applied to archived otoliths for selected years during the 1990s and 2000s.

To evaluate whether eastern Baltic cod produce recruits to the Western Baltic cod stock, the quality of the spawning area for successful egg survival and retention of eggs and larvae was tested using hydrodynamic modelling.

Results: Genotyping showed that the genetic fingerprint of Eastern and Western cod stocks differ significantly, provided a high-probability stock identification of virtually all individuals in the mixing area of SD 24. The analysis documented that in 2011, the proportion of Eastern cod in the western part of SD 24 was ~50% and in the eastern part > 90%.

Application of the otolith contour based stock discriminant functions showed that Eastern Baltic cod have historically been present in SD 24 during the 1990's and early 2000's with a relatively stable proportion of ca 20%. Between 2005 and 2008 the proportion of Eastern cod started to increase. Since then, the proportion of Eastern cod in SD 24 has increased steadily from 20% in 2005 to 100% in 2012. This immigration was initiated by medium sized fish (20-30 cm) and subsequently larger size groups. Immigration seems to have occurred primarily in the area north of Bornholm, with a strong spatial gradient towards smaller proportions of Eastern cod in the west of SD 24.

The spawning habitat used by cod in SD 24 was found to sustain only limited survival of Eastern Baltic cod eggs, with narrow and irregularly occurring windows of enhanced survival probability during May-June. On average < 20% of eggs and larvae are estimated to survive to the end of the yolk-sac stage. The primary agent of mortality was low salinity, which causes the eggs to sink to the bottom where they presumably die.

Conclusions: Two independent methods have identified SD 24 as a stock mixing area with a large contribution of Eastern Baltic cod. The immigration of Eastern cod started between 2005 and 2008, first in medium sized fish followed by larger fish. This large contribution of Eastern Baltic cod does not seem to contribute considerably to recruitment of the Western stock.

WD 3) Is cod condition affecting mortality? by Johan Lövgren (SLU Aqua, Sweden)

The condition factor (Fulton's condition index) of Eastern Baltic cod in three different size classes (under 20 cm, 20–39 cm and over 40 cm) was studied for three different time periods. The three different time periods were from 1991–1995 (early) 2000–2003 (mid) and (2010–2013) late. The proportion of cod in each size class that had a condition factor up to 0.8 increased in all the size classes over time, i.e. having the lowest condition in 2010–2013. The proportion of cod over 40 cm that had a low condition (≤0.8) increased from less than 5% in the early time period to 20% in the late period. The other size classes did show an increase in the proportion of cod that had lower condition but not to the same extent as or the large cod. The coupling of condition and natural mortality was further explored in the IBIS model produced during the week of the Benchmark meeting in Rostock.

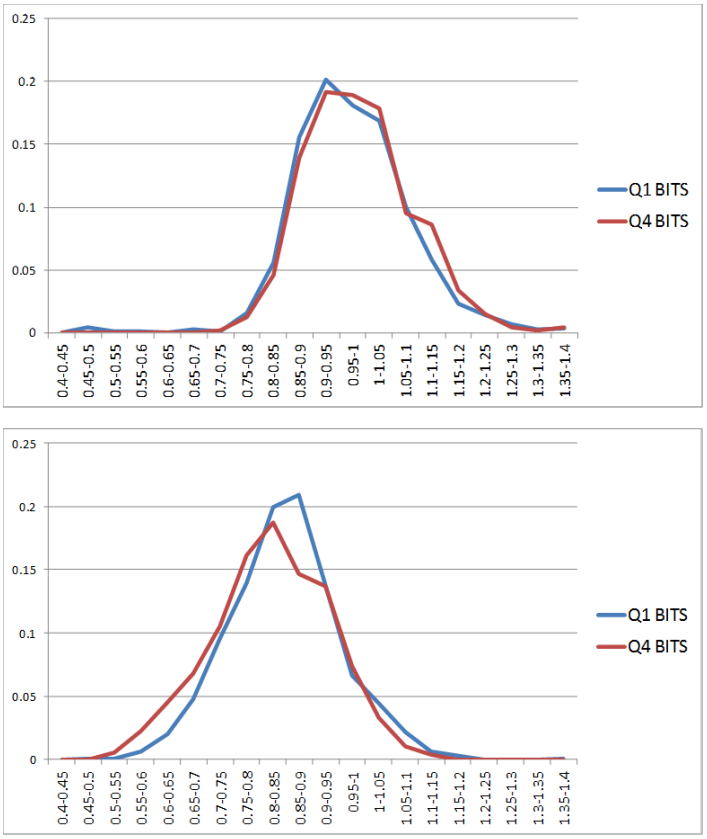


Figure 1. Condition distribution (Fultons K) of cod between 41–50 cm in 1994 (upper) and 2013 (lower).

WD 4) Remnants of megaspawners in the Western Baltic Sea (SD22)– implications for data collection, data raising and management (Uwe Krumme & Marie Storr-Paulsen, Thünen Institute of Baltic Sea Fisheries, Germany; DTU-Aqua, Denmark)

To assess whether fishers in Denmark (DK) land larger Western Baltic cod than fishers in Germany (GER), length distributions from commercial sampling data 2013 of the two countries were compared. The exercise revealed similar size distributions in SD24 but differences in SD22. Overall, the raised landings distributions of DK and GER are not readily comparable. GER employs an at-sea catch sampling; catch samples are raised by haul or trip to a given stratum. DK samples landings in harbours and discards at sea. In DK, for the landings part, EU size sorting categories (SSC) are sampled in the ports and the information from the fish boxes used to raise the landings from a given stratum. The size compositions of boxes by SSC from active and passive gear are assumed identical.

In a next step, the commercial SSC of the two countries from SD22 were compared by rectangle for the years 2002–2013. The proportion of SSC was similar in rectangle 37G1 (Mecklenburg Bight) but different remarkably in rectangle 38G0 (Kiel Bight) (Figure 1). Further analyses of the data revealed a fishery on (pre-)spawning aggregations in quarter 1 in 38G0, but also further north in the Large Belt. The archipelago around Fyn Island (DK) apparently serves as a refuge area for large cod, because trawling is not possible in larger areas. The analysis of a commercial sample of SSC1 cod from quarter 1, 2015, 38G0 showed a mean weight per cod of ~10 kg with 2.5 cod

per box. The approximate removals of megaspawners (SSC1) by DK and GER from SD22 is ~89 t (mean) or 8900 megaspawners y-1 (±2300 SE), from SD24 is ≥30 t or 3000 y-1 (±1000 SE), from SD25 is ≥104 t or 10 400 y-1 (±8600 SE; excluding the maximum of 1050 t in 2012: ≥18 t or 1800 (±400 SE); Figure 2). These minor, pulsed landings are difficult to cover both by a randomized at-sea observer sampling programme (GER) and the harbour sampling programme of DK. However, the sampling approach of DK may take into account the increased uncertainty in estimates with decreasing number of individuals per box from SSC 5 to SSC1 (Figure 2). The remnants of megaspawners in SD22 may have high relevance for stock health, and the uncertainty in the data on these large fish may have adverse effects on the stock assessment, which may be best evaluated by sensitivity analyses. Borrowing of data within InterCatch should take into account these dissimilarities (i.e. no borrowing from quarter 1-SD22 to other strata). Possible measures to reduce the catch of megaspawners in SD22 involve: Spatio-temporal closures, e.g. no fishing below 20 m depth in February/March in SD22, fishing only for vessels which can prove this (AIS, VMS, CCTV; or no fishing beyond 3 m in February/March in SD22; voluntary measures by fishers; make landings of size sorting category 1 in Q1 more expensive.

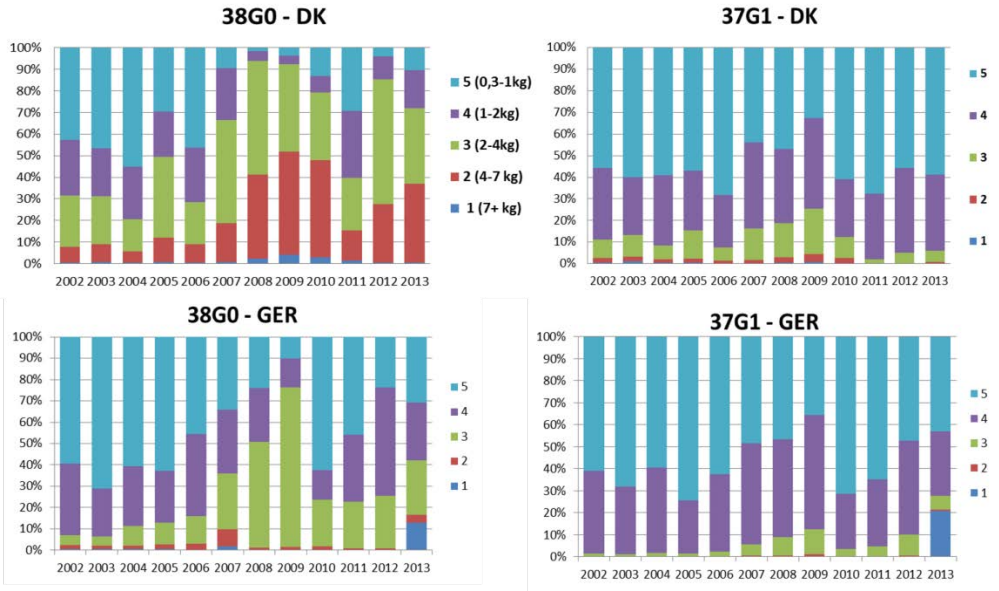


Figure 1. Composition of total annual landings of cod by EU size sorting category in 2002–2013 in the SD22 rectangles 38G0 (Kiel Bight) and 37G1 (Mecklenburg Bight). Denmark: upper panels; Germany: lower panels. Weight ranges per size sorting category are given in the legend of the upper left panel.

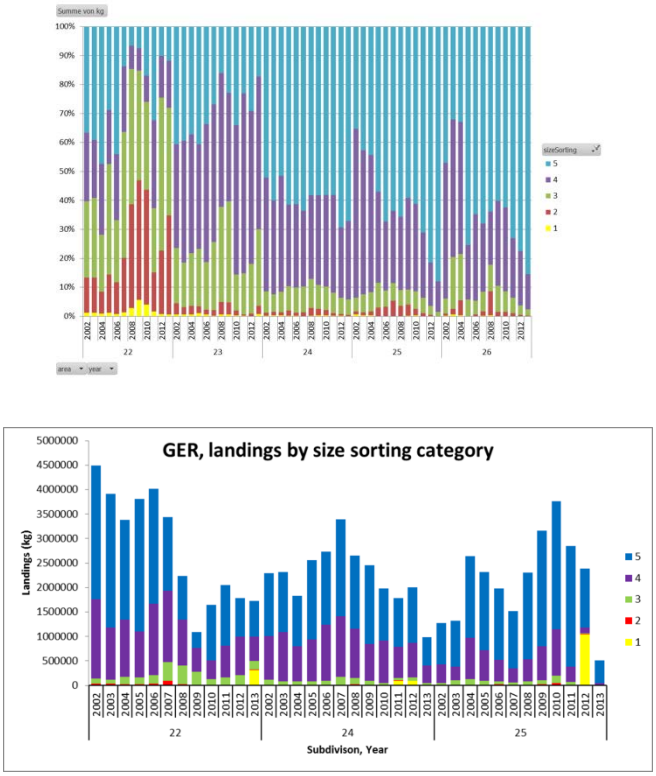


Figure 2. Composition of EU sorting categories of cod landings by Denmark (left) and Germany (right) from 2002–2013 in the SD22, 24, 25, 26.

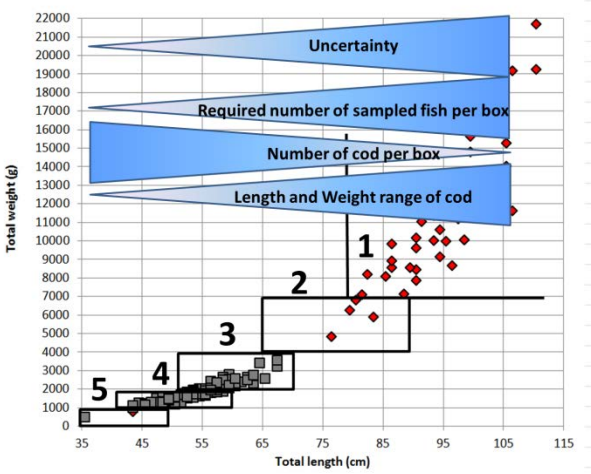


Figure 3. Schematic changes in characteristics of EU size sorting categories with fish length, to be considered in a harbour sampling programme.

WD 5) Different methods to split western and eastern Baltic cod by Rainer Oeberst (OF, Germany)

Quantification of the mixing of both Baltic cod stock in SD 24 during the BITS were estimated based on otolith shape and the discriminant function given by Paul *et al.* (2013). Cod larger than 27 cm were used for the analyses because uncoupling of the descriptors and length of cod by linear relation is not possible for smaller cod. Proportion of eastern Baltic cod varied between 34% in quarter 4 in 2007 and 43% in

quarter 1 in 2007.(WD of WCBALTCOD: Mixing of western and eastern Baltic cod in SD 24 based on otolith shape).

Slices of otolith centre have been used for ageing of cod since 2009 by Germany. The centre and the outer edge of hyaline zones as well as the edge of otolith were marked to document to ageing process. Distances between marked points were determined to the development of the otolith. Distances between the centre and first hyaline zone, R1, of western and eastern Baltic cod differed. Range of Rn (distances between centre and the hyaline zone) of both cod stocks overlap with increasing n. R1 can be used to assign individuals of one year and older to one stock and to quantify mixing of eastern Baltic cod stock (EBC) and western Baltic cod stock (WBC):

WBC, if 0.8 mm ≤ R1 <1.3 mm
EBC, if R1 < 0.8 or 1.3 mm ≤ R1 ≤2.3 mm

Distance between otolith centre and nth hyaline zone suggest was described by von Bertalanffy growth function. Otolith height of both cod stocks can be described by similar parameters D_∞ and k combined with a shift of t0 of about six month. Mean back calculated length based on Rn and the relation between length and the edge of otolith are comparable with estimated mean length-based on length frequencies in quarter 1 and 4 sampled between 1971–1972 and 1993–2000.

(WD of WCBALTCOD: Distance between centre and outer edge of hyaline zones of western and eastern Baltic cod)

Distance between the centre of the otolith and the outer edge of first hyaline zone was used to classify cod to western of eastern Baltic cod. Proportions of western Baltic cod (WBC) decreased from SD 22 to SD 24 and SD 25. Small proportions of eastern Baltic cod were estimated for cod captured in SD 24 with larger proportion in quarter 4. Proportions of eastern Baltic cod were higher in SD 24 and SD 25 with ~70%. The proportions varied from year to year and by quarter. It must be pointed out that the proportion of otolith without detectable hyaline zone increased from 6% in SD 22 to 19% in SD 24 and 42% in SD 25. Analyses suggested that most of these cod are eastern Baltic cod with high probability. Therefore, the proportion of eastern Baltic cod is underestimated in SD 24 and SD 25 with high probability.

(WD of WCBALTCOD: Distance between otolith centre and outer edge of first hyaline zone used to quantify proportion of western Baltic cod in SD 22, 24 and 25)

Different methods were applied to classify individuals to western or eastern Baltic cod. Classification based on two methods based on otolith shape agreed in 82% with classification based on genetic methods. Classification based on the distance between centre and outer edge of first hyaline ring agreed in 92% with classification based on genetic methods. Agreement between the classification based on readability of otolith during ageing process and other methods was lower 50% in all cases.

(WD of WCBALTCOD: Evaluation of different methods to assign individual Baltic cod to the Western or Eastern stock)

Evaluation of the development of growth of western and eastern Baltic cod based on different methods by Rainer Oeberst (OF, Germany)

Length–frequency distribution data of smaller cod (~10–<40 cm) sampled in the western Baltic Sea in 1971–1972, between 1993 and 2000, 2011 and 2013–2014were used to estimate growth of western Baltic cod. Clearly identifiable length ranges of cohorts could be separated by minima in the length–frequency distributions. The cohorts could be assigned to year classes and followed over time. The mean length of a given year class at any given month did not indicate any significant change in growth between the last 40 years. The mean length per age in month and year class from the different periods were used to estimate parameters of the von Bertalanffy growth function (VBGF) of western Baltic cod. In addition, estimates of mean daily growth rates from mark–recaptured cod (20–80 cm) were used to evaluate the estimated growth function. VBGF parameters of western Baltic were described by:

$$L = 175.15(1 - e^{-0.094((A_M + 0.047)/12)})$$

(WD of WGBALCOD, Growth of western Baltic cod (SD22): Estimates based on length-frequency distributions of smaller cod and mark-recapture)

Age–length data of cod captured in SD 25–28 during BITS in quarter 1 and 4 were used to estimate parameters of von Bertalanffy growth functions of eastern Baltic cod year class and country. In addition, mean length-at-age was determined by combining length frequency of BITS in SD 25 and age–length-keys by country. L∞ and k estimated by year class and country were highly negative correlated. The analyses further showed that changes in growth cannot be described by only one of the VBGF parameters. The observed changes of the VBGF parameters from year class 1995 to 2010 were mainly determined by the decreasing maximum length in the age–length data due to length-dependent mortality. Mean length-at-age of youngest age groups did not suggest a decrease of growth of eastern Baltic cod. VBGF parameters were additionally estimates based on the Polish and Swedish age–length data sampled in SD 25 and SD 26 between 1999 and 2001 and 2008–2011 with:

$$L = 155.6(1 - e^{-0.089((A_M + 2.56)/12)})$$

where the effect of length-dependent mortality was the lowest.

WD 5) Evaluation of factors influencing growth estimates of eastern Baltic cod by Daniel Stepputtis[1], Rüdiger Voss[2], Jörn Schmidt[2], Uwe Krumme[1]([1]Thünen Institute of Baltic Sea Fisheries, Rostock, Germany, [2] University of Kiel, Faculty of Economics, Germany)

In the Baltic trawl fishery for cod, several changes in technical measures were implemented during the last years. In 2010, the mesh size was increased from 110 mm to 120 mm for the two legal codend-types BACOMA and T90. The adverse effects of this change in selectivity (Figure 1) on catchability, discard rates and fishing pressure on larger individuals was already documented in STECF (2010, SGMOS10-06). Given the recent issues in Eastern Baltic cod, the known selectivity curves from the relevant gears (BACOMA 110 mm, BACOMA 120 mm, T90 110 mm, T90 120 mm) were ap-

plied on BITS Q1 length structures of cod from given areas and years. The theoretical catch profile (Figure 2) was used to estimate the effect of changed selectivity on the catch of given length classes and theoretical discard rates. The results suggest that:

a) The catchability of size classes up to 55 cm is reduced dramatically (compare dark grey and black curve in Figure 2); this causes a significant loss of commercial catch which has to be compensated by increased fishing effort; or may result in incomplete use of the TAC.

b) The relative fishing pressure on larger cod increased due to the reduction of catchability for small and mid-sized fish.

c) A larger mesh size does not automatically result in a lower discard-rate (in numbers) (Table 1). In the BACOMA codend, discard rates can even be significantly higher with a larger mesh due to dual-selection effects; this effect increases with left skewedness of the length structure (e.g. 2014 in Eastern Baltic cod).

These effects can help to explain some of the current changes in cod stocks and fisheries, especially in the eastern Baltic Sea: (1) TAC were not fished since 2010, (2) increasing discards in the national discard sampling programmes since 2011/2012 and evidence from the fisheries for even higher discards (>50%), (3) decrease of larger cod in recent years. Consequently, the findings have implications for the assessment (e.g. commercial tuning fleets cannot be used without correction) and needs to be discussed in the fisheries management context.

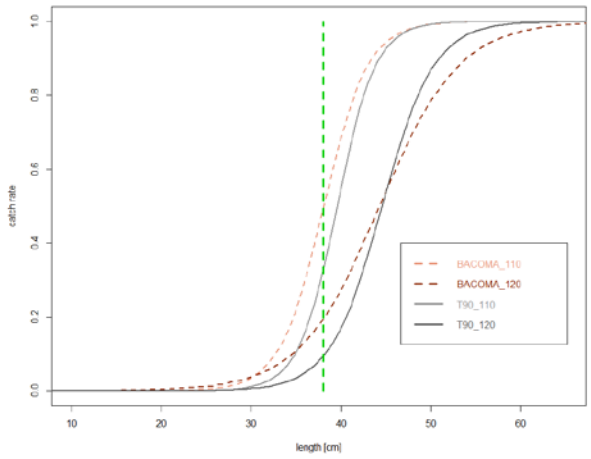


Figure 1. Selectivity curves of BACOMA and T90 codends with 110 mm and 120 mm mesh opening. Note the flatter curve of BACOMA 120 mm.

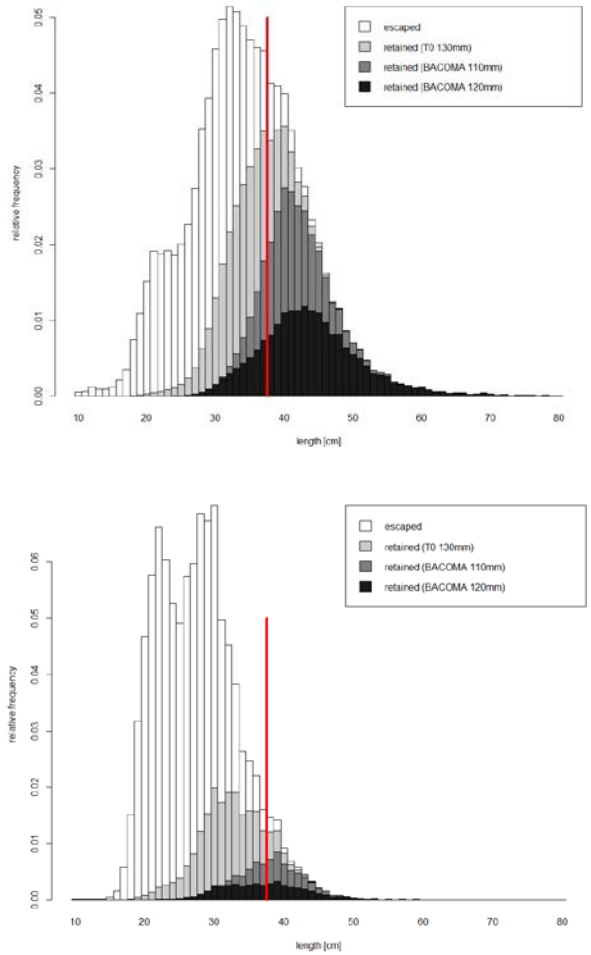


Figure 2. Examples of population structures from SD25 quarter 1 (white) and theoretical catch profiles (greyish colours) when using three different codends in 2010 (upper panel; i.e. the year when the 120 mm mesh codends were introduced) and 2014 (lower panel). For comparison with historical catch patterns, the theoretical catch of the T0 130 mm; codend (legal codend in the years 2002/2003) is shown.

Table 1. Estimated theoretical discard rates (in numbers) for different codend types. BITS Q1 length distributions from SD24 and SD25 were used.

	SD24		SD25	
CODEND	2010	2014	2010	2014
BACOMA 110 mm	29.0%	35.7%	19.5%	46.1%
BACOMA 120 mm	30.8%	40.7%	20.2%	61.4%
T90 110 mm	18.4%	23.7%	11.6%	33.5%
T90 120 mm	13.2%	19.1%	7.7%	32.2%

WD6) Larval Anisakidae in Baltic cod (*Gadus morhua*): Results from fish disease surveys 2011–2014 (Thomas Lang (thomas.lang@ti.bund.de), Lina Weirup, Uwe Krumme, Philipp Schneider

Thünen Institute of Fisheries Ecology (FI), Germany; Thünen Institute of Baltic Sea Fisheries (OF), Germany

Results of a study on parasitic larval nematodes belonging to the family Anisakidae in Baltic cod were presented. Six cruises (four cruises in December, two in September) with RV Walther Herwig III were carried out in the period 2011–2014, covering sampling stations in ICES Subdivisions 22, 24, 25 and 26. A total of 2632 cod was examined macroscopically for the presence of nematode larvae in the body cavity, including the surface of the organs, especially the liver. Macroscopic characteristics of the nematodes observed indicated that the majority represented the species *Contracaecum osculatum* ("liver worm") and *Anisakis simplex* ("herring worm"). In addition to nematode infestation (three infestation intensity grades), length, gutted body weight and liver weight were recorded to calculate Fulton's body condition factors (CF) and liver somatic indices (LSI). The results revealed a higher mean prevalence of nematode infestation in cod from SD 25 and 26 compared to SD 22 and 24 (Figure 1). There was a marked fluctuation between cruises/years, but trends were not obvious. Cod from SD 25 and 26 had lower mean CF than cod from SD 22 and 24 (Figure 2). There were no marked differences in LSI between the SD. Only in SD 25 and 26 was there a negative relationship between CF and infestation intensity grade (Figure 3a, b), so that effects of infestation on CF cannot be excluded. However, since the differences in mean CF between infestation intensity grades were found to be low, and since even non-infested cod from SD 25 and 26 had lower mean CF than infested and non-infested cod from SD 22 and 24, it may be concluded that other factors besides infestation with nematodes are contributing to the low CF of cod recorded in SD 25 and 26.

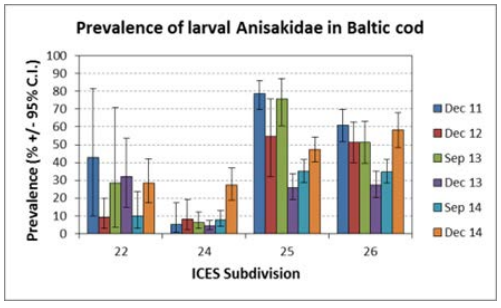


Figure 1. Prevalence of larval nematodes in Baltic cod.

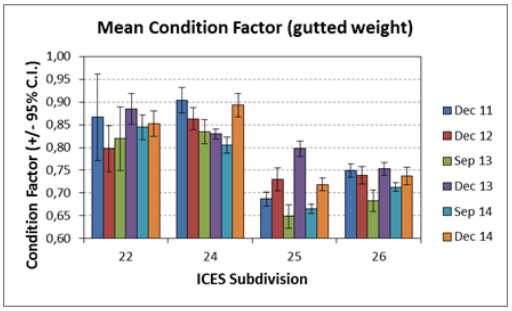


Figure 2. Condition factors in Baltic cod.

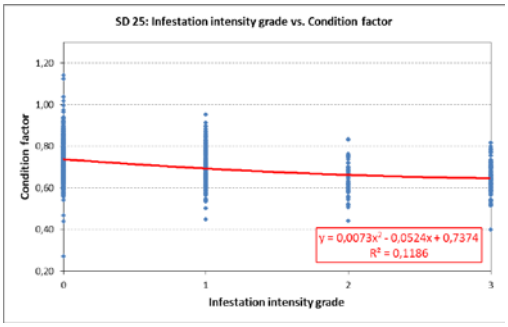


Figure 3a. Nematode infestation intensity grade vs. Condition Factor in ICES SD 25.

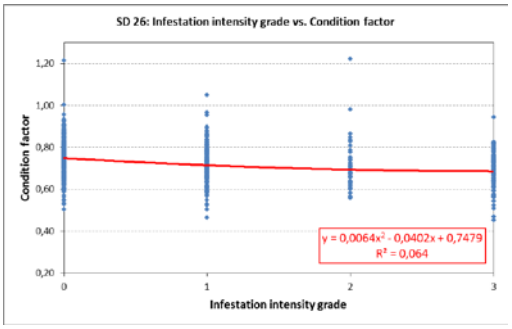


Figure 3b. Nematode infestation intensity grade vs. Condition Factor in ICES SD 26.

WD 7) Why are the eastern Baltic cod so thin? Possible mechanisms and management implications. Uwe Krumme, Rainer Oeberst, Martina Bleil, Christopher Zimmermann, Thünen Institute of Baltic Sea Fisheries, Rostock, Germany

The perception of stock trends of Eastern Baltic cod has changed in recent years, however partly in contradictory directions (e.g. low condition factor, disappearance of larger cod but good recruitment). This suggests that major mechanisms regulating stock dynamics are not understood, exacerbating stock assessment and management of the fisheries exploiting this stock. We used evidence from laboratory experiments and metabolic theory to test the role of hypoxia as a major driver of changes in Eastern Baltic cod stock dynamics and provide a possible mechanism explaining the interacting changes (Figure 1). We argue that chronic and repeated exposure of adults to hypoxic conditions in the Bornholm deep during the major spawning season has initiated a downward spiral of gradually decreasing energy reserves of individuals and the overall stock over the last decade. This has resulted in a measurable increase in gonadosomatic index, proportion of empty stomachs and a decrease in condition factor, hepatosomatic index, and overall stock productivity; and likely also in decreased activity and growth. These changes did not occur in the shallower Arkona basin or Kiel/Mecklenburg Bight. The maturation at earlier sizes may have led to increased recruitment in periods of improving environmental conditions which may have occurred since 2010.

Anoxia and hypoxia in the deeper basins of the Central Baltic likely contributed to a concentration of cod in SD25 and SD26 (habitat contraction). On a smaller scale, weak inflows after a long stagnation period led to the formation of a cap or tunnel effect, as shown for the Bornholm basin in the first half of the years 2011–2013: Dense, more saline and oxygenated water underlay older water. Cod displaced into the pelagial over many years by anoxic water at the bottom may have returned to their demersal habitat at least for part of the year. These "first re-colonizers" are likely to suffer from an environment poor in benthos, crowding, variable oxygen conditions due to hydrographic dynamics and a reduced incentive to conduct vertical movements. It is hypothesized that the first inflows may improve the overall environmental status but initially deteriorate the conditions of cod that - due to their affinity to demersal habitat - become trapped in the new, unstable body of inflow water, possibly aggravating the conditions, e.g. increased catchability, hypoxia-effects on cod metabolism, re-

duced food availability and intake, and even increased natural mortality, especially of larger specimens after the spawning period.

In addition, the introduction of the 120 mm codend in the trawl fisheries in 2010 may have caused both a rapid removal of larger cod and increased (absolute) discards (see abstract Stepputtis *et al.*). The loss of larger cod likely uncoupled positive feedbacks via scouts that could lead smaller cod to alternative, more appropriate habitats, and via cannibalism (larger cod supported by feeding on smaller cod would be in better condition).

We show that hypoxia-induced changes provide the most parsimonious explanations of the variety of changes that are observed in Eastern Baltic cod stock dynamics. However, the adverse simultaneity of changes may make it difficult to ultimately determine the contribution of the different causative factors involved. Yet it is important to note that our hypoxia hypothesis suggests that the productivity of the stock has decreased because of an environmental factor that can only be influenced by unpredictable inflows. In contrast, a density-dependence hypothesis (poor condition due to crowing and increased competition for food) suggests that stock productivity can be increased by increased removal of smaller cod. Consequently, an acceptance of the density-dependence hypothesis would result in a less precautionary management recommendation if the hypoxia hypothesis were true. A careful decision is required on which hypothesis is considered more likely to justify future measures. During WKBALTCOD, several arguments were given why the density-dependence hypothesis is less likely to explain the patterns observed in Eastern Baltic cod.

If hypoxia is a major variable in Baltic cod stock dynamics, metabolic theory suggests that the stock assessment should consider using a time-varied natural mortality (M), asymptotic length (L_{inf}) and mean size of maturity (L_{M50}), e.g. as a function of the condition factor.

In the central Baltic, climate change, eutrophication and fisheries have remarkably reduced ecosystem resilience. However, stable condition factors of immature fish suggest that once oxygen conditions improve significantly, the cod stock could quickly recover provided the removals were kept low during hypoxia periods. The Major Baltic Inflow in December 2014 provides an excellent case to test the hypoxia hypothesis.

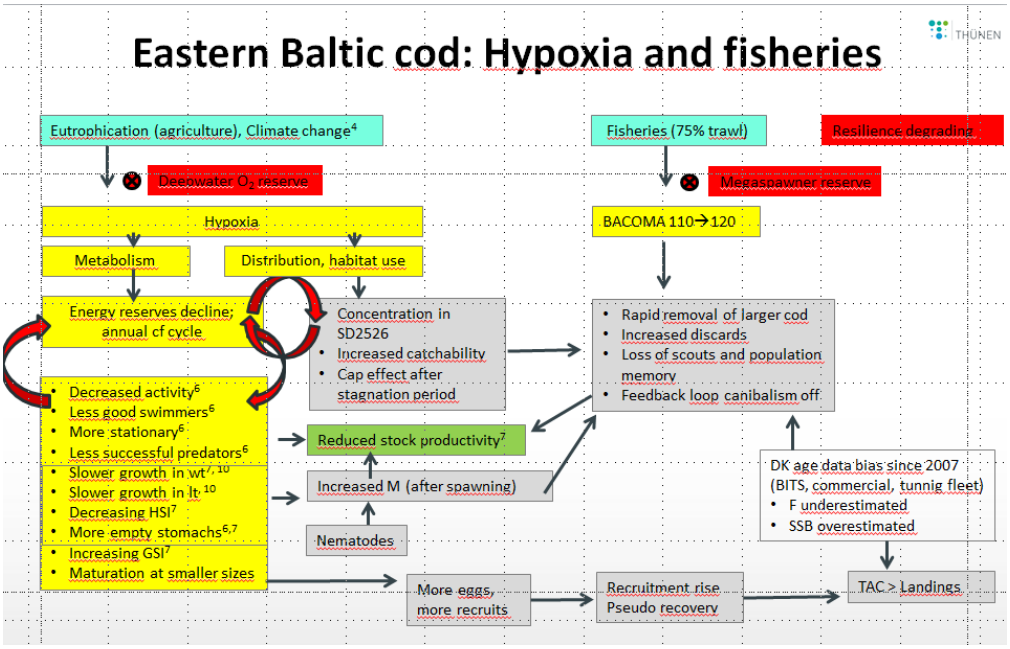


Figure 1. Possible explanation for the changes observed in Eastern Baltic cod.

Annex 4: SS3

Appendix

#C control file for Eastern Baltic cod (1 fishery, 2 surveys)

1 #_N_Growth_Patterns

1 #_N_Morphs_Within_GrowthPattern

4 #_Nblock_Patterns (eras where parameters may change)

3 3 2 2#_blocks_per_pattern

1991 2003 2004 2007 2008 2013

1995 1999 2000 2010 2011 2013

1998 2004 2005 2013

1991 2002 2003 2013

0.5 #_fracfemale 1 #_natM_type:_0=1Parm;

1 #0=single parameter; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate

13 #N_natMparms for segmented approach

0.5 1.5 2.5 3.4 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5 #NatM_breakages

#1.2 0.5 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2

1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=not implemented; 4=not implemented

1 #_Growth_Age_for_L1

999 #_Growth_Age_for_L2 (999 to use as Linf)

0.1 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)

0 #_CV_Growth_Pattern: 0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4 logSD=F(A)

1 #_maturity_option: 1=length logistic; 2=age logistic; 3=read age-maturity matrix by growth_pattern; 4=read age-fecundity; 5=read fec and wt from wtatage.ss

2 #_First_Mature_Age

1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b; (4)eggs=a+b*L; (5)eggs=a+b*W

0 #_hermaphroditism option: 0=none; 1=age-specific fxn

1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)

1 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds; 3=standard w/ no bound check)

#_growth_parms block fix=0 is multiplicative M_block = M_parameter * exp(Block_parameter.

#This multiplicative setup avoids having to worry about M going negative

#LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

0.1 1.3 1.13 0.85 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_1_PRODBIOM

0.1 1.2 0.52 0.35 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_2

0.05 1.0 0.40 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_3

0.05 1.0 0.35 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_4

0.05 1.0 0.32 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_5

0.05 0.8 0.30 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_3

0.05 1.0 0.29 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_4

0.05 1.0 0.28 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_5

0.05 0.8 0.27 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_3

0.05 0.8 0.27 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_3

0.05 1.0 0.26 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_4

0.05 1.0 0.26 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_5

0.05 0.8 0.25 0.2 -1 0.1 -1 0 0 0 0 0 1 2 #NatM_p_1_GP_3

8 40 15 10 -1 10 2 0 0 0 0 0 0 0 #L_at_Amin_GP_1

40 150 89.3 82.5 -1 10 -4 0 0 0 0 0 2 2 #L_at_Amax_GP_1

0.05 0.55 0.187 0.20 -1 0.8 2 0 0 0 0 0 2 2 # VonBert_K_GP_1

0.05 0.40 0.2 0.1 -1 0.8 3 0 0 0 0 0 0 0 # CV_young_GP_1

0.05 0.40 0.2 0.1 -1 0.8 3 0 0 0 0 0 0 0 # CV_old_GP_1

#LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

-3 3 0.6e-005 1.00e-005 -1 0.8 -99 0 0 0 0 0 3 2 # Wtlen_1

-3 4 3.1503 3.0021 -1 0.8 -99 0 0 0 0 0 3 2 # Wtlen_2

20 60 28 28 -1 0.8 -99 0 0 0 0 0 4 2 # Mat50%

-3 3 -0.20 -0.20 -1 0.8 -99 0 0 0 0 0 0 0 # Mat_slope

-3 3 1 1 -1 0.8 -99 0 0 0 0 0 0 0 # Eggs/kg_inter

-3 3 0 0 -1 0.8 -99 0 0 0 0 0 0 0 # Eggs/kg_slope_wt

#LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

0 0 0 0 -1 0 -99 0 0 0 0 0 0 0 # RecrDist_GP_1

0 0 0 0 -1 0 -99 0 0 0 0 0 0 0 # RecrDist_Area_1

0 0 0 0 -1 0 -99 0 0 0 0 0 0 0 # RecrDist_Seas_1

0 0 0 0 -1 0 -99 0 0 0 0 0 0 0 # CohortGrowDev

stuff for blocks for growth & M

1 #_custom_MG-block_setup (0/1)

#M

-5 5 1.13 0 -1 99 -4 # block change in M0 2005-2009

-5 5 1.13 0 -1 99 -4 # block change in M0 2010-2013

-5 5 1.13 0 -1 99 -4 # block change in M0 2010-2013

-5 5 0.52 0 -1 99 -4 # block change in M1 2005-2009

-5 5 0.52 0 -1 99 -4 # block change in M1 2010-2013

-5 5 0.52 0 -1 99 -4 # block change in M1 2010-2013

-5 5 0.40 0 -1 99 -4 # block change in M2 2005-2009

-5 5 0.40 0 -1 99 -4 # block change in M2 2010-2013

-5 5 0.40 0 -1 99 -4 # block change in M2 2010-2013

-5 5 0.35 0 -1 99 -4 # block change in M3 2005-2009

-5 5 0.36 0 -1 99 -4 # block change in M3 2010-2013

-5 5 0.37 0 -1 99 -4 # block change in M3 2010-2013

-5 5 0.32 0 -1 99 -4 # block change in M4 2005-2009

-5 5 0.35 0 -1 99 -4 # block change in M4 2010-2013

-5 5 0.39 0 -1 99 -4 # block change in M4 2010-2013

-5 5 0.31 0 -1 99 -4 # block change in M5 2005-2009

-5 5 0.36 0 -1 99 -4 # block change in M5 2010-2013

-5 5 0.39 0 -1 99 -4 # block change in M5 2010-2013

-5 5 0.33 0 -1 99 -4 # block change in M6 2005-2009

-5 5 0.44 0 -1 99 -4 # block change in M6 2010-2013

-5 5 0.40 0 -1 99 -4 # block change in M6 2010-2013

-5 5 0.32 0 -1 99 -4 # block change in M7 2005-2009

-5 5 0.43 0 -1 99 -4 # block change in M7 2010-2013

-5 5 0.39 0 -1 99 -4 # block change in M7 2010-2013

-5 5 0.31 0 -1 99 -4 # block change in M8 2005-2009

-5 5 0.42 0 -1 99 -4 # block change in M8 2010-2013

-5 5 0.38 0 -1 99 -4 # block change in M8 2010-2013

-5 5 0.31 0 -1 99 -4 # block change in M9 2005-2009

-5 5 0.42 0 -1 99 -4 # block change in M9 2010-2013

-5 5 0.37 0 -1 99 -4 # block change in M9 2010-2013

-5 5 0.30 0 -1 99 -4 # block change in M10 2005-2009

-5 5 0.41 0 -1 99 -4 # block change in M10 2010-2013

-5 5 0.37 0 -1 99 -4 # block change in M10 2010-2013

-5 5 0.30 0 -1 99 -4 # block change in M11 2005-2009

-5 5 0.41 0 -1 99 -4 # block change in M11 2010-2013

-5 5 0.37 0 -1 99 -4 # block change in M11 2010-2013

-5 5 0.30 0 -1 99 -4 # block change in M12 2005-2009

-5 5 0.41 0 -1 99 -4 # block change in M12 2010-2013

-5 5 0.36 0 -1 99 -4 # block change in M12 2010-2013

#Growth

-

#Maturity

20 60 26 28 -1 99 -4 # Mat50%_1991_2002

20 60 24 28 -1 99 -4 # Mat50%_2003_2013

#_seasonal_effects_on_biology_parms

#femwtlen1 femwtlen2 mat1 mat2 fec1 fec2 Malewtlen1 malewtlen2 L1 K

0 0 0 0 0 0 0 0 0 0

#_Spawner-Recruitment

3 #_SR_function: 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=B-H_flattop; 7=survival_3Parm

#LO HI INIT PRIOR PR_type SD PHASE

3 31 12 10.3 -1 10 1 # SR_LN(R0)

0.2 1 0.80 0.80 -1 99 -4 # SR_BH_steep (from Rose 2001)

0 1.6 0.6 0.6 -1 0.5 -1 # SR_sigmaR (from 2012 assessment)

-5 5 0 0.5 -1 1 -99 # SR_envlink

-5 5 0 0.5 -1 1 -4 # SR_R1_offset

0 1 0 0 -1 0 -4 # SR_autocorr

0 #_SR_env_link

0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness

1 #do_recdev: 0=none; 1=devvector; 2=simple deviations

1960 # Start year standard recruitment devs

2009 # End year standard recruitment devs; forecast devs start in following year

1 #_recdev phase

1 # (0/1) to read 13 advanced options

0 #_Start year for early rec devs (0=none; neg value makes relative to recdev_start)

3 #_recdev_early_phase

5 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)

1 #_lambda for Fcast_recr_like occurring before endyr+1

1971 #_Last recruit dev with no bias_adjustment

1979 #_First year of full bias correction (linear ramp from year above)

1999 #_Last year for full bias correction in_MPD

2023 #_First_recent_yr_nobias_adj_in_MPD

0.92 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)

0 #_period of cycles in recruitment (N parms read below)

-5 #min rec_dev

5 #max rec_dev

0 #_read_recdevs

#Fishing Mortality info

1.0 # F ballpark for tuning early phases (from SAM model 2013)

-1966 # F ballpark year (neg value to disable)

3 # F_Method: 1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)

2 # max F or harvest rate, depends on F_Method

4 # N iterations for tuning F in hybrid method (recommend 3 to 7)

#_initial_F_parms

#LO HI INIT PRIOR PR_type SD PHASE

0.0005 4 1 0.20 -1 0.4 1 # InitF_1FISHERY1

#_Q_setup

Q_type options: <0=mirror, 0=median_float, 1=mean_float, 2=parameter, 3=parm_w_random_dev, 4=parm_w_randwalk, 5=mean_unbiased_float_assign_to_parm

#Den-dep env-var extra_se Q_type

0 0 0 0 # FISHERY

0 0 0 0 # BITSQ1

0 0 0 0 # BITSQ4

#_Q_parms(if_any)

#LO HI INIT PRIOR PR_type SD PHASE

#0.001 1 0.1 0.01 -1 99 4 # additive value for BITSQ1_2-6

#0.001 1 0.1 0.01 -1 99 4 # additive value for BITSQ1_2-6_hist

#0 1 0 0.0001 -1 0.01 4 #Extra SD on BITSQ1_2-6_hist_first parameter

#0 1 0 0.0001 -1 0.01 4 #Extra SD on BITSQ1_2-6_hist_second parameter

#0.001 1 0.1 0.01 -1 99 4 # BITSQ4

#0.001 1 0.1 0.01 -1 99 4 # BITSQ4_hist

#_size_selex_types

#Pattern Discard Male Special

1 0 0 0 # 1 FISHERY1

24 0 0 0 # 2 BITSQ1

24 0 0 0 # 4 BITSQ4

#_age_selex_types

#Pattern Discard Male Special

12 0 0 0 # 1 FISHERY1

11 0 0 0 # 2 BITSQ1

11 0 0 0 # 4 BITSQ4

#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

#Selectivity length

0 100 65 50 -1 99 2 0 0 0 0 0 0 0 #

0.01 50 12.6848 6 -1 99 2 0 0 0 0 0 0 0 #

#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

5 50 12 15 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_1_BITSQ1_all

-12 6 4 -2 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_2_

-12 14 5.5 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_3_

-20 40 4.8 10 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_4_

#-20 50 40 20 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_5_

#-20 50 20 20 -1 99 4 0 0 0 0 0 0 0 # SizeSel_1P_6_

-999 -999 -999 -2 -1 0.01 -3 0 0 0 0 0 0 0 # SizeSel_1P_5_

#-999 -999 -999 0 -1 0.01 -4 0 0 0 0 0 0 0 # SizeSel_1P_6_

-20 50 20 20 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_6_

#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

5 50 7.5 15 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_1_BITSQ1_2-6_hist

-12 6 -6.7 -2 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_2_

-12 14 5.5 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_3_

-15 40 4.8 10 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_4_

#-20 50 40 20 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_5_

-999 -999 -999 -2 -1 99 -3 0 0 0 0 0 0 0 # SizeSel_1P_5_

#-999 -999 -999 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_1P_6_

-20 50 20 20 -1 99 3 0 0 0 0 0 0 0 # SizeSel_1P_6_

#Selectivity ages

#Fishery

#LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block Block_Fxn

-1002 3 -1000 -1 -1 0.01 -2 0 0 0 0 0 0 0 # 0.0 at age 0

-1002 3 -1000 -1 -1 0.01 -2 0 0 0 0 0 0 0 # 0.0 at age 1

-1 1 0.0 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Age 2 is reference

-5 9 0.1 -1 -1 0.01 2 0 0 0 0 0 0 0 # Change to age 3

-5 9 0.0 -1 -1 0.01 2 0 0 0 0 0 0 0 # Change to age 4

-5 9 0.0 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 5

-5 9 0.0 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 6

-5 9 0.0 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 7

-5 9 0.0 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 8

-10 9 -10 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 9

-10 9 -10 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 10

-10 9 -10 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 11

-10 9 -10 -1 -1 0.01 -2 0 0 0 0 0 0 0 # Change to age 12

0 10 0 -2 -1 0.01 -3 0 0 0 0 0 0 0 # min

0 20 15 0 -1 0.01 -3 0 0 0 0 0 0 0 # max

0 10 0 -2 -1 0.01 -3 0 0 0 0 0 0 0 # min

0 20 15 0 -1 0.01 -3 0 0 0 0 0 0 0 # max

0 10 0 -2 -1 0.01 -3 0 0 0 0 0 0 0 # min

0 20 15 0 -1 0.01 -3 0 0 0 0 0 0 0 # max

#4 #selparm_dev_Phase

#2 # selparm_adjust_method: 1=standard (replace with the new value); 2=parameter value is adjusted in order to stay within bounds of base parameter

Tag loss and Tag reporting parameters

0 # TG_custom: 0=no read; 1=read if tags exist

1 #_Variance_adjustments_to_input_values

#_fleet: 1 2 3

0 0 0 #_add_to_survey_CV

0 0 0 #_add_to_discard_stddev

0 0 0 #_add_to_bodywt_CV

0.4 0.6 0.5 #_mult_by_lencomp_N_050706

0.7 1 1 #_mult_by_agecomp_N_111

1 1 1 #_mult_by_size-at-age_N

#

#

1 #_maxlambdaphase

1 #_sd_offset

#

4 # number of changes to make to default Lambdas (default value is 1.0)

Like_comp codes: 1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;

9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-comp; 16=Tag-negbin

#like_comp fleet/survey phase value sizefreq_method

1 2 1 1 1 #survey:_1

1 3 1 1 1 #survey:_2

5 2 1 1 1 #survey:_1 age

5 3 1 1 1 #survey:_3 age

0 # Extra SD reporting switch

#2 2 -1 7 # selex type (fleet), len=1/age=2, year, N selex bins (4 values)

#1 1 # Growth pattern, N growth ages (2 values)

#1 -1 1 # NatAge_area(-1 for all), NatAge_yr, N Natages (3 values)

#2 3 4 5 6 7 # placeholder for vector of selex bins to be reported

#-1 # growth ages

#-1 # NatAges

999

#C data file for the assessment of Eastern Baltic cod (1 fishery, 2 surveys)

1965 #_styr

2013 #_endyr

1 #_nseas

12 #_months/season

1 #_spawn_seas

1 #_Nfleet

2 #_Nsurveys

1 #_N_areas

Fishery%BITSQ1%BITSQ4

0.50 0.25 0.75 #_surveytiming_in_season

1 1 1 #_area_assignments_for_each_fishery_and_survey

1 #_units of catch: 1=bio; 2=num

0.01 #_se of log(catch) only used for init_eq_catch and for Fmethod 2 and 3

1 #_Ngenders

12 #_Nages

#Catch Data

132168 #_init_equil_catch_for_each_fishery_(average of 1956–1964 from Margit paper_132168)

49 #_N_lines_of_catch_to_read

#_catch_biomass(mtons):

Catch year season

147352 1965 1

186053 1966 1

207179 1967 1

226053 1968 1

222814 1969 1

206076 1970 1

170266 1971 1

152323 1972 1

150655 1973 1

155748 1974 1

204225 1975 1

207644 1976 1

167770 1977 1

163884 1978 1

242275 1979 1

356163 1980 1

337827 1981 1

327600 1982 1

343146 1983 1

400473 1984 1

323282 1985 1

256406 1986 1

216421 1987 1

202040 1988 1

182640 1989 1

157733 1990 1

125258 1991 1

56786 1992 1

52269 1993 1

102812 1994 1

109590 1995 1

125632 1996 1

92062 1997 1

69727 1998 1

74833 1999 1

95308 2000 1

```
 94219 2001 1
 69202 2002 1
 71500 2003 1
 69779 2004 1
 56702 2005 1
 70176 2006 1
 54989 2007 1
 45981 2008 1
 51767 2009 1
 51477 2010 1
 53757 2011 1
 57249 2012 1
 36700 2013 1
26 #_N_cpue_and_surveyabundance_observations
#_Units:  0=numbers; 1=biomass; 2=F
#_Errtype:  -1=normal; 0=lognormal; >0=T
#_Fleet Units Errtype
 1  1  0 # FISHERY
 2  0  0 # BITSQ1
 3  0  0 # BITSQ4

#BITSQ1_all
2001  1  2  607.8  0.2
2002  1  2  1348.2  0.2
2003  1  2  617.4  0.2
2004  1  2  758.7  0.2
2005  1  2  1061.2  0.2
2006  1  2  818.0  0.2
2007  1  2  1261.2  0.2
2008  1  2  1994.3  0.2
2009  1  2  1868.0  0.2
2010  1  2  2392.1  0.2
```

2011 1 2 1745.4 0.2

2012 1 2 2386.9 0.2

2013 1 2 2662.8 0.2

#BITSQ4

2001 1 3 1546.1 0.2

2002 1 3 1726.4 0.2

2003 1 3 838.4 0.2

2004 1 3 1707.4 0.2

2005 1 3 1666.6 0.2

2006 1 3 1508.6 0.2

2007 1 3 1954.9 0.2

2008 1 3 2382.9 0.2

2009 1 3 2326.4 0.2

2010 1 3 2694.0 0.2

2011 1 3 1985.0 0.2

2012 1 3 2728.8 0.2

2013 1 3 2363.2 0.2

#Discard data

0 #_N_fleets_with_discard

0 #N discard obs

#Mean weight

0 #_N_meanbodywt_obs

30 #_DF_for_meanbodywt_T-distribution_like

#Lengths

3 # length bin method: 1=use databins; 2=generate from binwidth,min,max below; 3=read vector

#2 # binwidth for population size comp

#10 # minimum size in the population (lower edge of first bin and size at age 0.00)

#150 # maximum size in the population (lower edge of last bin)

65 # number of population length bins to be read

2 4 6 8 10 12 14 16 18 20 22
24 26 28 30 32 34 36 38 40 42
44 46 48 50 52 54 56 58 60 62
64 66 68 70 72 74 76 78 80 82
84 86 88 90 92 94 96 98 100 102
104 106 108 110 112 114 116 118 120 122
124 126 128 130

0 #_comp_tail_compression

1e-007 #_add_to_comp

0 #_combine males into females at or below this bin number

60 #N data LengthBins

2 4 6 8 10 12 14 16 18 20 22
24 26 28 30 32 34 36 38 40 42
44 46 48 50 52 54 56 58 60 62
64 66 68 70 72 74 76 78 80 82
84 86 88 90 92 94 96 98 100 102
104 106 108 110 112 114 116 118 120

40 #_N_Length_obs

#Yr Seas Fleet Gender Part Nsamp datavector(female-male)

#TRAWL

2000 1 1 0 0 100 0 0 0 0 638
1852 5020 27477 33874 50299 179841 455733 780304 1448086
23732873703746 5419625 6281937 6913607 9053528 12034474 13682172
13956284 10573357 6766947 3874319 2383256 1518055 806633
686027 544566 384134 417404 291592 256134 147045 82498 91104
50111 61470 59523 39282 22844 88714 67715 60746 39867
26175 32949 53329 30053 14096 11697 2983 11299 11986 0
0 0 0

2001 1 1 0 0 100 0 0 0 0 0
2698 8884 8709 39958 209872 216198 450396 686222 1018161
15680742950528 4163527 5118177 6692700 8874757 10319511 10711293
91762287323743 4948634 3159995 1892954 1035150 694380 638327 416380

	324572	226166	204334	147821	115055	76815	79675	96734	55960	
	56102	37979	69944	31813	27742	28616	23045	17955	13876	
	22433	9299	1061	3318	1931	968	125	0	1654	0
	0									
2002	1	1	0	0	100	0	0	0	0	911
	0	0	3644	33695	121975	324814	624736	996183	1705263	
	2405435	3817084	6753368	7820448	7781943	7309444	8572890	9013596	7690119	
	6415833	5179219	3143335	2003450	1336539	843997	613263	488241	338643	
	277779	197221	143837	134534	97860	72661	68130	59983	51035	
	54451	46173	34769	39215	28344	15900	23938	14592	9948	
	3873	4890	2286	552	4241	1027	75	25	1233	0
2003	1	1	0	0	100	0	0	0	0	0
	705	0	0	399	35017	75193	200724	417210	767519	
	887687	1725074	2816133	4971346	7177147	9299751	10938892		10935898	
	9151120	6884428	4871122	3389593	2178997	1361150	904115	668489	529905	
	341064	272671	248902	214831	144491	105798	82949	69752	72668	
	65343	43019	33171	38095	29284	25210	28890	11308	10354	
	6463	6841	3789	1846	4151	9060	1069	595	117	0
	627									
2004	1	1	0	0	100	0	0	0	0	0
	346	6115	42795	30534	57310	179916	245532	214739	321319	
	442819	730286	1318581	2086238	3490127	6370736	8951582	11048856		
	10529472		8095740	5672203	3536491	2156337	1401958	960489	726923	
	520358	393332	317671	254952	204611	153766	131404	110111	90368	
	73142	59056	48920	50718	28190	47409	25182	20332	19025	
	20810	14478	10752	3132	3679	2603	1745	6650	0	0
	0	0								
2005	1	1	0	0	100	0	0	0	0	0
	0	0	1508	28447	78988	163830	335498	601096	1019514	
	1380454	1852763	2083449	2986462	4261481	6701973	7942270	9322077	8442434	
	6058517	3859134	2606199	1670737	1023234	713442	458033	376131	272322	
	223404	200995	99298	115267	97391	71810	53958	48653	43726	
	25124	31910	21405	22345	15073	13430	8700	9298	9655	
	7627	5196	6395	1296	2319	5446	0	0	0	0
2006	1	1	0	0	100	0	0	0	0	0
	0	682	1493	2807	25288	26654	103605	157057	500406	
	1082369	2503617	5424477	8681666	11549563		13005305		12394785	
	10092721		8149937	5902406	3747906	2420033	1620352	1074084	729062	
	450196	299939	233801	252367	130734	97431	84600	75112	49839	
	50166	48830	33176	40901	30340	50327	17295	19254	18037	
	13914	15768	7377	6052	10740	5267	5154	1522	1972	
	7778	163	0	188						

2007	1	1	0	0	100	0	0	0	0	0
	0	0	395	7080	24479	99543	189024	297298	444701	
	843995	1650086	3018379	5096747	7434630	8321292	9222875	8574941	7143355	
	5179912	3688384	2073290	1313055	895206	580122	361990	267877	199290	
	174757	136864	103686	75277	44562	59031	34023	31233	25426	
	26244	21884	20357	21992	20464	16421	9199	9366	8634	
	4967	6676	2362	4953	3335	5058	0	0	0	0
2008	1	1	0	0	100	0	0	0	0	0
	0	0	1342	118	5032	48376	191419	438263	752197	
	680870	1051524	1946870	2477551	4525092	6196835	7545095	7379347	6580920	
	4612649	3312561	1999136	1294074	744039	517758	343054	286521	186529	
	132688	121802	88809	77776	59697	54666	44880	40506	28258	
	25232	41837	17511	23159	13242	8776	8245	5353	3290	
	4079	1984	1355	2736	889	2254	0	0	0	0
2009	1	1	0	0	100	0	0	0	0	0
	1613	127	3125	12944	37295	105774	131339	190375	453783	
	861315	1612235	2421217	3715045	5874090	7584283	8558959	7942140	6628422	
	4732302	3448715	2346085	1390505	1034292	670091	492062	352834	229644	
	192806	115596	109247	64048	49654	37658	32138	31023	39912	
	29027	33579	23306	26600	22862	9346	9705	9851	5954	
	15548	3233	1553	1129	768	725	0	0	0	0
2010	1	1	0	0	100	0	0	0	0	0
	0	0	0	2317	13531	49163	123201	202758	301277	
	809420	1528372	2439279	3577505	4874979	6233448	7496060	7662873	6777934	
	5272957	3714574	2590985	1808296	1211875	823029	550070	402660	257927	
	176351	149559	82610	80886	75443	49602	39142	31388	24805	
	33103	28302	39522	27113	22175	16780	15079	7358	9041	
	5624	2317	1489	4578	861	1046	0	0	0	0
2011	1	1	0	0	100	0	0	0	0	0
	0	0	0	0	3606	20441	45246	128934	434686	
	1172758	2441696	3629886	5062738	6747551	8363867	9279727	8334024	7513939	
	5587631	3991952	2464170	1562295	917967	629068	472117	291411	254458	
	166172	127415	81379	53154	53491	40766	35897	32339	20290	
	19412	13991	12632	9630	6716	4171	5333	3989	3707	
	1298	2105	1062	1337	1004	0	0	0	0	0
2012	1	1	0	0	100	0	0	0	0	0
	0	85	0	8078	1614	38421	98199	206363	406679	
	1181260	2884936	5496488	8200791	10583120		10981984		11074732	
	9426318	7064715	4864071	3608087	2015797	1254057	844800	506746	413711	
	293731	182829	127861	113893	73433	51900	45589	44222	44808	
	34498	29866	22361	17686	21788	27760	26556	3392	3036	
	7373	1577	722	5765	1	763	513	0	1	0
	0	0								

2013 1 1 0 0 100 0 0 0 0 0
0 94 377 5623 11938 94134 294752 531777 745367
1539094 2572245 4344961 6547954 8366461 10407437 9131465 6911191
4039748 2425054 1398995 761978 426691 288071 158277 120025 85280
43235 39484 23259 15543 15088 11658 9867 7984 5123
4517 3147 1873 2922 721 465 608 597 427 206
0 0 0 0 0 0 0 0 0 0

#BTSQ1

2001 1 2 0 0 100 0.00 0.03 3.07 14.11
29.29 34.63 23.59 9.38 3.16 7.25 19.67 39.10 54.88
54.10 50.39 41.26 32.87 26.54 27.56 29.98 28.38 25.81
20.56 12.42 7.41 4.12 2.09 1.81 0.81 0.51 0.71 0.34
0.18 0.25 0.24 0.16 0.39 0.00 0.03 0.17 0.15 0.28
0.07 0.03 0.00 0.00 0.01 0.00 0.00 0.00 0.03 0.01
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

2002 1 2 0 0 100 0.00 0.14 2.71 11.85
19.98 15.59 5.56 5.56 20.21 66.05 118.98 145.39 166.88
162.13 138.81 99.14 78.63 55.90 43.77 34.94 29.93 29.23
23.00 20.59 12.74 9.61 5.17 5.99 5.91 4.42 3.11 1.36
0.38 0.29 0.71 0.57 1.03 0.19 0.96 0.09 0.10 0.18
0.05 0.14 0.04 0.00 0.07 0.00 0.12 0.03 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

2003 1 2 0 0 100 0.00 0.05 3.26 12.37 4.23
3.42 1.79 1.05 1.97 5.00 14.67 30.23 36.29 49.68
46.21 48.42 52.48 62.08 63.07 54.34 42.33 31.59 20.61
11.61 7.25 4.16 1.81 1.82 1.18 0.79 0.47 0.66 0.18
0.46 0.65 0.26 0.19 0.15 0.07 0.04 0.08 0.10 0.07
0.06 0.04 0.06 0.04 0.00 0.07 0.00 0.02 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00

2004 1 2 0 0 100 0.00 0.03 4.83 34.00
54.11 49.01 47.34 41.96 40.72 28.15 22.16 24.21 43.28
64.66 58.10 36.79 26.25 23.52 26.49 28.12 26.56 20.63
17.21 11.21 7.84 6.71 3.38 2.82 2.24 1.39 0.78 0.98
0.67 0.31 0.28 0.40 0.21 0.40 0.25 0.21 0.22 0.00
0.03 0.04 0.01 0.06 0.02 0.07 0.01 0.01 0.00 0.00
0.00 0.00 0.02 0.00 0.00 0.00 0.00 0.00

2005 1 2 0 0 100 0.00 0.07 0.68 6.13 9.57
3.51 5.02 15.12 52.94 104.46 146.76 157.88 132.28 99.92
70.80 47.78 38.68 31.04 28.98 26.69 25.03 17.27 12.15 8.82
5.26 3.24 1.99 2.07 1.70 0.92 1.03 0.57 0.61 0.31
0.18 0.25 0.33 0.15 0.01 0.15 0.10 0.08 0.09 0.05

	0.08	0.09	0.15	0.03	0.02	0.07	0.04	0.00	0.00	0.00
	0.00	0.00	0.00	0.01	0.00	0.00				
2006	1	2	0	0	100	0.00	0.01	1.00	4.84	4.21
	3.78	2.03	0.87	3.16	9.86	21.22	38.78	57.08	78.94	
	96.13	101.45	97.95	80.66	65.47	47.23	32.50	21.97	14.98	
	10.12	7.37	4.58	3.43	2.13	1.79	1.31	0.96	0.32	0.23
	0.22	0.25	0.09	0.28	0.16	0.03	0.11	0.08	0.04	0.04
	0.10	0.01	0.02	0.16	0.05	0.00	0.00	0.00	0.00	0.00
	0.01	0.00	0.00	0.00	0.00	0.02	0.00			
2007	1	2	0	0	100	0.00	0.32	13.23	11.02	
	21.36	34.19	30.39	17.74	19.69	39.42	73.09	94.82	113.74	
	110.00	111.10	100.44	102.71	94.26	75.76	60.02	44.02	31.61	
	21.14	12.98	8.35	5.75	3.70	1.96	1.82	1.57	1.05	0.70
	0.72	0.40	0.42	0.25	0.33	0.07	0.05	0.06	0.22	0.31
	0.16	0.10	0.05	0.03	0.02	0.02	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
2008	1	2	0	0	100	0.00	0.08	1.81	11.43	
	10.22	9.76	8.84	8.57	31.60	82.29	137.88	173.48	203.08	
	204.13	185.68	173.52	161.47	150.40	127.09	96.75	67.67	49.79	
	34.30	22.22	13.10	8.23	5.71	3.20	2.98	1.81	1.19	1.41
	0.77	0.60	0.58	0.41	0.42	0.36	0.22	0.21	0.25	0.17
	0.10	0.13	0.16	0.09	0.00	0.09	0.02	0.01	0.01	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
2009	1	2	0	0	100	0.00	0.02	3.32	17.69	
	17.32	11.71	8.58	5.89	8.98	35.10	63.76	77.51	94.72	
	122.86	162.45	162.31	168.31	170.14	162.24	150.25	122.26	89.12	
	71.29	46.85	33.13	18.81	14.02	8.78	4.75	3.49	2.58	1.71
	1.68	0.58	0.94	0.73	0.55	0.65	0.42	0.38	0.27	0.43
	0.10	0.13	0.30	0.14	0.44	0.16	0.00	0.02	0.01	0.02
	0.02	0.00	0.00	0.02	0.01	0.00	0.00	0.00		
2010	1	2	0	0	100	0.00	0.00	0.20	1.81	3.07
	3.88	3.10	5.27	16.12	42.53	72.93	90.61	118.09	158.18	
	201.34	221.99	215.70	208.71	200.58	191.64	155.93	131.56	100.14	
	72.37	51.32	33.41	24.03	16.88	11.19	8.58	6.42	4.54	3.81
	2.60	2.53	2.49	1.72	1.20	0.63	0.42	1.10	0.93	0.36
	0.42	0.47	0.46	0.15	0.05	0.03	0.03	0.14	0.03	0.06
	0.00	0.26	0.03	0.02	0.00	0.00	0.00			
2011	1	2	0	0	100	0.00	0.00	0.67	2.52	2.47
	3.37	2.08	1.07	3.43	7.94	27.38	50.59	111.12	200.18	
	238.93	232.74	199.71	169.03	153.32	102.27	78.53	50.65	33.19	
	23.02	15.11	9.66	7.24	5.07	3.43	2.34	1.59	1.48	0.87
	0.72	0.60	0.60	0.33	0.40	0.32	0.36	0.30	0.30	0.07

	0.07	0.08	0.05	0.04	0.03	0.00	0.05	0.05	0.00	0.00
	0.04	0.02	0.00	0.00	0.00	0.00	0.00			
2012	1	2	0	0	100	0.00	0.05	1.29	3.73	4.51
	4.85	3.44	2.54	6.79	24.99	65.44	121.56	148.32	141.25	
	203.13	300.54	342.90	302.55	236.47	171.26	119.74	69.83	45.66	
	24.19	14.40	10.38	3.75	4.95	1.84	2.22	1.13	0.87	0.78
	0.78	0.17	0.05	0.06	0.06	0.10	0.00	0.13	0.09	0.00
	0.01	0.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2013	1	2	0	0	100	0.00	0.02	1.08	3.04	4.69
	2.90	1.64	3.09	30.60	128.26	326.00	460.36	385.08	291.66	
	213.98	206.79	167.95	149.50	119.89	71.46	45.67	19.85	13.03	5.93
	3.87	2.23	1.20	0.91	0.55	0.25	0.39	0.17	0.16	0.15
	0.07	0.03	0.08	0.00	0.03	0.10	0.00	0.06	0.00	0.04
	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00				

#BTSQ4

2001	1	3	0	0	100	0.00	0.29	8.23	5.95	1.02
	1.89	9.43	31.97	113.77	157.05	212.18	267.78	267.37	139.54	
	72.49	42.92	30.33	37.12	31.52	30.65	28.98	20.54	11.82	8.32
	6.07	2.25	1.18	0.71	0.73	0.65	0.14	0.49	0.31	0.22
	0.50	0.17	0.09	0.39	0.24	0.09	0.19	0.11	0.08	0.04
	0.09	0.08	0.12	0.05	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00				
2002	1	3	0	0	100	0.00	0.09	1.75	1.41	0.70
	0.51	1.94	6.07	20.48	46.58	76.82	74.86	58.18	73.59	
	120.56	183.94	232.94	230.83	195.91	136.91	92.95	58.70	37.81	
	22.69	16.16	9.32	7.21	5.18	2.86	2.13	1.44	1.28	1.34
	0.70	0.66	0.50	0.10	0.35	0.05	0.17	0.03	0.05	0.12
	0.08	0.09	0.09	0.12	0.05	0.00	0.09	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.05	0.00			
2003	1	3	0	0	100	0.00	0.83	16.71	41.13	
	44.58	30.48	16.61	12.20	18.48	35.93	64.08	70.53	53.09	
	24.12	17.67	25.22	43.06	51.55	51.16	52.56	48.43	38.06	
	28.11	17.53	10.88	6.67	4.75	2.55	2.36	1.68	1.51	0.75
	1.21	0.64	0.66	0.23	0.38	0.46	0.26	0.10	0.16	0.12
	0.28	0.11	0.17	0.10	0.03	0.11	0.04	0.04	0.00	0.00
	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
2004	1	3	0	0	100	0.00	4.14	6.57	2.18	2.44
	5.12	29.91	86.03	172.40	221.07	245.34	182.63	132.00	84.97	
	70.84	69.95	73.62	71.27	61.51	52.93	41.26	32.88	19.23	

	12.88	7.61	5.00	3.31	2.33	1.65	1.47	1.09	0.63	0.43
	0.57	0.53	0.20	0.36	0.02	0.14	0.08	0.19	0.12	0.10
	0.05	0.04	0.12	0.00	0.00	0.05	0.02	0.00	0.02	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2005	1	3	0	0	100	0.00	0.58	6.22	5.42	1.29
	1.03	5.45	14.41	29.30	37.32	41.03	76.88	135.46	173.89	
	207.40	228.64	187.56	145.37	113.95	78.67	52.86	39.15	27.03	
	18.89	12.26	7.49	5.73	3.49	2.02	1.51	1.35	1.20	0.46
	0.97	0.35	0.23	0.48	0.26	0.16	0.05	0.02	0.20	0.03
	0.05	0.04	0.06	0.18	0.05	0.00	0.03	0.10	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2006	1	3	0	0	100	0.00	0.32	5.86	17.80	
	10.08	5.07	11.14	33.80	73.10	101.11	110.90	114.19	102.68	
	87.67	105.12	126.51	128.24	118.94	103.93	91.17	56.67	36.52	
	22.25	13.19	8.19	6.14	3.83	2.96	2.18	1.33	1.11	1.08
	1.03	0.94	0.54	0.26	0.84	0.21	0.37	0.25	0.41	0.08
	0.14	0.05	0.10	0.12	0.00	0.06	0.00	0.00	0.00	0.00
	0.00	0.07	0.03	0.00	0.00	0.00	0.00	0.00		
2007	1	3	0	0	100	0.00	0.38	4.67	6.09	3.92
	2.08	7.53	25.66	59.87	93.22	140.57	164.87	169.40	160.96	
	164.23	171.83	164.25	148.00	127.34	99.63	77.49	55.82	35.79	
	23.19	14.40	9.01	5.51	3.48	3.02	2.59	1.39	2.21	1.21
	0.79	0.68	0.52	0.42	0.31	0.79	0.31	0.16	0.39	0.10
	0.16	0.20	0.19	0.15	0.08	0.04	0.03	0.02	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2008	1	3	0	0	100	0.00	1.99	11.49	13.57	8.25
	2.83	3.40	9.00	23.22	49.96	88.69	134.69	183.00	219.21	
	241.51	221.93	217.99	222.19	191.66	173.08	124.75	84.66	61.18	
	33.72	20.88	13.26	7.28	4.95	3.23	2.53	1.14	0.80	1.32
	0.75	0.39	0.68	0.26	0.44	0.69	0.45	0.07	0.30	0.36
	0.13	0.30	0.11	0.07	0.14	0.17	0.06	0.01	0.07	0.00
	0.00	0.06	0.00	0.00	0.01	0.00	0.00			
2009	1	3	0	0	100	0.00	0.09	2.44	7.16	9.05
	3.27	5.21	42.75	112.53	148.77	172.85	183.39	202.98	182.68	
	191.07	182.41	167.66	144.28	130.32	116.55	94.69	73.58	52.45	
	33.48	21.25	14.37	9.59	6.40	3.85	2.78	1.73	1.31	1.12
	0.83	0.36	0.48	0.27	0.37	0.32	0.24	0.20	0.25	0.29
	0.09	0.27	0.02	0.16	0.05	0.08	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.00	0.00	0.00	0.00			
2010	1	3	0	0	100	0.00	0.67	5.17	2.77	1.04
	1.18	2.04	7.89	14.26	21.25	38.98	71.14	140.15	221.56	
	281.87	309.91	293.35	272.68	240.23	198.75	167.19	121.90	89.94	

	59.14	43.91	25.96	18.87	12.21	8.50	6.80	3.88	2.73	1.83
	1.68	0.63	0.51	0.66	0.69	0.41	0.18	0.26	0.31	0.26
	0.06	0.24	0.17	0.11	0.03	0.04	0.00	0.00	0.02	0.02
	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2011	1	3	0	0	100	0.00	0.39	13.29	12.10	5.61
	1.93	1.39	5.57	13.50	40.98	90.25	116.49	104.74	107.12	
	168.00	245.52	287.01	254.09	189.39	137.30	79.24	43.12	27.79	
	15.59	8.62	5.51	2.92	2.17	1.26	0.90	0.64	0.45	0.48
	0.31	0.13	0.11	0.17	0.07	0.17	0.17	0.05	0.02	0.10
	0.00	0.07	0.07	0.05	0.00	0.03	0.00	0.05	0.00	0.00
	0.03	0.00	0.00	0.00	0.00	0.00	0.00			
2012	1	3	0	0	100	0.00	0.00	5.30	23.37	9.60
	1.80	2.97	11.14	41.54	162.62	348.46	368.88	241.63	192.39	
	191.32	242.56	243.26	208.66	167.16	111.15	69.10	36.63	22.38	
	11.71	4.90	2.88	1.95	1.10	0.76	0.81	0.60	0.38	0.17
	0.25	0.20	0.42	0.02	0.08	0.02	0.08	0.00	0.28	0.02
	0.04	0.00	0.05	0.05	0.00	0.02	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2013	1	3	0	0	100	0.00	0.05	4.32	8.59	1.76
	2.77	13.06	37.22	79.76	108.60	136.85	130.03	199.14	311.51	
	342.49	270.23	201.41	166.64	138.26	90.60	54.55	29.42	15.50	9.67
	4.34	2.45	1.50	1.07	0.24	0.36	0.35	0.03	0.12	0.00
	0.03	0.03	0.02	0.05	0.00	0.00	0.04	0.00	0.00	0.00
	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00				

7 #N data age bins

2 3 4 5 6 7 8

1 #_N_ageerror_definitions

0.5 1.5 2.5 3.5 4.5 5.5 6.5 7.5 8.5 9.5 10.5 11.5 12.5

0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01

40 #_N_Agecomp_obs

1 #_Lbin_method: 1=poplenbins; 2=datalenbins; 3=lengths

0 #_combine males into females at or below this bin number

1966	1	1	0	0	1	-1	-1	196	44273.7
	101532	34294.5	11980.3	2658	922	103			

1967	1	1	0	0	1	-1	-1	274	55469.9
	147237.1		50347.4	14436.4	5014	1330	580		
1968	1	1	0	0	1	-1	-1	265	45857.9
	119658	70714.6	23088.1	4787	653	85			
1969	1	1	0	0	1	-1	-1	252	57214.4
	114070.1		49951.6	24012.8	5570	1190	213		
1970	1	1	0	0	1	-1	-1	209	37794.9
	89209.9	51802.9	22800.3	5248	1439	512			
1971	1	1	0	0	1	-1	-1	150	30563.8
	52981.3	38804.7	21731.3	4606	948	405			
1972	1	1	0	0	1	-1	-1	198	50349.5
	77662.3	42951.3	18490	6003	1841	636			
1973	1	1	0	0	1	-1	-1	185	43023.7
	72010.9	42971.4	18347.6	5637	1138	1387			
1974	1	1	0	0	1	-1	-1	213	35472
	103999.4		49999.8	16209.4	4663	1510	1325		
1975	1	1	0	0	1	-1	-1	281	33459
	150840.7		70672.4	18804.9	5327	1256	1096		
1976	1	1	0	0	1	-1	-1	224	13035.3
	69879.7	86763.4	38436.1	13043	1936	1339			
1977	1	1	0	0	1	-1	-1	156	9312.9
	47146.3	46316.3	35685.2	13214	3250	1409			
1978	1	1	0	0	1	-1	-1	223	62227.9
	80317.7	46769.4	22814.4	7982	2467	867			
1979	1	1	0	0	1	-1	-1	355	77018.4
	159374.5		77294	26554.1	8697	3857	2006		
1980	1	1	0	0	1	-1	-1	404	30959.1
	124099.7		161002.7		62383.7	18267	4990	2206	
1981	1	1	0	0	1	-1	-1	314	33309.4
	58615.9	102347.2		83738.9	25397	7393	3364		
1982	1	1	0	0	1	-1	-1	363	57565.4
	133068.6		81521.9	53652.7	25122	7759	4465		
1983	1	1	0	0	1	-1	-1	377	56318.5
	120482.7		123083	46278.6	19729	8458	2399		
1984	1	1	0	0	1	-1	-1	412	33822.2
	115377.8		144956.9		84062.8	21340	7373	5553	
1985	1	1	0	0	1	-1	-1	283	49198.7
	69703.9	74510.5	57318.2	23214	5643	3696			

1986	1	1	0	0	1	-1	-1	213	18006.2
	44648.9	58730.9	43143.6	34113	9802	4180			
1987	1	1	0	0	1	-1	-1	214	63891.5
	61984.7	44452	23571.5	11387	5836	3102			
1988	1	1	0	0	1	-1	-1	208	32703.5
	93859.6	52390.5	17348.7	6741	3166	2158			
1989	1	1	0	0	1	-1	-1	178	6907.6
	65690.7	69604.6	23107.2	8703	2414	1677			
1990	1	1	0	0	1	-1	-1	131	25905.8
	33745.7	39953.9	20928	6850	2095	1642			
1991	1	1	0	0	1	-1	-1	105	9007.7
	43733	31541.2	13444.5	3854	1732	1586			
1992	1	1	0	0	1	-1	-1	51	11628.2
	16199.5	13403	6120.5	1906	982	525			
1993	1	1	0	0	1	-1	-1	46	13598.4
	19304.4	8344.2	3413.1	818.1	217	138			
1994	1	1	0	0	1	-1	-1	92	14293.8
	40498.8	23989.9	10486.9	2256.6	483.1	317.1			
1995	1	1	0	0	1	-1	-1	90	11528.3
	24516.1	31103.6	16991.8	3816.8	1137.9	722			
1996	1	1	0	0	1	-1	-1	101	13917
	31426.1	26502.4	21692.5	5936.4	1421.9	384			
1997	1	1	0	0	1	-1	-1	79	3422.9
	33497.9	22071.8	12454.4	4674	1983	1092			
1998	1	1	0	0	1	-1	-1	63	12582.1
	18277.2	17673.3	10089.2	2547	1241	907			
1999	1	1	0	0	1	-1	-1	76	9665.4
	35340.7	18530.7	8965.9	1983	671	778			
2000	1	1	0	0	1	-1	-1	123	33819.7
	41234	34253.8	10229	1964.3	603.3	683.2			
2001	1	1	0	0	1	-1	-1	120	19828.1
	49376.5	36169.5	11722.2	2211.3	694.3	420.6			
2002	1	1	0	0	1	-1	-1	82	11131.2
	31926.6	26777.2	9403.7	1972.1	668.3	527.2			
2003	1	1	0	0	1	-1	-1	90	16350.2
	34471.2	28344.7	8488.6	1667.7	525.8	359.2			
2004	1	1	0	0	1	-1	-1	75	9286.4
	26474.8	25476.7	9161.8	3192.3	876.8	496.6			

2005 1 1 0 0 1 -1 -1 61 13321.4
19850.4 18963.7 6824.7 1480.7 383 224.6

0 #_N_MeanSize-at-Age_obs

#Yr Seas Fleet Gender Part Ageerr Ignore datavector(female-male) samplesize(female-male)

0 #_N_environ_variables

0 #_N_environ_obs

0 # N sizefreq methods to read

0 # no tag data

0 # no morphcomp data

#

999

#

Annex 5: Recommendations

Workshop on Age Estimation of Baltic Cod (WKEABCod)

The **Workshop on Age Estimation of Baltic Cod** (WKAEBCod), chaired by Karin Hüssy, Denmark, will be established and will meet in XX, XXX, on XXX 2015 to:

a) Review existing methods to derive age information;

b) Test the applicability of different methods to the eastern Baltic cod case;

c) Design a protocol for future proceedings.

WKAEBCod will report by DATE for the attention of the ACOM and SCICOM.

Supporting information

Priority	This work is considered with high priority to support decision on age data for the two Baltic cod stocks assessmenst.
Scientific justification	Term of Reference a) The aim of the workshop is to review existing methods of deriving age compositions based on other approaches than traditional age reading, test the applicability of these approaches and to design a protocol for optimal procedures of Eastern Baltic cod. Term of Reference b) The trace element composition of otoliths has for some years served as tool to infer stock identity and migration patterns in anadromous fish species. Recently, targeted experiments have suggested a close copling between elemental concentrations and specific life-history events. Longitudinal analysis of elemental concentrations (from nuclues to the edge of otolith) will therefore provide information of fish migration, habitat occupation, growth and spawning periodicity. Other methods to derive growth estimates and age structures are based on tag–recapture programmes with concurrent marking of otolith and fish and length–frequency analysis. The usefulness of these approaches for the easter Baltic cod stock will also be explored.

Resource requirements	XX
Participants	Expert on age estimation. It is desireable that an external expert on age estimation/ validation and the use of ages information in stock assessmet attend the meething.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	ACOM, WGBFAS, SSGIEOM, WGPATA, WGBIOP.
Linkages to other committees or groups	SCICOM
Linkages to other organizations	None.