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Report of the Benchmark Workshop on Baltic Stocks (WKBALT)

7–10 February 2017

Copenhagen, Denmark

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Contents

Executive summary

The Benchmark Workshop on Baltic Stocks (WKBALT) 2017 included an initial data collection workshop (DCW) 7-9 December 2016 and a benchmark meeting 7–10 February 2017. The group worked by correspondence between the two physical meetings. No specific official ICES data call took place in relation to the meeting.

The DCW was chaired by an ICES chair: Margit Eero (Denmark). The benchmark meeting in February was chaired by an ICES chair Noél Holmgren (Sweden) with the assistance of the external chair Verena Trenkel (France) and an ICES chair Margit Eero (Denmark). Two external experts reviewed the work conducted and provided comments and input during the discussions: Niels Hintzen (Netherlands) and Jim Seeb (USA).

The benchmark addressed originally three stocks: cod in Division 3.a East (Kattegat) and Herring in Subdivisions 30 and 31. During the DCW, the decision was made to merge the two herring stocks into one, and the benchmark thus continued with assessing the combined herring stock: Herring in SDs 30 and 31 (named herring in the Gulf of Bothnia). The decision for merging the two previously separate stocks was based on biological evidences or lack of these, on lack of data for conducting a separate assessment for SD 31, as well as management considerations.

For cod in the Kattegat, the main issues were related to explaining the unallocated removals that have been estimated to have occurred in recent years. Genetic studies revealed substantial presence of North Sea cod in the Kattegat area, and data on seal diet and population abundance suggested a higher natural mortality than previously assumed in the stock assessment of this stock. The data were however considered insufficient to directly include them in the stock assessment. Nevertheless this new information substantially improved the understanding of the causes for the unallocated removals estimated by the assessment model. There was lack of consensus among the experts concerning the most appropriate assessment approach to proceed with under current data conditions. WKBALT concluded to continue developing an analytical stock assessment, with the aim to use the assessment results quantitatively instead of only indicative of trends, which was supported by the external experts. However, work is still needed before this can be achieved and that work was continued after the WKBALT meeting. Unfortunately, it was not possible to complete this work within WKBALT. Thus, WKBALT finally concluded that the WGBFAS 2017 assessment should be based on SPALY (the same procedure as last year), i.e. the assessment based on a SAM model, where the results are used in the form of trends only rather than absolute values, with a few revisions in catch and survey input data. At the same time, further work towards quantitative use of the stock assessment results is ongoing, possibly leading to an inter-benchmark process.

For herring in SDs 30 and 31, the modifications made to the input data included adjusting the age of the plus-group (increased from 9+ to 10+), revising natural mortality values, and revising the calculation procedures for the commercial tuning series. Excluding the commercial tuning indices from the assessment (that was one of the aims of the benchmark according to the issue list) was not successful, thus the assessment continued to include the commercial tuning indices. Reference points were re-estimated for the new combined stock, and considering the modifications to the input data.

1 Introduction

1.1 Terms of reference

A **Benchmark Workshop on Baltic Stocks** (WKBALT), chaired by External Chair Verena Trenkel, France and ICES Chairs Noél Holmgren, Sweden and Margit Eero, Denmark, and attended by two invited external experts Jim Seeb, US and Niels Hintzen, Netherlands will be established and will meet in Copenhagen, Denmark 7–9 December 2016 for a data evaluation meeting and in Copenhagen, Denmark for a five day Benchmark meeting 7–10 February 2017 to:

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

i) Stock identity and migration issues;

ii) Life history data;

iii) Fishery dependent and fishery independent data;

iv) Further inclusion of environmental drivers, multi-species information, and ecosystem impacts for stock dynamics in the assessments and outlook

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

a)If no analytical assessment method can be agreed, then an alternative method (the former method, or following the ICES data-limited stock approach) should be put forward;

c) Re-examine and update (if necessary) MSY and PA reference points according to ICES guidelines (see Technical document on reference points);

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

e) As part of the evaluation:

   i) Conduct a 3 day data evaluation workshop (DEWK). Stakeholders are invited to contribute data (including data from non-traditional sources) and to contribute to data preparation and evaluation of data quality. As part of the data evaluation workshop consider the quality of data including discard and estimates of misreporting of landings;

   ii) Following the DEWK, produce working documents to be reviewed during the Benchmark meeting at least 7 days prior to the meeting

Stocks	Stock leader
Herring (*Clupea harengus*) in Subdivision 30 (Bothnian Sea)	Jukka Pönni
Herring (*Clupea harengus*) in Subdivision 31 (Bothnian Sea)	Jari Raitaniemi
Cod (*Gadus morhua*) in Division 3.a East (Kattegat)	Johan Lövgren

2 Description of the benchmark process

A number of issues have been highlighted for cod in the Kattegat and herrings in SDs 30 and 31 during the last assessment, and in some cases for a couple of years. For cod in the Kattegat, the main issue has been an unexplained decline of fish numbers within cohorts. These unallocated removals have been modelled with annual parameters for recent years. The main aim of the benchmark on this stock was to improve accounting for these unallocated removals by improved understanding and potentially quantifying natural mortality (especially due to seal predation) and mixing with North Sea cod. Revisiting tuning indices and evaluating representativeness of discard estimates were additionally identified as important issues.

For herring in SDs 30 and 31, a key issue to be considered by the benchmark was stock identification, i.e. whether to combine the two areas in one assessment unit, or continue assessing them separately. Additionally, a commercial tuning index has been used in the herring assessment in SD 30, which is undesirable, given the declining number of traps used to derive the index and general issues with using commercial cpue in stock assessments. One of the aims of the benchmark was thus to decide how to deal with diminishing number of trapnets in the Bothnian Bay, and to investigate whether the scientific survey index can be used alone, i.e. by excluding the commercial indices. Additionally, there is a large number of old herring in these areas, which called for exploring the effect of the age of the plus group used in the model as well as assumptions on natural mortality.

2.1 Data evaluation meeting

For cod in the Kattegat, the data evaluation meeting focused on reviewing new information and planning the work on: i) mixing of North Sea and Kattegat cod within the Kattegat; ii) predation mortality due to seals; and iii) evaluation of the quality of Danish discard estimates. Concerning discard estimates, a number of analyses evaluating the quality of Danish discard estimates were presented to the group who concluded that estimates could be considered reliable from 2011 onwards. For herring in SD 30 and 31, an important decision taken at the data meeting was to combine the two areas into one assessment unit. This was done based on evaluating both the biological basis, as well as data availability for the two areas.

The external chair joined the data evaluation meeting via WebEx. The product of the meeting was a work plan for and up to the benchmark meeting.

2.2 Benchmark meeting

All participants were encouraged to submit their work in working documents at least a week prior to the benchmark workshop.

For cod in the Kattegat, the most essential issue addressed was explaining the estimated unallocated removals. A number of presentations were given related to this topic.

There was lack of consensus in the group on how to proceed with the stock assessment for cod in the Kattegat, given this new information. Suggestions for proceeding were solicited at the meeting and each member got to express his/her opinion.

It is recognized that the participants of the meeting had different levels of expertise in specific questions and may represent different interests, thus the actual number of supporters of one or the other solution may not be useful for finding the most appropriate solution. Importantly, in the case of Kattegat cod, a clear division of opinions among the stock assessment experts became obvious. The conclusion of the meeting in terms of the stock assessment approach to proceed with was supported by the external stock assessment experts.

For herring, the benchmark meeting saw a number of presentations on the background related to the ToRs. The herring of Bothnian Bay and Bothnian Sea were presented and treated as a single stock: Gulf of Bothnia herring. Changes to the input data, and assessment settings and resulting effects on the assessment were presented to the group. The proposed changes were accepted by the meeting. During the meeting, Carmen Fernandez gave an introduction to ICES guidelines for calculating MSY reference points. The work for estimating reference points for the new combined herring stock took place by correspondence shortly after the meeting, and was approved by the group.

After the final meeting, the report was edited by correspondence and reviewed by the external experts.

3 Cod (*Gadus morhua*) in Subdivision 21 (Kattegat)

3.1 Issue list

Issue	Problem / Aim	Work needed / possible direction of solution
(New) data to be considered or quantified	Stock identity: Relative proportion between North sea/Kattegat/ Western Baltic	Genetic analyses during the year, old tagging experiments, stock mixing/inflow from other areas.
(New) data to be considered or quantified	Additional natural mortality factors	Seal diet and abundance.
(New) data to be considered or quantified	Recreational fisheries	Assessing the impact of the recreational fishery on the stock.
Tuning series	Revising all tuning series in the assessment. Drift in the tuning series, changes in catchability.	Internal consistencies, sensitivity runs in assessment models.
Discards	Representatives of discard estimates	Revaluate discard rates, sensitivity runs, applying different raising methods.
Biological Parameters	For some of the ages; Catch weight, stock weight, maturity from commercial sampling	Due to increasing catches of large cod in the surveys, these can be used for estimates of biological parameters.
Fisheries & ecosystem issues and data	Connectivity of areas by abiotic factors	Hydrographical situation between years.

3.2 Stock ID and sub-stock structure

Genetic samples from cod in the Kattegat were analysed for selected years in the period from 1996 to 2016, about 1800 fish in total. The SNP panel used in the analyses demonstrated high power for identifying population of origin for cod collected in the Kattegat (either North Sea or wider Kattegat area). Results generally confirmed the overall hypothesis that North Sea cod enter the Kattegat at early life stages and leave at later life stages. Thus, generally a higher proportion of smaller cod in the Kattegat is of North Sea origin, compared to larger/older cod. Additionally, there is a spatial gradient with a higher proportion of North Sea cod in the northern part of the Kattegat compared to the southern Kattegat that mostly contains cod of Kattegat origin (Fig. 3.1). The results from genetic analyses are described in detail in WD 3.1.

The genetics method applied can be used for continuous monitoring of population mixing using samples from both surveys and fisheries, and can also be applied to archived otoliths to provide DNA based time–series of mixing proportions in the Kattegat.

The genetic results confirmed that a migration of North Sea cod from the Kattegat back to North Sea takes place. This could explain part of the unallocated removals that have been estimated by the stock assessment model. The migration of cod in and out of Kattegat is not fully understood.

If it is assumed that migration of North Sea cod into the Kattegat takes place during a short period, e.g. as juveniles, and that fishing mortality (F) and natural mortality (M) are the same for the two components within the Kattegat, the emigration mortality (I) of North Sea cod back to the North Sea can be estimated :

$$\frac{Nkat_{y+1,a+1}}{Nnor_{y+1,a+1}} = \frac{Nkat_{y,a} * e^{-(M\ a,y+F\ a,y)}}{Nnor_{y,a} * e^{-(M\ a,y+F\ a,y)} * e^{-I}} \qquad \Leftrightarrow$$

$$I = -log\left(\frac{Nkat_{y,a}}{Nnor_{y,a}} \Big/ \frac{Nkat_{y+1,a+1}}{Nnor_{y+1,a+1}} \right)$$

Nkat (number of cod with Kattegat origin) and Nnor (number of cod with North Sea origin) are not known, however we may obtain a reliable estimate of the ratio between the two stocks at a given year and year class from samples of genetic origin and survey abundance data (Table 3.1).

From cod density distributions and maps providing information on stock origin (**Error! Reference source not found.**) it is, for each location and time, possible to estimate density of cod and their origin. From this, the number (index) of Kattegat and North Sea cod can be calculated, by integrating over the full Kattegat area. This index can be used for a ratio between the two components, (not for the absolute numbers), provided that "catchability" is the same for the two components and in subsequent ages (*a* and *a*+1).

Table 3.1. Ratio (Kattegat cod N:North Sea origin cod N) estimated from quarter 4 survey data and stock origin model. (m82: AIC=1289.6 BIC:1472.1 Dev.expl:0.41

Model: factor(yc)+s(cage,bs="ts",k=6)+te(lon,lat,d=2,bs="tp",k=40)

m82	Kattegat N:North Sea N							Migration mortality				
	Age 1	Age 2	Age 3	Age 4	Age 5			Age 1	Age 2	Age 3	Age 4	Age 5
2009	1.62	NA	NA	NA	NA		2009	0.14				
2010	0.96	1.87	NA	NA	NA		2010	0.09	1.07			
2011	1.44	1.05	5.47	NA	NA		2011	0.27	0.94			
2012	0.49	1.88	2.68	NaN	NA		2012	-0.13	0.70	0.54		
2013	1.37	0.43	3.8	4.61	13.17		2013	0.03	0.40	0.55	0.10	
2014	1.14	1.41	0.64	6.6	5.09		2014	-0.12	0.58	0.64	0.07	
2015	1.36	1.01	2.51	1.21	7.09		2015					

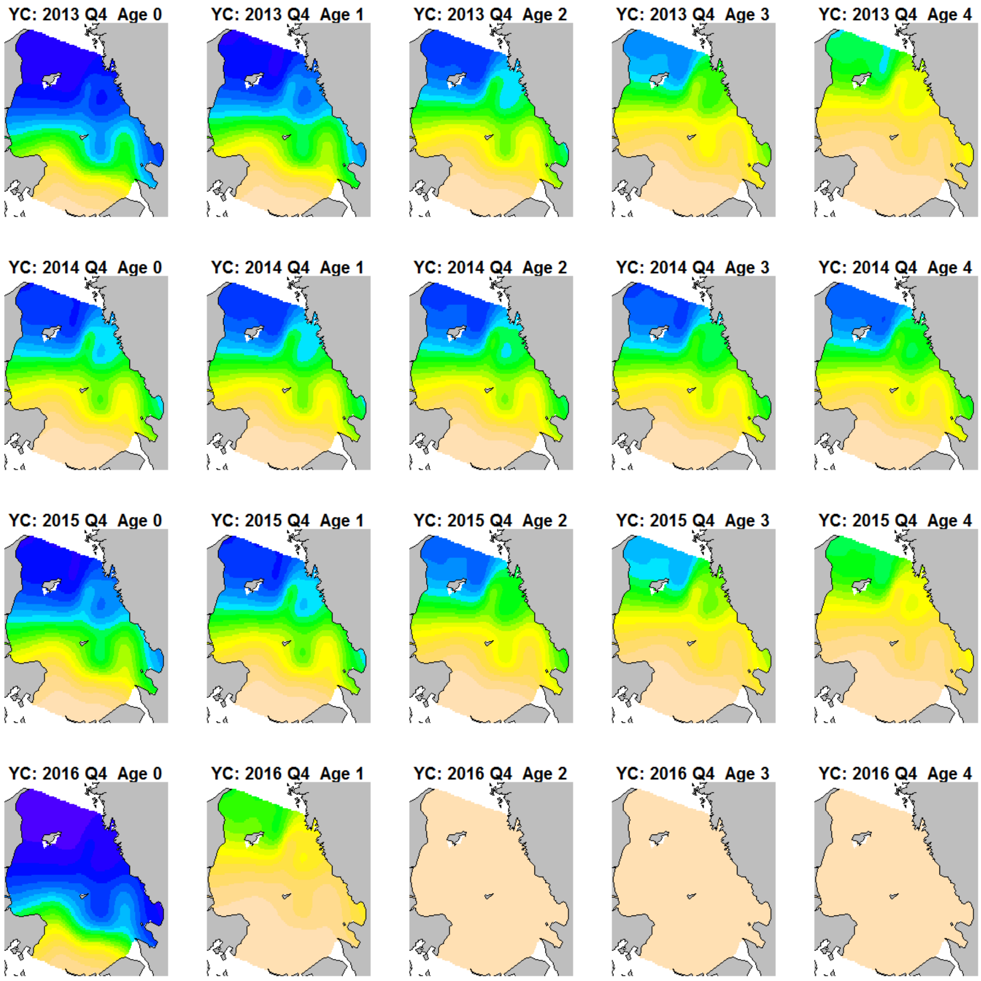

Figure 3.1 Predicted probability of Kattegat origin by year class (yc) and age. Blue colours indicate low probability of Kattegat cod. YC year class.

3.3 Scorecard on data quality

The data quality issues addressed at WKBALT focused specifically on discards and age reading. Scorecard was not used.

3.4 Multispecies and mixed fisheries issues

Cod in the Kattegat is currently mainly caught as a bycatch species. Background information on fisheries is provided in the Stock Annex. Mixed fisheries issues are central for fisheries management in relation to the landings obligation.

3.5 Ecosystem drivers

Ecosystem issues considered at WKBALT were related to inflow of cod from the North Sea and predation by harbour seals. These topics are covered in the Stock ID and Natural mortality sections, respectively.

3.6 Stock assessment

3.6.1 Catch data

3.6.1.1 Landings and Discards

The time–series of Danish discard data was revised to make the estimation procedures consistent across the entire time–series starting in 2000. The reasons for revision were: a) missing data were not imputed, b) the old time–series were based on two different estimation methods.

Previously, in the time–series up to 2010, a running 3-year mean had been applied to discard estimates, which implies that year-class effects had been smoothed out. The estimation method used for the old and the new time–series is fundamentally the same, the differences are mainly due to the revised stratification of the samples in the estimation and no longer smoothing.

Additionally, an error in landings-at-age data for 1997 was corrected. The difference between the revised and previous total international catch–at–age is shown in Figure 3.2. The effects of this revision on stock assessment results were relatively minor, though estimated fishing mortality in recent years was somewhat reduced (Figure 3.3).

The quality of Danish discard estimates in general was discussed as well. A number of analyses were presented to check for possible bias in the estimates due to refusal of some vessels to take observers on board, and due to possibly changed behaviour and thereby discarding practise of fishermen while having observers on board (See WD 3.2 for details). The analyses conducted did not detect severe biases in discard estimates. WKBALT concluded that since 2011, when statistically sound discard sampling commenced, the discard estimates from observer program are expected to reliably represent the order of magnitude of discards. Similar detailed analyses of Swedish discards were not presented, however WKBALT did not consider it likely that several orders of magnitude of discards would be missing from the estimates.

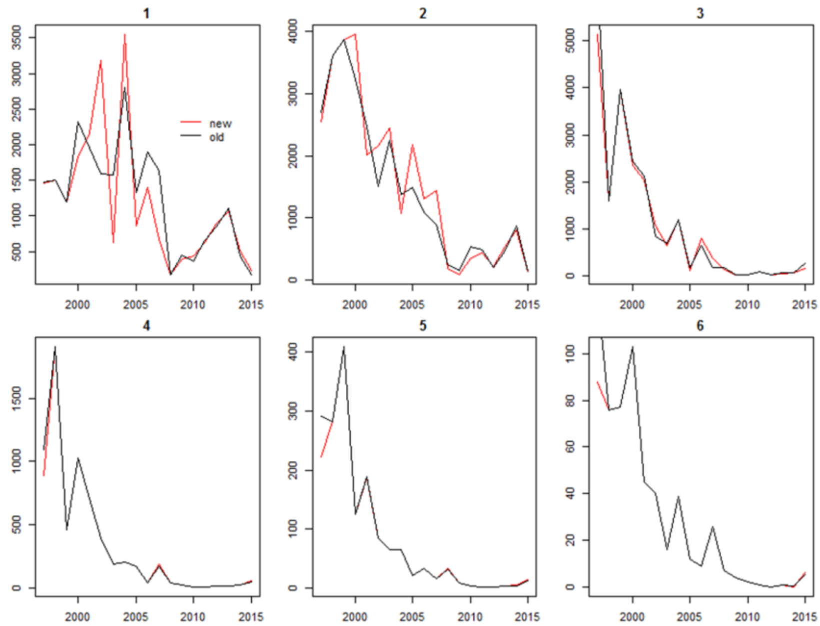

Figure 3.2. Revised catch-at-age (red lines), compared to the previous values (black lines) used in assessment in 2016.

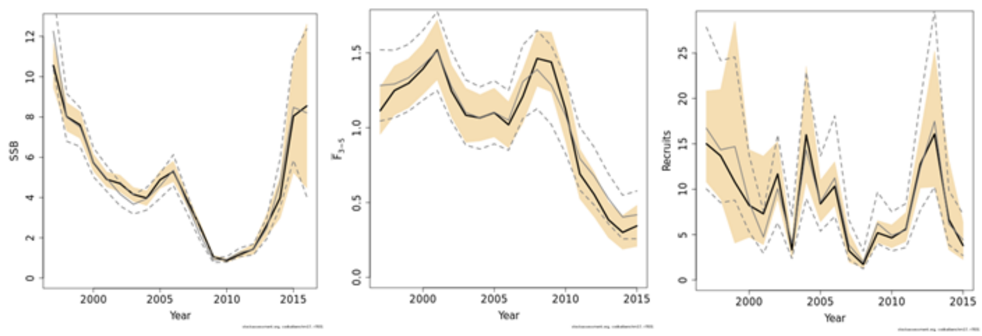

Figure 3.3. Comparison between the 2016 assessment (grey lines) with the assessment using revised catch-at-age data (black bold lines) (all other data and settings kept as in 2016 assessment).

3.6.1.2 Recreational catches

Recreational cod catches are monitored in Denmark by recall surveys. The estimation method has been reviewed by ICES WGRFS that concluded that the data would be suited for being integrated into assessment work though supporting data would be needed to verify effort and catch estimates and get biological samples. This conclusion was supported by WKBALT, i.e. recreational catch data are not considered to be ready to be included as input into the stock assessment.

3.6.2 Biological data on catch

In terms of the quality of biological data, an issue had been raised regarding possible bias in age reading. Consequently, WKBALT focused on clarifying this issue.

An exchange of otoliths between Sweden and Denmark was conducted (WD 3.3). The agreement between the primary age readers from Denmark and Sweden for Kattegat cod (SD21) was very high with no systematic bias between readers. These results mean that there are no consistent ageing errors which would have an effect on the stock assessment of Kattegat cod (SD21). However, the age reading comparison only included fish up to 3 years of age. Thus, age reading comparison for older ages is recommended to be conducted in the future.

3.6.3 Surveys

3.6.3.1 Distribution of cod

Distribution of cod by size-groups and at different seasons was modelled using cpue from survey data and GAM analyses. Predicted distribution maps are provided in WD 3.4.

A centre of gravity analysis for IBTS Q1 data indicated a shift in distribution with a more northerly distribution since around 1998 for the 40+ cm cod and since 2000–2006 for the smaller size classes. The distribution is not constant between years within sub-periods, e.g. before and after 1998, but the probability of a more northerly distribution is highest within the most recent sub-period.

3.6.3.2 Comparison of approaches for calculating survey indices

Statistical analyses were conducted to investigate whether the consistency of survey indices could be improved by better use of age-length information and different ways of calculating survey indices were investigated.

The results indicated that direct use of age samples from surveys seems sufficient to make empirical ALKs, as little was gained by modelling ALKs (e.g. using a continuation logit GAM). This conclusion is conditional on the use of pooled age–length data (all available survey data within a quarter and year) versus modelled ALK. Comparison with survey specific ALKs was not carried out.

The methodology (simple mean, stratified mean or weighted stratified mean) for calculating survey indices from trawl CPUE-at-age seemed to have limited effects on the final indices.

Catch curve analysis provided a total mortality Z (F+M+migration) in the range of 0.55–0.90 for the combined Q1 indices covering the period since 1997. The much shorter time–series for Q4 provided a Z around 1 for all age groups.

BITS Q4 indices have very low consistency between the age-groups of cod, thus providing limited information to stock assessment. WKBALT concluded to exclude BITS Q4 (Havfisken) indices from the stock assessment of Kattegat cod.

3.6.3.3 Survey indices taking into account stock origin

The available genetic data on proportions of North Sea and Kattegat cod within the Kattegat area were used to adjust survey indices so these would represent the Kattegat population only (Fig. 3.4, 3.5). Different approaches for splitting were explored which are described in WD 3.5. The trends in survey indices, including the pronounced increase in later years, were similar for the entire Kattegat area and for the stock. This suggests that the increase in cod biomass in the Kattegat in recent years represents a true increase of the Kattegat cod population. The exact values for survey indices vary between years, depending on the splitting approach used.

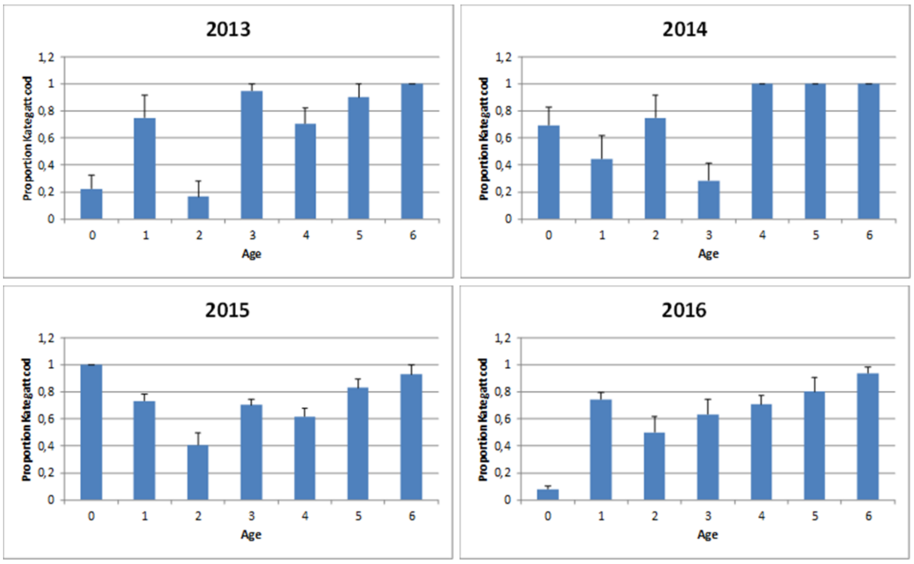

Figure 3.4. Yearly splitting keys for separating individuals of North Sea and Kattegat origin for 2013–2016.

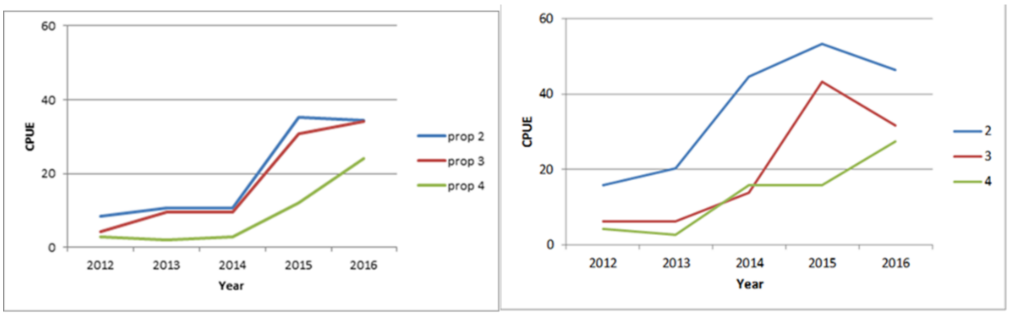

Figure 3.5. Survey index derived from IBTS Q1 2012–2016 for ages 2, 3and 4. Without using the origin splitting key (right) and with using the origin splitting key (left).

3.6.4 Alternative estimates of fishing impact

The predicted spatial distribution of cod based on survey data, combined with fishing effort for the TR2 fleet segment and an assumption on the selectivity of fishing gears was used to estimate the relative change in fishing impact on cod in the Kattegat since 2007. Both Danish and Swedish VMS data were used in the analyses. The calculation methods are described in Vinther and Eero (2013). The results suggest a reduction in fishing impact approximately by factor 5 since 2007 (Fig. 3.6). A similar trend was obtained for the Kattegat cod component, when taking into account the spatial distribution of the true Kattegat cod, based on the available genetic data.

Fig. 3.6. Relative fishing impact on cod in the Kattegat by size class created by the TR2 fleet segment. Numbers indicate body size ranges.

3.6.5 Mean weight and maturity

Mean weight or maturity data were not considered a major issue for this stock presently, thus these have not been investigated at WKBALT.

3.6.6 Natural mortality

The number of harbour seals in the Kattegat has increased 3-fold since the 1980s, presumably resulting in increased predation mortality on cod. Diet data from 52 seals hunted in the Kattegat was available for the period 2009–2011, mostly collected in the northern part of Kattegat during quarters 3 and 4. These data showed roughly 10% of cod in the diet of harbour seals, in terms of weight. The length distribution of cod in the diet indicated that harbour seals consumed mainly cod in the size range 12–25 cm.

Considering the number of harbour seals in the Kattegat (ca. 10 000 in recent years), assuming a daily consumption of 4 kg per individual, and assuming 10% of the diet to be cod, estimated that roughly 1500 t of cod are being eaten by harbour seals annually, which is a considerably larger amount than what is taken by fisheries.

Exploratory analyses were made to calculate a time–series of numbers–at–age eaten by seals and to include this in the stock assessment (see WD 3.6 for details). The analyses resulted in high predation mortality estimates for young ages (above 1.0), which was considered unrealistic. Furthermore, the dataset of seal diet was considered small and possibly not representative for the entire Kattegat and for all seasons. Moreover, WKBALT expressed concerns whether the proportion of cod in seal diet can be assumed constant between years, considering functional response to prey availability. Thus, further analyses of availability of other prey were recommended. In conclusion, WKBALT considered it to be immature to include the seal predation estimates directly in the stock assessment. However, it is recognized that a constant natural morality of 0.2 currently assumed for all years and ages is unlikely to represent true dynamics in natural mortality.

3.6.7 Stock assessment models

3.6.7.1 Exploratory SAM runs taking into account seal predation

Two ways to incorporate seal predation in the assessment were explored, one is to include them as a "fishing fleet" via catch numbers, the other way is to incorporate them as natural mortality, using the derived seal predation mortalities as described in WD 3.6.

The natural mortality in the SPALY run is 0.2 for all ages and all years.

SAM runs were performed:

1) With only natural mortality from the seals
2) Adding 0.1 to the seal natural mortality (all ages , all years)
3) Adding 0.2 to the seal natural mortality (all ages, all years)

As seal predation mortalities were estimated to mainly affect younger ages, the main effect of including seal predation was seen on recruitment, with considerably larger values (factor 2–3) in runs including seal predation, especially in later years. The effect on SSB and F_{bar} was limited, but SSB was generally higher without seal predation and F was lower. Similar results were obtained when including numbers–at–age eaten by seals as catch–at–age matrix, though the effect on recruitment estimates was even larger.

3.6.7.2 Exploratory runs taking into account stock origin

An exploratory run was made for the Kattegat cod population where both survey and catch data for the Kattegat area were split using the genetic information available. This exercise involved crude assumptions that the proportion of North Sea cod in the Kattegat is the same for all years. The results showed similar trends in SSB and F compared to the 2016 assessment for the area, but with lower estimates of recruitment and SSB.

3.6.7.3 Final assessment

There was lack of consensus at the meeting on how to proceed with the assessment for this stock. The most important outcome of the meeting for cod in the Kattegat was considered to be the improved understanding of the unallocated removals estimated in the model. Previously the explanations for this had been more hypothetical, while at WKBALT it was demonstrated that a large part of these unallocated removals can be explained by migration and possibly increased natural mortality. However, there were divided views among the experts on how to proceed with the assessment given this new knowledge.

Two approaches were favoured: i) to only base the assessment on relative cpue trends from surveys, or ii) continue with the analytical assessment with the aim to move the assessment towards a category 1 type with estimates to be used quantitatively. The external experts saw potential in and supported the latter approach. It was concluded to continue working with an analytical assessment. However, it was recognized that more work is still needed to be able to use the assessment results in quantitative terms. This is especially true regarding fishing mortality estimates that are not a direct outcome from the present SAM model code, as the mortality estimates from the model currently include fishing as well as migration and potentially unaccounted natural mortality.

Until this work is done, WKBALT concluded to continue with SPALY (the same procedure as last year), which implies that the assessment is conducted for cod in the Kattegat area using the SAM model, but the assessment results are only used in the form of trends to provide advice. The differences to be made compared to last year's assessment (SPALY) agreed upon at WKBALT were:

i) Catch-at-age data are revised, resulting from the Danish revision described in 3.6.1.1

ii) BITS (Havfisken) Q4 survey is excluded

At the end of the WKBALT meeting, the process with respect to further work on the assessment of cod in the Kattegat remained open, with a possibility to conduct additional work to be reviewed prior to WGBFAS 2017 and possibly allowing using the assessment results in quantitative terms in 2017.

After the meeting, the additional work required was initiated, however it was concluded not possible to complete the work, including forecast and estimating reference points, in this very short time frame to allow it to be reviewed prior to WGBFAS. Thus, it was finally concluded that the WGBFAS 2017 assessment should be based on SPALY (with the modifications described above). At the same time, the work towards a quantitative use of the assessment results should continue, possibly leading to an interbenchmark process.

3.7 Short-term projections

No short–terms projections are available for this stock and none have been discussed at WKBALT.

3.8 Appropriate reference points (MSY)

Reference points were not addressed at WKBALT.

3.9 Future research and data requirements

In order to improve understanding of the dynamics of inflow of North Sea cod into the Kattegat and outflow of Kattegat cod into the Skagerrak, it is necessary to extend the stock separation data further back in time, to cover different stock sizes of cod in the Skagerrak and Kattegat. This is because the proportion of North Sea cod within the

Kattegat may vary in time, and assuming the same proportions between years may thus be incorrect. Extended time–series of stock separation keys are a prerequisite for being able to evaluate the historical dynamics of the true Kattegat stock. Further, continued monitoring of the North Sea component in the Kattegat is needed to be able to account for stock structure in fisheries management in the future.

The work conducted for WKBALT revealed potentially much higher natural mortality on cod than presently assumed in the stock assessment, mainly due to seal predation. However, the available data are not sufficient to be included in the stock assessment. Extended spatio-temporal coverage of seal diet data would thus be needed to reliably estimate seal predation. This should include improved spatial coverage of the Kattegat, and better coverage of different seasons and years with different cod stock sizes and availability of other prey items.

3.10 References

Vinther, M., and Eero, M. 2013. Quantifying relative fishing impact on fish populations based on spatio-temporal overlap of fishing effort and stock density. ICES Journal of Marine Science 70 (3): 618–627

3.11 Working documents for cod in the Kattegat

WD 3.1 Cod population mixing in the Kattegat

WD 3.2 Danish discard data revision and evaluation of data quality

WD. 3.3 Cod age reading exchange

WD 3.4 Stock distribution of cod in the Kattegat from spatial GAM analysis of survey cpue.

WD 3.5 Survey indices taking into account stock origin

WD 3.6 Numbers of cod eaten by harbour seals

4 Herring (*Clupea harengus*) in Subdivisions 30 and 31 (Gulf of Bothnia)

4.1 Stock ID and sub-stock structure

The herring in the Gulf of Bothnia has been assessed as two separate stocks, herring in SD 30 and herring in SD 31, from 1990 to 2016. The SD 31 stock is very small compared to SD 30 stock; the later has increased since the early 2000's.

Biological information suggests that growth and maturity patterns are similar between the areas, but strong year-classes do not occur at the same time (WD 4.1).

No research surveys are made in SD 31, and such surveys are unlikely to start in the future. The only relative abundance index available for SD 31 comes from commercial fleets, which are uncertain especially for species like herring. Further, fishing effort is declining, and it is unknown whether it will be possible to continue the present time–series of commercial CPUE in the future.

It was concluded at the data evaluation WK to combine the herring stocks in SDs 30 and 31 as one stock assessment unit. The main arguments for combining these previously separate assessment units were:

i) There is no strong biological evidence either for combining or separating SDs 30 and 31 for stock assessment, the WK recommends to do genetic- and tagging studies in the future.

ii) Data availability (lack of survey in SD 31) does not support a good quality assessment for SD 31 and this is unlikely to be possible to improve in the future.

iii) There is no concern for overexploitation of the smaller stock component in SD 31 when merged together with a larger component in SD 30. This is because of natural conditions (ice and bottom features: difficulties in trawling) restricting fisheries in SD 31, and there is generally low economic interest in herring fisheries in SD 31.

4.2 Issue list

Before the WKBALT Data Evaluation Workshop meeting, the issues for Benchmark were stock-specific for two separate stocks (see table 4.2.1 below). After the decision of merging the stocks, most of the issues that were related to the Her-31 assessment (e.g. tuning series, testing of commercial CPUE series, Assessment method and Reference points) became irrelevant.

The issues left for the merged stock were:

- The issues related to the trapnet tuning series (expanding the age distribution in canum matrix from plus-group 9+ years)
- Rectifying and testing the acoustic tuning series (expanding the age distribution in tuning indices from previous plus-group 8+, and adding age 1 to the series). Also, an error was found in the way of using a plus-group for survey indices in the previous assessment, the effect of which was explored.
- Listing, checking and testing ecosystem issues (impact of seal-predation)
- Producing MSY reference-points

Table 4.2.1. Issue lists for Bothnian Sea (SD 30) and Bothnian Bay (SD 31) herring stocks

SD	Issue	Problem / Aim	Work needed / possible direction of solution	Data needed to be able to do this: are these available / where should these come from?
30	(New) data to be considered or quantified	**1)** Combining or **2)** leaving separate Her 30 and Her 31 stocks	**1)** data compilation **2)** no action	Data is available for both stocks
30	Tuning series	**1)** The faith of Trapnet tuning series	**1)** Trials to get rid of it. On the other hand it is holding back the model from producing unbelievably huge biomass estimates.	no
30	Tuning series	Acoustic series	**1)** Trying to leave out the years with bad coverage (2 years). **2)** Test adding age 1 to the series	Available from Datras
30	Discards	no	no	no
30	Biological Parameters	no	no	no
30	Fisheries & ecosystem issues and data			
30	Assessment method	no	no	no
30	Biological Reference Points	PA-values	Checking calculations with different methods/ different assessments (i.e. with and without Trapnet tuning)	No additional data needed
30	Other	no	no	no
SD	Issue	Problem / Aim	Work needed / possible direction of solution	Data needed to be able to do this: are these available / where should these come from?
31	(New) data to be considered or quantified	**1)** Combining or **2)** leaving separate Her 30 and Her 31 stocks	**1)** data compilation **2)** no action	Data is available for both stocks
31	Tuning series	Will exploratory runs be continued with the present fleet?	Trials with possible alternatives.	
31	Tuning series	no	no	no
31	Discards	no	no	no
31	Biological Parameters	Maturity data	Checking if maturity sampling is optimal	Data is available
31	Fisheries & ecosystem issues and data	Consistences in CPUE data (trapnet, trawls), maturity sampling	Testing with the data.	Data is available
31	Assessment method	XSA or SAM?	no	Data is available
31	Biological Reference Points	Only if category is raised.		
31	Other	no	no	no

4.3 Data compilation for her 30 and her 31

4.3.1 Merging the data for her 30 and her 31

The CANUMs from both stocks were summed by year (1980–2015) and age-groups 1–15+. The weights–at–age in the catch were combined by weighting the stock specific WECAs with the corresponding stock-specific catch numbers. The shares of mature individuals at age were also weighted by the catch numbers of the corresponding stocks (documentation in WD 4.1).

The time–series that previously started from 1973 in SD 30 was shortened to start from 1980 to be compatible with the time–series for SD 31 due to the unavailable Finnish catch data before 1980 and Swedish data even for years before 2010.

4.3.2 Age structure of input data

The catch sampling performed by Finland and Sweden (ICES, 2016a) is considered to be adequate and sufficient. The age readings for the herring stocks in the Gulf of Bothnia area were recently validated (in 2016 according to agreed procedure from WKNARC) and they showed very good agreement between readers (Raitaniemi pers. comm.).

According to the recommendation of the 2016 WKBALT Data Evaluation Workshop, setting a plus-group for herring in ICES SDs 30 and 31 was revisited, for which data were prepared by splitting former plus-group 9+ into ages 9 to 15+. This applies to *catch in numbers–at–age*, *weight–at–age in the catch* (also used as weight–at–age in the stock) and *maturity–at–age* for both stocks as well as *numbers–at–age* in the *trapnet tuning fleet*, which now comprises true ages 3 to 14 years. For the acoustic abundance indices (*acoustic tuning fleet*) the age–group 8+ was split into true ages 8–14 years, and also the age–group 1 was added, since it showed similar consistency as older ages.

The values corresponding to true ages from age 1 to the last true age in the former matrix were kept as they were in the former input. In all catch numbers (CANUM and trapnet tuning fleet) the former plus group was divided into individual ages using Finnish expanded quarterly ALKs. Since Swedish data was not available the Swedish catches were assumed to have the same age distribution for ages 9–15+ as the Finnish catches.

Weight–at–age and maturity–at–age for ages 1 to 8 were kept the same as in previous assessments. The expanded age distributions were derived from the raw data according to normal procedure (the annual weights at age quarterly weighted by respective catch numbers and the maturities–at–age by the share of mature individuals in all age groups).

No issues with weights–at–age in catches and maturities–at–age were presented by the data evaluation WK.

In the WKPELA 2012 benchmark we tested the sensitivity of the annually changing proportions of spawners in age–groups and even though there are clearly visible annual changes for mostly 2–year–olds, there was only negligible impact on e.g. estimates of SSB. It was concluded then that it was better to use the latest data on maturity at age (ICES, 2012).

During WKBALT meeting several different plus-groups (9+ to 15+) in the age-matrices of the assessment input data were examined and finally the age group 10+ was chosen to be used in the final assessment (see WD 4.6.)

4.3.3 Acoustic survey

The geographical coverage and sampling of annual surveys were examined according to recommendations of the WKBALT data evaluation workshop.

The coverage of the acoustic transects and trawl samples has mostly been good. In 2012 the coverage was only half of the "normal" because of a sudden 50% reduction in funding. In 2014 there were problems with the fishing gear, which reduced the number of trawl hauls, but the spatial acoustic coverage was not affected. In 2015 a storm damaged the ship so that the most northern part of the area had to be skipped due to lack of time after fixing the damage in harbour.

The 2012 50% reduction in the survey effort, as well as the 2014 and 2015 results were, however, considered acceptable for the index by the survey expert working group, ICES WGBIFS (ICES, 2013; ICES, 2015; ICES, 2016b).

4.4 Scorecard on data quality

Table.4.4.1:Scorecard

Scorecard on data quality				
	No bias	Potential bias	Confirmed bias	Comment
A. SPECIES IDENTIFICATION				
Species subject to confusion and trained staff				
Species misreporting				There is a small seasonal bycatch of sprat and stickleback, which may be ignored by the fishermen when repoting their catches
Taxonomic change				
Grouping statistics				
Identification Key				
Final indicator				
B. LANDINGS WEIGHT				
Recall of bias indicator on species identification				
Missing part				There are no observations nor any data on "missing part". This, however is not considered to have any consequences on the catch estimates.
Area misreporting				
Quantity misreporting				
Population of vessels				
Source of information				
Conversion factor				
Percentage of mixed in the landings				There is a small seasonal bycatch of sprat and stickleback, which may be ignored by the fishermen when repoting their catches
Damaged fish landed				
Final indicator				
C. DISCARDS WEIGHT				
Recall of bias indicator on species identification				
1. Sampling allocation scheme				There is no discarding in the fisheries
2. Raising variable				
3. Size of the catch effect				The total catch weight is estimated by the fishermen in the time of taking the sample
4. Damaged fish discarded				
5. Non response rate				
6. Temporal coverage				
7. Spatial coverage				
8. High grading				
9. Slipping behaviour				
10. Management measures leading to discarding behaviour				
11. Working conditions				
12. Species replacementFinal indicator				
D. EFFORT				
Recall of bias indicator on species identification				
1. Unit definition				
2. Area misreporting				
3. Effort misreporting				
4. Source of information				
Final indicator				
E. LENGTH STRUCTURE				
Recall of bias indicator on discards/landing weight				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Random sampling of boxes/trips				The sampling is more oppotunistic than random. The sub-sampling from catches is done -according to protocol- in a manner so that the whole catch will be presented in the sample (minimum of 3 batches presenting different parts of the catch)

5. Availability of all the landings/discards				
6. Non sampled strata				
7. Raising to the trip				
8. Change in selectivity				
9. Sampled weight				
Final indicator				
F. AGE STRUCTURE				
Recall the bias indicator on length structure				
1. Quality insurance protocol				
2. Conventional/actual age validity				The age-reading in done from cut otoliths, which is considered to be an accurate (reliable) method
3. Calibration workshop				
4. International exchange				
5. International reference set				
6. Species/Stock reading easiness and trained staff				Before 2002 age-reading from whole otoliths may have some bias
7. Age reading methods				
8. Statistical processing				none
9. Temporal coverage				
10. Spatial coverage				
11. Plus group				
12. Incomplete ALK				Usually all quarterly available age-classes are present in ALKs. The 0- and 1-year olds are short in commercial catches, and sometimes their age is estimated from the size of fish.
Final indicator				
G. MEAN WEIGHT				
Recall of bias indicator on length/age sturcture				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Statistical processing				
5. Calibration equipment				
6. Working conditions				
7. Conversion factor				
8. Final indicator				
H. SEX RATIO				
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Staff trained				
5. Size/maturity effect				
6. Catchability effect				
Final indicator				
I. MATURITY STAGE				
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Appropriate time period				
3. Spatial coverage				
4. Staff trained				
5. International reference set				
6. Size/maturity effect				
7. Histological reference				
8. Skipped spawning				
Final indicator				

4.5 Multispecies and mixed fisheries issues

Sprat is found especially in the southern parts of SD 30 in the winter months. In October–November, when it has been the most abundant in the commercial catch, its proportion in combined herring and sprat landings has in the recent years been 5–35% (Figure 4.5.1), but mostly its proportion is below 5%. Vendace (*Coregonus albula*), a pelagic freshwater fish sensitive to even low salinities, is a valuable species especially in the northern and northwestern parts of SD 31. The southeastern parts of SD 31 are herring areas, where vendace is not very abundant. Thus the catches of vendace in the herring fishery are low.

In the survey catches, a very common species in SD 30 in addition to herring, has been three-spined stickleback. The sticklebacks spend the daytime mainly in a different layer, i.e. in shallower water than catchable size groups of herring. A part of herring fingerlings are found close to the sticklebacks. The history of the abundance of sticklebacks is poorly known, however, their numbers are thougth to have increased over the long–term.

The number of predators on herring is low. Salmon and cod are occasionally predating on herring in SD 30, but their effect is insignificant. The number of grey seals has increased in the Gulf of Bothnia (WD 4.2), but total mortality of herring has still been estimated to be very low (0.188–0.305) and shows a decreasing time trend (0.188 in 2015; WD 4.3).

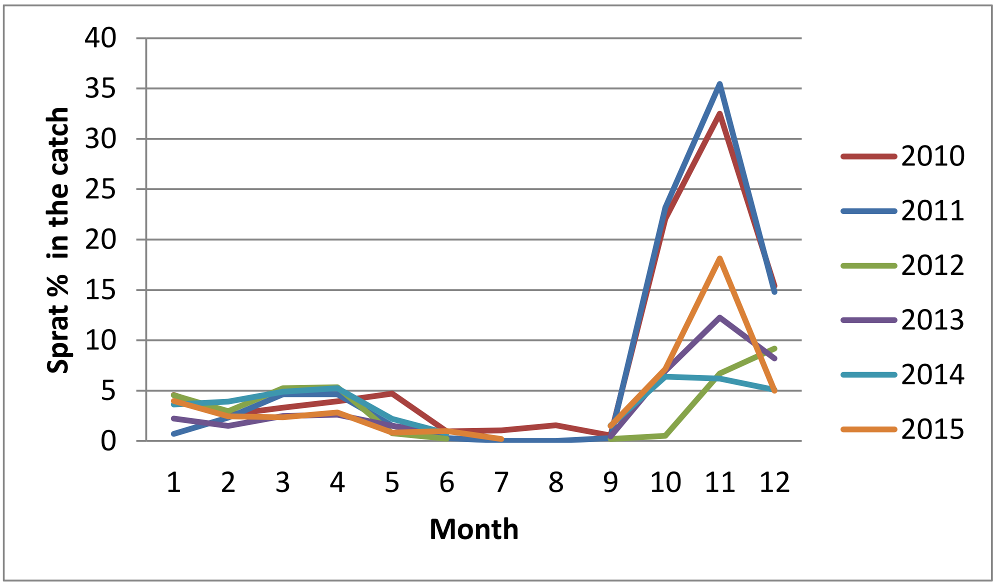

Figure 4.5.1. The proportion of sprat in each month for commercial, combined herring and sprat landings in the southern parts of the Bothnian Sea (squares G951, H051, G850, G950, and H050) in 2010–2015.

4.6 Ecosystem drivers

Temperature

Climate warming can be seen in the time–series of observations in the Gulf of Bothnia (Figure 4.6.1). Increasing temperatures have probably increased the production in the ecosystem and improved the feeding conditions of herring larvae. Several very abundant year classes of herring have developed in very warm years, which supports the evidence for an effect of temperature.

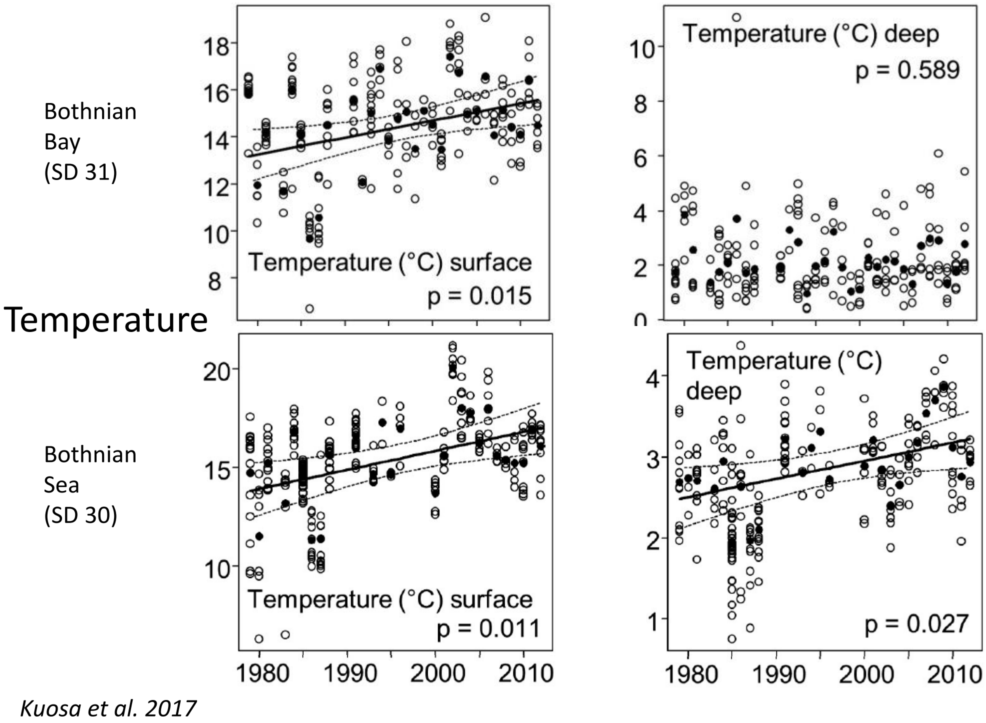

Figure 4.6.1. Long–term trends in temperature in the Bothnian Sea and the Bothnian Bay. For variables with a statistically significant trend (p > 0.05), a GAM curve (solid line) is plotted with a 95% confidence interval (dashed line). Raw data is plotted as open circles and annual averages as filled circles (From Kuosa *et al.*, 2017).

Nutrients

In addition to increases in temperature, the concentrations of dissolved organic phosphorus and dissolved organic nitrogen have increased since 1980 (Kuosa *et al.*, 2017), possibly having additional effects on herring recruitment, regardless of the reason for increased nutrient levels (Figure 4.6.2.).

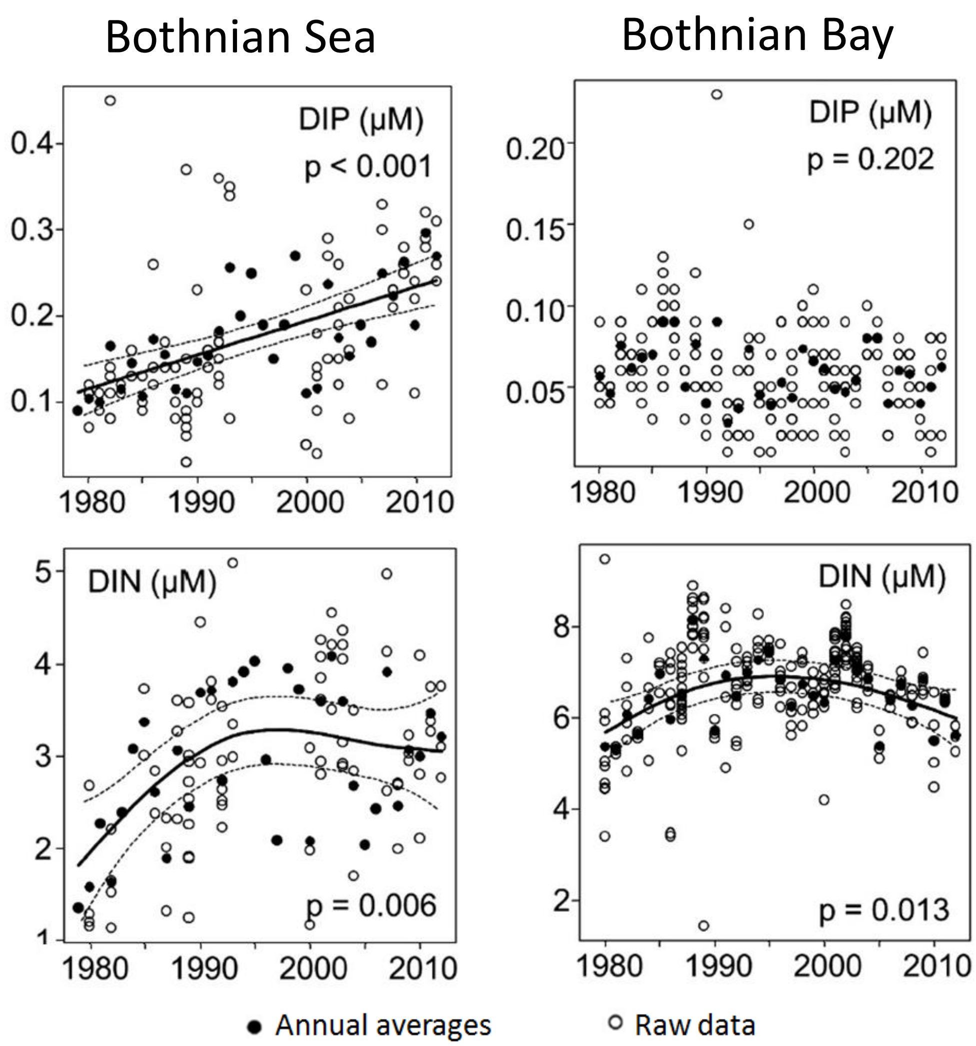

Figure 4.6.2. Long-term trends in dissolved inorganic phosphorus (DIP, above) and dissolved inorganic nitrogen (DIN, below) in the Bothnian Sea and the Bothnian Bay. For variables with a statistically significant trend ($p > 0.05$), a GAM curve (solid line) is plotted with a 95% confidence interval (dashed line). From Kuosa *et al.* (2017).

4.7 Stock assessment

4.7.1 Catch – quality, misreporting, discards

No changes to the catch data were made apart from combining the data for SDs 30 and 31 and expanding the age structure in the data as described in 4.2.2

4.7.2 Total mortality estimates from catch curve analyses

Total mortality estimates (Z) were derived using catch-curve analyses of commercial and survey catch–at–age data. The estimates of Z from commercial data analyses showed lower values in most recent years (2000–2010) than that in earlier years (1980–1999). However, the estimates of Z were somewhat variable caused by gear selectivity of trawls and trapnets (WD4.4).

The acoustic data should be preferred for such analyses, to avoid likely bias in Z estimation caused by gear selectivity. Annual acoustic data based estimation showed low

Z (0.188–0.305) and a decreasing trend in Z during 2007–2015 (WD4.3). The low estimated Z led to an exploration of lower M-values in the stock assessment (section 4.7.5).

4.7.3 Tuning fleets

In the previous assessment in 2016 Age 1 in the acoustic survey was not included in the assessment. Based on similar consistency between ages 1 and 2 as between older ages, during WKBALT it was decided that Age 1 should be included in the assessment data and the survey data were to be used up to age 9 (as a true age).

The herring trap-net fishery is a traditional herring spawning fishery occurring in spring (April–June) when the schools come close to the coastline in shallow areas to spawn. The trapnet index covers ages 3 to 9 and years 1990 to 2006. The trapnet abundance indices standardization model was changed from the previously used GLMM to a multi-layer perceptron (MLP) algorithm (WD 4.5). The statistical model performances of MLP and GLMM models were roughly comparable. However, in very high abundance years the MLP based model fit compared against observed data was better than that of GLMM. Hence, the MLP model was updated with additional age groups (3–14, previously 3–9). The statistical performance of the MLP model with age groups 3–14 was better than using age groups 3–9. Therefore (and altogether), the working group sequentially (3–9, 3–10,…, 3–14) tested MLP based cpue estimates of age groups 3–9, 3–10, …, 3–14 in 1990–2006 in stock assessment of the combined Gulf of Bothnia stock. The working group found that the tuning age groups 3–9 performed best in SAM.

4.7.4 Weights, maturity, growth, natural mortality

As for the other Baltic Sea herring stocks, weight–at–age has decreased in the Bothnian Sea and the Bothnian Bay herring starting in the 1980's (WD 4.1 figure 5.1). In both areas (SD 30 and 31) ages 3 and 5 show a similar weight development suggesting similar growth in the two areas. The maturity pattern comparing the two areas also showed a similar development as herring in SD 30 and 31 matured at age 2. Other than using the information to compare and investigate the stock identification of herring SD 30 and 31, the mean weight or maturity data were not considered a major issue for this stock presently, thus these have not been investigated at WKBALT.

Natural mortality was revised after the diagnostic runs that were made with FLSam during WKBALT and selected to be 0.15 (see WD 4.6 for exploratory assessment runs). In light of the relatively low total mortality suggested by the catch curve analyses, a natural mortality of 0.2 as previously used, seemed too high. Further, seals were considered as major predators on the stock, and thus a major source of natural mortality.

Numbers of grey and ringed seals have increased 3-fold during the last decade however, during WKBALT it was evaluated that the effect of seal predation on herring in SD 30 and 31 is minor compared to the effect of fisheries, and only low levels of M could be explained by seal predation. Thus, predation was not explicitly included in the natural mortality estimates (WD 4.2), while natural mortality used in the assessment of the combined Gulf of Bothnia stock was lowered from 0.2 to 0.15.

4.7.5 Assessment runs

In the 2016 assessment an error was detected in the acoustic tuning series where an 8 plus-group was used as the final age group. SAM treats the final age groups for CANUM and the survey the same so this had to be corrected at the benchmark. The run was repeated with the corrected data including 9+ plus-group for the CANUM and 8 true age as final age group in the acoustic tuning series. This correction it did not affect the results of the run in 2016 (Figure 4.7.1)

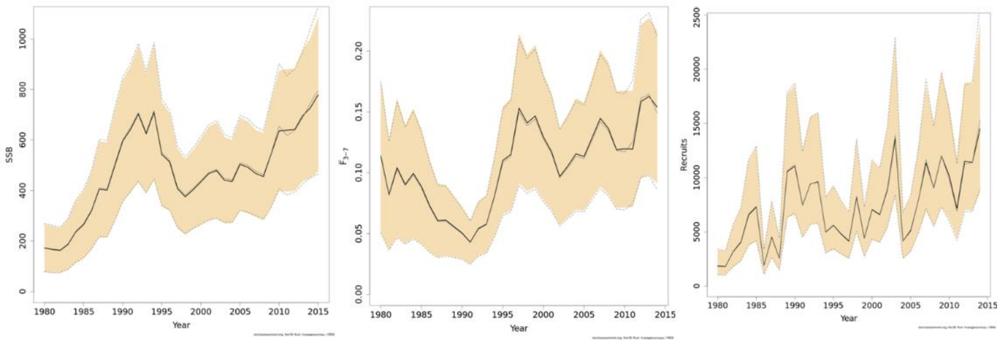

Figure 4.7.1. The stock assessment run from 2016 (grey line) compared with the run including 8 true age as final age group in the acoustic tuning fleet (black line).

WKBALT 2017 proposed to continue using SAM for stock assessment and subsequent forecast for the combined new stock comprised of SD 30 and 31 herring, which is now named Gulf of Bothnia.

In summary, the changes made to input data, besides combining SD 30 and 31, include: i) Plus group 10+ for the catch data, while the acoustic and trap-net tuning series go up to age 9 true age ; ii) trap net tuning indices were revised, and kept in the model until 2006; iii) natural mortality was reduced to 0.15 for all ages. The final selection of this input setup was based on diagnostics from FLSam runs made during the WKBALT, for more details please see WD 4.6.

The stock assessment for the Gulf of Bothnia herring stock was run and compared to the assessment results for herring in SD 30 accepted at the WGBFAS 2016, which formed the base of the advice in 2016 (WD 4.6). The assessment from WGBFAS 2016 for her 30 and the revised new stock assessment proposed here as the future assessment for her 30+31 can be viewed at https://www.stockassessment.org (username:guest, password:guest), under the stock name: **Her30_SPALY_newstock**. The comparison of stock assessment runs with trapnet and without trapnet can be found under the name **acousticincludingage1_withouttrapnet.** A stock assessment run conducted with and without age 1 included in the acoustic survey can be viewed under **Her30_SPALY_newstockage1.**

4.8 Short-term projections

No short–term projections were performed during WKBALT 2017. The same setup for forecast as previously used for herring in SD 30 is suggested to be applied for the combined herring stock in the Gulf of Bothnia.

4.9 Appropriate reference points (MSY)

The two stocks were merged and thus, reference points were re-estimated. The EqSim based reference point analysis used the newest (1980–2015) assessment results from the SAM assessment. The stock recruitment fit using the three models (Ricker, B&H and segmented regression) weighted by the default "Buckland" method available in EqSim gave a “straight” line for all models. Thus, a segmented regression model was used with a breakpoint set arbitrarily at the average observed SSB (i.e. B_{lim} = 405 980 t) as dictated by ICES guidelines for reference point estimation (ICES, 2017). However, this will result in a rather large value of $B_{trigger}$ and B_{pa}. Thus, the ICES reference points guidance were modified in this case. The first step was to estimate F_{MSY} using a hockey stick SR relationship with B_{lim} at the average SSB and without MSY $B_{trigger}$, but with assessment and advice error (i.e. using the default values). Once the F_{MSY} was estimated, the simulations were run again with the same hockey stick SR relationship and B_{lim} to estimate MSY $B_{trigger}$ defined as the 5th percentile of the SSB at F_{MSY}. Successively, B_{pa} was set as MSY $B_{trigger}$ and a new value of B_{lim} was estimated as B_{pa} divided by exp(1.645 x 0.2). After B_{lim}, B_{pa} and MSY $B_{trigger}$ were all defined, the ICES procedure for setting the reference points was used to estimate the remaining reference points. The SR relationship used for these runs was a hockey stick with the breakpoint set at the new B_{lim}. The number of samples used to fit the SR relationship and the number of runs used in all EqSim simulations were 1000 and 200, respectively. Autocorrelation of recruitment was used in all EqSim simulations. F_{pa} was estimated using the ICES standard procedure

$$F_{pa} = F_{lim} \times \exp(-1.645 \times \sigma).$$

Sigma was estimated as the uncertainty associated with the F in the last assessment year (i.e. 2015; $\sigma = 0.223$).

Thus, the procedure used to estimate the reference points for herring in SD 30 and 31 is not in strictly in accordance with the ICES reference points guidance but it has been modified to account for the specific SR relationship of this stock. Also, according to the EqSim estimations, $F_{P.05}$ is lower than F_{MSY} and thus F_{MSY} and F_{MSY} range are dictated by precautionary considerations in this case.

The proposed summary table of the combined Gulf of Bothnia stock reference points is:

STOCK	
Reference point	Value
$F_{P.05}$ (5% risk to B_{lim}) with MSY $B_{trigger}$	0.21
$F_{P.05}$ (5% risk to B_{lim}) without MSY $B_{trigger}$	0.180
F_{MSY}	0.21
F_{MSY} lower	0.151
F_{MSY} upper	0.25
F_{pa}	0.20
F_{lim}	0.29
F_{MSY} upper precautionary	0.20
F_{MSY} range with MSY $B_{trigger}$	0.15-0.21
F_{MSY} range without MSY $B_{trigger}$	0.15-0.18
MSY $B_{trigger}$	283180 t
B_{pa}	283180 t
B_{lim}	202272 t

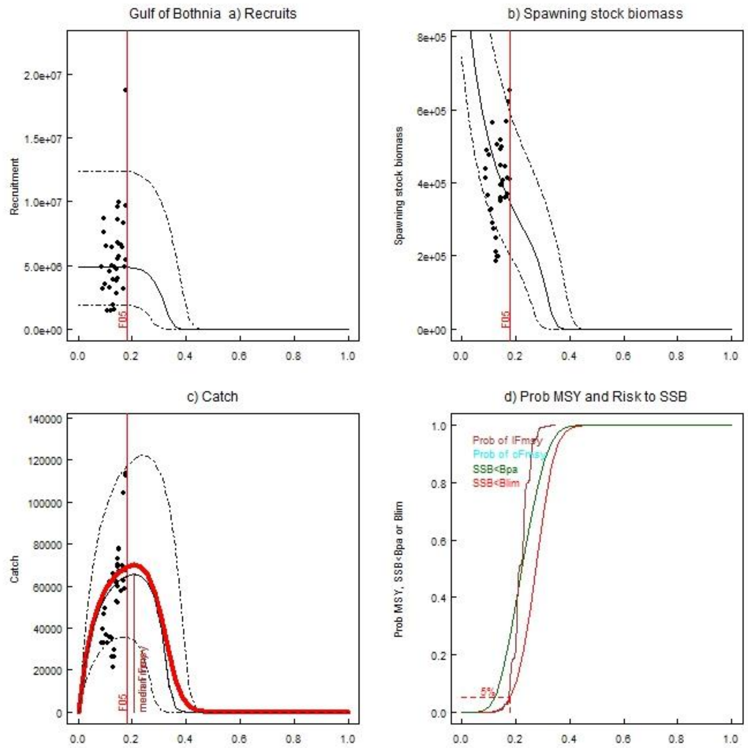

Figure 4.9.1. EqSim results for Herring in Subdivision 30 and 31 with $B_{trigger}$

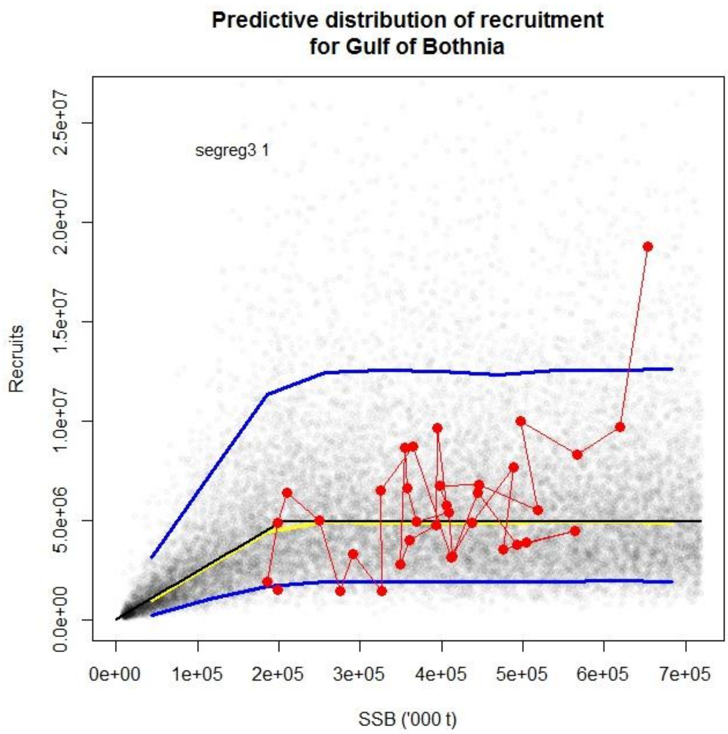

Figure 4.9.2. Stock recruitment relationship for Herring in Subdivision 30 and 31 used in the EqSim simulations for the estimation of the F_{MSY} reference points.

4.10 Future research and data requirements

Since there is no strong biological evidence either for combining or separating SDs 30 and 31 for stock assessment, it is recommended by WKBALT to consider genetic studies with more samples between the areas and tagging studies in future to provide supporting information for the combination or separation.

The possibilities of extending the acoustic survey to the suitable parts (i.e. deep enough waters in southern/middle parts) of SD 31 could also be considered in the future.

4.11 Working documents to herring in SDs 30 and 31

WD 4.1: Stock Identification and combining SD 30 and 31 herring as one stock assessment unit

WD 4.2: Seal predation on herring in the Gulf of Bothnia

WD 4.3: Total mortality estimation of SD30 stock using acoustic survey data

WD 4.4: Estimation of total mortality using catch curve method of Baltic herring SD30, SD31 and SD30+SD31 stocks combined

WD 4.5. Estimating trapnet abundance indices of SD30 herring stock

WD 4.6. Stock assessment runs

4.12 References

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5 External reviewers' report

Verena Trenkel (Chair, France), Niels Hintzen (The Netherlands), Jim Seeb (USA)

The External Review Panel met for a benchmark workshop on Kattegat cod and Gulf of Bothnia herring (WKBALT 2017) at ICES Headquarters in Copenhagen during February 7–10, 2017, to discuss the new assessment analyses and results with regional stock assessment scientists and ICES staff. Following the Terms of Reference, the External Review Panel's thoughts on the meeting were as follows:

a) Evaluate the appropriateness of the data to determine stock status.

To the fullest extent possible, objectivity was cornerstone of our collective decisions concerning data suitability and quality for both cod and herring.

For cod, during the meeting it was decided to remove the BITS survey Q4 time–series as it is in disagreement with other data sources and covers only part of the stock. These arguments seem reasonable. Any other data revisions of catches and discard estimates appear justified as they correct data mistakes. A seal predation dataset was prepared which could be included as an external fleet in future assessments as the current assessment model could not incorporate the data as yet.

For herring, merging the data for the new combined stock did not raise any data issues, in particular as there was no survey index for the previous area 31 herring stock. Age 1 for the acoustic index was added after some discussion during the meeting as there are no objective reasons for excluding it although in some years it might not cover the whole age 1 group. This index should be useful when making short–term predictions. The existing survey was standardized and was considered an improvement over the previous configuration. The new trapnet CPUE estimation method seems sound and provides estimates in good agreement with the raw data.

b) Document the preferred method for evaluating stock status.

The primary assessment model (SAM) chosen for both stocks has already been used before, so there are no changes in model for cod and herring.

For cod the intention is to move towards a category 1 stock assessment which requires extracting fishing mortality from the mortality estimate provided by SAM which includes fishing mortality, migration and additional natural mortality not accounted for by the assumed M=0.2. The method for doing this was using catch multipliers in the assessment model. Due to migration, some catches may be over- or underestimated and the catch multipliers were a useful tool to account for this dynamic. This procedure creates missing catches and the absolute value of these were contrasted with predation mortality and catch curves from the survey to see if these indicate similar missing catches. This lined up reasonably well.

For herring the main questions were with respect to the age of the plus group and the natural mortality value to be used. Previously the plus group was age 9 and M=0.2 for all ages and years. An extensive set of comparative model runs showed that as M decreased F increased proportionally. Therefore based on catch curve derived total mortality estimates and an interpretation of catchability coefficients for the acoustic survey it was concluded that M=0.15 would be more appropriate. The reviewers agree with this choice. The new plus group was set to age 10, which is supported by the analyses presented during the meeting. All other model changes are minor and well supported.

c) Re-examine MSY and PA reference points.

No sufficiently finalized proposals on the MSY and PA reference points were available to the External Review Panel for discussion with the working group during the benchmark workshop.

d) Evaluate the settings of the escapement strategy.

No sufficiently finalized proposals on the settings of the escapement strategy were available to the External Review Panel for discussion with the working group during the benchmark workshop.

e) Recommendations and general comments for improving future assessments.

Much progress has been made in understanding migration of cod from and to the North Sea using genetic data and the potentially increasing natural mortality due to seal predation. However, the available data and methods developed are currently not sufficient to include these processes formally into the stock assessment model. As a consequence, the review team suggests the following research and data collection for Kattegat cod:

(1) Genetic data collection and use for cod

Existing genetic data for 187 SNPs show strong differentiation of subpopulations of Atlantic cod inhabiting the Baltic region into three reporting groups: North Sea, Kattegat and Eastern Baltic Sea. Individual assignment of cod of unknown origin back to these reporting groups is robust. These results also suggest that incorporating more population samples with an updated SNP panel may provide enhanced resolution by subdividing some of the reporting groups.

The pilot study, sampling of 1800 cod from Kattegat over a five-year period, demonstrated varying presence of North Sea cod among years which exacerbates stock assessment. In extreme cases, sampling strata varied from 0% to 100% North Sea cod between years. Fate of these migratory North Sea cod is uncertain. They may stay long enough to be vulnerable to fisheries, or they may emigrate, leaving a more vulnerable and reduced biomass of true Kattegat stock. Expansion of these data hold the promise of answering key questions surrounding the impacts of stock migration on the assessment of Kattegat cod, but a longer time–series with much denser sampling is needed.

Future research should evaluate whether and how the Kattegat cod stock assessment could be improved by accounting for the annual variability of North Sea migrants to and from the Kattegat. Migration of Kattegat born fish into the North Sea should also be explored as this might explain part of the recent decrease observed for this stock.

More thorough genetic data collection could include:

a. Baseline data should be expanded on a routine basis. Improving and proofing baseline genetic data will further demonstrate the untapped potential of genetic data to aid assessments.
b. Future genetic analysis of cod of unknown origin, present in Kattegat, should be increased and stratified in a way to ensure that the sampling represents the entire Kattegat cod community across age classes (including eggs or larvae), space and time.
c. Time–series should be lengthened by analysis of DNA on otoliths if archival collections provide robust sample distribution.

With respect to the preparation and running of the benchmark the review team makes the following suggestions

(2) Model preparation

The external review team would have liked to have seen more of the exploratory modeling work completed prior to the meeting, so that as much as final model configurations would have been available at the start of the meeting for both herring and cod. For example, a thorough retrospective analysis with SAM and tests of forecasting skills are required for setting reference points.

(3) Benchmarking

Carrying out stock assessments with SAM requires advanced expertise not only about stock biology and fisheries, but also the technical details of the modelling framework. The team dealing with herring did not master all the necessary skills to perform this benchmark and postponing the benchmark would have been a wiser decision. To critically evaluate the modelling assumptions and choices used for stock assessment it is crucial to include in the general benchmark process a technical model evaluation step for which the external experts are experienced stock assessors for the same species elsewhere or persons with expertise in the actual model being used.

Final Comment

We believe that benchmark review of the two stocks could have been substantially more efficient. In general, the review team felt that too much time was spent on reviewing minor progress that could have been made prior to the benchmark meeting. In a number of instances, this left little time for the discussion of other substantially more important topics, such as how to derive an estimate of F for cod from the mortality estimate provided by SAM.

The stock assessment working group must produce the various working documents much further ahead of the review meeting. As it was, some working documents were only available and added to the website less than 24 hours before the start of the meeting, which deleteriously affected a comprehensive and objective review process. We believe that reviewers must have sufficient time to read and assimilate the contents of the documents prior to the meeting so that the productivity of the group is maximized and outcomes are clear and on-target! Owing to the tight timeline in preparation, the cod stock had to go into inter-benchmark to resolve some major issues that arose during the benchmark meeting. No time was reserved by the scientists ahead to resolve outstanding issues which put the final result, after a lot of hard work, at stake.

Annex 1: List of participants

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Annex 2: List of stock annexes

Stock ID	Stock name	Last updated	Link
Cod.27.21	Cod (*Gadus morhua*) in Subdivision 21 (Kattegat)	April 2017	cod.27.21_SA
Her.27.3031	Herring (*Clupea harengus*) in Subdivisions 30 and 31 (Gulf of Bothnia)	April 2017	her.27.3031_SA

Annex 3: Recommendations

Recommendation	Adressed to
1. WKBALT identified that clear guidelines or check-lists are lacking in ICES for which criteria should be fulfilled, before a certain area is defined as a separate assessment unit. This is both in terms of which biological evidence should be present, and which data should be available for conducting an assessment. Also, it is unclear what the default definition is, i.e. whether the default is a larger unit and sufficient evidence is needed to support that it is necessary to divide this into several smaller ones. Or opposite, the default is the smallest possible units, and evidence is needed to support that it is appropriate to combine these into a single larger unit. It was recognized that such decisions are currently largely based on personal preferences and views of the persons attending particular benchmarks and the basis for stock definitions is thus not entirely consistent across the stocks dealt with in ICES. Thus, WKBALT recommends establishing a group or allocating the task to an appropriate existing group, to work out clearer guidelines on this issue.	ACOM

Annex 4: Working Documents

WD 1. Estimating trapnet abundance indices of SD30 herring stock

Background

The trapnet fishery in SD30 targets spring spawning schools of herring. The catch reports are based on monthly fishermen reports that are supplemented with biological sampling. The annual fishing effort has varied with a major declining trend during the last decade. Hence, earlier statements (e.g. WKPELA 2012) on reliability of the trapnet dataset as a stock index have underlined the importance of using only those trapnets that are representative as a stock abundance index. Consequently, previous assessment working groups have solved the problem of uncertain dataset in recent years by using only years 1990 - 2006 as a stock index. Further, the variable cpue levels across sampling sites have been averaged over three sampling sites based on GLMM regression model.

Methods

The present working group was not able to successfully run the previously used GLMM model with additional age groups (3 - 14, previously 3 - 9). Hence, a new cpue standardization model was derived with a comparison with respect to GLMM used earlier.

The presented model estimates cpue patterns by age by year in three sampling sites. The model is a multi-layer perceptron (MLP) algorithm which utilizes a supervised learning technique called backpropagation for training the model (Rumelhart 1986). The MLP model was specifically derived to recognize patterns and its a modification of the standard linear perceptron and can distinguish data that are not linearly separable.

In preprocessing phase, the response was ln(cpue+1) transformed. The predictors (age, year, area) were dummy (zero - one) coded. The parameters (learning rate, momentum) of the MLP model were optimized using 10-fold cross-validation (CV, Kohavi 1995). Specifically, the best parameters and evaluation of a model performance was measured using 10 *non-overlapping* tests sets. Thereafter, the best parameters were employed using *another* model, which predicted ln(cpue + 1) patterns *using the data once* (i.e. not 10 times). The aim of ten-fold cross-validation is to estimate parameters, to avoid overfitting and, to estimate average model performance over 10 non-overlapping test sets (CV-performance). The CV performance is in most cases a slightly pessimistic performance measure when compared with commonly employed in-sample performance measures.

Results

Model comparison (MLP model vs GLMM)

The statistical performance of MLP model and GLMM model was roughly at the same level with age groups 3 - 9 in 1990 - 2013. The statistical performance of MLP was $R^2 = 0.75$ and GLMM was $R^2 = 0.8$. These performance measures, however, are not directly comparable because the statistical performance of MLP is 10-fold CV performance whereas GLMM performance was multiple R^2. To do visual inspection, we plotted cpue estimates of both models against raw data in three sampling sites (Figure 1).

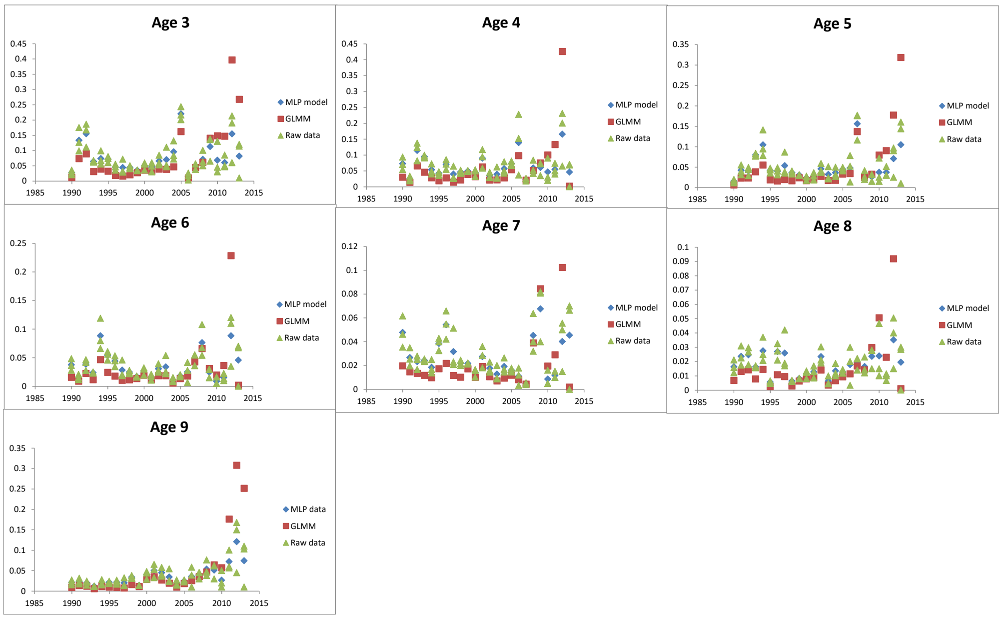


Figure 1. MLP (blue dots) and GLMM (red dots) models' average cpue estimates over three sampling sites and observed cpue (green dots; y-axis) in three sampling sites in 1990 - 2013 (x-axis). The MLP based model fit against observed data in very high cpue years seems to be better than that of GLMM.

MLP model with age groups 3 - 14

The MLP model was also used to estimate average cpue over three sampling sites with age groups 3 - 14 for years 1990 - 2006. The statistical model performance with age groups 3 - 14 was slightly better (R2 = 0.84) than that with age groups 3 - 9 (Figure 2).

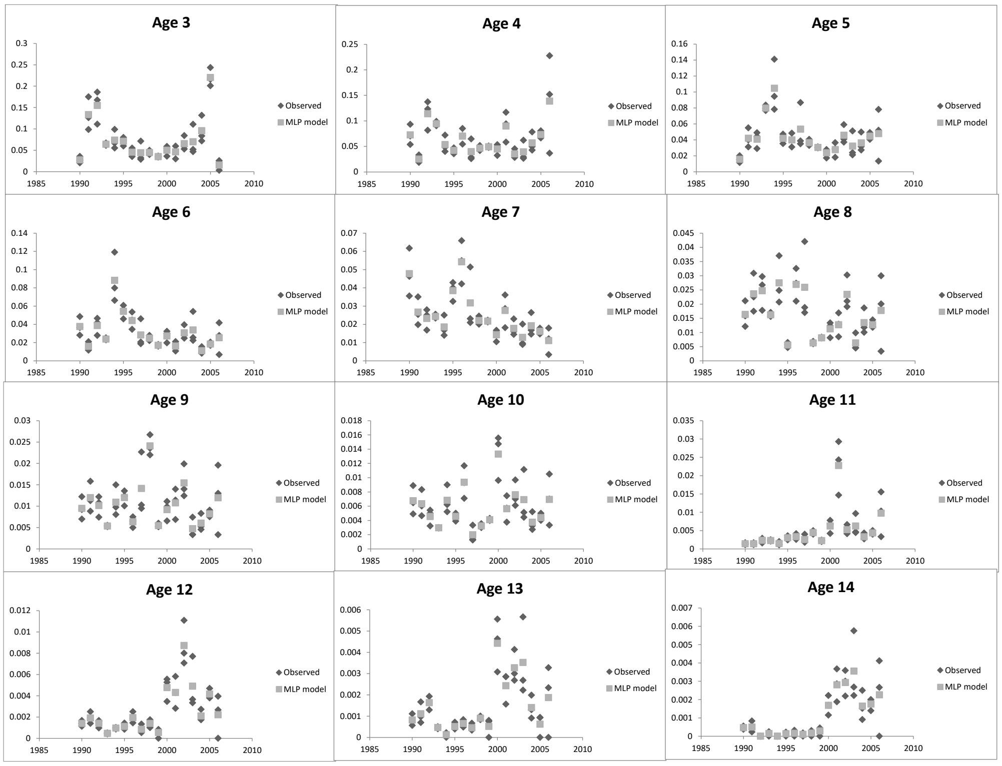


Figure 2. Observed cpue in three sampling sites (black dots) and MLP model based predicted average cpue over three sampling sites (y-axis) at age in 1990 - 2006 (x-axis).

Discussion

The statistical model performances of MLP and GLMM models were roughly comparable. In very high abundance years the MLP based model fit against observed data was better than that of GLMM (Figure 1). Hence, the working group decided to test MLP model using age groups 3 - 14.

The statistical performance of the MLP model with age groups 3 - 14 was better than that using age groups 3 - 9. Hence (and altogether), the working group decided to use MLP based cpue estimates of age groups 3 - 14 in 1990 - 2006 in stock assessment of SD30 stock.

References

Kohavi, R. 1995: A study of cross-validation and bootstrap for accuracy estimation and model selection. Proceedings of the fourteenth international joint conference on artificial intelligence. s. 1137–1143. Morgan Kaufmann. San Mateo.

Rumelhart, David E., Geoffrey E. Hinton, and R. J. Williams 1986. Learning Internal Representations by Error Propagation. David E. Rumelhart, James L. McClelland, and the PDP research group. (editors), Parallel distributed processing: Explorations in the microstructure of cognition, Volume 1: Foundations. MIT Press.

WD 2. Estimation of total mortality using catch curve method of Baltic herring SD30, SD31 and SD30+SD31 stocks combined

Background

In Copenhagen December 2016 meeting the data evaluation working group (DEWK) discussed the relevance of mortality rates used in the stock assessment of HerSD30 and SD31 stocks. In earlier years' stock assessments, the fishing mortality (F) and natural mortality (M) rate inputs have been fixed with no annual variation. Specifically, the SD30 herring mortality rate inputs for all age groups and years have been fixed to 0.15 F_before spawning, 0.33 M_before spawning, and 0.2 M. For SD31 stock the mortality rates have been F = 0.15 and M = 0.15. The working group discussed the relevance of these input values. In addition, the increased grey seal and ringed seal populations was speculated to have an effect on natural mortality rates and that an increase in SD30 stock size may have reduced or nullified the impact of seals on M on SD30 stock.

Methods

A (linearized) catch curve method is a graphical representation of the natural logarithms of numbers caught plotted against age. The aim of the catch curve method is to estimate total mortality rate for a given time period. This is done by estimating linear regression based slope parameters from fully recruited ln-transformed catch frequencies (ln-CANUM) by age. The (eigenvalue of) slope parameter is the estimate of Z for a given time period.

The usual data structure to estimate Z is either to use cohort or pseudo-cohort (i.e. regular catch frequencies by age by year). In addition, a common way to level out the impact of high annual variation in recruitment is the averaging process, where ln-catch frequencies are averaged over multiple time periods (here: years). By this way, the linear regression based slope parameter (Z) is more stable than that when using a single cohort or a single year (with pseudo-cohorts). So when using averaging the assumption of constant recruitment is not crucial. In addition, a common way to stabilize and increase confidence on Z estimates is to use several or all fully recruited age groups instead of using only a few fully recruited age groups (Figure 1).

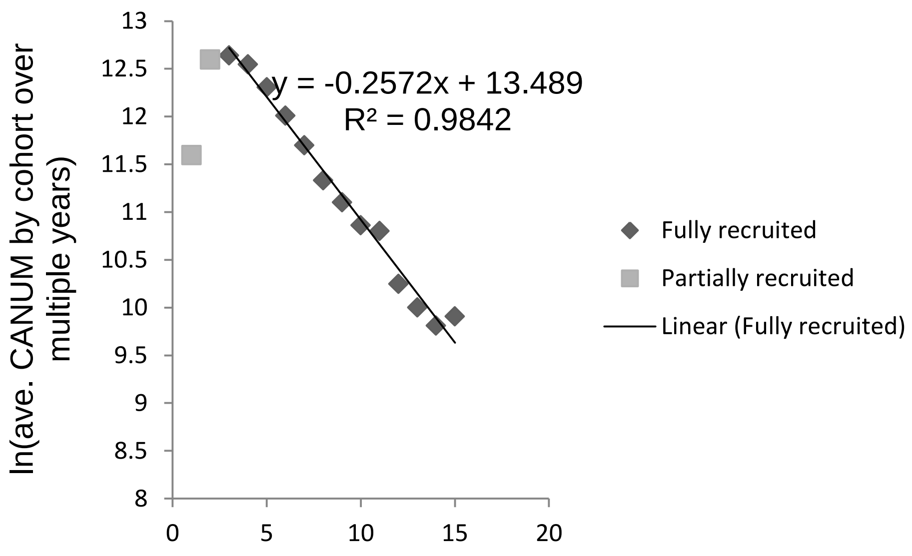


Figure 1. An example of linearized catch curve method to estimate Z (slope parameter, -0.25) using average ln-catch frequencies (ln-CANUM, y-axis) by all fully recruited age groups over multiple cohorts (x-axis).

Results

The age of full recruitment (max CANUM) varies between the years and areas. The annual variation in recruitment and different gear selectivity affects recruitment age (Figure 2).

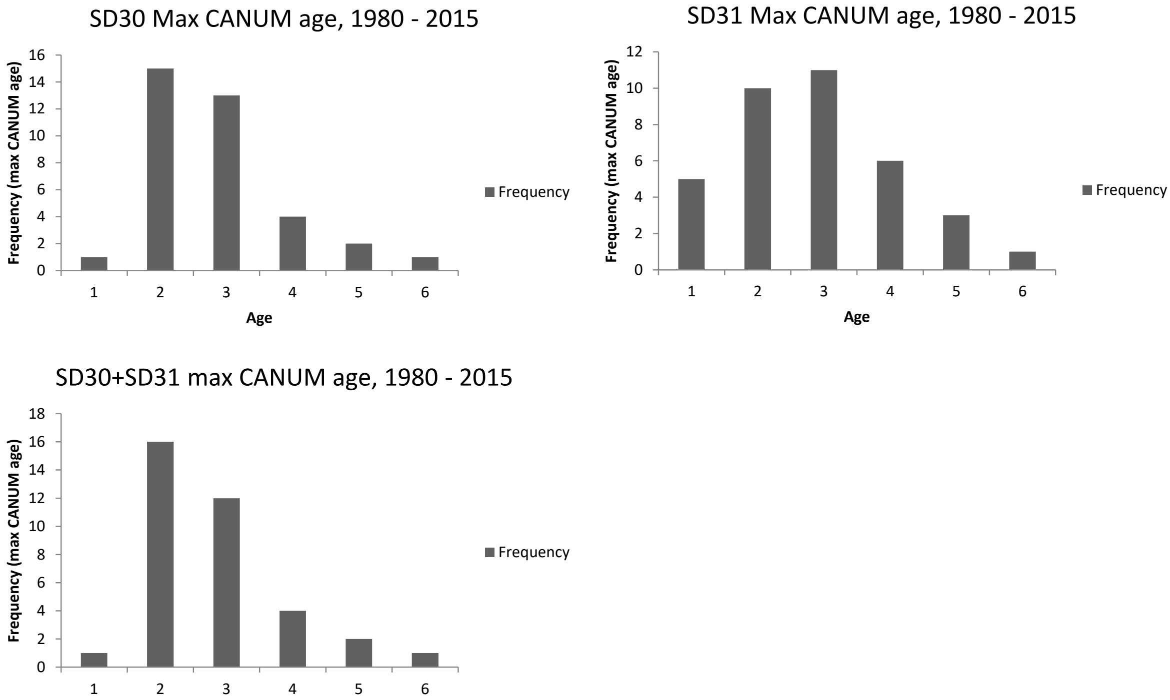


Figure 2. Full recruitment (maximum CANUM) age frequency distribution in SD30, SD31 and SD30+SD31 combined.

In the absence of a single superior catch curve method, we applied five alternative methods to estimate Z in SD30, SD31 and SDs 30+31 combined (Figures 3 - 5, respectively).

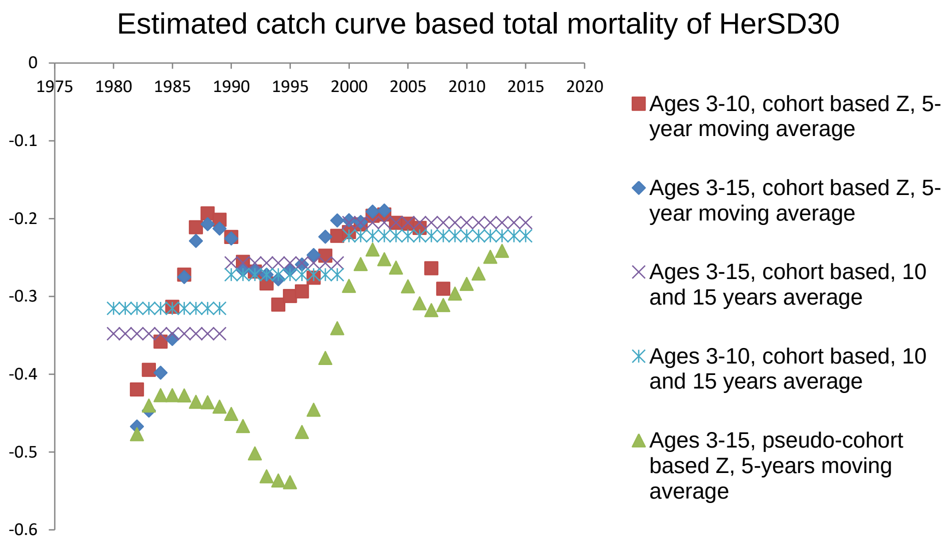


Figure 3. Estimated total mortality slope parameters (Z) for Baltic herring in SD30 in 1980 - 2015 using five different catch curve methods. The average Z over the years and across methods is Z = -0.30.

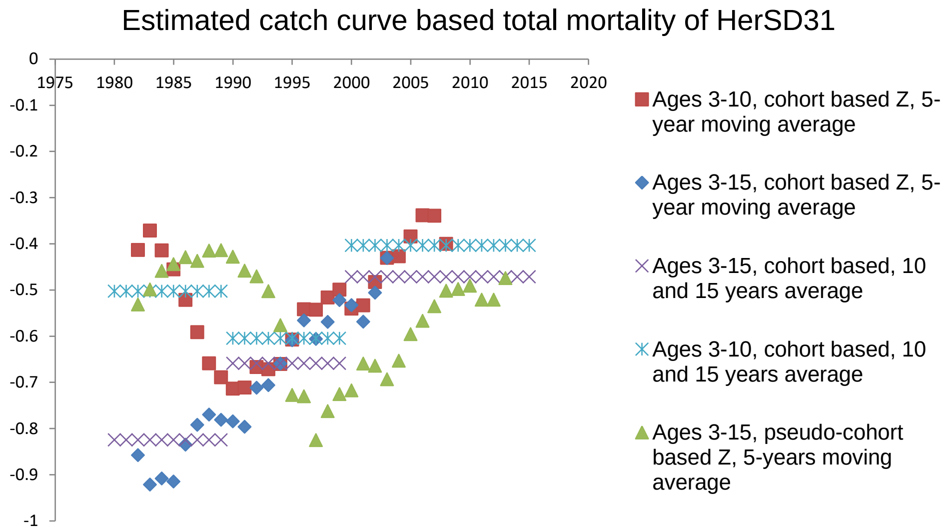


Figure 4. Estimated total mortality slope parameters (Z) for Baltic herring in SD31 in 1980 - 2015 using five different catch curve methods. The average Z over the years and across methods is Z = -0.58.

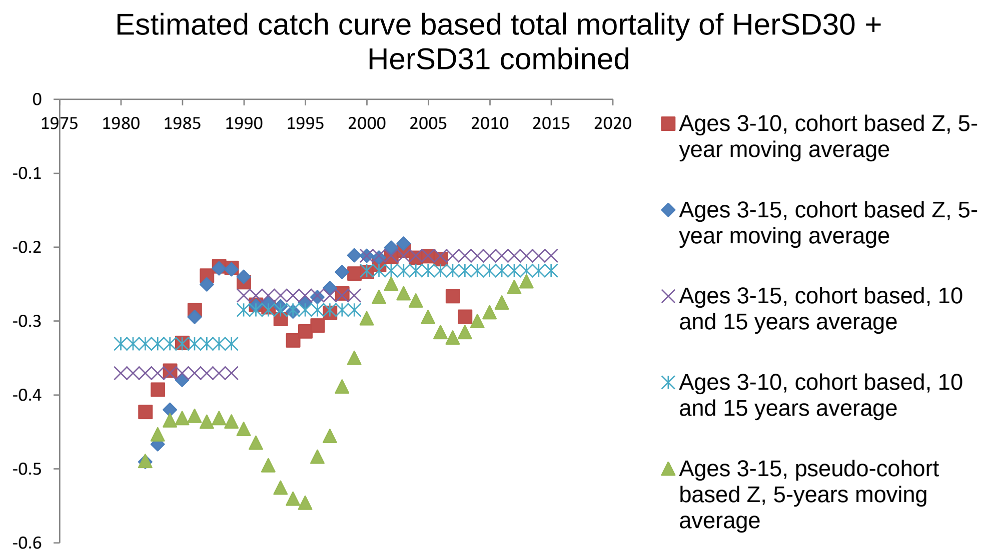


Figure 5. Estimated total mortality slope parameters (Z) for Baltic herring in SDs 30+31 combined in 1980 - 2015 using five different catch curve methods. The average Z over the years and across methods is Z = -0.31. The total mortality of combined stocks tracks the patterns of SD30 stock.

Discussion

The gear selectivity of trapnets especially in SD31 may affect mortality estimates. Hence the estimates of total mortality are likely somewhat biased in particular in SD31. In general, the total mortality in SD31 is somewhat higher than that in SD30. In addition, total mortality of SD30 and SDs 30+31 combined is currently lower than that in 1980's.

c) WD3. Scorecard

Scorecard on data quality				
	No bias	Potentia l bias	Confirme d bias	Comment
A. SPECIES IDENTIFICATION				
Species subject to confusion and trained staff				
Species misreporting				There is a small seasonal bycatch of sprat and stickleback, which may be ignored by the fishermen when repoting their
Taxonomic change				
Grouping statistics				
Identification Key				
Final indicator				
B. LANDINGS WEIGHT				
Recall of bias indicator on species identification				
Missing part				There are no observations nor any data on "missing part". This, however is not considered to have any consequences on the catch estimates.
Area misreporting				
Quantity misreporting				
Population of vessels				
Source of information				
Conversion factor				
Percentage of mixed in the landings				There is a small seasonal bycatch of sprat and stickleback, which may be ignored by the fishermen when repoting their
Damaged fish landed				
Final indicator				
C. DISCARDS WEIGHT				
Recall of bias indicator on species identification				
1. Sampling allocation scheme				There is no discarding in the fisheries
2. Raising variable				
3. Size of the catch effect				The total catch weight is estimated by the fishermen in the time of taking the sample
4. Damaged fish discarded				
5. Non response rate				
6. Temporal coverage				
7. Spatial coverage				
8. High grading				
9. Slipping behaviour				
10. Management measures leading to discarding behaviour				
11. Working conditions				
12. Species replacementFinal indicator				
D. EFFORT				
Recall of bias indicator on species identification				
1. Unit definition				
2. Area misreporting				
3. Effort misreporting				
4. Source of information				
Final indicator				
E. LENGTH STRUCTURE				
Recall of bias indicator on discards/landing weight				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Random sampling of boxes/trips				The sampling is more oppotunistic than random. The sub-sampling from catches is done -according to protocol- in a manner so that the whole catch will be presented in the sample (minimum of 3 batches presenting different parts of
5. Availability of all the landings/discards				
6. Non sampled strata				
7. Raising to the trip				
8. Change in selectivity				
9. Sampled weight				
Final indicator				
F. AGE STRUCTURE				
Recall the bias indicator on length structure				
1. Quality insurance protocol				
2. Conventional/actual age validity				The age-reading in done from cut otoliths, which is considered to be an accurate (reliable) method
3. Calibration workshop				
4. International exchange				
5. International reference set				
6. Species/Stock reading easiness and trained staff				Before 2002 age-reading from whole otoliths may have some bia
7. Age reading methods				
8. Statistical processing				none
9. Temporal coverage				
10. Spatial coverage				
11. Plus group				
12. Incomplete ALK				Usually all quarterly available age-classes are present in ALKs. The 0- and 1-year olds are short in commercial catches, and sometimes their age is estimated from the size of fish.
Final indicator				
G. MEAN WEIGHT				
Recall of bias indicator on length/age sturcture				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Statistical processing				
5. Calibration equipment				
6. Working conditions				
7. Conversion factor				
8. Final indicator				
H. SEX RATIO				
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Staff trained				
5. Size/maturity effect				
6. Catchability effect				
Final indicator				
I. MATURITY STAGE				
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Appropriate time period				
3. Spatial coverage				
4. Staff trained				
5. International reference set				
6. Size/maturity effect				
7. Histological reference				
8. Skipped spawning				
Final indicator				
Final indicator				

WD 4. Total mortality estimation of SD30 stock using acoustic survey data

Background

The total mortality estimates of SD30 herring stock were assessed using acoustic abundance indices data in 2007 - 2015. Reliable assessment advice on proper total mortality rates does not exist, and hence the assessment done. Acoustic data was used here to avoid possible (or likely) bias caused by gear selectivity of fishing gears that alter annual age frequency distributions. Previously used stock assessment mortality input values have been fixed to 0.15 F_before spawning, 0.33 M_before spawning, and 0.2 M.

Methods

The presented model uses pseudo-cohorts of acoustic data to estimate annual abundance indices by age. The multi-layer perceptron (MLP) algorithm was used here, which utilizes a supervised learning technique called backpropagation for training the model (Rumelhart 1986). The MLP model has been specifically derived to recognize patterns and it's a modification of the standard linear perceptron and can distinguish data that are not linearly separable. The presented model was similar to that used by working group to estimate annual trapnet cpue patterns by age groups over three sampling sites.

In preprocessing phase, the response (acoustic abundance indices) was ln +1 transformed. The predictors (age, year) were dummy (zero - one) coded so that neither of the predictors did not unduly affect predicted abundance indices. The parameters (learning rate, momentum) of the MLP model were optimized using 10-fold cross-validation (CV, Kohavi 1995). The slope parameter derived from predicted annual abundance indices was the estimate of total mortality.

Results

The predicted annual abundance indices were roughly in line with observed ones (CV performance R2 = 0.86; Figure 1).

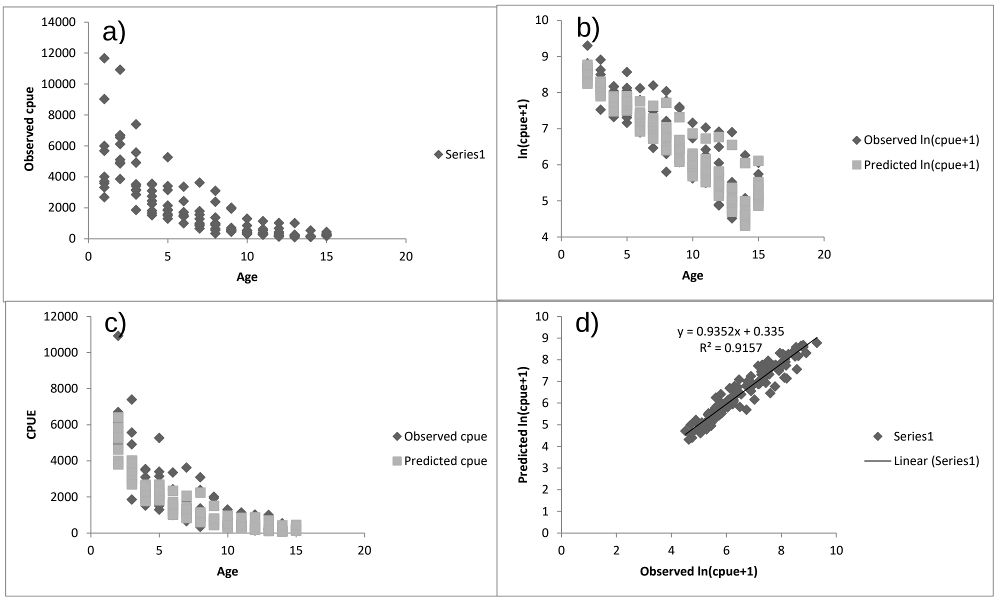


Figure 2. Observed abundance indices of all age groups 1 - 15 (a), observed (black) and predicted (grey) ln + 1 transformed abundance indices of age groups 2 - 15 (b), back transformed observed (black) and predicted (grey) abundance indices of age groups 2 - 15 (c) and, predicted (y-axis) and observed (x-axis) abundance indices in 2007 - 2015 (d). Age 1 was left out from the final mortality estimation because in most years maximum abundance indices age was 2 (a).

The predicted back-transformed annual abundance indices by age roughly tracked the annual patterns of observed abundance indices by age groups 2 - 15 (Figure 2).

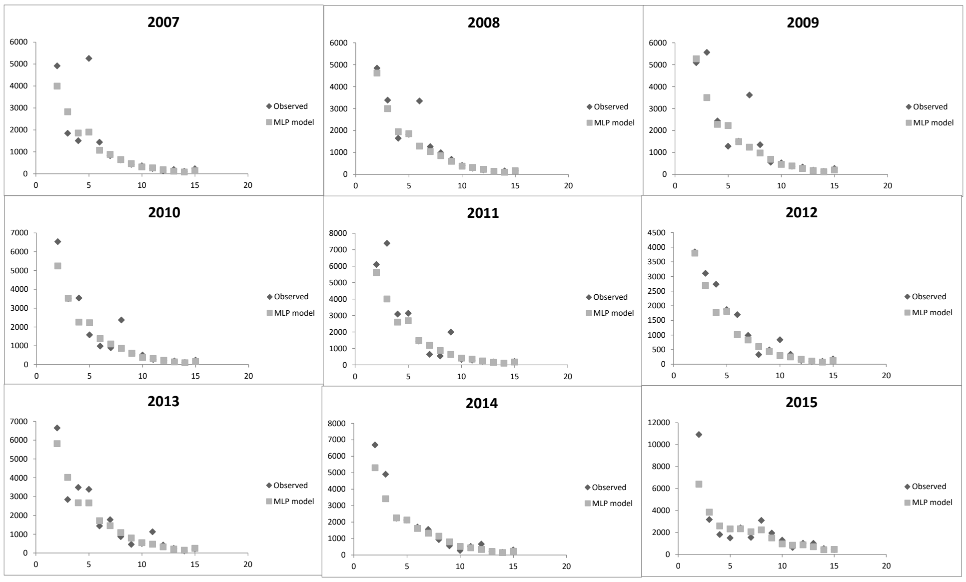


Figure 2. Predicted back-transformed annual abundance indices by age (grey dots) and observed abundance indices (y-axis) by age (x-axis) in 2007 - 2015.

The annual estimated slope parameters suggest decreasing trend in total mortality in 2007 - 2015.

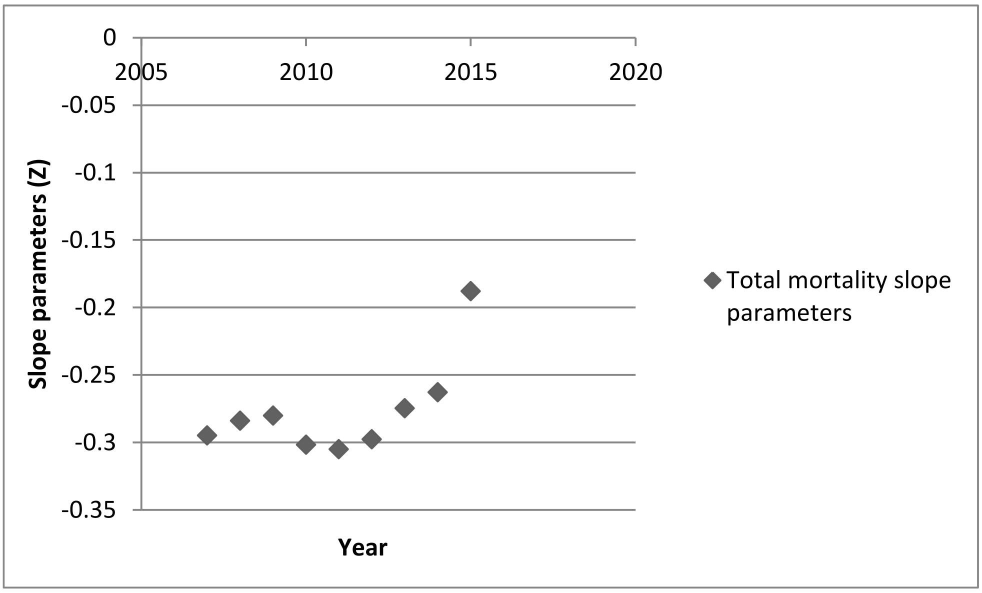


Figure 3. The estimated annual slope parameters i.e. total mortalities (Z) in 2007 - 2015.

Discussion

The total mortality estimates of the present model especially in most recent year (or years) were rather low compared with M + F in stock assessment of SD30. Hence, the previously used mortality inputs used in SD30 stock assessment could be adjusted accordingly.

References

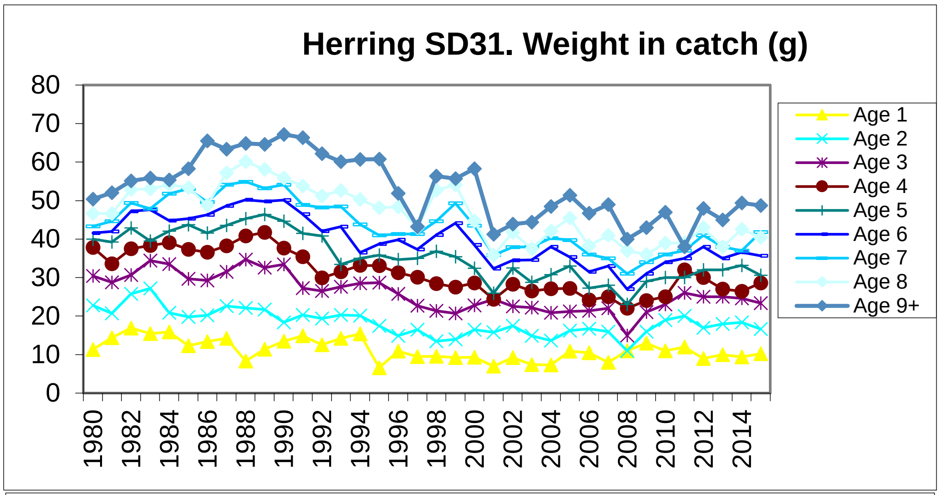
Kohavi, R. 1995: A study of cross-validation and bootstrap for accuracy estimation and model selection. Proceedings of the fourteenth international joint conference on artificial intelligence. s. 1137–1143. Morgan Kaufmann. San Mateo.

Rumelhart, David E., Geoffrey E. Hinton, and R. J. Williams 1986. Learning Internal Representations by Error Propagation. David E. Rumelhart, James L. McClelland, and the PDP research group. (editors), Parallel distributed processing: Explorations in the microstructure of cognition, Volume 1: Foundations. MIT Press.

WD 5. Stock Identification and combining SD 30 and 31 herring as one stock assessment unit

Background

The biological reasons for separating the stocks in SDs 30 and 31 has been unclear. There are factors that support their similarity and other factors that suggest they would be separate populations. During the data evaluation workshop we investigated both stocks in terms of annual mean weights at age, annual weight increase, Fulton's condition factor, maturity and recruitment. The results suggest that growth patterns were similar among the stocks over time (Figure 5.1), and that especially in age groups 3 and 5 (Figure 5.2). Also annual average Fulton's condition factors of age groups 3 and 5 were similar among the areas (Figure 5.3). Further, fish matured at age 2 in both areas (Figure 5.4) and based on catch samples annual average length distributions were also similar among the areas (Figure 5.5).



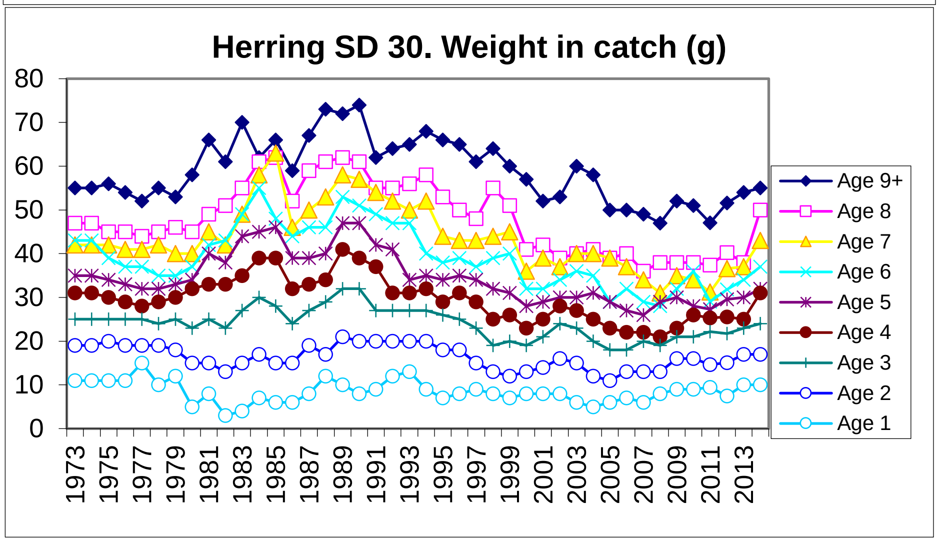


Figure 5.1. Annual average weight (y-axis) of herring age groups 1 - 9+ in SD31 (upper fig) and SD30 (lower fig) catch in 1973 - 2015 (x-axis).

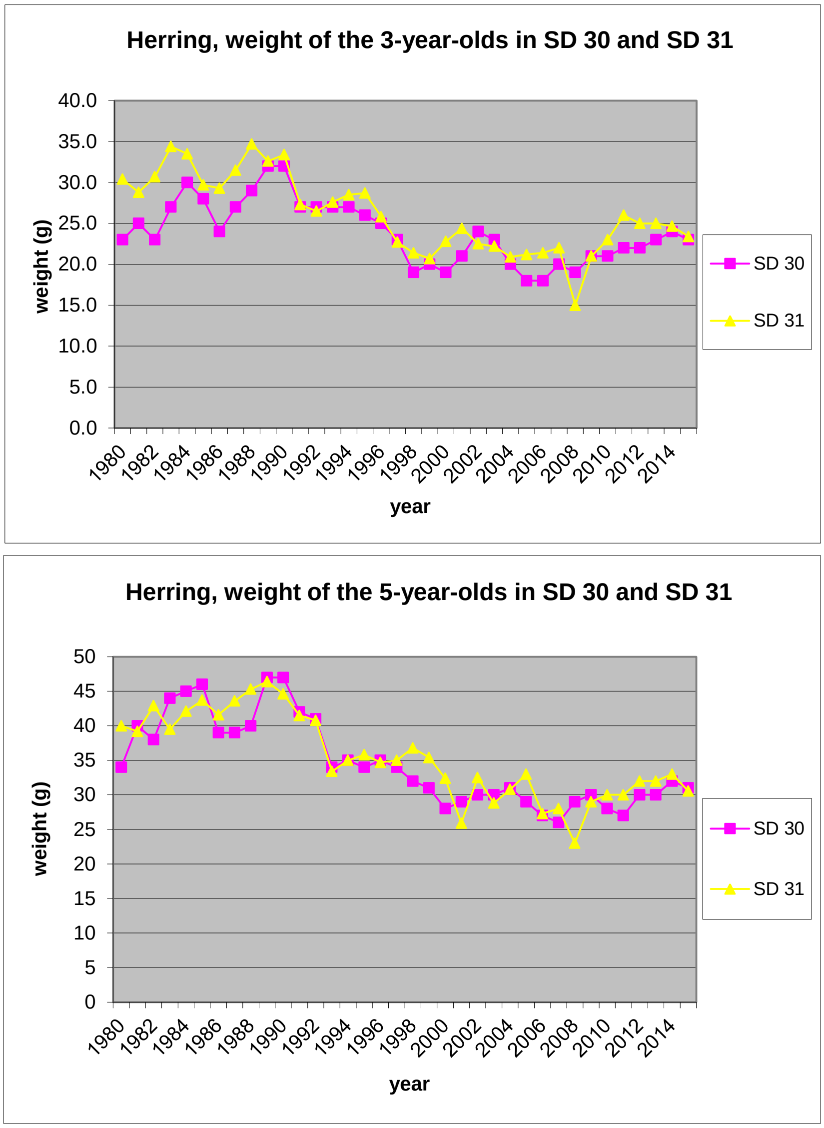
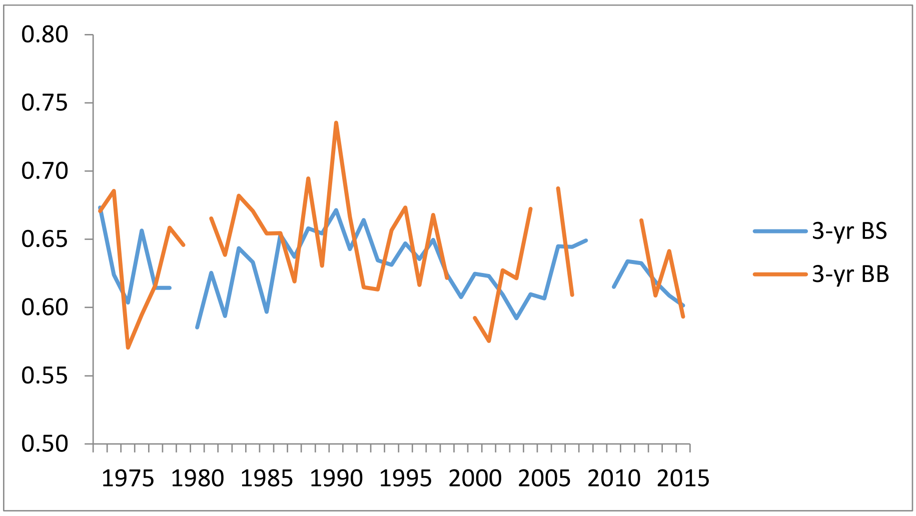


Figure 5.2. Annual average weight (y-axis) of age groups 3 (upper fig) and 5 (lower fig) in SDs 30 (red) and 31 (yellow) catch during 1980 - 2015 (x-axis).



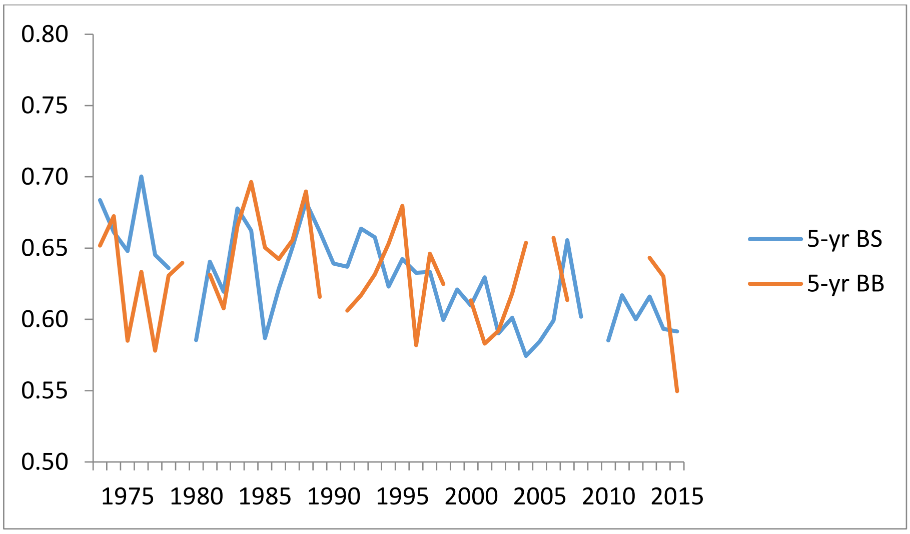
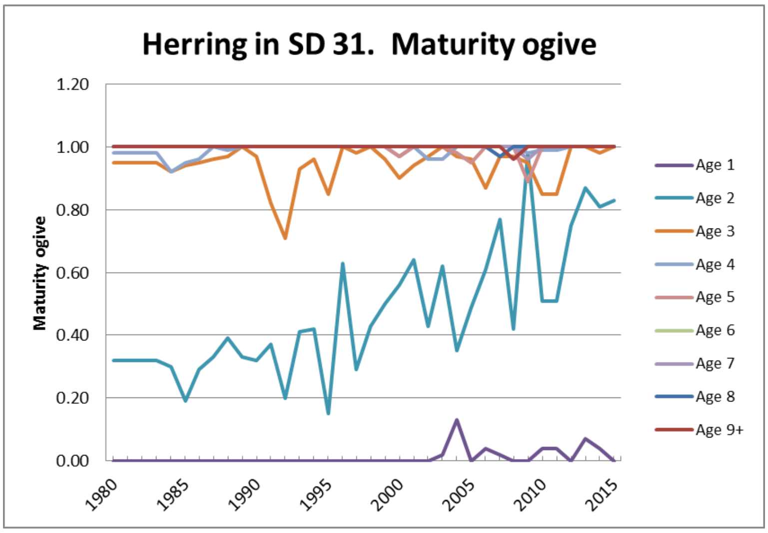


Figure 5.3. Annual average Fulton's condition factors (y-axis) for 3 (upper fig) and 5 (lower fig) year old fish in SDs 30 (BS) and 31 (BB) during 1973 - 2015 (x-axis).



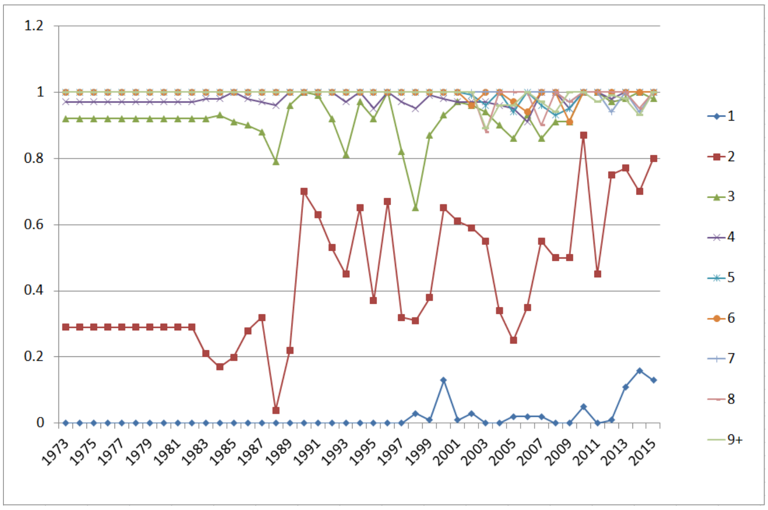


Figure 5.4. Maturity ogive for herring in SD 31 (upper) and SD 30 (lower). In both areas herring matured at age 2.

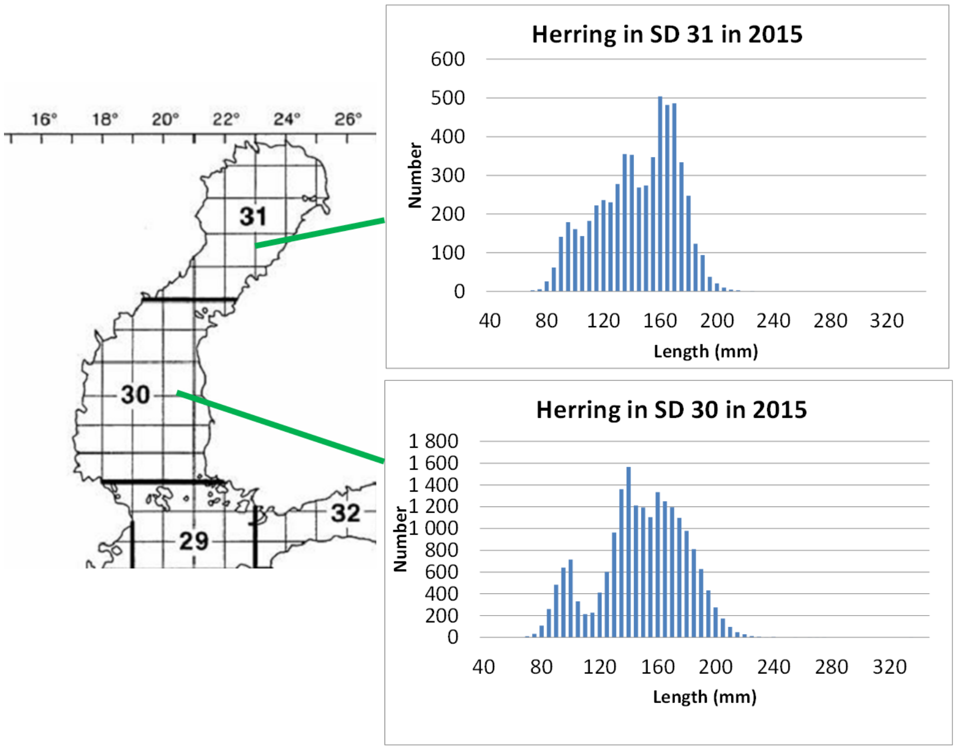


Figure 5.5. Length frequency distributions in commercial catch samples in 2015 for SDs 31 and 30.

Annual total commercial catch at age groups 1 - 9+ did not show similar pattern among SDs 30 and 31, which suggest that the herring stocks might be separate (Figure 5.6). However, considering the differences in climatic conditions in the two areas, Bothnian Bay has colder winters and ice coverage persists longer compared with that in the Bothnian Sea. The difference in year-class strength can be a result of different climatic conditions between the two areas.

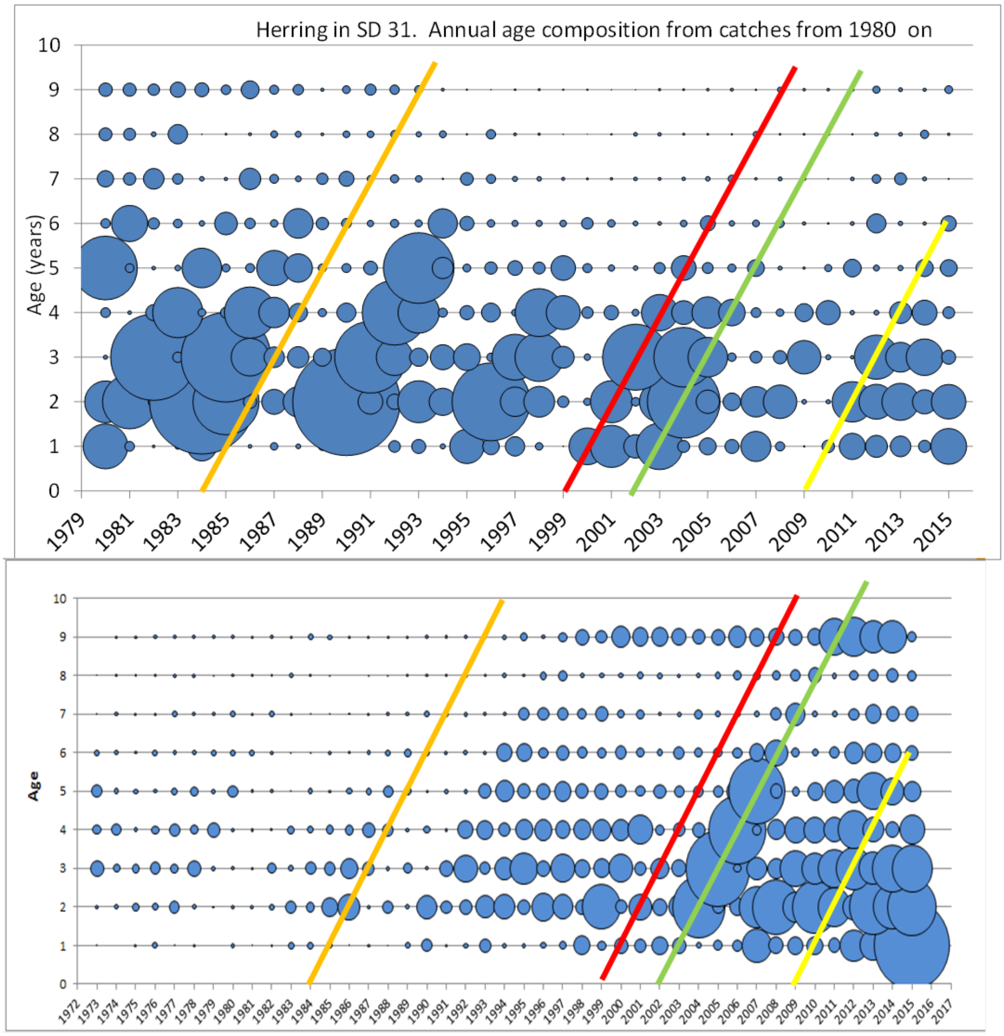


Figure 5.6. Annual total commercial catch at age groups 1 - 9+ (y-axis) did not show similar pattern among SDs 31 (upper) and 30 (lower) graph.

Recruitment and spawning time in the two areas also showed different patterns probably due to colder winters in SD 31 compared to SD 30.

Genetic evidence is not enough to conclude anything so far and more studies are needed. Also migration studies are needed to support any mixing. The narrow area between SDs 30 and 31 is extremely shallow indicating low or no mixing between the stocks (Figure 5.7).

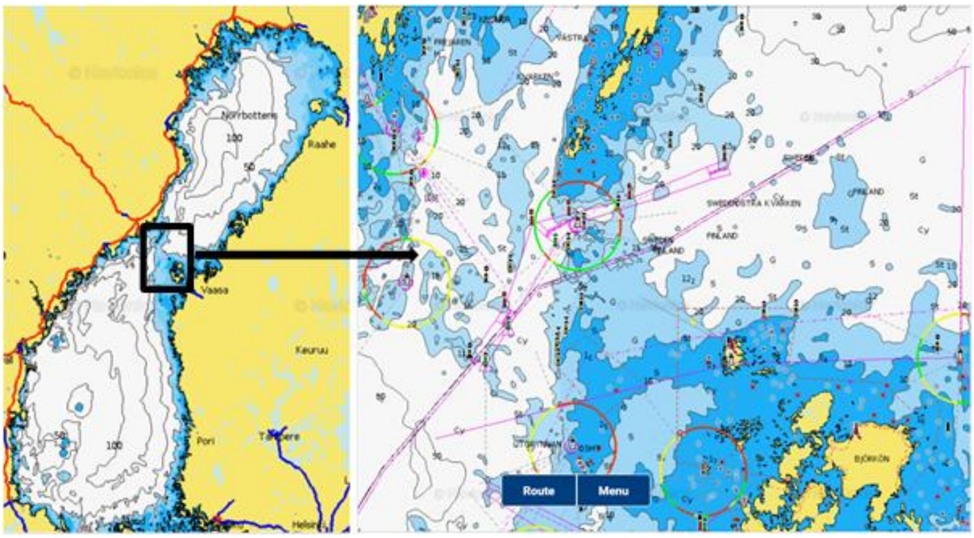


Figure 5.7. Gulf of Bothnia (left) and the shallow area between SDs 30 and 31 (left) with water depths mostly 0 - 5,…,10 m (dark blue).

Considerations of data availability for stock assessment: Acoustic surveys have not been done in SD31. The only abundance index available for SD 31 comes from commercial tuning fleets, which are uncertain especially for species like herring. Further, fishing effort is declining, and it is unknown whether present time series of commercial cpue will be possible to continue in future.

Based on the above information we concluded at the 2016 WKBALT Data Evaluation Workshop that we will combine herring in SD 30 and 31 as one stock assessment unit. The main arguments for combining these previously separate assessment units are:

There is no strong biological evidence either for combining or separating SDs 30 and 31 for stock assessment; recommendation to do some genetics, or tagging studies in future.

Data availability (lack of survey in SD 31) does not support a good quality assessment for SD 31 and this is unlikely to be possible to improve in future.

There is no concern for overexploitation of SD 31 stock with or without merging the stocks. This is because of natural conditions (ice and bottom features: difficulties in trawling) restrict fisheries in SD 31, and there is generally low economic interest in herring fisheries in SD 31.

Expanding the age-span of assessment input data from age-group 9+ into ages 9 to 15+

According to recommendation of 2016 WKBALT Data Evaluation Workshop, all the age-based data from herring in ICES SDs 30 and 31 were revised by splitting plus-age-group 9+ into ages 9 to 15+ for the WKBALT benchmark. The revision was made for *catch in numbers at age*, *weight at age in the catch* (also used as weight at age in the stock) and *maturity at age* for both stocks as well as *numbers at age* in the *trapnet tuning fleet*, which comprises of true ages 3 to 14, and from age-group 8+ to true ages 8-14 in the *acoustic tuning fleet*, where also the age-group one was added, because it did not seem to deviate more in consistency between ages than other ages (Figure 5.8)

The values corresponding to true ages from 1 to the last true age (8 or 7 depending on the former plus-group) were taken as they were in the former input. In all catch numbers (CANUM and tuning fleets) the plus group was divided by the age distributions calculated from the new annual catch numbers produced by Finnish expanded quarterly ALKs. Since Swedish data was not available for historical quarterly catches, nor to any corresponding sampling data, the Swedish catches were assumed to have the same age distribution as the Finnish catches.

Weights at age and maturities at age for the ages 1 to 15+ were also taken as they were in all the former age-based assessment input. The expanded age distributions were derived from the raw data according to normal procedure (the annual **weights at age** quarterly weighted by respective catch numbers and the **maturities at age** by the share of mature individuals in age group).

Methods and data used to combine the stocks her 30 and her 31

The total annual catches and CANUMs from both stocks were summed up by years 1980 - 2015 and age-groups 1 - 15+. The weights at age in catch were combined by weighting the stock specific WECAs with the corresponding stock-specific catch numbers. The shares of mature individuals at age were also weighted by the catch numbers of the corresponding stock (Figures 5.9 and 5.10).

The time series that previously started from 1973 in SD 30 was shortened to start from 1980 to be compatible with time series of SD 31 due to the unavailable Finnish catch data before 1980 and Swedish data even for years before 2010.

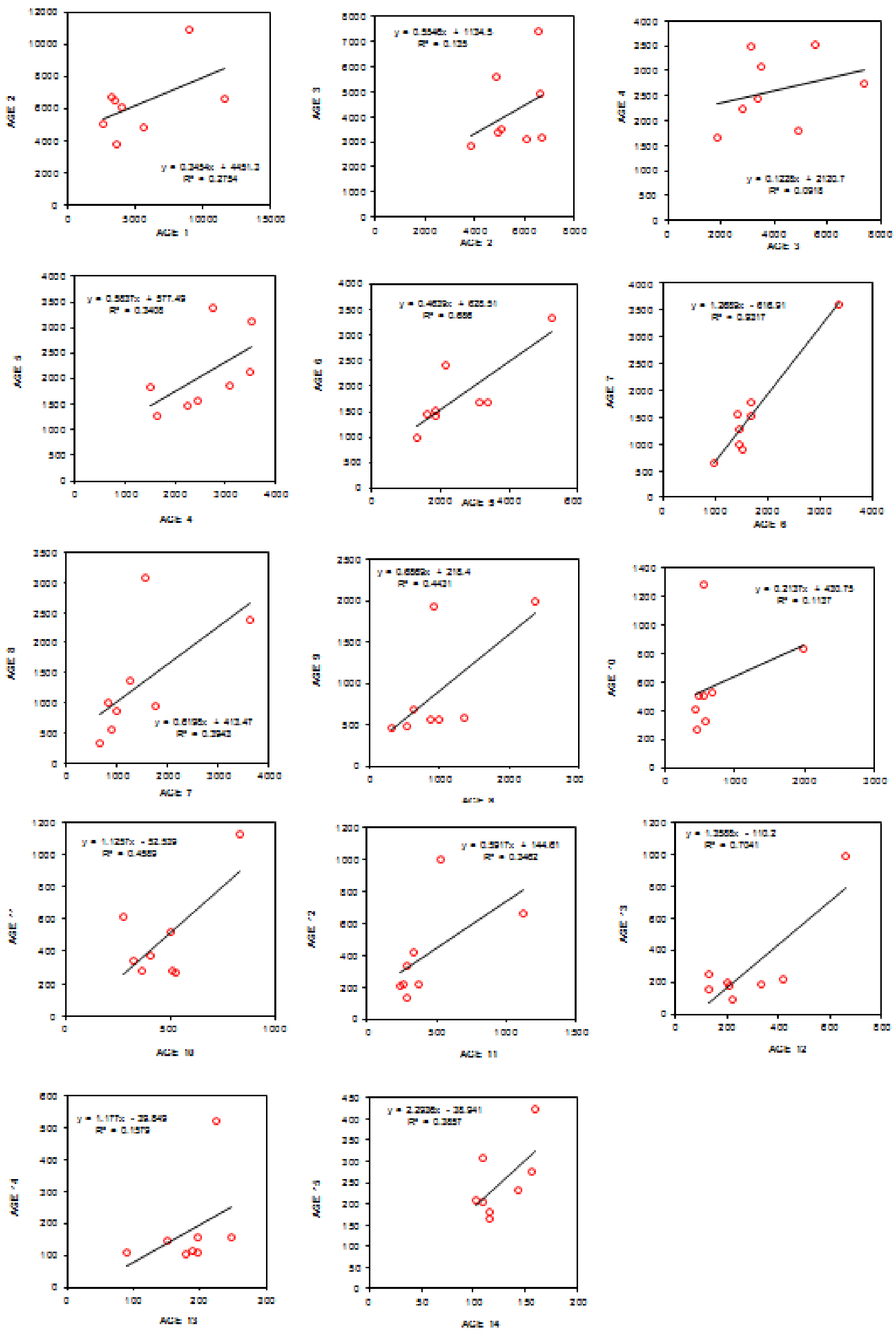


Figure 5.8. Consistency between age-groups s in the SD 30 acoustic abundance indices.

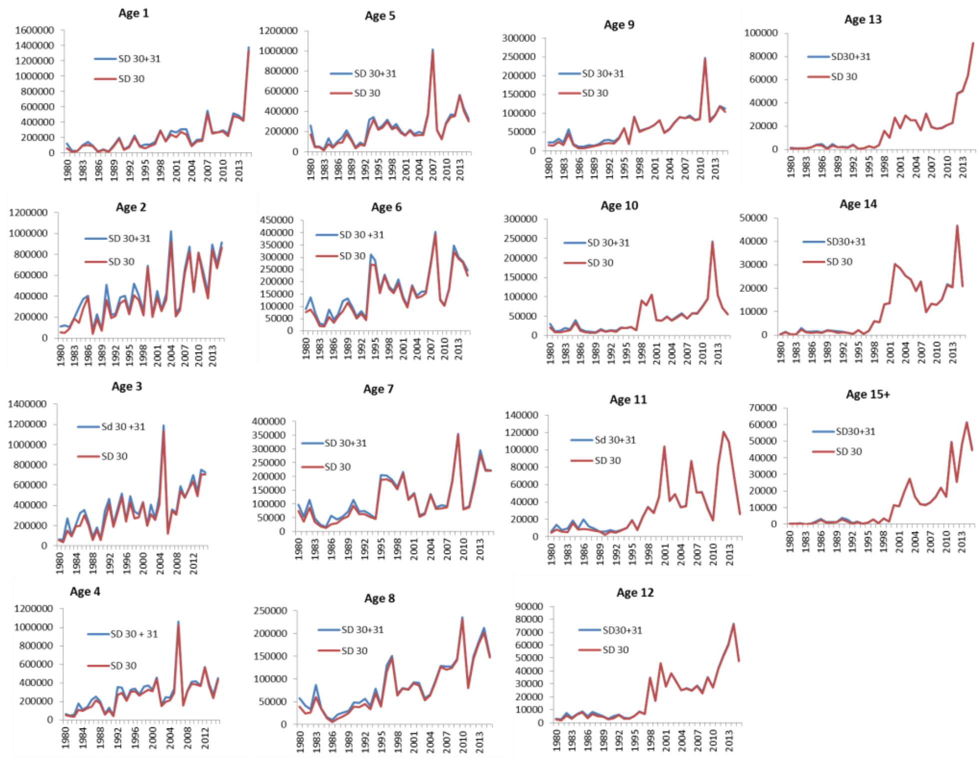


Figure 5.9. The commercial catch in numbers (CANUM, y-axis) in SD 30 (red) and in 30+31 combined (blue) with age groups 1 - 15+ during 1980 - 2015 (x-axis).

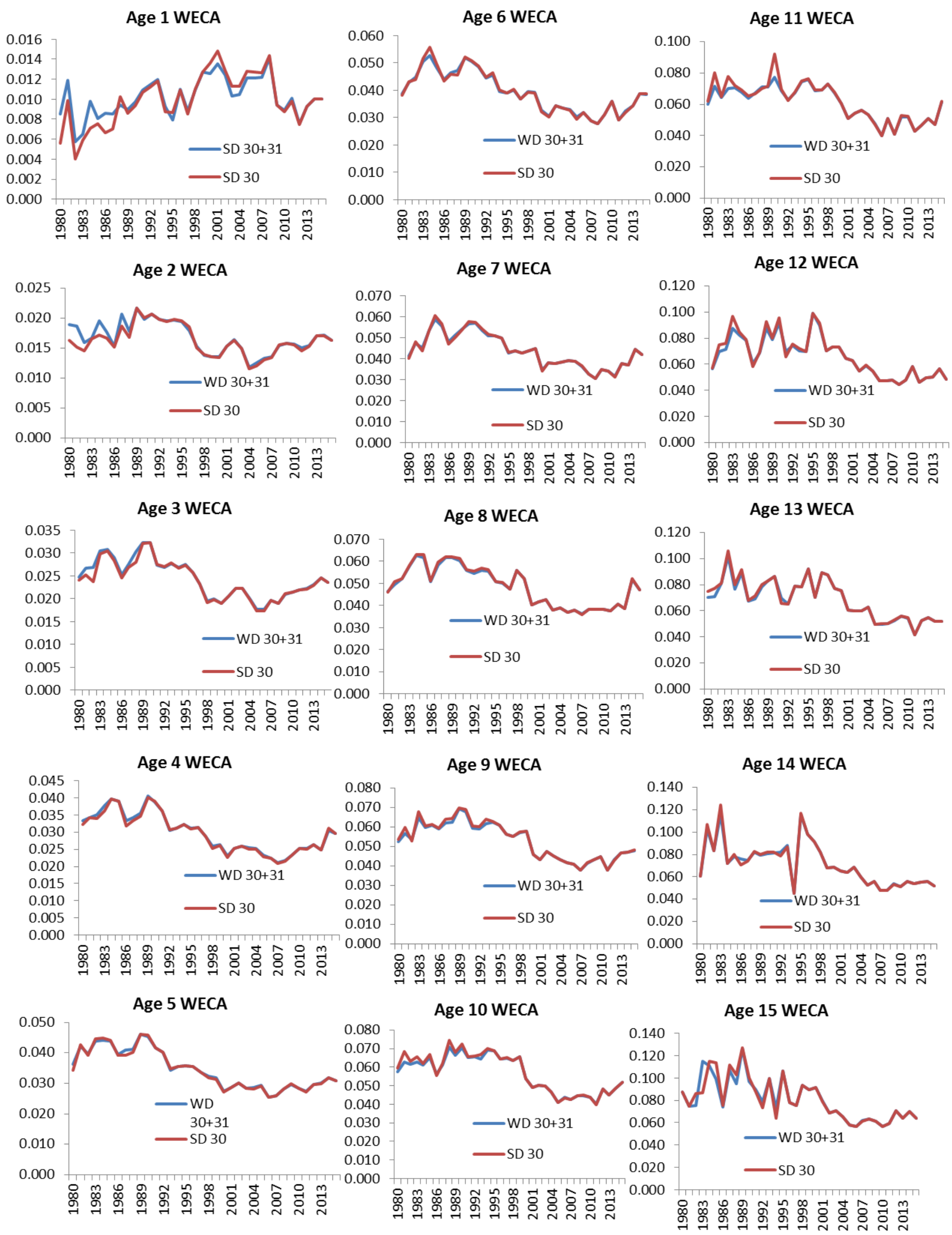


Figure 5.10. The annual mean weight in catch (WECA, y-axis) in SD 30 (red) and in 30+31 combined (blue) during 1980 - 2015 (x-axis) of age groups 1 - 15+.

WD 6. Assessment data

Sampling

The catch sampling performed by Finland and Sweden (table 6.1) is considered to be adequate and sufficient. The age readings in the herring stocks in Gulf of Bothnia area were recently validated (in 2016 according to agreed procedure from WKNARC) and they showed very good agreement between readers (Raitaniemi pers. comm.).

Table 6.1 Herring in SD´s 30 and 31. Landings and sampling by country in 2015

		Quarter	Landings in tons	Number of length samples	Number of fish measured	Number of age samples	Number of fish aged
30	Finland	1	23561	15	4725	10	190
		2	49869	30	5292	18	260
		3	12939	13	3335	11	204
		4	10045	15	4455	14	242
		Total	96414	73	17807	53	896
	Sweden	1	4258	3	3788	0	0
		2	8178	5	3071	3	217
		3	91	5	2616	3	238
		4	1473	1	1203	0	0
		Total	14001	14	10678	6	455
31	Finland	1	396				
		2	3187	12	3223	7	220
		3	750	6	1627	4	129
		4	35			3	140
		Total	4369	18	4850	14	489
	Sweden	1					
		2	35	3	1242	3	195
		3	48	2	543	2	230
		4	74				
		Total	157	5	1785	5	425
30 + 31	Finland	1	23958	15	4725	10	190
		2	53056	42	8515	25	480
		3	13689	19	4962	15	333
		4	10080	15	4455	17	382
		Total	100783	91	22657	67	1385
	Sweden	1	4258	3	3788		
		2	8213	8	4313	6	412
		3	138	7	3159	5	468
		4	1547	1	1203		
		Total	14157	19	12463	11	880
	Finland + Sweden	1	28216	18	8513	10	190
		2	61269	50	12828	31	892
		3	13827	26	8121	20	801
		4	11627	16	5658	17	382
		Total	114940	110	35120	78	2265

Acoustic surveys

Annual hydroacoustic surveys have been conducted in SD 30 in late September/October from 2007 until 2010 with Swedish R/V Argos. In 2011 and in 2012 the survey was performed with Danish R/V Dana and from 2013 to 2016 with Finnish R/V Aranda. This survey is coordinated by ICES (WGBIFS) within the frame of the Baltic International Acoustic Surveys (BIAS). The acoustic estimates are used as abundance indices (tuning fleet) for the assessment. In the acoustic tuning fleet, age-groups 1-14 (true ages) are applied (in comparison to former acoustic fleet the age-group one was added, since it showed similar consistency between ages as older ages (figure 6.2.).

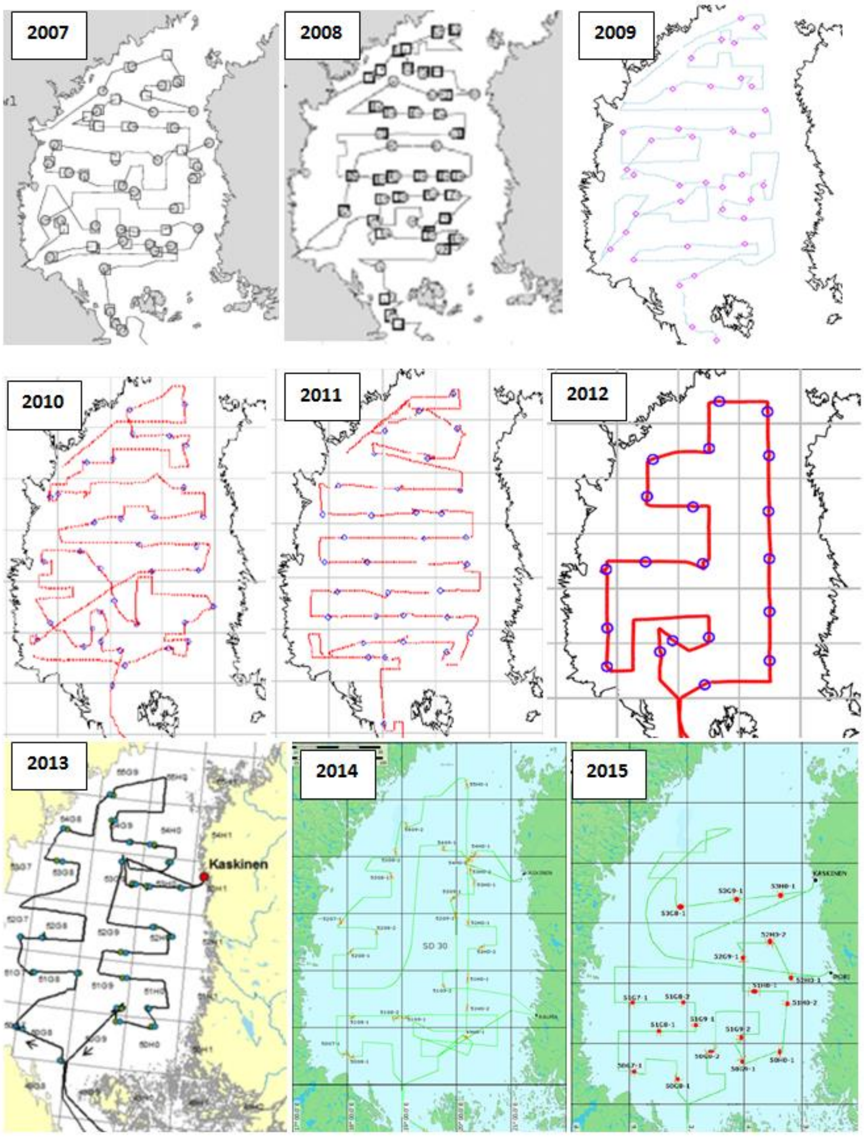


Figure 6.1. Spatial coverage of acoustic surveys conducted in Bothnian Sea in years 2007-2015.

The coverage of the acoustic transects and trawlsamples has mostly been good. In 2012 the coverage was only half of the “normal” because of a sudden 50 % reduction in funding. In 2014 there were problems with the fishing gear, which reduced the trawl hauls, but the spatial acoustic coverage was not affected that much. In 2015 a storm damaged the ship so that the most northern part of the area had to be skipped due to lack of time after fixing the damage in harbour.

The 2012 50 % reduction in the survey effort, as well as the 2014 and 2015 results were, however, considered acceptable for the index by the survey expert working group, ICES WGBIFS (ICES 2013, ICES 2015, ICES 2016).

The survey is based on IBAS (International Baltic Acoustic Survey) manual (ICES 2016) with the aim of 60 Nm of acoustic transect and 2 trawl hauls per statistical rectangle. In the catch sampling length distributions at least 300 fish are measured in 0,5 cm length-classes and 10 individuals from all prevailing length-class are aged per rectangle, comprising normally of about 20000 length-measurements and 2600 age-readings annually.

Calculation of catch at age

In Finland the calculation of catch at age is based on year-quarterly performed length-stratified random sampling of individual fish (at minimum 10 aged individual fish from all prevailing 0,5 cm length-classes) and length-samples of at least 300 specimens per sample from different commercial fisheries per quarter. The average number of individual-samples is 1101 from commercial fisheries and 2473 from surveys in SD 30 and 587 from commercial fisheries in SD 31 annually, and the average number of length measurements is 18537 and 5987 respectively.

The quarterly collected length distributions (from length sampling) are converted into age distributions with year quarterly prepared age-length keys, ALKs, which are derived from the sampling of individuals.

The quarterly catches from the main herring fisheries (OTM + PTM carried out in mid-water and deep midwater and trapnets, FPN + FYK) are divided by the mean weight of the herring from length samples of respective fisheries in order to get the total catch number of fish for all strata (all fisheries, 4 quarters). The total catch numbers from each fishery and year quarter are then multiplied by the proportions of the age-classes in the age distributions and summed up to get the annual catch at age.

In Sweden the length-samples of at least 300 specimens per sample from two (main) commercial fisheries [bottom trawls (XTB) and gillnets (GNS)] in SD 30 and only from gillnets in SD 31 are collected quarterly each year. The catches of pelagic trawl (OTM and PTM) fisheries are not sampled. Length-stratified random sampling of individual fish (app. 20 aged individual fish from all prevailing 0,5 cm length-classes per quarter) is performed only for gillnet fisheries. In SD 30 the average total number of annual length measurements is 5600 from bottom trawls and 2300 from gillnet fisheries, and the average total number of sampled fish individuals is 490, and in SD 31 the average total number of annual length measurements is 1700, and the average number of sampled fish individuals is 450.

The length distributions (from length sampling) are converted into age distributions with quarterly prepared age-length keys (ALKs). For that purpose, additionally Finnish ALK and mean weight at length data from trawl fisheries are borrowed.

The calculation of total annual catch-at-age follows the same procedure as in Finland.

Calculation of mean weight

The mean weights at age are derived from the individual data collected from commercial catches all year round as well as from the individual data of acoustic survey trawl samples during September-October (2600 individuals annually), and averaged over year-quarters. The annual mean weights at age for assessment are derived by weighting the year-quarterly mean weights by the year-quarterly catch numbers.

Maturity

The maturities are defined from the individual data that is collected all the year round from commercial catches with other so called “stock related variables” as length, weight and age, and from the trawl samples of the acoustic survey. The data for the maturity ogive used in assessments is collected from samples before spawning (i.e. January to March in SD 30 and March to May in SD 31) because the idea is to get the proportion of spawners by age from the whole population, before the spawning part separates itself from non-spawners by approaching the coastline to spawning areas.

The share of mature fish in each age-group is calculated from annual data and the annual number of the individual samples for maturity definitions that are used for the maturity ogives has been on average (2010-2015) 283 in SD 30 and 212 in SD 31.

The maturity scale (table 6.2) in use is the modified European standard 9-stage scale and the same scale is used both in Finland and Sweden. The stages II-VIII (VIII-A and VIII-B) are considered mature while stage I and IX are counted as "non-mature" although stage nine (abnormal) is usually mature, but not accounted to take part to spawning.

The maturities defined during a Swedish acoustic survey in 4th quarter and the maturities derived from Finnish 1st quarter sampling of commercial catches have showed very small differences.

In WKPELA in 2012 benchmark we tested the sensitivity of the annual changing proportions of spawners in age-groups (by several types of averages over time(1) and even though there are clearly visible annual changes in mostly 2-year-olds, there was only negligible impact to e.g. estimates of SSB. It was concluded then that it was still better to have the latest real information on maturity at age than assume something else.

1) Four new combinations of maturity ogives were introduced to XSA (maturity ogive with 3- and 5 years running averages for the whole time series, constant maturity ogive for the whole time series as an average of the whole time series and two different averages over the time series according to periods before and after the alleged regime shift (1973-1988 and 1989-2010)). Resulting estimates of SSB were compared to the annually updated maturity ogive in SPALY run, and the differences were found to be negligible with the exception of year 2010 only.

The reason for the "instability" was found to be the high inter-annual variation in the maturation of 2-year olds in the whole time-series and especially in 2010. The maturity calculations from raw data were examined carefully, and no mistakes were revealed.

Table 6.2. Maturity scale in use in Finland and Sweden.

Std Eur. Scale	Maturity stage (code)	Maturity stage
Ia	I	Immature, juvenile
Ib	II	Immature, early development
Iia	III	Maturing, early stage
Iib	IV	Maturing, late stage
IIIa	V	Spawning, prepared
IIIb	VI	Spawning, running
IV	VII	Spent
Va	VIII A	Regeneration, regressing
Vb	VIII B	Regenrating/skipped spawning
VI	IX	Abnormal

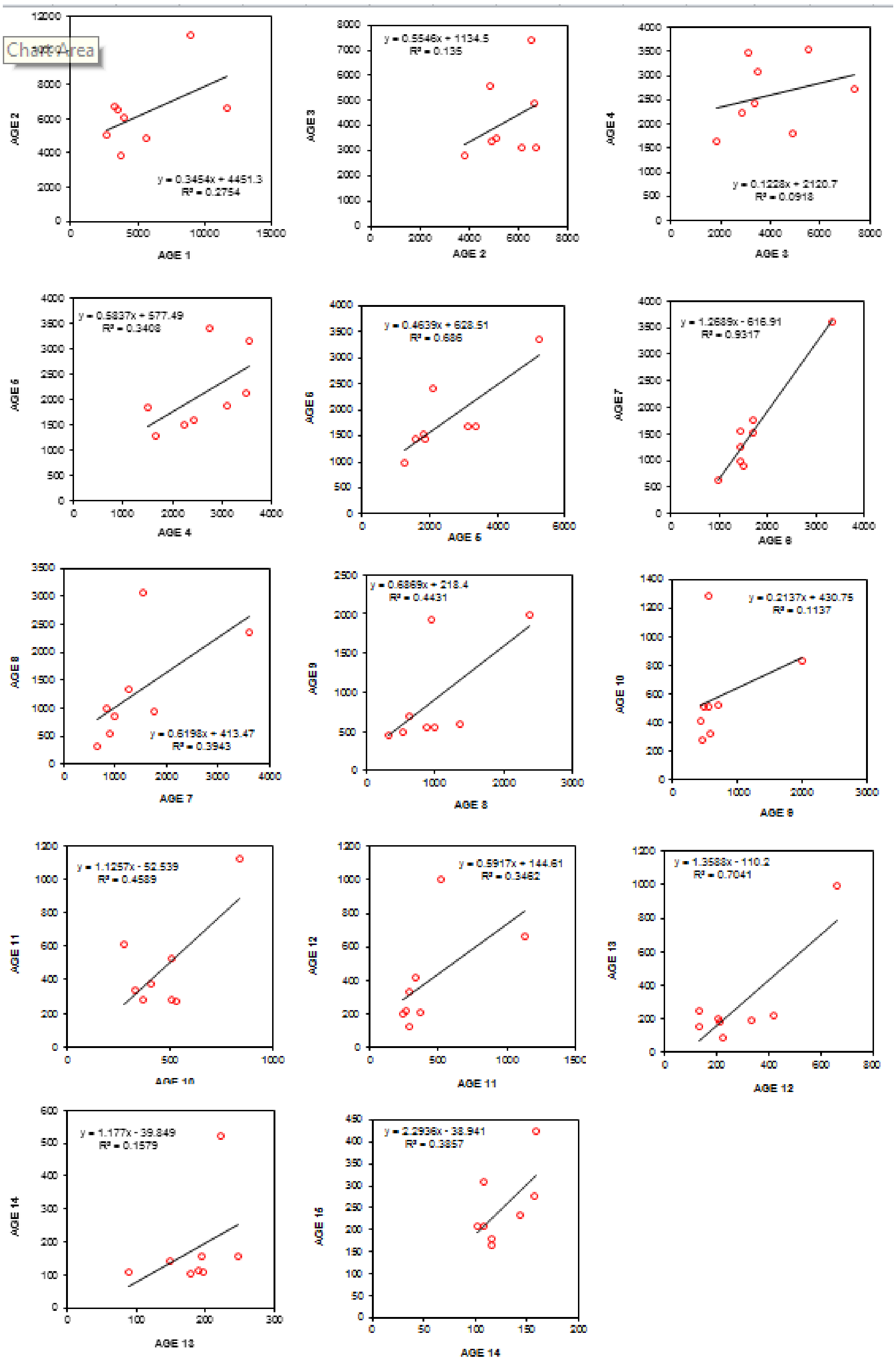


Figure 6.2. Consistency between consecutive age-classes in acoustic tuning fleet

WD 7. Stock assessment runs

FLSAM was rerun by varying age groups 8+, 9+ 10+, 11+, 12+, 13+, 14+ and 15+ (Figure 1). For each run the final age group for the tuning fleets was selected as true age and one less than the catch-at-age final plus group.

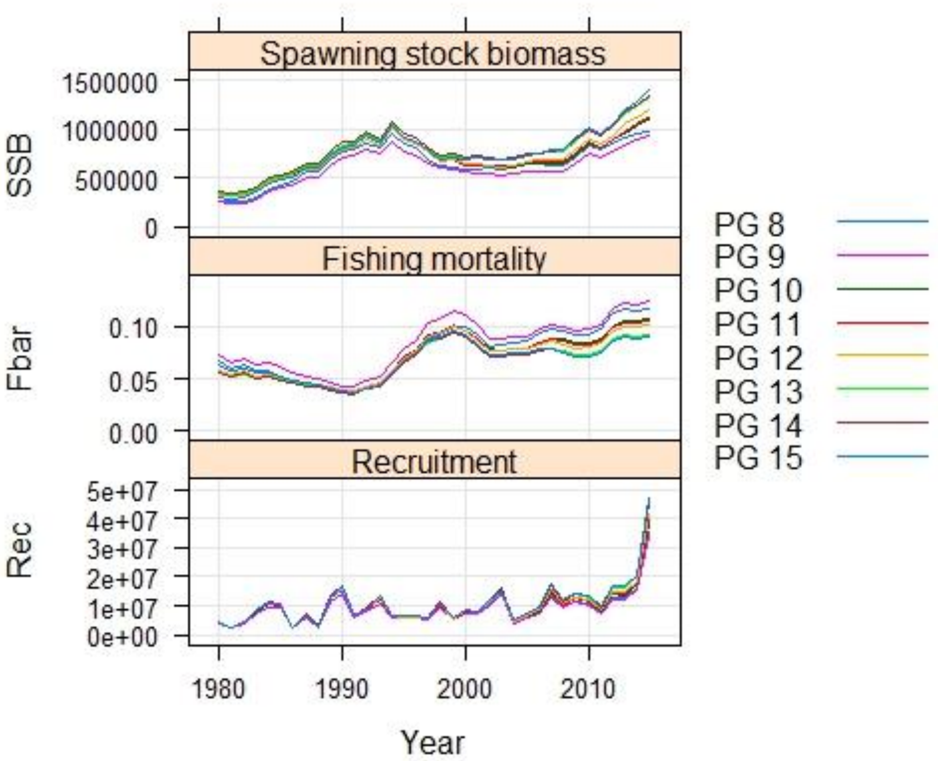


Figure 1. FLSAM based SSB, Fbar and recruitment by varying + age groups 8+, 9+ 10+, 11+, 12+, 13+, 14+ and 15+ (PGs 8 - 15, respectively, y-axis) in years 1980 - 2015 (x-axis).

The sensitivity of FLSAM was also diagnosed by varying natural mortality with a priori fixed age group +10 (Figure 2). Age group +10 was selected here based on residuals and, the tested natural mortality rates in FLSAM were based on total mortality estimation of SD 30 stock, which indicated rather low and declining trend in annual total mortality rates from 2007 (Z = 0.3) to 2015 (Z = 0.18, see WD4).

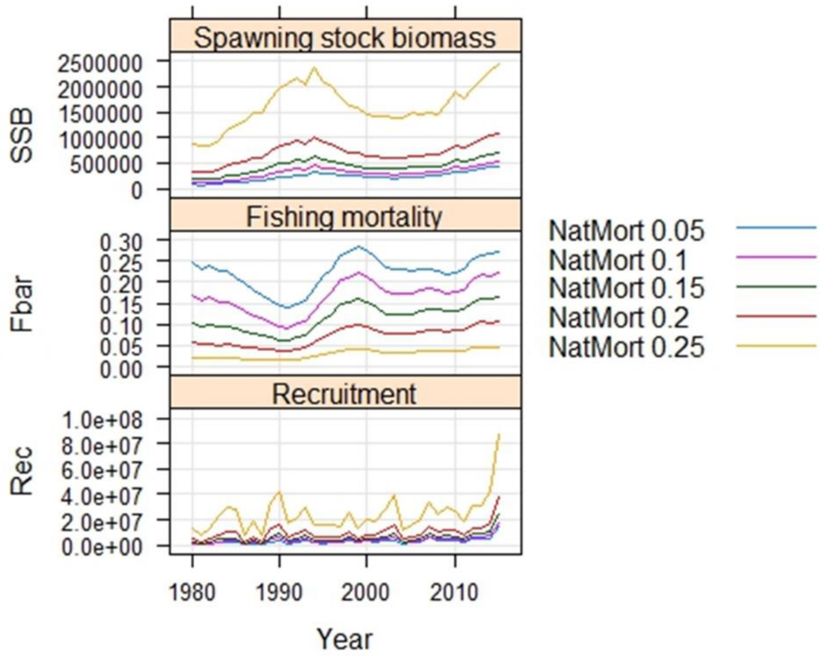


Figure 2. FLSAM based SSB, Fbar and recruitment by varying natural mortality between 0.05 - 0.25 (y-axis) in years 1980 - 2015 (x-axis).

The FLSAM simulations indicated plausible results with age group +10 and natural mortality of 0.15. These input values were selected and used in final FLSAM based retrospective analyses (Figure 3).

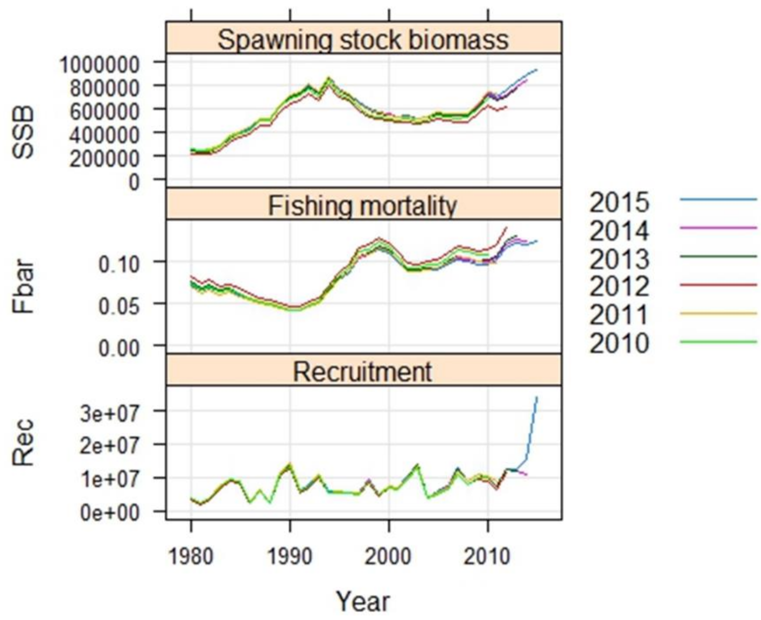
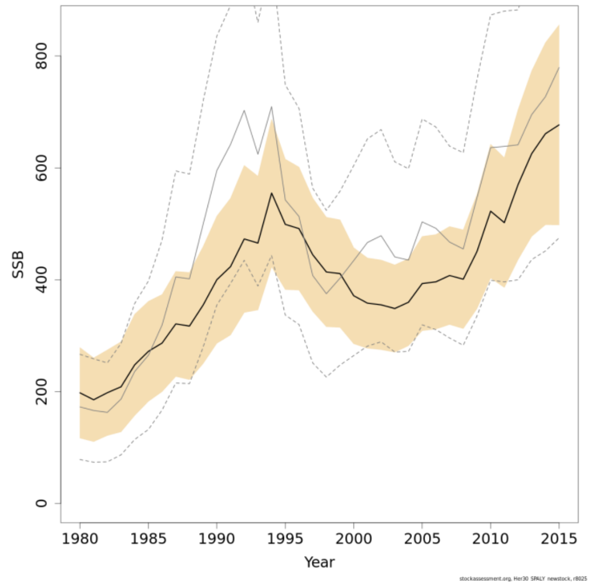
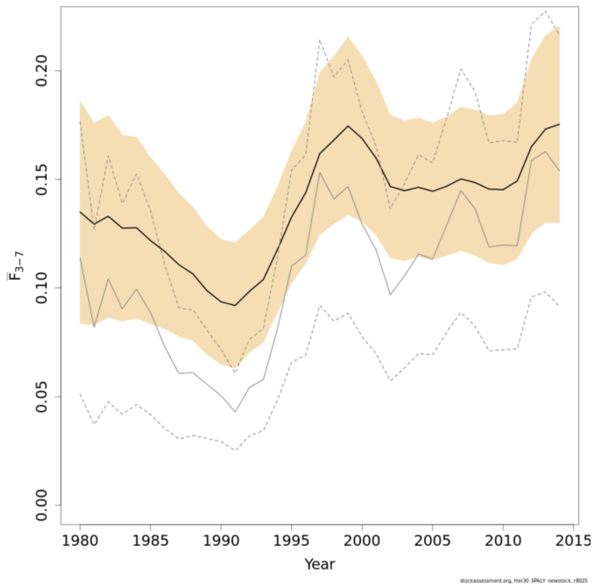


Figure 3. FLSAM based SSB, Fbar and recruitment in retrospective analyses (y-axis) in years 1980 - 2015 (x-axis) using natural mortality 0.15 and 10+ age as final age.

SAM runs with the final data set

Comparison of SPALY (2016 assessment run) with the final decided model set up with 10+ as final age group for the catch at age and acoustic and trapnet with final true age 9. Natural mortality is set to 0.15. This run is in stockassessment.org under Her30_SPALY_newstock.





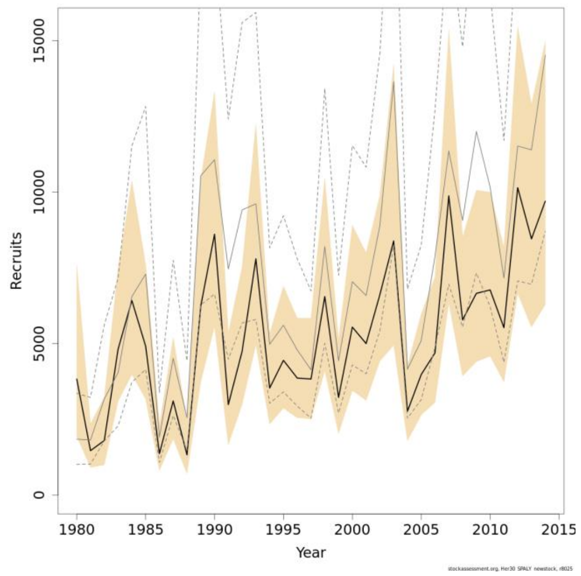
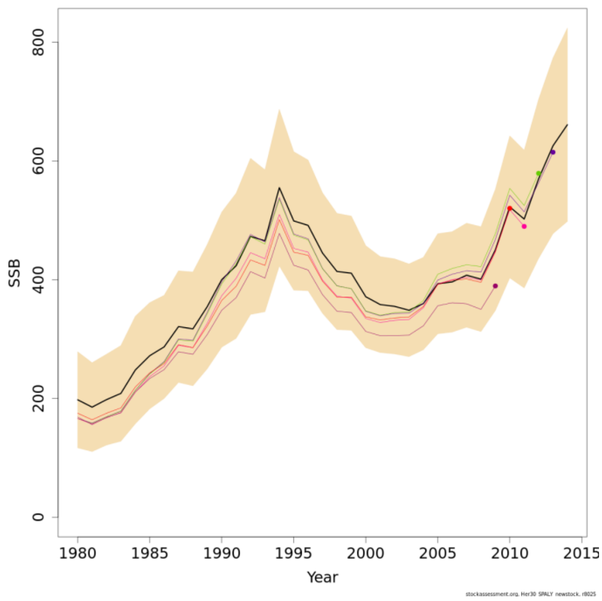
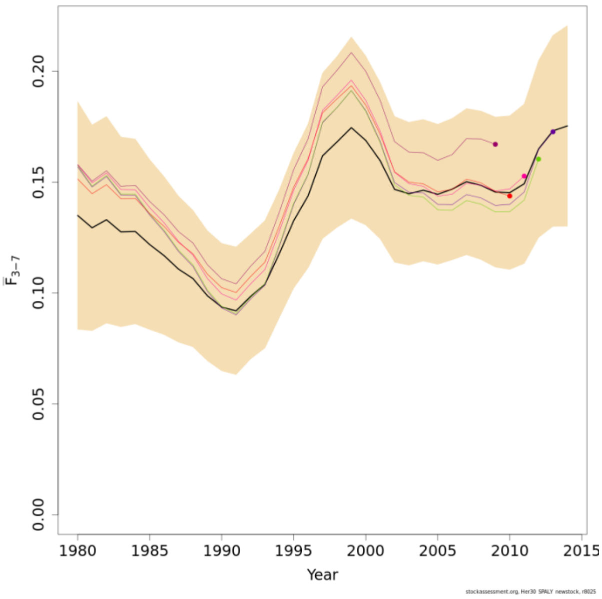


Figure 4. SAM based SSB, fishing mortality and recruitment estimates using the WGBFAS 2016 model (grey line) and the new model (black line) with combined SD 30 and 31 stocks with 10+ as final age for the catch and 9 as true final age for the acoustic and trapnet survey fleets.

Figure 5. Residuals with the new stock settings with combined SD 30 and 31 stocks with 10+ as final age for the catch and 9 as true final age for the acoustic and trapnet survey fleets.


SSB
0
200
400
600
800
1980
1985
1990
1995
2000
2005
2010
2015
Year


$\bar{F}_{3-7}$
0.00
0.05
0.10
0.15
0.20
1980
1985
1990
1995
2000
2005
2010
2015
Year

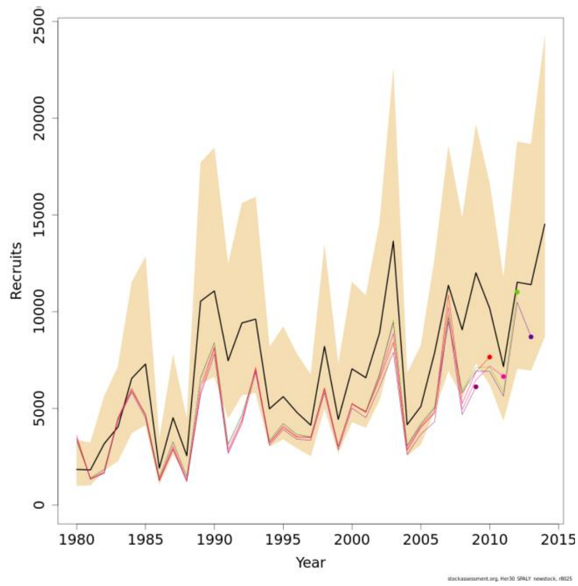
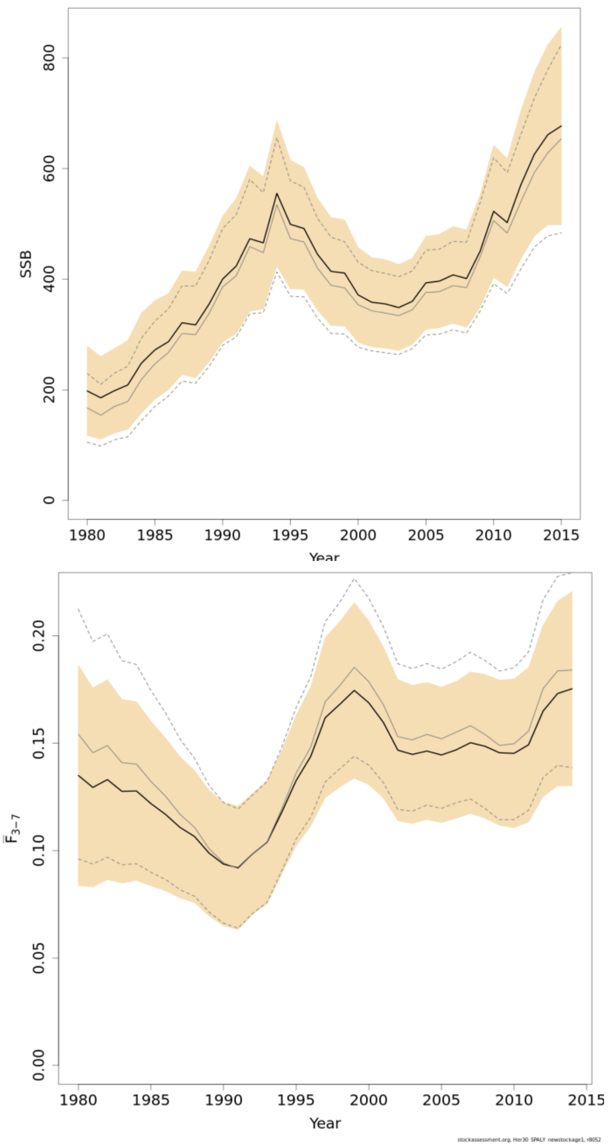


Figure 6. Retrospective runs for the new combined stock with 10+ age as final age and the survey fleets with 9 true final age.

The age 1 in the acoustic survey was included in the run and compared with not including the age 1 in the acoustics (Her30_SPLAY_newstockage1).


SSB
0
200
400
600
800
1980
1985
1990
1995
2000
2005
2010
2015
Year
$\bar{F}_{3-7}$
0.00
0.05
0.10
0.15
0.20
Year

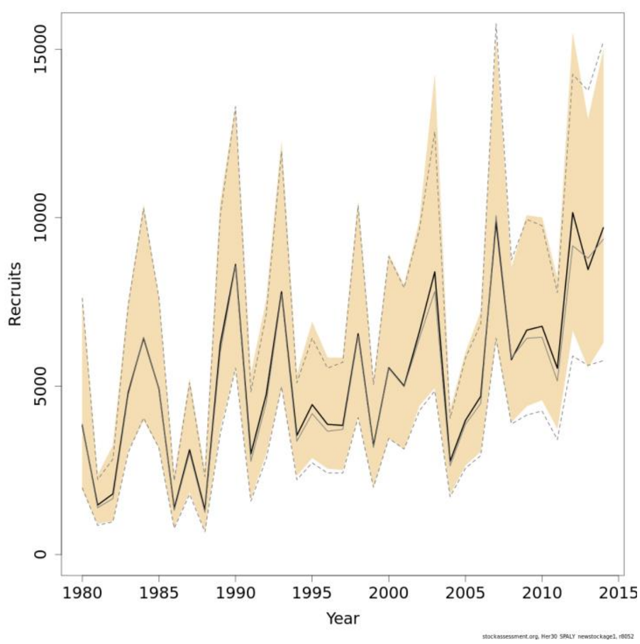

Recruits
0
5000
10000
15000
1980
1985
1990
1995
2000
2005
2010
2015
Year

Figure 7. Comparing assessment runs with the new stock without age 1 (grey line) and with age 1 in the acoustics (black line).

The assessment with the new stock was run (including age 1 in acoustics) with and without including trap net (acousticincludingage1_withouttrapnet)

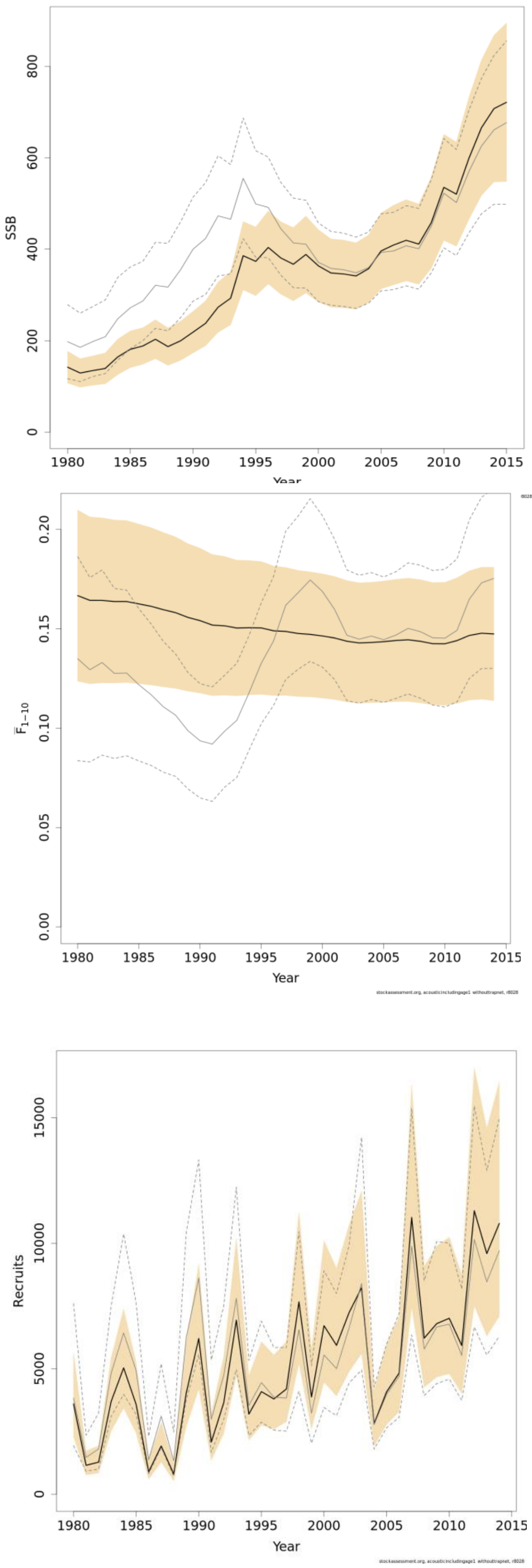


Figure 8. Comparing assessment runs with (grey line) and without (black line) trapnet included in the run with the new stock (acousticincludingage1_withouttrapnet).

WD9: Herring reference points

1) Reference points analysis

1.1) Herring in Subdivision 30 and 31 (Gulf of Bothnia)

1.1.1) Current reference points

Summary table of current stock reference points

REFERENCE POINT	VALUE	TECHNICAL BASIS
Current F_{MSY}	Not defined	
Current B_{lim}	Not defined	
Current B_{pa}	Not defined	
Current MSY $B_{trigger}$	Not defined	

This is a new stock as for the first time SD 30 and 31 were merged. Thus, no current reference points are available.

1.1.2) Source of data

The analysis in this report uses the newest (1980-2015) assessment results from the SAM assessment.

Equisim was used for this stock.

1.1.3) Methods used: EqSim

1.1.4) Settings

DATA AND PARAMETERS	SETTING	COMMENTS
SSB-recruitment data	Full data series	
Exclusion of extreme values (option extreme.trim)	Not used	
Mean weights, proportion mature and F at age pattern	2006-2015	
Exploitation pattern	2006-2015	
Assessment error in the advisory year. CV of F	0.212	
Autocorrelation in assessment error in the advisory year	0.423	

1.1.5) Results

1.1.5.1)Stock recruitment relation

The stock recruitment fit using the three models (Ricker, B&H and segmented regression) weighted by the default "Buckland" method available in EqSim gave a “straight” line for all models. Thus, a segmented regression model was used with a breakpoint set arbitrarily at the average observed SSB (i.e. B_{lim} = 405980 t) as dictated by ICES guidelines for reference point estimation. However, this will result in a rather large value of $B_{trigger}$ and B_{pa}. Thus, the ICES reference points guidance were modified in this case. The first step was to estimate F_{MSY} using a hockey stick SR relationship with B_{lim} at the average SSB and without MSY $B_{trigger}$, but with assessment and advice error (i.e. using the default values). Once the F_{MSY} was estimated, the simulations were run again with the same hockey stick SR relationship and B_{lim} to estimate MSY $B_{trigger}$ defined as the 5th percentile of the SSB at F_{MSY}. Successively, B_{pa} was set as MSY $B_{trigger}$ and a new value of B_{lim} was estimated as B_{pa} divided by exp(1.645 x 0.2). After B_{lim}, B_{pa} and MSY $B_{trigger}$ were all defined, the ICES procedure for setting the reference points was used to estimate the remaining reference points. The SR relationship used for these runs was a hockey stick with the breakpoint set at the new B_{lim}. The number of samples used to fit the SR relationship and the number of runs used in all EqSim simulations were 1000 and 200, respectively. Autocorrelation of recruitment was used in all EqSim simulations. F_{pa} was estimated using the ICES standard procedure (F_{pa}=F_{lim} x exp(-1.645 x σ). Sigma was estimated as the uncertainty associated to the F in last assessment year (i.e. 2015; σ = 0.223).

1.1.6) Proposed reference points

Summary table of proposed stock reference points:

Stock	
Reference point	Value
$F_{P.05}$ (5% risk to B_{lim}) with MSY $B_{trigger}$	0.21
$F_{P.05}$ (5% risk to B_{lim}) without MSY $B_{trigger}$	0.18
F_{MSY}	0.21
F_{MSY} lower	0.15
F_{MSY} upper	0.25
F_{pa}	0.20
F_{lim}	0.29
F_{MSY} upper precautionary	0.18
F_{MSY} range with MSY $B_{trigger}$	0.15-0.21
F_{MSY} range without MSY $B_{trigger}$	0.15-0.18
MSY $B_{trigger}$	283180 t
B_{pa}	283180 t
B_{lim}	202272 t

1.1.7) Discussion / Sensitivity

As explained above, the standard ICES procedure for setting B_{lim} reference point in this case would result in an unrealistically large value of B_{lim} and thus in an unrealistically low value of F_{MSY}. Thus, the procedure used to estimate the reference points for herring in SD 30 and 31 is not in strictly in accordance with the ICES reference points guidance but it has been modified to account for the specific SR relationship of this stock. Also, according to the EqSim estimations, $F_{P.05}$ is lower than F_{MSY} and thus F_{MSY} and F_{MSY} range are dictated by precautionary considerations in this case.

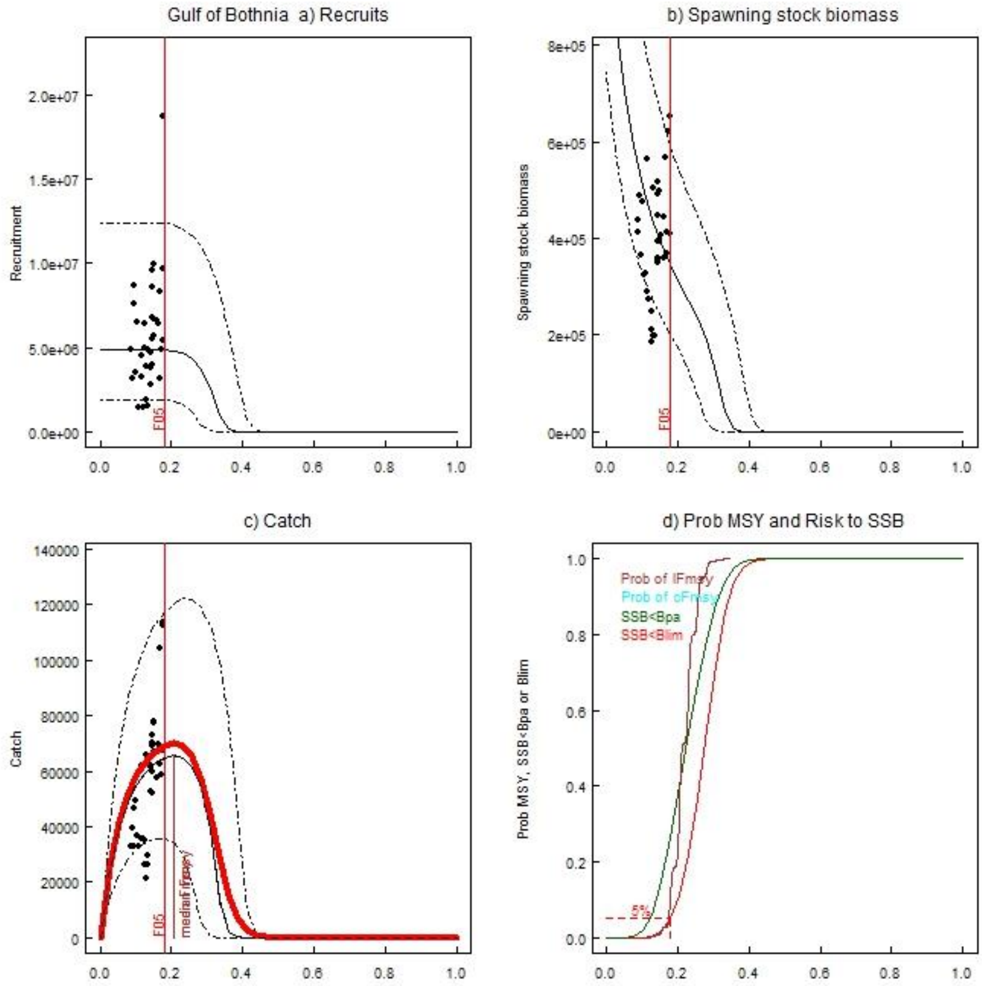


Figure 1. EqSim results for Herring in Subdivision 30 and 31 with $B_{trigger}$.

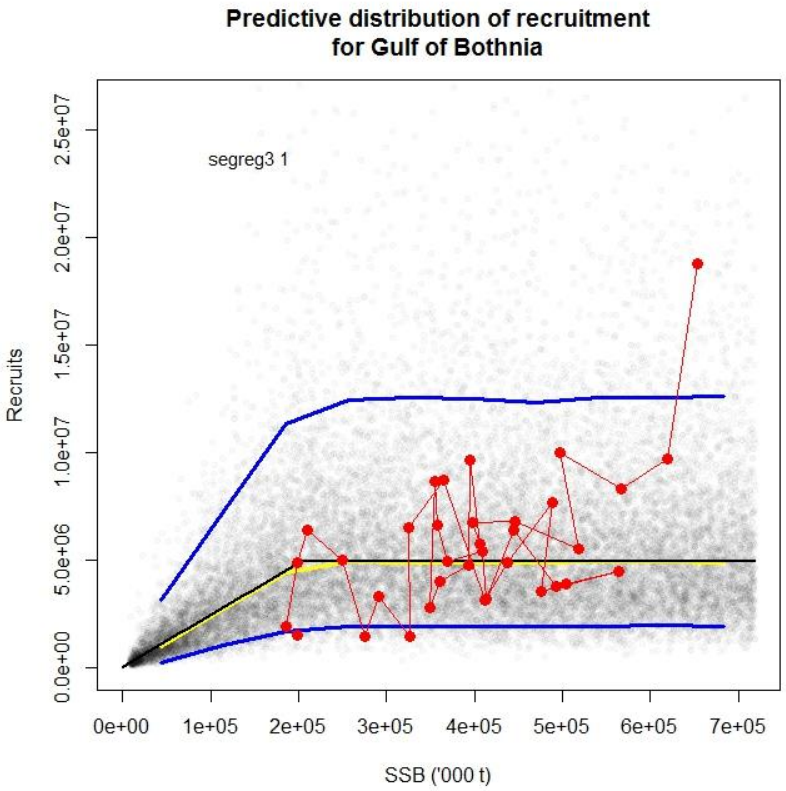


Figure 2. Stock recruitment relationship for Herring in Subdivision 30 and 31 used in the EqSim simulations for the estimation of the F_{MSY} reference points.

WD10- Cod population mixing in the Kattegat

Cod population mixing in the Kattegat

Working Document for ICES WKBALT, 7-10 February 2017

Cod population mixing in the Kattegat - results from genetic analyses

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Introduction

In Atlantic cod, population genetic research has identified a major genetic break between North Sea and Baltic Sea populations (Nielsen et al. 2003; Berg et al. 2015). The major genetic transition between the two regions is found in the western Baltic Sea, while populations within the transition zone are genetically more similar to each other and to the North Sea than to the Baltic Sea (Nielsen et al. 2003, Nielsen et al. 2005, Berg et al. 2015). Genetic and tagging data suggest a high degree of connectivity between the North Sea and Kattegat in the transition zone (Svedäng et al. 2007, André et al. 2016). It has been hypothesized that North Sea fish enter the Kattegat at early life stages and return to the North Sea at the age of maturation around ages 2-3 (Svedäng et al. 2007).

Here, we use a panel of single nucleotide polymorphism (SNP) markers to determine the population of origin of cod collected in the Kattegat. The aim of this study is to examine if North Sea cod are present in the Kattegat, and if so, to estimate the proportions of cod of North Sea and local origin at different life stages and years of capture. The data will feed into the working group efforts to improve our understanding of connectivity of cod populations and should thus ultimately help to improve stock assessment of Kattegat cod.

Methods

Baseline individuals consisted of 580 cod collected at spawning time from the North Sea, transition zone and Eastern Baltic Sea (Table 1 and Figure 1). These samples represent the major evolutionary units in this part of the species' distribution (see Heath et al. 2014, Nielsen et al. 2012, Berg et al. 2015).

Tissue samples from a total of 1800 cod in the Kattegat were collected from Danish and Swedish research cruises, discard trips and harbour sampling (Table 2). Sampling was concentrated in the most recent years, but did also include a few samples from the 1990s.

A panel of 192 SNPs with high power for identifying Baltic Sea, North Sea and local Kattegat/transition zone populations was identified by screening three different data sets for highly differentiated loci (data previously published in Nielsen et al. 2012, 1 Cod population mixing in the Kattegat Heath et al. 2014 and Berg et al. 2016). These markers were genotyped on a Fluidigm BiomarkTM HD System.

Independence of markers (i.e. linkage disequilibrium, LD) was examined by heatmaps of pairwise estimates of r2 for individual baseline samples with the package LDheatmap for R.

A principal component analysis (PCA) was used to examine patterns of baseline sample differentiation and to define reporting groups (i.e. groups of genetically related samples) used for assignment.

Individual assignment was based on genotype likelihoods, following the method by Rannala and Mountain (1997), implemented in the programme GeneClass2 (Piry et al. 2004). For each individual, an assignment score (likelihood in a given group divided by the sum of all likelihoods) was calculated for each of the possible reporting groups. Assignment of Kattegat samples was based on the maximum assignment score.

Statistical power for assignment to baseline groups was assessed by self-assignment using the leave-one-out procedure. Likelihood ratios (i.e. likelihood in reporting group of origin vs. likelihood in alternative group) were calculated for all three pairwise combinations of reporting groups. With this method, a clear separation of likelihood ratio distributions indicates high power for assigning individuals to the two groups (see also Ogden and Linacre 2015).

Results and Discussion

Of the 192 genotyped loci, five loci were removed due to poor or inconsistent clustering. Hence, the final data set consisted of 187 SNPs. After the removal of 24 individuals with more than half of the loci with missing data, genotyping success was generally high, with the majority of samples with more than 180 loci genotyped (Figure 2).

Heatmaps of linkage disequilibrium showed low levels of correlation between markers (Figure 3 for two examples), suggesting that the applied markers can be considered as providing independent information for population assignment.

The PCA of baseline individuals showed three main clusters of individuals, corresponding to the North Sea, transition zone and Eastern Baltic (Figure 4). Hence, these groups were used as reporting groups for assigning fish from the Kattegat. The groups were named "North Sea", "Kattegat" and "Eastern Baltic", respectively. Consequently, assignment to "Kattegat" means assignment to the collective group of individuals from the transition zone. Since genetic differences between samples collected in the transition zone are very small, we cannot reliably differentiate 2 Cod population mixing in the Kattegat between baseline samples on this very fine geographical scale with the current panel of 187 SNP loci.

Self-assignment to reporting groups showed that, as expected from the PCA, the likelihood ratios were clearly separated between the Eastern Baltic and Kattegat and North Sea, respectively, while the distributions were closer when comparing Kattegat and the North Sea. Still, the distributions for Kattegat and North Sea were well separated and consequently only few mis-assignments are expected between these groups (Figures 5a-5c).

In the Kattegat samples, few individuals had intermediate assignment scores (Figure 5), suggesting that the Kattegat is composed of a mix of pure parental individuals, as opposed to a scenario of intense hybridization between parental populations.

Of the 1800 fish analysed, only one (collected in quarter 1 2015) assigned to the Eastern Baltic reporting group. This fish was omitted from the detailed geographical presentation of assignment results. Results from assignment of individual fish are presented as proportions of North Sea and local Kattegat origin for different age groups, size groups and years in Figures 7-18.

The distributions of proportions showed a clear geographical cline from high proportions of North Sea fish in the northern parts of the Kattegat to lower proportions in the south. There was also an indication of a higher proportion of North Sea origin for younger/smaller fish. The oldest/largest fish, in the south in particular, were almost exclusively of Kattegat origin, and very few fish in spawning condition assigned to the North Sea (Figure 18). Furthermore, results suggested variation between years and cohorts. For example, data indicated that the 2011 yearclass in 2013 was dominated by North Sea fish while the proportion of North Sea fish in the 2013 yearclass in 2015 was much lower (compare age 2 fish in 2013 and 2015, Figures 11 and 14), indicating that mixing proportions are not temporally stable and may be driven by independent dynamics in the North Sea and Kattegat. Longer term temporal variation is difficult to evaluate with the present data due to limited sample material from the 1990s.

These results support the general hypothesis of immigration of North Sea fish at young life stages, followed by return migration at later stages. However, they do not provide a threshold age/size of migration nor do they show if individual North Sea cod migrate back and forth between the North Sea and Kattegat, or if they only enter the Kattegat once. More detailed analyses at the cohort level and supplementary data, for example from micro-chemical signatures in otoliths, will be needed to provide a full understanding of the dynamics of connectivity in the region.

The assignment results for individual fish have been distributed to WKBALT members for use with GAM modelling and stock assessment test runs. 3 Cod population mixing in the Kattegat

Conclusions

The SNP panel used here demonstrated high power for identifying population of origin for cod collected in the Kattegat. Results generally support the overall hypothesis that North Sea cod enter the Kattegat at early life stages and leave at later life stages. Hence, migration may be responsible for at least part of the unallocated mortality observed in recent stock assessments. The method applied here can be used for continuous monitoring of population mixing from both surveys and fisheries, and can also be applied to archived otoliths to provide DNA based time series of mixing proportions in the Kattegat.

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Table 1. Baseline samples

Area	Sample size
North Sea (ICES SD IV)	211
Viking Bank 2002/2003	97
German IBTS Q1 2016	3
Norwegian IBTS Q1 2016	49
Danish IBTS Q1 2014	17
Moray Firth 2003	45
Kattegat/transition zone (ICES SD 21-23)	289
Kattegat 2015	75
Kattegat 2004	48
Øresund 1997	44
Øresund 2003	43
Western Baltic 1996	44
Western Baltic 2012	35
Eastern Baltic (ICES SD 25)	80
Bornholm Basin 1997	40
Bornholm Basin 2007	40

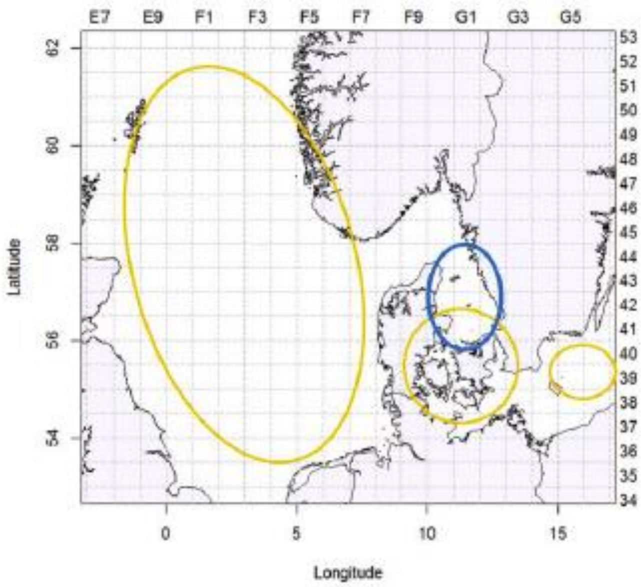


Figure 1. Baseline reporting groups in orange (from left to right: "North Sea", "Kattegat", "Eastern Baltic") and Kattegat region in blue.

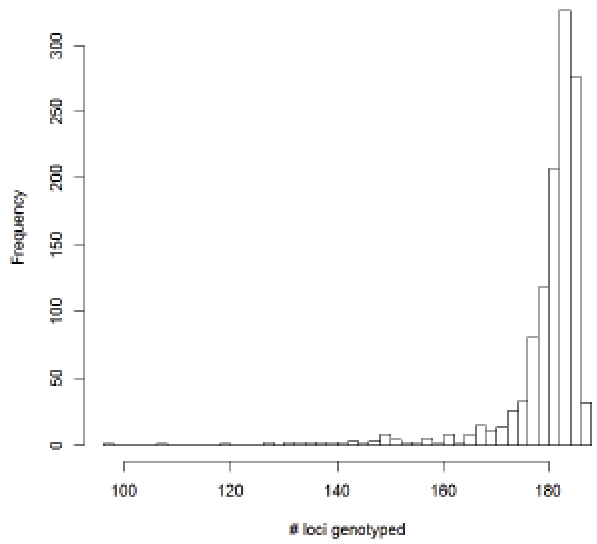
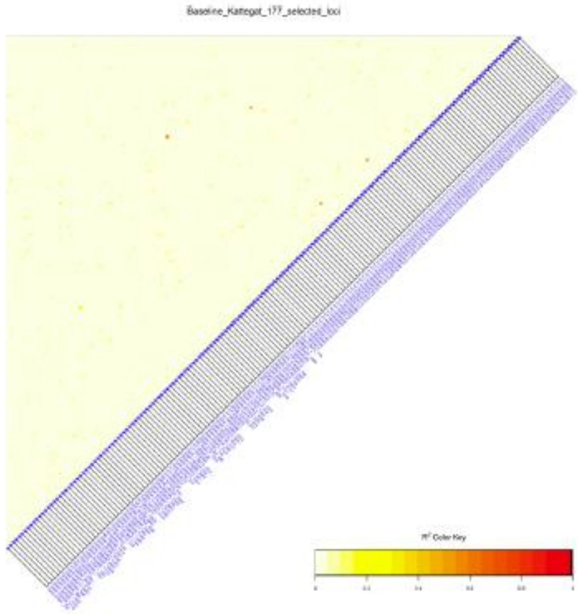


Figure 2. Number of loci successfully genotyped in a representative subset of Kattegat samples collected in 2013, 2015 and 2016, which were years with broad geographical coverage of sampling. 7 Cod population mixing in the Kattegat



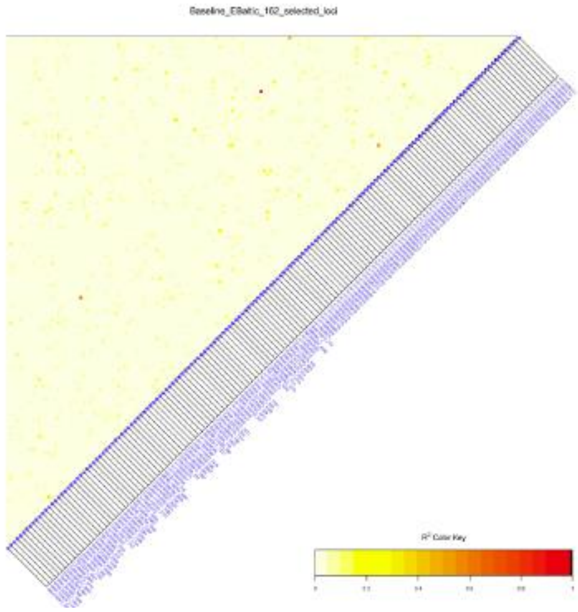


Figure 3. LD heatmaps between SNP markers in Kattegat (top) and Eastern Baltic (bottom) 8

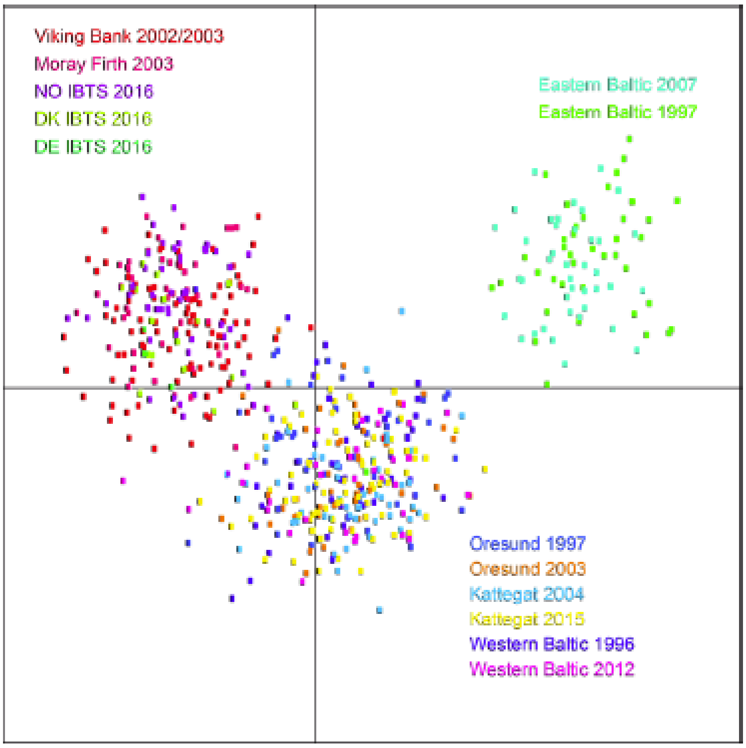


Figure 4. Principal component analysis of baseline individuals. 9 Cod population mixing in the Kattegat

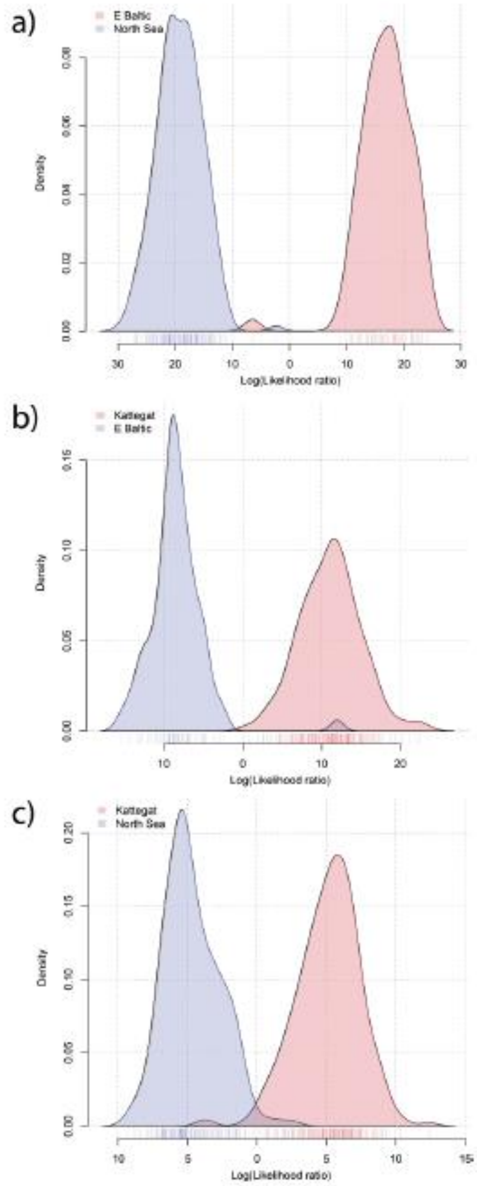


Figure 5. Distribution of likelihood ratios for assignment to baseline reporting groups. Assignment to Eastern Baltic and North Sea in a), Eastern Baltic and Kattegat in b) and North Sea and Kattegat in c). 10 Cod population mixing in the Kattegat

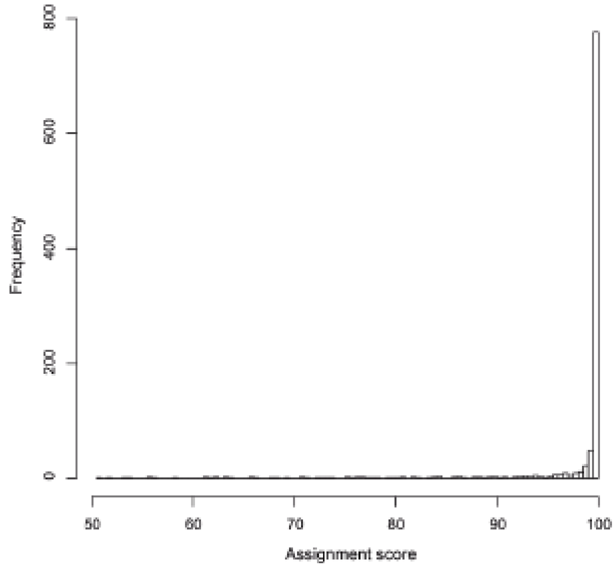


Figure 6. Distribution of assignment scores for a representative subset of Kattegat samples collected in 2013, 2015 and 2016, which were years with broad geographical coverage of sampling. 11

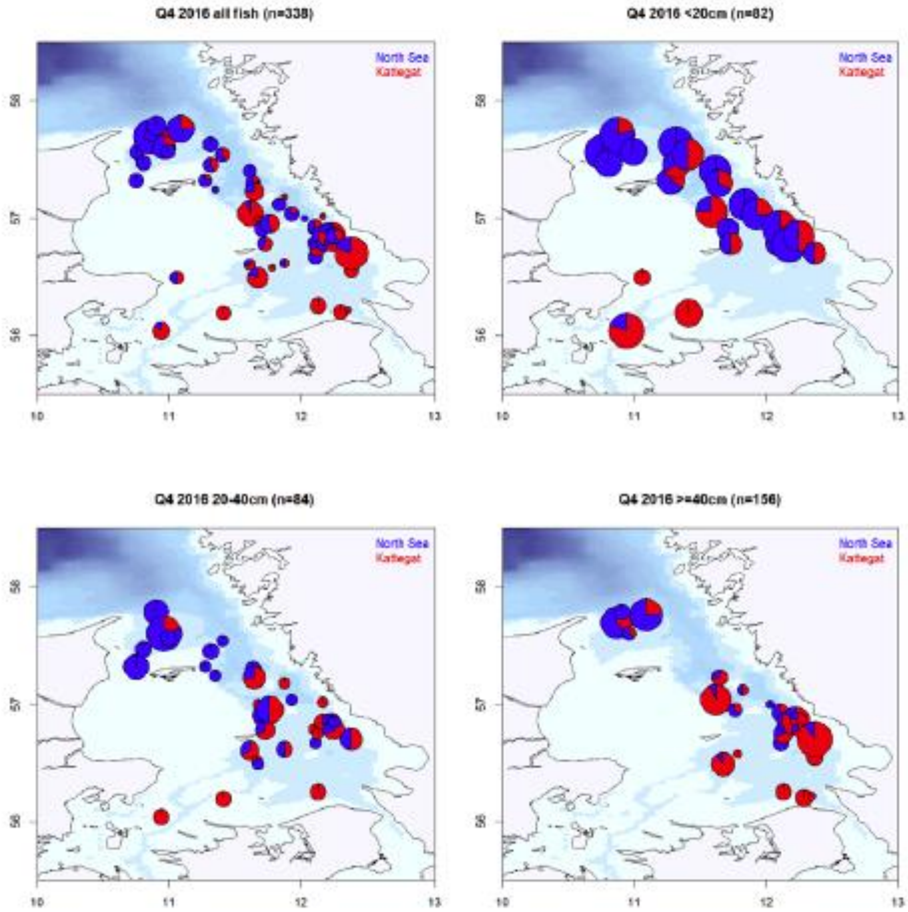


Figure 7. DK collections Q4 2016. Data split by length. 12

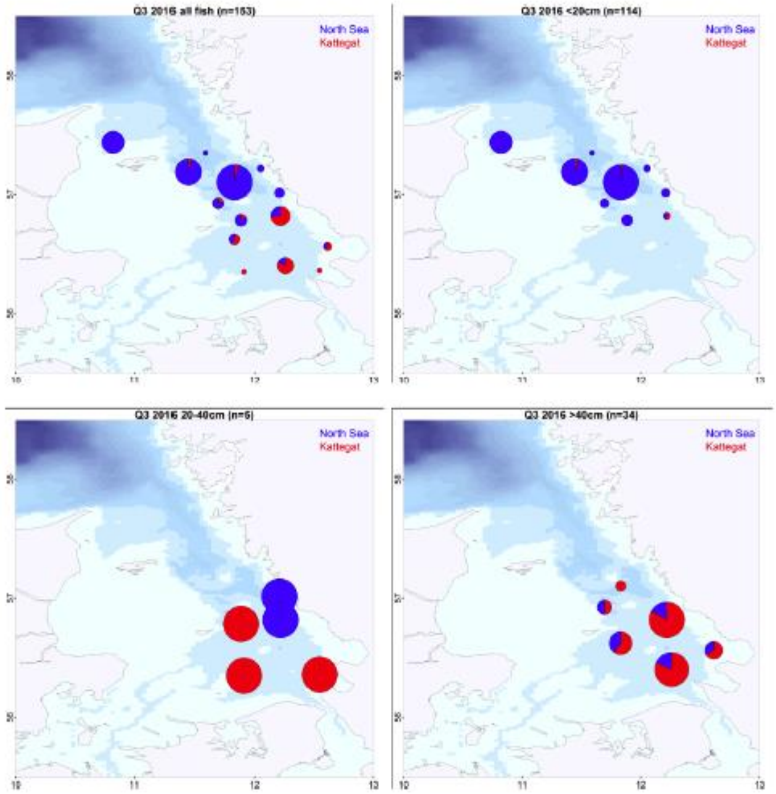


Figure 8. SE IBTS Q3 2016. Data split by length. 13

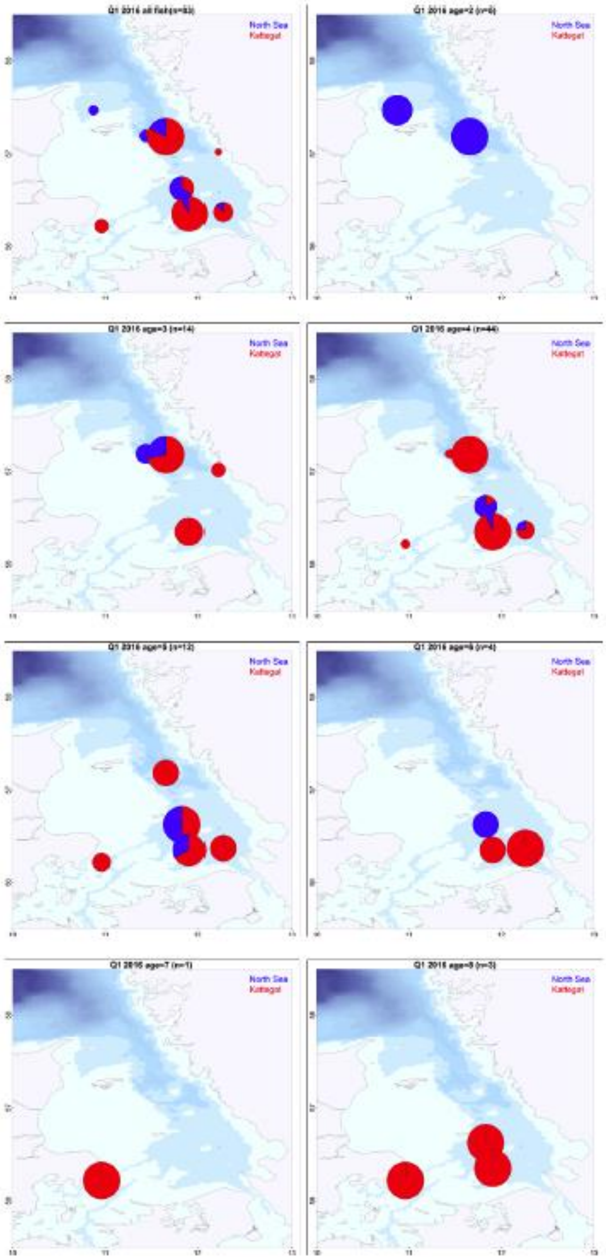


Figure 9. SE IBTS Q1 2016. Data split by age. 14

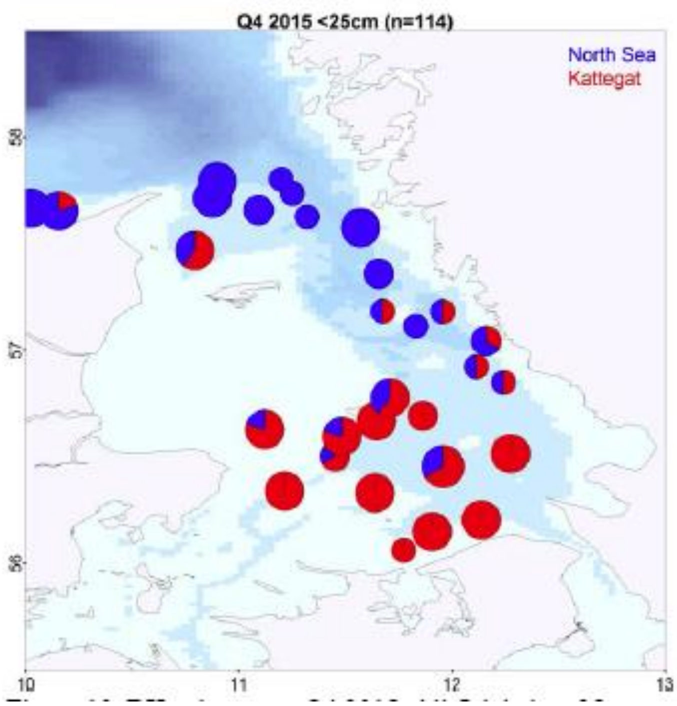


Figure 10. DK sole survey Q4 2015. All fish below 25 cm. 15

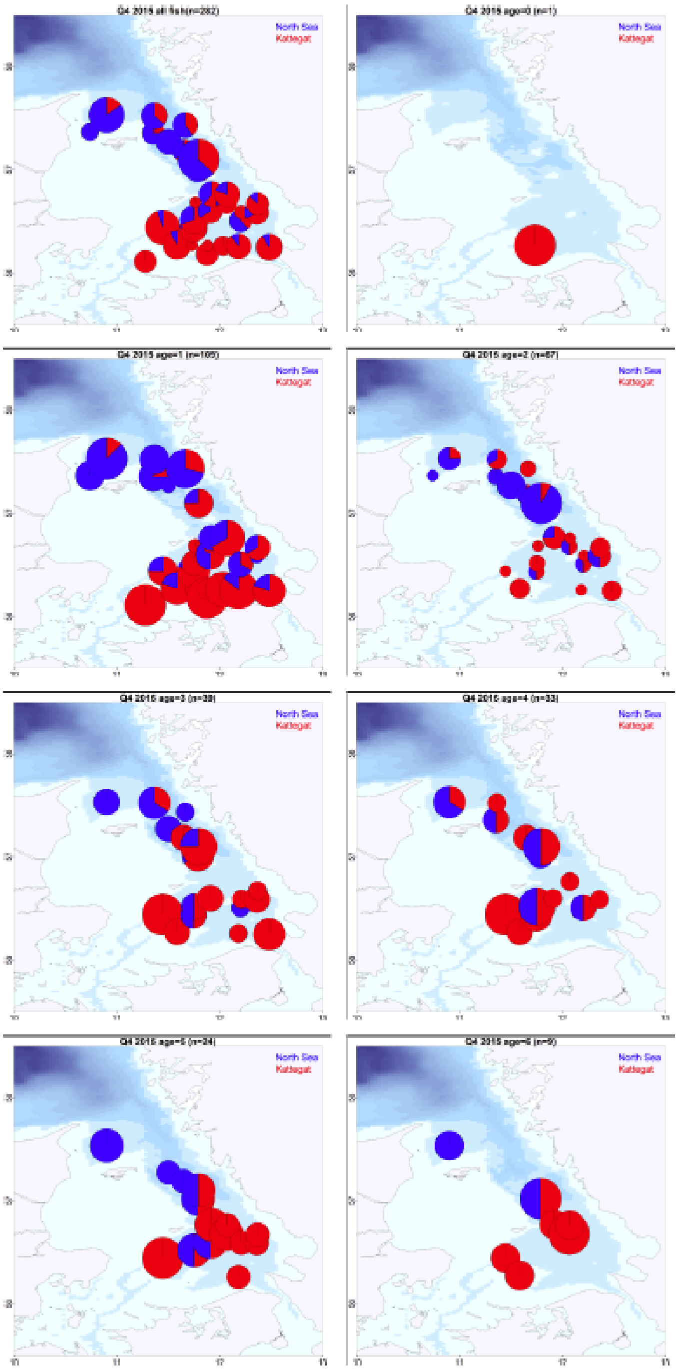


Figure 11. SE cod survey Q4 2015. Data split by age. 16

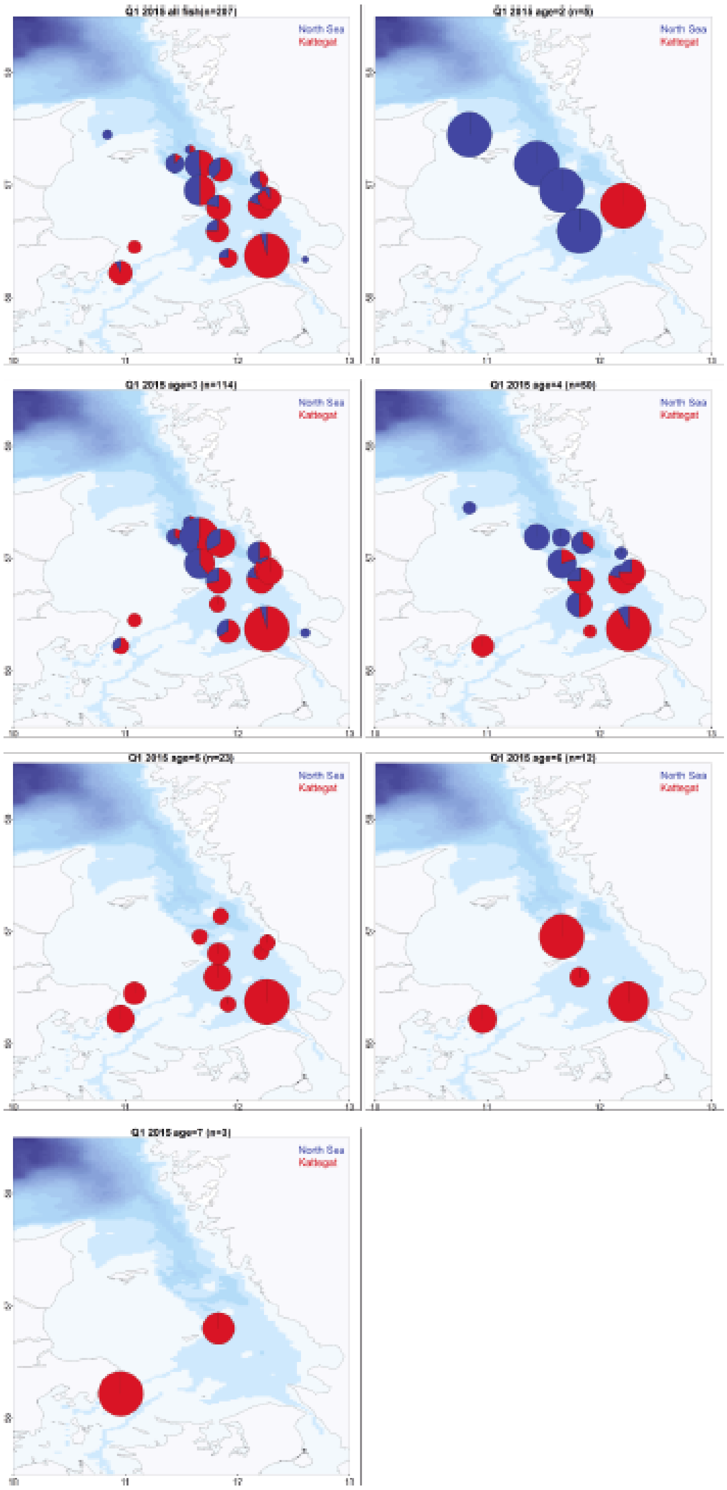


Figure 12. SE IBTS Q1 2015. Data split by age. 17

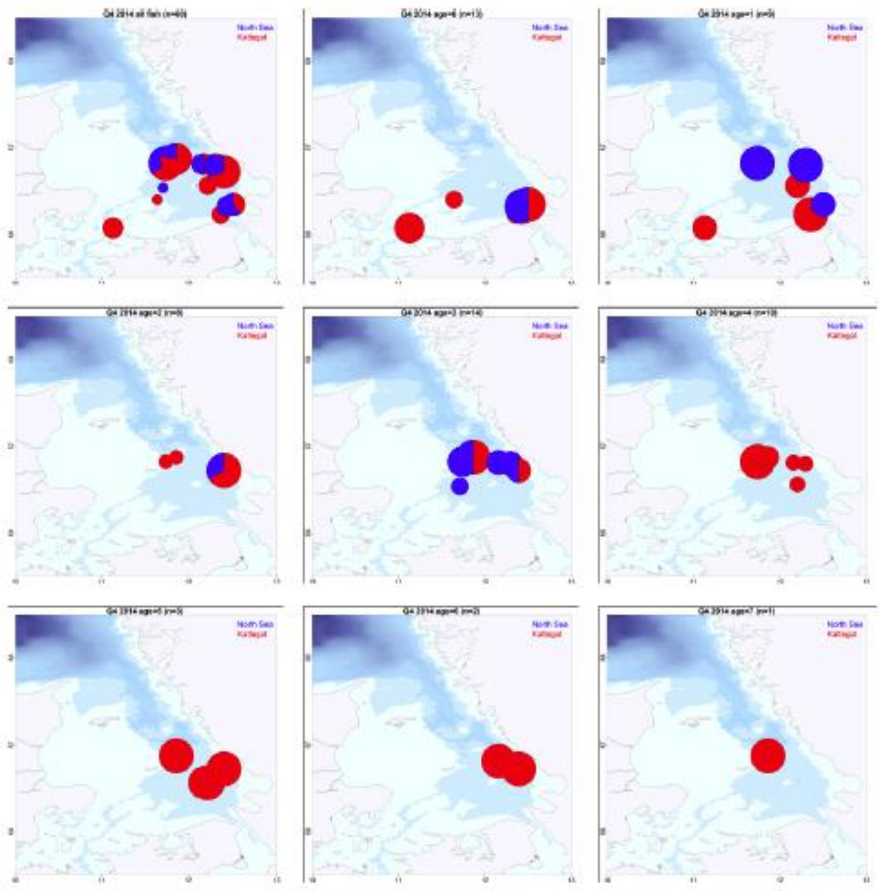


Figure 13. DK cod survey Q4 2014. Data split by age. 18

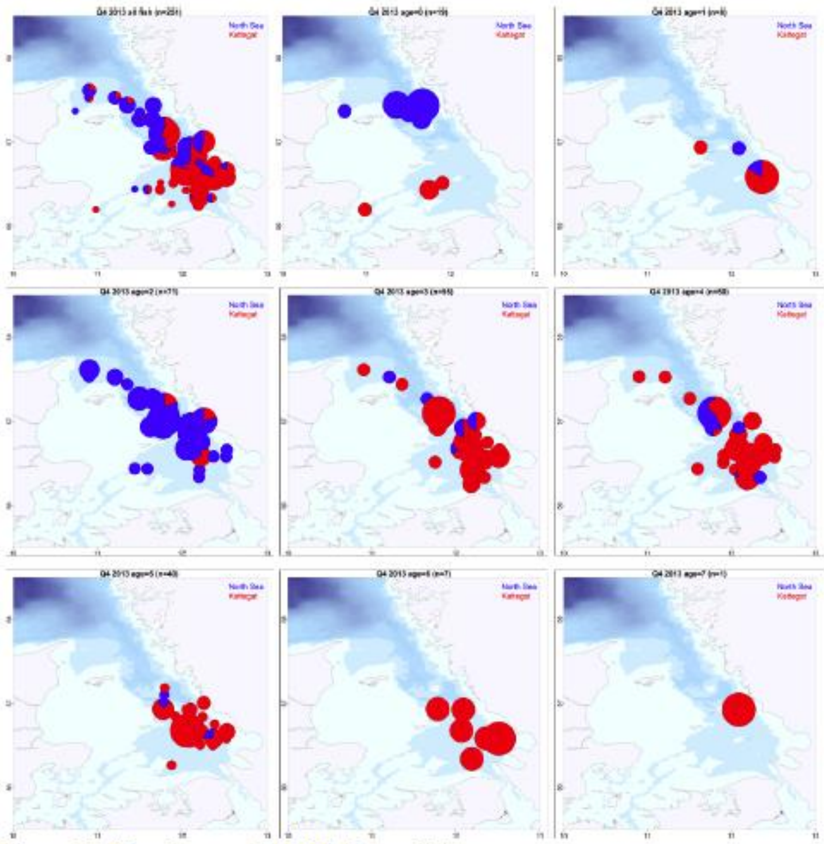


Figure 14. SE cod survey Q4 2013. Data split by age.

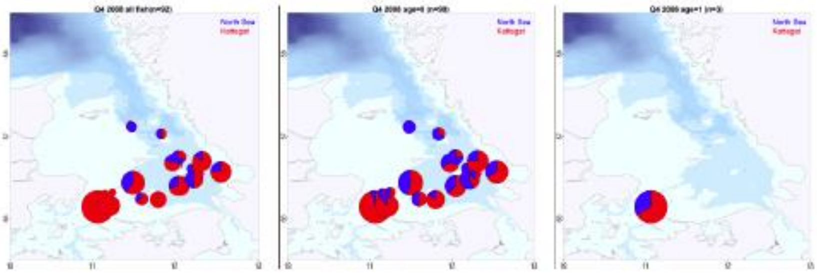


Figure 15. DK cod survey Q4 2008. 19 Cod population mixing in the Kattegat Figure 16. Cod

WD11 Kattegat cod numbers at age eaten by harbor seals

Kattegat cod numbers at age eaten by harbour seals

Karl Lundström (SLU), Johan Lövgren (SLU), Margit Eero (DTU Aqua)

1. Data on seal abundance and their diet in Kattegat

1.1.Number of seals in Kattegat

The Kattegat harbour seal population is monitored annually by aerial census during the moulting period in August. Each location is typically surveyed three times (Figure 3) and the number of counted seals is presented as the mean of the two highest counts (Teilmann et al. 2010). The average number of counted seals is assumed to be 56 % of the total population size (Härkönen et al. 1999), whereas the mean of the two highest counts is on average 9 % higher than the total mean and is thus assumed to constitute 65 % of the population. All seals south of Göteborg and north of Öresund are defined as the Kattegat population (Figure 1).

Figure 1. Major haul outs for harbor seals in the Kattegat (blue circles). Circle sizes correspond to the relative number of counted seals in the different locations. Map from Teilmann *et al.* 2010.

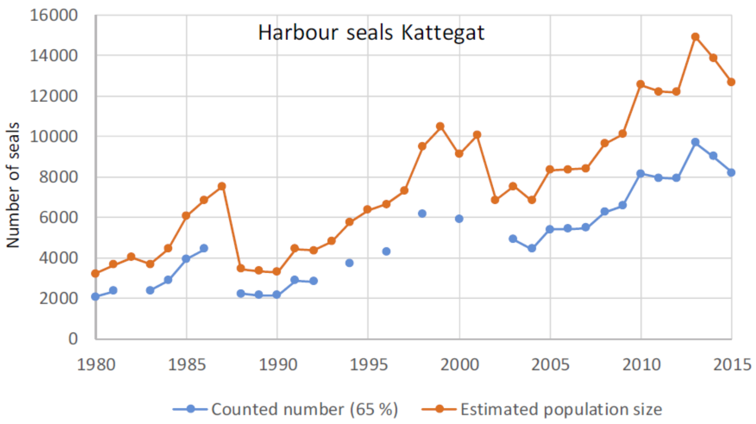


Figure 2. Number of counted harbour seals and estimated total number of harbour seals in the Kattegat. Data from HELCOM and the Swedish Natural Environmental Monitoring Programme (Swedish Museum of Natural History).

The number of harbor seals in the Kattegat are distributed relatively even between Danish and Swedish waters (Figure 3).

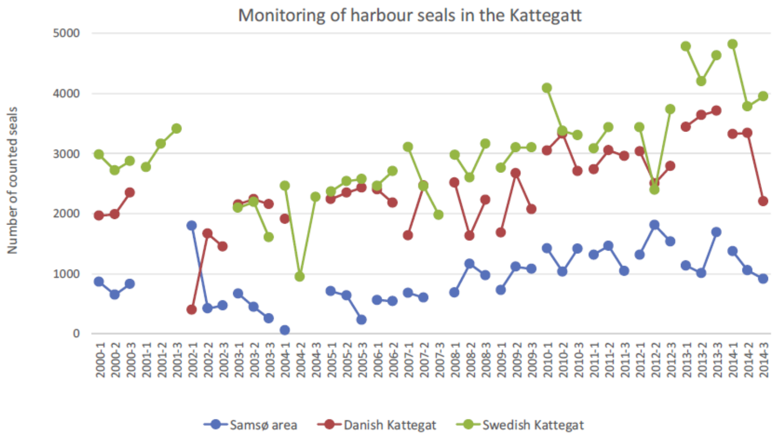


Figure 3. Number of counted seals in different areas in the Kattegat. X-axis indicates the different monitoring occasions, carried out during the moulting period in August. Data from HELCOM and the Swedish Natural Environmental Monitoring Programme (Swedish Museum of Natural History).

1.2. Spatial dynamics and movements of harbor seals in the Kattegat

In the Skagerrak, harbour seals have been shown to maintain within a range of between 7 km (females) and 50 km (males) during quarter 2-3 (Härkönen and Hårding 2001). The site fidelity of females is thus stronger than the site fidelity of males. In the Kattegat, the home range of harbor seals has been found to vary between 1,722 and 10,608 km2 (Dietz et al. 2013), representing a radius between 23 and 58 km (Figure 4). Similar results have been documented for harbour seals also in other areas (Thompson et al. 1996, Thompson et al. 1998, Tollit et al.1998).

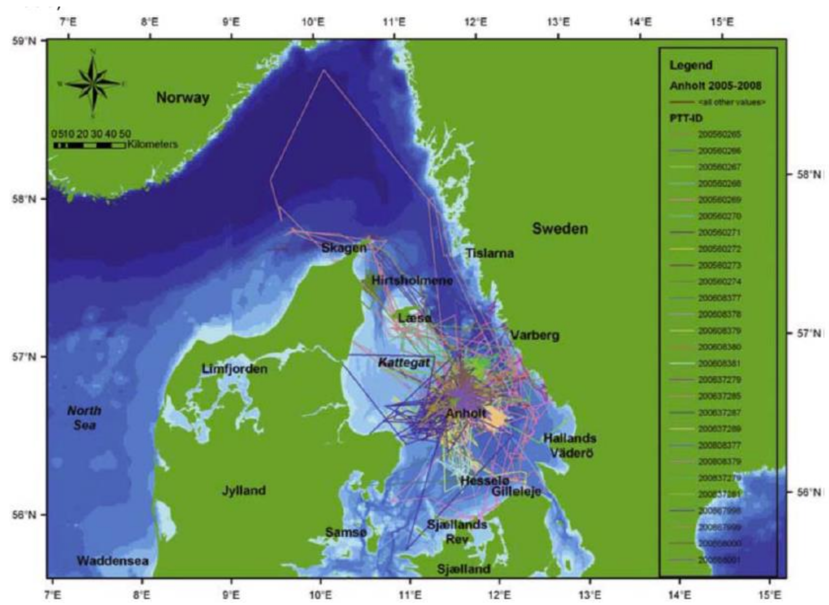


Figure 4. GPS tracks of harbour seals (n=27: 17 yearlings, 8 subadults, 2 adults) tagged on Anholt between 2005 and 2008 (Dietz et al. 2013).

In the study by Dietz et al. (2013), the dispersal was highest during winter and lowest during the breeding season in summer (Figure 5). The home range (90% kernel) varied between 10,608 km2 in the winter, 5,730 km2 in the spring, 1,722 km2 in the summer and 6,885 km2 in the autumn. Home ranges differed between age groups as well: from 1,713 km2 among to the adults to 2534 km2 among the subadults and 6,414 km2 among the yearlings (Figure 6).

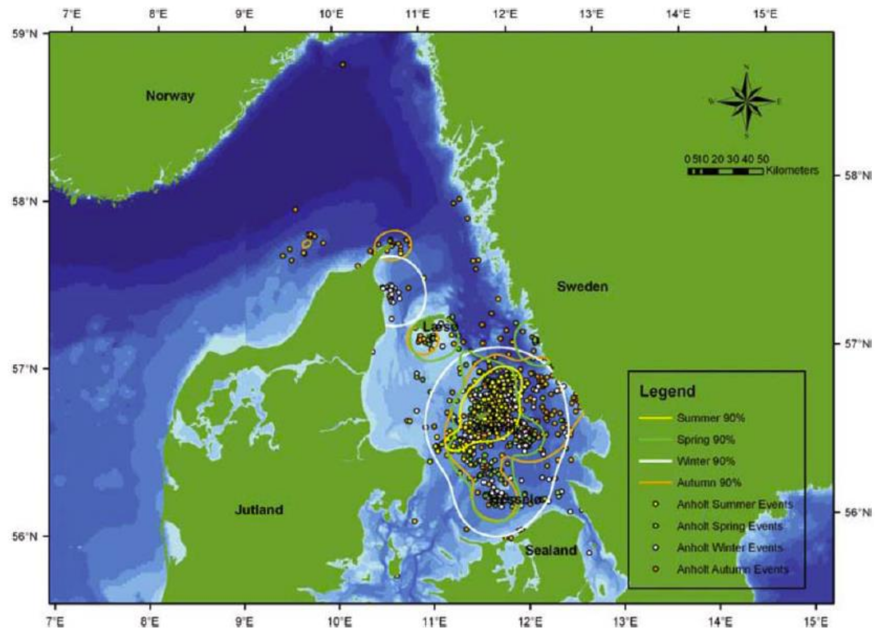


Figure 5. Seasonal distribution of harbour seals (n=27: 17 yearlings, 8 subadults, 2 adults) tagged on Anholt between 2005 and 2008 (Dietz et al. 2013).

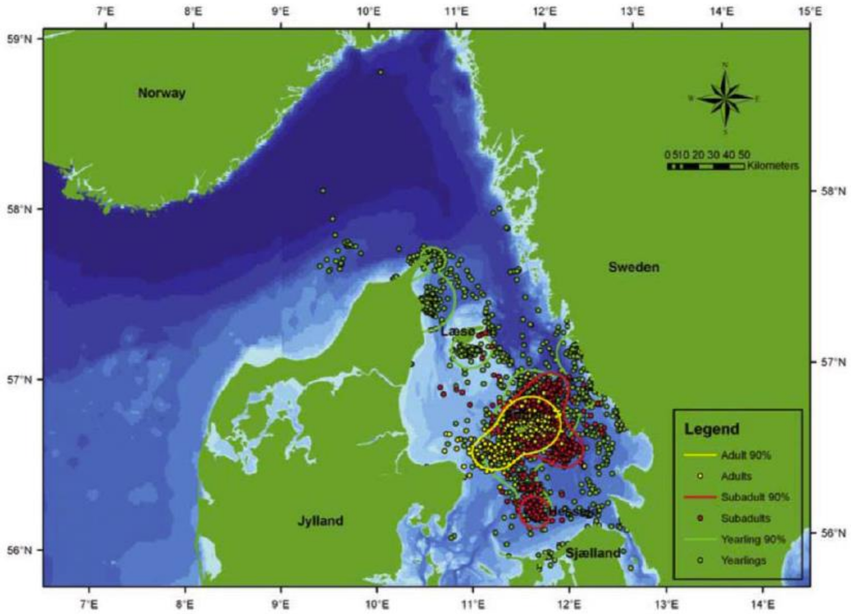


Figure 6. Age-related distribution of harbour seals (n=27: 17 yearlings, 8 subadults, 2 adults) tagged on Anholt between 2005 and 2008. Circles represent 90% kernel home ranges. (Dietz et al. 2013).

1.3.Samples of harbor seal diet in Kattegat

Dietary data is available from n=52 harbour seals collected (hunted) between 2009 and 2011 (Table1).

Table 1. Harbour seal diet samples from the Kattegat 2009-2011.

Group	n
Year	
2009	7
2010	27
2011	18
Season	
Q1	0
Q2	7
Q3	10
Q4	35
Area	
43G1	32
43G2	17
44G1	3
Sex	
Female	33
Male	19
Age	
0-1	13
2-4	5
5+	32
Unknown	2

The diet samples were collected from the northern part off the Swedish Kattegat coast (Figure 7).

Figure 7. Geographical distribution of harbor seal diet samples collected 2009-2011.

1.4. Proportion of cod in seal diet

The diet was estimated from otoliths found in the stomach and intestines of harbour seals hunted off the Swedish Kattegat coast 2009-2011. Prey remains that could be identified to G. morhua (species level) were found in 33 % of the seals whereas another 13 % of the seals contained prey remains that could only be identified to Gadidae (family level). Digestive erosion of size and number of otoliths was accounted for by using size and numerical correction factors (Lundström et al. 2007). Length and weight of consumed prey items was calculated from size corrected otoliths using regression equations from Leopold et al. (2001). The size of"Unknown Gadidae" was estimated by using an average equation based on regression equations of those Gadidae species found in the diet (except E. cimbrius). The weight proportions of the different prey taxa were estimated for each seal and the average weight proportion of each prey taxon was calculated (Figure 8). Due to digestive erosion, all prey remains (mainly otoliths) could not be determined to species level. As a consequence, some cod items could only be defined as "Unknown Gadidae". The proportion of cod in "Unknown Gadiade" was assumed to be similar to the proportion of cod in the Gadidae that could be determined to species level (43 %). The proportion of cod in the diet was estimated to 10 %, similar to a previous study, based on diet samples (faecal scats) from Anholt, collected during quarter 3 in 1980, in which the weight proportion of cod was estimated to 11 % (Härkönen 1988).

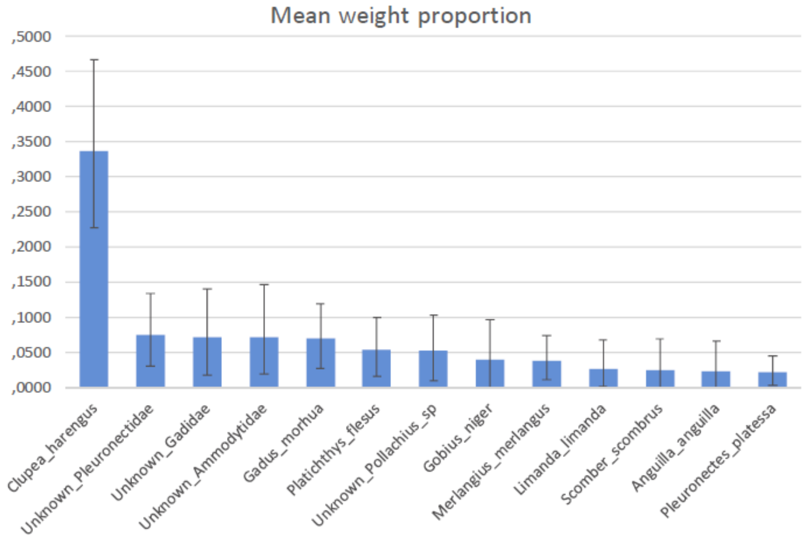


Figure 8. Average weight proportion of prey species in the diet of Kattegat harbor seals 2009-2011. Only species with average weight proportion above 2% are shown. Error bars indicate bootstrapped 95% confidence interval.

1.5. Length distribution of cod in seal diet

At present, the length and weight of the consumed cod is based solely on the regression equations in Leopold et al. (2001), as described in the previous paragraph. An alternative could be to estimate the length of consumed cod using the regression equation in Leopold (2011) and then use a length-weight key for the specific year to calculate the weight. Yet another alternative could be to construct our own regression equations based on otoliths from our own collections, from the specific area and the specific years, as has been done for some prey species in the Baltic Sea (Lundström et al. 2010).

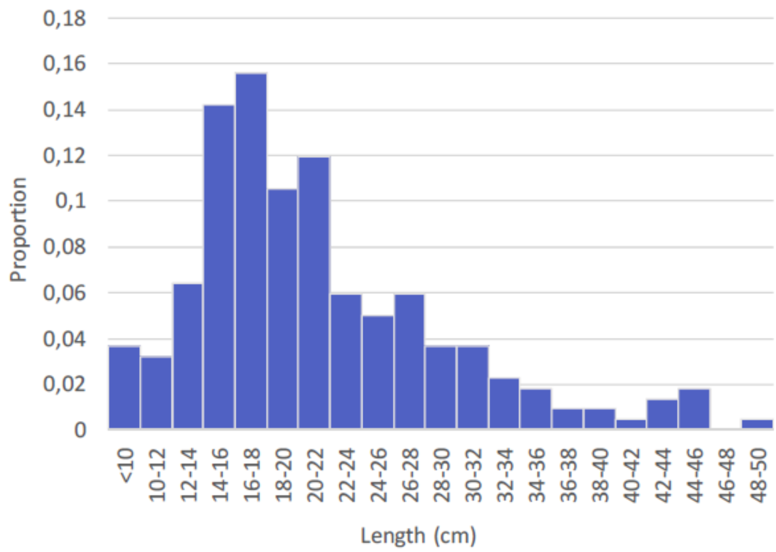


Figure 9. Length distribution of cod in the Kattegat harbour seal diet 2009-2011 estimated from otoliths.

The length distribution in the material is comparable to previous results from the Kattegat-Skagerrak area (Figure 10).

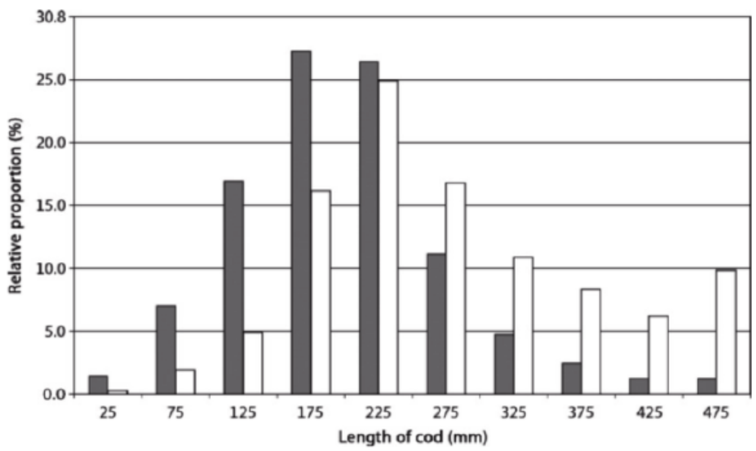


Figure 10. Relative distribution of length classes of cod in the diet of harbour seals, based on diet samples from both the Kattegat and the Skagerrak, collected throughout the year during the 1970s and 1980s. Grey bars represent numbers; white bars represent weight. Figure from Hansen & Harding (2006).

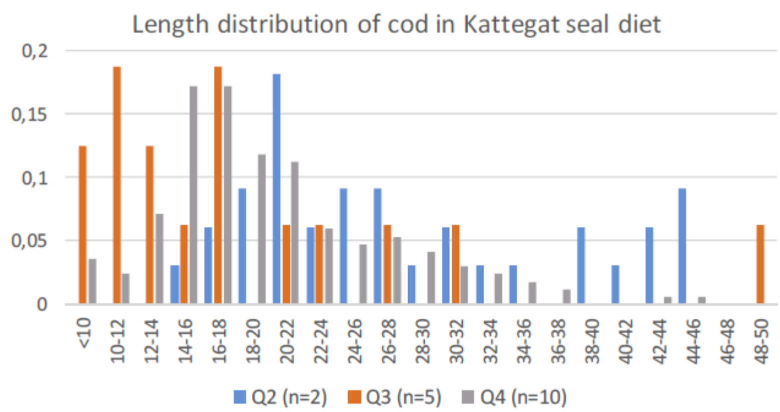


Figure 11. Relative distribution of cod in the diet of Kattegat harbour seals 2009-2011 from the second, third and fourth quarter of the year (Q2-Q4). Numbers in brackets represent the number of seals containing cod from each season. Seals containing unidentified Gadidae are not included.

1.6. Daily consumption of an individual seal

The average prey consumption of a Kattegat harbour seal was assumed to be 4 kg fish per day (Härkönen and Heide-Jørgensen 1991, Bjørge et al. 2002), resulting in an annual consumption of 146 kg cod x seal-1.

1.7. Additional diet samples

The collection of harbour seal diet samples have proceeded since 2011, and approximately 100 additional diet samples from the Kattegat are available for analysis. From these samples the morphological analysis can/will be combined with DNA-based diet analysis to further improve the dietary data, e.g. proportion of different Gadidae. In addition, focused collection of diet samples (e.g. faecal scats, hunting) can be conducted in specific areas.

2. Calculation of numbers of cod at age eaten by harbor seals

2.1 Age-length keys

Age-length-keys of cod from IBTS Q3 and BITS Q4 surveys in Kattegat (SD 21) were used. The datawere downloaded from DATRAS database. The data from these surveys were pooled to derive the proportions of age-groups for each length-class (by 1 cm), by year. The data were thereafter arranged by 2-cm length groups to match the dataset of length distribution of cod in seal diet, by averaging the proportions of age-groups within the 2 cm groups.

For length-groups for which no age data was available in a given year, average ALK for a given length-group over the years 1997-2016 was applied.

Data from Q3 and Q4 were used because most of the samples of seal diet originated from autumn. Thus, applying ALK from a similar time of the years was considered to provide most appropriate age-structure for the length distribution of cod measured.

2.2. Weight at length

A length-weight relationship was fitted to all individual cod data from IBTS Q3 and BITS Q4 surveys for all years from 1997-2016 combined. The parameters obtained from this fit where used to convert weight units to numbers and vice verca (described in 2.3 and 2.4).

2.3 Length structure of cod in harbor seal diet

Length frequency distribution of cod in harbor seal diet in numbers (Lngt_freq_no), described in 1.5 was used. As a next step, this was converted to length frequency in weight (Lngt_freq_wgt). Length-weight relationship, derived in 2.2. was used to obtained individual weights (Wgt_ind) for each length-group. A vector of relative length frequency in weight was calculated by multiplying length frequency in numbers (Lngt_freq_no) with respective individual weights (Wgt_ind) and dividing the values obtained for each length group by the sum over all length-groups:

$$Lngt\_freq\_wgt = \frac{Lngt\_freq\_no * Wgt\_ind}{sum(Lngt\_freq\_no * Wgt\_ind)}$$

2.4. Consumption of cod by an individual seal, by length

Each individual harbor seal was assumed to consume 4 kg of food per day, and cod was assumed to provide 10 percent of the diet, based on the analyses described in 1.4. From these values, annual consumption on cod in total weight by an individual harbor seal (Ind_consume_wgt) was derived.

Consumption of an individual seal in weight, by length-groups (Ind_consume_wgt L)was calculated by multiplying the total cod consumption by length frequency in weight:

$$Ind\_consume\_wgt_L = Lngt\_freq\_wgt * Ind\_consume\_wgt$$

Consumption of an individual seal in numbers, by length-groups (Ind_consume_no L) was subsequently calculated by dividing the amount eaten in weight (Ind_consume_wgt L) by mean weight of individual cod (Wgt_ind), for each length-group.

2.4 Consumption of cod by an individual seal, by age

As a next step, annual age-length-keys derived in section 2.1, were applied on the consumption of cod in length, by an individual seal *(*$Ind\_consume\_no_{L}$*)*. The numbers at age were subsequently summed across length-groups within a year, to obtain annual numbers of consumption by age *(*$Ind\_consume\_no_{A}$*)* .

2.5 Consumption of cod by entire harbor seal population, by age

As a final step, the annual consumptions of cod by an individual seal, by age (Ind_consume_no A) was multiplied by total number of harbor seals in Kattegat, described in section 1.1, to obtain numbers of cod eaten by harbor seals, by age and year (Table 2).

Table 2. Numbers (thousands) of cod eaten by harbor seals, by age.

Year	a0	a1	a2	a3	a4
1997	1011	5323	958	340	0
1998	3257	5144	1520	7	0
1999	2861	6985	912	160	0
2000	4457	3544	1302	193	30
2001	5582	4020	786	95	0
2002	1718	4901	523	8	5
2003	2658	3859	1345	7	0
2004	2701	3915	253	266	0
2005	5010	2751	919	0	21
2006	3567	4392	616	150	0
2007	4309	3663	745	36	43
2008	5712	3856	500	0	0
2009	3400	6703	358	69	7
2010	5894	5788	1367	20	4
2011	6489	5080	1125	53	0
2012	4368	7351	997	0	0
2013	6468	7722	1221	148	0
2014	7535	4582	2221	124	4
2015	5393	6166	1335	263	44

2.6. Testing for alternative length distribution of cod in diet

As most of the diet samples of harbor seals originated form second half of a year, applying this structure for the entire year could potentially overestimate predation on small cod. As a sensitivity analyses, the same calculation as described above was conducted, by applying the length structure in samples from Q2 only, and using age-length-key from Q1. The difference between the length distributions is shown in Fig. 11. This resulted in notable difference in the age-composition of cod in diet (Fig. 12).

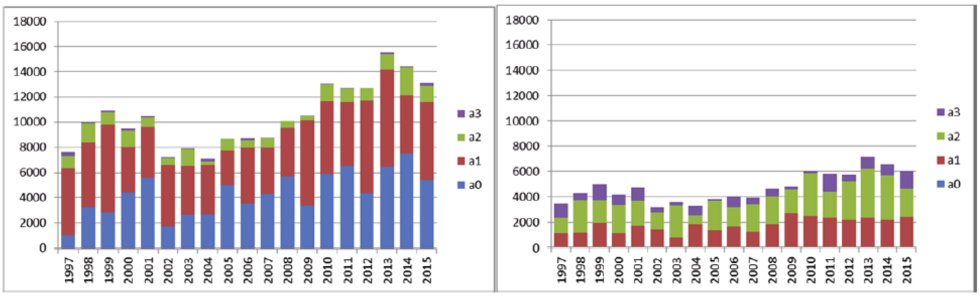


Figure 12. Numbers at age of cod eaten by harbor seals applying length frequency of all available samples (mainly originating from Q3 and Q4) (left panel) compared to sensitivity analyses applying length frequency from the few samples available for Q2 only (right panel).

3. Estimation of predation mortality due to seals

Predation mortality due to seals was derived via following steps:

i) The estimates of numbers of cod eaten by harbor seals (Table 2) were added to catch-atage matrix (the sum is hereafter called catch+predation-at age matrix), and used as input in SAM assessment run. In this run, unallocated removals were estimated for years 2003- 2010, separately for each year, but assuming the same fraction for each age-group within a year.

ii) For the years where significant unallocated removals were estimated from SAM,

catch+predation-at age matrix was adjusted accordingly.

iii) Fraction of seals in removals was estimated by dividing numbers eaten by seals by thecatch+predation, by age and year

iv) Mortality due to seal predation was calculated by multiplying the mortality estimated from

SAM (fishing +seal predation mortality) by the fraction of seal predation in

catch+predation-at age matrix.

v) The obtained seal predation mortalities were smoothed

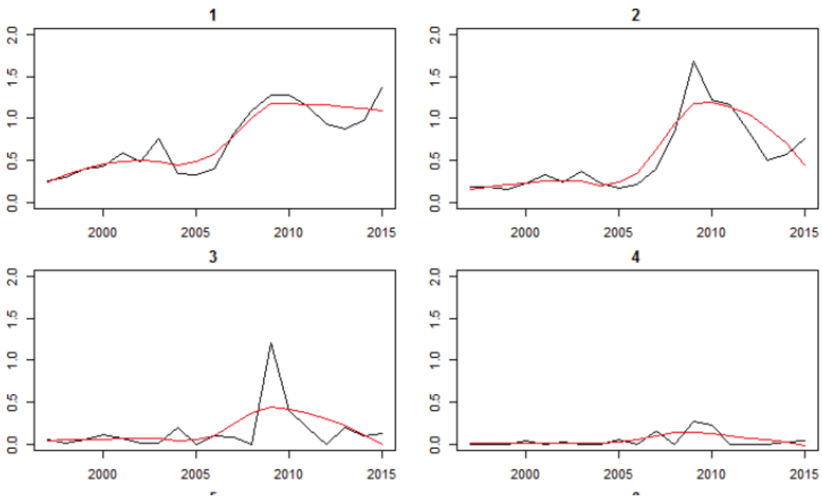


Figure 13. Predation mortalities due to seals, for ages 1-4. Red lines shows smoothed time-series.

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