ICES WKIDEBCA REPORT 2018

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Report of the Workshop on Evaluation of Input data to Eastern Baltic Cod Assessment (WKIDEBCA)

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Executive summary

The ICES **Workshop on Evaluation of Input data to Eastern Baltic Cod Assessment** (WKIDEBCA) met in Copenhagen, Denmark, 23–25 January 2018 (Chair: Michele Casini, Sweden), with 23 participants and 5 countries represented.

No analytical assessment has been produced by ICES for the Eastern Baltic stock since 2014 mainly due to lack of information about growth rates and natural mortality owing to the deteriorating quality of age determination. The main aim of WKIDEBCA was to evaluate the new information about growth and natural mortality, including proxies, that could be used in age/length based assessment models. Based on this evaluation, the objective of the WKIDEBCA was to decide whether the new available information would allow to have a benchmark in 2019, with the aim to re-establish an analytical assessment for the stock. Another aim of the WKIDEBCA was to evaluate the best methodologies to construct the survey indices, including stock mixing, to be used in any stock assessment method.

The report contains an introductory chapter about the current issues related to an analytical stock assessment for the Eastern Baltic cod stock and the relevance of WKIDEBCA in this context. The report continues with different chapters addressing the different ToRs.

Regarding growth, there was an overall agreement that growth has declined since the 1990s, both in small and large fish. For smaller/younger fish (< 3 years old) this was directly estimated from daily increments and length frequency distributions. For larger/older fish, due to the lack of trustful ageing after 2006, the changes in growth between 2006–2017 could not be directly estimated. Proxies for growth (based on earlier observed changes in growth corresponding to changes in condition, anoxic areas, length at maturity) were suggested to be used to inform the change in growth during this period to construct ALKs or estimate VBG parameters for stock assessment models. This was seen as an improvement from the present situation, until direct measurement of growth (from e.g. tagging or otolith microchemistry) may become available in the future.

Regarding natural mortality, the current quantitative and qualitative information suggests that it has increased. Independent analyses based on biological information and modelling suggest that natural mortality for adult cod could currently be as high as 0.5.

Concerning survey indices, two different approaches based on statistical modeling were presented. Intersessional work is planned to agree upon the settings of the models to be used in the future assessments.

WKIDEBCA decided to recommend a benchmark evaluation meeting in 2019, including a data preparation meeting in autumn 2018.

1. Terms of Reference

2017/2/ACOM: 36 A **Workshop on Evaluation of Input data to Eastern Baltic Cod Assessment** (WKIDEBCA), chaired by Michele Casini (Sweden) will be established and will meet in ICES HQ Copenhagen, Denmark 23–25 January 2018 to:

a) Assemble and review updates and new quantitative information on current and past growth (length/weight-at-age) and natural mortality of Eastern Baltic cod, which was not considered at WKBEBCA workshop in 2017.

b) Evaluate and conclude on the possible approaches/assumptions to inform growth in age/length based stock assessment models, based on the present scientific knowledge available. This includes proxies, e.g. based on changes in potential drivers for growth etc.

c) Evaluate and conclude on the possible approaches/assumptions to inform natural mortality in age/length based stock assessment models, based on the present scientific knowledge available.

d) Evaluate and conclude on the most appropriate method for calculating time-series of survey indices for age/length based stock assessment purposes, with specific focus on standardization across different gears, and considering the stock component in SD 24.

e) Agree upon and document the most appropriate approaches to derive stock assessment input data concerning growth, natural mortality and survey indices, addressed in a-d), to be taken forward to future benchmark assessment on Eastern Baltic cod.

f) Based on the conclusions from e), recommend the timing for future benchmark assessment on Eastern Baltic cod and develop corresponding workplan.

The Workshop will report by 10 February 2018 for the attention of ACOM.

2. Introduction

Assessing the status of the Eastern Baltic cod stock and providing management advice have been challenging during the past few years. No analytical assessment has been produced for this stock by ICES since 2014 mainly due to lack of information about growth rates and natural mortality owing to the deteriorating quality of age determination. Attempts are being made to re-establish quantitative stock assessment based on length information. However, such approaches still require information on growth of the fish, and natural mortality is an important input parameter for stock assessment models. Thus, biological understanding of the processes potentially affecting changes in growth and natural mortality is required to elucidate the likely direction of change in these variables and possibly quantify the likely magnitude of change.

The knowledge regarding possible changes in growth and natural mortality (and reproductive capacity) of EB cod was assembled and synthesised at the Workshop on Biological input to Eastern Baltic cod Assessment in Göteborg, Sweden (ICES, 2017b). At that time no new estimates of growth were available that could have led to an analytical stock assessment.

The main aim of WKIDEBCA was to evaluate additional information about growth and natural mortality, including proxies, that could be used in age/length based assessment models. Based on this evaluation, the WK had the objective to decide whether this new information would allow to proceed with the plans for having a benchmark in 2019.

3. ToR a) Assemble and review updates and new quantitative information on current and past growth (length/weight-at-age) and natural mortality of Eastern Baltic cod, which was not considered at WKBEBCA workshop in 2017

Growth

New information about growth of Eastern Baltic cod was provided at the WKIDEBCA.

A first empirical evidence for a decrease in somatic growth rate of Baltic cod was provided using length frequency mode progression and known-age samples, where size-at-age was back-calculated from daily otolith growth patterns. The decrease in growth of two strong year-classes (2003 and 2011) was estimated to be in the range between 7–37 % (WD 1). The observed link between growth, condition and maturation suggested also that the population's continuing decrease in somatic condition may eventually have a negative effect on recruitment.

Growth estimation from Swedish historical tagging data (period 1: 1959–1964 and period 2: 1965–1970) was performed using cod tagging data from the central Baltic Sea (SDs 25–28) complete with release and recapture dates and lengths (WD 2). Growth parameters were estimated using the method by Francis (1988). The analyses showed Linf = 105 and K = 0.153 for the first period and Linf = 116 and K = 0.105 for the second period. These estimates were similar to those presented in Bagge *et al.* (1994) using age data. The same approach, using more recent tagging data (e.g. from the TABACOD project), can be used to estimate the current cod growth parameters if enough recapture data are available (WD 3).

Natural mortality

Analyses of the stomach content database recently compiled and cleaned (Huwer *et al.*, 2014; ICES, 2014; ICES, 2016), showed that the frequency of occurrence of cod in the cod stomachs increased after the 2006 (WD 4). This suggests that mortality due to cannibalism could have increased during the same time although quantifications are still missing and analyses ongoing.

Empiric methods based on life span, body size as well as parameters of von Bertalanffy growth model were used to estimate changes in the natural mortality of EB cod in SD 26, using Russian bottom-trawl survey data. The analysis evidenced an increase in total M during the period 1991–2017 from 0.2 to 0.35 (average of all ages) (WD 5).

An estimation of the changes in natural mortality due to the condition decline has been done using results from published experimental literature linking cod condition to starvation and mortality. The analysis estimated a natural mortality due to low condition up to 0.2 for larger fish (Casini *et al.*, 2016a; WD 6), which in combination with the background natural mortality would result in a total M of up to 0.4 for larger fish. These estimates could be used in combination with other estimations of additional mortality (such as seal predation and parasite infestation) to adjust the natural mortalities used as input in analytical stock assessment.

4. ToR b) Evaluate and conclude on the possible approaches/assumptions to inform growth in age/length based stock assessment models, based on the present scientific knowledge available. This includes proxies, e.g. based on changes in potential drivers for growth etc.

The conclusions from the WKIDEBCA concerning the data usable for informing growth in stock assessment models (specifically the requirements of the SS3 model were discussed), including time-frame for their availability, are summarized in Table 1 below. A specific, more detailed section about the use of proxies to inform growth changes is developed under Table 1.

Table 1. Data usable for informing growth in stock assessment models (specifically the SS3 model), including time-frame for their availability

GROWTH	What we have	How to use/to be done	When
Catch at age	1950s-2006: ok to use	Input to assessment model	Available
ALK	1990s-2006: in principal ok to use. BITS Q4 before 2002 should not be used (age classes do not progress from Q1)	Can inform growth in SS3	Available (details need to be discussed)
Tagging	1960s-1970s, late 1980s 2017-2018:	Analyses to inform historical growth (Linf and K) Need to be checked whether representative and try to estimate growth (issues to check: stock mixing, fish length and condition, spatial coverage) Need to check for comparability with age readings method.	Spring 2018 First attempt spring 2018
Daily rings & LFD	2001, 2004, 2013: suggest lower growth for ages <= 3 in later years	Can be used for validation of other estimates. Daily rings estimates from 1980s-1990s to have baselines	Available Not before 2020
Microchemistry	Method under development Application of the new method to otoliths of different periods	If the method works, new methodological guidelines to age fish Can inform growth and/or used to construct ALKs in models	Early 2019 Maybe 2020
Proxies	2007-2015: compared to earlier years based on change in presumed drivers	Possibly to inform growth in assessment models. May need some refinement and possibly conversion to VBG parameters instead of ALK.	Available (refinements to be done)

Proxies for growth

A number of changes in the Baltic ecosystem and in the cod stock have taken place in the last decades, including a decline in nutritional condition of cod, reduced size at maturation and intensified hypoxia (Figure 1). These changes are hypothesized to have negative influence on cod growth (ICES, 2017b). Major trends in these potential drivers/indicators of cod growth are relatively similar and the magnitude of change in the combined index from 1991–1997 to 1998–2001 was similar compared to the magnitude of change in the period from 2002–2006 to 2010–2015. No information on the type of relationship between these potential drivers/indicators and cod growth is available. Thus, a simple assumption was made that the change in cod growth in the period from the average in 2002–2006 to the average in 2010–2015 is similar to the growth change from the average level in 1991–1997 to the average in 1998–2001. The observed mean length-at-age of younger ages (1–2) was similar in 1991–1997 and 1998–2001. For ages 3+, mean length-at-age was 5–7 percent (an average 6%) lower in the later time period. A similar change in mean length-at-age from 2002–2006 was applied to construct an age length key for 2010–2015, and the average of the two periods was used to construct the ALK for 2007–2009 (Figure 2). The resulting ALK for ages 2–3 was in line with length frequency distribution from BITS, where stronger years-classes from 2003 and 2011 can be followed until age 3.

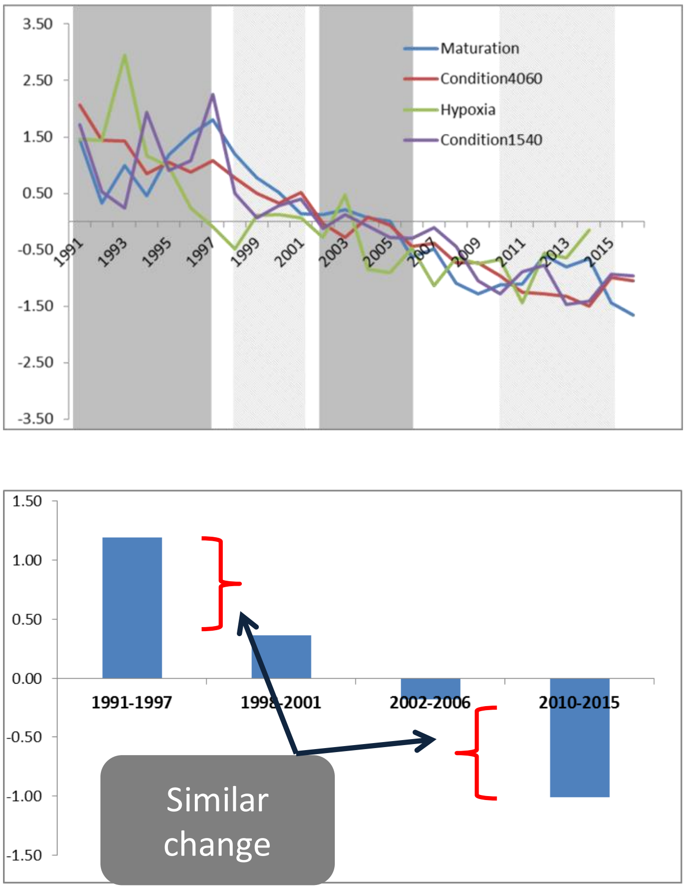

Figure 1. Upper panel: Standardized time-series of size at first maturation (L50) of cod (Köster *et al.*, 2017), condition of cod at 40–60 and 15–40 cm in length (Casini *et al.*, 2016a) and extent of hypoxic areas (Casini *et al.*, 2016b). The time-series of hypoxia is reversed to follow the same direction of trend as the other variables. Lower panel: Average values of the standardized four time-series shown in upper panel, averaged over the defined time periods

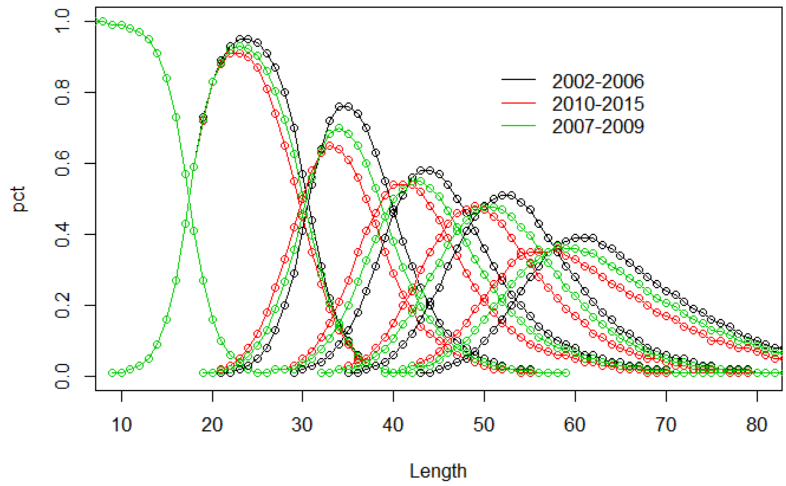

Figure 2. Average relative length frequency distribution (in proportion) of cod age-groups in 2002–2006, based on age reading data from BITS Q1 in SD 25–28, compared to the constructed ALK for 2010–2015 and 2007–2009. The length distribution modes are shown for ages 1–6.

5. ToR c) Evaluate and conclude on the possible approaches/assumptions to inform natural mortality in age/length based stock assessment models, based on the present scientific knowledge available.

The conclusions from the WKIDEBCA concerning the data usable for informing natural mortality in stock assessment models, including time frame for their availability, are given in Table 2 below. A specific, more detailed section about the use of proxies to inform natural mortality changes for mid-age groups is developed under Table 2.

Table 2. Data usable for informing natural mortality in stock assessment models, including time frame for their availability.

NAT. MORTALITY	What we have?	To be done	When?
1950s-early 2000s			
Total M	WGBFAS currently assumes constant values	Check whether we should use different values in different periods (not constant in entire period)	WGBFAS 2018
Early 2000s-present:			
Condition	M around 0.1-0-2 estimated		Available
Cannibalism (age 0-2)	Estimates from SMS until 2011	Needs extrapolation for 2012 onwards New direct estimates based on survey data and stomachs	 WGBFAS 2018
Starvation	Feeding level change	Estimate mortality corresponding to selected growth scenarios	WGBFAS 2018
Seal predation	Available data does not indicate it to be substantial		
Total M (mid-age groups)	• Levels around 0.5 suggested by analyses using growth proxies • Similar total level can be explained by available data (condition, sex ratio)	Can be used to validate/explain the values estimated in the model	Available
Total M by age	Can be estimated within the model (e.g. SS3)	Think carefully how to group ages as M of different ages is driven by different processes	

The constructed ALK (described above in the growth Section 4) was used to derive CPUEs at length from BITS, which were subsequently used in SURBA analyses to estimate total mortality Z. The analyses estimated Z to have increased by a factor of 2.5 from around 2006–2008 to 2011–2013. Given that fishing mortality in these periods was relatively stable, which is suggested by harvest rate analyses (ICES, 2017a), and M was at 0.2 in the earlier time period, this would correspond to M values around 0.5 in the later period. Part of the increase in M from 0.2 to 0.5 can be explained by low condition. Condition mortality at around 0.1 has been estimated for later years (Casini *et al.*, 2016a). Further, analyses of sex ratio in BITS data suggest a higher proportion of females in the size group around 40–55 cm (ca. 65–80 %) in later years compared to a more balanced sex ratio in earlier years. This suggests relatively higher mortality of males compared to females in these size groups in later years, corresponding to mortality at around 0.2 of the stock in these size groups in later years. These estimates (M of 0.2), combined with condition related natural mortality (0.1) and the baseline M (0.2), can explain total M values up to 0.5, in line with the estimates obtained from SURBA analyses. Possible natural mortality due to seal predation was investigated as well, based on the information presented at WKBEBCA (ICES, 2017b). It was concluded that the possible difference in natural mortality due to seal predation in recent years compared to early 2000s is unlikely to be above 0.1, and most likely is much lower. Thus, given present data and knowledge, seal predation cannot explain the substantial increase in natural mortality since the early 2000s.

6. ToR d) Evaluate and conclude on the most appropriate method for calculating time-series of survey indices for age/length based stock assessment purposes, with specific focus on standardization across different gears, and considering the stock component in SD 24.

CPUE indices from BITS and historical surveys

WKIDEBCA concluded that computation of the survey indices based on statistical modelling would be a better method than the method currently used. This can be of particular importance because modelling can allow to handle situations (e.g. years) with low spatial coverage. Also, the uncertainties associated with survey indices, which can be obtained from statistical models, are used as input in some stock assessment models (e.g. Stock Synthesis, SS).

Three different models were presented based on Generalized Additive Models (GAMs). (1) One model used standardized CPUEs using trawl geometries and GAMs to predict CPUE (using depth, position and quarter as explaining factors) on a fine spatial grid from which indices of adult cod biomass (≥ 30 cm) were calculated (Orio *et al.*, 2017; WD 7). (2) A second model used the raw CPUEs and, similarly to the previous model, GAMs to estimate CPUEs on a fine spatial grid from which indices of abundance were calculated. This second model estimates the gear-effect internally (gear is used as an additional explaining factor) and was presented for each length-class separately (WD 8). (3) A third model presented was a Log-Gaussian Cox Process model (LGCP) which was formulated as the GAM model (2) (WD 8).

Further work will be done before and after WGBFAS 2018 to improve the models. Especially, comparisons between the models will be carried out. Mixing between Eastern and Wester Baltic cod stocks will be accounted for in the estimation of the indices. Extensive work is ongoing to finalize the methods, based on genetics and otolith shape analysis to allocate the BITS survey catches to either stock (WD 9 and WD 10).

SSB indices corrected for the size-structure of the spawning fish, as derived from potential fecundity studies

A method to correct spawning-stock biomass (SSB) time-series, currently used in stock assessment to provide advice (sum of the weights of fish ≥ 30 cm), was presented (WD 11). This method is based on the quantification of the effect of fish length on potential fecundity. The study behind the method (Mion *et al.*, 2018) showed that the relation between fish weight and potential fecundity is not constant, but depends on fish length (the ratio of potential fecundity/fish weight increases exponentially with fish length). This means that the effect of length on reproductive potential is not currently accounted for in SSB estimates. Consequently, correcting SSB by the length distribution of the spawning component of the populations would provide a better estimate of stock reproductive potential and thus allow for better predictions of recruitment.

SSB indices from egg production methods

An alternative method to estimate SSB, based on egg production was also presented (WD 12). Egg production methods (EPM) provide a fishery independent source for determining stock trends and estimate stock sizes. EPM's have earlier been tested for EB cod (Kraus *et al.*, 2012) and having the advantage that they can provide absolute estimates of stock size independent of the inherent uncertainties linked to the estimation of growth and natural mortality. Two EPMs were applied which provided comparable results, and followed the large scale spawning-stock trends of the BITS surveys, but with less year to year variations than in the BITS survey indices. Future perspectives of the approach are to derive absolute estimates of SSB, which would, however, require addressing e.g., beta artresia and skip of spawning.

SSB index corrected for the size-structure of the spawning-stock and the EPM-based trends could presently be used as tuning series for stock assessments (e.g. in SS).

7. ToR e) Agree upon and document the most appropriate approaches to derive stock assessment input data concerning growth, natural mortality and survey indices, addressed in a-d), to be taken forward to future benchmark assessment on Eastern Baltic cod.

The discussion at WKIDEBCA was mainly concentrated to the input that the Stock Synthesis (SS) model can handle and the output that it can produce.

During the last 4 years, there have been numerous attempts to build up an assessment model for the Eastern Baltic cod stock using SS. This software provides a statistical framework for calibration of a catch-at-age population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population and with multiple stock subareas. Some key SS features include ageing error, estimation of growth, different spawner-recruitment relationship, movement between areas, the ability of incorporating tagging data and fishery discards, the use of environmental linkages, and allowing for time-varying parameters. SS is most flexible in its capability to utilize a wide diversity of age, size, and aggregate data from fisheries and surveys. The structure of SS consents for building of simple to complex models depending upon the data available. SS is a statistical age-structured population modeling framework that has been applied in a wide variety of fish assessments globally. It is widely tested, has a comprehensive manual and a dedicated website with about 250 scientists and a dedicated SS team to deal with bugs and continuously improve the model fitting and the representation of the model output through a dedicated R library (*i.e.* r4ss).

The status of the SS model for the Eastern Baltic cod stock was presented at WKIDEBCA with the current model structure, data input and model parametrization. The most plausible model structure to be used for Eastern Baltic cod stock were discussed. In case an agreement on some of the key parameter cannot be reached during the further development of the model for EB cod, an ensemble modelling approach (where different alternative runs are produced and then combined) was suggested as a way forward.

Growth

For the historical time period, the group decided to move forward using age information from standard otolith age readings until 2006. This is planned to be supplemented by estimates of VBG parameters from historical tagging data, which altogether will be used as input to stock assessment models (see Table 1).

For the years after 2006, the group agreed to proceed with the approach based on a proxy for the change in growth in recent years. The proxy is based on change in cod condition, size at maturation and the extent of hypoxic areas in the Baltic Sea. In the past, a change in growth has been observed concurrent to a change in these drivers/indicators. A similar magnitude of change in growth is assumed to have taken place in recent years, when a comparable change in the drivers/indicators has occurred. This information is then used to construct ALK which will inform growth (VBG parameters) in stock assessment model for the years since 2007, or alternatively, to derive changes in the VBG parameters as direct input for SS (see Table 1).

Natural mortality

For historical levels of natural mortality, the previously applied values by WGBFAS will be used. For recent years, when an increase in natural mortality is expected to have occurred, the feature of SS3 model allowing to estimate natural mortality within the model, is intended to be applied. The analyses conducted for WKIDEBCA on the possible levels of natural mortality from different drivers and indicators (condition, sex ratio, seal predation) will be used to validate/explain the levels estimated by the assessment model.

For younger age-groups which are exposed to cannibalism, the historical values from the SMS model will be used. These will be extrapolated to recent years, accounting for changes in cod stock size, or possibly new estimates of cannibalism will be used, which are planned to be developed.

Survey indices

Two different trawl survey indices, one for the historical part (< 1990) and one for the BITS period (1991 onwards, including the splitting between eastern and western stocks) will be used.

The GAM model (Orio *et al.*, 2017, WD 7) (modelling the pooled biomass of the fish ≥ 30 cm) will be used to estimate the historical part of the index (*i.e.* total biomass in 1978–1990) that will remain fixed in the SS model. For the BITS period (after 1990) the models presented by C. Berg (WD 8) (*i.e.* either the GAM or the LGCP), with aggregated abundance and size composition, will be used. Two checks have been suggested: 1) compare the total biomass trajectories between the two models in the overlapping period (after 1991); 2) compare the gear effects from C. Berg's model against the gear conversion factors from calibration experiments currently applied in the estimations of the tuning indices.

Additionally, the correction of SSB for the size composition of the spawning-stock will be attempted. Also, including information from ichthyoplankton surveys in SS model, *i.e.* relative stock trends from egg production methods, and possibly also larval abundances to inform recruitment, will be attempted.

8. ToR f) Based on the conclusions from e), recommend the timing for future benchmark assessment on Eastern Baltic cod and develop corresponding workplan

WKIDEBCA agreed that the current knowledge and modelling approaches allow to have a benchmark assessment WK for the EB cod in 2019. The data preparation meeting was suggested to take place together with the data preparation meeting related to Western Baltic cod stock Benchmark assessment (suggested dates and venue: 15–20 October at ICES HQ), while the Benchmark WK for the EB cod was suggested to be held as a separate meeting (suggested date: 4–8 February 2019, with venue to be decided at WGBFAS 2018).

WKIDEBCA prepared a workplan for the analyses to be performed during the next few months, especially before the WGBFAS 2018 (see Table 3 below). These analyses will be presented at WGBFAS 2018 for further discussions. The output of these analyses will be used to continue developing the SS3 model for the Eastern Baltic cod and used in the SS3 workshop planned for May 2018 in Ponza, Italy.

The issue list for the 2019 benchmark will be prepared at WGBFAS 2018.

Table 3. Workplan for the analyses to be performed during the next few months, especially before the WGBFAS 2018

Issue	To do	When ready and who
GROWTH		
ALK for 2007-		
Proxy approach (based on change in drivers/indicators)	Document in detail the proxy approach to estimate ALKs Check the technicalities in relation to SS3 (smoothed vs raw data; is it ok only from 2002 onwards or do we need a long time-series, etc.) Prepare final dataset to be used as input to SS3	WGBFAS 2018 (Margit) Before May 2018 (Max) Before May 2018 (Margit & Max)
Alternative ALK for comparison based on age readings	Compare the ALKs from the proxy approach with ALKs from selected national ageing	WGBFAS 2018 (Margit)
TAGGING		
Historical tagging	Calculate vBG parameters (incl. comparison with those from age data)	WGBFAS 2018 (Monica, Kate, Mich)
New tagging (TABACOD project)	Check whether representative and try to estimate vBG parameters (issues to check: stock mixing, condition, temporal and spatial coverage)	WGBFAS 2018 (Monica, Kate, Karin, Uwe, Mich)
NAT. MORTALITY		
Cannibalism	New estimates based on survey data and stomachs	WGBFAS 2018 (Stefan)
SURVEY INDICES		
Estimation's method and model formulation	Update on the model	WGBFAS 2018 (Casper, Alessandro)
Split of the survey	Update on the process	WGBFAS 2018 (Uwe, Rie)

9. References

Bagge O, Thurow F, Steffensen E, Bay J (1994). Dana, 10: 1-28.

Casini, M., Eero, M., Carlshamre, S. and Lövgren, J. 2016a. Using alternative biological information in stock assessment: condition-corrected natural mortality of Eastern Baltic cod. ICES Journal of Marine Science, 73: 2625–2631. doi:10.1093/icesjms/fsw117.

Casini M., Käll, F., Hansson, M., Plikshs, M., Baranova, T., Karlsson, O., Lundström, K., Neuenfeldt, S., Gårdmark, A., Hjelm, J. 2016b. Hypoxic areas, density-dependence and food limitation drive the body condition of a heavily exploited marine fish predator. Royal Society Open Science. **3**: 160416.

Francis, R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. New Zealand journal of marine and freshwater research, 22(1), 43–51.

Huwer B., Neuenfeldt S., Rindorf A., Andreasen H., Levinsky S.-E., Storr-Paulsen M., Dalmann Ross S., Haslund O.H., Horbowy J., Pachur M., Pawlak J., Ustups D., Kruze E., Sics I., Uzars D., Velasco A., Kempf A., Eberle S., Floeter J., Temming A., van Hal R., de Boois I., Pennock I., Hoek R., Pinnegar J., Hunter E., Plirú A., Casini M., Belgrano A. (2014) Study on stomach content of fish to support the assessment of good environmental status of marine food webs and the prediction of MSY after stock restoration. Final report for EU contract No MARE/2012/02. 56 pp.

ICES. 2017a. Report of the Baltic Fisheries Assessment Working Group (WGBFAS), 19–26 April 2017, ICES Headquarters, Copenhagen, Denmark. ICES CM 2017/ACOM:11.

ICES. 2017b. Report of the Workshop on Biological Input to Eastern Baltic Cod Assessment (WKBEBCA). ICES CM 2017/SSGEPD:19

ICES. 2016. Report of the Workshop on Spatial Analyses for the Baltic Sea (WKSPATIAL), 3–6 November 2015, Rome, Italy. ICES CM 2015/SSGIEA:13. 37 pp

ICES. 2014. 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.

Kraus, G., Hinrichsen, H-H., Voss., R, Teschner., E, Tomkiewicz., J, Köster, F. 2012. Robustness of egg production methods as a fishery independent alternative to assess the Eastern Baltic cod stock (*Gadus morhua callarias L.*). Fisheries Research 117: 75–85.

Mion, M., Thorsen, A., Dierking, J., Herrmann, J.-P-, Huwer, B., Vitale, F., von Dewitz, B. and Casini, M. 2018. Effect of fish length and nutritional condition on the fecundity of distressed Atlantic cod *Gadus morhua* from the Baltic Sea. Journal of Fish Biology, in press.

Orio, A., Florin, A.-B., Bergström, U., Šics, I., Baranova, T., and Casini, M. 2017. Modelling indices of abundance and size-based indicators of cod and flounder stocks in the Baltic Sea using newly standardized trawl survey data. ICES Journal of Marine Science, 74: 1322–1333.

Köster, F. W., Huwer, B., Hinrichsen, Hans-H., Neumann, V., Makarchouk, A., Eero, M., Dewitz, B. V., Hüssy, K., Tomkiewicz, J., Margonski,P., Temming, A., Hermann, Jens-P., Oesterwind, D., Dierking, J., Kotterba, P. and Plikshs, M. 2017. Eastern Baltic cod recruitment revisited—dynamics and impacting factors. ICES Journal of Marine Science, 74 (1): 3–19.

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Annex 2: Agenda

WKIDEBCA 23-25 January 2018

ICES, Copenhagen

Tuesday 23 January (10am – 6pm)

Morning

1. General information (Adriana Villamor, ICES)
2. Introduction (Michele Casini & Margit Eero)
3. ToRs and adoption of the agenda (Michele Casini)
4. Growth
   - Growth from daily rings (Karin Hüssy)
   - TABACOD project: current status and inputs for stock assessment (Karin Hüssy)
   - Pan-Baltic historical tagging data for growth estimations (Michele Casini)
   - Growth estimation from Swedish historical tagging data (Alessandro Orio)
   - Synthesis of current knowledge/evidence and expectations from ongoing activities

Lunch 13:00-14:00

Afternoon

5. Mortality
   - Condition-corrected natural mortality estimates. (Michele Casini)
   - Mortality due to cannibalism, starvation (Stefan Neuenfeldt)
   - Synthesis of current knowledge/evidence and expectations from ongoing activities
6. Stock assessment
   - Stock Synthesis model for EB cod: current status and options to include new growth/mortality information (Max Cardinale).
   - Possible assumptions to inform age/length based assessment and their consistency with available data/estimates (Margit Eero)
   - Synthesis of knowledge/evidence: do we have new direct estimates of growth/natural mortality? Do we have the data to have direct estimates for a potential benchmark 2019? In the case of lack of direct estimates, do we have reliable assumptions/proxies to be used in analytical age–length based models?

Wednsesday 24 January (9am – 6pm)

Morning

1. Estimation of natural mortality and growth rates of the Eastern Baltic cod (Victoria Amosova).
2. Discussion on the ways forward with stock assessment continues
3. Subgroup?
4. Writing of the report

Lunch 12:00–13:00

Afternoon

3. Survey indices
    - Update on status of survey split (east-west cod) (Marie Storr-Paulsen).
    - Stock Mixing (Franziska Schade)
    - BITS survey index calculation (Casper Berg).
    - BITS data standardization and survey index calculation (Alessandro Orio).
    - Effect of cod size on fecundity: implications for SSB index (Monica Mion)
    - SSB index based on egg production (Fritz Köster)
    - Discussion on how to proceed with the survey indices
    -

Thursday 25 January (9am – 4pm)

1. Subgroup on plans towards the benchmark 2019 (what to do for WGBFAS 2018).
2. Subgroup on plans for producing survey indices
3. Presentations of the subgroups plans in plenary
4. Benchmark together with EB cod?

Writing of the report

Annex 3: Recommendations

Recommendation	Adressed to
Insert the Eastern Baltic cod as stock to be benchmarked in early 2019, with a data prepeartion meeting in autum 2018	ICES secretariat/ACOM

Annex 4: Working Documents

WD1. Faster or slower: Has growth of eastern Baltic cod changed? *K. Hüssy, M. Eero, K. Radtke*

WD2. Growth estimation from Swedish historical tagging data. *A. Orio, R. Motyka, M. Mion, M. Casini*

WD3. TABACOD: Status and expected outcome. *K. Hüssy, M. Casini, K. Radtke, U. Krumme*

WD4. Eastern Baltic cod cannibalism and starvation. *S. Neuenfeldt*

WD 5. Estimation of natural mortality and growth rates of the Eastern Baltic cod. *V.M. Amosova, A.I. Karpushevskaya, I.V. Karpushevskiy*

WD 6. Using alternative biological information in stock assessment: condition-corrected natural mortality of Eastern Baltic cod. *M. Casini, M. Eero, S. Carlshamre, J. Lövgren*

WD 7. Modelling indices of abundance and size-based indicators of cod and flounder stocks in the Baltic Sea using newly standardized trawl survey data. *A. Orio, A.-B. Florin, U. Bergström, I. Šics, T. Baranova, M. Casini*

WD 8. Standardized CPUE by length group for Baltic cod. *C. Berg*

WD 9. Stock Split. *M. Storr-Paulsen*

WD 10. Mixing proportions of Baltic cod in SD24 and beyond. *F. Schade, U. Krumme*

WD 11. Effect of condition and length on Baltic cod fecundity: implications for Spawning Stock Biomass. M. *Mion, M. Casini*

WD 12. Application of the egg production method to estimate stock trends and spawning stock biomass. *F. Köster, B. Huwer, G. Kraus, R. Diekmann, M. Eero, S. Orey, J. Dierking, P. Margonski, D. Oesterwind, J.-P. Herrmann, J. Tomkiewicz, A. Makarchouk*

WD 1. Faster or slower: Has growth of eastern Baltic cod changed?

This Working Document is a summary version of a manuscript that will be appearing in Marine Biology Research in 2018.

Karin Hüssy[1], Margit Eero[1], Krzysztof Radtke[2]

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Summary

This study presents the first empirical evidence for a decrease in somatic growth rate of Baltic cod. Temporal patterns of growth, condition and maturation were analysed based on two complementary analyses: Length frequency mode progression and known-age samples, where size at age was back-calculated from daily otolith growth patterns. In the known-age samples, growth was positively related to somatic condition at capture with maturity dependent differences. Immature individuals had experienced significantly lower growth and were in lower condition at capture than mature individuals. Growth rates in the known-age samples were similar in the sampling years examined (2001, 2004 and 2013), estimated at 9.5, 7.8 and 5.7 cm per year for age classes 1, 2 and 3 respectively. But growth differed significantly between year classes within sampling years. Growth decreased significantly from 8.8 cm in the 1997 year class to 7.6 cm in the 2010 year class. However, the 2013 sample was biased towards individuals with a higher condition and growth, suggesting that growth in the most recent year classes might have been even lower. Complementary length frequency analysis of the population suggested a 37.5% lower growth in 2013 compared to 2005. The observed link between condition, growth and maturation suggests that the population's continuing decrease in somatic condition may eventually have a negative effect on recruitment.

Material and methods

Population data

In order to obtain growth estimates complementary to those derived from known-age samples, data on length frequency distributions of the eastern Baltic cod population were obtained from the Baltic International Bottom Trawl Surveys (BITS) for ICES Sub Division (SD) 25. Data were downloaded from ICES' database of trawl surveys (DATRAS) (http://www.ices.dk/marine-data/data-portals/Pages/DATRAS.aspx). In the 2000s, strong year classes occurred in 2003 and 2011 (Köster et al. 2017), visible in the survey length distributions as 2 year olds in the first quarter of 2005 and 2013 and as 3 year olds in 2006 and 2014, respectively. The distance between modes in the length distributions was used as an approximation of average growth of this year class from age 2 to age 3.
Additionally, data on length (L) and total weight (W) of individual fish in the size range 15 - 35 cm from the first quarter of the years 2001, 2004 and 2013 were obtained from DATRAS. These data thus correspond to the known-age samples with respect to fish size and sampling time. le Cren's condition index K was calculated as the relative difference between a fish's weight and the population average:

$$K_i = W_i \left(a\, {L_i}^{b}\right)^{-1}$$

Known-age

To establish samples of known-age cod, individuals in the size range 15 - 35 cm were selected randomly from the Danish samples collected during the Baltic International Trawl Survey (BITS) from the first quarter of the years 2001, 2004 and 2013 in ICES Subdivision (SD) 25 (Fig. 1). Fish length (L) and fish total weight (W) were measured to the nearest cm and weighed (g) on board. Le Cren's condition index was calculated as above.

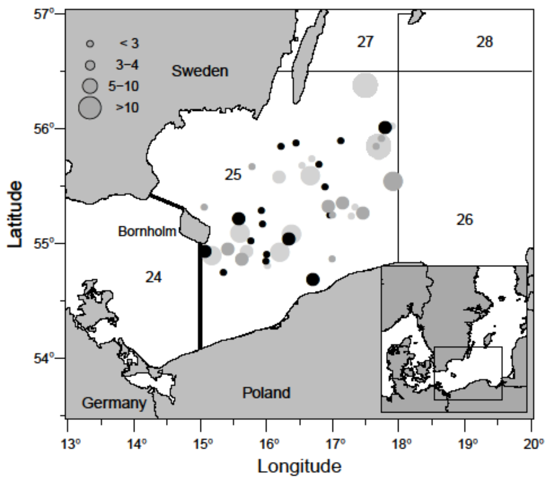


Figure 1. Map of the sampling locations in ICES Subdivision 25 in the eastern Baltic Sea, where the colours represent different years and the circle size the number of cod selected by station. Years: 2001 (black), 2004 (dark grey) and 2013 (light grey). The inset shows the entire Baltic Sea, where the rectangle outlines SD 25.

A segment was cut from the central transverse plane of the known-age otoliths (ISOMET 1000 Buehler), fixed on a microscope slide with thermoplastic glue (Buehler Thermoplastic Cement no. 40-8100), and ground to the central plane. The otolith sections revealed series of zones with clearly distinguishable increments, with increasing/decreasing widths in a dome-shaped pattern, interrupted by zones where there was no visible regular increment structure (Fig. 5 in Hüssy et al. 2010). The latter zones correspond to the time of the year when water temperatures are lowest (Hüssy 2010; Hüssy et al. 2010) and are henceforward referred to as winter zones. The count of winter zones, including the edge, corresponds to the fish's age. Each sampling year thus consist of three year-classes.

Fish size at previous ages was back-calculated based on the measurements of otolith size at the centre of each winter zone using the "biological intercept" back-calculation approach (Campana 1990; Francis 1990):

$$L_{age} = L_{catch} + \left(O_{age} - O_{catch}\right)\left(L_{catch} - L_0\right)\left(O_{catch} - O_0\right)^{-1},$$

where L = fish length O = otolith size and superscripts *age* and *catch* denote the time the measurement was taken and where L_0 = 4.3 mm and O_0 = 10 µm are the fish and otolith size of eastern Baltic cod at hatch (Nissling et al. 1998; Grønkjær and Schytte 1999).

This resulted in a growth curve (length at previous age) for each individual fish from hatch to capture. These growth curves were linearized by log-transforming length at previous age. Differences between sampling years were tested statistically by fitting Linear Mixed Effects Models from the nlme R package (Pinheiro et al. 2015) with previous age as dependent variable, and sampling year as fixed effect and individual fish as random effect. Subsequently, the analysis was repeated with year class instead of sampling year as fixed effect:

$$\log(L_i) = Age_i \times sampling\ year_i + (1|individual) + \varepsilon ,$$

Subsequently, pairwise comparison of growth curves between years was performed using Tukey Contrasts with the multcomp R package (Hothorn et al. 2008).

The relationship between growth and condition of the known-age fish was examined using a two-step approach. First, growth since the last winter zone ($L_{\text{catch}} - L_{\text{age -1}}$) was regressed on age of the fish for each sampling year separately. The residuals of this regression was regressed against le Cren's condition index. This analysis thus tests whether growth during the year prior to capture was correlated with the condition at capture.

All analyses were carried out using R ver. 3.3.2 (R Development Core Team 2009).

Results

Comparison of population and known-age samples

Prior to any growth analyses, we tested whether the known-age samples were representative of the population with respect to somatic condition and within the same size range. On the population level, le Cren's condition factor was similar in 2001 and 2004 (Tukey HSD, $p > 0.05$), but was significantly lower in 2013 (Tukey HSD, $p < 0.001$) (Fig. 2). The average le Cren index of the known-age fish in 2001 and 2004 was similar to the population. In contrast, the known-age sample from 2013 was biased towards individuals with a significantly higher condition than the population average within the same size range

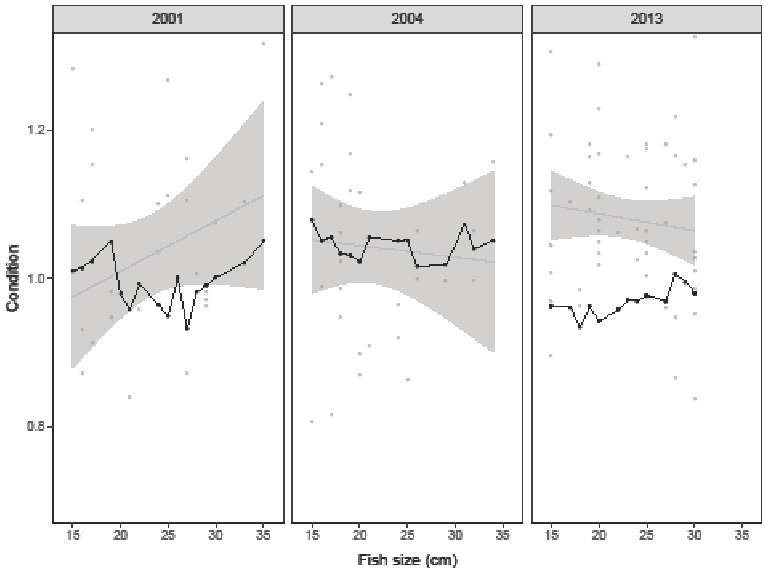


Figure 2. Relationship between le Cren's condition index and fish size of the known-age samples (grey symbols with 95% confidence interval band) and the average of the population in SD 25 in the first quarter of the same years (black symbols and line).

Growth of known-age samples

Sampling year effect: In the LME Model based on back-calculated size at previous age used for this analysis, the intercepts correspond to the size at age 0 while the slopes represent estimates of growth rate over the rest of the fish's life. In the analysis testing sampling year effect on growth, the best model (lowest AIC) resulted in significantly different intercepts between sampling years, but no difference in slopes. The intercepts of the growth curves of fish from 2001 and 2013 did not differ statistically from each other, they were both lower than the intercept of the growth curve for 2004 (Fig. 3). Average growth rates were estimated at 9.5, 7.8 and 5.7 cm per year for age classes 1, 2 and 3 respectively (2013 biased!). In samples from all three years, the individuals that were immature at capture had grown significantly slower than the individuals that were mature at capture (Fig. 4).

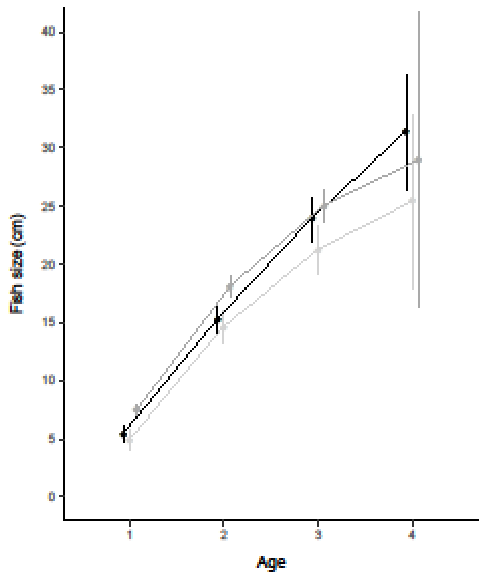


Figure 3. Growth patterns of Baltic cod, back-calculated from otolith measurements. Data shown are means ± confidence intervals, with x-values dodged for improved visibility of the growth curves. Years: 2001 (black), 2004 (dark grey) and 2013 (light grey).

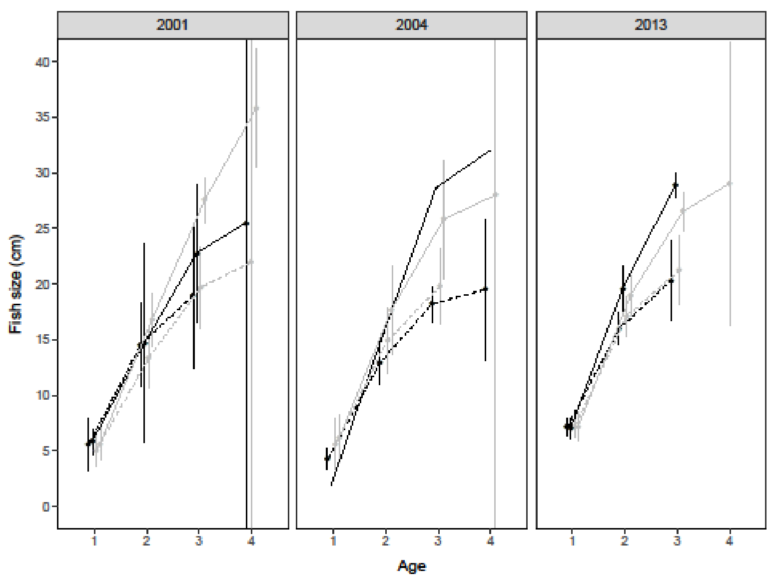


Figure 5. Growth patterns of Baltic cod by sex and maturity for each year separately. Data shown are means ± confidence intervals, with x-values dodged for improved visibility of the growth curves, where colours and line types represent females (black) and males (grey) as immature (dashed line) and mature (solid line) individuals.

Year class effect: In the analysis testing year class effect on growth, samples were restricted to year classes > age 3. And year classes 1997 (7), 1998 (15), 1999 (5), 2000 (5) 2001 (19), 2002 (6), 2010 (36) and 2011 (29), with number of individuals in brackets. Year classes 1997 grew significantly faster than 2002 and the year classes 2009 and 2010 had significantly slower growth rates than both 1997, 2001 and the 2002. In all other pairwise comparisons of year classes there were no significant differences in growth.

For comparison with the growth estimates from population length-frequency analysis, growth between age 2 and 3 was calculated for each year class. Growth decreased significantly from 8.8 cm in the 1997 year class to 7.6 cm in the 2010 year class (growth = 165 – 0.1 · year class, $p < 0.05$, df = 5, $r^2 = 0.67$) (Fig. 6). From this regression, growth of the two year classes used in the length frequency analysis was estimated as 8.3 cm for the 2003 year class and 7.7 cm for the 2011 year class.

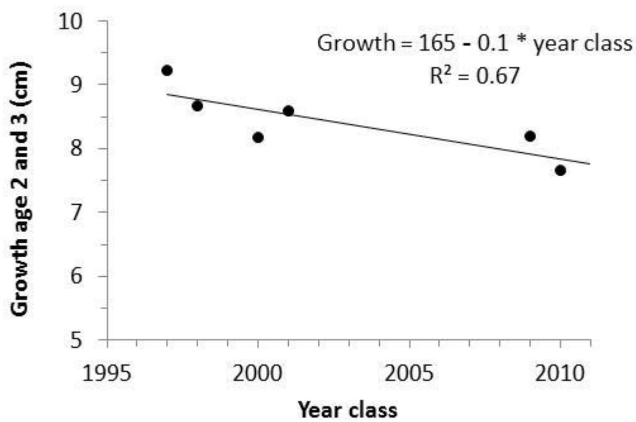


Figure 6. Growth between age 2 and 3 for the year classes 1997 to 2010.

Condition

Both year and maturity had a significant effect on condition, with immature individuals having a lower condition than mature ones (Fig. 7) and with different average condition for 2001 (0.99), 2004 (1.02) and 2013 (1.05). Condition of both immature and mature males was significantly lower than females in 2004 and 2013 but higher in 2001. In all years sampled, immature individuals had thus experienced lower growth rates and were also in lower condition than mature individuals.

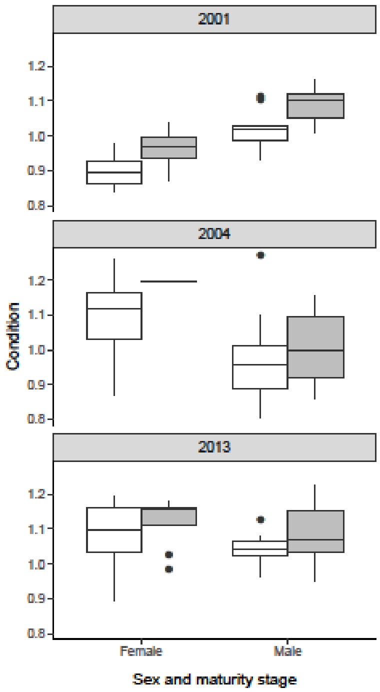


Figure 7. Boxplot of le Cren's condition index for Baltic cod by sampling year, sex and maturity stage (immature= white, mature = grey). Horizontal lines indicate mean, box upper and lower limits the 25% and 75% percentiles, whiskers represent the highest and lowest values within 1.5 · interquartile range and dots represent outliers.

Growth and condition

Residual growth was positively related with le Cren's condition index of the fish (Fig. 7) without significant difference between years. Even though the regressions were statistically significant, the variability explained is limited (only 3.4%).

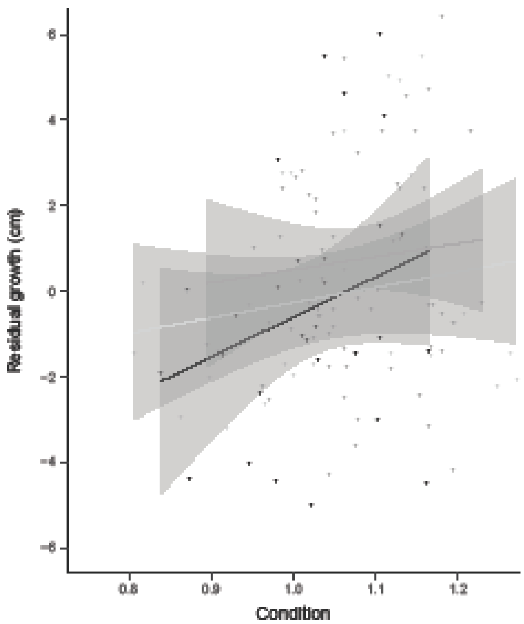


Figure 7. Relationship between residual growth and le Cren's condition index for Baltic cod. Positive residuals correspond to faster than average growth, negative values to slower growth. Data shown are means with 95% confidence interval bands. Years: 2001 (black), 2004 (dark grey) and 2013 (light grey).

Growth estimates from population length frequency analysis

The length distribution of the population, following the 2003 year class, showed a peak around 23 cm at age 2 (in 2005) and around 31 cm at age 3 in the following year (Fig. 8), corresponding to an average growth of 8 cm. For the 2011 year class, the peak in length distribution at age 2 (in 2013) was around 24 cm and around 29 cm at age 3, corresponding to an annual growth of 5 cm. Size at age 2 was thus similar between the two year classes. However, growth from age 2 to age 3 decreased from 8 to 5 cm in the 2011 year class - a decrease in growth of 37.5 %.

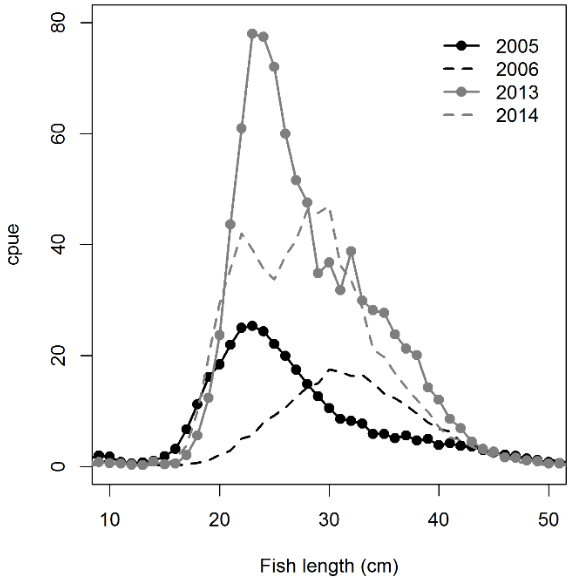


Figure 8. Length distribution of the eastern Baltic cod population in selected years, following 2 relatively strong year classes (2003 and 2011), at the age of 2 years in 2005 and 2013, and age 3 in 2006 and 2014, respectively.

WD 2. Growth estimation from Swedish historical tagging data.

Alessandro Orio, Roman Motyka, Monica Mion and Michele Casini

Growth estimation from Swedish historical tagging data was performed using cod tagging data complete with release and recapture dates and lengths. Two periods were taken as example: 1959 to 1964 and 1965 to 1970. The data used in the example consisted in only the fish with zero or positive growth.

Growth parameters were estimated using the "grotag" function in the R library "fishmethods", which is based on the paper of Francis (1988). This function needs tagging data complete with release and recapture dates and lengths. The growth estimation is done using a constrained maximum likelihood optimization. Extra parameters can be estimated by the "grotag" function: growth variability, bias parameter of measurement error, outlier probability and seasonal variation. Model selection can be based on AIC or log-likelihood.

For the period 1959-1964, 542 cod (length at release between 17 and 75 cm; length at recapture between 20.5 and 97 cm; time between release and recapture between 0.003 and 10.8 years) were used. For the period 1965-1970, 3108 cod (length at release between 13.3 and 85.5 cm; length at recapture between 18 and 98 cm; time between release and recapture between 0.003 and 7.6 years) were used.

Model selection was done as in Francis (1988), we started with the simplest model estimating only the growth parameters and then we add on extra parameter at a time to check if the model improved. In both period the full models where the best. The growth parameters obtained are the following:

	1959-1964	1965-1970
L_∞	105.22	116.41
K	0.153	0.105

References:

Francis, R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. New Zealand journal of marine and freshwater research, 22(1), 43-51.

WD 3. TABACOD: Status and expected outcome

Karin Hüssy, Michele Casini, Krzysztof Radtke, Uwe Krumme

Background

The biological advice for cod management in the eastern Baltic Sea is currently hampered by lack of proper assessment of the status of the stock. Deteriorated quality of some basic input data for stock assessment in combination with changes in environmental and ecological conditions has prevented an analytical assessment of the stock. Since 2014 it has not been possible to quantify the present stock status with the information available. One of the key issues that prevent understanding the present status of cod and providing adequate management advice is lack of information on true age of cod. Inconsistencies in age interpretation have become increasingly problematic and prevent the estimation of fish growth. This has consequences both for stock assessment and fisheries management.

TABACOD objectives

The objectives of the TABACOD project are to provide information on growth and mortality of the Eastern Baltic cod to aid in solving the issues with stock assessment and establish a solid scientific basis for cod management in the Baltic Sea. This requires two interlinked tasks:
1) establishment of a spatially comprehensive sample of cod with “known growth” over a known time period to understand the present status of the stock
2) the development of an objective method that continuously allows deriving growth information in the future.
Two methods that will yield the necessary information are i) tagging of individual fish and ii) analysis of the chemical composition of their otoliths. The aims of a tagging program are thus to provide information about size-specific growth of Baltic cod for stock assessment and current fisheries management purposes, but also to serve as validation for otolith chemistry-derived growth estimates. The chemical analysis of otoliths on the other hand will provide a cost-efficient tool for estimating growth in historic and future samples after the termination of the tagging program.

Work packages

Work package 1: Historic tagging data

Objectives: Compile data from historic tagging experiments
Data from historic tagging experiments will be collated to provide the empirical information for the development of statistical growth models for stock assessment purposes. A substantial body of data will be made available to this project, the majority thereof from several large-scale tagging projects:

Status:

Below is an overview over the historic tagging data with individual information of release and recapture (location, date and biological data) that have been identified by different countries and for different time periods. The data is being digitized and formatted to the database format used by TABACOD.

Eastern Baltic

Denmark 1950s – 1980s, 2000s
Poland 1950s – 1960s

Latvia 1950s – 1970s
Finland 1970s – 1980s
Sweden 1930s-1980s

Wester Baltic

Denmark 1950s – 1980s
Germany 1980-1995

Expected output for Benchmark 2019:

Finalised historic data base

Work package 2: Tagging program

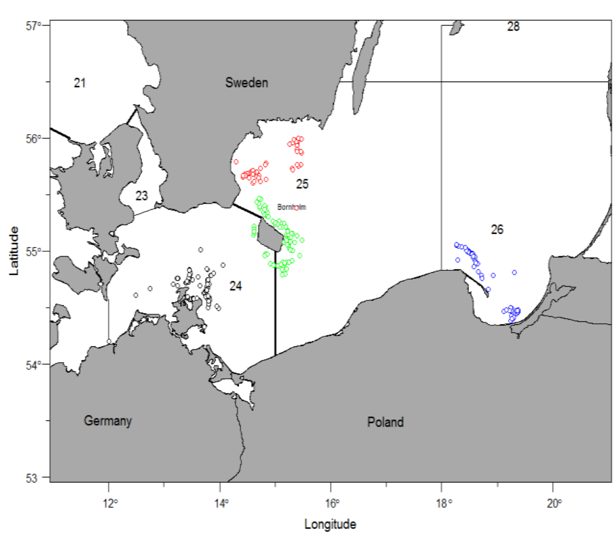
Objectives: To design and carry out an international tagging program

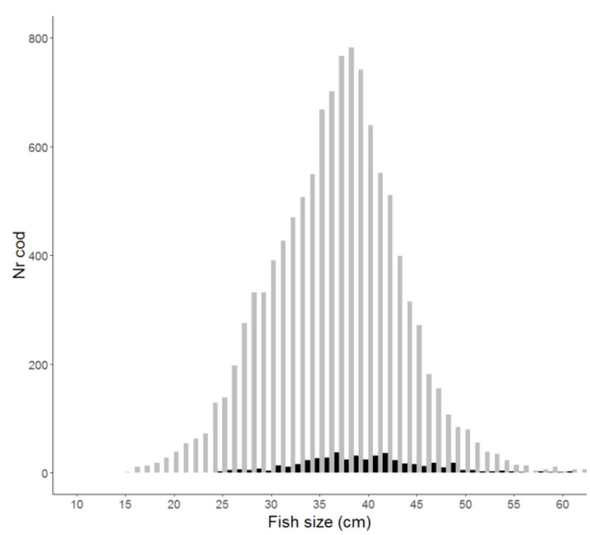
In this WP an international tagging program involving all countries with a major fishery in the Baltic Sea will be designed and carried out. It will involve the identification of the best practice for tagging, raising public awareness of the project, handling of a reward system for delivery of recaptured fish, handling the data emerging from the recaptured fish and maintenance of a common database. For successful reporting of recaptures it is essential that all actions are coordinated internationally.

A total of 20'000 cod will be tagged with T-bar tags over the years 2016-2019, with an additional 2'000 cod tagged with electronic Data Storage Tags recording temperature and depth.

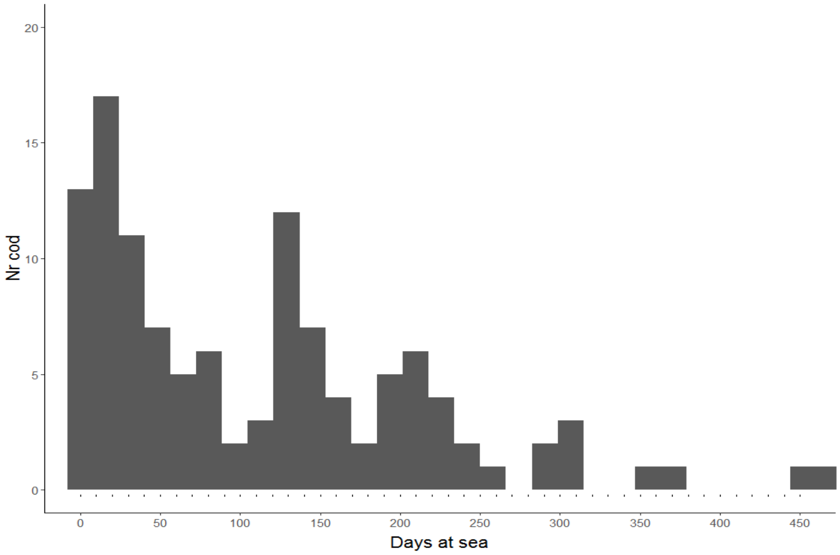
Status:

A total of 14'691 cod have been tagged with T-bar tags and Tetracycline during 2016-2017 and an additional 625 with DSTs. Overview over tagging locations by country (black: Germany, red: Sweden, blue: Poland, green: Denmark) and the length distribution of the tagged cod is shown in the figures below.





To date 161 tagged cod have been recaptured, thereof 15 with a DST. Most of these recaptures are from Q3 and Q4 and their size range corresponds to the release length distribution. Days at liberty varies from few days to a few fish that have been at sea for more than a year – see figure below.



Expected output for Benchmark 2019:
New data with all release and recapture information.

Work package 3: Data analysis for stock assessment
Objectives: Development of statistical growth models, independent estimates of mortality and implementation of tagging/growth data in stock assessment models
In this work the results obtained from WP1 and WP2 will be synthesized. The aim is to use these data to develop validated growth models and implement the use of tagging/growth data in stock assessment models. Within this WP we will also develop a manual for how to implement the best-practice routines for obtaining growth information in the future.

Status:
Growth: Modelling of growth based on historic data ongoing.
Mortality: A number of experiments have been carried out to test tagging mortality, reporting rates and tag loss

Expected output for Benchmark 2019:
- Growth
  - historic growth (ex. Linf, K): data available
  - new growth (ex. Linf, K): timing depends on reporting
  - trends: historical trends (1950s-1980s)
- Mortality
  - Migrations
  - quantification of E/W exchange
  - test of spawning migrations between SD 24/25

Work package 4: Method for future growth estimation
Objectives: To develop and implement a method for estimating fish growth based on otolith chemistry
In this WP we will develop a method for estimating a cod's growth based on the chemical profiles of all relevant elements from hatch to capture. The method development will be based on already existing otoliths of known age and/or growth but from a restricted size range described in WP1. This otolith chemistry-based method will subsequently be validated with analysis of otoliths from cod tagged during this project (WP2). Details of the chemical analyses are described in the "Methods used" below.

Status:
Historic otoliths have been analysed and data of microchemistry profiles are available. Development of a statistical tool to identify different growth zones is ongoing.

Expected output for Benchmark 2019:
Method developed and validation in progress.

WD 4. Eastern Baltic cod cannibalism and starvation

Stefan Neuenfeldt, DTU Aqua

Earlier studies have shown that cod might be considered the top piscivore predator in the Baltic Sea ecosystem. Based on stomach content data from 62 427 cod collected during 1977–1994 and food consumption rates, cannibalism in the Eastern Baltic cod stocks has been quantified using multispecies virtual population analysis. In the Eastern Baltic stock, depending on model assumptions, an average of 25–38% of the 0-group and 11–17% of the 1-group were estimated to be removed by predation by adults. Thus, between age 0 and age 2 a year class may lose on average about 31% and 44% of the initial number as a result of cannibalism.

A new, presently unused stomach content data set has been compiled within the frame of an EU financed tender project. More than 100 000 stomach content data from samples collected between 1963 and 2014 have been applied. The new data showed that the maximum cannibalism rates, so far observed in the time of high adult and juveniles stock abundance correspond to a frequency of occurrence for cod in cod stomachs of around 1.5%, meaning that in this period, 15 out of 1000 sampled cod stomachs contained preyed cod. The new data furthermore indicated, that since 2005 the frequency of occurrence of cod in cod stomachs has increased to an average of around 3.5%, with maximum values of 6% in 2009 and 2010. These increased frequencies imply a pronounced predation pressure on juvenile cod during the latest years.

Stomach sampling has been irregularly distributed over the year, with peaks during the standard survey periods in spring and late autumn. In July and August, sampling intensity was too low to low for a quantitative analysis of cannibalism, keeping in mind the generally low frequency of occurrence of cod in cod stomachs. Leaving these two month aside, the annual development of cannibalism indicates peaks during January-March, and again in November-December, with frequencies of occurrence around 8-10% in the respective months.

The predated cod were to the largest extent between 5 cm and 30 cm total length, and the predators started already at 20 cm total length. The relationship between predator and prey length appears to increase linearly above 40 cm predator length, i.e. the large predators do not consume small cod below 10 cm. Predators above 80 cm did not consume prey cod below 20 cm.

The vast majority of occurrences represents one cod ingested. Only in 3 out of 377 observed cases of cannibalism, more than one cod had been ingested (two-times 2, one-time 3).

Assuming that always one cod is ingested in 5% of the predators, and furthermore assuming an annual mortality of around 0.5, a very simple model, only containing 'large' age 4 cod and 'small' age 2 cod, can be set up to give an idea on the predation pressure of age 2 cod:

Out of 100 age 4 cod, at any given point of time, 5 contain 1 cod. Assuming an evacuation time per digested cod of 6 days, the age 4 cod will consume 304 age 2 cod per year. 'Back-calculating the age 4 cod, assuming a total mortality of 0.3 due to natural causes (0.2) and fisheries at F(msy) (0.3) yields 701 cod at age 2, plus the consumed 608 cod gives 1309. Predation mortality rate will hence be 708/1309, which is more than 50%. Elaborating this approach with survey based size distributions of predator and prey will low for a more reliable predation rate estimation for the latest years. It will furthermore low to investigate, if the observed increase in cannibalism frequency is density-dependent.

The five decades of stomach content data allowed detailed insight into the long-term changes in diet composition, energy uptake and the resulting changes in somatic growth of Atlantic cod in the Baltic

Sea. We estimated energy consumption rates and trends in feeding level. Growth rates were calculated using a bioenergetics model parametrized for cod. Preceding the inflow stagnation period starting in the early 1980s, small cod had the highest feeding level over the cod length range. However, today the small cod experience a substantial reduction of the amount of benthic food in their diet, leading to decreased consumption rates. An increased fraction of sprat in the diet of small cod is apparently not enough to maintain the level of consumption shown when a high fraction of benthic organisms dominated the diet. Large cod can compensate for the shortage of benthic food in their diet by increasing predation on larger forage fish and cannibalism. In consequence, small, pre-spawning cod have presently feeding levels that imply severe growth limitation and increased starvation-related mortality.

WD 5. ESTIMATION OF NATURAL MORTALITY AND GROWTH RATES OF THE EASTERN BALTIC COD

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Materials and estimation methodology

During estimation the period 1992-2016 (26 ICES SD, first quarter) was taken. Data obtained in the Russian bottom trawl surveys (DATRAS) in 1992-2016 were used. In the years when the surveys were not carried out (2012, 2014-2016) commercial data for the first quarter were used.

In this paper, we consider indirect empiric methods for estimating natural mortality, which are based on values of parameters of life span, body size as well as parameters of von Bertalanffy growth model (1938): Brody growth coefficient (K), asymptotic weight (W∞), and length (L∞). In order to estimate the possibility of using the parameters of von Bertalanffy growth model, mean approximation error (in %) was used between the observed and estimated data by age, which should not have exceeded 5%. The coefficients of von Bertalanffy growth equation were found by the least squares method based on the data on weight and length of individuals (females) by age groups.

The growth rate evaluation by I.I. Schmalhausen (to determine the length of fish at the age of 1, rate of linear growth as well as to determine growth rate by weight as a close one to isometric b = 3) was carried out:

$$W=qL^b \text{ и } L=ct^b, \text{ were q, b и c, b = const.}$$

Based on the equation the maximum theoretical age (Tmax) was found.

Two groups of methods for estimating natural mortality were applied (Table 1).

Table 1

Methods for estimating natural mortality

Reference	The equation
M=const	
Anthony (1982) ‘rule-of-thumb’	M=-Ln(0,05)/Tmax
1. Pauly (1980)	Lg (M) = -0,0066-0,279*Lg(Lmax)+0,6543Lg(K)+0,4634*Lg(T°C)
2. Pauly (1980)	Lg (M) = -0,2107-0,0824*Lg(Wmax)+0,6757Lg(K)+0,4627*Lg(T°C)
Jensen(1996)	M=1,5K
M≠const	
Peterson, Wroblewski(1984)	M=1,92W-0,25
Chen, Watanabe (1989)	$M=K/(1-\exp(-K(t-t_0)))$
Lorenzen (1966)	M=3,00W-0,288

Legend: M – natural mortality; W – weight of fish by age; Wmax – asymptotic weight; Lmax – asymptotic length; K – von Bertalanffy growth coefficient; Tmax – maximum theoretical age; t - age of fish; t_0 – conditional zero age when individual’s weight is zero; T°C – annual mean values of temperature in the bottom layer of the Gdansk Deep (station P1).

GSI-based method (Gunderson, Dygert, 1988) was not considered in view of presence of the incomplete data series.

The first one - mortality is constant for all ages (M = const). This approach uses empirical and semi-empirical relationships and takes into account growth or physiological state of fish. The second one - mortality varies by age.

An estimate of natural decline of ichthyobiomass from age was determined based on the boundary curve by V.N. Lukashev, for building of which the mean weight by age was used. The function of the boundary curve was as follows:

$$\varphi = - [(1-e^{-K(t-t0)}) / (1-e^{-K(t+1-t0)})]^3,$$

were K – von Bertalanffy growth coefficient; t - age of fish; t_0 – conditional zero age when individual's weight is zero

Results

Estimation of the parameters of von Bertalanffy growth model for age 1-8 showed rather high mean error of approximation between the estimated and observed data. The most significant values of errors were the ones obtained by weight (Table 2).

Table 2

Mean error of approximation between estimated and observed data by length and weight of cod aged 1-8

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Err, % length	2,4	3,3	1,7	4,2	1,4	1,4	1,9	1,0	2,0	4,1	2,1	4,4	**5,1**	2,3
Err, %, weight	4,1	3,9	**5,2**	**10,2**	**13,1**	4,5	**6,2**	3,1	4,0	**13,7**	**6,6**	**13,8**	**10,8**	**8,7**

Estimation of the parameters of von Bertalanffy growth model for age 2-7 showed mean error of approximation of less than 5% between the estimated and observed data (Table 3). Therefore, in order to estimate the natural mortality (Table 4, Fig. 1) mean length and weight for 2-7 age groups were used. The exception was 1993 (high approximation error) which was excluded from estimation of natural mortality.

Table 3

Mean error of approximation between estimated and observed data by length and weight of cod aged 2-7

Years	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Err, % length	2,02	**4,14**	2,47	0,58	0,53	0,63	2,90	1,24	1,52	2,20	4,83	1,77	2,01	0,84	2,67	0,98	2,35	1,35	0,79	1,26	2,05	2,84	1,50	1,80	1,92
Err, % weight	4,71	**5,52**	4,94	4,44	3,43	2,43	3,06	4,34	4,79	4,54	2,03	4,65	1,53	3,83	3,45	1,06	4,23	5,00	2,58	3,10	4,02	4,71	4,68	3,18	4,94

Table 4

Input data for estimation of parameters of von Bertalanffy growth model

		L, cm																							
age	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	26,6	**28,4**	29,3	27,6	28,3	29,8	28,1	28,2	27,5	28,9	29,9	25,4	25,5	25,0	27,8	27,4	27,3	26,6	27,7	26,0	29,0	24,3	27,4	34,5	30,9
3	36,8	**36,9**	42,3	39,5	39,3	38,1	37,6	37,4	36,1	39,1	41,2	32,3	32,5	33,6	37,2	35,5	36,6	35,5	36,2	33,2	36,8	34,4	34,2	38,6	37,2
4	47,7	**46,9**	51,5	49,7	47,6	44,7	42,0	44,2	42,2	47,4	46,4	41,0	41,4	40,2	41,6	42,4	43,0	41,0	42,8	39,4	42,9	39,2	41,2	43,8	42,3
5	57,3	**56,2**	57,4	55,9	55,1	50,1	47,7	51,2	47,3	53,4	51,5	48,0	47,6	47,0	47,8	47,8	47,0	48,8	49,0	44,1	50,9	44,1	46,0	47,6	48,3
6	66,7	**68,7**	64,2	62,9	62,6	56,8	55,7	58,2	54,7	59,8	56,8	54,6	55,2	53,7	54,5	53,1	54,7	54,1	56,0	49,5	56,0	49,1	50,3	50,7	52,3
7	72,8	**73,5**	72,5	67,9	68,1	62,0	62,2	65,0	60,5	67,9	66,5	60,1	59,9	59,8	60,9	58,6	60,9	60,5	60,7	55,1	59,3	54,7	52,1	51,8	53,8

		W, g																							
age	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	213,7	**261,2**	277,1	242,8	253,6	295,0	247,9	263,6	213,4	268,3	230,0	154,3	169,1	152,9	221,8	204,3	203,1	178,4	199,1	183,6	173,2	160,1	203,5	447,0	286,0
3	558,3	**598,5**	847,2	698,2	700,2	570,0	508,8	606,6	503,3	687,1	447,1	327,7	394,0	381,3	471,3	442,8	486,8	450,7	455,6	336,5	351,8	387,8	403,8	618,1	453,7
4	1297,2	**1214,4**	1500,3	1369,1	1159,8	984,1	784,0	938,7	795,9	1233,9	712,7	723,0	678,4	664,0	709,3	771,6	782,1	697,4	778,0	581,7	563,1	561,9	740,0	870,4	688,1
5	2247,9	**2110,9**	2277,6	1900,4	1753,4	1414,1	1146,2	1499,6	1117,3	1759,6	1114,1	1125,0	1069,0	1070,3	1100,0	1091,1	999,6	1137,8	1125,3	803,1	878,5	782,4	1012,3	1095,4	968,7
6	3047,1	**3214,3**	3568,1	2626,2	2475,9	1969,7	1788,0	2404,8	1807,1	2260,5	1605,0	1535,5	1595,8	1562,8	1512,3	1453,4	1607,9	1472,7	1613,0	1076,1	1012,2	1072,5	1282,4	1241,5	1256,3
7	4200,0	**4269,7**	4870,2	3529,4	3202,8	2705,3	2342,0	3170,5	2415,0	3094,5	2098,2	2117,4	2153,3	1917,2	2035,1	1819,2	2044,3	2047,6	2148,4	1460,1	1389,8	1347,7	1430,0	1354,5	1417,7

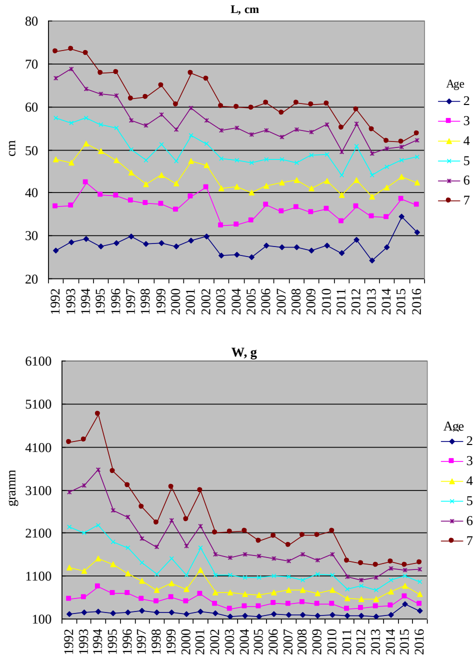

Fig.1. Mean length and weight of cod by age for the period 1992-2016

As it can be seen from Fig. 1, the main changes in the mean values of length and weight by age in the long-term period are noted for age groups of 3 and more. Based on the data presented in the Table 4, the natural decline of ichthyobiomass from the age, the value of which reliably decreases for all ages from 1992 to 2016 (Figure 2) was estimated.

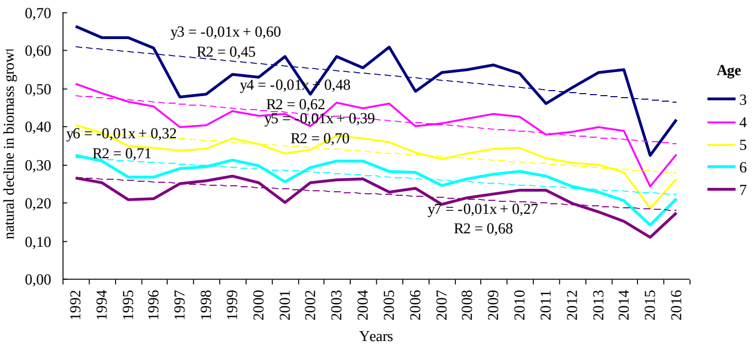

Fig.2. Natural decline of cod ichthyobiomass for the period 1992-2016

So, what **is the natural decline?** This is a reduction in the amount of something due to natural causes. Thus, in our case, a decrease in ichthyobiomass by all ages was recorded by 2016 (especially, for the ages 4-7) which is due to a decrease in cod growth rates.

Estimated parameters of von Bertalanffy growth model of cod aged 2-7 for the period 1992-2016 are presented in the Table 5 and in the Figure 3.

Table 5

Estimated parameters of von Bertalanffy growth model

of cod aged 2-7 for the period 1992-2016

Years	Lmax, cm	t0	К	Wmax, g	t0	К	Tmax	L at age 1, cm	linear growth rate	isometric growth (b close to value 3)
1992	144,4	0,047	0,100	22064	0,095	0,123	15,7	15,1	0,820	2,95
1994	104,3	-0,064	0,170	22544	-0,062	0,130	11,7	18,9	0,696	3,21
1995	87,3	0,301	0,224	8347	0,127	0,202	9,4	17,5	0,717	2,93
1996	103,0	-0,115	0,152	8281	-0,058	0,185	12,3	17,8	0,699	2,86
1997	109,4	-1,101	0,103	42581	-1,593	0,060	18,7	20,0	0,580	3,03
1998	161,5	-1,342	0,059	42998	-1,551	0,056	34,5	18,5	0,612	2,89
1999	156,5	-0,999	0,068	53139	-1,017	0,062	27,0	17,9	0,658	3,01
2000	129,2	-1,113	0,078	21596	-0,959	0,083	24,3	18,0	0,618	3,07
2001	129,8	-0,709	0,097	7486	-0,169	0,191	18,8	18,5	0,664	2,89
2002	121,6	-1,048	0,101	32901	-1,532	0,060	20,5	20,4	0,592	2,95
2003	144,5	-0,733	0,069	15291	-0,477	0,097	23,1	15,9	0,703	3,03
2004	124,9	-0,585	0,085	22003	-0,773	0,080	19,8	15,5	0,699	2,89
2005	139,4	-0,763	0,072	6156	-0,129	0,158	24,0	15,6	0,690	2,96
2006	132,4	-1,207	0,076	15010	-1,253	0,088	26,0	18,4	0,606	2,88
2007	97,3	-0,868	0,118	4510	-0,455	0,180	16,3	18,3	0,600	2,92
2008	114,0	-0,913	0,098	6379	-0,509	0,153	19,7	18,1	0,618	2,91
2009	123,1	-0,869	0,086	7350	-0,463	0,142	21,2	17,1	0,646	2,95
2010	104,2	-0,731	0,113	10367	-0,715	0,117	16,5	18,0	0,626	3,00
2011	114,1	-1,298	0,080	13100	-1,673	0,076	24,4	17,3	0,591	2,79
2012	84,5	-0,542	0,159	3957	-0,823	0,156	12,4	19,3	0,587	2,80
2013	73,1	-0,212	0,191	2661	-0,326	0,216	11,2	16,5	0,618	2,67
2014	62,7	-0,266	0,244	2323	-0,143	0,267	9,3	19,2	0,532	3,03
2015	61,4	-1,820	0,207	2034	-1,932	0,231	10,9	27,1	0,343	2,70
2016	65,9	-0,803	0,215	3569	-1,537	0,154	10,3	22,5	0,461	2,87

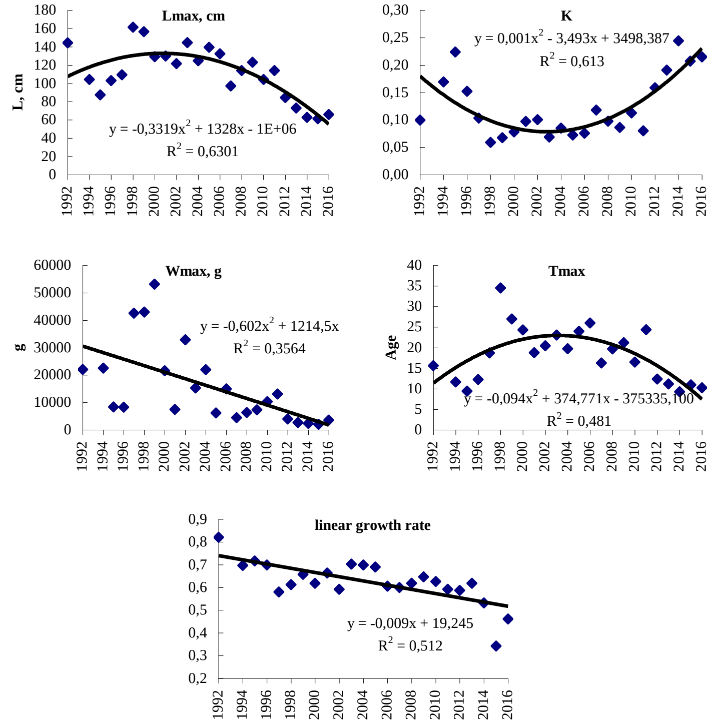

Fig.3. Some parameters of von Bertalanffy growth model by year

Values Lmax - asymptotic length, K - von Bertalanffy growth coefficient and Tmax – maximum theoretical age close to the values of the early 90's. Wmax - asymptotic weight and rate of linear growth significantly decreased by 2016.

Values of the estimated natural cod mortality for M=const are presented in the Table 6 and in the Figure 4.

Table 6

Values of natural cod mortality for M=const

Years	**Anthony (1982) 'rule-of-thumb'**	**1.Pauly (1980)**	**2.Pauly (1980)**	**Jensen(1996)**	*Average*
1992	0,191	0,122	0,148	0,149	*0,153*
1993					
1994	0,257	0,172	0,139	0,254	*0,206*
1995	0,318	0,230	0,215	0,336	*0,275*
1996	0,244	0,158	0,187	0,228	*0,204*
1997	0,160	0,135	0,085	0,155	*0,134*
1998	0,087	0,094	0,092	0,088	*0,090*
1999	0,111	0,097	0,090	0,101	*0,100*
2000	0,123	0,113	0,118	0,117	*0,118*
2001	0,160	0,125	0,219	0,146	*0,162*
2002	0,146	0,144	0,097	0,151	*0,135*
2003	0,130	0,096	0,130	0,103	*0,115*
2004	0,152	0,129	0,123	0,128	*0,133*
2005	0,125	0,110	0,212	0,109	*0,139*
2006	0,115	0,113	0,130	0,114	*0,118*
2007	0,184	0,171	0,244	0,177	*0,194*
2008	0,152	0,141	0,207	0,146	*0,162*
2009	0,141	0,133	0,203	0,129	*0,152*
2010	0,182	0,159	0,166	0,169	*0,169*
2011	0,123	0,114	0,111	0,120	*0,117*
2012	0,242	0,192	0,199	0,238	*0,218*
2013	0,268	0,223	0,252	0,287	*0,257*
2014	0,324	0,284	0,305	0,367	*0,320*
2015	0,274	0,285	0,312	0,311	*0,295*
2016	0,292	0,280	0,221	0,322	*0,279*

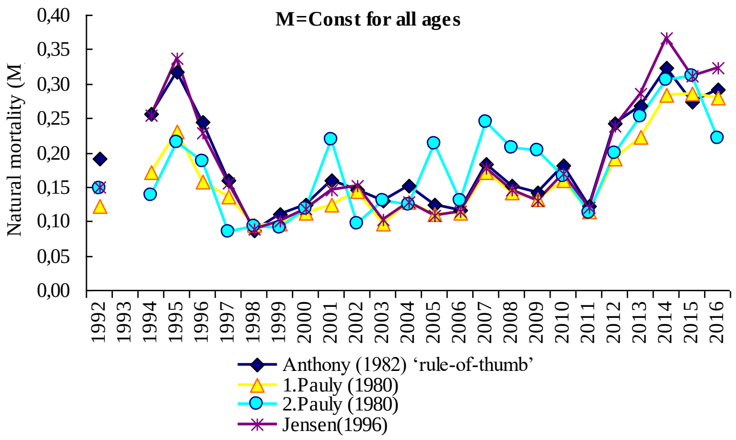

Figure 4. Natural cod mortality for M=const for all ages for the period 1992-2016

Now we can check Pauly rule (1980): Natural mortality is associated with growth rates, life span and water temperature (Fig.5).

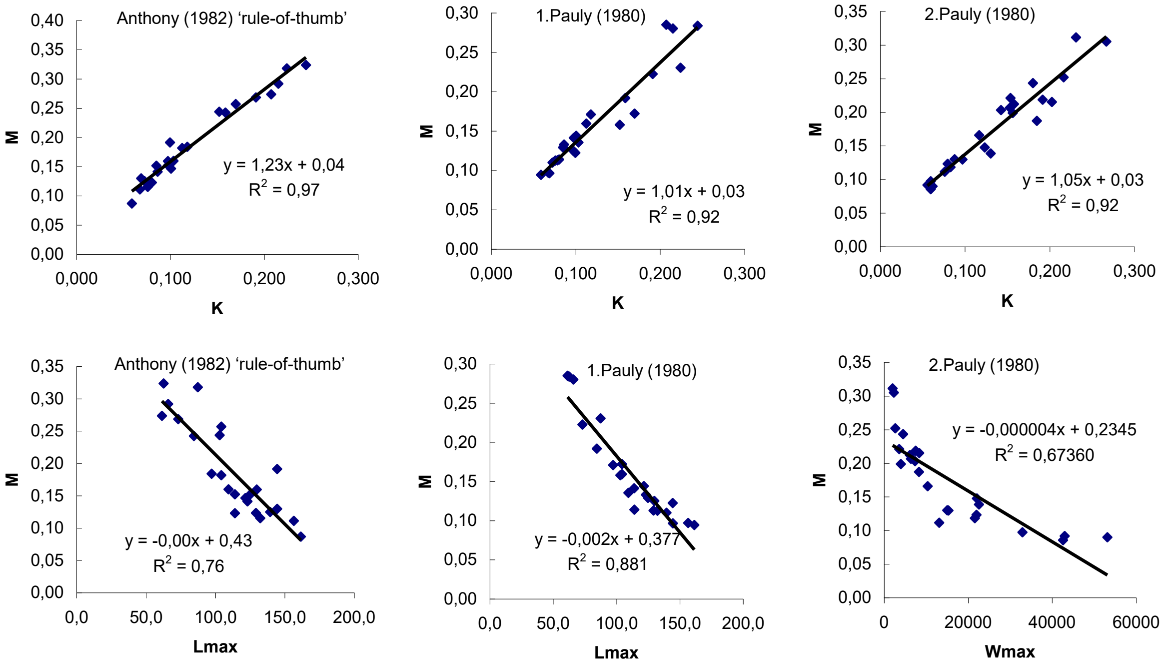

Fig.5 Dependence of the estimated natural mortality (M) on von Bertalanffy growth model (Wmax – asymptotic weight; Lmax – Brody growth coefficient)

Results of estimation of cod mortality by age for M≠const are presented in the Table 7 and in the Figure 6.

Table 7

Values of natural mortality (M) coefficients by age

Chen, Watanabe (1989)																							
Age	**1992**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	0,56	0,57	0,71	0,55	0,38	0,33	0,37	0,36	0,42	0,38	0,40	0,43	0,40	0,35	0,41	0,39	0,39	0,43	0,35	0,48	0,55	0,57	0,52	0,48
3	0,39	0,42	0,49	0,40	0,30	0,26	0,29	0,28	0,32	0,30	0,30	0,32	0,30	0,28	0,32	0,31	0,30	0,33	0,28	0,37	0,42	0,44	0,41	0,38
4	0,31	0,34	0,40	0,33	0,25	0,22	0,24	0,24	0,26	0,25	0,25	0,26	0,25	0,23	0,27	0,26	0,25	0,27	0,23	0,31	0,35	0,38	0,36	0,33
5	0,26	0,29	0,34	0,28	0,22	0,19	0,20	0,21	0,23	0,22	0,21	0,22	0,21	0,20	0,24	0,22	0,22	0,24	0,20	0,27	0,30	0,34	0,32	0,30
6	0,22	0,26	0,31	0,25	0,20	0,17	0,18	0,18	0,20	0,20	0,19	0,20	0,19	0,18	0,21	0,20	0,19	0,21	0,18	0,25	0,27	0,31	0,30	0,28
7	0,20	0,24	0,29	0,23	0,18	0,15	0,16	0,17	0,18	0,18	0,17	0,18	0,17	0,16	0,20	0,18	0,18	0,19	0,17	0,23	0,26	0,29	0,28	0,26
Peterson, Wroblewski(1984)																							
Age	**1992**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	0,502	0,471	0,486	0,481	0,463	0,484	0,477	0,502	0,474	0,493	0,545	0,532	0,546	0,497	0,508	0,509	0,525	0,511	0,522	0,529	0,540	0,508	0,488	0,467
3	0,395	0,356	0,374	0,373	0,393	0,404	0,387	0,405	0,375	0,418	0,451	0,431	0,434	0,412	0,419	0,409	0,417	0,416	0,448	0,443	0,433	0,428	0,422	0,416
4	0,320	0,308	0,316	0,329	0,343	0,363	0,347	0,361	0,324	0,372	0,370	0,376	0,378	0,372	0,364	0,363	0,374	0,364	0,391	0,394	0,394	0,368	0,371	0,375
5	0,279	0,278	0,291	0,297	0,313	0,330	0,309	0,332	0,296	0,332	0,332	0,336	0,336	0,333	0,334	0,341	0,331	0,332	0,361	0,353	0,363	0,340	0,342	0,344
6	0,258	0,248	0,268	0,272	0,288	0,295	0,274	0,294	0,278	0,303	0,307	0,304	0,305	0,308	0,311	0,303	0,310	0,303	0,335	0,340	0,336	0,321	0,322	0,322
7	0,239	0,230	0,249	0,255	0,266	0,276	0,256	0,274	0,257	0,284	0,283	0,282	0,290	0,286	0,294	0,286	0,285	0,282	0,311	0,314	0,317	0,312	0,313	0,313
Lorenzen (1966)																							
Age	**1992**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	0,640	0,594	0,617	0,609	0,583	0,613	0,602	0,640	0,599	0,627	0,703	0,685	0,705	0,633	0,648	0,649	0,674	0,653	0,668	0,680	0,695	0,649	0,619	0,588
3	0,485	0,430	0,455	0,455	0,482	0,498	0,474	0,500	0,457	0,517	0,566	0,537	0,542	0,510	0,519	0,505	0,516	0,515	0,562	0,554	0,539	0,533	0,524	0,515
4	0,381	0,365	0,375	0,393	0,412	0,440	0,418	0,438	0,386	0,452	0,451	0,459	0,462	0,453	0,442	0,440	0,455	0,441	0,480	0,484	0,484	0,447	0,452	0,457
5	0,325	0,324	0,341	0,349	0,371	0,395	0,365	0,397	0,349	0,398	0,397	0,403	0,402	0,399	0,400	0,410	0,395	0,397	0,437	0,426	0,440	0,409	0,411	0,414
6	0,298	0,284	0,311	0,316	0,338	0,347	0,319	0,346	0,324	0,358	0,363	0,359	0,361	0,364	0,368	0,358	0,367	0,358	0,402	0,409	0,402	0,382	0,383	0,384
7	0,271	0,260	0,285	0,293	0,308	0,321	0,294	0,318	0,296	0,331	0,331	0,329	0,340	0,334	0,345	0,334	0,334	0,329	0,368	0,373	0,377	0,370	0,371	0,371
Average Natural mortality																							
Age	**1992**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	0,568	0,546	0,604	0,548	0,474	0,476	0,482	0,501	0,498	0,500	0,550	0,549	0,550	0,494	0,522	0,517	0,531	0,530	0,512	0,562	0,597	0,577	0,544	0,510
3	0,424	0,402	0,441	0,410	0,391	0,388	0,382	0,397	0,384	0,412	0,440	0,430	0,427	0,400	0,420	0,407	0,412	0,419	0,428	0,456	0,463	0,469	0,454	0,439
4	0,336	0,338	0,363	0,350	0,336	0,340	0,333	0,346	0,325	0,359	0,356	0,366	0,363	0,352	0,359	0,353	0,360	0,359	0,367	0,396	0,408	0,398	0,393	0,389
5	0,287	0,299	0,325	0,309	0,302	0,304	0,292	0,312	0,291	0,317	0,313	0,321	0,317	0,312	0,323	0,325	0,314	0,322	0,333	0,350	0,369	0,362	0,358	0,353
6	0,260	0,266	0,297	0,280	0,275	0,270	0,257	0,275	0,269	0,286	0,285	0,287	0,284	0,284	0,297	0,287	0,290	0,291	0,306	0,332	0,338	0,338	0,334	0,329
7	0,236	0,244	0,274	0,260	0,252	0,250	0,237	0,253	0,246	0,265	0,260	0,263	0,266	0,261	0,278	0,267	0,265	0,268	0,281	0,305	0,316	0,326	0,321	0,316

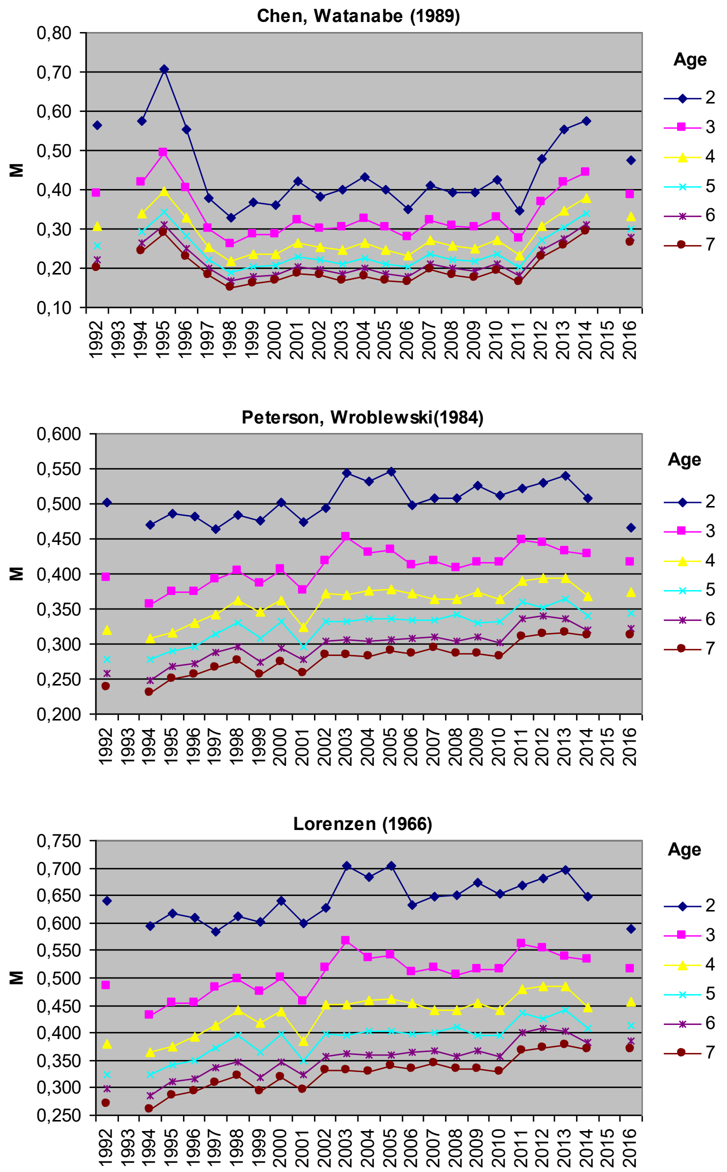

Figure 6. Natural mortality (M) for cod by age 2-7 in the period 1992-2016

Estimation for M = const by different methods/approaches showed significant convergence of the results. Increase in natural mortality of cod after 2010, the values of which are close to the ones of the early 90's.

Estimation of mortality by age using three methods showed similar values of mortality by age. Chen method, Watanabe (1989), as well as for M=const approach, showed convergence of current values with the ones of the early 90’s. Estimation by the methods of Peterson, Wroblewski (1984) and Lorenzen (1966) showed an increase in natural mortality after 2010 for older age groups (age 3 and more).

Conclusions

1. Obtained estimates of natural mortality coefficients can be used when assessing stock of cod aged 2-7.
2. For M = const for all ages, the values of natural mortality, based on calculation methods that take into account biological parameters (growth rate, life span...) are similar to methods including also abiotic factors (water temperature).
3. Taking into account some scattering in the values of the estimated natural mortality, it is possible to take their arithmetic mean value (Fig. 7-8).

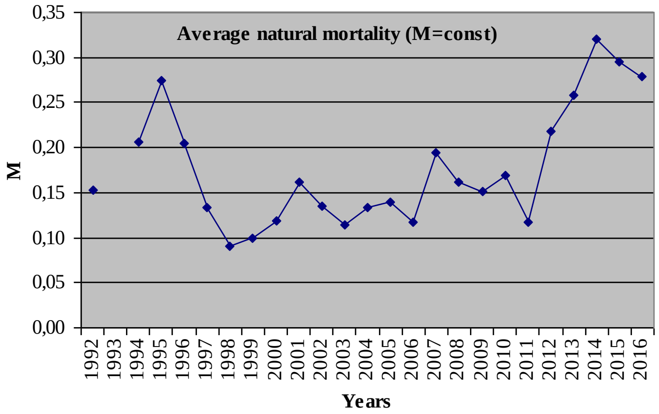

Fig. 7. Mean values of natural cod mortality for M=const

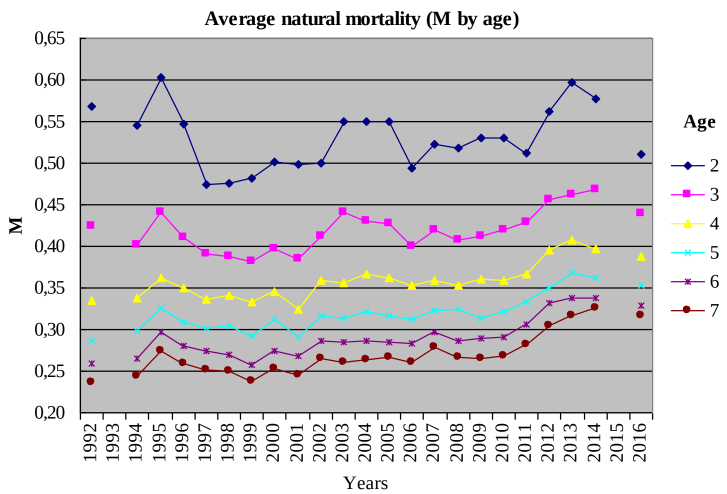

Fig.8. Mean values of natural mortality of cod by age

4. Taking into account the loss of ichthybiomass from age and the calculations by the method of Peterson, Wroblewski (1984) and Lorenzen (1966), the main increase in the values of natural mortality after 2010 was noted for older age groups (3 years and more).

References

Anthony, V. C. 1982. The calculation of F0.1: a plea for standardization, 16 p. Northwest Atlantic Fisheries Organization (NAFO) Serial Document N557, SCR 82/VI/64. NAFO Secretariat, P.O. Box 638, Dartmouth, Nova Scotia B2Y 3Y9, Canada.

Bertalanffy L. von. 1938. A Quantitative Theory Of Organic Growth // Human Biology. V. 10. № 1. P. 181–213.

Chen S., Watanabe S. 1989. Age Dependence of Natural Mortality Coefficient in Fish Population Dynamics // Nippon Suisan Gakkaishi. V. 55. P. 205–208.

Jensen A. 1996. Beverton and Holt Life History Invariants Result from Optimal Trade-Off of Reproduction and Survival // Canadian Journal of Fisheries and Aquatic Sciences. V. 53. P. 820–822.

Lorenzen K. 1996. The Relationship between Body Weight and Natural Mortality in Juvenile and Adult Fish: A Comparison of Natural Ecosystems and Aquaculture // Journal of Fish Biology. V. 49. P. 627–647.

Pauly D. 1980. On the Interrelationships between Natural Mortality, Growth Parameters, and Mean Environmental Temperature in 175 Fish Stocks // Journal du Conseil International pour l’Exploration de la Mer. V. 39 (2). P. 175–192.

Peterson I., Wroblewski J. 1984. Mortality Rate of Fishes in the Pelagic Ecosystem // Canadian Journal of Fisheries and Aquatic Sciences. V. 41. P. 1117–1120.

Шмальгаузен И.И. Рост животных. М.; Л: Биомедгиз. 1935 С. 8-60.
(*Shmal'gauzen I. I.* Rost zhivotnykh [Animal growth]. Moscow – Leningrad, Biomedgiz, 1935, pp. 8–60).

Лукашов В. Н. 1970. Метод расчета наименьшей промысловой меры на рыбу // Биологические основы рыбного хозяйства и регулирование морского рыболовства: Тр. ВНИРО. Т. 71, вып. 2. С. 281–293.
Lukashov V. N. Metod rascheta naimen'shei promyslovoi mery na rybu [Method of calculation of the lowest commercial size of fish]. *Biologicheskie osnovy rybnogo khoziaistva i egulirovanie morskogo rybolovstva. Trudy VNIRO*, vol. 71, iss. 2, pp. 281–293.

WD 6. Using alternative biological information in stock assessment: condition-corrected natural mortality of Eastern Baltic cod

Michele Casini, Margit Eero, Sofia Carlshamre and Johan Lövgren

The inclusion of biological and ecological aspects in the assessment of fish population status is one of the bases for an ecosystem-based fisheries management. During the past two decades the Eastern Baltic cod has experienced a drastic reduction in body condition, and likely also in growth, that may have affected its survival. We used results from published experimental literature linking cod condition to starvation and mortality, to estimate the annual proportion of cod close to the lethal condition level in the Eastern Baltic cod stock. Thereafter we applied these results to adjust the natural mortality (M) assumed in the analytical stock assessment model. The results in terms of Spawning Stock Biomass (SSB), Fishing mortality (F) and Recruitment (R) in the final year from the stock assessment using M values adjusted for low condition were up to 40% different compared with the assessment assuming a constant M=0.2. These estimates could be used in combination with other estimations of additional mortality (such as seal predation and parasite infection) to adjust the natural mortalities used in analytical stock assessment.

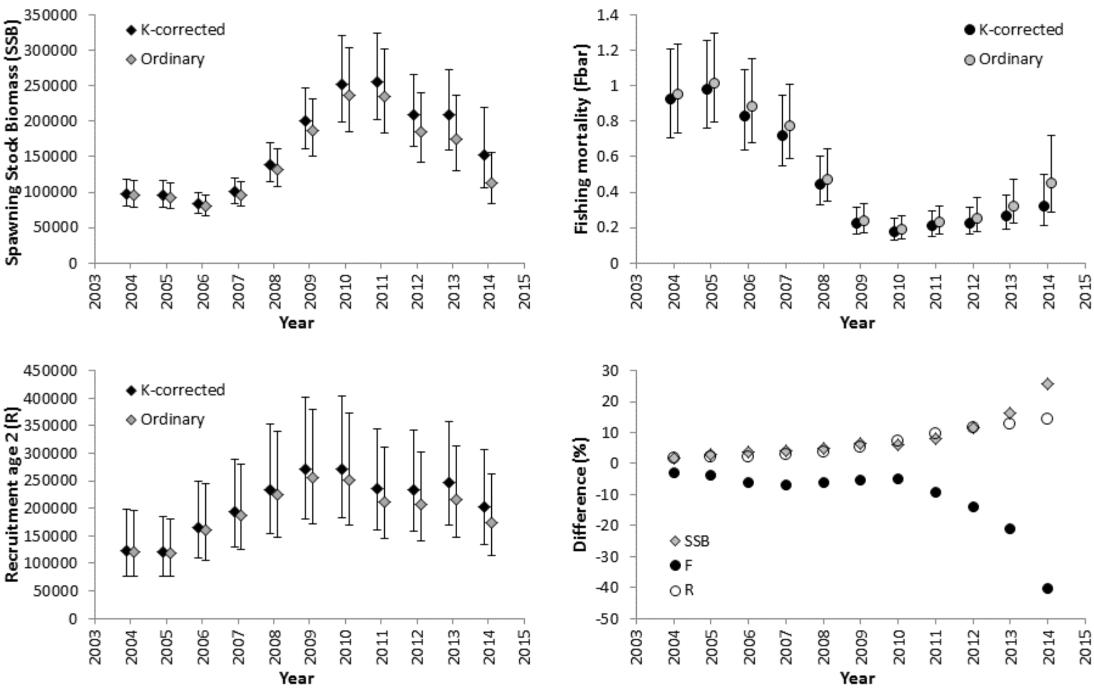

Figure. Comparisons of Spawning Stock Biomass (SSB), Fishing mortality (F) and Recruitment (R) by year for the SAM runs with constant natural mortality of 0.2 and the SAM runs with K-corrected natural mortalities. The symbols represent the final year estimate of 11 runs where we excluded step-by-step one year at a time back to 2004 (i.e. they represent the final year of 11 retrospective runs ending from 2004 to 2014). The relative differences in SSB, F and R using SAM runs with constant natural mortality of 0.2 and the SAM runs with K-corrected natural mortalities are also shown. Bars show 95% confidence intervals.

Reference

Casini, M., Eero, M., Carlshamre, S. and Lövgren, J. (2016). Using alternative biological information in stock assessment: condition-corrected natural mortality of Eastern Baltic cod. ICES Journal of Marine Science, 73: 2625-2631. doi:10.1093/icesjms/fsw117.

WD 7. Modelling indices of abundance and size-based indicators of cod and flounder stocks in the Baltic Sea using newly standardized trawl survey data.

Alessandro Orio, Ann-Britt Florin, Ulf Bergström, Ivo Šics, Tatjana Baranova, and Michele Casini

Long time-series of standardized indices of abundance and size-based indicators are important for monitoring fish population status. This study's objectives were to (i) combine and standardize recently performed trawl survey with historical ones, (ii) discuss the trends in abundance, and (iii) in maximum length (L_{max}) for cod (*Gadus morhua*) and flounder (*Platichthys flesus*) stocks in the Baltic Sea.

Only the results for the trends in abundance of cod stocks were presented.

Catch and individual data for cod collected during the BITS in ICES Subdivisions (SDs) 22–29 between 1991 and 2016 were downloaded from the ICES DATRAS database. Additionally, we compiled historical catch and individual data collected during bottom trawl surveys in the Baltic Sea carried out in the years 1928–1990 by the former Swedish Board of Fisheries (currently the Swedish University of Agricultural Sciences, Department of Aquatic Resources) and in the years 1976–1990 by the former Baltic Fisheries Research institute (BaltNIIRH; currently the Latvian Institute of Food Safety, Animal Health and Environment).

Standardization of catch per unit of effort (CPUE) from trawl surveys from 1928 to 2016 to swept area per unit of time was conducted using information on trawling speed and horizontal opening of the trawls, following the approach proposed by Cardinale *et al.* (2009).

CPUE data for cod stocks from 1978 to 2014 were modelled using delta-generalized additive models (GAMs). The CPUE time series of the Eastern Baltic cod stock closely resembles the spawning stock biomass trend from the last accepted analytical stock assessment.

The pros of this method of standardization are:

- The standardization is published and available
- It is based on gear geometry and it is not species specific so it can be applied to other species
- Historical survey can be added to the database and can be easily standardize as long as gear information are available
- The standardization is not changing every year

The cons of this method of standardization are:

- It does not take into account different selectivity for different size of fishes
- We are still missing some gear geometries to have 100% of the BITS standardized
- If we want to add other effects (e.g. depth) in the estimation of the index of abundance we still need to model the CPUE (i.e. the index changes every year)

It is concluded that the standardization of long time series of fisheries-independent data constitutes a powerful tool that could help improve our knowledge on the dynamics of fished populations, thus promoting a long-term sustainable use of these marine resources.

For more detailed information please refer to Orio *et al.* (2017).

References:

Cardinale, M., Linder, L., Bartolino, V., Maiorano, L., and Casini, M. 2009. Conservation value of historical data: reconstructing stock dynamics of turbot during the last century in the Kattegat-Skagerrak. Marine Ecology Progress Series, 386: 197–206.

Orio, A., Florin, A.-B., Bergström, U., Šics, I., Baranova, T., and Casini, M. 2017. Modelling indices of abundance and size-based indicators of cod and flounder stocks in the Baltic Sea using newly standardized trawl survey data. ICES Journal of Marine Science, 74: 1322–1333.

WD 8. Standardized CPUE by length group for Baltic cod. *Casper Berg*

Two models for calculating standardized CPUE estimates and uncertainties using data from the BITS survey were presented (Casper W. Berg, DTU Aqua). One model is a generalized additive model (GAM) and the other is a Log-Gaussian Cox Process model (LGCP). Both models were fitted independently by length-group and use spatial coordinates, time, depth, gear type, haul duration, and time of day as explanatory variables.

The CPUE is standardized by using the models to predict CPUE in an artificial survey, which is carried out (in silico) each year and quarter in the data period using the exact same experimental setup (same positions, time, gear, etc for each time step). A bathymetry database is used to define the positions and their corresponding depth for the artificial survey. Since depth is a strong predictor of catch in the models, the bathymetry can be used to improve predictions of unsampled areas. The general form of both models is:

log(catch) = Gear + s1(time, position.x, position.y) + Depth:Quarter + Depth^2:Quarter +

+s2(timeOfDay) + log(HaulDur)

where s1 is some form of space-time smoothing function. Depth was modelled as quadratic function in order to force a decreasing effect away from the vertex of the parabola, which can be interpreted as a preferred depth for a given size group.

BITS data from both quarters (1 and 4) and all positions in the EBcod and WBcod assessments areas were used as input to the model (with a few exceptions), 12591 hauls in total. By using all the data more precise estimates of global effects such as gear effects compared estimates based only on the data from the stock specific assessment areas. Also, the same model may be used to provide standardized CPUE estimates for cod in both the EB and WB assessment areas.

The standardized CPUEs from the models were compared with the standard DATRAS mean CPUE by length (weighted mean CPUE by sub-area with weights equal to the geographical area of the sub-area).

There was overall agreement in trends for ICES, GAM, and LGCP produced CPUEs, however substantial di
fferences (and uncertainties) in were present in the early years. This was the case for both the estimated length distributions as well as total biomass.
This uncertainty is due to both reduced number of hauls especially in Q4, but also due to the different gears used before 2000. The GAM and LGCP approaches produced even more similar results, however three out of 33 GAM models had some convergence problems (to be investigated further), whereas the LGCP model produced a bit more smooth results and did not have convergence issues.
Residual QQ-plots were not perfect, so there is still room for improvement, although this issue is likely to mostly affect confidence intervals (too narrow) but not the estimated CPUEs.
The CPUE uncertainties were generally larger in Q4 compared to Q1 and considerably larger before 2000. If early CPUEs (before 2000 and especially Q4 estimates) are to be used, then this change in uncertainty should be included.

WD 9. Stock Split.

Marie Storr-Paulsen

Since the last Baltic stock benchmark in 2015 a split has been applied in the SD 24 on the commercial data. The split is conducted by a combination of genetics and otolith shape (Fourier analysis) on Danish data only. For the survey conducted in SD 24 (Solea) the area has been split in a western component where all fish are assumed to be of western origin and a eastern component presently not used in either stock assessments.

However, in later years it seems as if an increasing proportion of the larger cod are present in SD 24 in the eastern part and these cod are presently not used in the stock assessment. During last years WGBFAS (2017) a sensitivity run was conducted with some preliminary data on the SD 24 survey split and this resulted in a much improved retrospective pattern in the western Baltic cod assessment. As the stock is due to a benchmark in 2019 and a data compilation workshop in fall 2018 it is the ambition to improve the commercial split by incorporating the German otolith shape pictures and genetics. For the survey in SD 24, the otolith shapes and genetics has been partly worked up by Germany, however the method has to be discussed and agreed upon at a workshop. The workshop is scheduled to be conducted in March and here the method for the splitting and the baseline will be agreed upon.

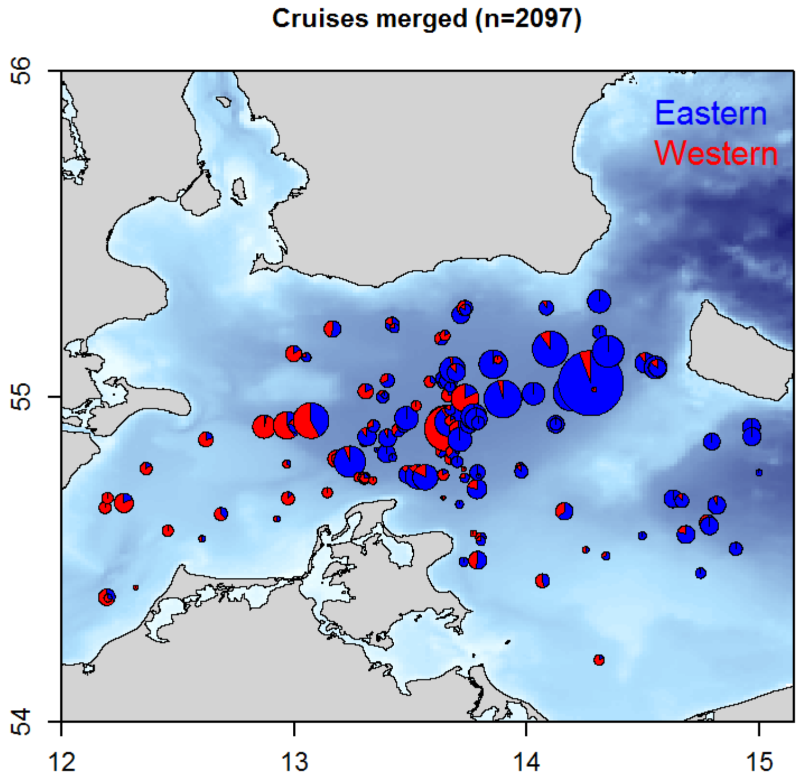

Figure XX. SD24. The size of the pies indicates the numbers of cod with genetics and the color is a symbol if the cod is of eastern (blue) or western (red origin).

WD 10. Mixing proportions of Baltic cod in SD24 and beyond

Since the cod benchmark 2015, mixed Baltic cod stocks in SD24 (Arkona Basin) are expected to be separated according to their stock assignment (ICES WKBALTCOD 2015). This requires reliable methods for stock separation. By combining genetics and otolith shape analysis the Thuenen Institute of Baltic Sea Fisheries (Germany) established a genetically validated baseline with stock-specific shapes, providing the basis for an individual assignment of unknown fish otoliths to their stock of origin. This combined approach enables the quantification of present and past mixing proportions of Baltic cod stocks with a classification success of 85%.

Survey data

A time series of annual mixing proportions of western Baltic cod (WBC) and eastern Baltic cod (EBC) in SD24 was developed, using cod otoliths (N=14273) from the German BITS in quarter 4 between 1992 and 2016. In the first half of the 1990s the proportion of WBC increased from 39% in 1992 to 68% in 1996 and decreased until the late 2000s to 27%. During the past ten years the mixing of WBC and EBC in SD24 was relatively stable with an average mixing proportion of 34% WBC and 66% EBC, reflecting the mean mixing proportions based on Danish commercial samples from 7 data years covering the period 2007 to 2016 (37% WBC to 63% EBC).

In addition to the overall mixing proportion in SD24, the time series separated by longitude revealed a remarkable occurrence of WBC in the eastern part of the Arkona Basin (14 to 74%) and EBC in the western part of SD24 (15 to 68%), suggesting that a mixing of the cod stocks may also occur beyond SD24.

The comparison of mixing proportions based on cod samples from German BITS in quarter 4 and quarter 1 (selected years only, N=3858 otoliths) did not show significant differences (3 to 10% deviation between quarters).

Commercial data

Otolith shape analysis of German commercial cod samples (N=2864) from 2015 and 2016 detected considerably different mixing proportions between active and passive gear fisheries in SD24. Lower proportions of WBC were found in catches using active gears (37% in 2015, 20% in 2016), confirming the results from survey catches (37% in 2015, 26% in 2016), and higher proportions of WBC were revealed in catches using passive gears (64% in 2015, 65% in 2016).

Additional analysis on German commercial cod samples from active gear fisheries in 2015 (N=2565) showed substantial proportions of WBC in SD25 and SD26 (on average 16%), as well as EBC in SD22 (17%). Differences between mixing proportions in active and passive gear fisheries were rather low in SD22 (active: 82% WBC, passive: 85% WBC).

In addition, commercial samples from 2014 to 2016 provided by Sweden (N=1824; SD24 and SD25) and by Poland (N=738; SD25 and SD26) were investigated (passive gear fisheries only). Otolith shape analysis revealed a significant occurrence of WBC in the northern part of SD24 and the western part of SD25 (24 to 26%), as well as in the southern part of SD25 and SD26 (19 to 40%).

Conclusion

Based on German survey data, it was shown that EBC dominate SD24 the past 10 years with an average proportion of 66%. Otolith shape analysis of German commercial catches revealed different mixing proportions in active (lower proportion of WBC) and passive gear fisheries (higher proportion of WBC), with the highest difference in SD24. Additionally, substantial mixing was detected also beyond SD24, with considerable proportions of EBC in SD22 and WBC in SD25 and SD26. WBC seems to be distributed more in shallow coastal areas while EBC seem to dominate the deeper areas. These findings challenge some prevailing paradigms and verification by genetic analyses is needed. Mixing is of concern because it is not yet clear if stock affiliation does cause bias in growth and mortality estimates (per SD).

WD 11. Effect of condition and length on Baltic cod fecundity: implications for SSB

Mion M.[1]*, Casini M.*[1]

[1]*SLU Aqua, Department of Aquatic Resources, Lysekil, Sweden;* [2]*IMR, Institute of Marine Research, Bergen, Norway*

An increasing number of studies have shown that SSB fails to accurately account for stock specific features that can produce different number of recruits at the same spawning biomass level, such as length composition and condition (Marshall *et al.*, 2006). Consequently when a stock is dominated by small individuals and/or with low condition, as in the case of the Baltic cod stock, this leads to an overestimation of the reproductive potential.

In this study we applied the auto-diametric fecundity method, as described by Thorsen and Kjesbu (2001), to estimate potential fecundity of 114 ovary sampled in 2015 and 2016. To investigate the relationship between potential fecundity and possible predictors (body size, gonadosomatic index, Fulton's condition factor and hepatosomatic index), a series of generalized linear models were used.

Body size, specifically length more than weight, was the best predictor of fecundity in terms of proportion of explained variance. The addition of condition and hepatosomatic index to the fecundity/length relationship increased the explained variance respectively of 5% and 6%.

The results of this study revealed that condition is already accounted for in the estimation of SSB (an increase in condition, and thus weight, is linearly related by an increase in potential fecundity), while length-structure of the spawning fish is not. Analyses based on the results from this study applied to time-series of SSB from BITS survey (currently used in advice) show that during the past 25 years, not accounting for changes in the length-structure of the mature fish, would give a bias of up to 30% in the estimation of stock reproductive potential.

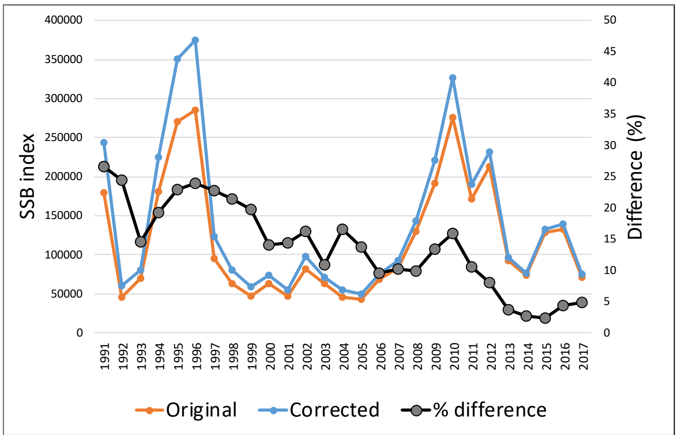

Fig. 1. Time series of SSB as currently used in assessment and for advice (orange line) and adjusted for changes in the size-structure of the mature fish (blue line). The black line shows the difference (%) in the two time-series. Only quarter 1 BITS was used in this analysis.

WD. 12 Application of the egg production method to estimate stock trends and spawning stock biomass

Fritz Köster, Bastian Huwer, Gerd Kraus, Rabea Diekmann, Margit Eero, Serra Orey, Jan Dierking, Piotr Margonski, Daniel Oesterwind, Jens-Peter Herrmann, Jonna Tomkiewicz, Andrei Makarchouk
DTU Aqua, GEOMAR Kiel, NMFRI Gdynia, IHF Hamburg University, TI-OSF Rostock, BIOR Latvia

Data and Methods

Egg production methods (EPM) provide a fishery independent source for determining stock trends and estimate stock sizes (for a recent review see Dickey-Collas et al. 2012 and contributions to the special volume of Fisheries Research 117). Additionally, they provide estimates of the stock reproductive potential. EPM's have earlier been tested for EB cod (Kraus et al. 2012) and are having the advantage that can provide absolute estimates of stock size independent of the uncertainties related to growth and natural mortality, which have prevented quantitative assessment of EB cod in the last years.

Since 30 years, ichthyoplanton surveys in the Eastern Baltic have been carried out regularly in a cooperation between Denmark, Germany, Latvia and Poland (ICES 2014). Additionally, Russia has conducted similar investigations in eastern Baltic areas, but the data are so far not included in international data base. In the present analysis, EPM is deployed for the Bornholm Basin, the most important spawning area of Eastern Baltic cod through the last 30 years (Fig. 1). The annual egg production method (AEPM) and the daily egg production method (DEPM) were deployed for the period 1991-2015.

The AEPM requires full egg survey coverage of the spawning season to estimate the annual egg production, and in addition relative fecundity (eggs/g body weight) as well as sex ratios. Relative fecundity values from Kraus et al. (2002) and Örey (unpubl.) were used in the present analysis with linear interpolation for missing years. A major concern in the application of EPM for EB cod was that low individual condition might have impacted on relative fecundity. However, Mion et al. (2018) found relative fecundity not affected by changes in condition and Örey (unpubl.) found even an increase in relative fecundity from 2005-2016, a trend which is factored into the present analysis.

The DEPM requires an estimate of the daily egg production at peak spawning time, individual spawning frequency (how many females are participating in spawning at a given date) as well as relative fecundity and sex ratios.

Results

Applications of both methods provided comparable results, and followed the large scale spawning stock trends of the BITS surveys, but with less year to year variations than in the BITS survey indices (Fig. 2). Until 2008, when BITS and SSB estimates from the past stock assessments follow similar trends, EPM yielded SSB's in the same order of magnitude, being however consistently lower at low and intermediate stock sizes.

The generally lower SSB estimates than estimated in stock assessments can be explained by two reasons: 1) not all spawning happens in the Bornholm Basin. The existing ichthyoplankton data can be used to roughly estimate SSB in eastern areas, but would benefit from integration of the AtlantNIRO data into the analysis and 2) the realized egg production from ichthyplankton surveys being generally lower than the potential egg production by the stock, due to a number of processes (Kraus et al. 2002) . At least some of these can be taken into account, such as lack of fertilization and sinking to the bottom as well as removal of eggs from the water column by predation, but this was not done in the analyses presented.

Processes which may affect the present estimates especially for recent years, but are more difficult to address, are: 1) beta atresia, i.e. atresia when the spawning activity progresses, ii) skip of spawning of sexually mature fish. Maturity staging on the Q1 BITS survey may be too early to quantify skip of spawning and the trawl surveys conducted during spawning time in parallel to the ichthyoplankton surveys are confined to the spawning area and thus may not cover sexually mature fish not entering the spawning areas. Both processes need to be studied for situations with low individual condition of sexually mature fish, to provide a better estimate of the reproductive potential of the stock.

The DEPM is based on the assumption, that at peak spawning time all sexually mature individuals are on the spawning ground, which historically was the case, but the assumption might not be met in most recent years with a prolonged spawning time and predominantly small fish in the spawning stock as their individual spawning time is shorter than in larger fish. In the present application, this is not considered and may explain the consistently lower SSB estimates in 2006-2012 derived by DEMP compared to AEPM.

Conclusions

Egg production estimates from ichthyoplankton surveys are quite robust (well defined and relatively small spawning area, no catchability problems etc.) and results from AEPM and DEPM are quite similar. The form of the seasonal egg production curve and extension of individual vs. population spawning period are methodologically most critical in the AEPM and the DEPM, respectively, but have limited impact on the overall trends in the estimated SSB. Thus, EPM based SSB trends can be recommended as tuning series for stock assessments. The SSB index could also be converted to stock abundance indices by applying length specific maturity ogives, weight at length and length structure in the stock from BITS.

To account for spawning in other spawning areas of the central Baltic, existing ichthyoplankton survey results can be used, but would benefit from the inclusion of AtlantNIRO data into the analysis. The impact on the trend in SSB is expected to be limited, as stock densities in eastern Baltic basins have been low throughout the last 25 years. However, the potential effect of low individual condition on beta atresia and skip of spawning should be investigated, especially to be able to apply EPMs to derive absolute SSB values in future.

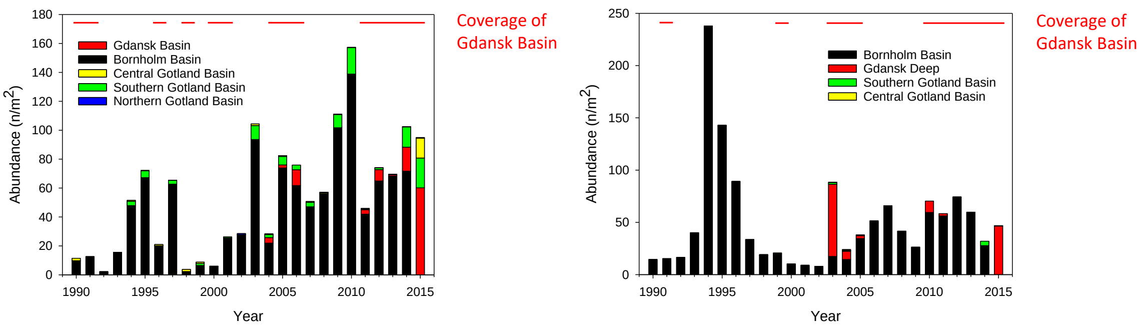

Fig. 1 Average egg abundance in May/June (above) and July/August 1990-2015 in different basins of the eastern Baltic from ichthyoplankton surveys, including an indication in which years the Gdansk Deep was covered (the other areas were covered annually).

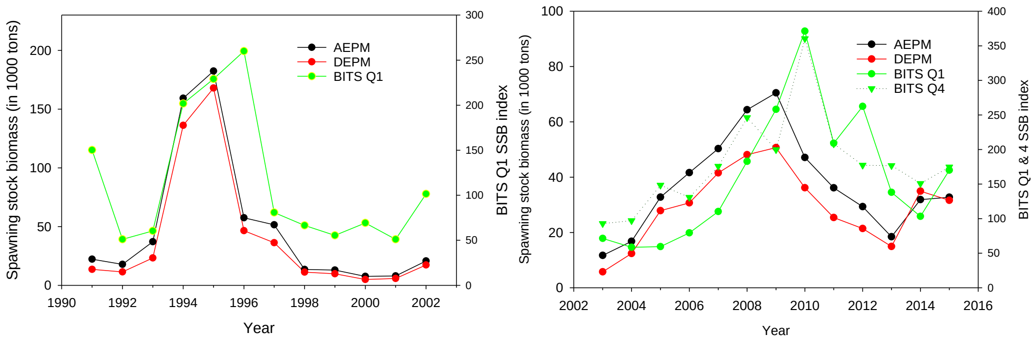

Fig. 2 Annual egg production (AEPM) and daily egg production (DEPM) method derived SSB in comparison to BITS SSB indices in 1st and 4th quarter 1991-2002 and 2003-2015.

References

Dickey-Collas, M, Somarakis, S, Witthames, PR, van Damme, CJG, Uriarte, A, Lo, NCH, Bernal, M (2012) Where do egg production methods for estimating fish biomass go from here? Fisheries Research 117: 6-11.

Kraus, G, Hinrichsen, H-H, Voss, R, Teschner, E, Tomkiewicz, J, Köster, F (2012). Robustness of egg production methods as a fishery independent alternative to assess the Eastern Baltic cod stock (*Gadus morhua callarias L.*). Fisheries Research 117: 75-85.

Kraus, G., Tomkiewicz, J., Köster, F.W., 2002. Egg production of Baltic cod in relation to variable sex ratio, maturity and fecundity. Can. J. Fish. Aquat. Sci. 59: 1908–1920.

Mion et al. (2018) Effects of fish length and nutritional condition on the fecundity of a distressed Baltic Sea cod Gadus morhua. Journal of fish biology (in press)

ICES 2014. First Interim Report of the Working Group on Atlantic Fish Larvae and Egg Surveys (WGALES), 1-5 December 2014, San Sebastian, Spain. ICES CM 2014/SSGESST:02. 66 pp.