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Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2013)

4–8 February 2013

Copenhagen, Denmark

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Executive Summary

The Benchmark Workshop on Pelagic Stocks (WKPELA) 2013 was convened between 22 November 2012 and 8 February 2013. It met three times and worked intersessionally by correspondence. Its remit was to determine and review the appropriate stock assessment methods for three pelagic stocks: anchovy in Subarea VIII (Bay of Biscay), herring in Division IIIa and Subdivisions 22–24 (Western Baltic Spring spawners) and sardine in Subarea VII and Divisions VIIIa, b, d (Celtic Sea, English Channel and Bay of Biscay).

26 People participated from seven countries including stakeholders. Two independent scientists from outside the ICES community took part in the process and reviewed with the findings of the workshop. See the participants list in Annex 1.

The main outcomes of the workshop were:

Anchovy in Subarea VIII (Bay of Biscay)

The input data and assessment method were reviewed in order to improve the assessment and make it more transparent. Points raised by the fishing industry, such as a retrospective improvement of historical biomass, were analysed. The final assessment is based on the CBBM model, with changes to settings of natural mortality rates, the DEPM was considered as a relative index of SSB, and the JUVENA juvenile acoustic biomass is included as an index of recruitment next year. The inclusion of JUVENA makes it possible to check in December if the advice basis of the June advice needs to be updated or not.

An important point is that the WKPELA model assumes the precision of the observation equations of biomass from the DEPM and acoustic surveys as fixed (not estimated). After the meeting another option was tested which showed different results (variances of SSB observation equations from the surveys split into partly fixed and estimated variances, see Annex 3). WKPELA was unable to decide which of these settings (the original settings as noted in the stock annex; and the alternative option) was preferred.

The new assessment differs from the original assessment and the limit biomass reference point was redefined. Given the changes in the assessment model and settings, WKPELA considers that the new assessment method does not comply with the current long-term management plan proposal.

Herring in Division IIIa and Subdivisions 22–24 (Western Baltic Spring spawners)

An effort was made to improve on the stock identification of fish in commercial and survey catches, separating out the North Sea and Central Baltic herring. Datasets with historic estimates catches by area were improved and annotated with help from the fishing industry.

The applied assessment model was changed and all applied surveys (and age classes) are now used as input data. The new SAM model will estimate the weighting given to the different sources of information. The forecast is improved by the use of information from the fishing industry on the best assumption on catch distribution in the intermediate year. A new limit biomass reference point was defined, while other

reference points will be considered later on in the light of management strategy evaluations.

Sardine in Subarea VII and Divisions VIIIa, b, d (Celtic Sea, English Channel and Bay of Biscay)

This is the first time this stock was benchmarked, and there are data deficiencies that hamper the stock assessment. The stock identity of sardine in VIIIabd and VII can be considered as a single stock unit, but it is important to note that there are large regional differences between fisheries as there are some locally important fisheries operating in some areas. Several exploratory assessments were put forward during WKPELA but these suffer from lack of input data and are sensitive to assumptions made without sufficient tuning data to validate them. It was concluded that the main relevant descriptors of stock status were a number of survey indices for the Bay of Biscay (Subarea VIII), and trends in length frequencies are the main information for the Celtic Sea (Subarea VII).

The outputs of the workshop are this report and the new stock annexes to be used for the assessment of the stocks in the ICES advisory process.

1 Introduction

This benchmark workshop considered the assessment method (including projections) and appropriate reference points for three stocks:

- Anchovy in Divisions VIIIa,b,d,e (Bay of Biscay);
- Herring in Division IIIa and Subdivisions 22–24 (Western Baltic Spring spawners);
- Sardine in Subarea VII and Divisions VIIIa, b, d (Celtic Sea, English Channel and Bay of Biscay).

The benchmark took place over three months with an initial data collection meeting for the northern stock 22–23 November 2012; a southern stocks data collection meeting 12–13 December 2012 and a five day meeting 4–8 February 2013.

Two independent scientists from outside the ICES community reviewed all stages and provided comments and input during the discussions: Jim Ianelli (US) and Tim J. Miller (US).

This report documents and justifies the decisions made by the workshop to establish new assessment and forecast methods that form the basis for the annual ICES fisheries advice. The report should be used as a record of the rational for the new stock annexes. The stock annexes provide the “recipe card” for the recommended stock assessment methods and will be used until the next benchmark (approximately every 3–5 years).

2 Description of the Benchmark process

2.1 Terms of Reference WKPELA – Benchmark Workshop on Pelagic Stocks

2012/2/ACOM48 A **Benchmark Workshop on Pelagic Stocks** (WKPELA), chaired by ICES Chair Barbara Schoute (ICES), and attended by invited external experts Tim Miller (USA) and Jim Ianelli (USA) will be established and will meet at ICES for a northern stocks data collection meeting 22–23 November 2012; a southern stocks data collection meeting in Bordeaux, France 12–13 December 2012 and at ICES for a five day meeting 4–8 February 2013 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 fishery-dependent, fishery-independent, environmental, multispecies and life-history data.

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

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

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

e) As part of the evaluation:

   i) Conduct a one day data compilation workshop. Stakeholders shall be 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 compilation workshop consider the quality of data including discard and estimates of misreporting of landings;

   ii) Consider further inclusion of environmental drivers, including multispecies interactions, and ecosystem impacts for stock dynamics in the assessments and outlook;

   iii) Evaluate the role of stock identity and migration.

Stock	Assessment Lead	WG
Herring in Division IIIa and Subdivisions 22–24 (Western Baltic Spring spawners)	Lotte Worsøe-Clausen	HAWG
Anchovy in VIIIabd (Bay of Biscay)	Leire Ibairaggiaga	WGHANSA
Sardine in Subarea VII and Divisions VIIIa, b, d	Lionel Pawlovski	WGHANSA

The Benchmark Workshop will report by 5 March 2013 for the attention of ACOM.

2.2 The benchmark process

ACOM, under the advice of the assessment expert groups recommended that three pelagic stocks undergo a benchmark assessment in 2013. Each expert group compiled a provisional "issue list" of reasons why the assessment methods for each stock needed to undergo a benchmark examination. These issue lists formed the basis of the benchmark process.

An individual scientist was asked to lead for each stock. These stock leaders were responsible for their team, the investigations and were asked lead discussions in plenary. They were also responsible for the completion of the report sections and the stock annex.

The stock leaders were:

Anchovy in Divisions VIIIa,b,d,e	Leire Ibaibarriaga (SP)
Herring in Division IIIa and Subdivisions 22–24	Lotte Worsøe Clausen (DK)
Sardine in Subarea VII and Divisions VIIIa,b,d	Lionel Pawlowski (FR)

The initial data compilation meetings in November/December 2012 used the issue list as a basis to open discussion about the approach and to encourage sharing of ideas across the stock teams and with stakeholders. The external reviewers joined the pre-meetings via WebEx. The product of the pre-meeting was a workplan and a prioritisation of the issue list. The group emphasised that the data availability, quality and properties would play a dominant role in determining the appropriate assessment models. The practicalities of the assessment models would also be taken into account.

The stock teams worked by correspondence between the two meetings (via email, Skype and WebEx). One plenary WebEx was held to introduce the stocks and identify progress and address problems. All stock teams were encouraged to submit their work in working documents at least a week prior to the final workshop in February 2013 for preparation of the external experts. The teams were encouraged to define criteria based on model diagnostics, rather than the final population dynamics, as the most appropriate way to judge the models.

The final meeting used the prioritise issue list, the working documents and input from the reviewers to justify the choice of stock assessment method for each stock. The first day of the meeting was used to discuss the issues in plenary. Then the stock teams (one for herring, one discussing both anchovy and sardine) split into separate rooms to examine and test the appropriate stock assessment. The plenary was reconvened on Tuesday afternoon to consolidate decisions made in subgroup. After a further round of subgroup sessions, a plenary starting Thursday afternoon was used to "force decisions" about the assessment approaches. The workshop also looked at reference points, especially when the perceived dynamics of a stock had changed as a result adjustments to the methodology.

After the final meeting, the report was edited by correspondence. It turned out that for anchovy an alternative setting to the one finalised at the meeting could be presented that improved the results according to the external reviewers but could not be agreed upon within the subgroup. This option is presented in Annex 3 and needs to be discussed within ICES to determine the best way forward.

3 Anchovy in Subarea VIII (Bay of Biscay)

3.1 Stock ID and substock structure

There is no change in the stock identity by this benchmark. The Anchovy (*Engraulis encrasicolus*, L) inhabiting Subarea VIII (Bay of Biscay) is considered to be isolated from a small population in the English Channel and from the populations in western Iberia (Division IXa) (Magoulas *et al*., 2006; Zarraonaindia *et al*., 2012). Morfometrics and meristic studies suggest some heterogeneity at least in morphotipes (Prouzet and Metuzals, 1994; Junquera and Pérez-Gandaras, 1993). Along the North of Spain (in Division VIIIc) Junquera and Pérez-Gandaras (1993) had already reported significant morphological differences in anchovies between Galicia, Asturias, and the Basque Country, and recently Borrell *et al*. (2012) have pointed out that there is some genetic isolation of anchovies in the middle west side of this division from the eastern one. In addition, some genetic heterogeneity, based on allozyme loci, have been found between the Garonne spawning regions and southern regions in the Bay of Biscay (Adour and Cantabrian shores) (Sanz *et al*., 2008). Despite the evidence for some heterogeneity and perhaps subpopulation in parts of the Bay of Biscay (western Cantabria), there is ample evidence that the major part of the population, which inhabits the eastern and northern parts of the Bay of Biscay, show rather homogenous recruitment pulses and have rather well understood spatial dynamics of summer migrations, autumn feeding areas and return in winter to the spring spawning areas (Uriarte *et al*., 1996) which leads ICES to consider that the anchovy in this area should be treated as a single stock for assessment and management.

3.2 Issue list

The list of issues to be discussed at the benchmark is the following:

1) Tuning series:
   - a) The DEPM historical series of spawning–stock biomass are being revised within WGACEGG due to changes in the procedure for estimating spawning frequency.
   - b) There is a potential new index on biomass arising from egg abundances collected with CUFES from the acoustic PELGAS survey. This index will be presented and discussed in WGACEGG.
   - c) This working group considered the juvenile abundance index from the JUVENA surveys useful for describing the state of the stock, given its relationship with recruitment (age 1 biomass next year). In the benchmark the potential of including this index into the assessment as an index of recruitment could be evaluated.
   - d) Currently the assessment is scaled by the assumption of absolute catchability of DEPM surveys. Although the perception of the stock in relative terms is insensitive to the use of the DEPM as absolute and relative, the absolute level of the biomass and the absolute level of the harvest rates are dependent on this catchability assumption. In the benchmark the assumptions on survey's catchability should be evaluated.

2) Biological parameters:
   - a) In the current assessment model mortality and growth rates are assumed to be constant across ages and from year to year. There are evi-

dences that these assumptions might not be appropriate. The possibility of estimating these parameters by age class using an extension of the BBM assessment model or any other assessment model should be investigated.

3) Assessment method:

   a) The current assessment method presents some shortcoming, as the strong assumptions on natural mortality and growth rate parameters explained above. There is an extension available of the BBM that allows the growth and natural mortality rates to be estimated and to vary across age groups. In addition, the catches are modelled and included into the observation equations. This model seems to be more adequate, but also more data and computer-time demanding. The possibility of changing the assessment method to this extended version or to any other assessment model considered more appropriate should be studied in the benchmark.

4) Forecast method:

   a) The current forecast methodology is considered appropriate as a complementary tool for the assessment model (BBM). However, if the assessment model is changed, the most appropriate forecast method should also be revised.

   b) In June when the short-term forecast is done there are no indications on the next year recruitment. However, the JUVENA juvenile abundance index has proven its potential in forecasting recruitment. In the last years ICES did not revise its advice based on the JUVENA results, but new projections based on a loglinear model between the juvenile abundance index and recruitment were available under request. The best use of the JUVENA juvenile abundance index to improve the forecast once the results of the survey are available in November should be discussed in the benchmark.

5) Biological reference points:

   a) Any changes into the above points might imply a revision of the biological reference points.

3.3 WKACCU scorecard

The accuracy (potential bias) of input data for the assessment is evaluated according to the scorecard developed by the Workshop on Methods to Evaluate and Estimate the Accuracy of Fisheries Data used for Assessment (WKACCU, ICES, 2008). The workshop developed a practical framework for detecting potential sources of bias in fisheries data collection programs. A scorecard was applied to indicators of bias for a suite of parameters that are important for stock assessments. The scorecard can be used to evaluate the quality of data sources used for stock assessments, and to reduce bias in future data collections by identifying steps in the data collection process that must be improved.

For this stock, no major biases are considered to occur in the data:

WKACCU Scorecard	No bias	Potential bias	Confirmed bias	Comment
A. SPECIES IDENTIFICATION				
1. Species subject to confusion and trained staff				
2. Species misreporting				
3. Taxonomic change				
4. Grouping statistics				
5. Identification Key				
Final indicator				
B. LANDINGS WEIGHT				ICES estimates of landing data are considered to be a fair reflection of the actual catches
Recall of bias indicator on species identification				
1. Missing part				
2. Area misreporting				
3. Quantity misreporting				
4. Population of vessels				
5. Source of information				
6. Conversion factor				
7. Percentage of mixed in the landings				
8. Damaged fish landed				
Final indicator				
C. DISCARDS WEIGHT				
Recall of bias indicator on species identification				
1. Sampling allocation scheme				According to on-board observations, the rejection of fish after coming to the deck is rare. Purse seiners (both Spanish and French) have slipping behaviour related to quota limitations, illegal size and mixture with unmarketable bycatch. Quantifying slipping at a population level is extremely difficult because it varies considerably between years, seasons, species targeted and geographical region. There are no estimates of slipping in the purse seine fleet due to the limited number of trips/catch monitored by year. French pelagic trawlers seems to have almost negligible discards when they target anchovy (*WKPELA, Anchovy WD 01*)
2. Raising variable				
3. Size of the catch effect				
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 replacement				
Final indicator				

WKACCU Scorecard	No bias	Potential bias	Confirmed bias	Comment
D. EFFORT				
Recall of bias indicator on species identification				
1. Unit definition	NA			no effort data used in the assessment
2. Area misreporting	NA			
3. Effort misreporting	NA			
4. Source of information	NA			
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				
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 of bias indicator on length structure				
1. Quality insurance protocol				The last calibration workshop on age reading took place in 2009 and showed an agreement of 92% between the readers of the bay of Biscay, with a CV about 7%.
2. Conventional/actual age validity				
3. Calibration workshop				
4. International exchange				
5. International reference set				
6. Species/stock reading easiness and trained staff				
7. Age reading method				
8. Statistical processing				
9. Temporal coverage				
10. Spatial coverage				
11. Plus group				
12. Incomplete ALK				
Final indicator				
G. MEAN WEIGHT				
Recall of bias indicator on length/age structure				

WKACCU Scorecard	No bias	Potential bias	Confirmed bias	Comment
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Statistical processing				
5. Calibration equipment				
6. Working conditions				
7. Conversion factor	NA			
8. Final indicator				
H. SEX RATIO				
Recall of bias indicator on length/age structure				
1. Sampling protocol	NA			sex ratio used in the calculation of the DEPM index but not used in assessment
2. Temporal coverage	NA			
3. Spatial coverage	NA			
4. Staff trained	NA			
5.Size/maturity effect	NA			
6. Catchability effect	NA			
Final indicator				
I. MATURITY STAGE				
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Appropriate time period				all along the year
3. Spatial coverage				
4. Staff trained				
5. International reference set				
6. Size/maturity effect				
7. Histological reference	NA			exclusively for the DEPM
8. Skipped spawning	NA			
Final indicator				
Final indicator				

3.4 Multispecies, mixed fisheries and stakeholder input

3.4.1 Multispecies and mixed fisheries

No new information is available at this point.

3.4.2 Stakeholder input

Stakeholder input was provided by members of the South Western Waters Regional Advisory Council (SWWRAC), represented by CNPMEM, Les Pêcheurs de Bretagne

PO, Cofradia de San Vicente de la Barquera. This was done by filling in a questionnaire:

Fishing conditions

Is the fleet in this fishery primarily owner-operators or owned by larger companies?

The French fleet is essentially an "artisanal", composed of operator-owned vessels. French fleet is composed of three kinds of vessels:

1) Pure pelagic pairtrawlers [16–24 m], for which generally a stakeholder holds two vessels;
2) Accessory trawlers [14–18 m]for which generally a stakeholder holds one vessel;
3) Purse-seiners [15–17 m] for which generally a stakeholder holds one vessel. Two larger companies are involved in operating respectively 2 and 3 purse-seiners each.

Following the closure of the fishery, a French regulation (Ministerial Arrêté of October 10th of 2007) has introduced access regulation to the fishery. About 90 couples of stakeholders' vessels were then authorized to fish anchovy: around 30 vessels for pure pelagic trawling, 30 as accessory pelagic trawling and around 30 purse-seiners.

The Spanish fleet fishing for anchovy in the Bay of Biscay is composed of about 140-150 artisanal purse-seiners. All are operated by their owners and no big companies dedicated to this species.

Is the fleet renovating or are vessels aging?

According to this previous regulation, and to other EU regulation, French fleet is getting older and older. By the way, we can consider that the youngest vessels in this fishery have entered the fleet in 2007:

Age class	<10 years old	[10-15]	[15-20]	[20-25]	[25-30]	>30 years old
No. of vessels	8	7	1	22	32	25

The Spanish average fleet age is 14.5 years and is very technologically renovated.

Is the average age of vessel operators increasing steadily (i.e. younger fishermen are not tending to participate)?

In France the age of vessel operators is steadily increasing.

In Spain the understanding is that young fishermen do enter the fisheries in recent times; when family businesses, there is a change in families.

Has the methods and approaches used by fishermen changed much in the past two decades?

In France, fishing methods have not changed a lot since the beginning of 1990s. Many changes have occurred for fleets and approaches.

Fleet 1: The main change is the calendar of fishing. Until 2005, pelagic trawlers could fish during the winter. Since 2009, a professional agreement with Spanish stakeholders has modified the authorized period for pelagic trawling of anchovy. They are now only authorized from the 1st of June until the 30th of November. The majority of the landings for this fleet occures between the 1st of September until the 30th of November, depending on the catchability of albacore tuna for some part, and the level of consumption of quota.

Fleet 2: The fishing season is more or less the same than for the previous fleet. Those vessels are essentially fishing for *Nephrops* and demersal species, generally beginning their anchovy season just after the *Nephrops* one. Due to national regulation, this fleet is not authorized to catch anchovy when the TAC is limited.

Fleet 3: It's necessary to divide this fleet into two subfleets:

- 3A: Basque purse-seiners: due to regulation (control measure of the minimal size): this fleet is more or less unable to fish anchovy since 2010.
- 3B: Brittany purse-seiners: due to abundance and good value of sardine, the numbers of purse-seiners has increased in Brittany since the beginning of 1990. The "good month" for this is generally mid-September–to mid-October, depending on migration of anchovy.

In Spain, fishing methods have not seen major changes in the last 20 years, what has changed are: improvement in quality arts and technological advances in equipment, fish detection devices, etc.

If so, has it been gradual or a step change in a particular year (if step please specify years)?

In France the closure of the fishery during five years has changed a lot of things. The fleet 1 has been divided per 2 as regards the number of vessels, and many vessels have been obliged to modify their activity due to this closure. Since 2009 and the professional agreement, the calendar has changed essentially for fleet 1.

In Spain, changes have been technological developments and therefore progressive.

What proportion of vessel operators rely on this fishery for their primary source of income in recent five years or so?

In France:

- Fleet 1: most;
- Fleet 2: none;
- Fleet 3: none.

Some vessels of fleet 1 could be fishing anchovy during four months some years, with good levels of quotas. Anchovy is one of the three key species for this fleet with albacore tuna and sea bass.

The primary income of Fleet 2 is *Nephrops*, but anchovy can represent a good complementary source of income.

The primary income of fleet 3 is in general sardine, but anchovy can represent a good complementary source of income.

For the Spanish fleet currently anchovy represents a 20.00% compared to 35–40% of the years before the closure of the fishery. The fishery was reopened in 2010 with a decline in value by the closure of the fishery for five years, which now has reduced its importance.

What sources of error in catch statistics may be likely?

All French vessels authorized to fish anchovy are obliged to declare electronically their catches. Since the informatics developments of ERS is recent, some errors in statistics can occur. All the production of anchovy is sold in auction centers and is well declared.

In Spain there are no problems with the catch data, digital methods are used for the transmission of data in near real time. landings fishermen control more accurately and faster than the government, proposing in many cases the closure of the fishery to detect which is close to completion of the TAC (for example the years 2010 and 2011).

What if any bycatch issues are a concern in this fishery?

In French waters at the end of the year, sardine and anchovy can mix, so then sardine can be a bycatch of anchovy. There's not a lot of bycatch for the three fleets.

In Spain it is believed that no bycatch, fishing in certain dates and there is a 99% certainty with current equipment fishing what you really want.

What environmental conditions if any are of obvious concern in considering impacts on fishing and/or survey data?

None reported.

Please provide any other relevant information for ICES assessment process that you feel is appropriate.

In France, catches of anchovy have begun very early in 2012 summer compared to normal years, and have been very productive until mid-October, for the majority of the fleets. The 2012–2013 quota has been very limitative for French vessels, which was not the case in 2011–2012.

French stakeholders are working with Ifremer during Pelgas survey, and have been realizing sentinel fishing in order to improve anchovy knowledge. They pay then much attention to ICES advice, and are sorry to consider discrepancies between Azti and Ifremer spring surveys for one part, and the recurrent underestimation of biomasses.

The French fishery takes place during summer and autumn, after the spawning season, and catches age 1+, 2+ and 3+, with a majority of mature adults aged 1+ in the anchovy population and catches.

It is essential that this summer and autumn French fishery management (TAC level) can rely on an accurate assessment of the entire adult population (three age classes included) provided from the spring surveys.

3.4.3 Management objectives

Preferred management objectives (biological/economic/social) for fishery of interest (please list at least three, in priority order):

1) Avoidance of any new closure of the fishery;
2) Stability of the catch possibilities;
3) High yields;
4) Political Decision making based on a very reliable assessment coupled with a LTMP adopted, which objectives shared by all the parties.

Suggest indicators of management performance towards achieving objectives:

INDICATOR	OBJECTIVES TO WHICH INDICATOR APPLIES
Percentage of interannual variation of TAC	Interannual variation of TAC should not be outside +/-15%
Number of closure /_ten years	No closures
Medium Price	

3.5 Ecosystem drivers

The majority of the past studies regarding ecosystem drivers for Bay of Biscay anchovy have been focused on relating recruitment and environmental indices. Recent information following this line was added to the stock annex. This information might be useful in outlining potential levels of recruitment (Fernandes *et al.*, 2010 and in press), but the methods are still evolving. Currently the JUVENA series provides actual observations on the level of recruitment and it is considered a better basis for the projections.

3.6 Stock assessment

3.6.1 Catch-quality, misreporting, discards

Commercial catch data are obtained from the national laboratories of Spain and France following the sampling protocols dictated by the European Commission Programme on Fisheries Data Collection Regulation. Landings are not considered to be underreported and fishing statistics are considered accurate since 2000.

Discards are not routinely measured and hence not included in the assessment, but nowadays they are considered not relevant. A recent study carried out by Ifremer in 2012 confirmed that the anchovy discards are almost negligible (around 2%) for the French pelagic trawlers (this report, Anchovy WD 01). In the past (late eighties and early nineties for the French pelagic trawlers and sixties and seventies for the Spanish purse-seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified.

3.6.2 Surveys

The research surveys used for the assessment of the Bay of Biscay anchovy are summarised in the following table:

SURVEY NAME	SURVEY ACRONYM	TYPE	DATA USED FOR ASSESSMENT	AREA	MONTH	PERIOD
French acoustic survey - spring	PELGAS	Acoustic	SSB, Age 1 proportion	VIII	April–May	1989–present (except 1990, 1993–1996,1998–1999)
DEPM anchovy - Bay of Biscay	BIOMAN	DEPM	SSB, Age 1 proportion	VIII	May	1987–present (except 1993)
Autumn surveys on juveniles	JUVENA	Acoustic	Juveniles abundance	VIII	September–October	2003–present

All these research surveys are planned, coordinated, reviewed and developed in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG). The descriptions of the surveys are included in the stock annex.

Revision of the DEPM

Since 1987 the Daily Egg Production Method (DEPM; Lasker, 1985) has been applied to the Bay of Biscay anchovy yearly with the only exception of 1993 (Santiago and Sanz, 1992; Motos *et al*., 2005).

In 2008 a new method for classifying the postovulatory follicles was presented (Alday *et al*., 2008, 2010). This implied changes in one of the adult reproductive parameters of the DEPM: the spawning frequency (S). The revision (Uriarte *et al*., 2012) gave values of S between 0.33 and 0.5 (females spawning every two or three days), instead of S between 0.2 and 0.33 (females spawning every three or five days) as perceived previously (Motos *et al*., 1996).

The methods for estimating the total daily egg production have also been under development in the last years. New methodology, such as generalised linear models (GLM), new criteria for cutting the tails, the incorporation of CUFES as an auxiliary sampler in the egg surveys have been incorporated gradually to routine applications of the DEPM. However, these methods have not been used to provide a complete updated of the time-series of total daily egg production.

New series of SSB and population-at-age estimates from the DEPM were revised according to the new S estimates and the latest and standardised methods for estimating the total daily egg production. The results were presented to this benchmark workshop (Santos *et al*., 2013, WD 5).

The revised SSB estimates show similar year to year fluctuations but are on average 33% lower than the previous ones. (Figure 3.6.2.1). This revision is mainly due to the spawning frequency, as the changes in the total daily egg production are relatively small. The population age structure remains basically as before (Figure 3.6.2.2).

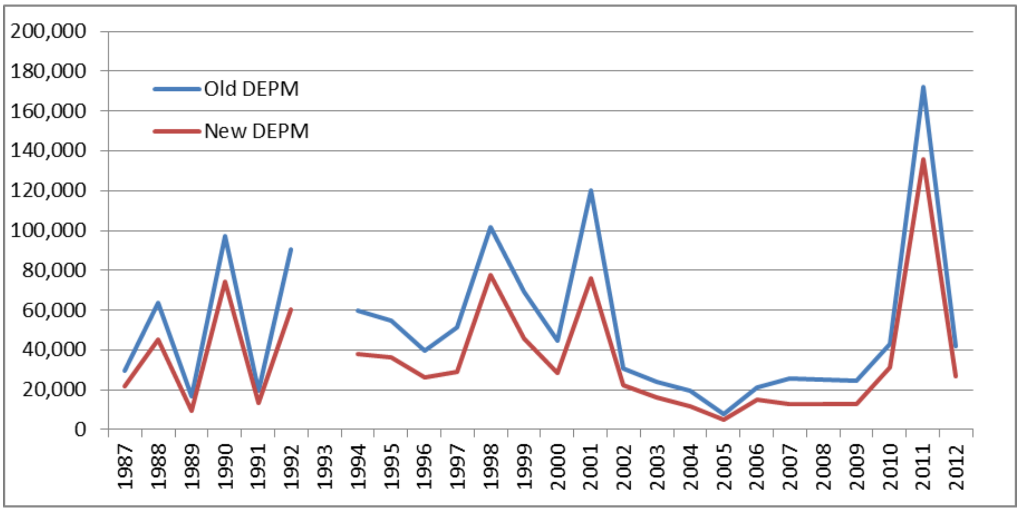


Figure 3.6.2.1. Comparison between the old (in blue) and revised (in red) DEPM SSB estimates.

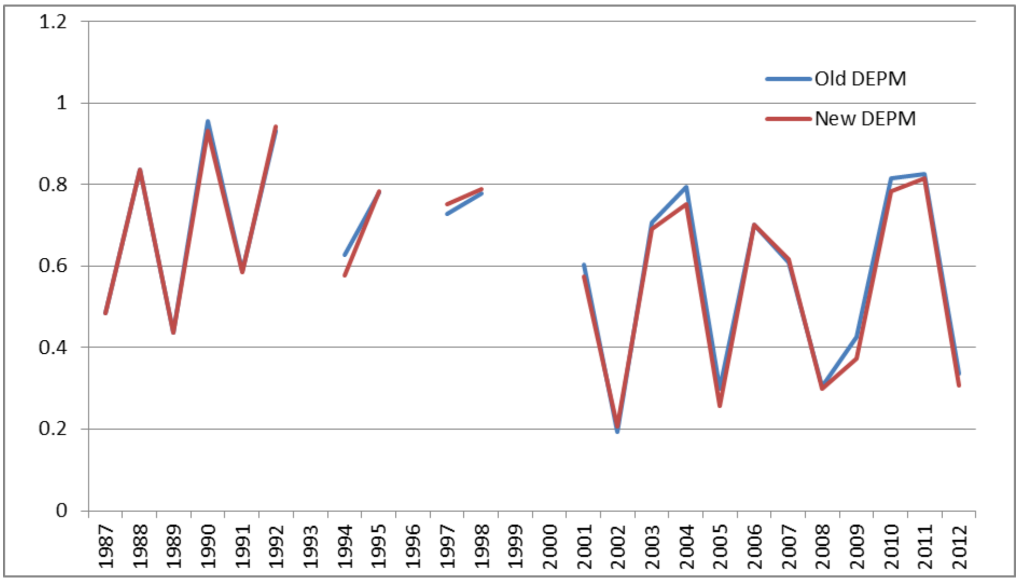


Figure 3.6.2.2. Comparison between the old (in blue) and revised (in red) DEPM age 1 proportion (in mass) estimates.

When the new DEPM estimates are included in the last ICES assessment (ICES, 2012), the spawning–stock biomass result in lower estimates (Santos *et al*., 2013, WD 5). The ICES assessment up to June 2012 relied on the assumption of DEPM SSB being considered an absolute index (DEPM survey catchability fixed at 1). However, the new estimates might not be compatible with some observed catch levels, e.g. 2004, and therefore the assumption on survey catchability needed to be revisited. See further discussion in Section 3.6.4.1.

Inclusion of JUVENA in the assessment

Since 2003 an autumn juvenile acoustic survey called JUVENA (Boyra *et al*., 2013) has been conducted annually. The times-series of the JUVENA anchovy juveniles abundance index and the estimates of recruitment (median values of age 1 biomass in January as estimated by the Bayesian two-stage biomass-based assessment model - BBM) from the last ICES assessment in 2012 (ICES, 2012) are compared in Figure 3.6.4.3. The high estimate of anchovy juveniles in JUVENA2010 was followed by strong anchovy recruitment at age 1 in 2011. In addition, the low juvenile abundance indices of 2004, 2007 and 2008 are associated with the lowest recruitments estimated by the assessment since 2003.

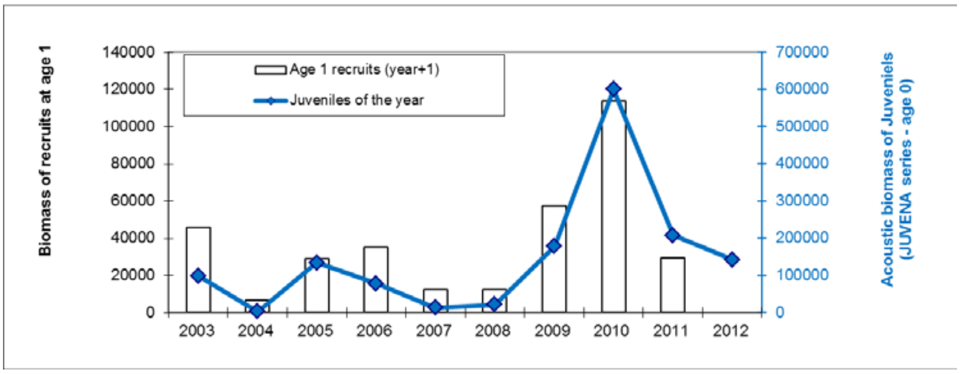


Figure 3.6.4.3. Times-series of the JUVENA anchovy juveniles abundance index (blue line) and of the recruitment (median of the age 1 biomass at the beginning of the next year) as estimated by the 2012 ICES assessment (ICES 2012).

The relationship between the JUVENA's juvenile abundance index and the ICES estimates of recruitment next year (age 1 biomass in January,) has been statistically significant since 2009. The Spearman rank correlation between the JUVENA series and the assessment estimates of recruitment at age 1 is 0.81, which is statistically significant with p-value=0.01, and the Pearson correlation is 0.94, which is statistically significant with p-value=0.000163. In addition, JUVENA's juvenile abundance index shows also statistically significant (Pearson's) correlations with the series of recruit estimates provided independently by each of the spring surveys (R=0.94 P(R=0)=0.000 for DEPM and R=0.89 P(R=0)=0.001 for Acoustics).

Nowadays, among several simple candidate models the best fitting of the ICES recruitment assessment and the juvenile abundance index is achieved with a loglinear model. The model is significant (p-value= 1.6E-04) with R^2=0.89%. WGHANSA (ICES, 2012) considered that the JUVENA acoustic index of juveniles is a valid indicator of the strength of the incoming recruitment and hence useful for improving the forecast of the population and potentially its assessment. The potential use of JUVENA for the assessment and forecast of the population is discussed in a working document presented to the benchmark workshop (Uriarte *et al.*, 2013, WD 7) and in Sections 3.6.4.1.3 and 3.7 in this report.

Inclusion of the DEPM and acoustic survey variances

In the current assessment of the stock using the two-stage biomass-based model the variance related parameters of the observation equations of the SSB and age structure estimates from the DEPM and acoustics methods are estimated. However, the coefficients of variation (CV) of the DEPM and acoustic SSB indices are estimated in the survey (with an average of 20% and 13% on average respectively). The benchmark workshop considered the possibility of including this information in the assessment as explored in Section 3.6.4.1.2.

New index from CUFES egg data from acoustic survey

A new index derived from the egg abundance collected with CUFES (Continuous Underwater Fish Egg Sampler) in the spring acoustic survey PELGAS was available to the benchmark workshop (Petitgas, P., 2013, WD 4). Subsurface CUFES egg concentrations are converted to vertically integrated egg abundances using a biophysical model of egg vertical distribution (Petitgas *et al.*, 2006; 2009; Gatti, 2012). Then, a procedure similar to the DEPM is applied to obtain an index of total daily egg production. A linear regression model between the CUFES total daily egg production and the acoustic biomass estimates is used to estimate an average daily fecundity, which is afterwards used to convert the CUFES total daily egg production into an index of spawning biomass. The benchmark workshop considered this as a promising approach. However, the WG noticed that unless the relationship is forced through the origin (intercept forced to be 0) the relationship between the CUFES total daily egg production with acoustics or with DEPM spawning biomass estimates was not statistically significant. Besides this, the method was presented as an approach to investigate the coherence between the different surveys and the benchmark workshop could not evaluate whether the index could be considered as a reliable index of anchovy abundance.

The potential inclusion of this index into future assessments was postponed until the CUFES series is complete (two years are lacking) and, more importantly, the series is verified and supported by WGACEGG as a reliable index of anchovy egg production.

3.6.3 Weights, maturities, growth and natural mortality

The biological sampling made for monitoring catches allows having good knowledge of the basic biological parameters of the population, particularly at spawning time when two research surveys take place.

Mean lengths and weights-at-age at the stock at spawning time and in the catches all across the year are well known.

The assessment model allows estimating average growth rates for two age classes (age 1 and age 2+) from the stock weight-at-age data (see Section 3.6.4.2).

Maturity is well known all age classes are fully mature at spawning time. Other reproductive parameters such as spawning fraction or batch fecundity are also known from the application of the DEPM.

Up to now natural mortality rates have been assumed to be constant across ages and years have been fixed to 1.2 in the assessment. However different studies have suggested that natural mortality could be lower for age 1 than for older individuals. A working document (Uriarte and Ibaibarriaga, 2013, WD 6) updated some of this work and suggested a natural mortality of 0.5 for age 1 and 1.5 for age 2 and older individuals. The different options considered for the natural mortality rates and the sensitivity of the assessment to each of them are described in Section 3.6.4.1.

3.6.4 Assessment models

WKSHORT (ICES, 2009) assessed the state of the Bay of Biscay anchovy stock using the Bayesian two-stage biomass-based model (Ibaibarriaga *et al*., 2008). This model describes the population dynamics in terms of biomass and separates recruits from the rest of the population. Catches are assumed to occur instantaneously and are simply subtracted from the population at two time instances each year. The model is statistically sound but makes some assumptions that might not be fully adequate for this stock. For instance growth and natural mortality are described by a single parameter g that is assumed to be constant across age groups and years. In addition there might be some retrospective pattern that might have a direct impact for the management of the stock (Ibaibarriaga and Uriarte, 2013, WD 3). Ibaibarriaga *et al*. (2011) proposed an extension of this model trying to overcome some of these issues. In the model extension, called in what follows CBBM, rates of growth and natural mortality are considered separately and additionally split by age class. The annual intrinsic growth rates are estimated from observations, whereas rates of natural mortality are either assumed known or treated as unknown model parameters. In addition, catch is assumed to be continuous in time. Fishing mortality is separated by semester, representing two distinct fishing patterns. Two stochastic observation equations for commercial catch (one for total catch, the other for proportion by age class, in biomass) are included per semester. This model was presented to WKPELA (Ibaibarriaga and Uriarte, 2013, WD 2) and was used for data and model exploration in the following subsection. Other models (SICA, AMAK and TASACS) making use of the full age structure of the population and describing the population dynamics in terms of numbers were used for comparison with exploratory purposes.

3.6.4.1 Data and model exploration

In this subsection the main issues identified for the Bay of Biscay anchovy (see Section 3.2) are addressed.

3.6.4.1.1 Natural mortality

Up to now natural mortality rates have been assumed to be constant across ages and years and have been fixed to 1.2 in the assessment. During the benchmark workshop several approaches were followed to check whether this assumption could still be valid, and if not, to define a new vector of natural mortality rates at age.

Evaluation of natural mortality from surveys' population-at-age estimates

The number-at-age estimates from the spring surveys (DEPM and acoustic) were used for estimating total and natural mortality (Z and M respectively) rates (Uriarte and Ibaibarriaga, 2013, WD 6). The closure of the anchovy fishery in the Bay of Biscay between 2005 and 2010 provided a unique occasion to check the actual level of natural mortality and the potential for a pattern of natural mortality changing across age classes.

Raw total mortality (Z) estimates by survey and age group are shown in Figure 3.6.4.1.1. The closure of the fishery produced a significant reduction on the Z levels estimates from surveys. At the closure time (2005–2009) total mortality Z1+ was around 0.81 (SD=0.18, CV=22%) while by ages Z1 was about 0.45 and Z2+=1.6. Among the five years of closure, 2005 resulted in contradictory negative mortalities being estimated (positive generation of individuals) by both surveys indicating that either the estimates of 2005 were too low or the 2006 too high. After removing the 2005 and 2006 estimates the average total mortality rates for the remaining three years of closure (2007–2009) (n= 6 = 3 Years * 2 Surveys) yieldedZ1+=0.87 (SD=0.25, CV=29%) Z1=0.65 (SD=0.27, CV=41%) and Z2+=1.63 (SD=0.30, CV=18%). Total mortality rates for age class 2+ were higher than for age class 1 (Z1<Z2+) not only for the closure period but for the whole time-series and for both surveys (Figure 3.6.4.1.1).

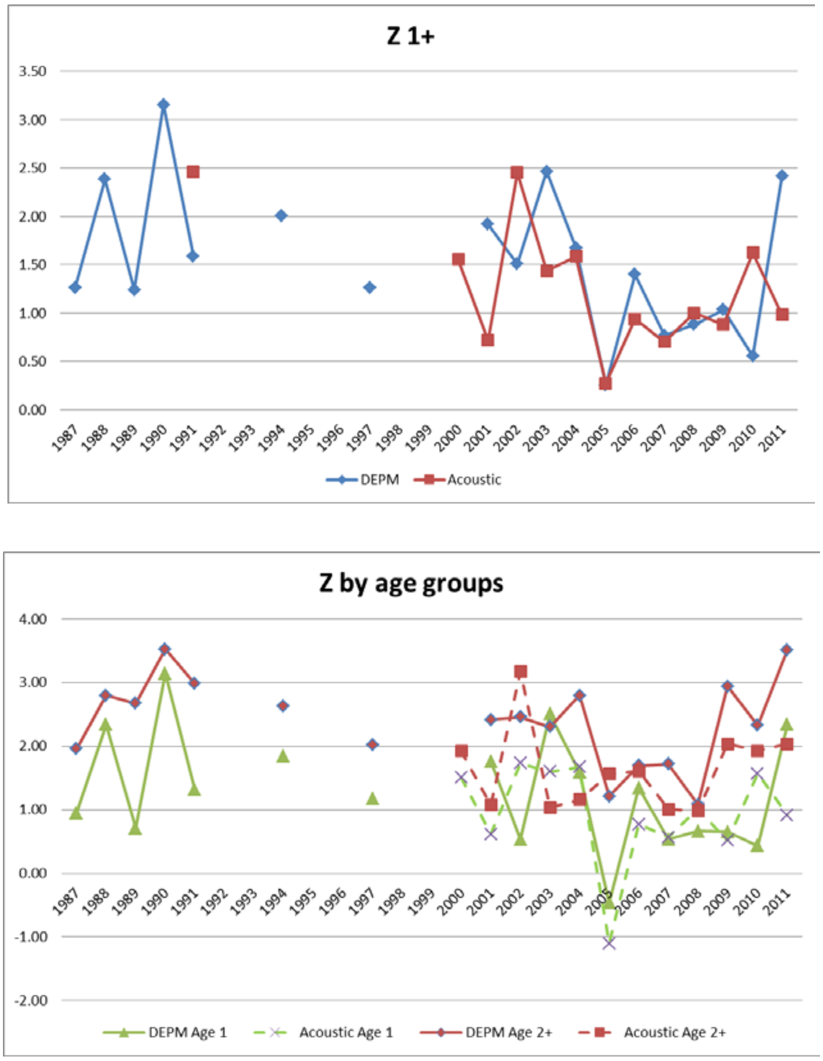


Figure 3.6.4.1.1. Total mortality (Z) between consecutive survey estimates from 1987–2011 for all ages (upper panel) and for distinct age classes (bottom panel). The line types and colours represent distinct surveys and age classes as indicated in the legends.

Linear regression models between the raw total mortality rates and an indicator of fishing mortality denoted as RC (relative catch) were fitted to the whole time-series (Uriarte and Ibaibarriaga, 2013, WD 6). Natural mortality rates were then estimated as the model intercept depending on the age classes, the survey type, the fishery closure and the definition of the RC index. After removing high RC values (RC>0.8), negative Z values and the 2012 survey observations (as presumed to be too noisy), it was found that:

a) Overall M1+ (all ages) could be between 0. 7 and 1, with actual estimates of 0.78 (CV=22%) for the RCJoint2 indicator (the mean of both surveys starting and ending consecutive estimates) and around 0.91 (CV=22%) for the RCSurvey2 indicator (the mean of the initial and final respective consecutive survey estimates).

b) Catchability between ages (the slopes) did not differ significantly between ages within surveys. The differences between surveys were not significant when working with RCJoint2. So the analysis gives support to the assumption of flat catchability across ages for each survey.

c) The analysis of M by ages showed that the level of natural mortality is always significantly higher for the ages 2+ than for age 1, regardless the concrete RC estimator used for the analysis. Actual estimates (Figure 3.6.4.1.2) were M1 around 0.72 (CV=27%) and to M2+ around 1.6 (CV=17%) for RCJoint2 and of M1 around 0.97 (CV=19%) and to M2+ around 1.48 (CV=18%) for RCSurvey2.

Consequently, the benchmark workshop considered that from the raw survey data M1+ would be somewhere around 0.75 and 0.95 (well below the formerly assumed value of 1.2) and that natural mortality is higher for the older ages than age 1 with M1 between 0.65 (raw data minimum value) and 0.97 (linear model RCSurvey2 maximum value) and M2+ between 1.4 and 1.65.

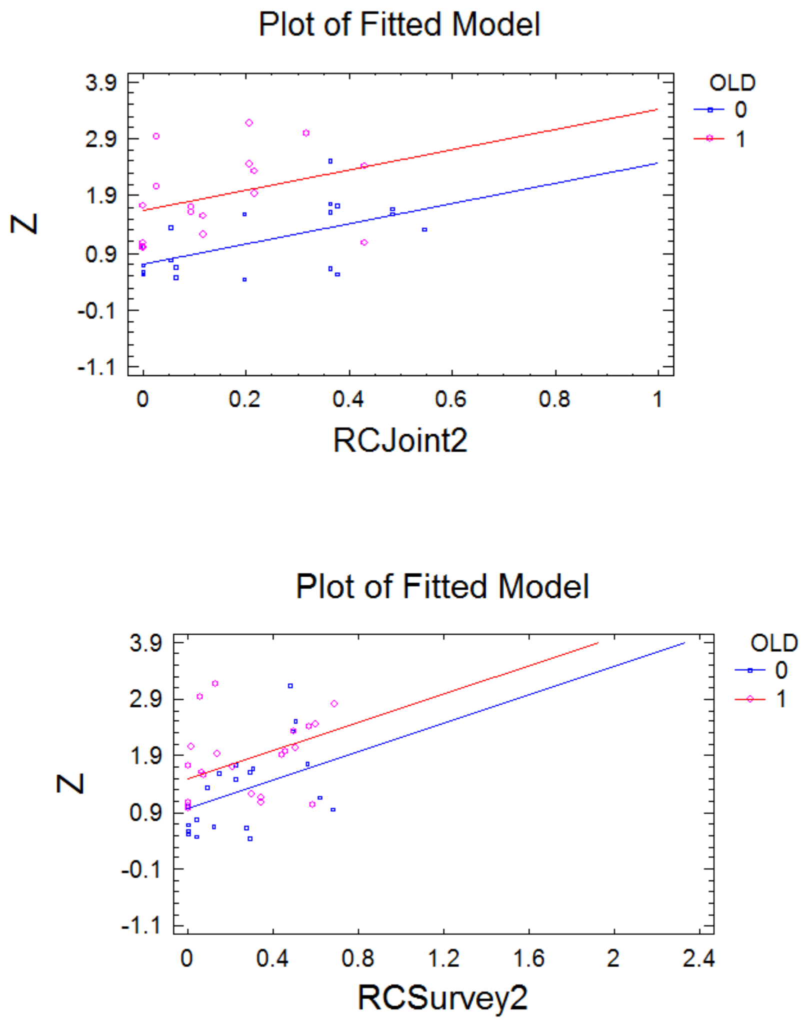


Figure 3.6.4.1.2. Natural mortality estimated by the intercepts from the linear models of Z between surveys and the indicators of fishing mortality RCJoint2 (the mean of both surveys starting and ending consecutive estimates) in the upper panel and RCSurvey2 (the mean of the initial and final respective consecutive survey estimates) in the bottom panel. The blue and red lines represent the age 1 and age 2+ classes respectively.

Seasonal ICA (SICA) evaluations

The Seasonal ICA (SICA) model was used to examine contrasting assumptions about selectivity and natural mortality with a goal to inform settings for the CBBM approach. This model is similar to Integrated Catch-at-age Analysis (ICA; Patterson and Melvin, 1996) but works on half year basis. It is age structured with fishing mortality by semester separated into age effects and year effects and it is fitted (running in Excel workbook) by minimization of the weighted sum of squares of total catch and catch-at-age by semester and biomass and population at age from the two spring surveys (DEPM - BIOMAN- and Acoustic –PELGAS).

An important feature was that the second semester catch data had very few age 3 and older anchovy and early evaluations considered that selectivity must be lower for this period. Whereas some movement to offshore areas may be occurring and hence those fish becoming less available, it was noted by stakeholders that the fishery targets the largest (oldest) anchovies. Consequently, the group considered this was an indication that natural mortality might be higher for those ages and thus would cause less of an accumulation of a "cryptic biomass" of adults (i.e., older fish that are assumed to exist even though they are rare in the fisheries and surveys).

SICA was used to explore the response of the general fitting of the model to different patterns of natural mortality-at-age, conditioned to equal catchability-at-age for each of the surveys. Searching for an optimum single constant natural mortality across ages (M1+) showed a minimum around 0.9 although with little contrast over a wide range of M1+ values (from 0.8 to 1.1) (Figure 3.6.4.1.3).

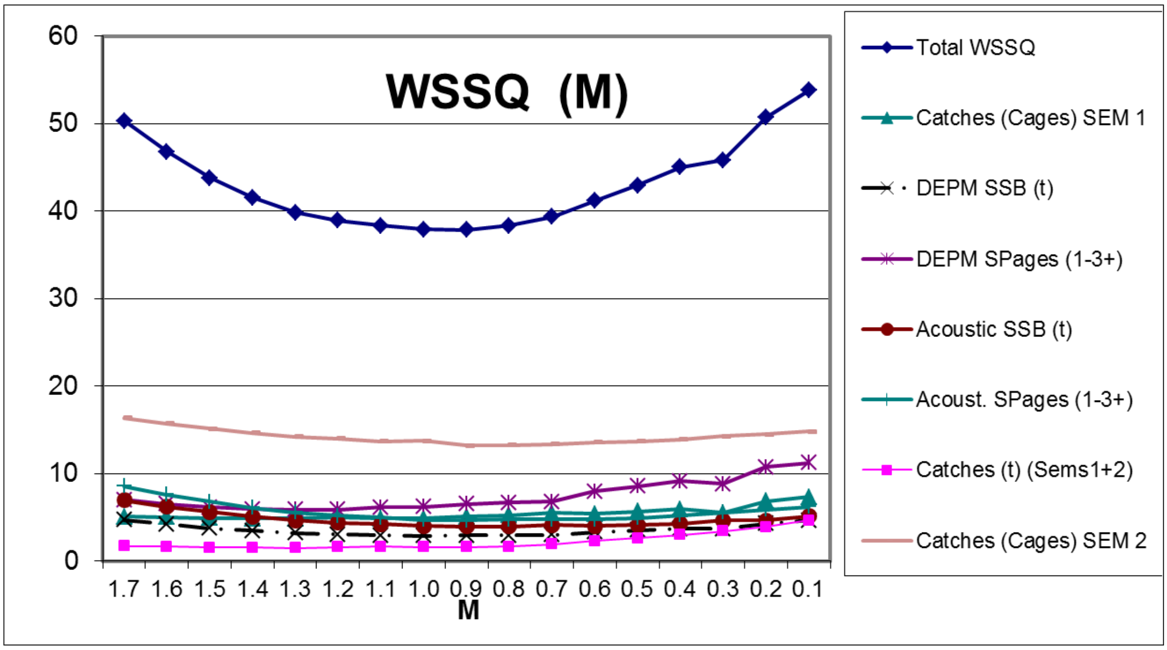


Figure 3.6.4.1.3. Weighted sum of squares from the fitting of SICA to the Bay of Biscay anchovy for a range of constant natural mortality for all ages (M1+) detailed by Total or by the different components of the objective function.

The search for an optimum pattern of natural mortality by ages for two age groups (natural mortality at age 1 M1 and natural mortality at age 2 and older M2+) showed that the lower the natural mortality at age 1 the lower the weighted sum of squares although with little improvements for the range of M1 values below 0.8 (Figure 3.6.4.1.4). The natural mortality of the older fish (M2+) decreased slightly as the natural mortality at age 1 (M1) increases (Figure 3.6.4.1.5).Over most of the potential M1 values range (0.5–1.2) M2+ ranged between 1.1 and 1.23 (Figure 3.6.4.1.5).

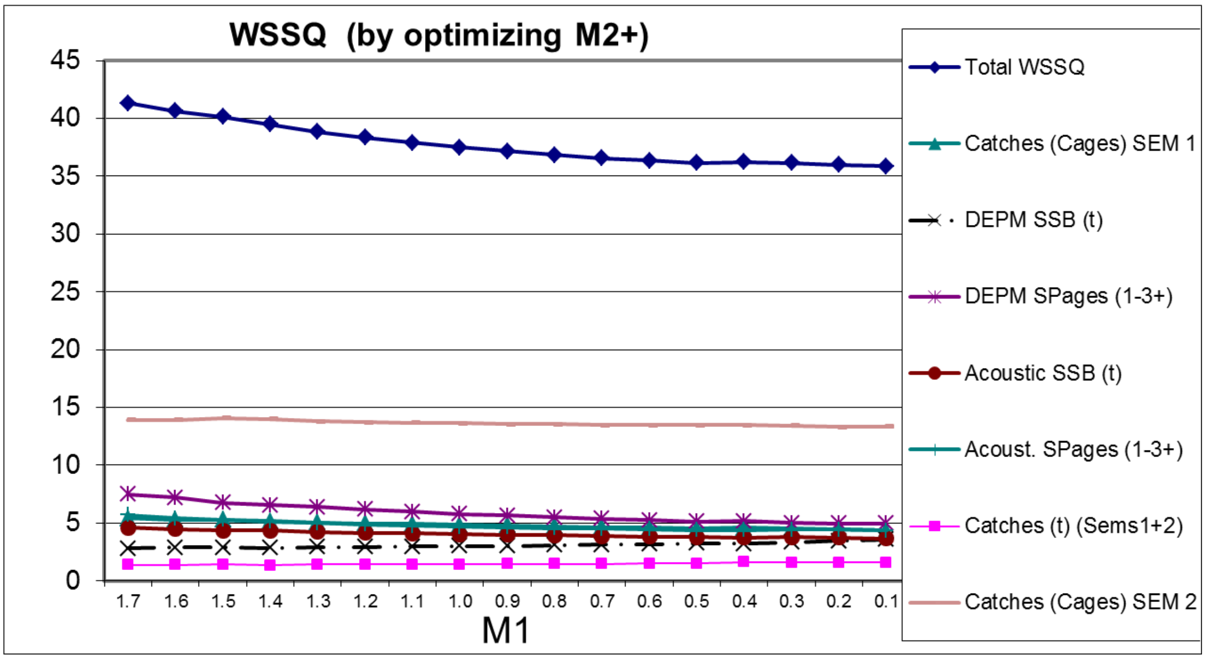


Figure 3.6.4.1.4. Weighted sum of squares from the fitting of SICA to the Bay of Biscay anchovy for a range of natural mortality at age one (M1) when the natural mortality at ages 2 and older is estimated (M2+), detailed by Total or by the different components of the objective function.

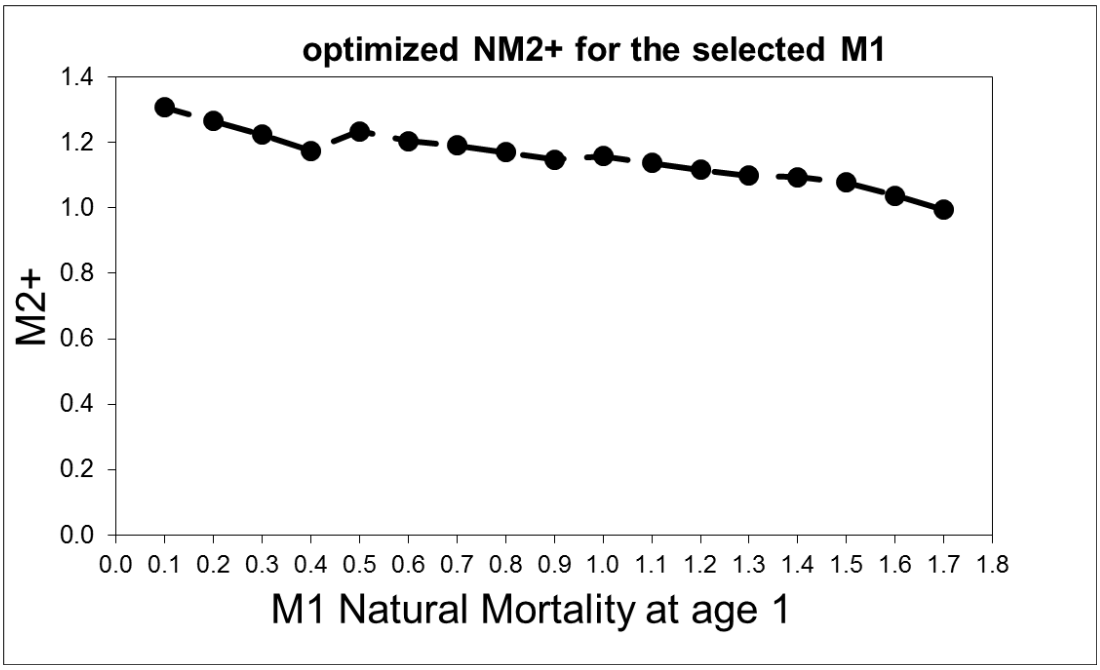


Figure 3.6.4.1.5. Estimates of M2+ conditioned to M1 for the SICA modeling of anchovy fishery and flat catchability at age within surveys.

It was also found that the results were rather insensitive to the inclusion or exclusion of the last year (2012) survey observations. In the latter case optimum M1+ would raise from 0.9 to 1 but again with little contrast over a wide range of M1+ values (from 0.8 to 1.1). In this case the lower M1 the better (lower weighted sum of squares) with little contrast for M1 values below 0.7. The corresponding values of natural mortality of the older fishes were rather invariantly between 1.1 and 1.23 for M1 values less than 1.

The members of the subgroup took these results as indicative that optimum M1+ would be somewhere between 0.8 and 1 and that M1 could be somewhere between 0.5 and 0.8 whilst M2+ would be higher and probably around 1.2, so not necessarily so high as suggested by the raw survey data before.

Time- and age-varying natural mortality using AMAK

The available data (all surveys including the CUFES and JUVENA indices) were applied in a simple annual time step age structured model. This model is designed for biomass index data and treats fishery catch biomass as the fundamental information for determining the annual fishing mortality rates. Parameters estimated include the recruitment in each year, annual fishing mortality rates, selectivity (for the first two ages but constant over time), and parameters relating to natural mortality which may or may not vary by age and over time. Ages 1 through 4 were modeled since age composition data were available for the fishery and the PELGAS surveys (the DEPM data only were available to age 3 hence for this evaluation they were excluded; preferably these data would have been included in this analysis).

Three main model configurations were evaluated: one with age-specific natural mortality fixed but allowed to vary by ages 1, 2-3, and 4. In this model the surveys were treated with a diffuse prior on survey catchability (effectively treating them as relative indices). A second model constrained the catchability of the PELGAS survey to be close to 1.0, and a third model was the same as the first but with natural mortality allowed to vary over time from 2000–2009. The parameterization approach was added to an ADMB model (an extension of the AMAK model from the NOAA applications: http://nft.nefsc.noaa.gov/).

Results of these models were examined and found to have generally similar results. For illustration Figures 3.6.4.1.6 and 3.6.4.1.7 compare the observed and fitted data on age composition and total abundance indices from the surveys respectively. Recruitment, spawning biomass and fishing mortality rates are shown in Figures 3.6.4.1.8 and 3.6.4.1.9. The probability intervals of the biomass in the last two years are wider than in the past, reflecting the surveys discrepancies in 2012.

When natural mortality is allowed to vary by three age groups (age 1, ages 2 and 3 and age 4 and older) the highest natural mortality rates were found for age 4 and older individuals (more than twice the natural mortality rates at ages 2 and 3). Natural mortality at age 1 was slightly larger than at ages 2 and 3 (Figure 3.6.4.1.10). When natural mortality is allowed to vary over time from 2000–2009 there was a decreasing trend from 2002 to 2009 (Figure 3.6.4.1.10).

Figure 3.6.4.1.6. Example fit to available fishery (top) and survey (bottom) age composition data. The different colour bars represent data on cohorts through time whereas the dotted lines are the model fits.

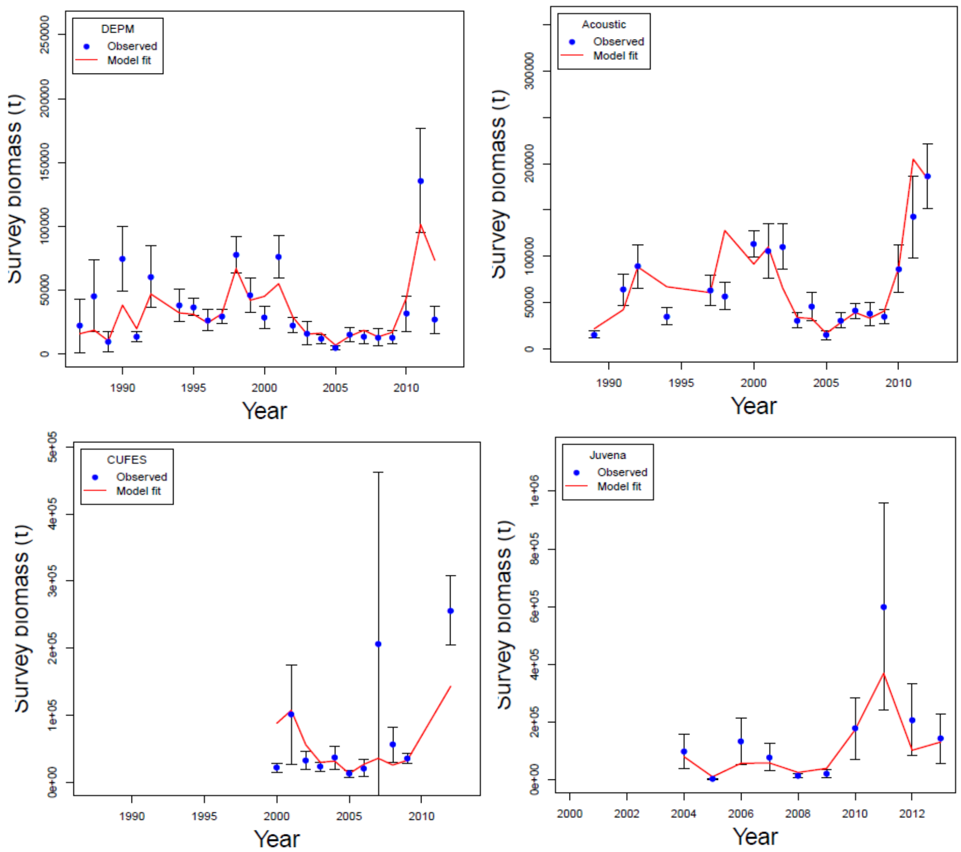


Figure 3.6.4.1.7. Example results of fit to different indices used in the model. Error bars represent the uncertainty specified as input to the model.

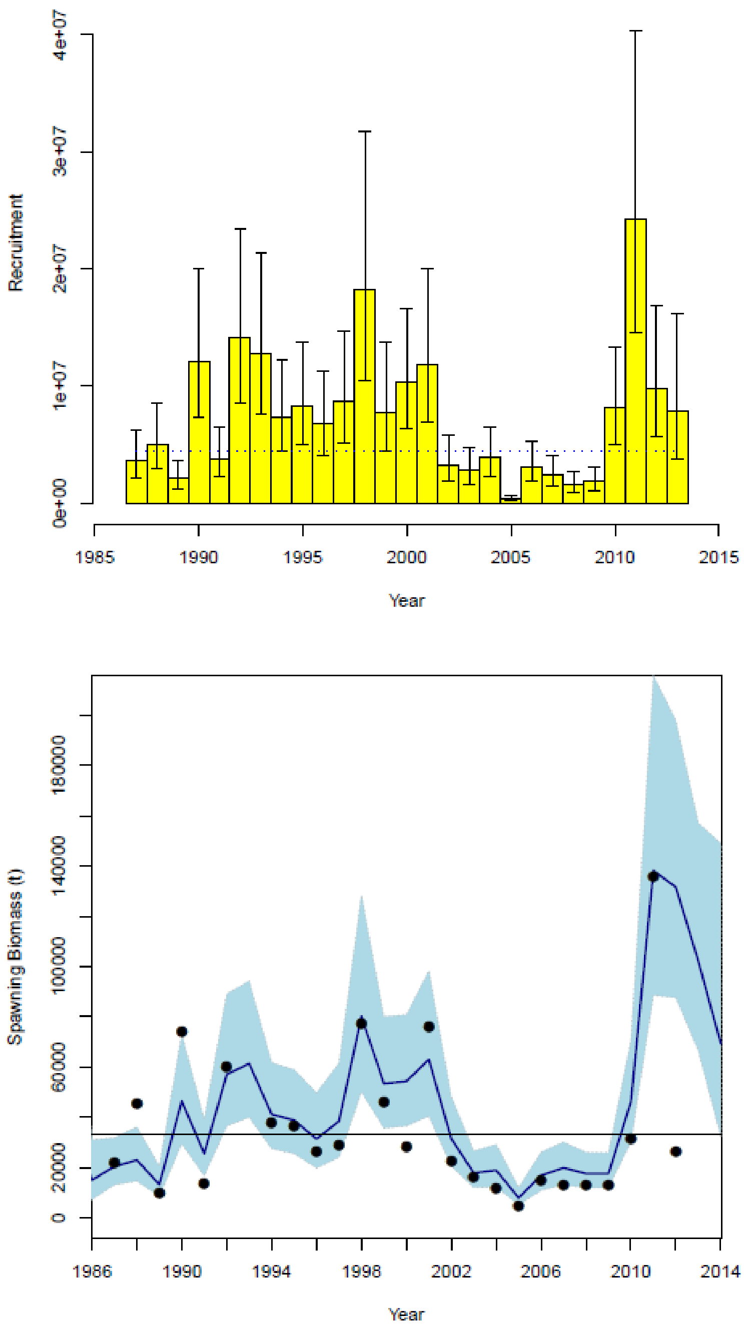


Figure 3.6.4.1.8. Example results showing recruitment estimates (top) and spawning biomass (bottom, bullets represent the DEPM estimates).

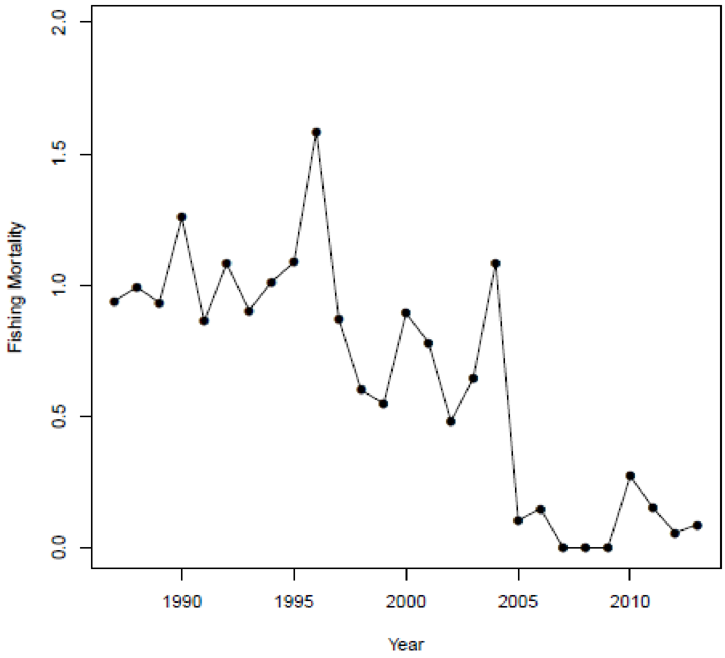
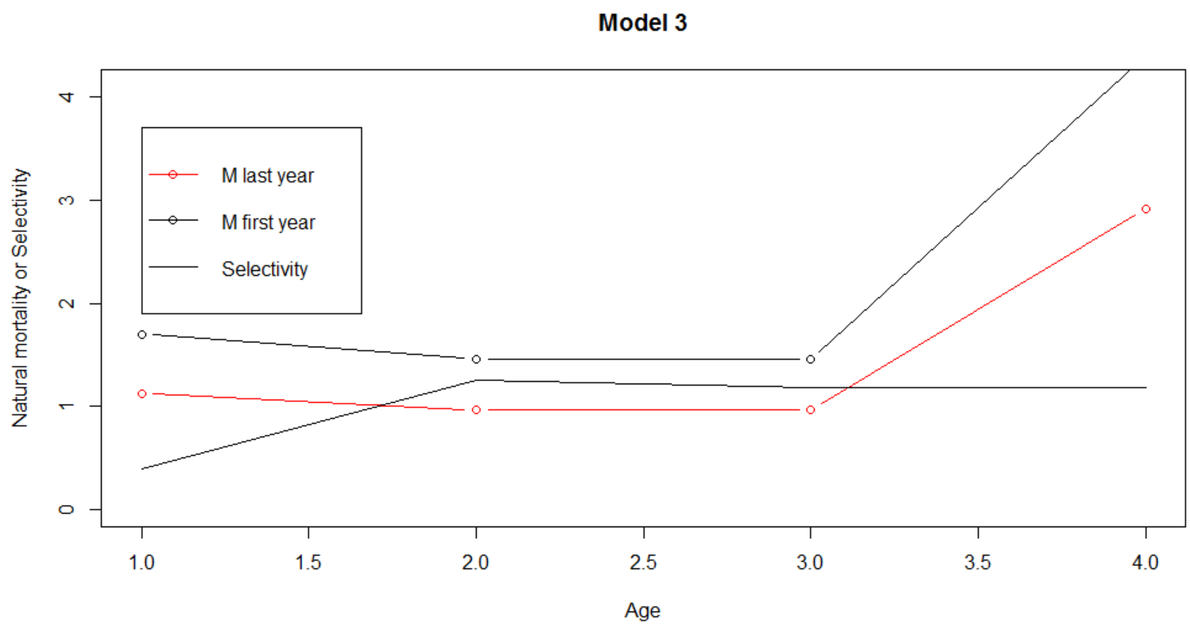


Figure 3.6.4.1.9. Example results showing fishing mortality rates.



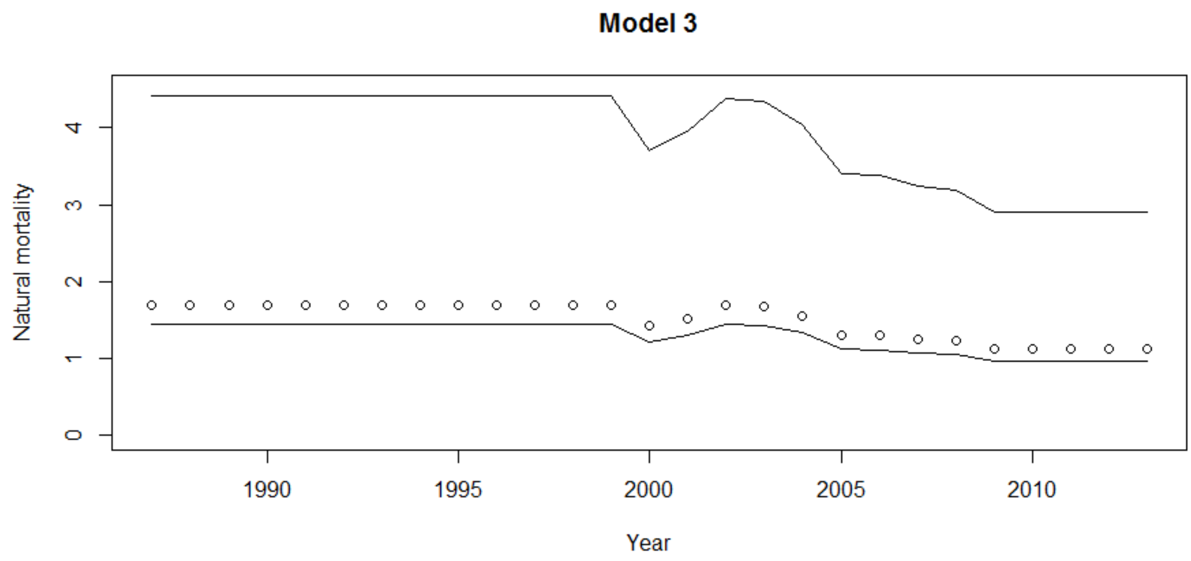


Figure 3.6.4.1.10. Example result of natural mortality estimates at age in 1987 and 2013 for model which allowed a random walk in natural mortality from 2000–2009 (bottom panel) and fishery selectivity estimates (top panel). In the bottom panel each line corresponds to a different age group.

CBBM natural mortality exploratory estimates

The model extension of the BBM, called CBBM, was used to explore different options for natural mortality-at-age groups 1 and 2+ (Ibaibarriaga and Uriarte, 2013, WD 2): natural mortality by age were assumed known and equal by ages (M1=M2+=1.2) or known and distinct by ages (M1=0.5 and M2+ =1.5) or unknown (M1 and M2+ estimated). In general, the fixed pattern of M1=M2+=1.2 produced a worse fit of the observations than those allowing changing natural mortality across ages. When natural mortality rates at age were estimated, natural mortality for age 2+ was larger than for age 1(0.7 and 0.84 for age 1 and age 2+ respectively when the DEPM was taken as absolute and at 0.82 and 0.86 when the DEPM was taken as relative). In addition, M1 and M2+ showed a high posterior negative correlation (Figure 3.6.4.1.11); so that on average the sum of M1 and M2+ was constant around 1.5 or 1.7 depending upon the DEPM was taken as absolute or relative.

The retrospective pattern in SSB estimates was minimized when natural mortality rates at age were estimated (Ibaibarriaga and Uriarte, 2013, WD 2). However some trends were found in the natural mortality rates at age. While M1 was around 0.8 for the last ten years, M2+decreased from 1.2 to 0.86 in the same period (Figure 3.6.4.1.11).

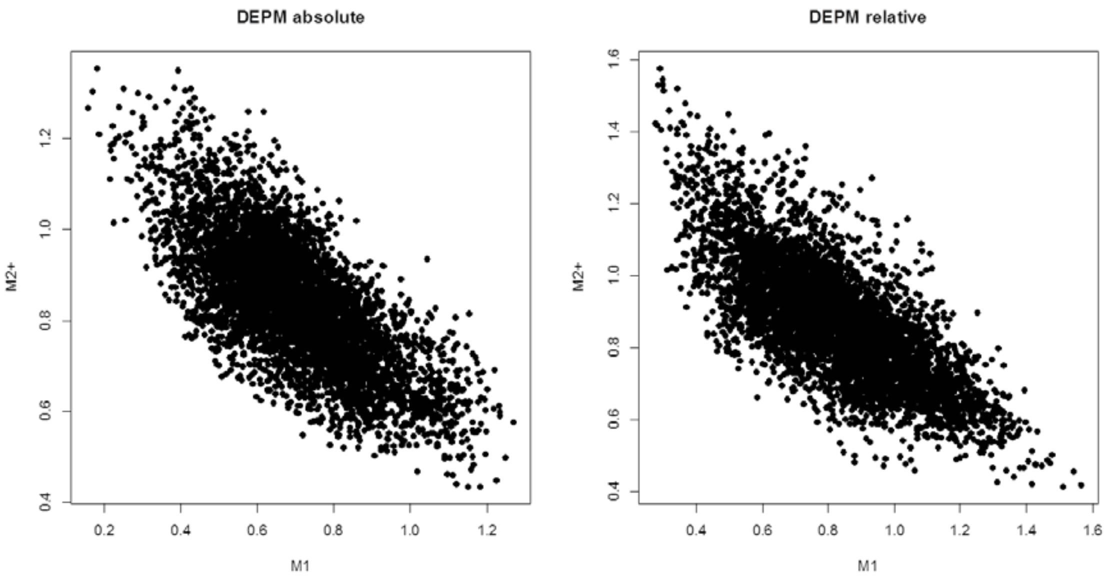


Figure 3.6.4.1.11. Posterior correlation between M1 and M2+ from the CBBM when the DEPM is taken as absolute (on the left) and the DEPM is taken as relative (on the right).

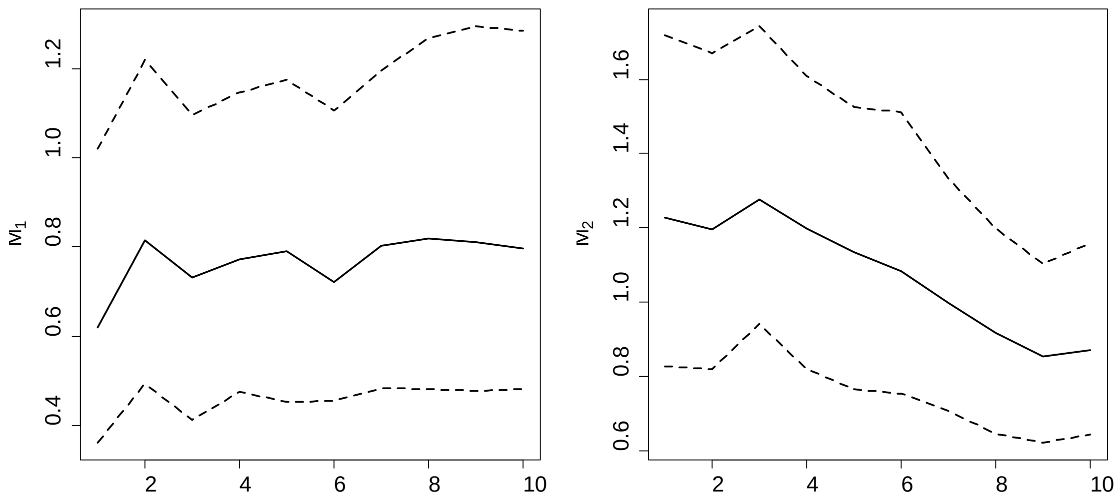


Figure 3.6.4.1.12. Retrospective pattern of natural mortality rates at age when the DEPM is taken as relative and the mortality rates are estimated (for the last ten years) by the use of the CBBM analysis.

Conclusions on natural mortality

a) All analysis suggest that overall natural mortality (all age groups pooled, M1+) could be comprised between 0.75 and 1, so well below former assumption of constant natural mortality rates across ages at 1.2.

b) The raw data strongly suggest that M1 is smaller than M2+. Although the integrated catch-at-age models (SICA or AMAK) and the biomass based model (CBBM) suggest that differences are not so remarkable across ages. In these models there is confounding (high correlations) between M1 and M2+ and the selectivity-at-age.

c) WKPELA decided pursuing an intermediate assumption on Ms by age which roughly would satisfy that

  i) global M1+ resulting from the weighted mean of M1 and M2+ (according to survey mean age structure) would fall within the likely range of M1+ obtained from all previous analysis (a);

  ii) M1<M2+ and around the mean M1+. The difference should not be as large as pointed out by the raw data but not as small as pointed out by the integrated assessments.

d) The proposal was M1=0.8 and M2+=1.2 which resulted in M1+ according to surveys' proportion at age 1 of:

		M1	M2+	M1+
Age 1	Mean Proportior	0.8	1.2	
DEPM	0.82500818	0.8	1.2	**0.87**
acoustic	0.765190912	0.8	1.2	**0.89**

The workshop considered this assumption better than the former assumption of constant natural mortality across ages (M1=M2+=1.2), but still deserving further analysis and future work.

3.6.4.1.2 DEPM catchability assumptions

Up to now the DEPM was considered as an absolute index of SSB (catchability of the DEPM was assumed to be equal to 1) and the assessment was considered to be scaled by this assumption. The assessment was examined in relative terms (SSB/SSB1989) given that these were insensitive to the use of the DEPM survey as absolute or relative (ICES, 2012).

For the benchmark workshop the DEPM SSB and numbers-at-age estimates were revised according to the new methods for estimating spawning frequency and total daily egg production (Santos *et al*., 2013, WD 5). The revised percentages at age were very similar to the previous ones, while the revised SSB estimates were on average 33% lower than the previous ones (see Section 3.6.2). When including these new estimates in the last ICES assessment (ICES, 2012) the spawning–stock biomass resulted in lower SSB estimates (Santos *et al*., 2013, WD 5).

The benchmark workshop noted that new SSB estimates might not be compatible with some observed catch levels. For instance in 2004 the DEPM estimates were lower than the recorded catches and in other years like in 1996 and 2000 the difference between the recorded catches and the DEPM estimates was low (less than 3000 t). Thus the effect of different catchability assumptions for the DEPM (absolute vs. relative) was studied. The implications for the last ICES assessment based on the BBM were studied in Santos *et al*. (2013, WD 5) and for the CBBM under different vectors of natural mortality rates at age were presented in Ibaibarriaga and Uriarte (2013, WD 2).

The DEPM catchability assumptions (absolute vs. relative) were explored using the CBBM when the natural mortality rates are fixed at M1=0.8 and M2+=1.2 (see conclusions from Section 3.6.4.1.1). When the DEPM is taken as absolute, the posterior median of the catchability of the acoustic index is about 1.6, whereas when the DEPM is taken as relative the catchability of the DEPM and acoustic SSB estimates are 0.6 and 1.4 respectively (Table 3.6.4.1.1). The precision of the DEPM and acoustic surveys, the initial biomass, the annual recruitments and the year effects of the fishing mortality also change depending on the assumptions on the DEPM survey catchability. When the DEPM is taken as relative, the initial biomass and the annual recruitments are larger and the year effects of the fishing mortality by semester are lower than when the DEPM is taken as absolute (Figure 3.6.4.1.13).

Table 3.6.4.1.1. Posterior quantiles for the CBBM under different catchability assumptions when M1=0.8 and M2+=1.2.

	DEPM ABSOLUTE			DEPM RELATIVE		
	$M_1 = 0.8$ and $M_{2+} = 1.2$			$M_1 = 0.8$ and $M_{2+} = 1.2$		
Parameter	5%	50%	95%	5%	50%	95%
q_{depm}	-	-	-	0.532	0.652	0.802
q_{ac}	1.284	1.609	1.997	1.096	1.360	1.736
ψ_{depm}	2.134	3.804	6.475	2.981	5.121	8.310
ψ_{ac}	2.382	4.760	8.752	2.822	5.478	10.131
ξ_{depm}	3.402	4.226	5.671	3.087	3.994	5.067
ξ_{ac}	2.685	3.398	4.137	2.630	3.352	4.078
ξ_{catch}	2.371	2.821	3.262	2.448	2.884	3.320
B_0	16106	20806	25848	16932	21873	28854
μ_R	9.879	10.210	10.540	10.010	10.350	10.660
ψ_R	0.675	1.108	1.693	0.725	1.181	1.833
$s(\text{sem}_1, 1)$	0.410	0.497	0.608	0.406	0.484	0.582
$s(\text{sem}_2, 1)$	1.055	1.280	1.586	1.025	1.300	1.629
G_1	0.481	0.552	0.626	0.459	0.526	0.599
G_{2+}	0.182	0.249	0.322	0.162	0.227	0.296
ψ_G	17.670	27.810	40.851	19.450	29.485	42.782

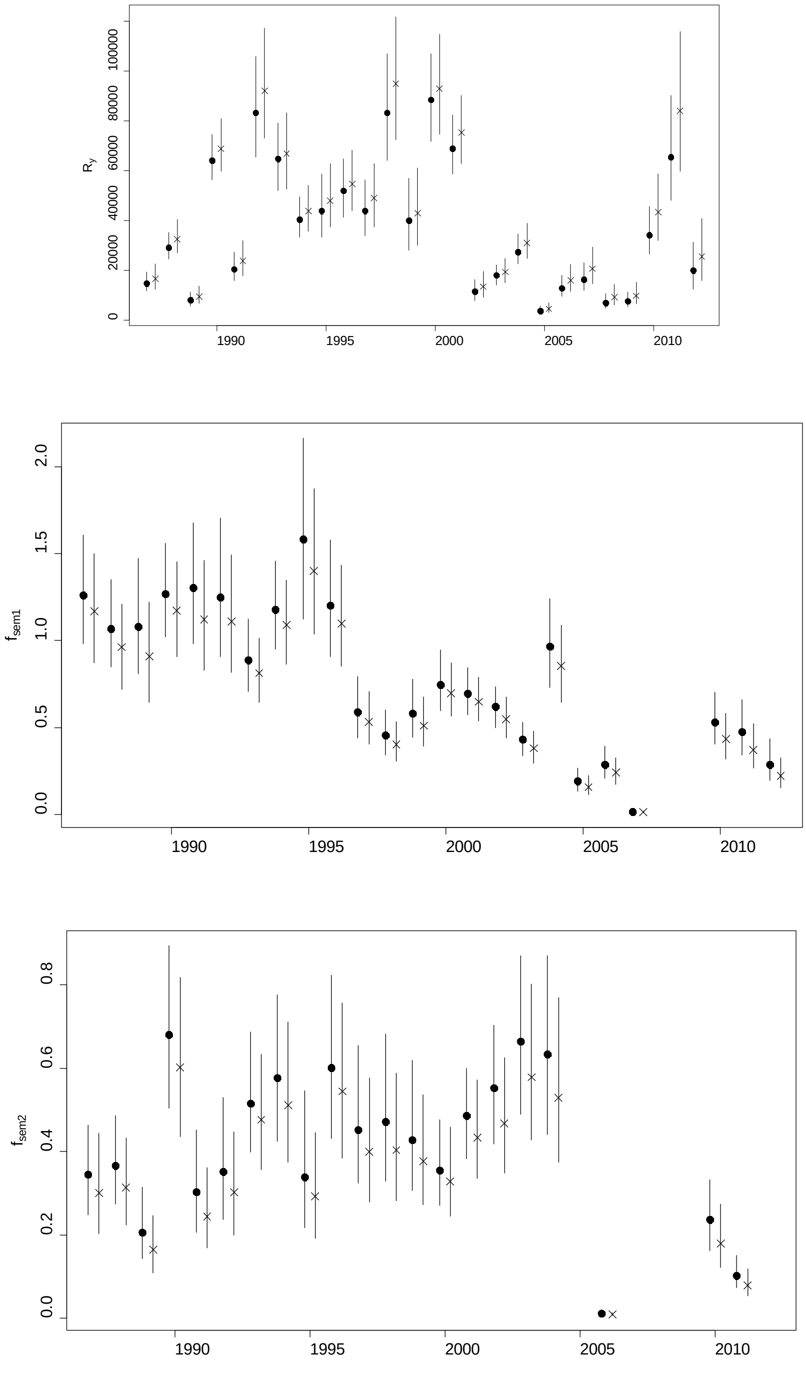


Figure 3.6.4.1.13. From top to bottom comparison of recruitment, fishing mortality in the first and in the second semester when the DEPM is taken as absolute (bullet) and relative (cross). Natural mortality rates are fixed at M1=0.8 and M2+=1.2.

Pearson residuals of the DEPM SSB were mostly negative when the DEPM was taken as absolute (Figure 3.6.4.1.13). No major trends were found when the DEPM was taken as relative (Figure 3.6.4.1.14).

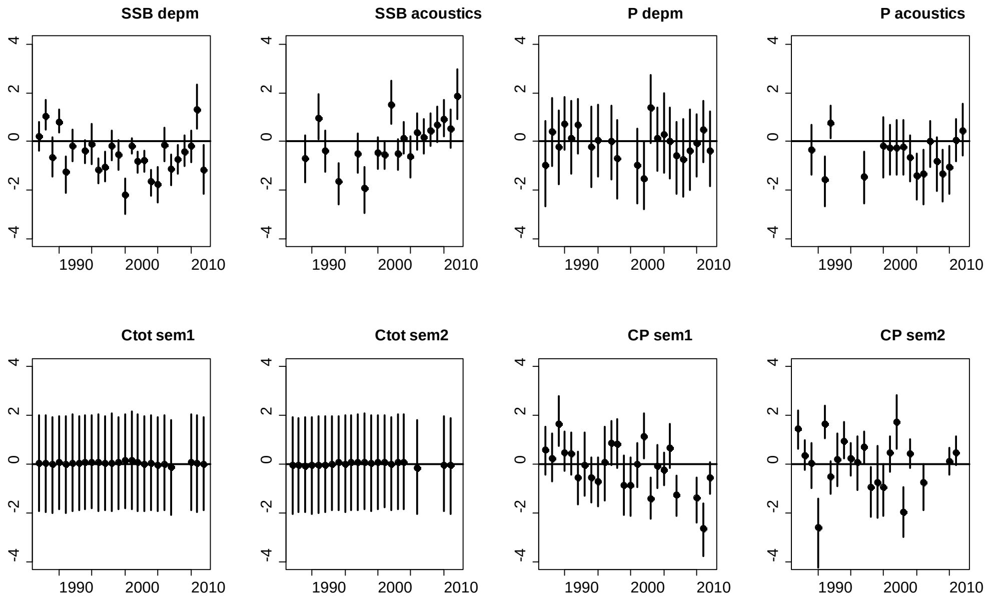


Figure 3.6.4.1.14. Residuals from the CBBM when the DEPM is taken as absolute and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

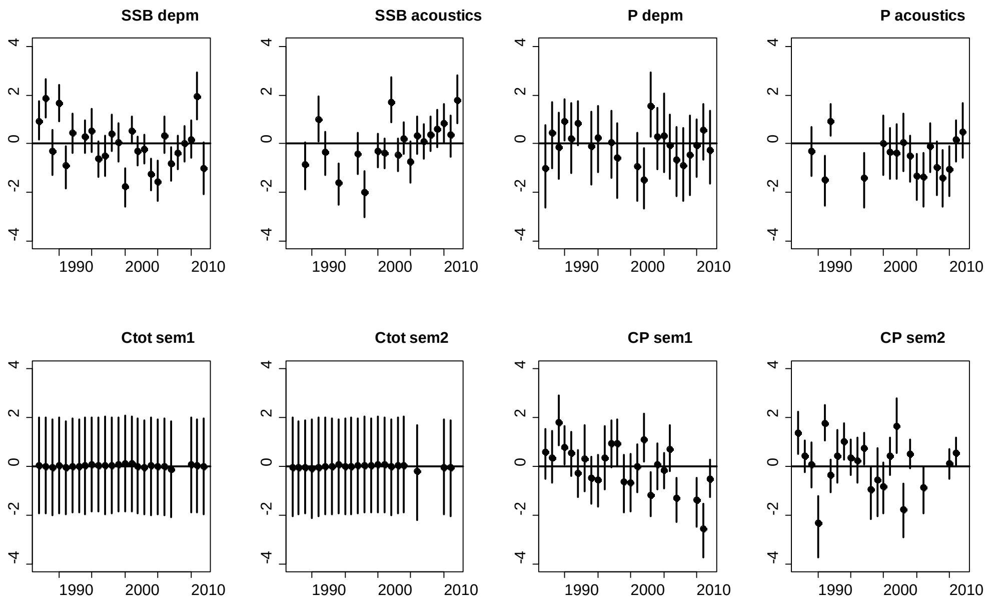


Figure 3.6.4.1.15. Residuals from the CBBM when the DEPM is taken as relative and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

Figure 3.6.4.1.16 compares the spawning biomass estimates depending on the DEPM catchability assumption. Although the trends are similar, estimating the catchability of the DEPM survey (relative index) results in larger SSB estimates.

Based on the incompatibility between the absolute levels of the catches and the DEPM estimates and the residual patterns, the benchmark workshop considered more appropriate to estimate the catchability of the DEPM survey.

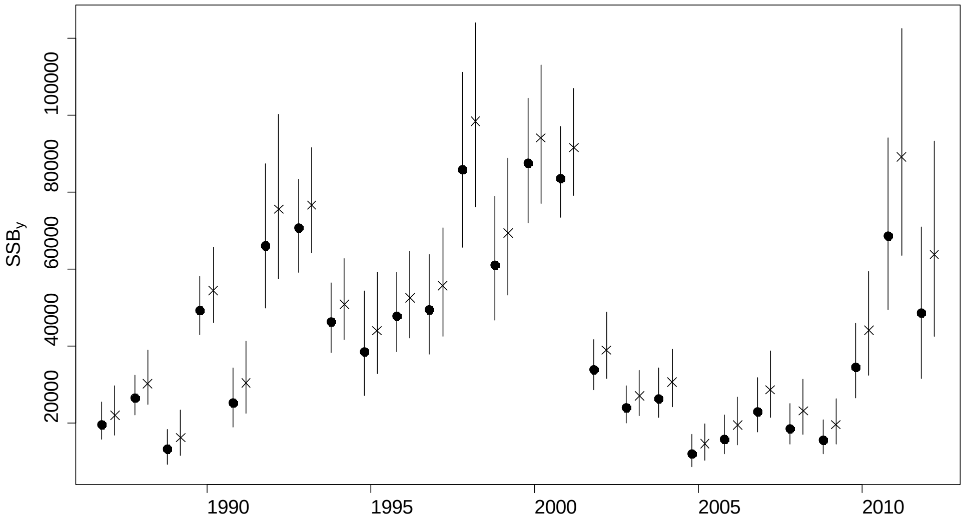


Figure 3.6.4.1.16. Comparison of SSB estimates from the CBBM when the DEPM is taken as absolute (bullet) and relative (cross). Natural mortality rates are fixed at M1=0.8 and M2+=1.2.

3.6.4.1.3 Inclusion of the JUVENA index

Since 2003 an autumn juvenile acoustic survey called JUVENA (Boyra *et al*., 2013) has been conducted annually (see Section 3.6.2). WGHANSA (ICES, 2012) considered that the JUVENA acoustic index of juveniles is a valid indicator of the strength of the incoming recruitment and hence useful for improving the forecast of the population and potentially its assessment. The index can be included in the current June assessment, but can also be used to update the assessment and forecast in autumn to give advice for the first semester of the next year. The potential use of JUVENA for the assessment and forecast of the population is discussed in a working document presented to the benchmark workshop (Uriarte *et al*., 2013, WD 7).

Including JUVENA in the June assessment

The JUVENA index can be included in the assessment based on the CBBM following the same principles as for the DEPM and acoustic spring surveys but with the particularity of only tunning the abundance of a single age group (recruits age 1 in January next year). The JUVENA recruitment index for year y $R_{\text{juv}}(y)$ (resulting from the survey conducted in year y-1) follows the following observation equation:

$$\log\left(R_{\text{juv}}(y)\right) \sim \text{Normal}\left(\log\left(q_{\text{juv}}\right) + \log\left(R_y\right), \frac{1}{\psi_{\text{juv}}}\right),$$

where q_{juv} and ψ_{juv} are respectively the catchability and the precision of the JUVENA surveys that need to be estimated.

The results of the CBBM when the DEPM is taken as relative and the natural mortality rates are fixed at M1=0.8 and M2+=1.2 are given in Table 3.6.4.1.2 and Figure 3.6.4.1.17. The catchabilities of the DEPM and acoustic surveys are slightly smaller when JUVENA is included in the assessment. The time-series of recruitment and fishing mortality rates by semester are basically the same, except for 2010–2012 that including JUVENA leads to larger estimates of recruitment. The catchability of the JUVENA index is estimated at 2.6 (median) with a posterior 95% probability interval between 1.5 and 4. The precision of the observation equation of JUVENA has median 1.5, corresponding to a larger CV than the DEPM and acoustic biomass indices.

Table 3.6.4.1.2. Posterior quantiles for the CBBM without and with JUVENA when the DEPM is taken as relative and M1=0.8 and M2+=1.2.

	WITHOUT JUVENA			WITH JUVENA		
	DEPM relative			DEPM relative		
	$M_1 = 0.8$ and $M_{2+} = 1.2$			$M_1 = 0.8$ and $M_{2+} = 1.2$		
Parameter	5%	50%	95%	5%	50%	95%
q_{depm}	0.532	0.652	0.802	0.502	0.626	0.759
q_{ac}	1.096	1.360	1.736	1.034	1.296	1.606
q_{juv}				1.511	2.562	4.031
ψ_{depm}	2.981	5.121	8.310	2.982	5.151	8.386
ψ_{ac}	2.822	5.478	10.131	3.177	6.280	11.491
ψ_{juv}				0.609	1.513	3.194
ξ_{depm}	3.087	3.994	5.067	3.194	3.989	4.922
ξ_{ac}	2.630	3.352	4.078	2.703	3.393	4.182
ξ_{catch}	2.448	2.884	3.320	2.393	2.843	3.242
B_0	16932	21873	28854	17466	22471	29144
μ_R	10.010	10.350	10.660	10.060	10.390	10.701
ψ_R	0.725	1.181	1.833	0.718	1.170	1.793
$s(\text{sem}_1, 1)$	0.406	0.484	0.582	0.401	0.484	0.577
$s(\text{sem}_2, 1)$	1.025	1.300	1.629	1.022	1.287	1.631
G_1	0.459	0.526	0.599	0.454	0.523	0.594
G_{2+}	0.162	0.227	0.296	0.163	0.225	0.296
ψ_G	19.450	29.485	42.782	19.380	29.685	43.881

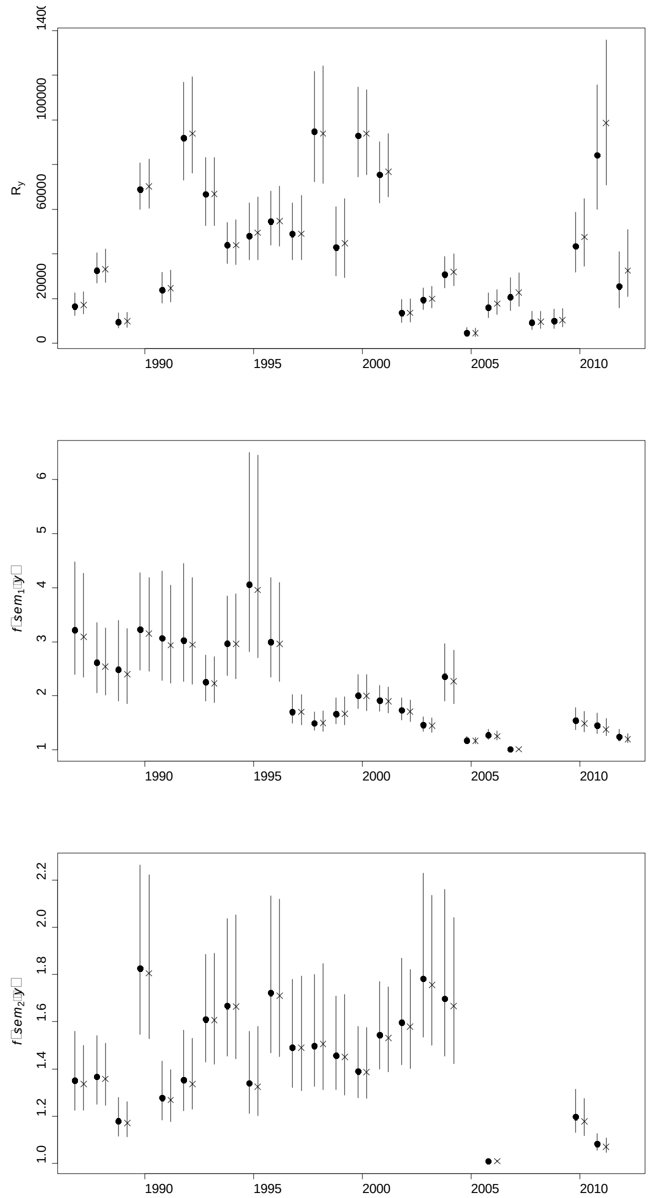


Figure 3.6.4.1.17. From top to bottom comparison of recruitment, fishing mortality in the first and in the second semester when JUVENA is not included (bullet) and when JUVENA is included (cross). The DEPM is taken as relative and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

The residuals of the CBBM when including JUVENA do not show any major pattern (Figure 3.6.4.1.18).

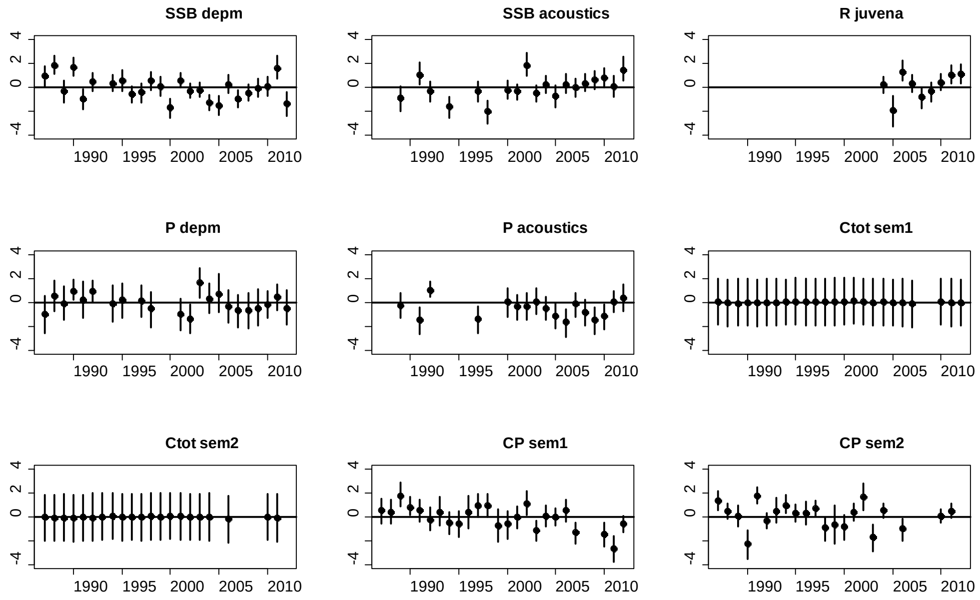


Figure 3.6.4.1.18. Pearson residuals when JUVENA is included in the CBBM. The DEPM is taken as relative and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

The comparison of the SSB estimates depending on whether JUVENA is included or not is shown in Figure 3.6.4.1.19. The inclusion of JUVENA from 2004 (survey conducted in 2003) leads to slightly larger estimates in 2007 and larger estimates for 2010–2012.

The benchmark workshop considered the inclusion of JUVENA in the June assessment an improvement.

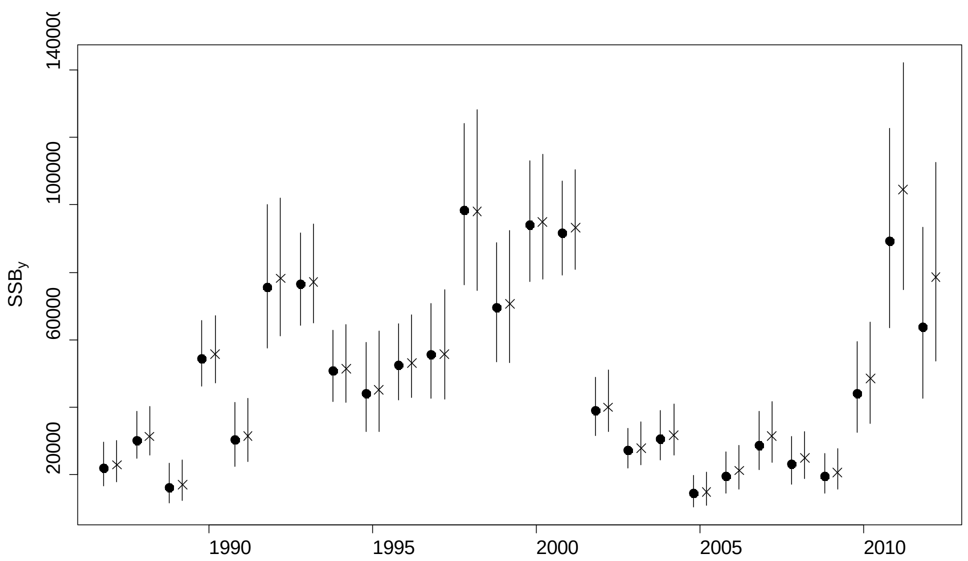


Figure 3.6.4.1.19. Comparison of SSB estimates from the CBBM when JUVENA is not included (bullet) and when it is included (cross). DEPM is taken as relative and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

Assessment update in December

The assessment conducted in June as described in the previous subsection could be updated (same model settings) as soon as the JUVENA index would become available in November/December. This assessment would include the catches up to the end of the year, the JUVENA index for the last year and any revision of the spring cruise results (as for instance expected for the DEPM). Such assessment will result in the population of survivors plus recruits in year Y+1. This would allow testing different catch options on the projected population and calculating the probability of the population falling below B_{lim} and/or any other statistic of interest. The assessment update and its use for advice based on the short-term projections are detailed in Section 3.7.

3.6.4.1.4 Observation variance

In the CBBM there is one parameter related to the variance of each observation equation from the surveys and from the catch (namely ψ_{depm}, ψ_{ac}, ψ_{juv}, ψ_{catch}, ξ_{depm}, ξ_{ac} and ξ_{catch}). In Ibaibarriaga *et al*. (2011) and in Ibaibarriaga and Uriarte (2013, WD 2) these parameters are assumed constant across years and are estimated (except ψ_{catch} that is fixed at 400). The DEPM and acoustic surveys provide coefficients of variation (CV) for the spawning biomass estimates. The benchmark workshop proposed using these estimates in the observation equations of spawning biomass from DEPM and acoustics. This means that the precision of the observation equations of spawning biomass from DEPM and acoustics were fixed and varying across years $\psi_{depm,y}$, $\psi_{ac,y}$. For acoustic biomass estimates before 2000 when no value was available the median value of $\psi_{ac,y}$ for years 2000–2012 (54.6) was taken. In addition, the variance related parameters of the observation equations of the age 1 proportion from the surveys and the catch (ξ_{depm}, ξ_{ac} and ξ_{catch}) were fixed equal to 4 for all years.

The comparison of the recruitment and fishing mortality rates by semester when the natural mortality rates are fixed at M1=0.8 and M2+=1.2, the DEPM is considered relative and JUVENA is included depending on whether the variances of the observation equations are fixed or estimated is shown in Figure 3.6.4.1.20. The trends are very similar, however for some of the years fixing the variances leads to slightly larger (as in 2010–2012) or smaller estimates (as in 2003 and 2004) in recruitment. The rest of parameters are compared in Table 3.6.4.1.3. In general they are quite similar, with slightly larger values for the DEPM, acoustic and JUVENA catchability parameters and smaller values of initial biomass B_0 when the variance related parameters of the observation equations are not estimated.

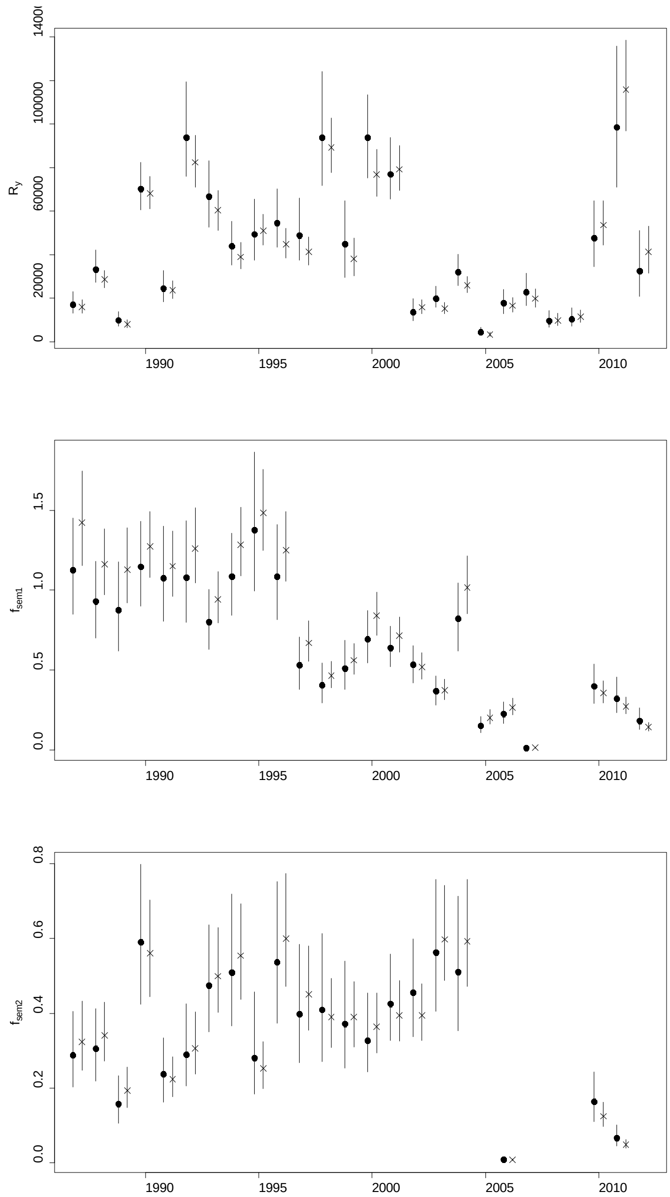


Figure 3.6.4.1.20. From top to bottom comparison of recruitment, fishing mortality in the first and in the second semester when the variances of the observation equations are estimated (bullet) and fixed (cross). The DEPM is taken as relative, JUVENA is included and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

Table 3.6.4.1.3. Posterior quantiles for the CBBM depending on whether variances are estimated or fixed when the DEPM is taken as relative, JUVENA is included and M1=0.8 and M2+=1.2.

	VARIANCES ESTIM			VARIANCES FIXED		
	WITHOUT JUVENA			WITH JUVENA		
	DEPM relative			DEPM relative		
	$M_1 = 0.8$ and $M_{2+} = 1.2$			$M_1 = 0.8$ and $M_{2+} = 1.2$		
Parameter	5%	50%	95%	5%	50%	95%
q_{depm}	0.502	0.626	0.759	0.597	0.673	0.757
q_{ac}	1.034	1.296	1.606	1.265	1.426	1.602
q_{juv}	1.511	2.562	4.031	1.707	2.671	3.975
ψ_{depm}	2.982	5.151	8.386			
ψ_{ac}	3.177	6.280	11.491			
ψ_{juv}	0.609	1.513	3.194	0.770	1.959	3.998
ξ_{depm}	3.194	3.989	4.922			
ξ_{ac}	2.703	3.393	4.182			
ξ_{catch}	2.393	2.843	3.242			
B_0	17466	22471	29144	14750	17854	21742
μ_R	10.060	10.390	10.701	9.981	10.310	10.640
ψ_R	0.718	1.170	1.793	0.703	1.128	1.707
$s(\mathrm{sem}_1, 1)$	0.401	0.484	0.577	0.413	0.463	0.518
$s(\mathrm{sem}_2, 1)$	1.022	1.287	1.631	1.224	1.432	1.691
G_1	0.454	0.523	0.594	0.493	0.564	0.641
G_{2+}	0.163	0.225	0.296	0.214	0.283	0.364
ψ_G	19.380	29.685	43.881	15.590	25.185	37.951

The trends for spawning biomass are very similar, but with larger or smaller values in given years. The effect of fixing some of the parameters is reflected in the reduction of the uncertainty in the posterior probability intervals (Figure 3.6.4.1.21). However, the Pearson residuals when the variance related parameters of the observation equations are not estimated (Figure 3.6.4.1.22) are larger than when they are estimated (Figure 3.6.4.1.18).

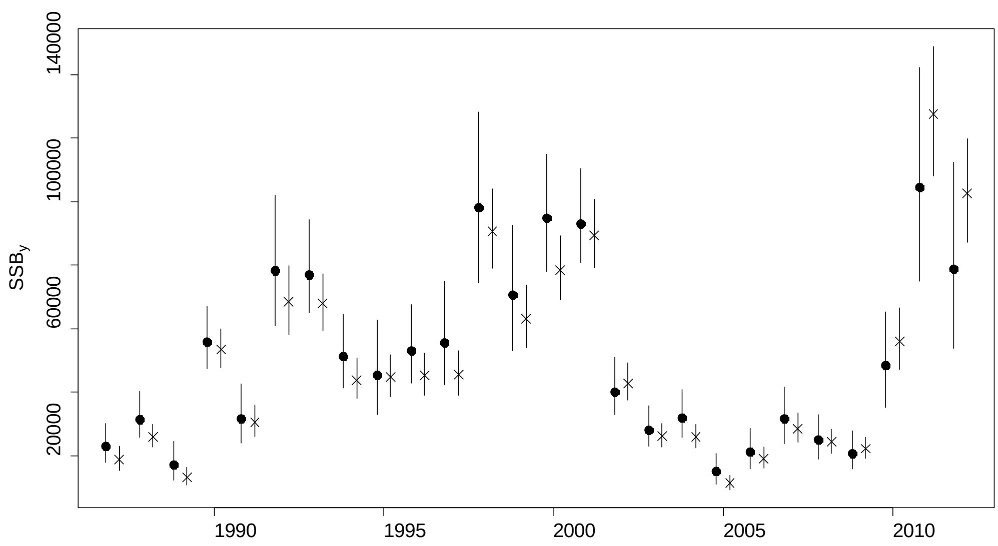


Figure 3.6.4.1.21. Comparison of SSB estimates from the CBBM when variances are estimated (bullet) and fixed (cross). DEPM is taken as relative, JUVENA is included and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

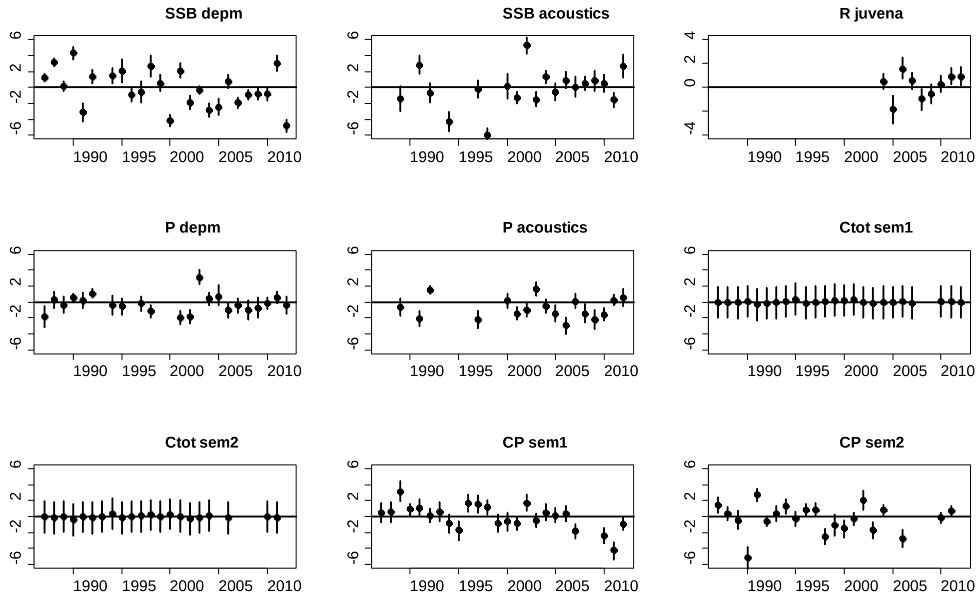


Figure 3.6.4.1.22. Pearson residuals when variance related parameters from the observation equations are fixed in the CBBM. The DEPM is taken as relative, JUVENA is included and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

The retrospective analysis when the variance related parameters from the observation equations are fixed is shown in Figure 3.6.4.1.23a. The past SSB estimates are slightly revised upwards when data from 2006 onwards are included. However the probability intervals of the last year estimates always comprise the median biomass resulting from subsequent assessments. Other parameters such as the catchabilities from the DEPM and acoustic surveys also change when adding years to the assessment (Figure 3.6.4.1.23b).

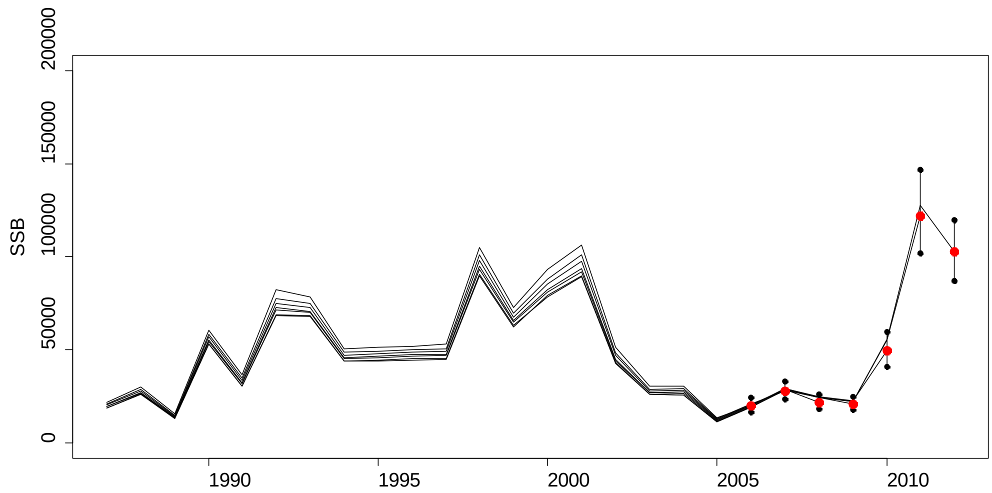


Figure 3.6.4.1.23a. Retrospective analysis for the spawning–stock biomass estimates from the CBBM when the variance related parameters from the observation equations are fixed. The DEPM is taken as relative, JUVENA is included and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

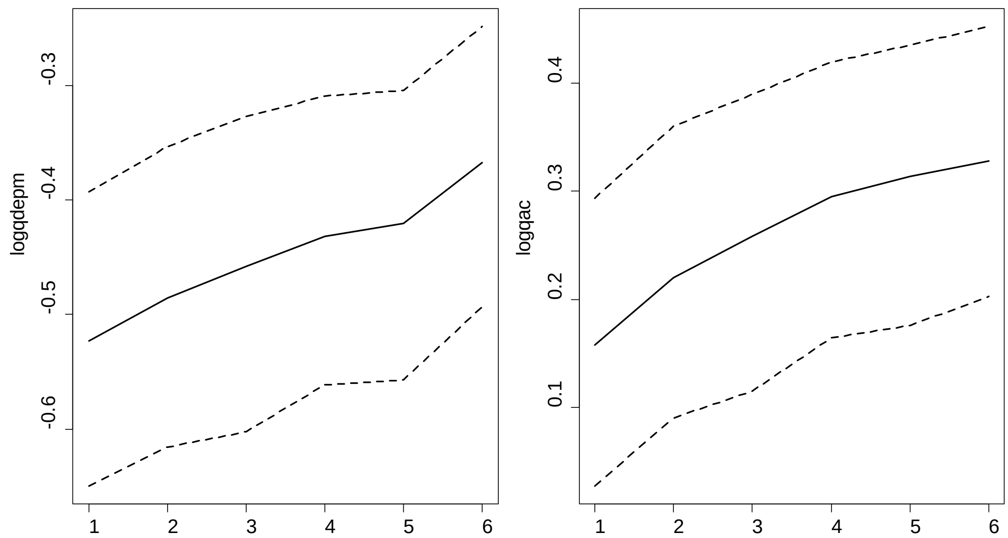


Figure 3.6.4.1.23b. Retrospective analysis for the catchability (in log scale) of the DEPM and acoustic surveys from the CBBM when the variance related parameters from the observation equations are fixed. The solid line is the median and the dashed lines are the posterior 95% probability intervals. The DEPM is taken as relative, JUVENA is included and natural mortality rates are fixed at M1=0.8 and M2+=1.2.

3.6.4.1.5 Other models

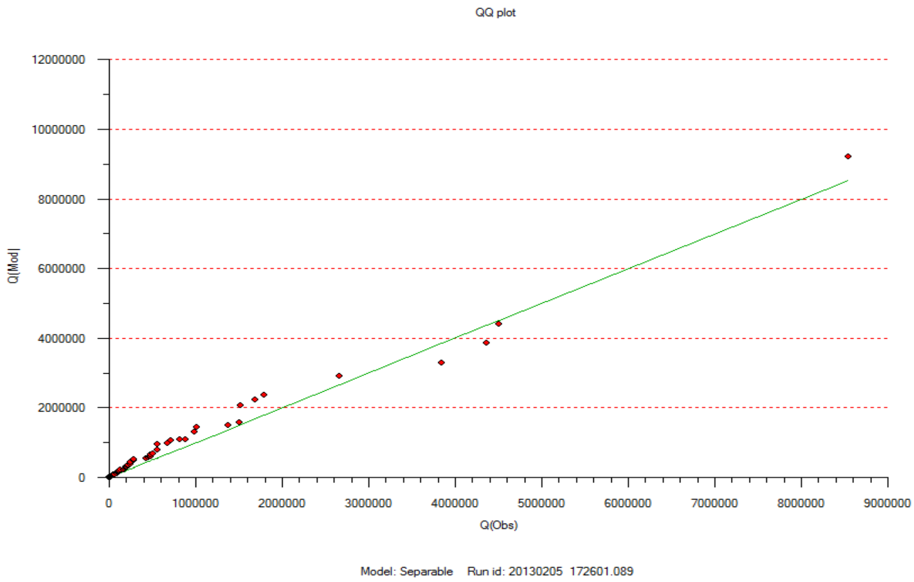
The CBBM was presented to WKPELA as an extension of the current assessment model BBM that tried to overcome some of its main drawbacks, such as the assumption of constant natural mortality across ages or not using information from the commercial catches. During the benchmark workshop other models were run in parallel with exploratory purposes. The SICA model and the extension of AMAK were used to obtain natural mortality estimates and are discussed in Section 3.6.4.1.1. In this section the additional runs performed using TASACS are described. By the time being, all these runs are preliminary, but WKPELA supports their continuation and development as a complement to the CBBM.

TASACS

A series of exploratory TASACS runs were carried out on the Bay of Biscay anchovy stock. The settings were set to match in terms of parameter the regular assessment using the BBM as best as possible. The time frame of the runs was set for the period 1987–2012. As TASACS is an age structured model, the age range 1 to 4+ was used. Natural mortality was set to 1.20. Maturity was set to 1 for all ages. Commercial landings were used from 1987 to mid-2012. Age structure data were provided from both PELGAS and BIOMAN surveys and sampling on the French commercial vessels as follows:

Commercial fleets:	Number-at-age (0–5 y.o.)
	Weight-at-age (0–5 y.o.)
PELGAS survey (2000–2012):	Number-at-age (1–5 y.o.)
	Weight-at-age (1–5 y.o.)
BIOMAN survey (1987–2012):	Number-at-age (1–3 y.o.)

Recruitment was considered as the average from the two average numbers of age 1 individuals from both surveys from 2000 to 2012.A standard run was done using both surveys. QQ plots (Figure 3.6.4.1.24) show the model seems to be driven by the BIOMAN time-series which is longer than the PELGAS one. As a consequence of potential bias of having surveys, two additional runs were carried out and presented later in this section where one survey was only used at a time.



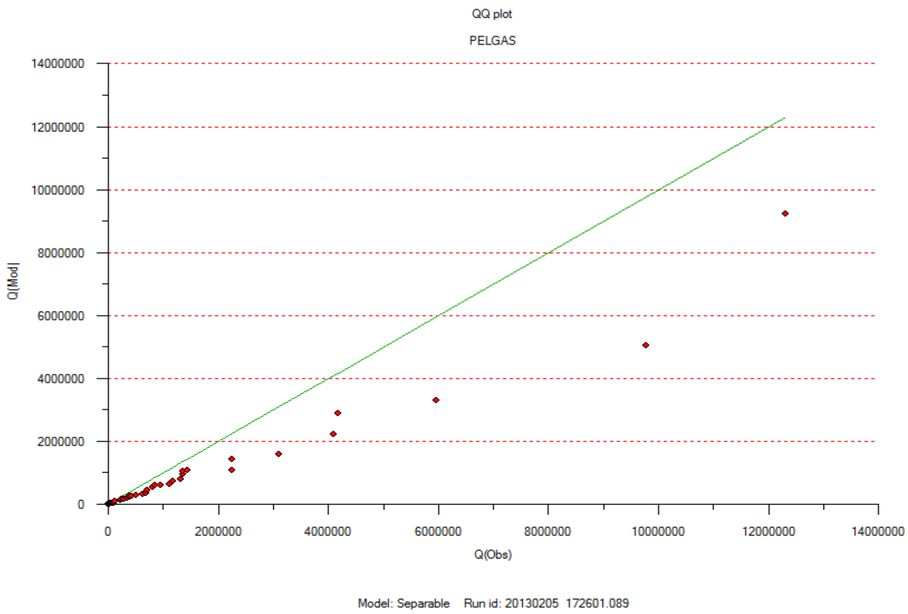


Figure 3.6.4.1.24. QQ plots for the standard TASACS run. Top (BIOMAN survey), Below (PELGAS survey).

Residuals were not available for PELGAS due to a software bug but available for both commercial fleets and BIOMAN (Figure 3.6.4.1.25). Residuals do not have lots of contrast except for years where no survey data were available. This suggests a strong constraining role of the surveys indices for the general model behaviour.

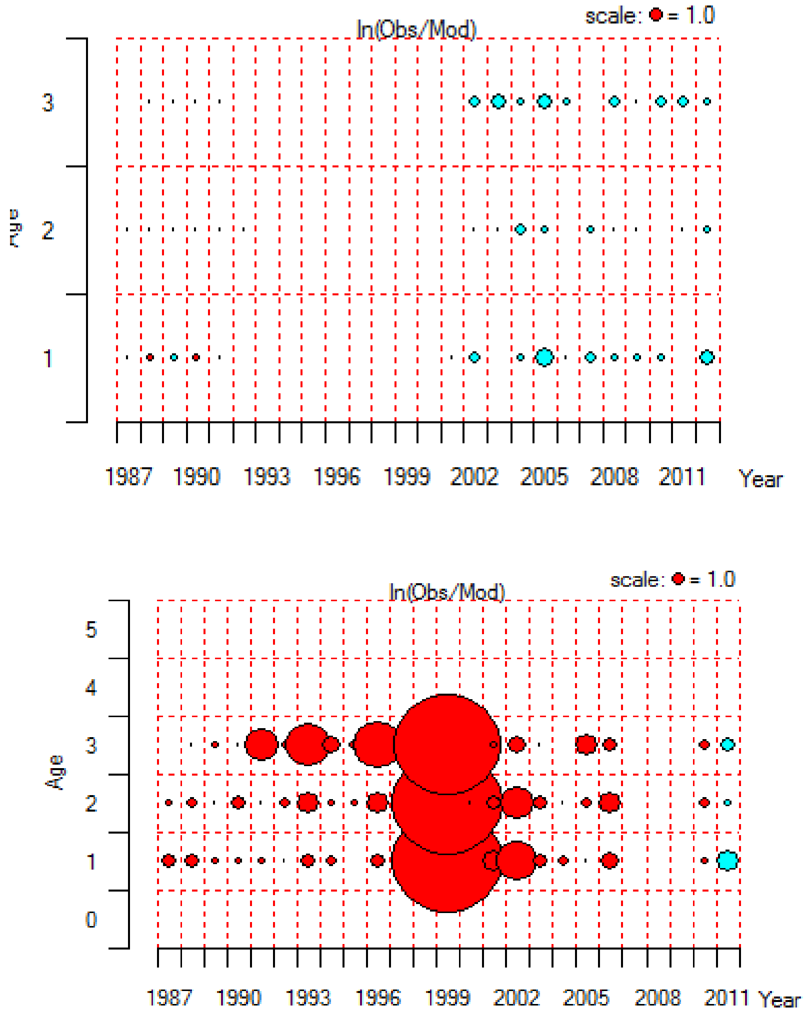


Figure 3.6.4.1.25. Residuals for the standard run (upper part: BIOMAN survey, lower part: commercial fleet).

A comparison between model outputs (BBM and TASACS) with reference to survey indices is presented on Figures 3.6.4.1.26–3.6.4.1.29. The general trends observed are somewhat following those of the surveys and BBM outputs with occasionally some strong differences. The SSB tends to be at close level to those simulated by the BBM after 2000. Before, the SSB is generally lower. In 1999, there is a strong peak of biomass which is not explained by the surveys. The 1999 peak is probably the results of the lack of any survey data this year giving lots of freedom for adjustment for the model. Recruitment provides results close to the BBM and in line with the survey indices except for the year 2011 where the simulated recruitment by TASACS is unusually higher than surveys indices and BBM output. TASACS also provides estimates of fishing mortality. There is no point for comparison for these plots but the two peaks in 1992 and 1995 are suspicious. Retrospective analysis (Figure 3.6.4.1.30) does not show any clear trend.

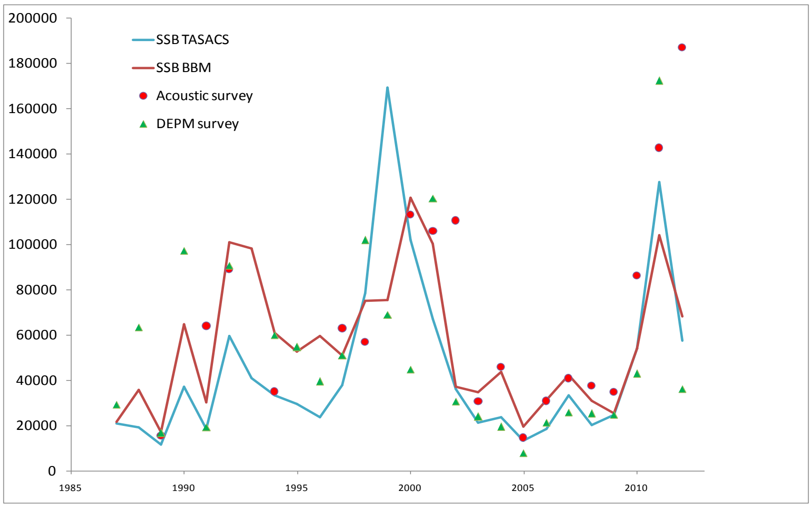


Figure 3.6.4.1.26. Simulated SSB (tons) using the TASACS model.

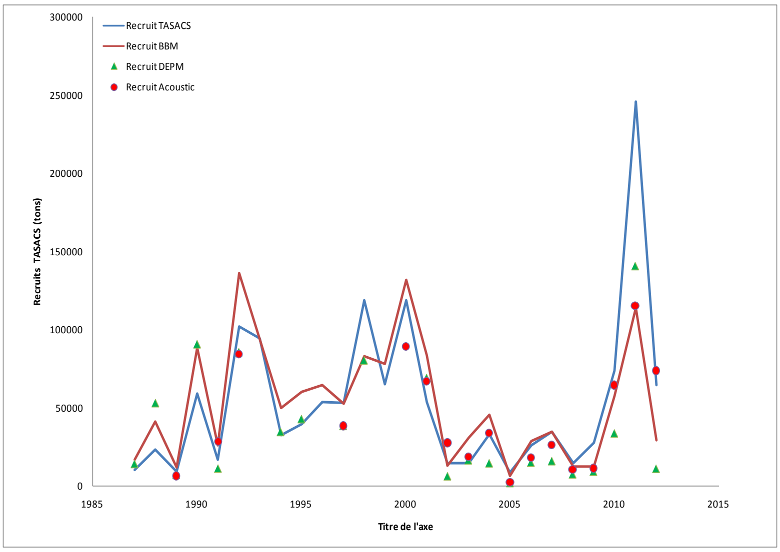


Figure 3.6.4.1.27. Simulated recruitment using the TASACS model.

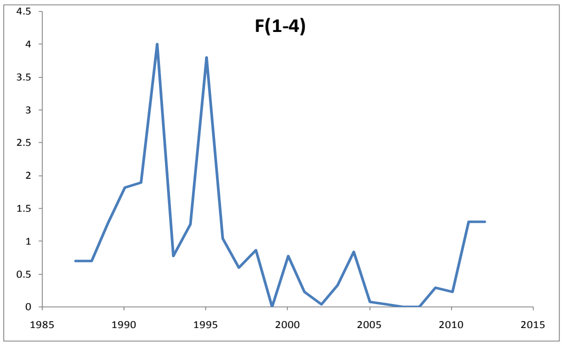


Figure 3.6.4.1.28. Fishing mortality using the TASACS model.

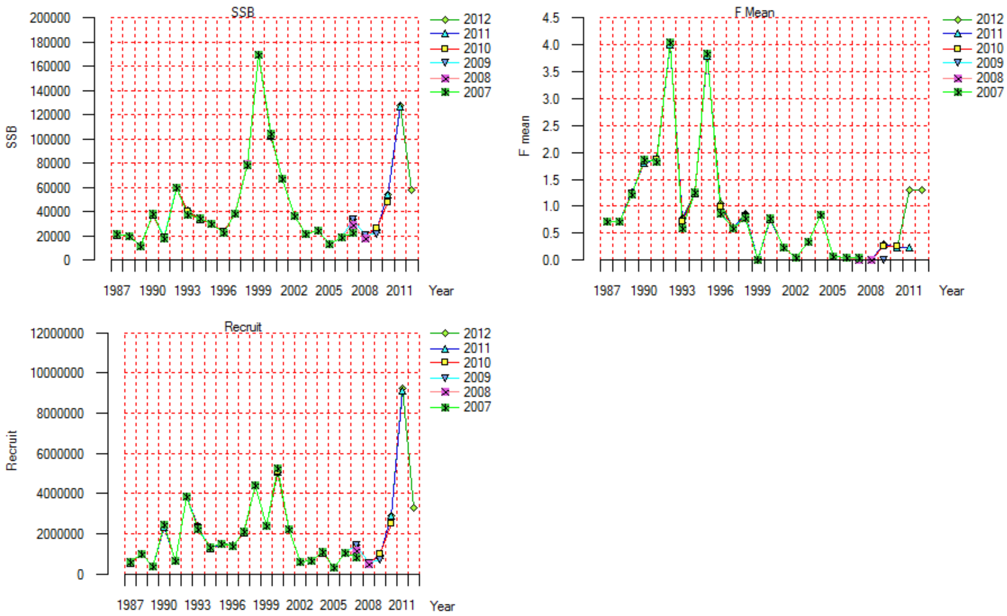


Figure 3.6.4.1.29. Retrospective plots.

Two additional runs were carried out by removing one of the two surveys (Figure 3.6.4.1.30–3.6.4.1.32). The removal of PELGAS leads to an unexplained peak of SSB in 2005 despite low abundance indices and a strong peak of recruitment in 1999 for no clear reasons as well. Despite those two peaks the model follows closely the survey data and results stay coherent with the BBM output. The removal of BIOMAN leads to no SSB and recruits before 1998 as there no acoustic survey indices before. SSB and R are following the trends observed during the survey but are generally higher. For both runs the estimates of fishing mortalities show some rather erratic estimates which suggest some excessive lag in the model parameters.

Overall those runs suggest both surveys have to be included in the assessment in order to drive correctly the model. The poor fitting achieved for some years (1992, 1995, 1999) suggest further refinement of the model tuning setting are still required. The use of TASACS as a primary model for the assessment of anchovy could be evaluated once the additional work to properly tune the model parameters is made, one advantage being the short time required to provide an assessment.

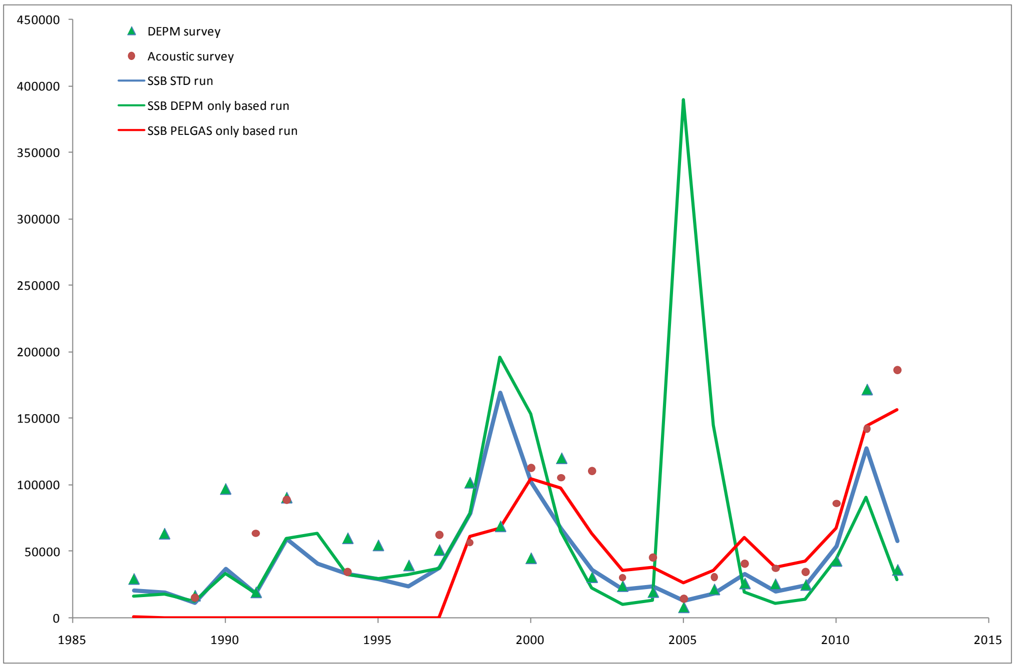


Figure 3.6.4.1.30. Estimates of SSB based on runs without one survey.

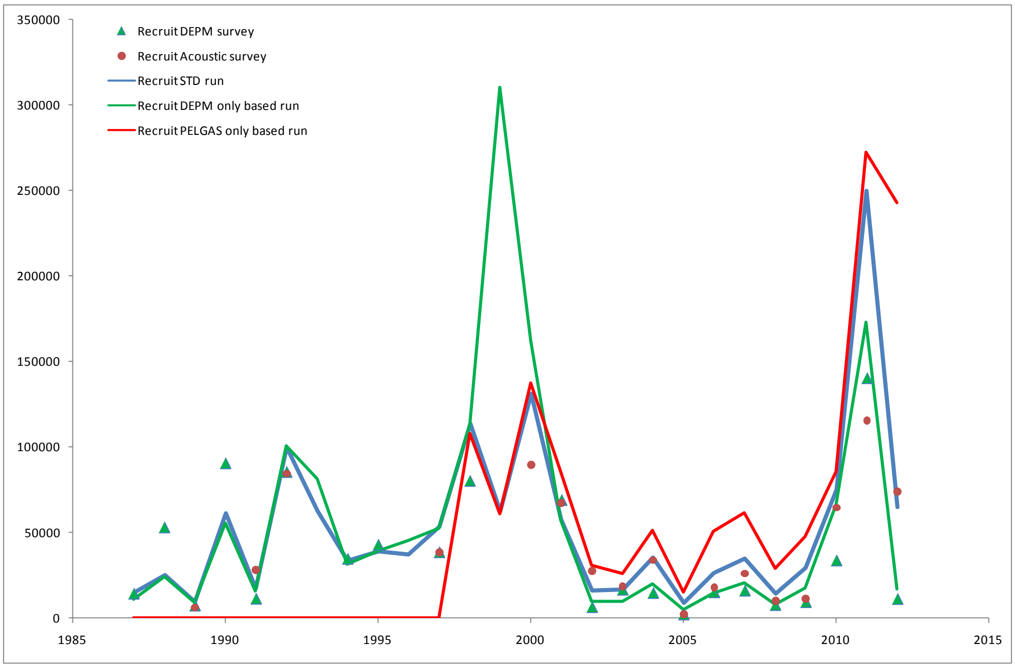


Figure 3.6.4.1.31. Estimates of recruits based on runs without one survey.

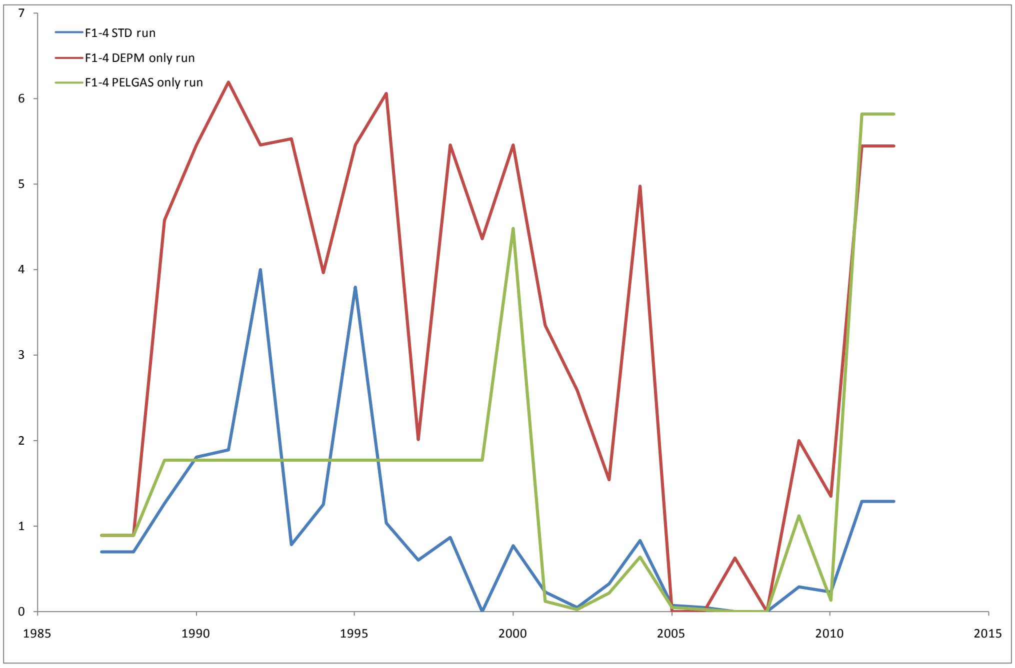


Figure 3.6.4.1.32. Estimates of fishing mortality based on runs without one survey.

3.6.4.2 Final assessment model

The final assessment model for the Bay of Biscay anchovy is based on the CBBM (Ibaibarriaga *et al.*, 2011) the main differences being the following ones:

- Natural mortality rates were fixed at M1=0.8 and M2+=1.2.
- DEPM was considered as a relative index of SSB (catchability of the DEPM estimated).
- The JUVENA juvenile acoustic biomass is included as an index of recruitment next year.
- The precisions of the observation equations of biomass from the DEPM and acoustic surveys are fixed (not estimated) according to the coefficients of variation from the survey each year. Other variance related parameters of the observation equations of the DEPM and acoustic surveys and of the catch observation equations by semester were also fixed.

A full and detailed description of the model is given below.

State equations

Let $B(t, y, a)$ denote the biomass of age a at time instant t ($0 \leq t \leq 1$) in year y (where age class $a+$ denotes individuals aged a and older). Recruitment in year y refers to age 1 biomass at the start of the year and is assumed to be lognormally distributed with mean μ_R and precision (inverse of variance) ψ_R for the log of recruitment, i.e.

$$\log(R_y) = \log(B(0, y, 1)) \sim \text{Normal}\left(\mu_R, \frac{1}{\psi_R}\right).$$

Biomass at age a ($a = 1, 2+$) evolves during semester j ($j = 1, 2$) as follows:

$$B(t, y, a) = B\left(b_{\text{sem}_j}, y, a\right) \exp\left\{\left(G_a - M_a - f(\text{sem}_j, y)s(\text{sem}_j, a)\right)\left(t - b_{\text{sem}_j}\right)\right\}$$

where t is a time-point during the semester, b_{sem_j} denotes the beginning of the semester, G_a and M_a are the intrinsic growth and natural mortality rates at age, and $f(\mathrm{sem}_j, y)$ and $s(\mathrm{sem}_j, a)$ represent the year and age factors of the fishing mortality rate in that semester.

Two monitoring surveys, an acoustic one and a DEPM, take place at time t_{surv}. For modelling purposes, it is assumed that both surveys take place on 15 May each year ($t_{\mathrm{surv}} = 0.375$). Then biomass of ages 1 and 2+ at survey time will be

$$B(t_{\mathrm{surv}}, y, 1) = R_y \exp\{(G_1 - M_1 - f(\mathrm{sem}_1, y)s(\mathrm{sem}_1, 1))t_{\mathrm{surv}}\},$$
$$B(t_{\mathrm{surv}}, y, 2+) = B(0, y, 2+)\exp\{(G_{2+} - M_{2+} - f(\mathrm{sem}_1, y)s(\mathrm{sem}_1, 2+))t_{\mathrm{surv}}\},$$

where $B(0, y, 2+)$ is the biomass surviving from the previous year, which may be computed as:

$$B(0, y, 2+) = \sum_{a=1,2+} B(t_{\mathrm{surv}}, y-1, a)\exp\{(G_a - M_a)(1 - t_{\mathrm{surv}}) - f(\mathrm{sem}_1, y-1)s(\mathrm{sem}_1, a)(0.5 - t_{\mathrm{surv}}) - f(\mathrm{sem}_2, y-1)s(\mathrm{sem}_2, a)0.5\}.$$

The total biomass at the time of the survey is the sum of the two age groups:

$$B(t_{\mathrm{surv}}, y, 1+) = \sum_{a=1,2+} B(t_{\mathrm{surv}}, y, a),$$

and the age 1 biomass proportion is given by

$$BP(t_{\mathrm{surv}}, y) = B(t_{\mathrm{surv}}, y, 1)/B(t_{\mathrm{surv}}, y, 1+).$$

According to the Baranov catch equation, the catch at age a (in biomass) in semester j of year y is

$$C(\mathrm{sem}_j, y, a) = B(b_{\mathrm{sem}_j}, y, a)\frac{f(\mathrm{sem}_j, y)s(\mathrm{sem}_j, a)}{M_a - G_a + f(\mathrm{sem}_j, y)s(\mathrm{sem}_j, a)}$$
$$\{1 - \exp\{(G_a - M_a - f(\mathrm{sem}_j, y)s(\mathrm{sem}_j, a))\,0.5\}\}.$$

The total catch is the sum of the two age classes:

$$C(\mathrm{sem}_j, y, 1+) = \sum_{a=1,2+} C(\mathrm{sem}_j, y, a),$$

and the age 1 biomass proportion in the catch is

$$CP(\mathrm{sem}_j, y) = C(\mathrm{sem}_j, y, 1)/C(\mathrm{sem}_j, y, 1+).$$

Observation equations

The observation equations for the survey biomass indices $B(t_{\mathrm{surv}}, y, 1+)$ and age 1 biomass proportion $BP(t_{\mathrm{surv}}, y)$ are:

$$\log(B_{\mathrm{surv}}(t_{\mathrm{surv}}, y, 1+)) \sim \mathrm{Normal}\left(\log(q_{\mathrm{surv}}) + \log(B(t_{\mathrm{surv}}, y, 1+)), \frac{1}{\psi_{\mathrm{surv},y}}\right),$$
$$BP_{\mathrm{surv}}(t_{\mathrm{surv}}, y) \sim \mathrm{Beta}\left(e^{\xi_{\mathrm{surv}}} BP(t_{\mathrm{surv}}, y), e^{\xi_{\mathrm{surv}}}(1 - BP(t_{\mathrm{surv}}, y))\right),$$

where for each survey surv = depm, ac (DEPM and acoustics), q_{surv} denotes catchability, $\psi_{surv,y}$ is the precision for each year, and ξ_{surv} is related to the variance of the observation equation for the age 1 biomass proportion. In particular, the variance of

$BP_{surv}(t_{surv}, y)$ is given by $\left(1+e^{\xi_{surv}}\right)^{-1} BP(t_{surv}, y)\left(1-BP(t_{surv}, y)\right)$.

The observation equations for the recruitment index $R_{juv}(y)$ from the JUVENA survey (conducted in year y-1, which is an index of the recruitment in year y) is:

$$\log\left(R_{juv}(y)\right) \sim \mathrm{Normal}\left(\log\left(q_{juv}\right)+\log\left(R_y\right), \frac{1}{\psi_{juv}}\right),$$

where q_{juv} and ψ_{juv} are respectively the catchability and the precision of the JUVENA surveys.

The total catches observed by semester $C_{obs}(\mathrm{sem}_j, y, 1+)$ are assumed to be lognormally distributed with the mean given by the actual catches (on a logscale) according to the model and precision ψ_{catch}:

$$\log\left(C_{obs}(\mathrm{sem}_j, y, 1+)\right) \sim \mathrm{Normal}\left(\log\left(C(\mathrm{sem}_j, y, 1+)\right), \frac{1}{\psi_{catch}}\right).$$

The observation equation for the age 1 biomass proportion in the catch (CP) is taken as:

$$CP_{obs}(\mathrm{sem}_j, y) \sim \mathrm{Beta}\left(e^{\xi_{catch}} CP(\mathrm{sem}_j, y), e^{\xi_{catch}}\left(1-CP(\mathrm{sem}_j, y)\right)\right),$$

where ξ_{catch} is a parameter related to the variance of the observation equation.

In addition, the stock weights-at-age estimated from the surveys are used to include observation equations for the intrinsic growth parameter G_a, as follows:

$$G_{obs}(y, a) \sim \mathrm{Normal}\left(G_a, \frac{1}{\psi_G}\right),$$

for $a = 1, 2+$, where $G_{obs}(y, a) = \log(w_{y+1,a+1}/w_{y,a})$ is the logarithm of the weights-at-age ratio estimated from surveys in consecutive years. Basically, ages 1, 2, and 3+ are observed in the surveys, and the observations for the growth parameter at age 2+ are computed from the weights at ages 2 and 3+, using an average weighted by abundance-at-age.

All the observation equations are assumed to be independent of each other, as well as independent across years $y = 1, \ldots, Y$, age groups $a = 1, 2+$, semester $j = 1, 2$, and surveys surv = depm,ac.

Parameters and prior distributions

The unknown parameters are the initial biomass, $B_0 = B(0, 1, 2+)$, defined as the age 2+ biomass at the start of the first year ($t = 0, y = 1, a = 2+$), the average logrecruitment level, μ_R, the precision of the normal process for logrecruitment, ψ_R, the surveys catchabilities, q_{depm} and q_{ac}, the catchability and precision of the JUVENA surveys

q_{juv} and ψ_{juv}, the year and age components of the fishing mortality by semester, $f(\mathrm{sem}_j, y)$ and $s(\mathrm{sem}_j, a)$ for $j = 1{,}2$ and $a = 1{,}2+$, the annual intrinsic growth rates by age, G_a for $a = 1{,}2+$ and the precision of the observation equations for growth, ψ_G. Fishing mortality is the product of $f(\mathrm{sem}_j, y)$ and $s(\mathrm{sem}_j, a)$, so it is not possible to estimate the absolute value of each factor separately as these parameters only intervene in product form in all equations. To resolve this issue, the 2+ age-class selection parameters have been fixed to 1, i.e. $s(\mathrm{sem}_j, 2+) = 1$ for both semesters. Therefore, $f(\mathrm{sem}_j, y)$ corresponds to the fishing mortality of the 2+ age class and $s(\mathrm{sem}_j, 1)$ to the fishing mortality of age 1 with respect to that of age 2+. The annual natural mortality rates by age are fixed at $M_1 = 0.8$ and $M_{2+} = 1.2$. No discards or catch underreporting are expected for this stock, and the recorded total landings are assumed to be very close to the actual stock catches. Hence, the parameter ψ_{catch} is fixed at 400 in the total catch observation equation, which corresponds to a 5% CV for observed catch in original (non-logged) scale. The parameters affecting the precision of the observation equations of the total biomass from the DEPM and acoustic surveys, $\psi_{\mathrm{depm},y}$ and $\psi_{\mathrm{ac},y}$ are fixed according to the coefficients of variation (CV) from the surveys each year. When these are not available (as for the acoustic survey before 2000) an average of the available precisions for each survey is used. The parameters affecting the variance from the age 1 proportion observation equations from the surveys and the catch are all fixed at $\xi_{\mathrm{depm}}=\xi_{\mathrm{ac}}=\xi_{\mathrm{catch}} = 4$.

In a Bayesian context, a prior distribution has to be elicited for all unknown parameters. It is assumed that all are independent *a priori*, so that the joint prior distribution is the product of the individual prior distributions, which are chosen to be:

$$\log(q_{\mathrm{surv}}) \sim \mathrm{Normal}\left(\mu_{q_{\mathrm{surv}}}, 1/\psi_{q_{\mathrm{surv}}}\right) \text{ for surv} = \mathrm{depm, ac, juv}$$

$$\psi_{\mathrm{juv}} \sim \mathrm{Gamma}\left(a_{\psi_{\mathrm{surv}}}, b_{\psi_{\mathrm{surv}}}\right)$$

$$\log\left(f(\mathrm{sem}_j, y)\right) \sim \mathrm{Normal}\left(\mu_f, 1/\psi_f\right) \text{ for j} = 1{,}2 \text{ and y} = 1, \ldots, \mathrm{Y}$$

$$s(\mathrm{sem}_j, 1) \sim \mathrm{Unif}(a_s, b_s) \text{ for } j = 1{,}2$$

$$\log(B_0) \sim \mathrm{Normal}\left(\mu_{B_0}, 1/\psi_{B_0}\right)$$

$$\mu_R \sim \mathrm{Normal}\left(\mu_{\mu_R}, 1/\psi_{\mu_R}\right)$$

$$\psi_R \sim \mathrm{Gamma}\left(a_{\psi_R}, b_{\psi_R}\right)$$

$$\log(G_a) \sim \mathrm{Normal}\left(\mu_{\log(G)}, 1/\psi_{\log(G)}\right) \text{ for } a = 1{,}2+$$

$$\psi_G \sim \mathrm{Gamma}\left(a_{\psi_G}, b_{\psi_G}\right).$$

The hyperparameters of the prior distributions and corresponding medians and 90% probability intervals for the parameters are listed in Table 3.6.4.2.1.

Inference

From Bayes' theorem, the joint posterior probability density function (pdf) of the unknowns is proportional to the product of the pdf's of observations, states and priors. Markov chain Monte Carlo (MCMC) techniques (Gilks *et al.*, 1996) were used to sample from the posterior distribution. The implementation was done using the software

BUGS (Bayesian inference Using Gibbs) together with WinBUGS development interface to reduce run times.

Results

The recruitment and year effects of fishing mortalities by semester are shown in Figure 3.6.4.2.1. Posterior quantiles of the rest of parameters are given in Table 3.6.4.2.2.

The resulting SSB estimates show large year to year fluctuations (Figure 3.6.4.2.2) as expected for short-lived species.

Pearson residuals and the retrospective analysis have been presented in Section 3.6.4.1.4.

Additional considerations

This model and the final adopted settings imply important changes with respect to previous assessment (ICES, 2009). Given that the current long-term management plan proposal for the stock was based in the old assessment, the SSB estimates obtained by this new assessment cannot be used to apply the harvest control rule within the LTMP proposal.

Table 3.6.4.2.1. Hyperparameters specifying the prior distribution and corresponding medians and 90% central probability intervals for the model parameters. For semester- or age-specific parameters, the prior distributions are assumed to be the same for both semesters or ages.

	Hyperparameters	Median (90% P.I.)
q_{surv}	$\mu_{q_{surv}} = 0$ $\psi_{q_{surv}} = 2$	1 (0.3, 3.2)
ψ_{surv}	$a_{\psi_{surv}} = 0.9$ $b_{\psi_{surv}} = 0.02$	29.8 (1.7, 139.9)
B_0	$\mu_{B_0} = 10.3$ $\psi_{B_0} = 1.0$	29 733 t (5740, 154 022)
μ_R	$\mu_{\mu_R} = 9.8$ $\psi_{\mu_R} = 1.0$	9.8 (8.2, 11.4)
ψ_R	$a_{\psi_R} = 2.0$ $b_{\psi_R} = 3.0$	0.6 (0.1, 1.6)
$s(\text{sem}_j, 1)$	$a_s = 0$ $b_s = 2.0$	1.0 (0.1, 1.9)
$f(\text{sem}_j, y)$	$\mu_f = -0.9$ $\psi_f = 1$	0.4 (0.1, 2.1)
G_a	$\mu_{\log(G)} = -0.7$ $\psi_{\log(G)} = 2$	0.5 (0.2, 1.6)
ψ_G	$a_{\psi_G} = 1.5$ $b_{\psi_G} = 0.1$	11.8 (1.8, 39.1)

Table 3.6.4.2.2: Posterior median and 95% probability intervals of the parameters estimated.

	VARIANCES FIXED		
	WITH JUVENA		
	DEPM relative		
	$M_1 = 0.8$ and $M_{2+} = 1.2$		
Parameter	5%	50%	95%
q_{depm}	0.597	0.673	0.757
q_{ac}	1.265	1.426	1.602
q_{juv}	1.707	2.671	3.975
ψ_{juv}	0.770	1.959	3.998
B_0	14750	17854	21742
μ_R	9.981	10.310	10.640
ψ_R	0.703	1.128	1.707
$s(\text{sem}_1, 1)$	0.413	0.463	0.518
$s(\text{sem}_2, 1)$	1.224	1.432	1.691
G_1	0.493	0.564	0.641
G_{2+}	0.214	0.283	0.364
ψ_G	15.590	25.185	37.951

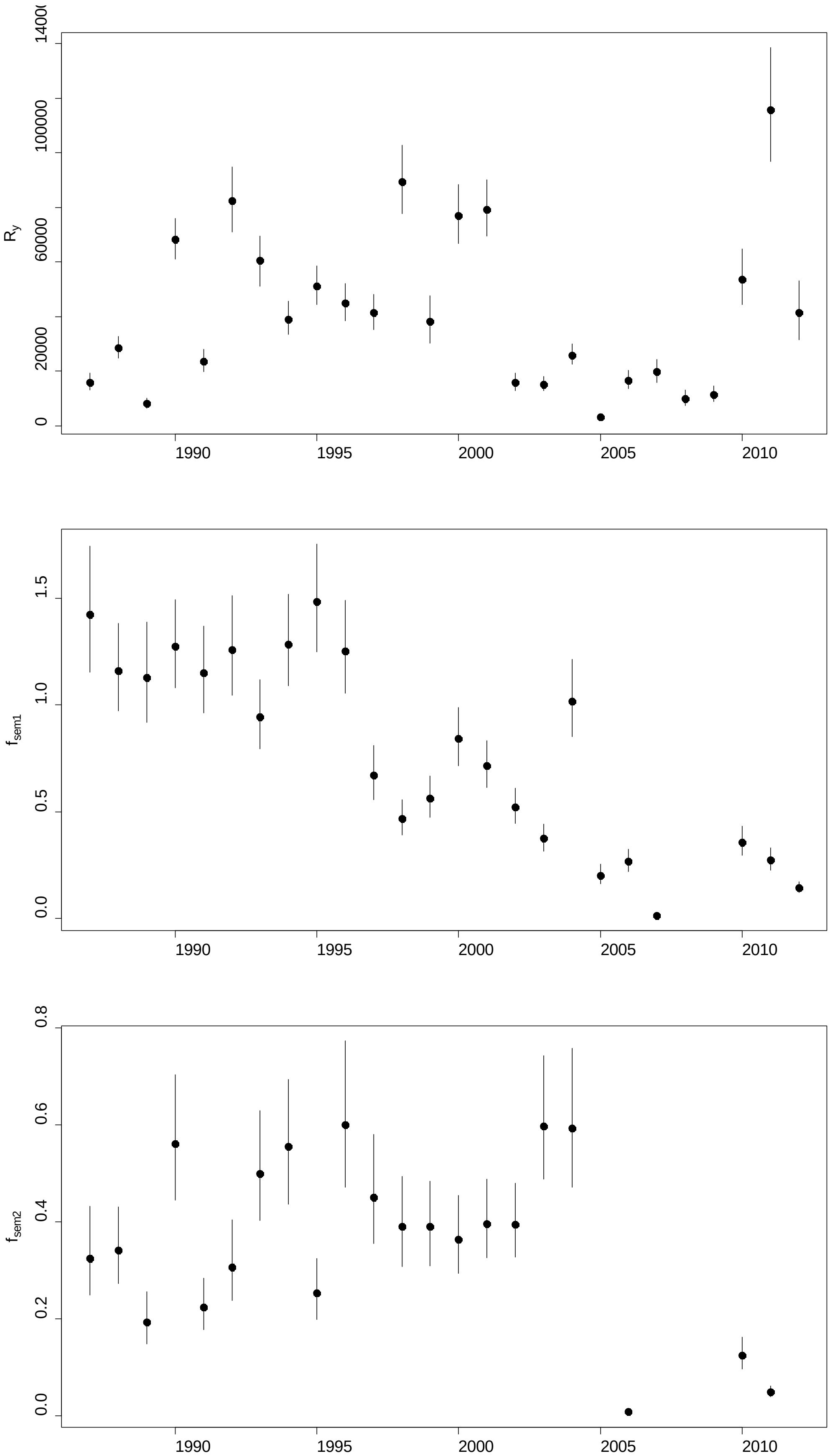


Figure 3.6.4.2.1. From top to bottom posterior median and 95% probability intervals of recruitment, fishing mortality by semester respectively.

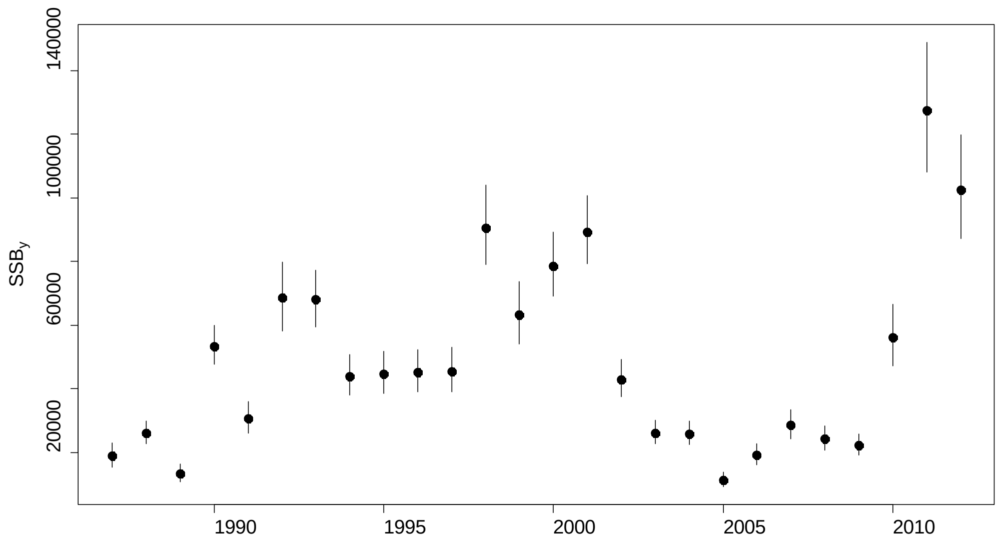


Figure 3.6.4.2.2. Posterior median and 95% probability intervals of SSB.

3.7 Short-term projections

The assessment of Bay of Biscay anchovy is conducted in the ICES WGHANSA that takes place in June. At that time of the year there is no indication on next year recruitment and the short-term projections can be based on an undetermined recruitment scenario, in which any past recruitment is equally likely. In the proposed assessment model (see Section 3.6.4) the JUVENA abundance index is included in the assessment. This index is considered a reliable index of recruitment next year. So, the assessment conducted in June can be updated in December, once the results from the JUVENA survey and the catches for the second semester of the year are available. This would directly provide a distribution of recruitment next year that could be used to update the short-term projection of the population. In this section the short-term projections based on the June and on the December assessments are described.

3.7.1 Short-term projections based on the June assessment

The prediction of the population for next year in order to explore catch options requires predicting recruitment entering the population.

Following Ibaibarriaga *et al.* (2008) the predictive distribution of recruitment in year $Y+1$ can be constructed as a mixture of the posterior distributions of the past recruitment-series:

$$R_{Y+1} \sim \sum_{y=1}^{Y} w_y p_y(\cdot\,|\mathrm{obs}),$$

where $p_y(\cdot\,|\mathrm{obs})$ denotes the posterior distribution of R_y, and w_y are the weights of the mixture distribution, such that $\sum_{y=1}^{Y} w_y = 1$. These weights can be set based on information on incoming recruitment or on assumptions regarding future recruitment scenarios. At the time of the WGHANSA meeting, there are no indications about next incoming recruitment, so an undetermined recruitment scenario, where all Y past years are equally weighted can be considered. The resulting recruitment distribution, with median at 36 700 t and 95% probability interval between 7500 and 94 800 tonnes, is shown in Figure 3.7.1.1.

The population can be projected forward using the population dynamic equations given in Section 3.6.4.2, based on the posterior distribution of the annual intrinsic growth and natural mortality parameters by age, G_1, G_{2+}, M_1, M_{2+}, the initial biomass, B_0, the annual past recruitments $R_1, \dots, R_Y$ and the past age and year components of fishing mortality by semester, $s(\mathrm{sem}_j, 1)$ and $f(\mathrm{sem}_j, y)$, for $j = 1{,}2$ and $y = 1, \dots, Y$. The exploitation levels can be explored in terms of the year effect of fishing mortality $f(\mathrm{sem}_2, Y)$ and $f(\mathrm{sem}_1, Y+1)$. Figure 3.7.1.2 shows the median SSB and the probability of SSB being below 21 000 t for different combinations of $f(\mathrm{sem}_2, Y)$ and $f(\mathrm{sem}_1, Y+1)$. When no catches are taken, the median SSB in 2013 is at 81 200 t with zero probability of SSB in 2013 being below 21 000 t. The implications of each year component of fishing mortality by semester in terms of resulting catches could then be calculated using the catch equations given in Section 3.6.4.2 (see Figure 3.7.1.3). The TAC fixed from July 2012 to June 2013 of 20 700 t corresponds approximately to fishing mortalities in the second semester of 2012 between 0.2 and 0 and fishing mortalities in the first semester of 2013 between 0 and 0.6. Results presented here as figures could also be shown in a tabular form, so that the catch options are analysed in more detail.

Following the short-term projections framework used up to now for Bay of Biscay anchovy, the exploitation levels could be explored in terms of: (a) the allowable catches for the second semester of year Y and first half of year Y+1 or (b) total catch from the second semester of year Y and first semester of year Y+1 and % of the total catch corresponding to the second semester of year Y. In both cases the short-term projections will be based on the fishing mortalities by semesters required to yield these levels of catches.

3.7.2 Short-term projections based on the December assessment

The assessment described in Section 3.6.4.2 and conducted in June in WGHANSA can be updated in December once the results from the JUVENA survey and the catch levels during the second semester are available. In addition, the definitive DEPM estimates which are obtained after the full processing of the adult samples is completed by November can be used in this update assessment. It must be taken into account that only preliminary estimates of the total catch of the interim year Y would be available in December. This means that on the one hand no age structure of the catches for the second semester of the interim year will be available in November and hence the total catch estimates of the interim year will be revised in the next assessment in June next year (Y+1).

The JUVENA survey in 2012 gave a recruitment index around 142 000 t. The preliminary total catch in the second semester was of 5833 t. The last year DEPM estimates don't change in this case as the estimates provided to WKPELA were definitive. By including these new observations, the assessment described in Section 3.6.4.2 can be updated in order to provide population and catch estimates up to the beginning of 2013. Figure 3.7.2.1 compares the recruitment and fishing mortalities by semesters for the assessment conducted in June and in December. The estimates are basically the same, with slightly lower estimates for recruitment in 2011 and 2012 for the December assessment.

The assessment conducted in December provides estimates of the fishing mortality in the second semester in 2012 that is the last assessment year (bottom panel in Figure

3.7.2.1) and of recruitment next year (biomass of age 1 at the beginning of 2013). The distribution of recruitment in 2013 has median at 42 200 t and 95% probability interval between 16 900 and 106 900 tonnes (Figure 3.7.2.2) and it is basically based on the last observation from the JUVENA surveys.

The population projections are conducted as described above based on the posterior distribution of the annual intrinsic growth and natural mortality parameters by age, G_1, G_{2+}, M_1, M_{2+}, the initial biomass, B_0, the annual past recruitments $R_1, \ldots, R_Y$ and the past age and year components of fishing mortality by semester, $s(\mathrm{sem}_j, 1)$ and $f(\mathrm{sem}_j, y)$, for $j = 1{,}2$ and $y = 1, \ldots, Y$ of the assessment conducted in December. The short-term projections start from the population at the beginning of 2013 and to update a TAC going from July to June next year only the year effect of fishing mortality for the first semester $f(\mathrm{sem}_1, Y+1)$ is explored. Figure 3.7.2.3 shows the median SSB and the probability of SSB being below 21 000 t for different values of $f(\mathrm{sem}_1, Y+1)$. When no catches are taken, the median SSB in 2013 is at 83 000 t with zero probability of SSB in 2013 being below 21 000 t. Even if the range of fishing mortalities is wide (up to $f(\mathrm{sem}_1, Y+1) = 3$ that correspond to catches around 61 000 t) the probability of SSB in 2013 being below 21 000 t is always below 0.02. The implications of the year effect of fishing mortality for catches are shown in Figure 3.7.2.4. Given that the TAC set from July 2012 to June 2013 is 20 700 t and that the catches in the second semester of 2012 have been around 5800 t, the remaining catch for the first semester in 2013 would correspond to a fishing mortality in the first semester in 2013 around 0.5. For this case the median SSB in 2013 is around 72 200 t with zero probability of being below 21 000 t.

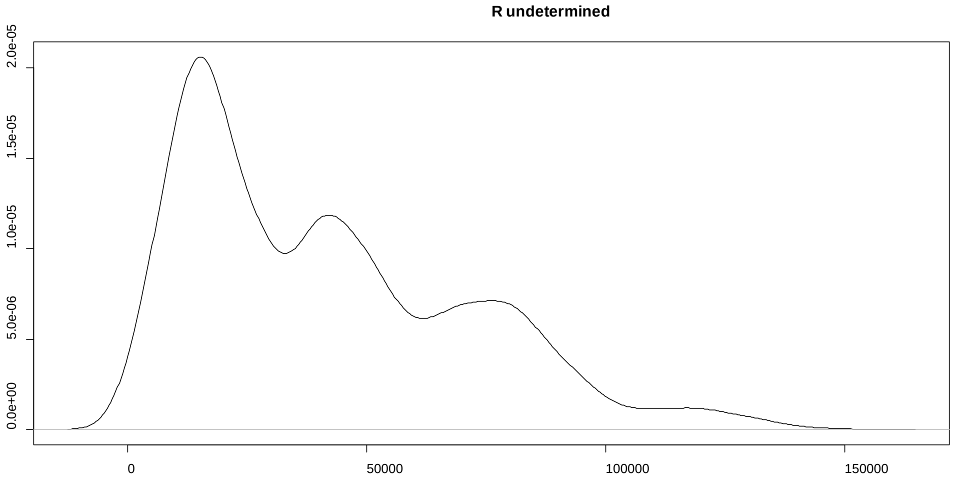


Figure 3.7.1.1. Undetermined recruitment scenario for the short-term projections based on the June assessment.

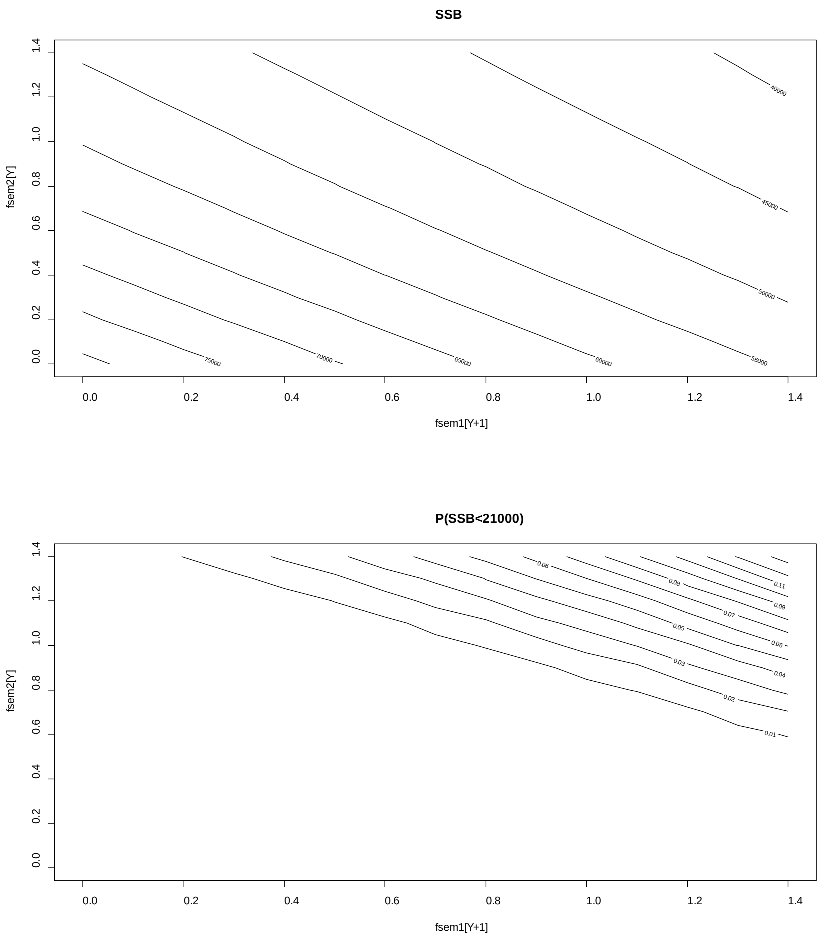


Figure 3.7.1.2. Contour lines of the median SSB (top panel) and the probability of SSB being below 21 000 t (bottom panel) under the recruitment scenario for the short-term projections based on the June assessment.

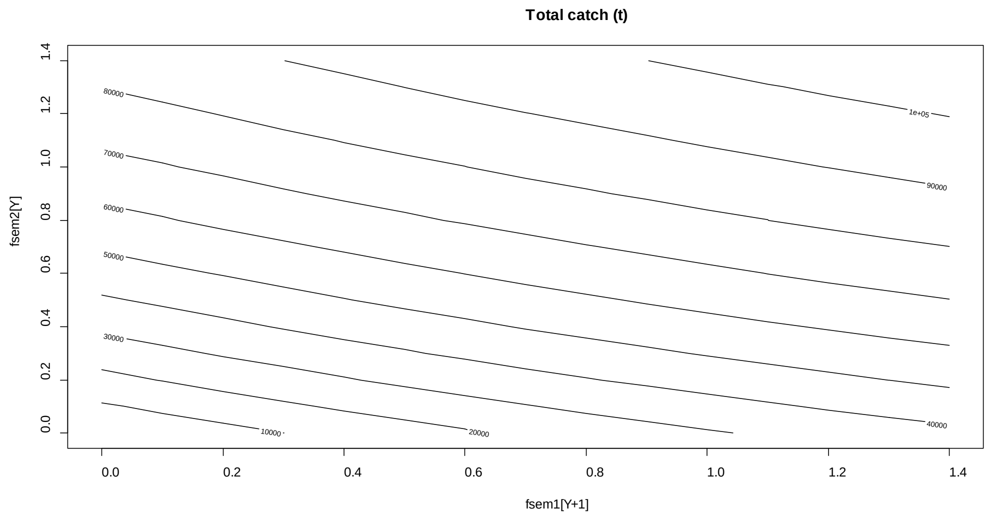


Figure 3.7.1.3. Contour lines of total catch under the recruitment scenario for the short-term projections based on the June assessment.

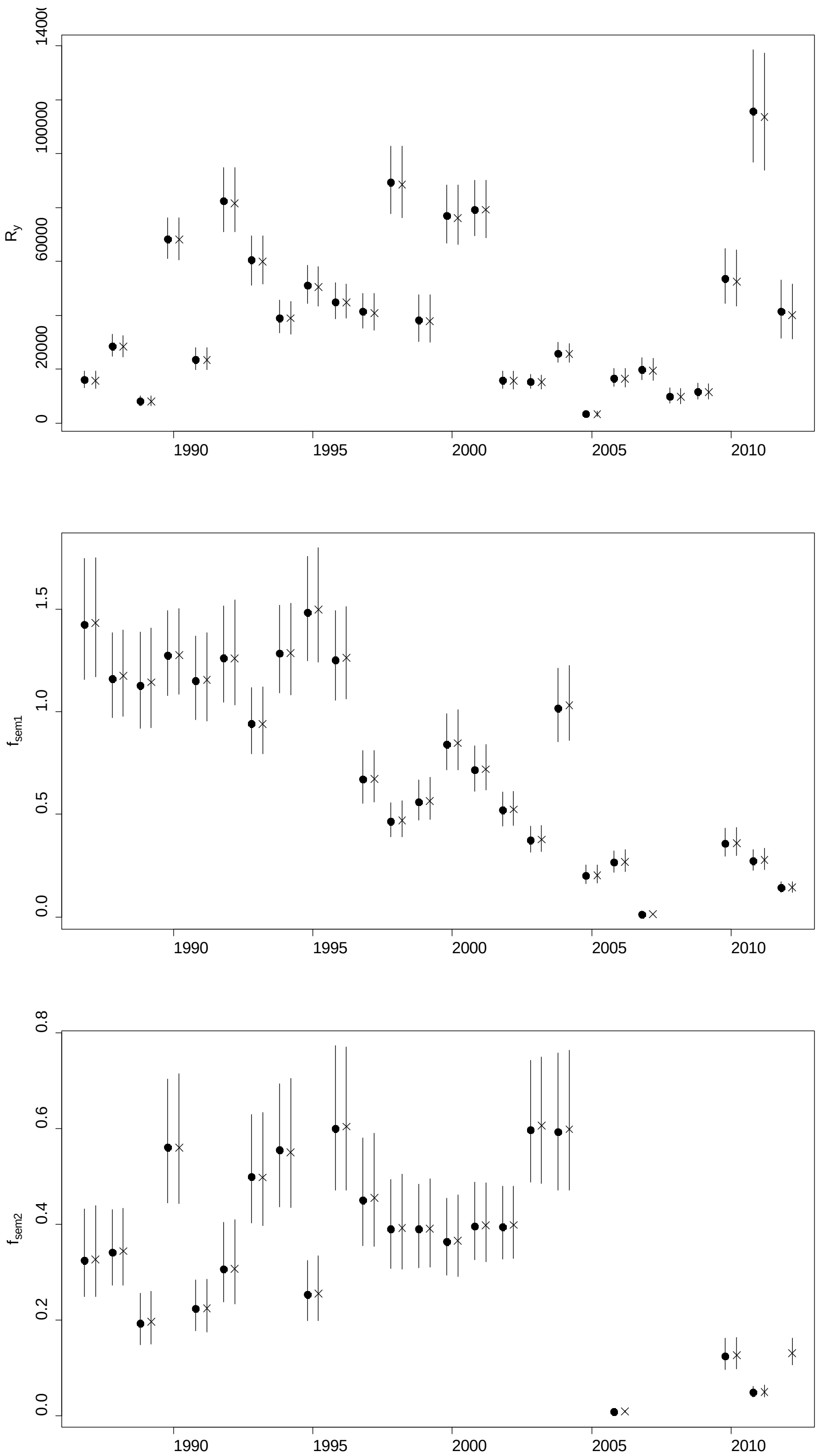


Figure 3.7.2.1. From top to bottom comparison between the recruitment and fishing mortalities by semester from the assessment conducted in June (bullet) and in December (cross).

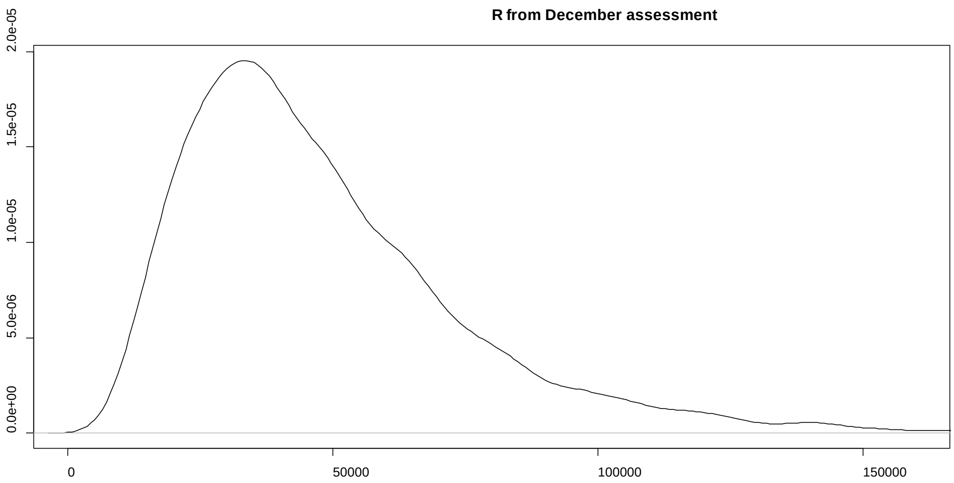


Figure 3.7.2.2. Recruitment scenario for the short-term projections based on the December assessment.

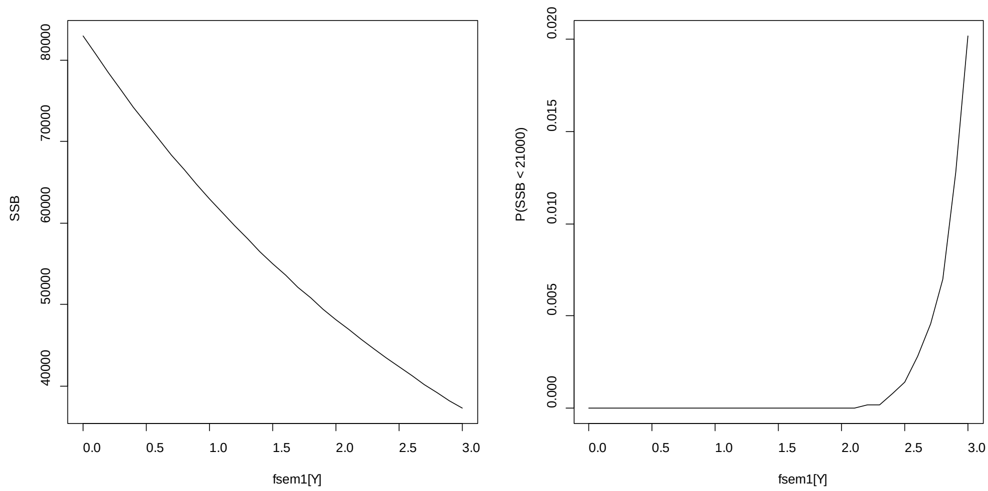


Figure 3.7.2.3. Median SSB in 2013 (left) and probability of SSB in 2013 being below 21 000 t (right) for different levels of fishing mortality during the first semester of 2013 for the short-term projections based on the December assessment.

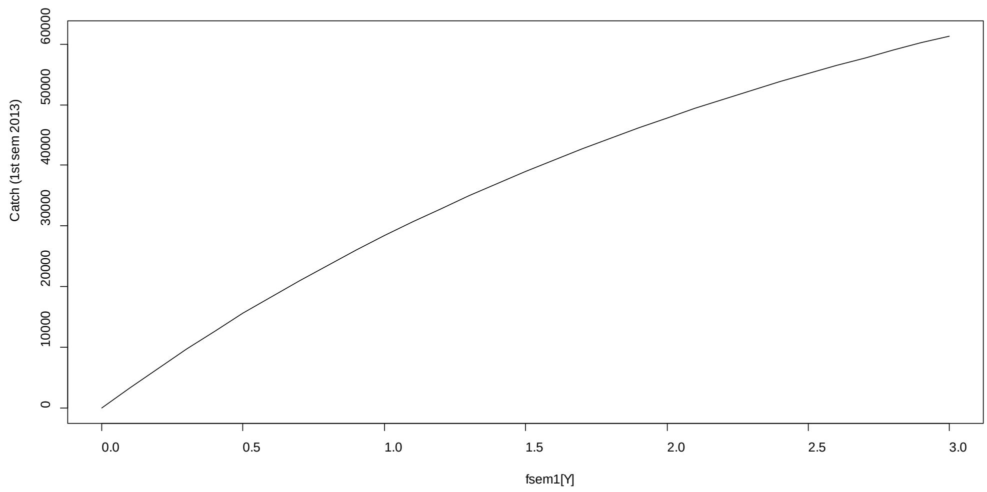


Figure 3.7.2.4. Catch levels (y-axis) corresponding to the year effect fishing mortalities (x-axis) during the first semester of 2013 for the short-term projections based on the December assessment.

3.8 Consideration of reference points

The ICES MSY approach for short-lived stocks is aimed at achieving a target escapement (MSY-$B_{escapement}$, the amount of biomass left to spawn). MSY-$B_{escapement}$ is in principle the lower bound of the 95% confidence interval around the biomass resulting from fishing at equilibrium F_{MSY}. Since this value could not be determined for anchovy, B_{pa} was used as a proxy for this point.

With this MSY-$B_{escapement}$ reference point the approach has not led to precautionary levels of catches (implying a high biological risk for this population) in the last years. The ICES advice has instead been based on the precautionary approach that is aimed at maintaining the probability of SSB being below B_{lim} less than 0.05. For the Bay of Biscay anchovy the assessment and forecast are produced in a probabilistic way, so that the probability of SSB being below B_{lim} can be readily obtained. Other reference points like B_{pa} (defined to avoid being below B_{lim} according to the typical assessment uncertainties) become useless. WKPELA considered that B_{lim} is the key reference point to provide management advice for the Bay of Biscay anchovy stock.

WKPELA explored several ways to define B_{lim}:

a) Based on a deterministic age-structure approach, estimate the unfished biomass corresponding to the average recruitment (B_{zero}). A proxy for B_{MSY} can be calculated as a fixed percentage (between 30 and 50%) of the unfished biomass B_{zero}. Then B_{lim} is simply half of B_{MSY} proxy. In particular, the steps are the following:

i) The average age-1 recruitment in mass from the CBBM model is 41 400 t.

ii) Convert this into numbers according to the average weight-at-age 1 (0.012 kg).

iii) Compute equilibrium numbers-at-age for ages 2–5 (assuming that no fish survive beyond age 5) applying the specified natural mortality-at-age implied from the CBBM model (0.8 for age 1 and 1.2 for older individuals):

	1	2	3	4	5
Body mass	0.012322	0.02615	0.029846	0.042594	0.043078
Natural mortality	0.8	1.2	1.2	1.2	1.2
Numbers unfished	3,359,746	1,509,631	454,692	136,951	41,249
Unfished Recruiting Biomass January	41,400	39,477	13,571	5,833	1,777
Spawning Population	2,488,961	962,583	289,925	87,324	26,301
Average SSB unfished (t)	30,670	25,171	8,653	3,719	1,133

iv) The unfished biomass (B_{zero}) computed as the sum of the subsequent mass-at-ages is 69 300 t.

v) Estimate a proxy B_{MSY} level as a fixed percentage (30, 40 or 50%) of B_{zero}.

vi) Compute B_{lim} at half of the proxy of B_{MSY} proxy.

The table below summarizes the results according to different percentages for computing the proxy of B_{MSY}:

Bmsy proxy rate	0.3	0.4	0.5
Bzero	69,300	69,300	69300
Bmsy proxy	20,800	27,700	34,700
Blim = 1/2 Bmsy	10,400	13,900	17,400

According to Mace and Sissenwine (1993), the higher the natural mortality, the bigger should be kept the percentage of spawning biomass in relation to the virgin state (SBR, spawning biomass ratio). They also indicated that the small pelagic species could be poorly resistant to exploitation and for these species the %SBR corresponding with the F_{med} can be as high as 40% or even in some cases 60%. This means that from the above proxies for B_{MSY} that corresponding to 30%SBR would be too low and it would be better to select between the 40% or 50%SBR as a sustainable exploitable biomass as a proxy for B_{MSY} and hence half of it as a proxy for B_{lim}.

b) An analogous approach based on the percentage of SBR can be followed using the posterior draws from the CBBM assessment model. For each draw from the posterior distribution the ratio between SSB and the "unfished" biomass (using the same draws but setting the fishing mortalities by semester equal to 0) can be computed (Figure 3.8.1). From 1987 to 2006 SBR ranges between 0.4 and 0.7. In the last five years SBR was above 0.8. This suggests that 30% SBR might be low for this stock and values around 50% would be more in agreement with the stock trajectory.

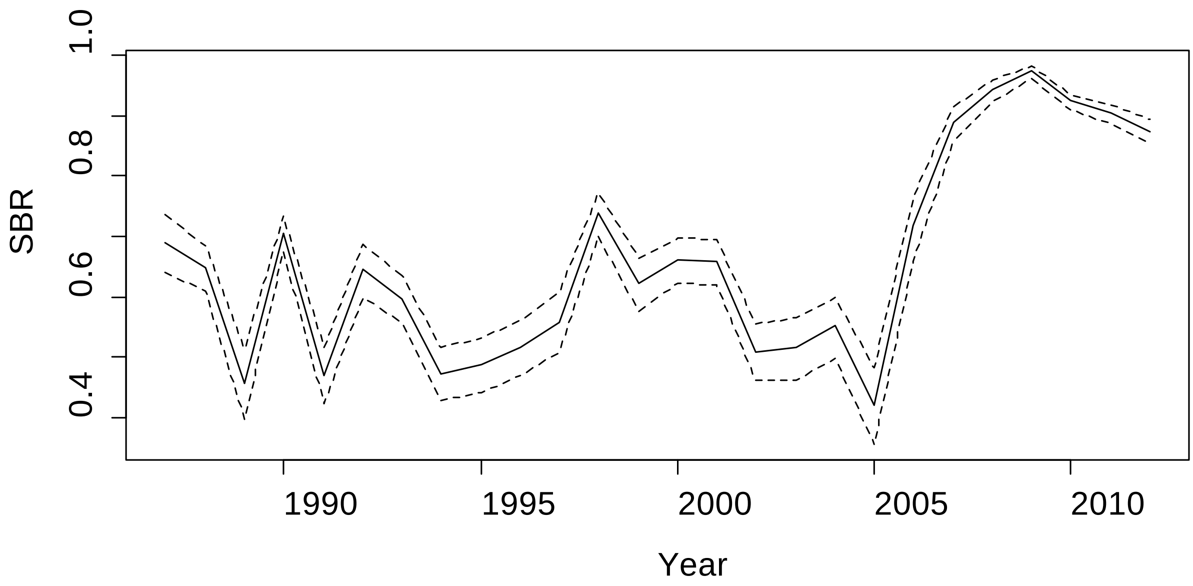


Figure 3.8.1. Posterior median (solid line) and 95% probability intervals (dashed) of the spawning biomass ratio.

c) ICES SGPA (Study Group on the Further Development of the Precautionary Approach to Fishery Management, ICES 2003) proposed the segmented regression as a statistically objective tool for estimating B_{lim}. The method assumes that recruitment is independent of SSB above some change point, below which recruitment declines linearly towards the origin at lower values of SSB. The stock–recruitment plots of anchovy are rather noisy, although recruitments levels tend to decrease as the spawning biomass decreases (Figure 3.8.2).

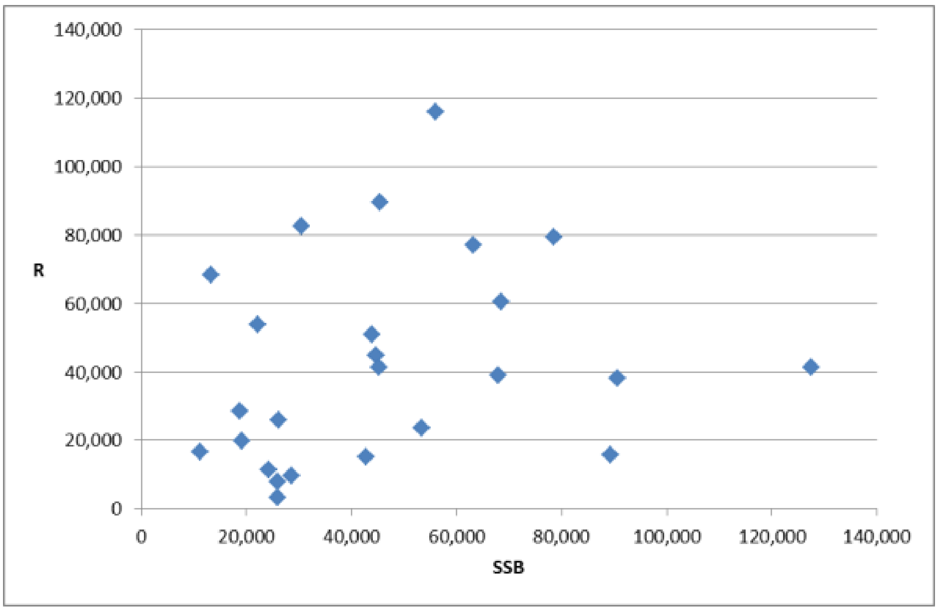


Figure 3.8.2. Stock–recruitment plot for Bay of Biscay anchovy.

Segmented regressions applied to this series revealed inflection points around historical mean of estimated SSB from the assessment, i.e. around the mid-point in the cloud of data S–R pairs. If accepted this would imply a B_{lim} around mean historical SSB values, which certainly seems to be a too high B_{lim} reference. For this kind of cases with rather noisy pattern of residuals with no clear or marked pattern, this inflection point might rather be considered in the framework of definition of $B_{trigger}$ points to start decreasing target fishing mortality rates in a Harvest Control rule framework. This work will be delayed for future and therefore the group did not support at current stage the use of the segmented regression for definition of B_{lim}.

d) The mixture distribution of the past recruitment posterior distributions (all equally weighted) lead to the distribution shown in Figure 3.8.3. The distribution has three well-defined peaks representing low, medium and high recruitment levels. The local minimum defining the low recruitment level is at 32 000 t. The probability of having a low recruitment can then be computed from the posterior distributions of recruitment as the probability of recruitment being below 32 000. A logistic model between the probability of low recruitment and the SSB in the previous year (as estimated in the assessment) can be explore to identify the SSB levels than result in low/high probability of having a low recruitment. Figure 3.8.4 shows the fitted logistic model. The probability of recruitment being low equal to 0.5 is obtained for SSB levels around 40 200 t. This value seems to be too high for B_{lim}, but maybe other values for defining low recruitment than the local minimum could be explored and used to define B_{lim} accordingly.

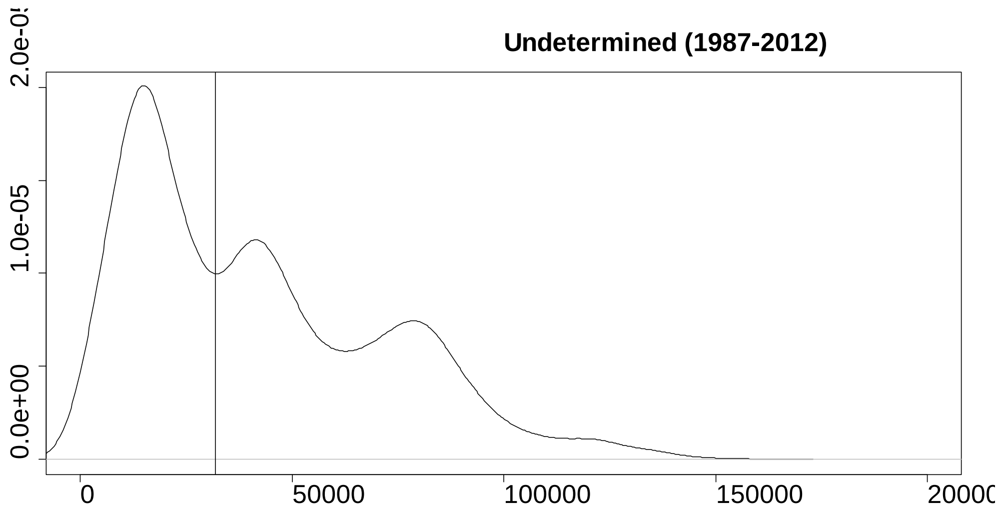


Figure 3.8.3. Mixture distribution of past recruitment posterior distributions. The vertical line located at 32 000 t is the local minimum defining the low recruitment peak.

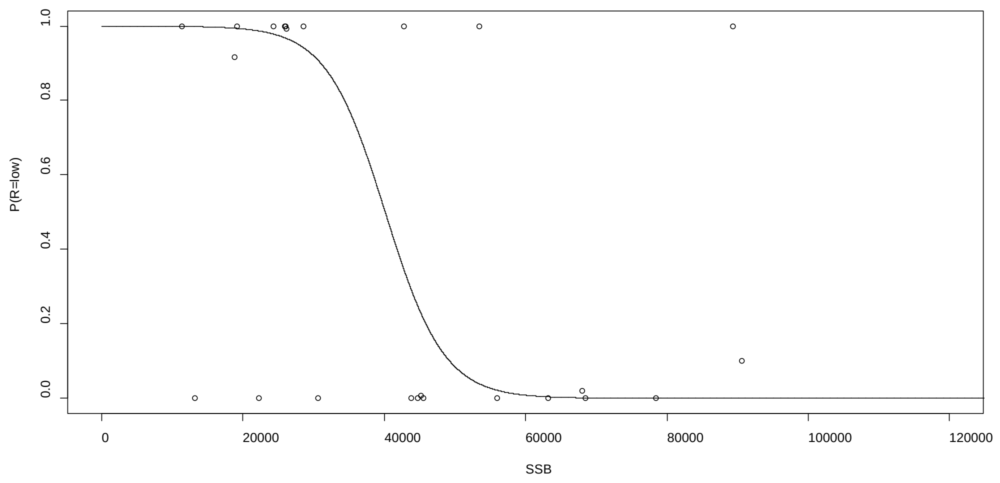


Figure 3.8.4. Logistic model between the probability of recruitment being low and the SSB in the previous year.

e) In the past B_{lim} was set equal B_{loss} or the minimum estimated biomass which still produced a substantial recruitment. This was established at B_{loss} = SSB 1989 = 21 000 t from the assessment carried out in 2003 with the Integrated Catch-at-age Analysis software. This had been the minimum biomass estimated between 1987 and 2004[1]. Subsequently when the assessment model was changed to BBM in 2004 no need for changing B_{loss} or B_{lim} was found given the consistency between the estimates from both models.

In 2005 the estimated SSB fell below B_{lim}, the fishery failed and it was subsequently closed. The re-opening of the fishery in 2006 resulted in another complete failure of catches for the purse seine boats (even for a SSB above the 1989 level) and therefore the fishery was finally closed again in July until March 2010. So the recent history of the fishery shows that the fishery can suffer complete failures around the levels of the SSB in 1989 (not only below that level). Furthermore, from the reduced levels of SSB in 2005 it took five years for the population to have a significant recovery well above B_{lim} levels. It is worth also noting that in 2003 the fishery was so abnormally poor that fishermen claimed for a downward revision of the TAC and a reevaluation of the situation (International Catches in the first half of 2003 around 4000 t supposed the lowest level recorded since 1987).

In the current assessment the lowest biomass corresponds with the SSB in 2005, followed closely by that in 1989. However the failure of the fishery in 2006 corresponds with a biomass above that estimated for 1989 by about 45%.

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[1] In all assessments in previous years, the DEPM survey input for 1989 had been arbitrarily raised by its CV (by 40%) as the authors suspected that some underestimate could have happened in that survey, because coastal areas within 50 m could not be sampled in that year. In the current assessment, and after the revision of the DEPM series the 1989 input has not been raised upwards by its CV of 40%, because the choice was considered too arbitrary for an unknown amount of underestimate.

The 1989 SSB might be underestimated, but the magnitude of such underestimation is uncertain. An alternative option could be taking the SSB value in 2006 as B_{lim}, the only inconvenient of that approach is that SSB in certain years can suffer quite high retrospective pattern depending on the final model settings. For the assessment described in Section 3.6.4.2 (variances fixed) there is almost no retrospective pattern in the 2006 SSB estimates:

Retrospective analysis	2006						
Assesment in	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**
Lower 5%	16 067	16 130	16 682	16 966	17 130	17 324	16 598
Median	19 108	19 219	19 815	20 196	20 500	20 818	20 149
Upper 95%	22 681	22 915	23 677	24 257	24 953	24 770	24 319

However, when variances from surveys are a sum of fixed and estimated variances, SSB in 2006 is always corrected upwards when more years are added:

Retrospective Analysis	2006						
Assesment in	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**
Lower 5%	16 190	15 406	15 821	15 181	13 385	11 875	10 601
Median	21 389	21 266	20 955	20 455	18 127	16 921	17 045
Upper 95%	27 869	29 423	28 237	28 673	25 307	23 235	24 849

From the comments above we should admit that the past history of the fishery and the population suggests that the minimum levels of biomasses required for quick recovery of the population (normal recruitments) and rentable levels of catches have been touched. These levels are at or below the SSB levels in 2003. B_{lim} could be thus searched for within the 2003 level and the minimum level of 2005. For this range of biomasses (between the 2003 and the 2005 SSB levels) there have been some normal or high recruitments but more often low recruitment levels. The reference of the SSB in 2006 when the fishery also failed seems unstable according to the retrospective pattern. For these reasons a pragmatic and simple approach could be that of selecting the mean or the median level of the biomass below the SSB in 2003. This approach will fit the definition of B_{lim} as the spawning–stock biomass below which the population has a high probability of suffering impaired recruitment. For the median approach this results in SSB values close to those in 2006.

Searching Blim among all years below 2003: 1987 / 1989 /2003 / 2005 / 2006 /2008 /2009				
		5%	50%	95%
	Mean	16,260	19,299	22,831
	Median	16,067	19,108	22,892
	Blim		19,000	
	Year 2006		19,108	
	Year 2009		22,202	

Searching Blim among all years below 2003: 1987 / 1989 / 2005 / 2006 /2008 /2009				
		5%	50%	95%
	Mean	15,183	18,163	21,638
	Median	15,183	18,163	21,638
	Blim		18,000	
	Year 2006		19,108	
	Year 2009		22,202	

f) Alternatively, the definition of B_{lim} based on B_{loss} could be updated. B_{loss} is the minimum estimated biomass which still produced a substantial recruitment. The lowest SSB value in the historical series corresponds to the year 2005. However this year the fishery failed and it was subsequently closed. It took five years the population to recover. So, this value should not be taken as B_{loss}. The next lowest value corresponds to 1989. The recruitment generated by this biomass was at the mid-high range of values of recruitments in the series (sixth highest value in the series, around 70 000 t). However the posterior distributions of the 1989 and 2005 biomass levels overlap to a great extent (Figure 3.8.5). Around the 1989 biomass levels the probability of producing an impaired recruitment was therefore considered still high. The next lowest biomass value corresponds to 1987, whose posterior distribution does not overlap with the 2005 biomass one (Figure 3.8.5). The recruitment generated from this biomass was 30 000 t (medium recruitment). Thus B_{loss} could be set as the median of the 1987 posterior distribution, around 19 000 tonnes.

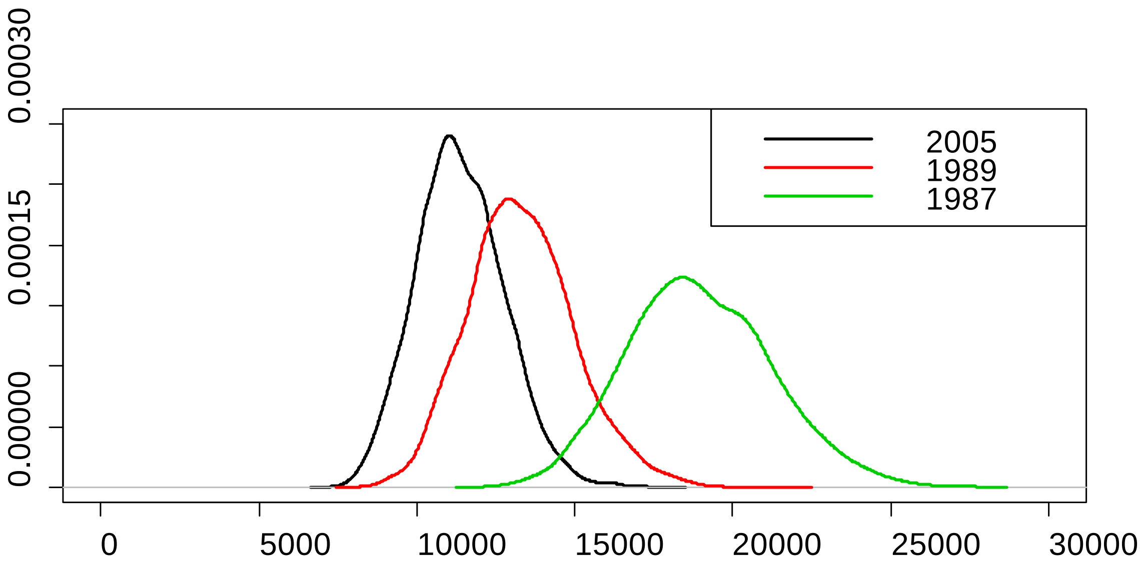

Figure 3.8.5. Posterior distribution of biomass of 2005, 1989 and 1987. The x-axis represents the SSB (in tonnes) and the y-axis the corresponding probability density function.

3.8.1 Conclusions

Among the several approaches above, WKPELA considered that the approaches based on stock–recruitment models (c and d) were not useful to set B_{lim}, given the high recruitment variation for similar biomass levels. Strict application of these approaches lead to B_{lim} around average biomass values, which is considered too high for this stock. Approaches e and f, based on the historical observed values were considered more valuable. Approach e calculates the spawning–stock biomass below which the population has a high probability of suffering impaired recruitment as the median SSB levels comprised between the 2003 and the 2005. Within this range of biomasses (between the 2003 and the 2005 SSB levels) there have been some normal or high recruitments but more often low recruitment levels. Alternatively, approach f) calculates B_{loss} (the minimum estimated biomass which still produced a substantial recruitment) as the median of the 1987 biomass. Both approaches resulted in B_{lim} around 19 000 t. This corresponds to B_{lim} around the 30%SBR. This %SBR could be considered a high value compared to other stocks, but it would just be at half the upper range of the %SBR suggested by Mace and Sissenwine (1993) as B_{MSY} proxy (i.e. between 40%SBR or 60%SBR) for small pelagics.

3.9 Future research and data requirements

Before the next benchmark, the following issues should be looked at:

a) A global agreement on the method to calculate pelagic cpue is needed for both purse-seiners and pelagic trawlers. There are many possibilities including the implication of the navigation time to get detection, number of fishing hauls per ton of fish caught, number of days at sea, substitution species, etc.

b) Improved data on environmental conditions (all over the year) should be available to try to link with the larval survival and recruitment.

c) Complete the estimation of discards on the pelagic trawlers.

d) Any further experiment of the survival of slipping anchovy (in both Spanish and French purse-seiner fishery) might be considered.

e) Further investigation on natural mortality and potential implication on trends is needed.

f) The exploration of alternative assessment models that can provide contrast to the CBBM and that can are computationally less expensive should be continued.

g) In the current implementation of the CBBM the variance related parameters of the observation equations are fixed. In the annex an alternative, where the variances of the biomass observation equations from the DEPM and acoustic surveys are written as a sum of survey estimation error and model residual variance, is presented. The best way of dealing with the variance related parameters of the observation equations needs to be further discussed.

h) In the current implementation of the CBBM the observation equation for the JUVENA survey is based on a linear model in logscale. Alternative models, such as the potential relationship in logscale, should be tested. If an agreement was achieved on the convenience of using another catchability model, then the stock annex should be updated as this would affect the adopted assessment and the forecast and potentially the reference points.

If possible before the next benchmark WGACEGG is asked to consider:

i) The CUFES index seems to be a very promising index and the WGACEGG is asked to decide on the reliability on the series as an indicator of Egg Production, as well as finalise the dataset.

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4 Herring in Division IIIa and Subdivisions 22–24 (western Baltic spring spawners)

4.1 Stock ID and substock structure

Most herring populations are migratory and often congregate on common feeding and wintering grounds where aggregations may consist of mixtures of individuals from several populations. Thus herring spawning components uphold significant levels of reproductive isolation, possibly affected by selective differences among spawning and/or larval habitats (Limborg *et al*., 2012). Genetic stratification is likely maintained by mechanisms of natal homing, larval retention and natural selection (Gaggiotti *et al*., 2009). In the Western Baltic tagging and genetic studies suggest that three to four more or less well-described stock components, that either spawn and use the area as nursery or migrate through it: Rügen herring (abbreviated RHS), local (autumn) spawning Fehmarn herring, herring from the Kattegat and Inner Danish waters, and potentially other Western Baltic herring stocks, each of which have different contributions to the fishery and ecosystem. The RHS are assumed to make up the majority of the western Baltic Sea herring in the area (ICES, 2010) and the stock spawn around the Geifswalder Bodden, mainly in March–May, but with some autumn spawning also (e.g. Nielsen *et al*., 2001; Bekkevold *et al*., 2007).The other herring populations occurring in the area are found in many of the bays in the area, where at least Kiel, Møn, Schlei, Flensburg, Fåborg, and Fehmarn have been reported as spawning sites for these apparently less abundant herring stocks. Thus the WBSS stock has a complex mixture of different herring populations predominantly spawning during spring, but also local spring-, autumn- and winter spawning stock components. The exact proportions of these stocks are hitherto unknown; however, they are observed in the area to some degree and could potentially be important parts of the total amount of herring available for the fishery.

Given a complex stage-dependent migration pattern, the different components mix during part of the year (Figure 4.1.1) and most likely experience different fishing pressures but are assessed and managed as one unit.

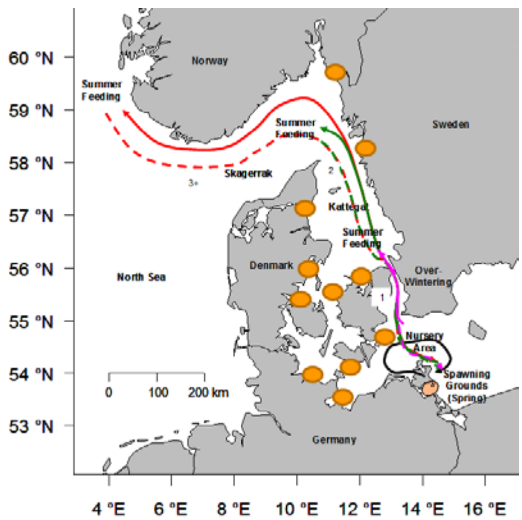


Figure 4.1.1. General migration patterns of the WBSS; the numbers indicates the age-dependent migration pattern; the yellow circles indicates local spawning populations (redrawn from M.Payne).

The majority of 2+ ringers ((HAWG nomenclature for age of herring refers to the number of winterrings counted due to the several spawning times of the herring stocks; a 2+ ringer is essentially a two year old herring despite spawning season) migrate out of the area during the 2nd quarter of the year, through the Sound and Belt Sea and propagate into the Western part of the Skagerrak and the Eastern North Sea to feed (Payne, 2009). The extent of the migration is age dependent, where the younger individuals migrates up into Kattegat and Skagerrak and the older fish migrate all the way out into the eastern North Sea. Towards the end of summer the herring aggregate in the eastern Skagerrak and Kattegat before they migrate to the main wintering areas in the southern part of the Kattegat, the Sound and the Western Baltic (ICES, 1991; Nielsen *et al*., 2001). The extent of the migration is season dependent and variable over time (Clausen *et al*., 2006).

These distribution patterns had yet to be fully quantified prior to the WKPELA, however, they have been examined in a recent study of the temporal and spatial coverage of all available data in terms of current biological understanding of stock components and their distribution in the Western Baltic and IIIa. This study used combined information from fisheries catches and International surveys in the Western Baltic Sea (including the Sound) and Kattegat, Skagerrak over the past decade. The major migration routes indicated by the temporal-spatial distribution of the herring stock components over time shows for the largest herring stock (the Rügen herring) an outmigration from the spawning sites during April–June through all Belts. This migration is not performed in large dense schools; these form during the summer feeding in Skagerrak and Kattegat. The school formation is retained during the overwintering, which mainly occurs in the Southern Kattegat and the Sound.

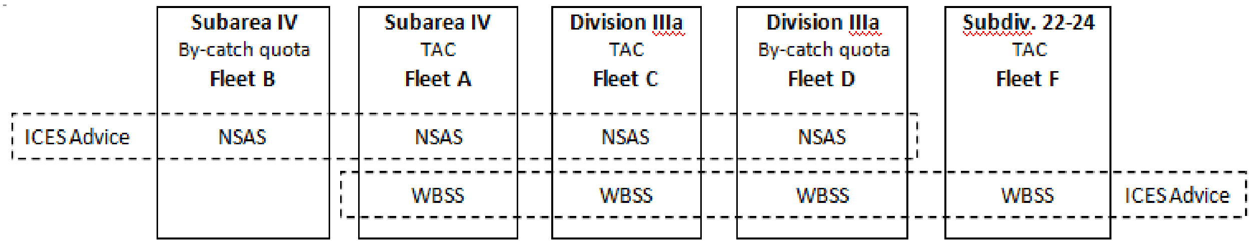
The fishery on WBSS takes place in the eastern North Sea, Division IIIa and the Western Baltic. In these areas the stock complex mixes with another large herring stock complex; the North Sea Autumn Spawners (NSAS). All spring-spawning herring in the eastern part of the North Sea (IVa&b east), Skagerrak (Subdivision 20), Kattegat (Subdivision 21) and the Western Baltic (Subdivisions 22, 23 and 24) are treated as one stock despite the local stock diversity. Given the mixing with the NSAS, the ICES Herring assessment Working Group (HAWG) make use of biological samples routinely collected to estimate the stock composition of the annual catches. The analysis of stock composition in commercial samples for stock assessment and management purposes of the herring populations in the North Sea and adjacent areas has been routine since the beginning of the 1990s. Recent development of the stock identification methodology has opened for a monitoring of the local stock components beyond the general spawning components of spring-autumn-and winterspawners, however this is not part of the routine treatment of herring catches yet.

The current definition of the Western Baltic herring stock of spring, autumn and winter spawners as a single management unit appears to have been operational in the past, despite potential changes in the relative strengths of the different spawning components and in their relative importance during collapse and recovery. The benchmark concludes there is no basis to update the stock unit.

4.1.1 The reliability of the methods currently used to estimate the proportions of WBSS and NSAS in the catches

Background

ICES advises on catch options by fleet for the entire distribution of WBSS and NSAS herring stocks separately. However, the fisheries are managed by areas covering the geographical distribution of the stocks (see the following text diagram).



The method for separation of the herring stock components in the catches has developed over the past decade. Prior to 1996, the splitting key between NSAS and WBSS herring used by ICES was calculated from a sample-based mean vertebral count. This uses a cut off algorithm for calculating the proportion of western Baltic spring-spawning herring (WBSS) in a sample as:

MIN(1,MAX(0,(VSsample-55.8)/(56.5–55.8)))

where VSsample is the sample mean vertebrae count and assuming a population mean VS of 55.8 for WBSS and 56.5 for NSAS. This method is still being used to split samples of Norwegian catches from the transfer area in IVa East.

In the period from 1996 to 2001 splitting keys were constructed using information from a combination of vertebrae count and otolith microstructure (OM) methods (ICES, 2001). From 2001 and onwards, the splitting keys have been constructed solely using the otolith microstructure method which uses visual inspection of season-specific daily increment patterns from the larval origin of the otolith, with the exception of the splitting key made for the mixture area in Subdivision IVa East, where vertebrae counts currently is the only method used to split the mixed-stock (Mosegaard and Madsen, 1996; ICES, 2004; Clausen *et al.*, 2007).

Otolith shape analysis has been used to discriminate between populations for a variety of species and for herring this approach has had increasing success with development of imaging techniques and statistical methods. Both temporal and geographical separation of populations gives rise to variation in the shape of otoliths (Messieh, 1972; Lombarte and Lleonart, 1993; Arellano *et al.*, 1995). These variations may suggest differences in the environmental conditions of the dominant habitats of populations within a species. However both genetic and environmental influences have been reported as important in determining otolith shape (Cardinale *et al.*, 2004). Using Fourier Series Shape Analysis on otoliths from Alaskan and Northwest Atlantic herring, Bird *et al.* (1986) showed that otolith shape reflects population differences as well as differences between year classes of the same population. Sagittal otoliths have certain morphological features that are laid down early in the ontogeny of the fish (Gago, 1993), and measurements of internal otolith shape in adult herring has proven a powerful tool for stock discrimination (Burke *et al.*, 2008).

Image analysis software (MATLAB) has been developed to automatically extract otolith contour curves and calculate 60x4 Elliptic Fourier Coefficients from one or two herring sagittal otoliths per image in batches with more than 1000 images.

From 2009 and on otolith shape analysis has been used as a supplementary method to increase sample size for estimating stock proportions of NSAS and WBSS in the mixing areas of Division IIIa. For each assessment year individual population identity has been established by OM visual inspection and used as a baseline for assignment of shape characteristics to the involved stock components. A baseline of about 800–1200 otoliths with known hatch type has then been used as calibration in an age structured discriminant analysis where additionally 3000–4000 otolith shapes have been assigned to one of the two hatch types using a combination of shape Elliptic Fourier Coefficients, otolith metrics, fish metrics, length, weight and maturity as well as longitude–latitude and seasonal parameters.

Validation

The purpose of classifying individual spawning type is to estimate proportions of the two major stock components by age in catches and surveys from the different areas and seasons. Combining OM with otolith shape and fish meristic characters in a discriminant analysis approach will increase precision of the estimated stock proportions if errors in estimated proportions are low. Validation of the shape and meristic based methodology may be performed using samples of known spawning type (from OM analysis) and classifying subsets by shape/meristics to test for bias and variation in estimated proportions.

OM and otolith shape data from the 2010 HAWG were used as a typical example of the procedure for estimating proportions of hatch type representing North Sea autumn and winter spawners and western Baltic spring spawners in the samples. The data were disaggregated into age groups 0, 1, 2 and 3+ and individuals of known autumn/winter or spring hatched types were used to assign the corresponding shape parameters and fish metrics from the same individuals by cross-validated nonparametric nearest neighbour discriminant analysis.

The accuracy of individual assignment of 1279 otoliths into known hatch type varied somewhat among hatch types and ages (2%–100% error) but exhibited an overall error rate of 15.7% (see Table 4.1.1). However, more importantly, the average absolute error of the proportions of WBSS was only 2%, indicating a reasonably robust method for up-scaling the baseline to the larger production sample.

Table 4.1.1. Stock assignment data from 2009 commercial samples of herring in Division IIIa, comparing assignments of known types, the estimated numbers, deviation and error %.

		assigned to type		known type	estimated	deviasion		% error in	
Age group	known type	WBSS	NSAS	number	number	Individ. assignm.	prop.	Individ. assignm.	prop.
0	WBSS	34	13	47	44	13	3	27.7%	-6.4%
	NSAS	10	145	155	158	10	3	8.2%	1.9%
1	WBSS	188	72	260	254	72	6	27.7%	-2.3%
	NSAS	66	204	270	276	66	6	26.1%	2.2%
2	WBSS	288	14	302	305	14	3	4.6%	1.0%
	NSAS	17	3	20	17	17	3	82.4%	-15.0%
3+	WBSS	216	4	220	221	4	1	1.8%	0.5%
	NSAS	5	0	5	4	5	1	100.0%	-20.0%
		824	**455**	**1279**	**1279**	**201**	**26**	**15.7%**	**2.0%**

Conclusions

The two management stocks (NSAS and WBSS) mixing in Division IIIa represent complex underlying subpopulation structure where local adaptation, especially in the WBSS component (Bekkevold *et al*., 2005), may drive an evolutionary divergence of otolith shape and create within-stock variation with many local centres of shape similarity. Nearest neighbour discriminant analysis has been chosen to avoid biased proportions in this situation; however, the results still exhibit a small trend in size of proportion error with changing proportions. The overall proportion error of 2% is in the order of, or less than, reported individual assignment errors using OM visual inspection (Clausen *et al*., 2007) and would probably increase precision of the total production sample in relation to the baseline. However, the subject needs a more thorough analysis including all years in the emerging time-series. The clear distinction between the stocks may be based on genotypic as well as phenotypic expressions of contrasting life-history characteristics. This means that precision will mainly be a function of sampling effort both with regards to baseline and production samples.

The current VS based estimation of WBSS in catches of herring in the transfer area of IVa East should be combined with an OM calibrated method in order to exploit differences in meristic characters among stocks such as maturity index, length–weight–age relationships, etc. This may lead to more reliable estimates of the proportion WBSS in catches in the North Sea.

The separation of Downs and other components of the NSAS are yet to be implemented. Assessments which evaluate the effect of alternative splitting could provide insight into the sensitivity of the current catch estimates. Alternative splitting methods for commercial and survey catches-at-age might include approaches such as a weighted spatial model.

Developing an assessment model capable of accounting for several stocks simultaneously and hence the catch apportionment uncertainty is encouraged. Such a tool could also help evaluate the cost-benefit for sampling strategies for stock composition and proportions-at-age.

4.1.2 Central Baltic Herring (CBH) in WBSSH management area

Similar to the NSAS / WBSSH issue described in 4.1.1, the separation of WBSSH from the easterly adjacent (SD 25–29, 32) Central Baltic Herring (CBH) stock for assessment purposes currently is based on a spatial separation (subdivisions). However, according to NSAS/WBSSH, the spatial separation does not address a possible and likely overlap and mixing of both stocks at the borders of their geographical distribution range. Accordingly, with an unknown degree of mixing in the predefined areas, the indices generated for management purposes can be biased. Indications for variable degrees of mixing were evident from GERAS/BIAS survey data from recent years, when conspicuous changes in lengths-at-age and weights-at-age of "WBSSH" caught especially in SD 24 were observed in some years. An increase of older, slow growing herring in the corresponding subdivision(s) was allocated to stronger contributions of CBH to survey catches.

Despite a variety of measures available for the possible separation of WBSSH and CBH according to e.g. genetic, meristic, etc. methods (see Gröhsler *et al.*, 2012 and references therein), a fast and reliable descriptor based on data readily available from the survey time-series was required to identify and remove the CBH fraction from WBSSH indices. Growth curve analyses of both WBSSH and CBH from survey data showed that a significant difference in growth parameters can be used to allocate an individual herring of unknown stock to either WBSSH or CBH based on a Stock Separation Function (SF) with length-at-age as measure (WD 04: Oeberst, Gröhsler and Schaber).

The application of the resulting Stock Separation Function to survey and commercial data from ICES SD 22 and 24 for the years 2005–2011 showed a variable but distinct fraction of CBH so far erroneously allocated to WBSSH and thus affecting the abundance and biomass indices generated for WBSSH from survey data (WD 01 and WD 03: Gröhsler, Oeberst and Schaber). Generally, the highest degree of mixing was observed in SD 24. Removing the CBH fraction from the dataset led to a higher consistency of survey results. However, a corresponding analysis for the years 1994–2004 did not result in a higher precision which was attributed to changes in growth in this period rendering the SF derived from 1994–2011 data less applicable for this period (WD02: Oeberst, Gröhsler and Schaber).

It is recommended to establish the SF for assessment purposes to generate more precise estimates for WBSSH indices derived from survey data.

4.2 Issue list

Stock coordinator Lotte Worsøe Clausen

Stock assessor Tomas Gröhsler/Valerio Bartolino

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this	External expertise needed at benchmark type of expertise
Tuning series	1a. Larval survey coverage of the stock(s) available to fishery 1b. Larval components in the area 1c. Spawning components in the area (for the SSB estimation) 2. Do the available surveys really reflect the abundance of the respective year classes? 2b. The Sound survey 3. Survey indices back in time (acoustic (HERAS) and IBTS) are not split into stock components 4. Central Baltic herring; how much do the potential migration into the area affect the indices?	1a. Recent evaluation of the N20; can we expand our knowledge of larvae in the area (recent research; larval drift models) 2. Detailed analysis of survey data; examination of precision of indices; Survey fit will be investigated in assessment. 2b. Look into application of data; possibility of re-starting this survey 3. Split of survey dataseries based on a modelled split 4. Split back in time of GerAS survey (2005–2011) based on the SF. Include Swedish, Polish and German data	Data are easily available and supplied by survey groups (IBTSWG and WGIPS). Check MuPED surveys too. Historic working group reports. *1) Polte P., Rainer O. Check Larval fish congress reps.* *1c) Lotte check FB results; HM, DB to help us* *2) Berg C, Bartolino V, RO; TG (acoustic)* *2b) Mosegaard H* *3) Mosegaard H, Worsøe Clausen L, Berg C* *4) Gröhsler T. et al.*	*Comments:* *Survey indices; Casper doing research; perhaps new approach as how to incorp. data different from the ICES approach. IBTS; BITS* *Internal/external consist in acoustics: TG et al.* *Re 3) Examine the opportunity for the application of split model on GERAS* *Re 4) only back to 2005; will check the remaining time-series*
Data	1. Misreporting from NS to Div IIIa (1991–2008) are going to be estimated and corresponding catches corrected; 2. Historical data are poorly utilised but can provide value information about stock 3. Central Baltic herring; how big an impact does this potential migration into the area have on the catch-at-age data	1. Collaboration between DK and SWE industry and national institutes scrutinizing existing databases. 2a. retrieve historical data from archives 2b. Incorporate historical catch data from archived information into assessment model. These data obviously need to be split, using a modelled split on the historical data 3. Split back in time catch data (2005–	Logbook and sales slip data and for later years VMS (vessel level). Archives (specifically SWE), biological sampling data should all be available at the national institutes. *1) Worsøe Clausen L, Bartolino V* *2a) Mosegaard H, Worsøe Clausen L, Bartolino V?* *2b) Mosegaard H, Worsøe Clausen*	National stakeholders (possibly through BSRAC) *Comments:* *Comm with Valerio-Lotte; include Reine Johs.* *Uncertainty estimates on catch data: Casper has ideas……* *(Re 2b) Survey info check (Valerio), Catches is in a black box.* *Re 3) TG got results to show for the German data; not on other countries – perhaps expand analysis to Swedish and Danish catches.* *Weight estimates with correct splitting; HM will look into this.*

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this	External expertise needed at benchmark type of expertise
	4. Database on input data	2011) in SD 24 based on the SF (including Polish, German, Danish and Swedish data) 4. Input files, keeping track of historic data	*L, Berg C* *3) Gröhsler T et al, Bartolino V, NN Poland* *4) Gröhsler T*	
Discards	Not an issue			*Comments:* *Esben to help out writing a small section on this; with the BSRAC (LAW)*
Biological Parameters	1. Stock components in the Western Baltic 1b which stocks should be separated? NS-issue Baltic issue and transition zone issue how should we report to the other groups especially the Baltic benchmark 1c i) Historical reconstruction ii) management considerations 2. Age and size-at-age 3. Constant natural mortalities are currently used 4. Constant maturity ogives are currently used/Fecundity	1. Investigative model of growth and maturity 1b. Precision of stock separation methodologies (including also the CBH issue) 1c. Migration and mixing (modelling spatio-temporal resolution) 2. Revision of the precision of ageing and the sampling for age structures 3. Revision of natural mortalities 4. Revision of maturity ogives; probability of spawning: We need a time-series for an annual varying maturity ogive to have an effect.	Need unified dataset from Surveys and also data from stock coordinator Data also from published studies and literature; what about Polish indications of migration to >Kattegat in C.Baltic herring? *1) Mosegaard, H., Worsøe Clausen, L., Bekkevold, D.,* *1b) Was A?, Mosegaard H, Bekkevold D, Oeberst R?, Gröhsler T et al* *1c) Kasper Kristensen and Mosegaard H.* *2) Worsøe Clausen, L. And others* *3) Neuenfeldt S* *4) Jonna et al*	Ana Was (Poland) Stefano Mariani (IR) Audrey Geffen (IMR) *Comments* *Re 1b) Precision on CBH: done (RO). DB have something on the genetic results more or less done. HM to look into the otolith morph.This is on-going (Incl. CLU)* *Re 1c) FehmBelt results will be the fundament (LAW, DB, SP/CLU, vTi).* *2) LAW; internal consistency in lab. RO done this already for German readers we should use Caspers age-length model to look for institute effects* *Re 3) Check with Stefan Neuenfeldt (LAW); write a section on this in the migration perspective too (include AR).* *Re 4) VB to drive this issue; Fran, Henrik and Jonna on when to estimate/consequences of components, etc.*
Assessment method	1. Current assessment model is not optimal and cannot be maintained 2. Investigate the impact on the assessment results given the outcomes of the input data analyses as proposed under Tuning Series and Biological data 2c Analysis of any retrospective bias	1. Develop new model and specify how to deal with splitting error 2a. Investigation of input data. 2b. Comparison of available stock assessment models and assumptions. 2c. Perform sensitivity runs with different model input data configurations	Data from HAWG, IBTSWG and WGIPS. Models from DTU-AQUA, IMR, IMARES,CEFAS and MSS *1–2) Nielsen A, Berg C, Bartolino V, Grohsler T, Mosegaard H*	*Elizabeth Brooks (USA)* *Chris Francis (NIWA)* *Comments:* *SAM is fully able to go with WBSS now; 'walk in the park'. Valerio to join forces with Casper and Anders. RO would like to be fully informed about the model specs.* *Re 3) AN is working on this part of the model; LAW Niels*

Issue	Problem/Aim	Work needed / possible direction of solution	Data needed to be able to do this	External expertise needed at benchmark type of expertise
	3. Forecast methodology	3. Migration and mixing shall be dealt with in forecasting on the stock(s).	*3) Mosegaard H, Nielsen A, Hintzen, N*	*H and AN to figure out a procedure suitable for WBSS; Scrutinize the forecast methodology; simplify and review in the light of what was learned during GAP/JackFish/WATSUP. (Transferarea/TAC uptake/50:50 rule, TAC transfer….) – LAW driving (CLU, PelRAC, etc help out).* *Consider implementation of the Fishermen perception of stock as done in North Sea assessment (Clara)*
Biological Reference Points	1. Investigate reference points under benchmarked assessment outcomes and in relation to the management plan 2. Investigate alternative reference points 3. Management considerations	1. Calculate new reference points based on assessment results, with main focus on F_{MSY} and $B_{lim}/B_{trigger}$. 2. Literature / other assessment work review 3. Handling the advice structure to keep managers satisfied with the information given to provide management	HAWG, multispecies WG and literature. *1–2) Mosegaard H, Grohsler T, Berg C, Ulrich Rescan C, Rindorf A?* *3) Worsøe Clausen, L., and the old gang from URSIN, GAP and others.*	Laurie Kell (ICCAT) Geir Huse (Nor) Mike Heath (UK) *Comments:* *HM will drive this work; explore on the available data (historical Recruitment index, etc. RO to corr. with HM on this)* *Re34). GAP, etc. consider simplifying the system, especially the advice part*

4.3 Scorecard on data quality

The assessment input data for the assessment have been revised a number of times in HAWG and in these revisions, the changes have not always been fully documented. In order to establish the quality of the input data files and ensure a state-of-the-art input data shape, the input files were scrutinised (WD05: Gröhsler). The implementation of a database to store historical assessment input data at least down to the level by stock (NSAS, WBSS), area (Division IV and IIIaN/IIIaS, SD 22, SD 23 and SD 24), fleet (A, C, D, E), age groups (= WRs) 0-8+ and year (1991–now) was part of the work and the input files are now quality assured. The WKPELA encourages HAWG to continue the population of this database.

The accuracy (potential bias) of input data for the assessment is evaluated according to the scorecard developed by the Workshop on Methods to Evaluate and Estimate the Accuracy of Fisheries Data used for Assessment (WKACCU, ICES, 2008). The workshop developed a practical framework for detecting potential sources of bias in fisheries data collection programs. A scorecard was applied to indicators of bias for a suite of parameters that are important for stock assessments. The scorecard can be used to evaluate the quality of data sources used for stock assessments, and to reduce bias in future data collections by identifying steps in the data collection process that must be improved.

For this stock, no major biases are considered to occur in the data:

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
A. SPECIES IDENTIFICATION				
1. Species subject to confusion and trained staff	1			
2. Species misreporting	1			
3. Taxonomic change	1			
4. Grouping statistics	1			
5. Identification Key	1			
Final indicator				
B. LANDINGS WEIGHT				
Recall of bias indicator on species identification				
1. Missing part	1			
2. Area misreporting			1	earlier misreporting corrected for HAWG, but still in official landings
3. Quantity misreporting	1			no current misreporting
4. Population of vessels	1			all vessels sampled? Norway?
5. Source of information	1			
6. Conversion factor	1			
7. Percentage of mixed in the landings	1			
8. Damaged fish landed	1			
Final indicator	0.5			
C. DISCARDS WEIGHT				
Recall of bias indicator on species identification				
1. Sampling allocation scheme		1		discarding is not considered to happen but very few observers - slipping may occur but not when observers are on board
2. Raising variable	1			
3. Size of the catch effect	1			
4. Damaged fish discarded	1			
5. Non response rate	1			
6. Temporal coverage	1			
7. Spatial coverage	1			
8. High grading	1			
9. Slipping behaviour	1			

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
10. Management measures leading to discarding behaviour	1			
11. Working conditions	1			
12. Species replacement	1			
Final indicator	0.5			
D. EFFORT				
Recall of bias indicator on species identification				
1. Unit definition				not relevant for herring fisheries
2. Area misreporting				not relevant for herring fisheries
3. Effort misreporting				not relevant for herring fisheries
4. Source of information				not relevant for herring fisheries
Final indicator				
E. LENGTH STRUCTURE				
Recall of bias indicator on discards/landing weight	0.5			
1. Sampling protocol	1			stratified random
2. Temporal coverage	1			
3. Spatial coverage	1			
4. Random sampling of boxes/trips	1			
5. Availability of all the landings/discards	1			
6. Non sampled strata	1			
7. Raising to the trip	1			
8. Change in selectivity	1			
9. Sampled weight	1			
Final indicator				
F. AGE STRUCTURE				
Recall of bias indicator on length structure				
1. Quality insurance protocol	1			
2. Conventional/actual age validity		1		there are possibilities to construct accurate age sets
3. Calibration workshop	1			
4. International exchange	1			
5. International reference set	1			
6. Species/stock reading easiness and trained staff	1			
7. Age reading method		1		whole otolith readings - very old may be underestimated
8. Statistical processing	1			
9. Temporal coverage	1			
10. Spatial coverage	1			
11. Plus group	1			
12. Incomplete ALK	1			
Final indicator	0.5			
G. MEAN WEIGHT				
Recall of bias indicator on length/age structure	0.5			
1. Sampling protocol	1			
2. Temporal coverage	1			
3. Spatial coverage	1			
4. Statistical processing	1			
5. Calibration equipment	1			
6. Working conditions	1			
7. Conversion factor	1			
8. Final indicator				
H. SEX RATIO				sex ratio not used
Recall of bias indicator on length/age structure	0.5			
1. Sampling protocol	1			
2. Temporal coverage	1			
3. Spatial coverage	1			
4. Staff trained	1			
5.Size/maturity effect	1			

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
6. Catchability effect	1			
Final indicator				
I. MATURITY STAGE				
Recall of bias indicator on length/age structure	0.5			
1. Sampling protocol	1			
2. Appropriate time period		1		needs a whole extra survey
3. Spatial coverage		1		needs a whole extra survey
4. Staff trained	1			
5. International reference set	1			
6. Size/maturity effect		1		using constant maturity ogive
7. Histological reference	1			
8. Skipped spawning	1			
Final indicator	0.5			
Final indicator				

4.4 Multispecies, mixed fisheries issues and stakeholder input

The Western Baltic herring fishery is a multinational fishery that seasonally targets herring in the eastern parts of the North Sea (Eastern IVa,b), the Skagerrak and Kattegat (Division IIIa) and Western Baltic (SD 22–24). The main fleets come from Denmark, Sweden, Norway and Germany, while Poland has a minor fishing activity in the area. After 1996 the fishery is roughly concentrated in the first and the third quarter of the year, whereas earlier the fishery was more spread over the year since it constituted a substantial part of the 16 mm industrial fishery.

The fishery is regulated according to an area TAC (herring catches in the IIIa and SD 22–24), but the assessment and fisheries advice is stock based (Western Baltic spring spawning herring (WBSS) to which estimates of potential WBSS catches from the neighbouring area of the eastern North Sea are added.

The fishery for human consumption has mostly single-species catches, although in recent years some mackerel bycatch can occurred in the trawl fishery for herring. Discarding in the herring fishery in the eastern North Sea is low, with 2–4% discarded by weight (van Helmond and Overzee, 2011). In Division IIIa and SD 22–24 discarding is considered negligible because all sizes are equally valuable and hence there are no incentives for highgrading since hence.

The bycatch of sea mammals and birds is low enough to be below detection levels based on observer programmes (ICES, 2011a). At present there is a very limited industrial fishery in Division IIIa and hence a limited bycatch of juvenile herring. Further, herring bycatch quota is allocated in both the North Sea and Area IIIa. The sprat fishery in SD 22–24 operates with a certain degree of herring bycatch which is closely monitored and counted against the sprat quota (up to 8% herring allowed).

The pelagic fisheries on herring claim to be some of the “cleanest” fisheries in terms of bycatch, disturbance of the seabed and discarding (ICES, 2010). Pelagic fish interact with other components of the ecosystem, including demersal fish, zooplankton and other predators (sea mammals, elasmobranchs and seabirds). Thus a fishery on pelagic fish may impact on these other components via second order interactions. There is a paucity of knowledge of these interactions, and the inherent complexity in the system makes quantifying the impact of fisheries very difficult. As such the discard ban is not believed to make any changes in the fishery or fishing pattern.

Another potential impact of the Western Baltic herring fishery is the removal of fish that could provide other "ecosystem services." The ecosystem needs a biomass of herring to graze the plankton and act as prey for other organisms. If herring biomass is very low other species, such as sandeel, may replace its role or the system may shift in a more dramatic way. There is, however, no recent research on the multispecies interactions in the foodweb in which the WBSS interact.

Western Baltic Spring Spawning Herring constitute an important species in the German commercial fisheries in ICES Subdivisions (SD) 22 and 24. As shown from data sampled in German acoustic surveys (GERAS) in ICES SD 21–24, a varying but distinct fraction of herring in SD 24 belong to the Central Baltic Herring stock (WD 01: Gröhsler, Oeberst and Schaber). Therefore, a Stock Separation Function (SF) that was established from survey data was employed to identify the fraction of Central Baltic Herring in German commercial herring landings from SD 22 and 24 in the years 2005–2011. Results showed a rather low share of CBH in landings from all métiers but indicated that the actual degree of mixing might be underrepresented in commercial landings as German commercial fisheries target pre-spawning and spawning aggregations of WBSSH (WD 03: Gröhsler, Oeberst and Schaber).

4.4.1.1 Stakeholder input

Questionnaire

A questionnaire was put forward to the stakeholders at the final benchmark meeting.

Major fishery of interest

WBSS (those responding represent the pelagic consumption fishery for species such as herring, mackerel and sprat).

In order to weigh our replies to the questionnaire, the table below shows the 2013 TAC allocation between IIIa and SD22–24 per country.

Country	TAC IIIa (tonnes)	TAC 22-24 (tonnes)	Bycatch IIIa (rollover)
Denmark	23.073*	3.617	3.984
Germany	370*	14.234	36
Finland		2	
Poland		3.357	
Sweden	24.135*	4.590	641
EU TAC	47.665	25.800	4.661
Norway	7.335		
TAC	55.000	25.800	

***approximate value.**

Fishing conditions

Is the fleet in this fishery primarily owner-operators or owned by larger companies?

> Denmark: Large pelagic trawlers and purse seiners and ITQ.
>
> Sweden: Approximately 95% of the quota is taken with large pelagic trawlers, and approximately 5% is with gillnets. Sweden has ITQs. Like for Denmark the pelagic vessels in Sweden only operate on pelagic species.

Germany: Relative many small sized pelagic vessels operating mainly coastal using both gillnets and trawls. Most of these vessels are exclusively fishing on pelagic species. No ITQ system exists in Germany. Three of the vessels are owned by a company hence the majority of the vessels engaged in the Baltic Sea herring fishery are owned by fishermen.

Poland: No large companies owning vessels. Relatively small and many pelagic vessels using both gillnets and trawls operating in a mixed fishery, with cod and flatfish. Polish fishermen can apply each year for transfer of quota if quota has not been used completely, but no selling of quotas ("semi" ITQ without selling of quota).

Is the fleet renovating or are vessels aging?

Denmark: Renovated and average age of larger pelagic vessels is less than ten years. All vessels with refrigerated seawater tanks (RSW).

Sweden: Renovated and average age of larger pelagic vessels is less than ten years. All vessels with refrigerated seawater tanks (RSW).

Germany: Fishery and quotas do not allow investment in new ships. Vessels are maintained best possible, but are aging. RSW capacity is not common. The youngest ships are about 20 years old, many ships are from the 1950s–1970s. A lot of ships employed in herring fishery are made out of wood and have a size mostly between 60–100 GT. German law restricts ships to 221 kW machine power.

Poland: Older vessels. But there is definitely fleet renovation going on. In particular in the sprat and herring fleet, investment being made in modernization and RSW facilities.

Is the average age of vessel operators increasing steadily (i.e., younger fishermen are not tending to participate)?

Sweden/Denmark: With the introduction of ITQ the incentive for younger capacities to start fishing has decreased the average age of those employed in the fishery.

Germany/Poland: The trend is an increasing age. For Poland there is a slower process of regeneration with a few younger fishermen entering the sector.

Has the methods and approaches used by fishermen changed much in the past two decades?

Sweden/Denmark: Gear (purse seine, trawls) are the same, however the processing after the catch has been changed. Further the haul-duration has also been decreased in order to meet the increasing demand for high quality fish.

Poland: Poland highlighted changes in mesh sizes and introduction of pumping systems and RSW.

Germany: No.

If so, has it been gradual or a step change in a particular year (if step please specify years)?

See additional information below on changes in the fishery as perceived by the fishery.

What proportion of vessel operators rely on this fishery for their primary source of income in recent five years or so? All, most, some, none.

Denmark: Pelagic vessels=some.

Sweden: Gillnetters=some; Pelagic vessels=all, some.

German: TAC situation, considerable and unforeseeable increases and decreases in herring quotas forces fishermen to look for alternative target species or other ways to generate income.

Poland: Almost all the larger vessels rely on pelagic fishing. Small-scale vessels rely on herring fishery for spring spawners in the Szczecin Bay; only fishing for herring for five to six weeks during the spawning season.

What sources of error in catch statistics may be likely?

ALL countries and both areas. However, Denmark was the first country to implement various improvements to improve the accuracy in the catch statistics by:

1991–the late 1990/early 2000s. Errors in quantity. This was gradually solved during the 1990 as weighing of the catch became standard in the harbours. This first started in Denmark, but other countries soon followed. The water percentage in the catch was also accounted for.

1996–2008: Area misreporting began to be a problem during this period, but was solved with the implementation in 2008 of a regulation that forbids fishing in both areas on one trip.

2008– No catch errors (minor) due to ITQ and flexibility.

What if any bycatch issues are a concern in this fishery?

No bycatch in the fishery targeting herring. Herring constitute a bycatch problem in the small meshed sprat fishery. Poland reports that bycatch could be occasionally significant in the summer; but only bycatches of cod. According to Germany gillnetting suffers under the discussion of effects on seabirds and porpoises although no scientific evidence is available.

What environmental conditions if any are of obvious concern in considering impacts on fishing and/or survey data?

None

Poland highlights the problem of bycatch of birds: it is not serious now, but could be so in the future in pelagic trawling. No major impacts noted on harbour porpoise.

Please provide any other relevant information for ICES assessment process that you feel is appropriate.

Changes observed in the herring fishery as perceived by the industry

The herring fishery in IIIa has experienced two dramatic changes which in turn have changed the fishing pattern dramatically. The aim of in this section is to provide a description of these changes as perceived by represents from the Danish and Swedish pelagic fishery.

<u>The 1996 management change and the effects seen in both Swedish and Danish fishery</u>.

In 1996, a series of management measures for the North Sea autumn spawning herring (NSAS) was implemented, and this had an indirect effect on the IIIa herring as well. The change in management measures was a response to calls for action due to observations of an abrupt and dramatic decrease in the NSAS herring biomass. The total allowable catch (TAC) was reduced in the middle of the year 1996; partly as a result of lower than expected commercial catches, and new ways of managing the stock were initiated.

One of the new management practices implemented was to set a target F for adult herring and an upper acceptable F for juvenile herring. This resulted in the bycatch quota which restricted the amount of herring that could be taken as bycatch in the small meshed industrial fishery to a certain quantity. In practice, the way to distinguish between these two quotas was that all the herring caught in gear with a mesh size lower than 32 mm was ascribed to the bycatch quota and the herring caught in gear with a mesh size larger than 32 mm was ascribed to the quota for consumption. The fleet was also divided into four different segments: the A fleet operating with a mesh size >32 mm for consumption herring, the B fleet using <32 mm targeting industrial species (especially sprat), both operating in the North Sea, and a C fleet/D fleet which is the equivalent of the A/B fleets, but operating in IIIa instead of the North Sea. There is also an F fleet which is the consumption fleet operating in SDs 22–24.

Implementing the ITQ system

Denmark

In 2001 it was decided to implement ITQs as a management measure in Denmark. As a result of discussions on how this should be done, it was started in the pelagic fishery. On 1st January 2003 the details were in place and the system was implemented.

At the time when quotas were allocated to the individual vessels, a total of approximately 100 vessels were fishing herring in the North Sea and around 60 in the Skagerrak. As expected, as a consequence of the ITQ system these numbers decreased. In 2013 there are 15 vessels operating in the North Sea and 14 in Skagerrak.

This concentration of quotas has led to a radical change to the pelagic fleet in Denmark. Before the ITQ system was introduced, the vessels in the Danish fleet were generally old and old fashioned (compared to the fleet in the Northeast Atlantic). Nowadays, the average vessel age is less than ten years, and they are much larger and more modern (e.g. equipped with Refrigerated Sea Water (RSW) systems). This gave rise to a new way of thinking in the fishery where quality was put in focus compared to earlier when the emphasis was on quantity.

Sweden

The Swedish ITQ system was implemented a few years later than in Denmark, but led to the same result with fewer, but more modern vessels. Today there is a sprat fishery for consumption and a purse seine fishery for herring in the Skagerrak. The size of the herring quotas has fallen and it is not possible to fish throughout the year. Herring fishery takes place in two seasons: the winter and the autumn.

Management objectives

Preferred management objectives (biological/economic/social) for fishery of interest (please list at least three, in priority order):

1) Fishing at MSY;

2) High and stable yield;
3) Balanced allocation of fishing opportunities between 22–24 and IIIa;
4) Introduction of a management plan;
5) Flexibility between IIIa and North Sea.

Suggest indicators of management performance towards achieving objectives:

INDICATOR	OBJECTIVES TO WHICH INDICATOR APPLIES
a) F equals F_{MSY}	Fishing at MSY
b) IAV	Stable yield

4.5 Ecosystem drivers

Although knowledge on crucial variables affecting larval herring survival increased since the latest stock collapse in the 1970s, the understanding of particular mechanisms of early herring life-history mortalities is still a major task of fishery science in the North Atlantic Ocean. Dominant drivers of larval survival and year class strength of recruitment are considered to be linked to oceanographic dispersal, sea temperatures and food availability in the critical phase when larvae start feeding actively. However, research on larval herring survival dynamics indicates that driving variables might not only vary at the population level and by region of spawning but also by larval developmental stage. Since WBSS herring relies on inshore, transitional waters for spawning and larval retention, the suit of environmental variables driving reproduction success potentially differs from other North Atlantic stocks recruiting from coastal shelf spawning areas.

To address various questions on early herring life-history ecology, several supplementary samplings were integrated into the Rügen herring larvae survey (See Section 4.6.2) during recent years (see WD 09 for details) to understand composition and distribution of macrophyte spawning substrate, egg predation, effects of storm events on egg mortality, larval herring nutrition and larval dispersal by prevailing wind drift.

Rügen herring is considered a significant component of WBSSH. Results on time-series analysis of larval herring growth and survival dynamics indicate that distinct hatching cohorts contribute differently to the number of 1+winter ring (wr) recruits in the overall Western Baltic Sea. The abundances of the earliest larval stage (5–9 mm TL) explains 62% of the variability of later stage larval abundance and 61% of the variability of surviving (1+ group) juveniles. This indicates important pre-hatching survival bottlenecks associated with spawning and egg development. Furthermore, findings demonstrate that hatching cohorts occurring later during the spawning season contribute most to the surviving year class whereas earlier hatching cohorts do not result in significant growth and survival. This could be explained by limited food supply at hatching prior to spring plankton blooms, indicating an additional bottleneck at the critical period when larvae start feeding.

4.5.1 Rügen herring egg mortality

To investigate potential mechanisms responsible for the early survival bottleneck most probably occurring at the egg stage, predator exclosure experiments were performed to quantify direct predation effects on the density of deposited herring spawn. In total, four different experimental designs were applied in the field during the 2012 spawning period. Results indicate a significant egg reduction at nonenclosed control sites proving predation pressure by the regional fish community, dominated by three-spined sticklebacks (*Gasterosteus aculeatus*) to be an important factor influencing egg mortality rates. Interestingly, studies on predator–prey overlap revealed that predation pressure by sticklebacks was higher during later spawning cohorts, which could represent the cohort correlated with recruitment strength. Since predators can feed on herring eggs *ad libitum* a laboratory experiment was conducted to investigate digestion rates of herring eggs in stickleback stomachs at different temperatures to estimate potential predation intensities by individual fish. Preliminary analyses show a strong temperature dependence of feeding and digestion rate. Together with results on predator abundances on the spawning beds further analyses will allow for an estimate of total egg consumption by the local fish community. Exceptional storm events are another potentially important factor affecting egg mortality that was only anecdotally reported in the area. Strong winds from particular directions can evidently harm Greifswald Bay's vegetated spawning beds occurring shallower than 2 m depth. Results of a pilot. Results of a pilot study conducted on two index transects on geographically opposite locations in NW and SW Greifswald Bay during the 2012 spawning season, indicate extensive egg loss due to storm induced turbulence. Further processing of data will provide pre- and post-impact data on egg densities and therefore provide a suitable background to quantify egg loss caused by extensive storm periods.

4.5.2 Larval nutrition, -distribution and -dispersal

Since larval WBSSH hatch in the littoral zone which cannot be covered by regular ichthyoplankton surveys on board large research vessels, a potential "blind spot" of larval distribution exists in the shallow water zones of the lagoonal retention area of Greifswald Bay. Preliminary results indicate that shallow water habitats in a range of 2–3 m water depth are frequented by herring larvae with site-specific abundance variation depending on shore zone topography. However, in general no habitat-specific aggregations were found and littoral abundance was not found higher than in the pelagic zones of the bay broadly covered by the annual larvae survey. Since the shallow waters of Greifswald Bay (6 m average depth) are generally well mixed and non-stratified in respect of all physico-chemical parameters, the vertical larval distribution within the water column used to be considered similarly homogenous. However, results of pilot studies on differing depth strata including surface, mid-water and bottom sampling indicate significant differences of larval abundances and length groups according to depth strata. These findings provide an important base line for future studies on predator-prey overlap and hydrodynamic dispersal models. Drivers of larval dispersal and the function of inshore lagoons as retention areas are a major task for both understanding local effects on mortality and interpreting survey results focusing on inshore larval abundance. In the absence of significant tides and major current regimes, larval dispersal is considered predominantly driven by wind drift. Results of Lagrangian drift models, where particles were tracked under constant and variable wind conditions underlined the role of Greifswald Bay as an important larval retention area represented by variable wind conditions preventing significant passive export of larva to adjacent coastal waters. An additional approach using a Eularian particle tracking model indicate low spawning site fidelity. However, these results contradict results of field observation and require scientifically sound future testing.

Availability of suitable prey at the critical period after yolk consumption is generally considered the predominant survival bottleneck in larval fish ecology. However, analyses of zooplankton prey abundance in strong vs. weak year classes did not reveal significant food limitation in the eutrophic waters of Greifswald Bay. However, besides prey abundance larval growth and survival might also be affected by the nutritional quality of prey. Comparative results on essential fatty acid contents of larvae and prey from two different spawning grounds showed no significant differences of larval growth conditions in Kiel Canal and Greifswald Bay. The food quality, however, was found to be generally important for larval growth. Accordingly, even when prey availability is plentiful in mixed, natural feeding conditions, larval growth is affected by nutritional value of prey.

Along the inshore–offshore gradients of Western Baltic watersheds, transitional waters, such as bays, lagoons and estuaries seem to represent significant areas for herring reproduction as i) important spawning grounds and ii) retention of early development stages. It still remains a major challenge to quantify the role of small-scale drivers and stressors for overall recruitment strength. The rationale in hypothesizing cascading scale effects is supported by current WBSSH recruitment time-series and the relationship of indices derived on differing spatial scales. The regular correspondence of the regional larval index (4.6.2) with recruitment patterns of WBSSH stock implies a relation between larger scale recruitment success and regional survival bottlenecks. On the other hand the N20 time-series provides a sound background to test the magnitudes of regional effects on the overall WBSSH stock.

4.5.3 Distribution of 0-group juveniles

Pilot studies conducted in Greifswald Bay showed that early juvenile stages after metamorphosis are not abundant in the inshore lagoon but in the near shore area of outer coastal zones. There they are difficult to quantify by standard means of ocean-going surveys such as hydro acoustics and trawling. Therefore current analyses on recruitment ecology neglect the 0-group stage in that there is a lack of sufficient datasets on abundance and spatial distributions.

4.5.4 Migration patterns of the WBSS

Migration studies on WBSS herring were in earlier times performed by mark–recapture experiments on the Rügen component (Biester, 1979) indicating that post-spawning migrations to the Kattegat and Skagerrak take place in smaller schools through the Sound and the Danish Belts.

Herring become infected with *Anisakis simplex* larvae in the Danish Straits or the North Sea by feeding on euphausiids which are the first intermediate host for the parasitical nematode. Since euphausiids do not occur in the Baltic, the presence of *A. simplex* larvae in herring is an indicator of migrations outside the Baltic. Large proportions of WBSSH >20 cm are infected with *A. simplex* (Gröhsler *et al*., 2012). Also in SD 25 and SD 26, infected herring are found. Podolska et al. (2006) concluded that infected herring represent a mixed group of western and central Baltic herring. In western waters, up to 16% of infected herring had morphometric characteristics of central Baltic herring, while in the central Baltic 25–60% of infected herring had morphometric characteristics of western Baltic herring.

Proportions of herring sampled in the Danish commercial fishery and scientific surveys in SD 22–28 were allocated to WBSSH and CBH by applying the SF. In addition, the proportions of infested herring in WBSSH and CBH were estimated (Table 4.5.1). About 68% of herring assigned to WBSSH were infected with *Anisakis*. This estimate is similar to the infestation rates of WBSSH in SD 23. On the other hand, only low numbers of herring which were, based on the SF, assigned to CBH were infected with *Anisakis*. These results correspond with the estimates based on German acoustic surveys and commercial fishery. Only few herring which were assigned to CBH based on SF were infected with Anisarkis. In addition, the estimates support the German findings (Gröhsler *et al*., 2012) that the proportion of infected herring of WBSSH increases with length and is generally low in herring <20 cm. The results clearly support the hypothesis that WBSSH and CBH mix in areas SD 22–24 and SD 25. The influence of mixed catches of the two stocks clearly needs more attention in future research. To verify and improve the quality of assignment of stock identity, novel genetic methods should be additionally applied (Limborg *et al*., 2012).

Table 4.5.1. Infestation rates of herring from Danish samples 2008–2012 from scientific cruises and commercial catches combined.

YEARS	2008–2012			NUMBER ANALYSED	
SubDivision	Age range	<=SF	>SF	N (<=SF)	N(>SF)
22	1	0%	0%	116	125
22	2	0%	1%	1	88
22	3–5	0%	14%	2	7
22	6–9	0%	0%	1	1
23	1	0%	4%	22	261
23	2	0%	24%	8	349
23	3–5	8%	68%	13	689
23	6–9	0%	90%	3	187
23	10–19		100%	0	11
24	1	0%	7%	12	246
24	2	0%	13%	12	272
24	3–5	2%	55%	53	573
24	6–9	0%	90%	21	135
24	10–19	0%	82%	1	11
25	1	0%	0%	99	143
25	2	0%	3%	85	101
25	3–5	0%	37%	470	404
25	6–9	0%	24%	444	246
25	10–19	0%	5%	29	59
26	1	0%	0%	12	4
26	2	0%	0%	16	14
26	3–5	0%	0%	146	16
26	6–9	1%	0%	167	13
26	10–19	0%	0%	14	2
28	1	0%	0%	2	1
28	2	0%		24	0
28	3–5	2%		60	0
28	6–9	3%		30	0
29	1	0%		2	0
29	2	0%	0%	11	1
29	3–5	0%		75	0
29	6–9	0%		42	0
29	10–19	0%		3	0
32	1	0%		1	0
32	2	0%		4	0
32	3–5	0%		10	0
32	6–9	0%		1	0

4.6 Stock assessment

The stock assessment on WBSS was changed considerably during the WKPELA benchmark. The applied assessment model was changed and the numbers of applied surveys (and age classes within these) were revised. This section describes first the scrutinising of the available data from catches, then the selection procedure of survey indices, the base of the biological parameters and last the applied assessment method.

4.6.1 Catch-quality, misreporting, discards, sampling

Catches of WBSS herring are taken by several fleets which are defined as follows:

> Fleet A: Directed herring fisheries with purse-seiners and trawlers (32 mm minimum mesh size) in the North Sea. Bycatches in the Norwegian industrial fisheries are included.
>
> Fleet B: Herring taken as bycatch in the small-mesh fisheries in the North Sea under EU regulations (mesh size less than 32 mm).
>
> Fleet C: Directed herring fisheries in Skagerrak and Kattegat with purse-seiners and trawlers (32 mm minimum mesh size).
>
> Fleet D: Bycatches of herring caught in the small-mesh fisheries (mesh size less than 32 mm) in Skagerrak and Kattegat.

Catch data quality

Every year, the HAWG reports the sampling coverage, the handling of unsampled métiers and the raising of catch data based on the available biological sampling. Looking through the reports over the past decade, there is no reason to doubt the procedures performed by the HAWG and the catch data quality as such seems reasonable. The HAWG recommends that all métiers with substantial catch should be sampled (including bycatches in the industrial fisheries), and that catches landed abroad should be sampled based on criteria provided by the HAWG, and information on these samples should be made available to the national laboratories.

The transparency of data handling by the Working Group is high and all data handling prior to the actual input to assessment is available in an archive system held by ICES. The archived data contains the disaggregated dataset, the allocations of samples to unsampled catches, the aggregated dataset and (in some cases) a document describing any problems with the data in that year. Since 2007, the corresponding datasets are also stored in InterCatch, where they are accessible to the stock coordinators only.

The catch-at-age matrix, an integral part of the assessment of Western Baltic Spring Spawning herring, is constructed by combining this information from all national laboratories with North Sea and Western Baltic herring sampling programmes. The national sampling programmes have all been shaped under different restraints and therefore differ in their approach to sampling catches. The data are aggregated only after national sampling information has been used to raise the numbers of herring caught at age to national catch levels, ensuring the constraints inherent in national sampling procedures are respected as far as possible. Although the Herring Assessment Working Group investigates the sampling coverage routinely to ensure the quality of the catch data in this respect, there is at the moment no requirement for national data submitters to provide a measure of the uncertainty associated with the estimated numbers-at-age provided to the HAWG, neither has it been possible to easily incorporate such information into the present assessment.

With the move towards an assessment model that can readily incorporate information regarding uncertainty in the input data it is essential to formalize the provision of catch precision estimates and to develop methods for aggregating these to reflect the uncertainty in the aggregated catch data. Although several institutes already routinely calculate the uncertainty associated with the numbers-at-age through the COST raising procedure, it was not feasible to achieve the provision of such estimates from all nations within the time limit of this benchmark, and certainly not for the historical data.

Area misreporting

Misreporting of commercial catches induces bias on the estimated fishing mortality and stock size. The potential of such a bias should be taken into account when decisions on reference points and long-term management plans are taken. Misreporting is not only a question of landing species under a different name but can also be a result of reporting catch in a different area than the catches took place. Area misreporting has probably taken place in IIIa and the adjacent North Sea, where catches from the North Sea have been reported in IIIa. The reason for this misreporting has been due to the size differences of herring in the two areas, where the optimal sized herring were caught in the North Sea but reported as taken from IIIa.

Misreporting is understood to have taken place for the Danish catches during the period from 1997 to 2008. The Danish reported landings have been corrected for this misreporting each year in the period 2002–2009 based on information from the industry, week-by-week evaluation of the fishing trips, and since 2004 by using VMS data.

All Norwegian herring catches in IIIa between 1995–2001are understood to have been taken in the North Sea and this was corrected for. However, since 2008 management has allowed optional transfers (flexibility in terms of where to take the IIIa TAC), where part of the TAC in IIIa legally could be caught in the North Sea.

It is unclear to what extent Swedish catches reported in IIIa in period 1991–2008 have been reported to the correct area. Similar to Denmark it is suspected that some North Sea catches have been reported as IIIa catches. For the period post 2008 misreporting in Danish and Swedish fishery has been judged unlikely primarily due to new regulations prohibiting the vessels to fish in two management areas in one trip; the flexibility in where to take the IIIa TAC (North Sea or IIIa) is also thought to decrease the incitement for area misreporting.

According to Swedish fishers it was not possible to come up with any solid documentation on the degree of misreporting. Further, those investigating the issue were under the impression that misreporting out of IIIa roughly equaled the misreporting into IIIA. This was based upon discussion with fishers that had been active during the period in question. The motive for reporting IIIa herring as North Sea herring could be that for those periods with good fishing in IIIa the steaming distance to the fishing position would be somewhat shorter when staying in IIIa and landing in Gothenburg compared to a trip to the North Sea.

As such, no basis for moving any of the Swedish catches was documented. In addition none of the Norwegian catches was moved for the period after 2008 as it could not be documented that the Norwegian misreporting found during the period 1991–2008 had been continued.

Given that the catch data has been corrected wherever possible each year, the applied catch data table (Table 4.6.1) consists of the corrected data and matches the input table with catch in numbers in the HAWG report (ICES 2012).

Table 4.6.1. Historic catch-at-age in numbers.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+
1991	118958	825969	541246	564430	279767	177486	46487	13241	4933
1992	145090	456707	602624	364864	333993	183200	139835	52660	22574
1993	206102	530707	495950	415108	260950	210497	102768	63922	24535
1994	263202	249398	364980	382650	267033	168142	118416	49504	33088
1995	541302	1660683	438136	226810	194870	84123	60096	32878	20459
1996	171144	638877	400585	199681	144155	130086	65274	30705	25111
1997	376795	668616	289336	276919	75283	43119	39916	21211	24134
1998	549774	623072	430903	182860	146685	45322	23759	15400	14112
1999	569599	616124	334339	246212	90259	55919	15481	9478	6084
2000	152581	934545	496396	186615	128625	71727	38262	13777	10689
2001	756285	523163	488816	257837	108097	68376	39092	18307	6687
2002	150271	659130	281840	321311	172285	57160	38532	13842	8329
2003	53489	126876	264855	161251	189432	103648	29117	17452	8819
2004	243554	457754	197812	164766	93214	91242	48957	14876	11013
2005	106906	305171	319225	177833	130394	60639	65695	31231	12620
2006	7946	148909	187674	233214	150654	98751	42459	32418	17312
2007	10721	172044	184735	143904	126861	64996	30199	21256	14759
2008	9610	149436	136988	135753	92305	89436	45930	17216	17410
2009	20734	181083	243007	101330	69937	48091	39750	20907	12529
2010	12394	75083	136419	82970	46833	29979	18589	10996	11262
2011	11813	98516	46282	38787	49324	27630	22632	12236	9335

Discards

The indications are that large-scale discarding is not widespread in the directed Div. IIIa, SD 22–24 herring fishery. Observations have been available since observer trips were introduced in both fleet C and D, and the observed discards were negligible. Discard data have not been consistently available for the whole time-series and are only included in the assessment when reported. Besides discarded catches, loss of herring may occur during catch processing, e.g. flushing of tanks and slippage from the net. Little information is available about the amount of this loss, but these practices may result in discards not currently assumed in the assessment.

Catch sampling for size-at-age and stock identity

In terms of method reliability, the issue of sampling for biological data for the splitting between NSAS and WBSS is an important factor; without a robust and appropriate sampling strategy, the basis for the splitting is somewhat impaired. When sampling commercial catches for the biological composition concerning the proportions of the two herring stocks it is crucial that the sampling scheme and coverage either mirrors or can be raised to the actual distribution of the fishery. The sampling coverage compared to the reported catches by ICES rectangle over the period 2002–2011 is shown in Figure 4.6.1.

It is apparent that catches concentrate in the northwestern part of Area IIIa, while sampling intensity is highest in the northeastern area.

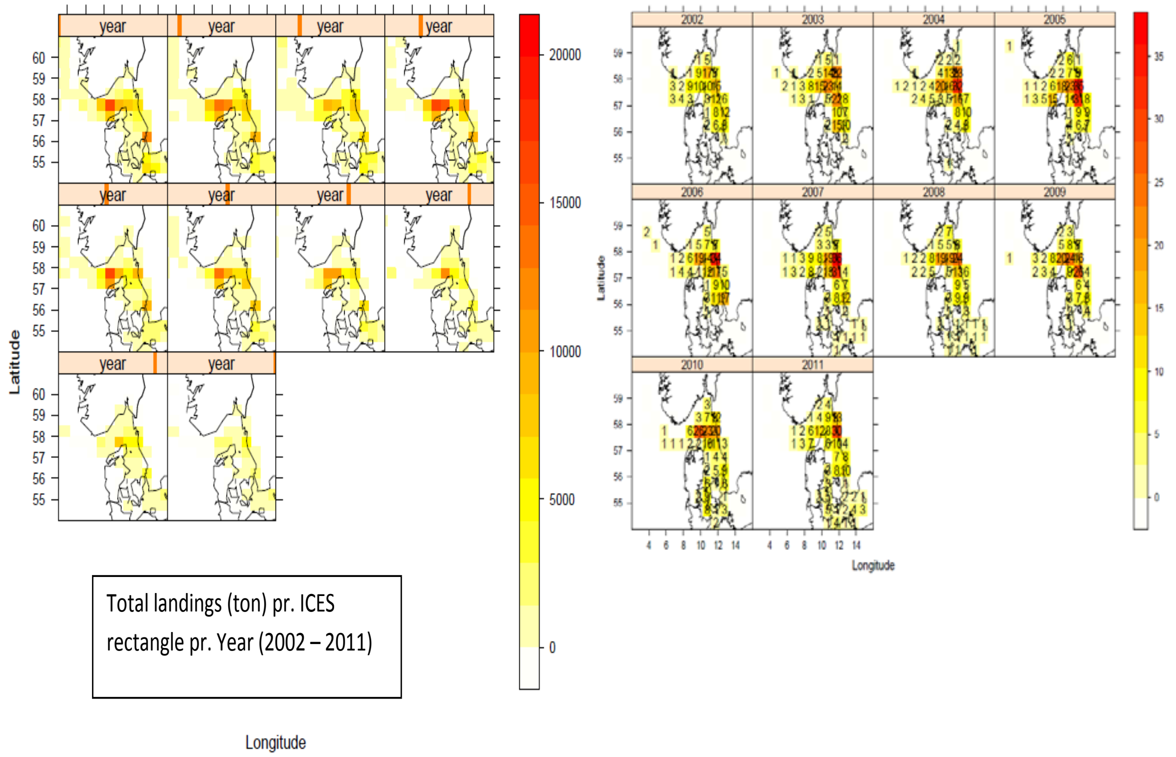


Figure 4.6.1. Number of samples by rectangle (right panel) and average landings in tonnes per year by ICES rectangle (left panel) over the period 2002–2011.

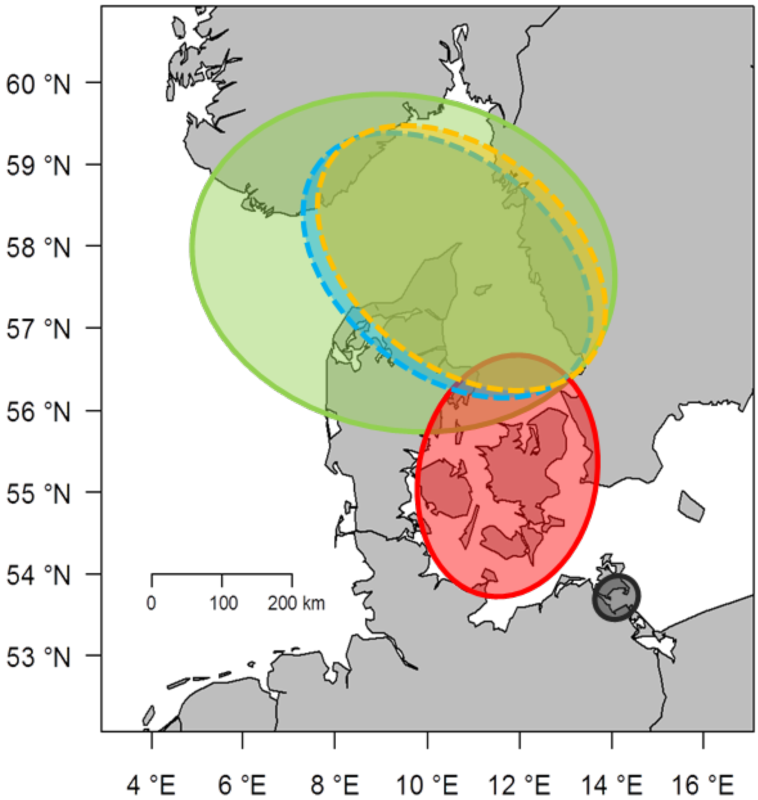
In order to get a solid base for estimation of the removals by the fishery, it is of utmost importance that all parts of the distribution area and the fishery herein are covered by the biological sampling. Though the sampling coverage has improved the past years and at present covers the entire distribution area and follows the spatial and temporal distribution of the catches, there is still room for improvement; the sampling in recent periods very poorly covers the Area IVaE (Figure 4.6.1). Thus it is highly recommended that the sampling intensity in Subdivision IVaE and eastern parts of IVb is substantially increased. The presence of local stock components in IIIa may also call for a modification of the current sampling strategy if those components are to be given higher priority to be included in the assessment of the stock mixing in the area.

In the period up to 2008 there is an apparent high concentration of catches in one specific ICES rectangle immediately to the east of the North Sea; Division IIIa border. All examples of identified misreporting of catches from the North Sea are reported to this rectangle. Scrutinising the Danish database for catch composition in this rectangle in relation to other areas of Division IIIa indicate a high frequency of samples with close to 100% NSAS in the OM analyses. Also the age distribution appears skewed toward older alder ages in relation to other parts of Division IIIa. These circumstances infer that samples of North Sea catches misreported to IIIa are included in the database and to an unknown degree influence the estimated stock proportions an thus the estimated catches of WBSSH.

The raising of biological composition related to size-at-age and stock affiliation need to be reanalysed according to the historic area misreporting. This can be done either by a thorough screening for deviating fishing pattern coupled to individual vessel ID in the database or by statistical analysis of similarity of catch composition from the suspected ICES rectangles with either verified North Sea or Division IIIa catches.

4.6.2 Surveys

The WBSS stock has several survey indices available as tuning indices for the assessment (Figure 4.6.2). During the benchmark process, an objective selection of survey datasets for inclusion in the stock assessment was performed. In essence, any dataset included should increase the net amount of information, adding more signal than noise. The signal-to-noise ratio in a survey depends on both the noise level and the magnitude of the underlying signal itself (i.e. for a given constant noise level, signals that vary slightly will always be harder to detect than those that vary widely). For example, sample size, survey design, spatial coverage (including how well the spatial distribution of the stock is captured), and consistency of performance can all contribute significant amounts of noise to survey data. In the following the available surveys are described shortly as well as their status as tuning indices.



Survey name	Method	Season	Time-series	Ages	Colour code
GERAS	Acoustic	October	1991-2011	0 to 8	
HERAS	Acoustic	June/July	1991-2013	0 to 8+	
IBTS Q1	Bottom trawl	February/March	1991-2014	1 to 4	
IBTS Q3	Bottom trawl	September	1991-2015	1 to 4	
N20	Larvae sampling	September	1992-2011	0	

Figure 4.6.2. Conceptual illustration of the spatial and temporal survey coverage of the WBSS herring stock complex.

GERAS

The GERman Acoustic Survey (GERAS) has since 1993 included the Subdivisions 21 (Southern Kattegat, 41G0–42G2) to 24 as a part of BIAS (Baltic International Acoustic Survey). The survey is being carried out on the German R/V 'Solea' in October (GERAS). Further details of GERAS can be found in ICES reports from the Working Group of International Pelagic Surveys (WGIPS) and Baltic International Fish Survey Working Group (WGBIFS). The survey design and the specific settings of the hydroacoustic equipment follow the guidelines of the 'Manual for the Baltic International Acoustic Surveys (BIAS)', which is part of the WGBIFS report (ICES, 2012).

Recent results of GERAS indicated that in SD 24, which is part of the WBSSH management area, a considerable fraction of CBH is present and correspondingly erroneously allocated to WBSSH stock indices. Accordingly, a Stock Separation Function (SF) based on growth parameters was established to identify the fraction of CBH in the WBSSH area and applied to survey data from the German Acoustic Survey GERAS from 2005–2011. Results showed a distinct fraction of CBH in SD 24 and indicated that applying the SF greatly improved both abundance and biomass indices for WBSSH (WD 01: Gröhsler, Oeberst and Schaber).

Length and age data from GERAS sampled in Subdivision (SD) 21 and 23 between 1994 and 2004 were used to estimate the parameters of the Bertalanffy growth function (BGF) in order evaluate the existing SF (WD 02: Oeberst, Gröhsler and Schaber). The analyses showed a slight shift of the parameters and a change of growth within this period. Therefore, the SF cannot be extrapolated to the period between 1994 and 2004. An application of the SF to the period 1994–2004 would result in an overestimation of the fraction of CBH. Possible changes in age reading procedures did not determine changing growth parameters. It is needed to estimate a separate SF for the period between 1994 and 2004.

Three methods were evaluated to assess the quality of a stock separation function (SF) derived for identifying the fraction of CBH in western Baltic Subdivisions 22–24. Length distributions of GERAS in SD 24 were split up into normally distributed length components (WD 04: Oeberst, Gröhsler and Schaber). The effect of ageing errors related to the overlap of the length distribution of the same age group of both stocks based on simulated data were studied. The length ranges age groups of herring captured during acoustic surveys and in the commercial fishery were compared with the expected data. Additionally, effects of ageing errors originating from an overlap of length distributions of the same age groups of both stocks were studied based on simulation data. Furthermore, length ranges of different age groups of herring captured during acoustic surveys and in commercial fisheries were compared with the expected results from simulation data. Analyses of the length frequencies indicated that CBH can be identified from length distributions, but the estimates are uncertain due to the high fluctuation of the length frequencies within small length ranges and the strong overlap of the length frequencies of age group 2+ of CBH. The simulated data showed that ageing errors are important for age groups 1 and 2. Especially important are underestimations of the age of CBH and overestimation of the age of WBSSH. The length ranges of age groups support the results of SF in most cases. Unexpected results were observed in SD 25 which are partly determined by ageing errors.

The internal consistency of GERAS was analysed based on pairwise correlations of index time-series for all age combinations by cohort within each survey time-series in order to investigate to what extent a given signal (i.e. high or low value) for age class x in year i can be recognized in age class x+1 in year i+1 and again in age class x+2 in year i+2, etc. The analysis was carried out for both the 'old' GERAS survey-series and the 'new' where the Central Baltic Herring (CBH) were removed.

GERAS displayed relatively high internal consistency between age 1–2, and to some extent also age 2–4 in the new GERAS time-series (Figure 4.6.3). There was no internal consistency for fish older than 4. Overall the internal consistency was highest in the new GERAS time-series.

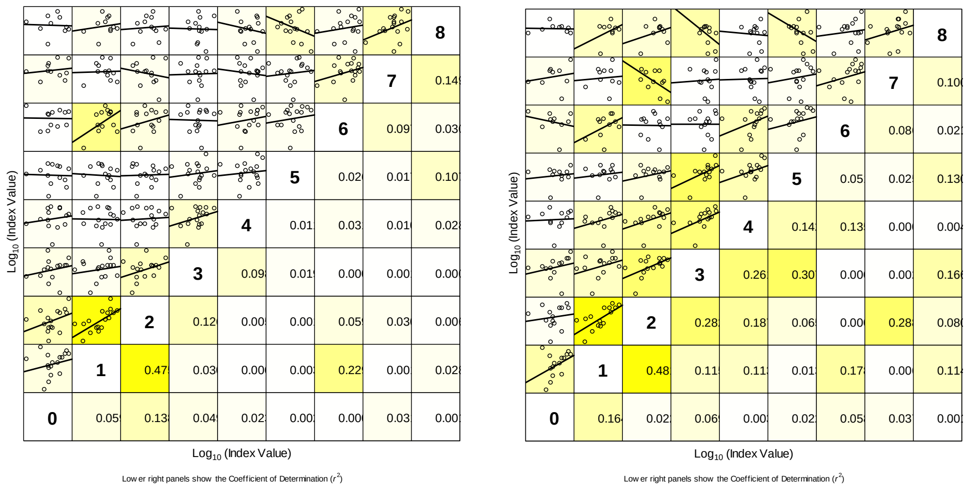


Figure 4.6.3. Correlation coefficient diagram for acoustic survey by cohort for the 'old' GERAS (left panel) and the 'new' GERAS (right panel).

In order to analyse the external consistency between GERAS and the non-larvae surveys, the pairwise correlations of index time-series between all combinations surveys and for each age class respectively in order to analyse to what extent surveys indicate the same development in herring abundance over time. GERAS displayed high external consistency with IBTS-Q1 for age 3 and for the larval survey when correlating the larvae index in year i with age class 1 in year i+1 and age class 2 in year i+2, etc.

Conclusion

The index generated after exclusion of Central Baltic Herring (CBH) in 2005–2011 seemed far more reliable as this led to the removal of unexplained/unobserved strong year classes and unrealistic mean weights-at-age in WBSSH. Comparing abundance indices of consecutive year classes before and after the application of the SF in 2005–2011 showed a far better correlation of corresponding abundances throughout the year classes after removal of CBH (WD 01: Gröhsler, Oeberst and Schaber). It is recommended to apply the SF to future survey data for an improvement of survey indices used in WBSSH stock assessment.

HERAS

The ICES Coordinated acoustic surveys for herring in the North Sea, Skagerrak and Kattegat gives an index of numbers-at-age for 1–9+-ringers, mean weights-at-age in the stock and proportions mature-at-age. This index has been used in assessments of NSAS since 1994 with the time-series data extending back to 1989. Over the years the survey has been extended to cover Division IIIa to include the overlapping western Baltic spring-spawning stock, the whole of VIa (North) and since 2008 the whole Malin Shelf. By carrying out the coordinated survey at the same time from the Kattegat to Donegal, all herring in these areas are covered simultaneously, reducing uncertainty due to area boundaries as well as providing input indices to three distinct stocks. The surveys are coordinated under the ICES Working Group for International Pelagic Surveys (WGIPS) and full technical details of the survey can be found in the latest WGIPS report (ICES, 2012).

The internal consistency of HERAS was analysed following the same procedure as applied for GERAS.

As shown in Figure 4.6.4, HERAS displayed high internal consistency for ages 3–6, but no internal consistency for ages 1–3.

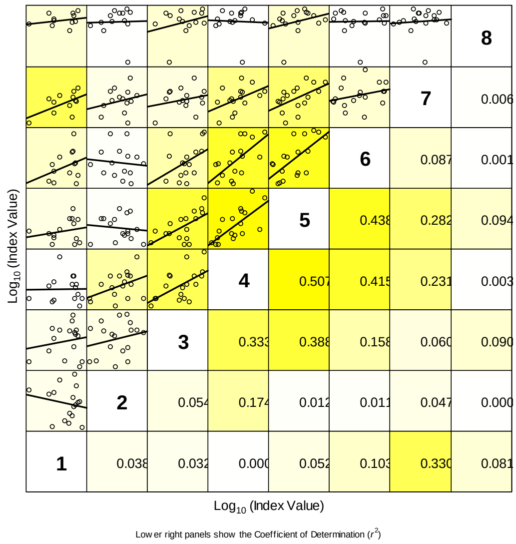


Figure 4.6.4. Correlation coefficient diagram for acoustic survey by cohort.

The external consistency between HERAS and the non-larvae surveys was analysed following the same procedure as described for GERAS above. HERAS showed a relatively high consistency with IBTS-Q3 for age 4.

Conclusion

The HERAS index consistently provides age-disaggregated information on WBSS herring. There is a strong internal consistency when tracking cohorts as obtained from the acoustic survey time-series and it correlates with other indices on the older age groups. Thus the time-series derived from the acoustic survey from 1996 to the present is regarded as a relatively good and precise indicator for abundance-at-age. It is continued to be used as one of the tuning indices in the assessment.

IBTS Q1 and Q3

The International Bottom Trawl Survey (IBTS) in Division IIIa is part of the IBTS surveys in the North Sea. The survey started out as the International Young Herring Survey (IYHS) in 1966 with the objective of obtaining annual recruitment indices for the combined North Sea herring populations (Heessen *et al.*, 1997). It has been carried out every year since. The survey is considered fully standardized from 1983 onwards, when it became known as the International Bottom Trawl Survey (IBTS). Examination of the catch data from the 1st quarter IBTS showed that these surveys also gave indications of the abundances of the adult stages of herring, and subsequently the catches have been used for estimating 2–5+ ringer abundances. The surveys are carried out in

1st quarter (February) and in 3rd quarter (August–September). During the HAWG 2002 the IBTS survey data (both quarter) were revised from 1991 to 2002 and was deemed unfit as indices for the WBSS, however, as part of the WKPELA benchmark the suitability of these indices were re-evaluated.

The internal consistency of both surveys was analysed following the procedure described for GERAS, and in general the internal consistency in the two IBTS time-series was less than for the acoustic surveys. Overall consistency was highest among older fish and in IBTS-Q1 (Figure 4.6.5).

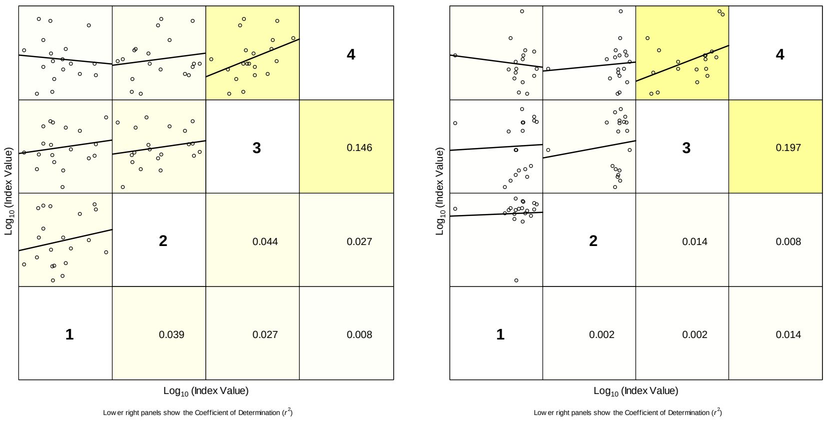


Figure 4.6.5. Correlation coefficient diagram for IBTS Q1 (left panel) and IBTS Q3 (right panel) survey by cohort.

The external consistency between the IBTS surveys and the non-larvae surveys was analysed following the same procedure as described for GERAS above. The external consistency between HERAS and IBTS-Q3 for age 4 and between IBTS-Q1 and IBTS-Q3 for age 1 was relatively high.

Conclusion

Given the apparent external consistency between the two IBTS surveys and the acoustic surveys, the WKPELA found no reason to exclude the surveys in the initial set-up for the assessment of the WBSS.

N20

The inshore waters of Strelasund/Greifswalder Bodden (ICES SD 24) are considered the main spawning area of Ruegen herring which represents a significant component of the WBSS stock. The German Institute of Baltic Sea Fisheries (TI-OF), Rostock, monitors the density of herring larvae as a vector of recruitment success since 1977 within the frame work of the Ruegen Herring Larvae Survey (RHLS). N20 delivers a unique high-resolution dataset on larval herring growth and survival dynamics in the Western Baltic Sea (see WD 09; Oeberst *et al.*, 2009 for detailed description).

In 2006 the rationale and methodology of the survey has been reviewed twice by external scientists (Dickey-Collas and Nash, 2006; Dickey-Collas and Nash, 2011) and the conclusions of this process were that the survey design of the RHLS was greatly improved and efforts were made to test many of the underlying assumptions (WD 09). The data collected provide an important baseline for detailed investigation of spawning- and recruitment ecology of WBSS herring stocks. As a fishery-independent indicator of stock development, the recruitment index is incorporated into the ICES Herring Assessment Working Group (HAWG) advice since 2007 as the only 0-group recruitment index for the assessment of WBSS herring.

The consistency/ability of the N20 to match the recruitment of the WBSS stock was analysed by correlating the larvae-index in year i with age class 1 in year i+1 and age class 2 in year i+2, etc. Figure 4.6.6 shows the consistency between the N20 and the 'New GerAS' which proved to be the survey fitting the N20 best. The index from the Larvae survey is externally highly consistent with GERAS age 1 (best for the new time-series) and to some extent with age 0 in the same survey.

Conclusion

WKPELA found no reason to exclude the survey in the initial set-up for the assessment of the WBSS.

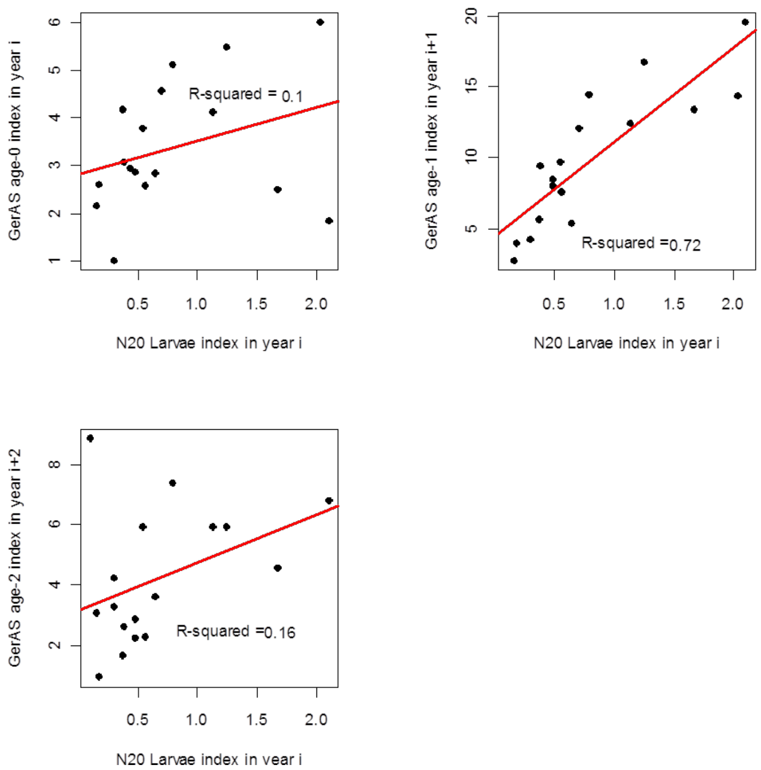


Figure 4.6.6. Correlation coefficient diagram for N20 with the 'New GerAS' Survey by age-group.

Concluding – all surveys

There are no surveys which are deemed unfit for testing as suitable indices for the WBSS stock complex in an assessment model. There are unfavourable external consistencies with several of the surveys, but the conclusion in the group was to let the chosen assessment model determine the degree to which each of the surveys inform the estimation of stock size and effects of harvest in the first run.

4.6.3 Weights, maturities, growth

As preparation for the WKPELA, the precision of ageing was analysed for both German and Danish readers. Sets of otoliths were reread by the same age reader, which had performed the first age reading and the readings were then compared to examine the potential drift of age readings. The precision of the age readings was very high with a correlation of >90% between the two age readings for both laboratories; the procedure is further described in WD07.

Catch-at-age data (catch numbers-at-age, mean weights-at-age in the catch, mean length-at-age) are derived from the raised national figures received from the national laboratories. The data are obtained either by market sampling or by on-board observers, and processed as described above. Information on recent sampling levels and nations providing samples should be provided as part of the HAWG annual working group report.

Mean weights-at-age in the stock is taken as the mean weight-at-age in the catch at spawning time, which is defined as Quarter 1.

Maturity ogives of WBSS has been evaluated in WD06 (Oeberst and Gröhsler) and WD10 (Bartolino *et al*.). Growth and maturation variations are the expression of phenotypic plasticity in response to variability in environmental factors such as food level (Berrigan and Charnov, 1994), temperature (Atkinson, 1994), and density-dependent processes (Engelhard and Heino, 2004). Thus the application of a constant maturity ogive vector for the stock needed to be evaluated. Two surveys were investigated as potential sources of annually updated maturity ogives; the GerAS (WD06) and the IBTS Q1 (WD10).

The survey time of GERAS is not optimal to estimate any maturity ogive for the total stock, and any estimates from this survey most likely give an underestimation of the fraction of spawners. The GERAS results indicate that the values of Proportion Spawners (PS) of age groups 2 and 4, which are presently used within the assessment, represent an underestimation of the fraction of spawners at least since 2007.

The variations of PS from year to year are most likely driven by the variable beginning of maturation of herring in October. The processes triggering maturation are unclear.

An increasing proportion of herring with maturity stage 6 and 7 in October within the last years indicates increasing spawning activities in late autumn and winter. The reasons for the observed shift are still unclear.

The available IBTS Q1 data on herring maturity are representative of the pre-spawning period for WBSS, but do not sample the whole distribution of the stock during that time of the year. In particular, during the 1st quarter of the year a large part of the mature WBSS have left the Kattegat and Skagerrak areas, and can be found in the western Baltic which is not sampled by the IBTS survey. Moreover, we found that mixing between WBSS, NSAS and local winter spawners represents a relevant issue for correct estimation of maturity ogives of WBSS. Before 2002, no information on stock identification is available from the IBTS data, and it is not possible to account for the confounding effect of stock mixing before this period. We found that information from vertebral count is not of help in this respect. Besides the existence of an interannual variability in the proportion mature at age from IBTS data, which may be expected to have a high influence on the estimation of the spawning–stock biomass of WBSS herring, it is not possible for the time being to reconstruct a time variable maturity ogive representative of the whole WBSS stock and for the whole time period covered by the assessment.

Concluding: WKPELA decided to carry on with the application of the constant maturity ogive vector for WBSS:

Age/W-rings	0	1	2	3	4	5	6	7	8+
Maturity	0.00	0.00	0.20	0.75	0.90	1.00	1.00	1.00	1.00

4.6.4 Assessment model

The assessment model ICA (Integrated Catch-at-Age with a separable period and VPA part) has been used to assess the WBSS herring stock for more than a decade. Despite the computational limitations when the model was first created, it was generally regarded as performing well and was considered ahead of its time. However, after several years of successful use, a number of issues related to the use of ICA have been found to affect the assessment of WBSS. Thus, the working group decided to include the evaluation of other methods for the assessment of WBSS during this benchmark.

A number of problems in the ICA assessment have been noted. Some of these include non-convergence of the model, its ability to only take a maximum of 59 years of data, the inability to fix technical issues (the core minimization library is no longer maintained resulting in the inability to compile the Fortran code of ICA), but also the assumption part of ICA. Another undesirable feature of ICA is that it is not a fully statistical model, mixing aspects of a deterministic VPA model (i.e., fishery catches are assumed to be without any error) with elements of a statistical model (i.e., model parameters estimation). Due to its limited flexibility, ICA does not give the opportunity to evaluate these and other critical assumptions which are behind the assessment of WBSS. Moreover, it has little potential for including relevant new information on the complex biology of WBSS which could improve representation of the available input data for this stock. These issues, together with the wish to have more control to create a tailor-made assessment model for WBSS, has increased the need to include a model evaluation in the benchmark assessment for this stock. The aim is primarily to test a statistical assessment model representing the current state-of-the-art, while still being relatively simple to understand and explain to the outside world (as managers and stakeholders demand a clear description of the assessment models from scientists.

- The new assessment method for WBSS aims to incorporate both existing and new scientific knowledge and better treat the available data. A multi-step approach has been proposed according to the following steps:
  - Modelling framework selection: identification of a suitable modelling approach for the assessment of WBSS and model initialization;
  - Data selection: a coarse-scale approach to identifying which datasets should be excluded and which should be included, using an all-in model as the starting point;
  - Data refinement: examination of fine-scale aspects of the selected data;
  - Model refinement: reduction in the number of parameters estimated to produce the simplest model that can adequately represent the data;
  - Final evaluation: detailed examination of the final model to identify any outstanding issue and potential improvements to the model.

4.6.4.1 Model selection

AD Model Builder (ADMB) is state of the art statistical software that is tailored to analyse nonlinear dynamic models and efficiently estimate large numbers of parameters including both fixed and random effects. The extra flexibility of the random effects allows the estimation of alternative settings of population model parameters and to statistically compare them allowing the model to weigh the contributions of all relevant individual data sources that may inform the assessment.

After evaluation of the assessment tools available, of the biology of WBSS herring stock and its fishery, and also of the working group competences, we identified the state–space assessment model SAM as an appropriate model to be compared to the current assessment model (integrated catch analysis ICA) for this benchmark (https://www.stockassessment.org). Thus, for the initial selection of the assessment framework we compared the identical ICA configuration used for the assessment of WBSS herring in 2012 (ICES 2012, HAWG) and an "equivalent" SAM run.

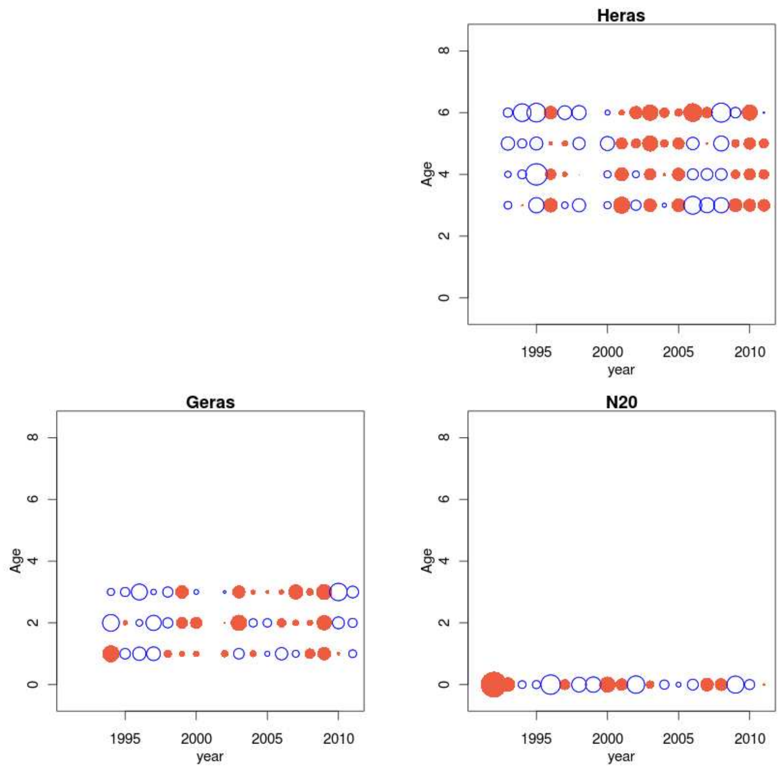


Figure 4.6.7. Bubble plot of survey residuals by year and age from the ICA model used for the assessment of WBSS herring in 2012.

The main purpose of this initial comparison was to set a SAM model as similar to the current ICA model as possible. To initialize this run of SAM (SAM0) we used a slightly modified version of the default configuration setting where survey catchability is allowed to be estimated independently for each age, while estimation of the observation variances are constrained to be equal among the ages within each data component (i.e., catch and surveys). The variances in the F random walk were also constrained to be equal for all the age classes. In addition, this initial SAM run assumed correlated random walk on fishing mortality. This setting was adopted as it is able to estimate correlated variations in the fishing mortality which may quantify the degree of separability of year and age effects on fishing mortality (Fay = Fy ∗ Sa) applied in ICA (in ICA this is restricted to the last six years of the model).

Comparison of the survey residuals between SAM0 and ICA shows an overall very similar pattern (Figures 4.6.7 and 4.6.8). This suggests a general ability of SAM to reproduce consistent fitting to the survey components with ICA. A more detailed comparison shows that the problem of temporal autocorrelation in the residuals from some of the survey fit is slightly reduced by SAM, such as in the HERAS fit age4 years 1993 and 2004, in the GERAS fit age3 year 1996 and 2005.

Beside the fact that the two models are evaluated and compared mostly in relation to how they fit the different survey data, we also wanted to inspect the estimations of SSB, F and R from the two models to determine whether they are depicting similar dynamics of the WBSS herring stock (Figure 4.6.9). In general, the two models show high congruence in the patterns of SSB (R-sq=0.97, p-value<0.001), R (R-sq=0.89, p-value<0.001), and F(R-sq=0.75, p-value<0.001). Moreover, the ICA estimates of R and F lay mostly within the 95% CI of the SAM estimates, while some differences were found for SSB with ICA estimating values somewhat higher than SAM during the second half of the time-series (Figure 4.6.9).

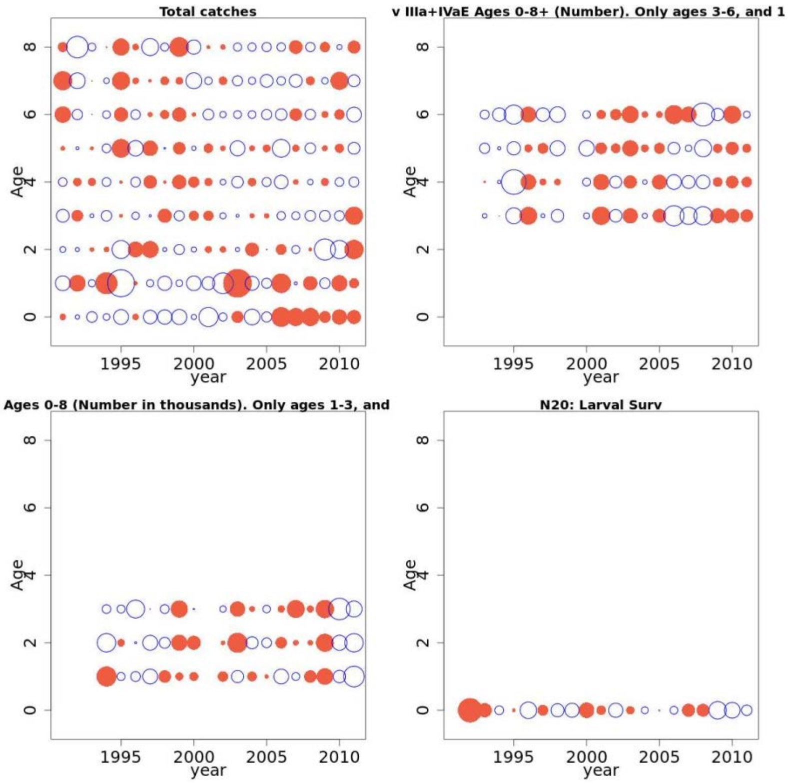


Figure 4.6.8. Bubble plot of catch and survey residuals by year and age from the initial SAM run (SAM0).

According to these results, we concluded that SAM is able to make a similar use of the survey information as ICA, and slightly improve the fitting by reducing part of the temporal autocorrelation affecting ICA. The overall stock dynamics are also comparable, beside the existence of differences, particularly in the SSB levels.

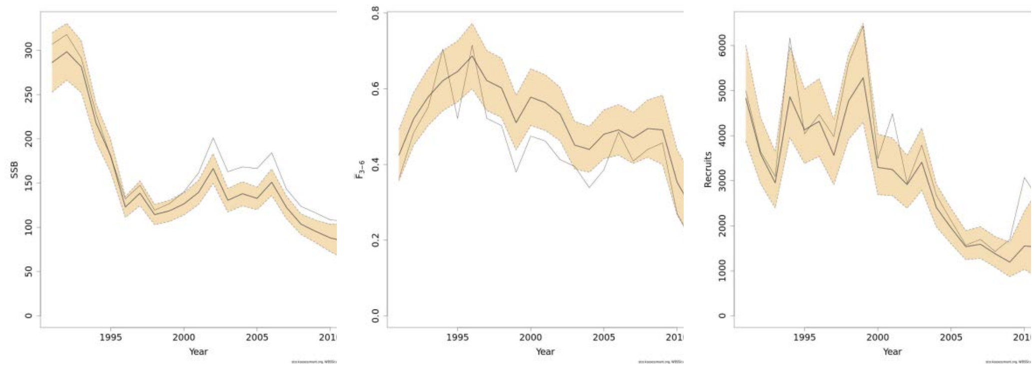


Figure 4.6.9. Comparison of SSB, F and R from ICA-based assessment of WBSS herring in 2012 (thin line) and SAM (black line with 95% CI) based on the same input data.

As described above, WKPELA decided to apply SAM as the primary assessment model tool, however, in addition the group used the AMAK for exploration of the fit of both ICA and SAM.

Statistical catch-age model with time- and age-varying selectivity (AMAK)

An alternative age structured model was applied for contrast and to gain further insights on the data and potential sensitivities of model assumptions. The application used is also an ADMB model like SAM (and an extension of the AMAK model from NOAA: http://nft.nefsc.noaa.gov/). The data from the HERAS and GERAS surveys were compiled into aggregated biomass indices and proportions-at-age. Similarly, the fishery catch data were converted into total biomass of landings and the catch-at-age in each year were treated as proportions. Parameters estimated include the recruitment in each year, annual fishing mortality rates, selectivity (for a pre-set number of ages) and depending on configuration, additional parameters allowed changes in selectivity over time. Results from this approach provide an alternative way to judge the data and goodness of fit (Figures 4.6.10 and 4.6.11). Survey catchability was estimated (with a diffuse prior with mean 1.0) to be about 1.6 indicating that stock estimates from the model were smaller than those from the survey. Spawning biomass was estimated to be highly uncertain but increasing recently (Figure 4.6.12). The age-specific natural mortality used for sardine in the Iberian region was used (Figure 4.6.12). As this is the first time SAM has been applied to WBSS data, providing a simple approach for evaluating alternative specifications (e.g. evaluating the impact of specifying annually varying sampling variability between different datasets) may help in guiding future modifications/specifications of SAM.

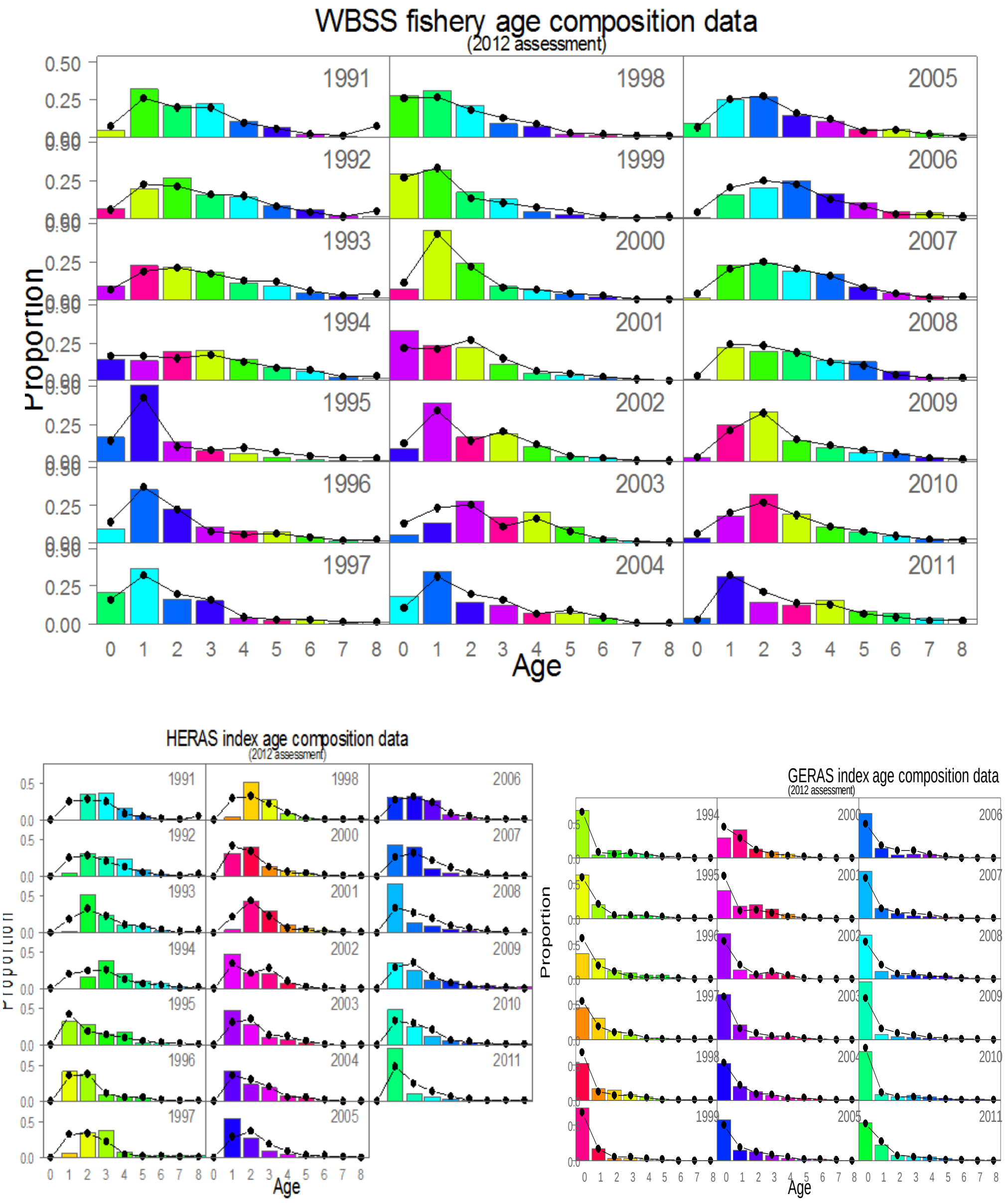


Figure 4.6.10. Example fit to available fishery (top) and survey (bottom) age composition data. The different colour bars represent data on cohorts through time whereas the dotted lines are the model fits.

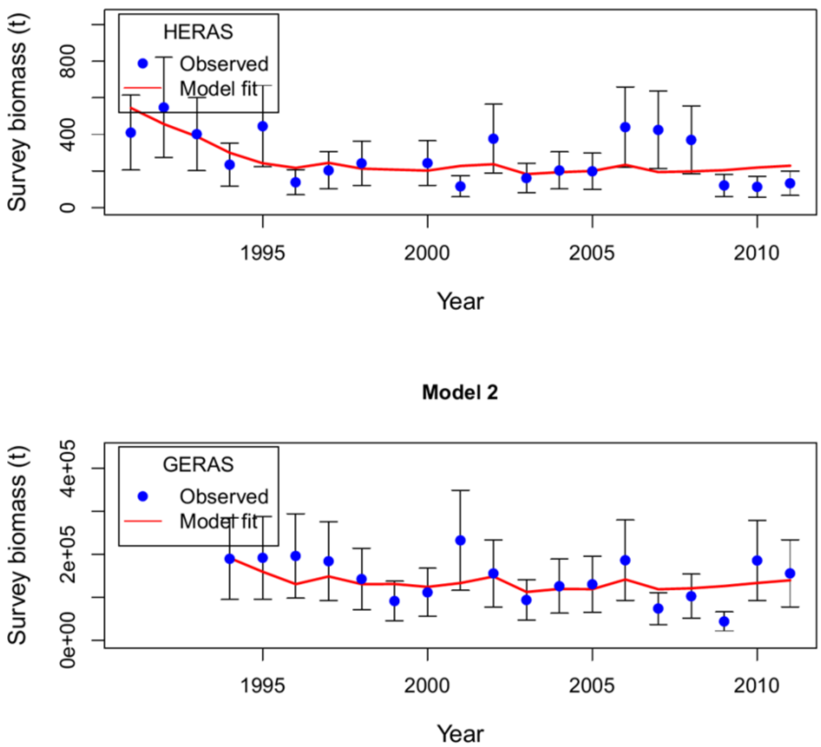


Figure 4.6.11. Example results of fit to different indices used in the model. Error bars represent the uncertainty specified as input to the model.

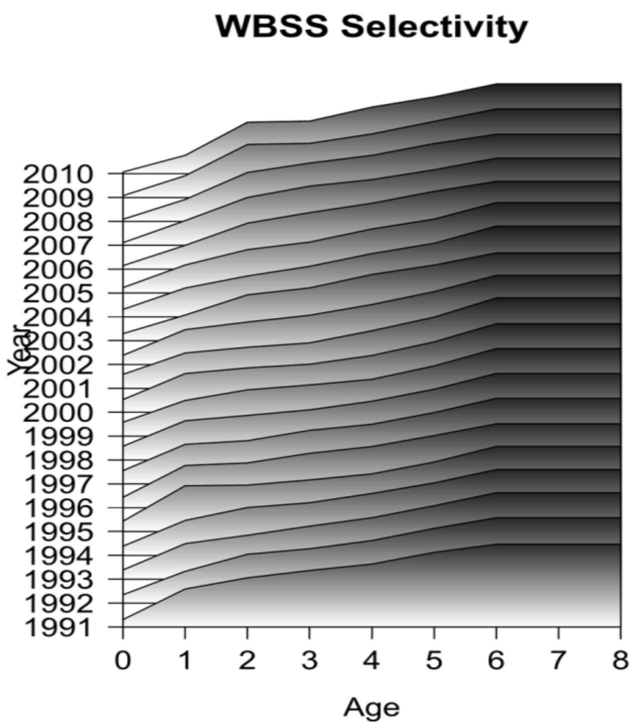


Figure 4.6.12. Example result of fishery selectivity illustrating the semi-separable ability to allow changes over time.

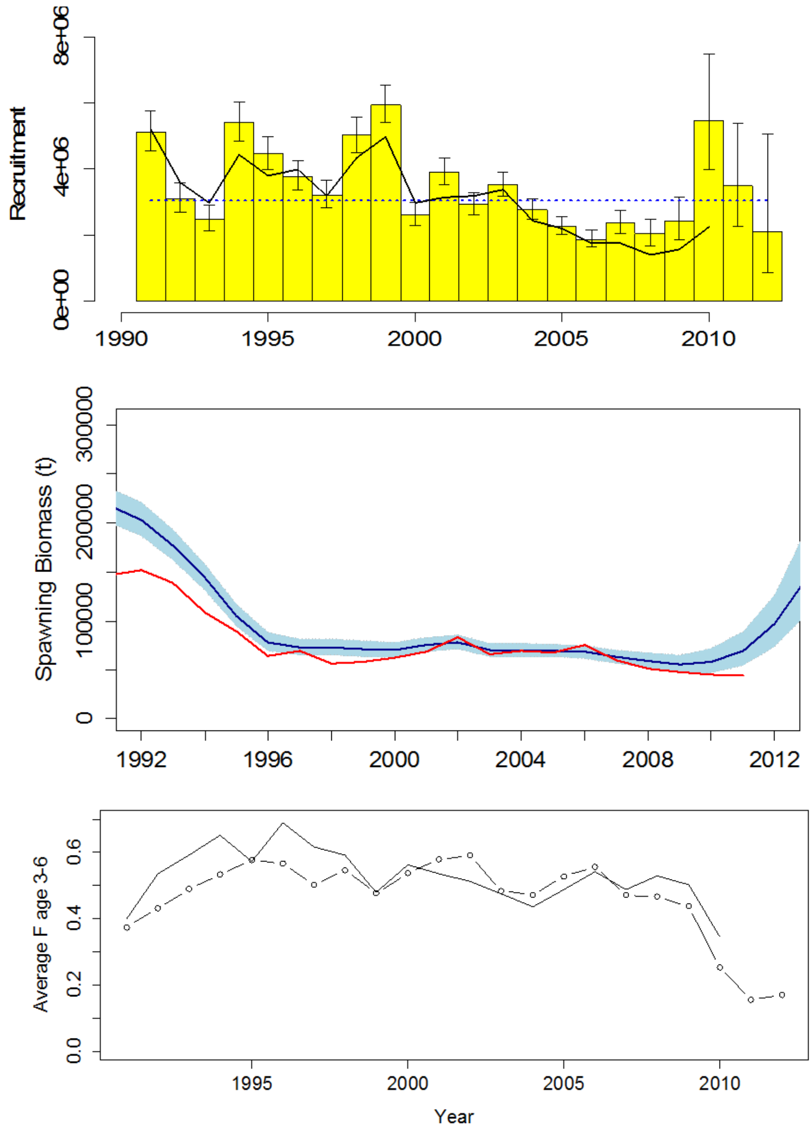


Figure 4.6.13. Example results showing recruitment estimates (top) and spawning biomass (middle) and age 3–6 fishing mortality (bottom) 1991–2012. Lines represent results from SAM model (note: spawning biomass for the SAM model uses time-varying mean body mass-at-age whereas the AMAK model uses a single mean vector based on the mean over 2009–2011.

4.6.4.1.1 Data selection

During the preparation of the benchmark assessment, all potential data sources, including both those used in the current configuration and other alternative data sources (extra survey tuning-series, historic catch data and alternative estimates of natural mortality) were considered. As a starting point for this process, an 'all-in' model was created where all data available would be fitted within the assessment model.

4.6.4.1.2 Choice of surveys

All available surveys are described in Section 4.6.2. All were used in the 'all in model', including the new GerAS index, which appears to have some better internal consistency that would support its use for the assessment of WBSS herring. However, we decided to investigate also the impact that this choice may have within the assessment model. For this reason, the old and new GerAS indices have also been evaluated within SAM under "equivalent" default settings of the model.

Inspection of model residuals on the fit of catch and survey data showed very minor differences between the two runs, and we could not find major evidence that the assessment model fits better one of the two versions of the GerAS survey, or that this may improve fitting of the other data. Minor differences have been found in the main model outputs, and as expected only in the last few years of the time-series.

This information and additional data have been carefully scrutinized and presented in separate working documents (WDs 01–04; WD08). WKPELA had no *a priori* information to exclude any of the available survey indices or parts of them, thus all the datasets available have been evaluated within the model assessment.

4.6.4.1.3 Natural mortality

The main tool utilized for multispecies assessment in the Western Baltic Sea has been multispecies virtual population analysis (MSVPA, ICES 1997/J:2). Basically, MSVPA (Sparre, 1991) has integrated the prey–predator suitability concept of Andersen and Ursin (1977) with traditional virtual population analysis.

The last multispecies run for the Western Baltic Sea has been performed in 1999 (ICES, 1999). In this run, natural mortalities were calculated, accounting for predation in herring by cod, and assuming an annual residual morality rate of 0.2.

The predation mortality rates for Western Baltic herring have not been updated since. The cod stomach data from 1977 to 1992 were used for the 1999 estimates. There is presently no additional data available. Furthermore, the multispecies model currently applied used quarterly commercial catch numbers, which have not been compiled for the Western Baltic, yet. The predation mortality rates estimated at the time are probably not transferrable to the present situation. There is an increased recognition of a migratory pattern for Western Baltic herring, and the predation rates based on the old stomach material cannot be assumed to reflect the actual average overlap between herring and its major piscine predator cod. Both the abundance of alternative fish prey, for example sprat, and perhaps more importantly, changes in the availability of benthic food, add further evidence of the invalidity of the old predation rates. New stomach sampling is currently in progress. However, the stomachs have to be analysed first, and the catch data have to be re-compiled back to 1999. Both of these activities, and also the model implementation, depend on the funding situation and a time frame is currently not predictable. Furthermore, it appears obligate to account for the variable spatial overlap between herring, sprat and cod, and whether the model is able to reproduce observed cod stomach content compositions remains to be seen.

WKPELA finds it necessary to apply a spatial and temporal explicit MSVPA in order to account for the migrating nature of the main herring components within the WBSS herring stock complex.

4.6.4.1.4 Sampling/modelling of stock component splits

The estimation of stock proportions (the split) of samples from mixed stock fisheries and surveys rely as earlier described on different methods depending on which stocks that mix.

In the past, both survey and landing samples were used to get full coverage of the distribution area. These were supposed to be raised to proportions of total landings using the distribution of landings by ICES rectangle and quarter. Due to unidentified misreporting to some ICES rectangles in Division IIIa this procedure has been postponed awaiting a revision of the sampling data base and exclusion of samples from identified misreported landings.

Since 2008 samples are collected from the commercial herring fishery proportional to landing weights, and because misreporting is considered not to take place since 2008, the basis for the split in recent years is assumed to be more robust. A table with proportions of WBSS herring in catches by Subdivision (Kattegat=SD21 and Skagerrak=SD20), quarter and age 0–8+ is produced from the combined Danish and Swedish samples. A similar table based on primarily Norwegian samples of vertebra counts is made for a subunit of the ICES Area IVa East (the so called transfer area).

The split table of catches of NSAS and WBSS in Division IIIa is applied to the numbers caught by Subdivision, quarter, and age. The calculated numbers by age of NSAS in Division IIIa are then transferred from the assessment of WBSS to the assessment of NSAS, and the numbers by age of WBSS caught in the transfer area are moved from the NSAS assessment to the WBSS assessment.

Due to the frequent event of low numbers of old age individuals in some of the cells in the tables, pooling of adjacent old ages is performed when sample sizes are less than ten individuals. Although the proportion mature WBSS in Division IIIa is generally close to 100%, pooling will hide any useful cohort information in the split data. Attempts to model spatial and temporal signals of WBSS proportions in the stock distribution area show promising results. However, underlying bias from sampling of misreported catches prevent any meaningful recalculation of the time-series of stock proportions.

For a revision of the proportions WBSS in the early part of the time-series samples from misreported landings should be identified and excluded from the database before recalculating or modelling the split. Identification may be based directly on vessel ID and deviating fishing pattern. If such ID is difficult to verify due to inconsistency between logbook dates and sampling dates, indirect methods may be applied using catch composition in forms of length, weight and maturity-at-age together with observations of stock proportions to identify likely misreported catches.

4.6.4.1.5 Maturity ogives

As described in Section 4.6.3 the input on maturity ogives was decided to be kept as in the existing assessment.

4.6.4.1.6 Final refined input data

To identify the final refined input data, we used an initial highly flexible setting on the observation variances estimated by the model (SAM1; 32 observation variance parameters). In practice we left the model to estimate an observation variances parameter for each age class (only age 7 and 8+ were coupled) and dataset (both catch and survey data), so that we could determine the model estimation of the relative influence of the different data sources. Moreover, this preliminary run was also used to inform the initial setting for the variance structure assumed for the observations (SAM2).

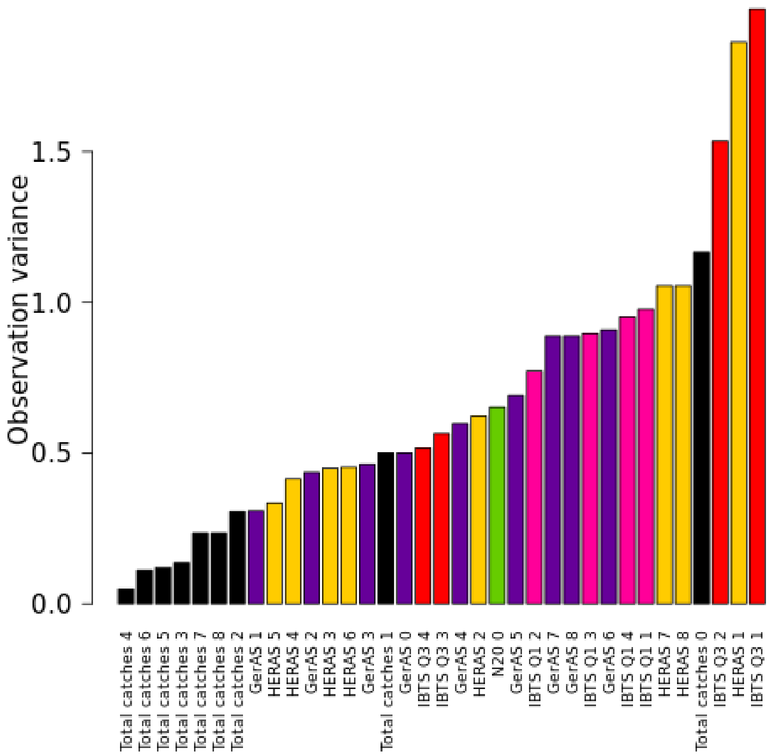


Figure 4.6.14. Estimated observation variance for the run SAM1 with all independent observation variance parameters.

Interestingly, we found that the model mostly estimates lower observation variances for those surveys and ages which are used in the ICA assessment (i.e., age 1–3 GerAS, age 3–6 Heras), supporting our previous perception of the data and their associated uncertainty (Figure 4.6.14). Similarly, greater observation variances were estimated for those ages and surveys which were not used in the 2012 assessment (i.e. generally IBTS, age 7–8+ of both GerAS and Heras). The wide range of observation variances estimated by SAM, and the high values estimated for some of the data, allowed for differences in goodness-of-fit for each of the data sources. In practice, the model downweights the influence of data on the fitting when variances are large, but they do not have to be rejected as still provide some information. Figure 4.6.15 shows the datasets used in the SAM model and in the previous ICA assessment.

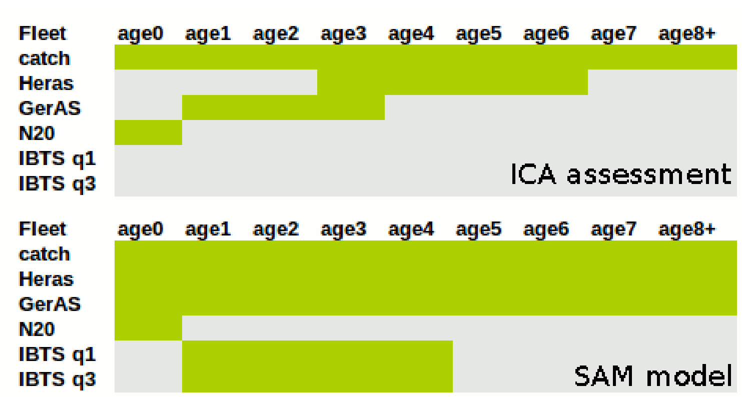


Figure 4.6.15. Plot with the age classes used in the previous ICA assessment and current SAM models (in green).

4.6.4.2 Model refinement

4.6.4.2.1 Catch observation variances, including bindings

The observation variance estimated during the preliminary run (SAM1; Section 4.6.4.1.6) was used to inform the binding of the catch observation variance (SAM2). Accordingly, the observation variance was coupled and estimated as a single parameter for age 2–8+, while age 0 and 1 had their own estimated variance (age 0,1,2+; Figures 4.6.14 and 4.6.16).

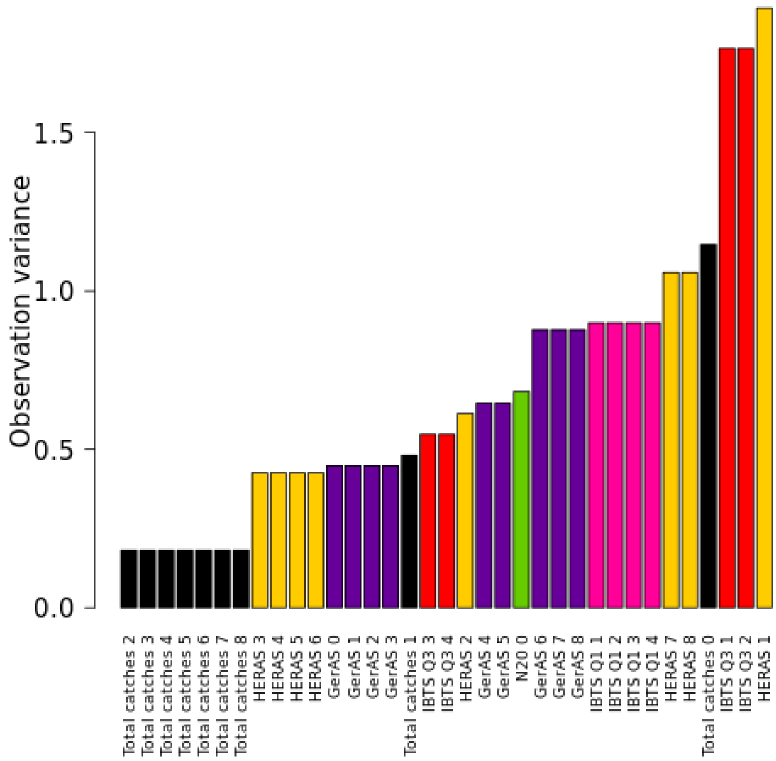


Figure 4.6.16. Estimated observation variance for the run SAM2 after initial binding.

Inspection of the residuals for the catch shows a good fitting of the catch-at-age matrix. No major patterns are observed in the residuals both over time or ages. We found that age 0 in catch is estimated to be larger than the observed during the last six years, but in general the catches may be considered properly fit also in comparison to the other data components.

The initial parameterization of the catch observation variance (age 0,1,2+) appears appropriate to represent major differences in the catch composition of the different fleets targeting herring, with fish of age 0–1 dominating the industrial fishery (D-fleet), and larger age classes in the consumption fishery (C-fleet). However, the composition of the catch in the consumption fishery is highly diverse in space, with different age classes representing the peak of the catch. In particular, the C-fleet catch has a peak of age 1 fish in Subdivision 22, age 2 dominates the catches in Subdivision 20 and 21, while age 3 and age 4 are highly represented in Subdivisions 24 and 23, respectively. For this reason, we tested two alternative parameterizations of the catch observation variance as follows: four parameters for ages 0,1,2, and 3+ and five parameters for ages 0,1,2,3, and 4+ (SAM3 and SAM4, respectively). We found that these additional parameters (one and two more compared to run SAM2) have no appreciable impact on the model fitting in terms of residual as well as on the output (Figure 4.6.17). Moreover, their log-likelihood was significantly no different from the likelihood estimated for SAM2. Based on this comparison the most parsimonious setting of the catch observation variance (age 0,1,2+) appears to be sufficient and appropriate for describing the uncertainty in the catch data. As a final evaluation, in Section 4.6.4.1.6 we analysed the potential interaction between the binding of the variance in the F and the catches observed, to identify the best setting of these two relevant parts of the model.

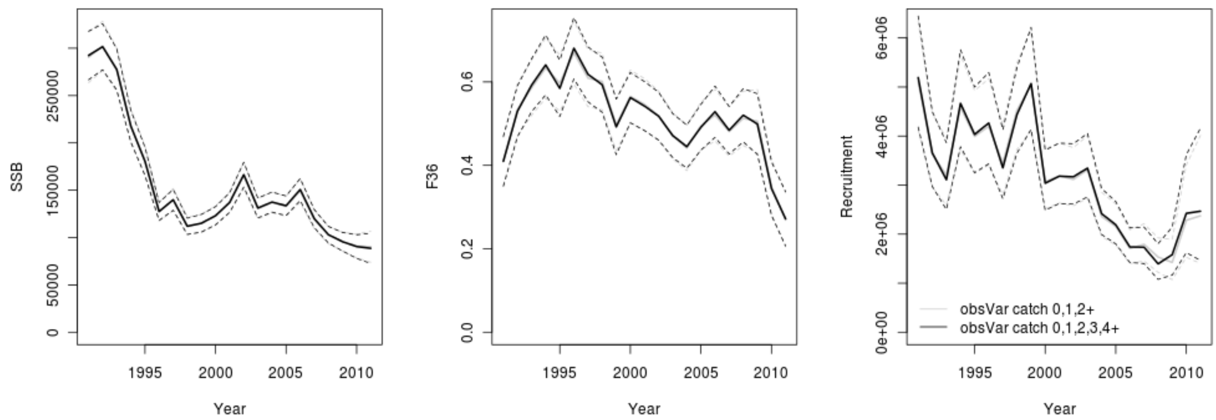


Figure 4.6.17. Comparison of SSB, F and R for the models SAM2 (grey line) and SAM4 (black line).

4.6.4.2.2 Survey observation variance bindings

The observation variance estimated during the preliminary run (SAM1) was also used to inform the parameterization of the survey observation variance as follows:

- Heras; four parameters for ages 1,2,3–6, and 7–8+;
- GerAS; three parameters for ages 0–3,4–5, and 6–8+;
- IBTS q1; one parameter for ages 1–4;
- IBTS q3; two parameters for ages 1–2,and 3–4.

Overall, the parameterization maintained the observation variance ranking of the main data components in the model. This drastically reduced the number of parameters in the model from 60 in the preliminary run (SAM1) to 42 (SAM2).

The analysis of residuals from the surveys revealed a generally good fit of all the datasets used (Figure 4.6.18). There are no age classes which are poorly fitted for most of the time-series in any of the surveys. At time larger residuals occur in some ages and specific years (i.e. Heras age 8+ in 2006). Overall the residuals show no worrisome patterns. The distribution of positive and negative residuals is considered good, with no large patches of positive and negative residuals (Figure 4.6.18). Some more pronounced year effects may be observed in the residuals of the surveys, particularly in 1996, 1997 and 2008, 2009 of the GerAS, but they are still considered appropriate in relationship to the complexity of the model and the amount of information used in the model. Alternative parameterizations of the observation variance for the GerAS have been tested (SAM5), releasing the constrain between age 0 and age 1–3 (binding: age 0,1–3,4–5, and 6–8+). No improvement was observed in the residual pattern, as well as no significant improvement in the log-likelihood of the model.

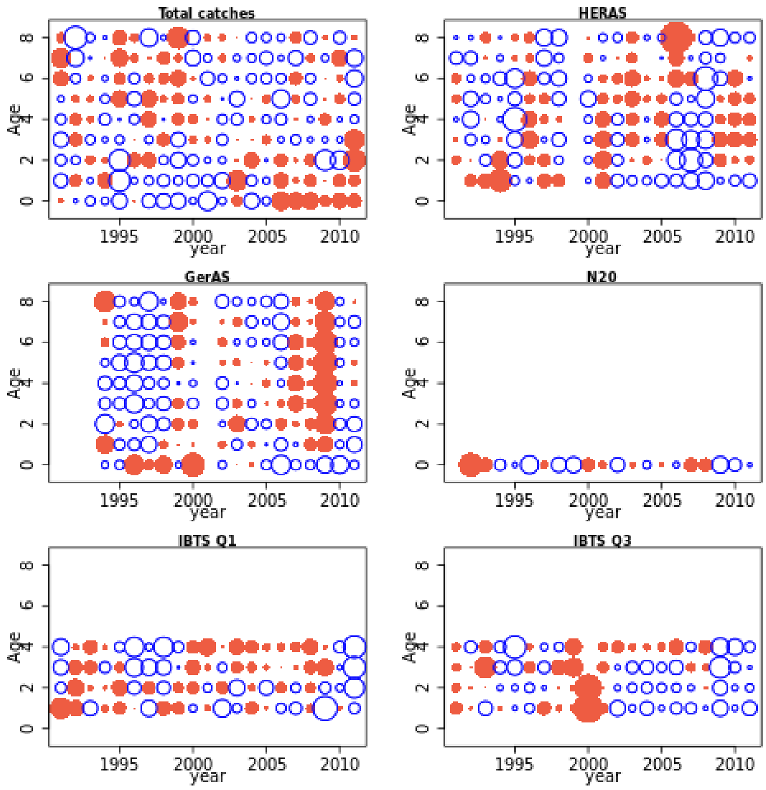


Figure 4.6.18. Bubble plot with normalized residuals for the run SAM2. Blue circles indicate positive residuals (observed larger than predicted) and filled red circles indicate negative residuals.

4.6.4.2.3 Fishery selectivity

Estimation of the selectivity pattern shows an increase in the selectivity with age, with lack of a real plateau level for the selectivity for the oldest age classes. The selection pattern resulted to be highly stable throughout the time period of the assessment, regardless the estimation of a correlated or independent random walk on F (See Section 4.6.4.2.5 below for explanation). Releasing the constraint on the F estimate for ages 7 and 8+ did not have significant impact on the selection pattern of the fishery nor the main model outcomes.

4.6.4.2.4 Survey catchabilities

Examination of the estimated surveys catchability shows rather different patterns for the surveys, with comparably higher catchability in the young age classes than in the oldest ages in several of the surveys (Figure 4.6.19). In the GerAS survey, age 0 has the highest catchability, which rapidly drops for age 1 and 2. Then it progressively increases up to age 5 to level a bit lower in ages 7–8+. In the Heras survey, age 1 has the lowest catchability, while ages 2–3 have the highest catchability which declines for the oldest age groups. Even more pronounced reduction in catchability is estimated from age 1 to age 4 in both the IBTS surveys. The patterns estimated were stable to alternative parameterizations of the catchabilities. At the current stage there is no real interpretation behind the specific catchability patterns detected. Likely a number of reasons including ontogenetic differences in the spatial distribution and behaviour of the different age classes at the time of the surveys may affect their relative availability to the different samplings. In none of the runs did the residuals suggest erroneous estimation of catchability given the available data and the current assumptions on natural mortality.

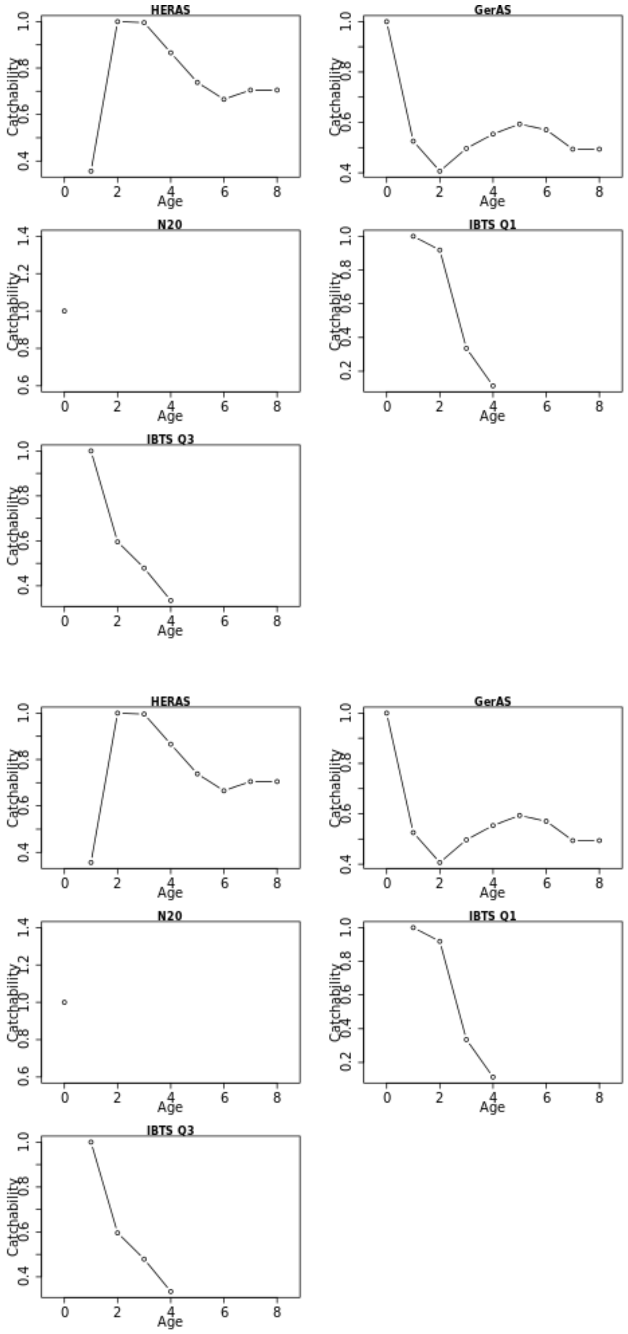


Figure 4.6.19. Survey catchability as estimated by the model (SAM2).

4.6.4.2.5 Fishing mortality random walk variances and correlations

The previous assessment of WBSS herring assumed separability of age and time effects on fishing mortality for the last years of the assessment. The SAM framework offers to some extent the opportunity to evaluate the validity of this assumption. The model fitting in SAM is based on a random walk on the fishing mortality for each age class (hereafter also referred as F random walk). The random walk in F for each age class is specified by a variance parameter and the correlation of the F at age in a given year can either be specified or estimated. When the correlation in the F at age is 1, the age and time effects are separable (selectivity is the same over time). When the correlation is 0, the F at age are independent. Leaving the model to estimate this correlation parameter (as in all the runs above), may allow to estimate whether there is an invariant selection pattern of the fishery.

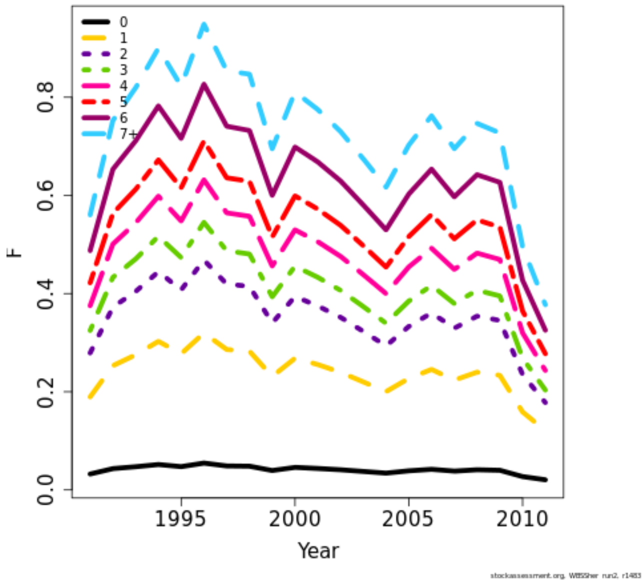


Figure 4.6. 20. Time-series of fishing mortality-at-age under correlated random walk (SAM2).

In all the runs tested, the correlation parameter on the F random walk was estimated to be very high, and in most cases 0.99 (the upper bound allowed for the parameter). This would suggest a high tendency toward a multiplicative model (Figure 4.6.20), i.e. a separable model for fishing mortality. Also comparison of the negative log likelihood and AIC of two equivalent runs with independent (SAM6) and correlated (SAM1) F random walk favoured the latter (log-likelihood: 656.3 against 623.6; AIC: 1431 against 1367).

Detailed inspection of weight- and length-at-age from both catch and surveys suggested possible explanation of why the model estimates so high correlation in the F random walk from the WBSS herring data (Figure 4.6.21). Both individual weight and length show interannual variability and a synchronous pattern among the different ages (especially for ages 3+).

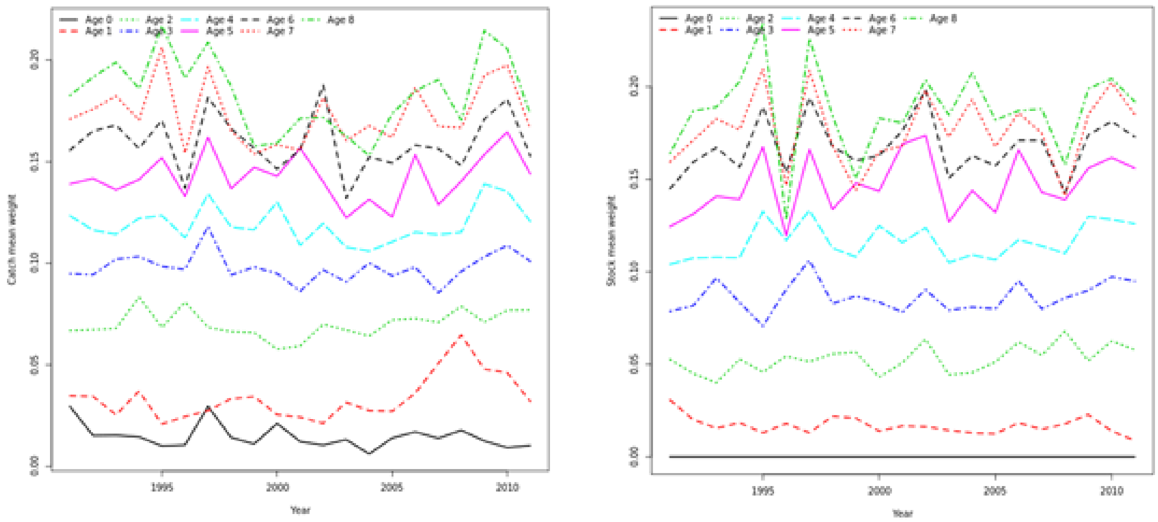


Figure 4.6.21. Time-series of weight-at-age in the catch (left) and in the stock (right) as used in the model.

Moreover, the pattern in the individual weight and length from the catch is also correlated between several subdivisions. This would suggest limited ability of the fishery to change its selection pattern according to variations in the size composition of the stock in different areas and years. The selection pattern and behaviour of the fishery is certainly changed over the whole period of the assessment, as also reported by the fishery itself, but it seems that it is hardly changed from one year to another. In this case, the selection pattern of the fishery has very small interannual variability, and we should expect that synchronous changes in the size of the fish in the stock, as observed in the data, could be translated into synchronous changes in the F at age, as actually represented by the high estimated correlation in F random walks.

A high correlation value in the F random walks represents an important structural feature of the model, with implications not only for the reconstruction of the stock dynamics during the last decades, but particularly for the use of the model in the forecasts. In practice the forecast of the stock may be informed by correlation in the F-at-age potentially increasing the prediction power of the model.

In the attempt to improve the fitting of the age 0 and 1 in the catch during the last few years, we tested a release in the constraint of the F random walk variance for the first age classes (SAM7). To do so, we left the model to estimate specific variance parameters for age 0 and age 1 and constrained those for ages 2+. In addition to a non-significant reduction in the negative log-likelihood of the model, we found some minor improvement in how the model was fitting the catch data for the young ages (Figure 4.6.22). This suggested that the model fitting could potentially benefit from having some flexibility in the variance of the random walk for the youngest ages. However, we postponed our decision on the final setting, after inspection of other model diagnostics such as the retrospective analysis on the F.

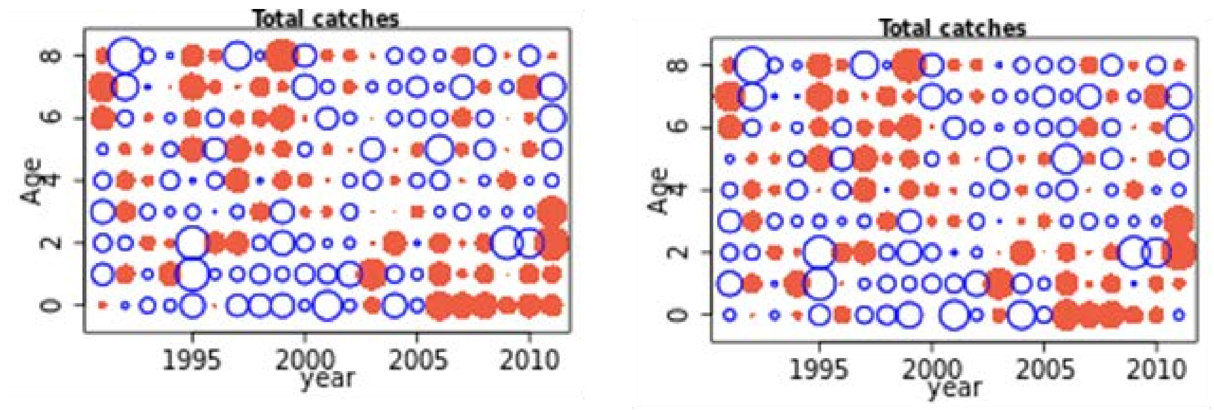


Figure 4.6.22. Bubble plot with normalized residuals for a model with coupled variance in the F random walk for all ages (SAM2: age 0+) and for a model with released constrain for the first two age classes (SAM7: age 0,1,2+). Blue circles indicate positive residuals (observed larger than predicted) and filled red circles indicate negative residuals.

4.6.4.2.6 Final model diagnostics

Further inspection of the model residuals confirmed what found in the residual analysis of previous runs. This confirmed minor patterns in the residuals which do not appear worrisome within the overall diagnostic and evaluation of the model.

Sensitivity of leaving out one survey at a time suggests generally stable estimates of SSB, F and recruitment. The Heras survey appears to be the most influential on the estimated trajectories, particularly on the SSB and F estimates. However, all the leave-one-out runs lay largely within the 95% confidence intervals of the model estimate.

We found the retrospective analysis of the model particularly useful to identify the most appropriate parameterization of the variance in the F random walk, and how this choice may interact with selection of the binding in the observation variance of the catch. This resulted in a trade-off between these two parts of the model where SAM allocates part of the process and observation uncertainty.

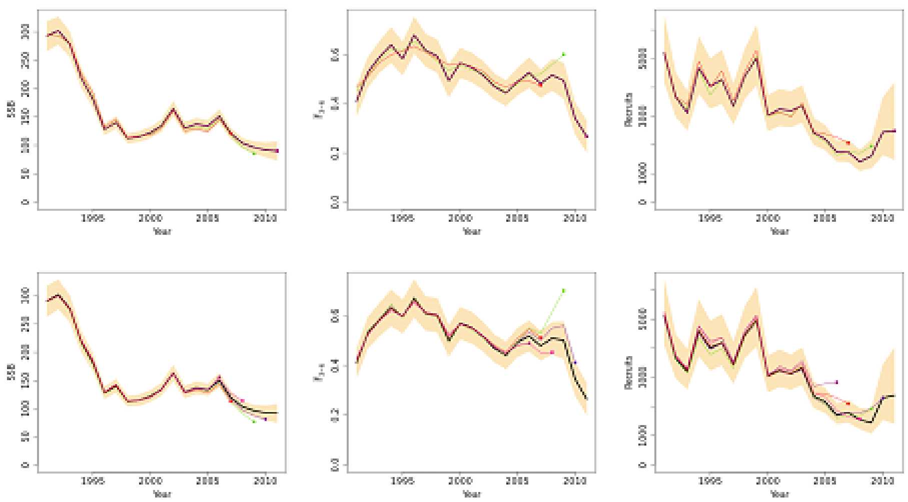


Figure 4.6.23. Retrospective plot of SSB, FBAR and R for two candidate final settings of the catch observation variance. Top: age 0,1,2,3,4+ as in SAM4; bottom: age 0,1,2+ as in SAM2, in combination with a more flexible binding of the variance on the F (age 0,1,2+ as in SAM7). The retrospective analysis on top line failed to properly estimate 3 over 5 of the retrospective runs (in this case only the red and green lines have to be considered valid for comparison).

In fact, we found that when the more flexible setting on the variance of F (SAM7; binding scheme age 0,1,2+) was associated with a more flexible setting for the catch observation variance (SAM4; binding scheme age 0,1,2,3,4+) the model failed in estimating a positive Hessian matrix in 3 over 5 retrospective runs (Figure 4.6.23). Moreover, the model tended to have smoother F pattern under this more flexible setting, as it is revealed by the complete loss of the 1994 and 1996 peaks in F (Figure 4.6.23). On the contrary, leaving higher flexibility on the variance of both F and the observed catches turned to have some improvement in the final year estimates of both F and SSB, but not for the second retrospective (Figure 4.6.23: green line, -2 years) where both the settings overestimate F largely outside the model 95% CI. This is a quite predictable and unavoidable misbehaviour of the model which had no element to predict the drastic reduction in F that followed the year after. The alternative setting with coupled observation variance of the catches for age 2+ promoted reconstruction of a more stable pattern in the first 15 years of the retrospective, still leaving final year estimates within the 95% CI for most of the retrospective runs.

This would suggest that larger freedom in both the random walk on F and catch observation variance may increase the probability that the model would significantly readjust the reconstructed pattern on F by the removal (or addition) of one or few years, which may be considered a quite undesirable feature. Thus, some more constraint on one of the two components (in this case on the catch observation variance) may allow a more stable reconstruction of the pattern, particularly for F, providing still reliable estimates throughout the whole time-series.

In conclusion, considering that the final model outputs were highly comparable between the two settings, the working group choose the more parsimonious option of mirroring the binding of the random walk on F and catch observation variance (age 0,1,2+).

4.6.4.2.7 Final model and configuration

In conclusion the analyses and tests presented largely support some of the main assumptions of the previous ICA assessment of the WBSS herring stock. Evaluation within SAM of the observation variance associated to the different data components is congruent with a priori considerations and analyses that in the previous assessment determined the exclusion of specific datasets. SAM has the ability to internally weight the influence of the different sources of information, with the possibility to include also datasets with larger noise but which are considered still informative.

The final setting of the SAM model (SAM7) is based on a correlated random walk on F which the model estimated to be highly correlated. The final model setting was specified as follows:

```
# Min Age
0
# Max Age
8
# Max Age considered a plus group (0=No, 1=Yes)
1
# Coupling of fishing mortality STATES

1      2      3      4      5      6      7      8      8
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
# Use correlated random walks for the fishing mortalities
# ( 0 = independent, 1 = correlation estimated)
1
# Coupling of catchability PARAMETERS
0      0      0      0      0      0      0      0      0
0      1      2      3      4      5      6      7      7
8      9      10     11     12     13     14     15     15
16     0      0      0      0      0      0      0      0
0      17     18     19     20     0      0      0      0
0      21     22     23     24     0      0      0      0
# Coupling of power law model EXPONENTS (if used)
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
# Coupling of fishing mortality RW VARIANCES
1      2      3      3      3      3      3      3      3
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
0      0      0      0      0      0      0      0      0
# Coupling of log N RW VARIANCES
1      2      2      2      2      2      2      2      2
# Coupling of OBSERVATION VARIANCES
1      2      3      3      3      3      3      3      3
0      4      5      6      6      6      6      7      7
8      8      8      8      9      9      10     10     10
11     0      0      0      0      0      0      0      0
0      12     12     12     12     0      0      0      0
0      13     13     14     14     0      0      0      0
# Stock recruitment model code (0=RW, 1=Ricker, 2=BH, ... more in time)
0
# Years in which catch data are to be scaled by an estimated parameter
0
# Define Fbar range
3 6
```

4.6.5 Perception of stock as a result of the benchmark assessment

As a final consideration, we may compare the estimated dynamics of the WBSS herring stock with the current ICA assessment. The new model estimates a less pronounced reduction of fishing mortality during the second half of the 1990s and higher F up to the mid-2000s (Figure 4.6.23). During the same period ICA also estimates higher recruitment, but mostly within the CI of the SAM estimates. The differences in the patterns of F and recruitment are likely the reasons for lower estimates of SSB approximately during the same period under SAM. Final year estimates tend to get closer between the two models, and ICA estimates of both SSB and F lay just at the 95% CI of the SAM estimates. The distribution of the residuals shows that the catches are well fitted by the model, particularly during this central time period (Figure 4.6.2.4), suggesting appropriate estimates of F given the current assumptions on natural mortality. One of the reasons of this difference may be found in the assumption of ICA that catches have no associated uncertainty, while they do in the fully statistical approach implemented by SAM. Despite this, our perception of the WBSS herring stock dynamics is generally unchanged under SAM, with comparable estimates of SSB and F during the rest of the time-series.

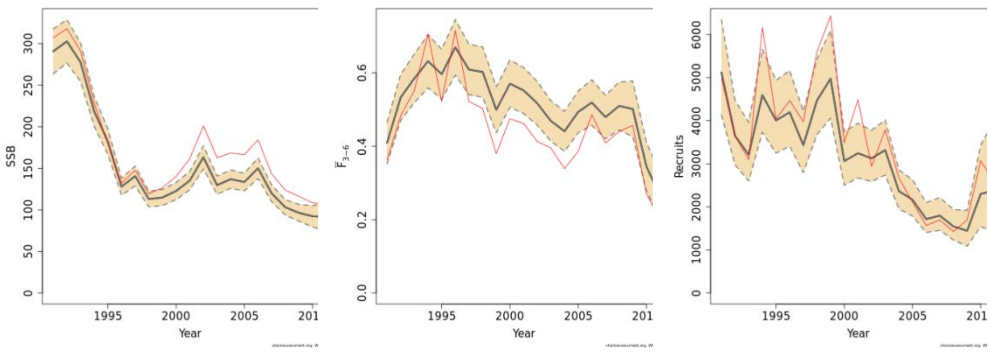


Figure 4.6.2.4. Plot of SSB, F and R for the final SAM models with 95% CI (black line and shaded area, respectively). The red line is the ICA assessment.

4.7 Short-term projections

The modifications made to the short-term projections are minor and to a great extent the procedure is identical to the short-term prediction methods used before. The main change is that this procedure is now based on an R code included within the SAM web-interface software.

In the short term predictions recruitment is assumed to be constant, and it is calculated as the geometric mean of the last five years prior the last year model estimate (i.e. for the 2012 assessment, recruitment for the forecasts was calculated on the period 2006–2010). Age 1 in the current year is calculated according to the adjusted geometric mean recruitment in the previous year. As in the previous assessment, the mean weights-at-age in the catch and in the stock, as well as the maturities-at-age were calculated as the arithmetic averages over the last three years of the assessment (in this example, 2009–2011). Based on earlier considerations in the herring working group, the different periods were chosen to reflect recent levels in recruitment and weights in a robust way, however we recommend that this reasoning should be reevaluated.

The steps for providing an operational management advice after performing the short-term forecast procedure were discussed within the WKPELA ending up with suggestions based on input from both science and stakeholders. One reoccurring concern for ICES when setting the catch option table for management advice is the division of the WBSS TAC between the two management areas for WBSS. The conclusion from the discussions was that when splitting the catch options between Div IIIa and SD 22–24 a constant split of 50:50 on the TAC should be continued following the procedure from recent years.

In 2011 and 2012 managers decided an optional transfer of 50% of the quotas for human consumption in Division IIIa to the North Sea, of which 41.9% was effectuated. In order to include this optional transfer % in the predictions, HAWG need information of the intended utilisation of this optional transfer in the intermediate year. This is to be predicted by start-of-year by the industry and thus facilitate a solid procedure for catch prediction for the intermediate year; for the TAC year HAWG will assume the same % transfer unless otherwise informed by the industry.

The catch options for Division IIIa further depend on the expected proportions NSAS and WBSS in the catches of the two fleets operating in the area (see Sections 4.1.1 and 4.5). Uncertainty of the magnitude of sampling bias in earlier years (primarily before 2008) when a large proportion of the catches taken in the North Sea where misreported to the Skagerrak prevent a robust modelling of the predicted proportions NSAS and WBSS (see Section 4.6.1 "Catch sampling for size-at-age and stock identity"). As a pragmatic way forward until a revision of the stock composition of Division IIIa catch composition, WKPELA decided to apply a three years average proportion by age as has been done in the recent years' assessments.

4.8 Appropriate reference points (MSY)

There were no precautionary approach reference points set for WBSS. The approach taken in HAWG has been based on yield per recruit analysis and simulation carried out during HAWG (ICES, 2007) and WKHMP (ICES, 2008), which gave a proxy for long-term maximum sustainable exploitation rate (i.e. a proxy for F_{MSY}) should be a level of fishing mortality should not exceed F = 0.25. Using a similar approach during the HAWG (2010 Section 1.3) a candidate F_{MSY} would be in the range of 0.22–0.30.

ICES approach to defining PA reference points has been developed through a number of workshops and expert meetings. The study group on the Precautionary Approach to Fisheries Management (ICES, 2003) and later WKREF (ICES, 2007) presented the following concept:

a) revised framework for estimating reference points, starting with B_{lim}, and leading on to the estimation of F_{lim}, F_{pa}, and B_{pa};

b) the methodology for estimating B_{lim}, using segmented regression;

c) a methodology for estimating F_{lim} from B_{lim} deterministically;

d) a proposed new methodology for estimating F_{pa} and B_{pa} in order to take into account assessment uncertainty;

e) clarification of the risks to be accounted for in this framework.

Based on this framework the B_{pa} should be set at a sufficient high level so that the risk of being below B_{lim} due to assessment uncertainty is small (<5%).

The risk is determined by the uncertainty of the estimated SSB in the assessment year (most often the least certain estimate). Provided the assessment model performs without bias, an average CV could be estimated from an appropriate time-series of assessment year CVs.

Because of a lack of a breakpoint in the stock–recruit plot, WKPELA took the approach of adopting B_{lim} as B_{loss}. The lowest observed SSB was observed in the last year of the time-series available for the benchmark (SSB=89 769 t in 2011) and the 95% upper confidence limit of B_{lim} (108 019 t) was also available as the output of the uncertainty of the assessment. This value was very close to the B-F_{MSY} breakpoint of 110 000 t used in recent years' advice and B_{pa} was therefore chosen to be equal to 110 000 t.

Yield per recruit and MSY reference points and their associated uncertainties will be estimated by means of the "plotMSY" software (WKFRAME 2010; WKMSYref 2013). The software was not fully developed at the time of WKPELA 2013 but will be available to the group in due time before HAWG 2013, where the MSY reference points will be presented and applied to the WBSS for advice setting.

The timing of benchmarks of stocks and the revision/creation of a Long-Term Management Plan for the actual stocks must be coordinated to avoid situations where a benchmarked assessment with potentially new perceptions of the stock is used to give advice according to a LTMP which was preconditioned on the previous assessment and perception of the stock. In the most recent agreed record between EU and Norway on the regulation of fisheries in Skagerrak and Kattegat on 2013, it is suggested that a Working Group on management measures for herring in ICES Division IIIa (Skagerrak) consistent with maximum sustainable yield is formed. WKPELA 2013 suggest that such a group will perform work to establish a management plan that can respond to large changes in the biology of the stock or assessment uncertainty. In order to address this issue, establishing a collaborative iterative process between scientists, managers, and stakeholders is of utmost importance.

4.9 Future Research and data requirements

i) The naming of the stock as spring spawners should be reconsidered, since spawning times of local populations in the stock vary between autumn and spring. For now, it is considered that the major part of the stock consists of spring spawners.

ii) It is recommended to establish the Stock Separation Function (SF) for assessment purposes to generate more precise estimates for WBSSH indices derived from survey data.

iii) The results on the Stock Separation Function (SF) clearly support the hypothesis that WBSSH and CBH mix in areas SD22–24 and SD25. The influence of mixed catches of the two stocks clearly needs more attention in future research. To verify and improve the quality of assignment of stock identity, novel genetic methods should be additionally applied.

iv) Presently the "fishery" is treated as a single entity yet it's clear that there are diverse fisheries targeting this stock in different areas and that they vary over time (e.g., small-mesh industrial fisheries and human consumption fisheries). Alternative models should be considered with the principle fleets; particularly as such advice could inform allocation discussions between regions and fleets.

v) The accuracy of splitting the catches between WBSS and NSAS with otolith microstructure (OM) and otolith shape needs a more thorough analysis including all years in the emerging time-series.

vi) Due to issues regarding splitting out WBSS from CBSS and NS Herring areas, there should be some evaluation of the magnitude of the effect of splitting out the stock on the catch time-series. If the model had specified multiple fisheries, perhaps some additional variance terms could be applied to compare fleets for which the splitting out of WBSS herring could be more appropriately considered (e.g., some fleets may have higher variance in catch than others). The ability to evaluate the resource with data prior to 1991 should also be pursued. However, this is complicated due to the fact that the fleet composition (e.g. industrial fleet B) changes over time. In addition, apportioning out WBSS is complicated since recorded landings apparently occurred as a mixture of other species (including sprats) thus would require more assumptions with different levels of uncertainty on the data input.

vii) Developing an assessment model capable of accounting for several stocks simultaneously and hence the catch apportionment uncertainty (Section 4.1) is encouraged. Such a tool could also help evaluate the cost-benefit for sampling strategies for stock composition and proportions-at-age.

viii) A major concern with the SAM approach remains that the variance components of observations used as input are omitted. The ability to use such information would have the advantage of accounting for interannual variability in sampling errors (presently SAM is configured to only have a single variance for each index over time). For WKPELA 13, estimates of variances from the different data sources coming into the model were unavailable during the week (but presumably some of this information exists). Future assessments should include observation variances both within the model and for direct comparisons and evaluations for what the final estimates indicate. For example, if due to sampling error and index had a coefficient of variation of say 25% (assuming that the survey method, etc. was correctly applied) yet the model estimated the analogous observation errors to be 50%, then this would provide an indication that there may be model misspecification or perhaps attention to an alternative index (which may have a lower-than-expected CV estimated by the model).

ix) It would be ideal for this situation if in addition to accounting for actual sampling errors of input data (for interannual variability and as a check against the observation errors that are estimated within the model), if the model was able to accommodate uncertainty in the splitting of WBSS herring from other stock complexes (including sprats and others from the early period).

x) In the short term predictions recruitment and weight assumptions are unchanged from earlier considerations in the herring working group. The different periods were chosen to reflect recent levels in recruitment and weights in a robust way, however we recommend that this reasoning should be reevaluated.

xi) The reference point options, output provided, and flexibility of parameterization of the current SAM implementation are somewhat limited. There appears to be features for projections, but methods for calculating MSY proxies of SSB and Catch (e.g., %SPR) would be very useful for making catch advice. It would be useful to provide more detailed diagnostic plots such as observed and predicted values for both total and age-specific catches and for aggregate survey indices. Finally, adaption of the ADMB program behind SAM to allow a wider array of specifications would be helpful. For example, allowing estimation selectivity functions and annual fishing mortalities rather than having them be hidden processes but retaining process error in the population would allow a more direct comparison of other existing statistical catch-at-age models. Also allowing observation errors to be supplied as estimates of sampling error variances for different indices and catch composition would be helpful to allow the observation errors to vary over time according to changes in sampling effort. Whereas this can be developed by the assessment authors directly within the source code of SAM, the benchmark/assessment setting is inappropriate for such sensitivities to be tested due to time constraints.

xii) For management plan development: In relation to the optional transfer from IIIa to the North Sea; for the prediction year HAWG will suggest a 'banking-and-borrowing' approach to solve this issue. The scenario implies that industry will provide an estimate of the expected utilisation of the quota transfer on which the advised fishing opportunities will be calculated. An underutilisation of the IIIa TAC by a higher than expected transfer to the North Sea will result in banking of WBSS and the opposite situation will result in borrowing. Management scenario evaluations should investigate the sustainability and consequences of this procedure. Remember in this process to invite **all** necessary parties!

4.10 External reviewers comments

Reviewer comments were included in the drafting of the report.

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5 Sardine in Subarea VII and Divisions VIIIa, b, d

5.1 Stock ID and substock structure

European sardine (*Sardine pilchardus*; Walbaum, 1792) has a wide distribution extending in the Northeast Atlantic from the Celtic Sea and North Sea in the north to Mauritania in the south. Populations of Madeira, the Azores and the Canary Islands are at the western limit of the distribution (Parrish *et al*., 1989). Sardine is also found in the Mediterranean and the Black Seas. Changing environmental conditions affect sardine distribution, with fish having been found as far south as Senegal during episodes of low water temperature (Corten and van Kamp, 1996; Binet *et al*., 1998).

The sardine in the Bay of Biscay is neighbour to the stock covering ICES Areas VIIIc and IXa, extending to the south to the Strait of Gilbrator. The limit with the Bay of Biscay is arbitrary as they were set for management purposes.

Further efforts should be done to clarify the sardine population structure in the stock area as well as the potential exchanges between Bay of Biscay and the Iberian sardine stock in order to take account of any dynamics that may exist between those regions. Because of its continuous distribution in the Northeast Atlantic, it is likely that there is movement of fish between areas but the magnitude of the exchange between the Bay of Biscay and Iberian Peninsula is currently unknown. However, catch and survey-at-age data appear to indicate that some strong year classes in the Cantabrian Sea (VIIIc East) originated from recruitment areas in the Gulf of Biscay (VIIIa,b) (Riveiro *et al*., 2012).

Sardine maturity-at-length seems to decline substantially in northern France while growth might increase in the English Channel (Silva *et al*., 2008). Young sardine are not usually observed in this northern area (although juveniles have been recently sampled in the North Sea), suggesting that older (2+) spawning individuals from the English Channel possibly originate in the French coast. Microsatellite analyses revealed no significant genetic differentiation among sardines in Subareas VII and VIII (Shaw *et al*., 2012). Recent genetic analyses (B. Roel, Cefas, pers. comm.) conducted in the Celtic Seas and Western Channel show that no genetic differentiation has been detected between the Bay of Biscay and Cornwall for the sardine stock. These results are in agreement with previous data that suggested that sardine in the Eastern Atlantic represents a single panmictic evolutionary stock (i.e. high levels of connectivity on evolutionary time scales, over thousands of generations). There is the potential for cryptic stock differentiation on ecological time scales (10–100 generations) which may be relevant for sustainability but the lack of data does not encourage treating Celtic Seas and English Channel as separate substocks.

Therefore, the sardine stock in VIIIabd and VII can be considered as a single-stock unit but it is important to note that there should be some distinction within the stock structure to take account of some regional differences between fisheries as there are some locally important fisheries operating in some area.

5.2 Issue list

The following issues were compiled during the preparation of the benchmark, the main problem being the contrast of data availability between the Bay of Biscay and the Celtic Seas and English Channel:

- The stock identity is not defined. There is no reason to think there is more than one stock for VIIIabd and VII. Some mixing is assumed between VIIIc and VIIIb but the magnitude of the mixing is unknown.
- No existing tuning-series in VII despite substantial landings from some countries. Effort data are not available for many fleets.
- The level of discards is poorly known because of undersampling. It is known that fleets may exhibit different discard patterns depending on the fishing gear and market opportunity for some fish of a given range of sizes.
- Biological parameters are not available in VII because of lack of sampling but available in VIII. There is evidence that fish caught in the English Channel are bigger but the reason (selectivity or environment) is unknown.
- No biological reference points have been set.

Given the contrast of data availability between the southern and northern component of the stock unit, the underlying issue is to find out if Bay of Biscay data can be extended to the northern component. This is a strong assumption as environmental conditions, fishing activities and market opportunities differ. If those data cannot be extended, the way forward could be to do a separate stock assessment for the Bay of Biscay and the northern component (English Channel and Celtic Sea as a whole subregion).

Note: Within ICES, the English Channel generally refers to Divisions VIId and VIIe. There is a connection between fleets operating in the English Channel and Division VIIh. In this report, "**English Channel**" refers to **VIId, VIIe, VIIh**. As a consequence, "**Celtic Seas**" refers to **Subarea VII, excluding the English Channel** (i.e. Divisions VIIa, VIIb, VIIc, VIIf, VIIg, VIIj, VIIk).

5.3 Scorecard on data quality

The accuracy (potential bias) of input data for the assessment is evaluated according to the scorecard developed by the Workshop on Methods to Evaluate and Estimate the Accuracy of Fisheries Data used for Assessment (WKACCU, ICES, 2008). The workshop developed a practical framework for detecting potential sources of bias in fisheries data collection programs. A scorecard was applied to indicators of bias for a suite of parameters that are important for stock assessments. The scorecard can be used to evaluate the quality of data sources used for stock assessments, and to reduce bias in future data collections by identifying steps in the data collection process that must be improved.

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
A. SPECIES IDENTIFICATION				
1. Species subject to confusion and trained staff				
2. Species misreporting				
3. Taxonomic change				
4. Grouping statistics				
5. Identification Key				
Final indicator				

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
B. LANDINGS WEIGHT				The French and Spanish landings data are considered by ICES to be well estimated and a fair reflection of the actual catches.
Recall of bias indicator on species identification				
1. Missing part				
2. Area misreporting				
3. Quantity misreporting				
4. Population of vessels				
5. Source of information				
6. Conversion factor				
7. Percentage of mixed in the landings				
8. Damaged fish landed				
Final indicator				
C. DISCARDS WEIGHT				
Recall of bias indicator on species identification				
1. Sampling allocation scheme				According to on-board observations, Rejection of fish after coming to the deck is rare. Purse seiners (both Spanish and French) have slipping behaviour related to market limitations, illegal size and mixture with unmarketable bycatch. Quantifying slipping at a population level is extremely difficult because it varies considerably between years, seasons, species targeted and geographical region. There are no estimates of slipping in the purse seine fleet due to the limited number of trips/catch monitored by year. French pelagic trawlers seem to have low discards in 2012 but this study was mostly based on trawlers when they targeted anchovy (WD 1).
2. Raising variable				
3. Size of the catch effect				
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 replacement				
Final indicator				
D. EFFORT				
Recall of bias indicator on species identification				
1. Unit definition	NA			no effort data used in the assessment
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				
5. Availability of all the landings/discards				

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
6. Non sampled strata				
7. Raising to the trip				
8. Change in selectivity				
9. Sampled weight				
Final indicator				
F. AGE STRUCTURE				
Recall of bias indicator on length structure				
1. Quality insurance protocol				The last calibration workshop on age reading took place in 2008 and showed an agreement of 75% between all readers (not only the specialists of this area), with a CV about 12%. (report of the WKARAS, ICES CM 2011/ACOM:42)
2. Conventional/actual age validity				
3. Calibration workshop				
4. International exchange				
5. International reference set				
6. Species/stock reading easiness and trained staff				
7. Age reading method				
8. Statistical processing				
9. Temporal coverage				
10. Spatial coverage				
11. Plus group				
12. Incomplete ALK				
Final indicator				
G. MEAN WEIGHT				
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Temporal coverage				
3. Spatial coverage				
4. Statistical processing				
5. Calibration equipment				
6. Working conditions				
7. Conversion factor	NA			
8. Final indicator				
H. SEX RATIO				
Recall of bias indicator on length/age structure				
1. Sampling protocol	NA			sex ratio used in the calculation of the DEPM index but not used in the assessment
2. Temporal coverage	NA			
3. Spatial coverage	NA			
4. Staff trained	NA			
5.Size/maturity effect	NA			
6. Catchability effect	NA			
Final indicator				
I. MATURITY STAGE				

WKACCU scorecard	No bias	Potential bias	Confirmed bias	Comment
Recall of bias indicator on length/age structure				
1. Sampling protocol				
2. Appropriate time period				all along the year
3. Spatial coverage				
4. Staff trained				
5. International reference set				
6. Size/maturity effect				
7. Histological reference	NA			exclusively for the DEPM
8. Skipped spawning	NA			
Final indicator				
Final indicator				

5.4 Multispecies, mixed fisheries and stakeholder input

5.4.1 Multispecies and mixed fisheries

No new information was presented at this benchmark.

5.4.2 Stakeholder input

A questionnaire was filled by some representatives of the industry operating in the Bay of Biscay. Representative from the other areas (Celtic Seas, English Channel) were absent from the meeting therefore no information was available from them. The following information should be treated as representative as the situation in the Bay of Biscay and is likely to be different for the Celtic Seas and English Channel.

Fishing conditions

- *Is the fleet in this fishery primarily owner-operators or owned by larger companies?* The French fleet targeting sardine in the Bay of Biscay is an owner-operators coastal fleet, referred to as an "artisanal" fleet.
- *Is the fleet renovating or are vessels aging?* Both. The fleet is composed of old units (over 25 years) and few recent ones (~five years). The specialized seiners fleet has increased since the 1990s.
- *Is the average age of vessel operators increasing steadily (i.e., younger fishermen are not tending to participate)?* Compared to other fleets of the country, the average age of operators is quite low, but there is no recent change within the operators. Entries into the fisheries are limited by national regulation: licensing scheme for seiners and licensing scheme for anchovy fishery.
- *Has the methods and approaches used by fishermen changed much in the past two decades?* Seiners on board storage conditions have been largely improved to provide a better quality of fish, especially for export markets. Fishing methods are the same, with echo sounder improvement. The small number of pelagic trawler units involved in the fishery has also changed their fishing behaviour, in order to improve the quality of fish landed.
- *If so, has it been gradual or a step change in a particular year (if step please specify years)?* Unknown.

- *What proportion of vessel operators rely on this fishery for their primary source of income in recent 5 years or so?* All, most, some, none. For about 25 Britton purse seiners, sardine is the main source of income. For some pelagic and other purse seiners, sardine is a complementary source of income next to anchovy, mackerels or tuna.
- *What sources of error in catch statistics may be likely?* Few catches are sold through private contract with buyers and might have not been registered by the market places. Anyway vessels are equipped with VMS and ERS.
- *What if any bycatch issues are a concern in this fishery?* The seiner fishing vessels do not have any "lost" bycatch. They are able to let encircled fishes escape alive in case of unexpected and invaluable catch composition (species or size). The few pelagic trawlers targeting sardine occasionally can have mixed valuable catches with other small pelagic. Bycatch issues are not a concern for these fleets.
- *What environmental conditions if any are of obvious concern in considering impacts on fishing and/or survey data?* Unknown

General comment for assessment and management advices

ICES should keep in mind that fishermen are expecting objective elements for reasonable fishery management at short and medium terms. A well-documented fishery (sardine in the Bay of Biscay) should not be managed together with a data poor one. Contrary to many other fisheries, the main driver of this fishery is the market. Many fishers could catch more sardine as regards sardine availability, but this would not be suitable due to poor levels of prices. Thus, the industry data should not directly be put in relation to variation of sardine abundance.

Management objectives

Preferred management objectives (biological/economic/social) for fishery of interest (please list at least three, in priority order):

1) Stock in safe biological condition is a preliminary condition to management objectives;

2) Consolidate market value of catches;

3) Socio-economics: renewal of the fleet.

Suggest indicators of management performance towards achieving objectives

INDICATOR	OBJECTIVES TO WHICH INDICATOR APPLIES
a) Global value and average price	Socio-eco
b) Number of boats	Socio-eco
c) Age of boats	Socio-eco
d) F/F_{MSY}	Biological

5.5 Ecosystem drivers

No new information was presented at this benchmark. The majority of the past studies regarding ecosystem drivers for Bay of Biscay have been focused on the relationship between anchovy and environmental indices.

5.6 Stock assessment

5.6.1 Catch-quality, misreporting, discards

A compilation of available landings data prior to the benchmark was done by two data calls sent to the industry and national laboratory. The compilation of landings data from the FAO FishStat dataset allows going back in time to 1950.

However, the level of aggregation of those datasets is variable between countries. For example, Spain before 1988 has very high catches. The drop the next year cannot be attributed to a collapse of the fisheries but rather to a data compilation problem. The same comment also applies to the information on effort. Data were provided by France, Spain, Netherlands and UK as different spatial and temporal scale. Considering sardine is a shoaling species, it is difficult to estimate and include cpue in any assessment.

5.6.2 Surveys

No new information was presented during the Benchmark. The sardine assessment in the Bay of Biscay used to be carried out using the PELGAS age structured data. Comparison between acoustic data from the PELGAS survey (Figure 5.6.2.1) and DEPM data (Figure 5.6.2.2) from the BIOMAN survey shows a relatively good agreement to track the evolution of biomass. Additional survey data were provided after the meeting from the SAREVA survey (IEO). Those data have not been evaluated. They are not provided annually but should be considered for years they are available (see Stock Annex).

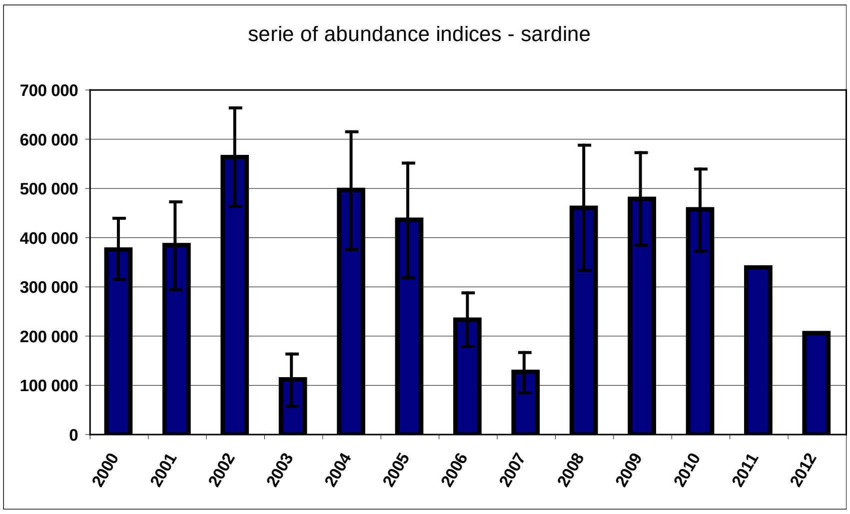

Figure 5.6.2.1. Time-series of sardine abundance (Bay of Biscay) based on acoustic data from the PELGAS survey.

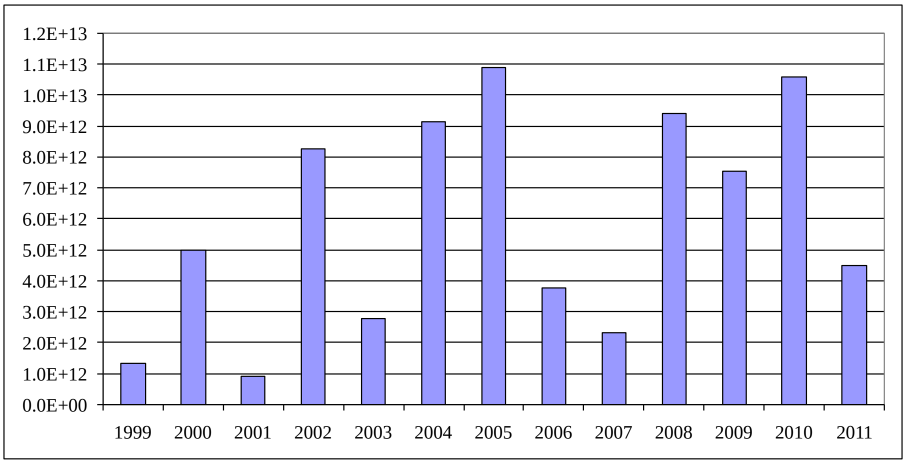

Figure 5.6.2.2. Time-series of sardine abundance (Bay of Biscay) based on DEPM data from the BIOMAN survey.

5.6.3 Weights, maturities, growth

No new information was presented during the Benchmark.

5.6.4 Assessment model

5.6.4.1 TASACS

TASACS has been used so far to carry exploratory assessment for the sardine regional stock the Bay of Biscay using the separable model part of its implementation. The population model was fit to the PELGAS survey numbers-at-age. Input data consisted of catch-at-age from the Spanish and French fisheries and weights-at-age in the catch and the survey. The survey sampling CVs were used to weight the survey data. The 2003 survey was excluded given very low survey estimates linked to unusual high temperatures. Mortality-at-age was fixed as for the Iberian data (M=0.33 constant across years and ages); maturity-at-age was based on data collected in the acoustic survey. The model time framework is from 2000 to 2012. However, although survey coverage with PELGAS goes from 2000 to 2012, catch-at-age data are only available from 2002 to 2011 so, fishing mortality was fixed in 2000 and 2001 at the same as the estimated for 2002. Survey catchability was fixed = 1. Recruitment in 2012 was fixed equal to the arithmetic average of the historic series.

a) Standard run for the Bay of Biscay

These standard runs are similar than those in the WGHANSA (ICES, 2012) report and are here mainly for reference. Residuals are higher for some years (2004 for the commercial fleet, 2003 for PELGAS respectively on Figures 5.6.4.1 and 5.6.4.2). 2003 was an unusual year due to the heat wave in Europe. The PELGAS survey has also been delayed that year. Therefore 2003 is usually discarded from the survey time-series.

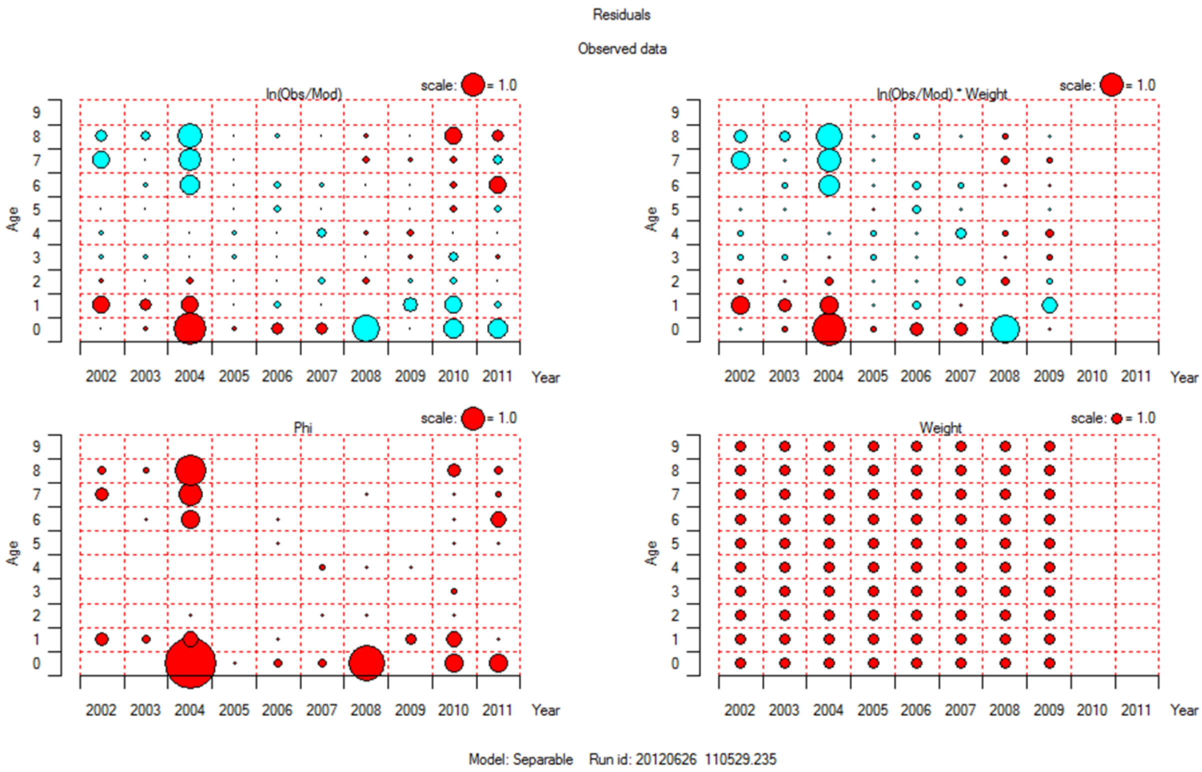

Figure 5.6.4.1. Residuals of the TASACS assessment for the commercial fleet.

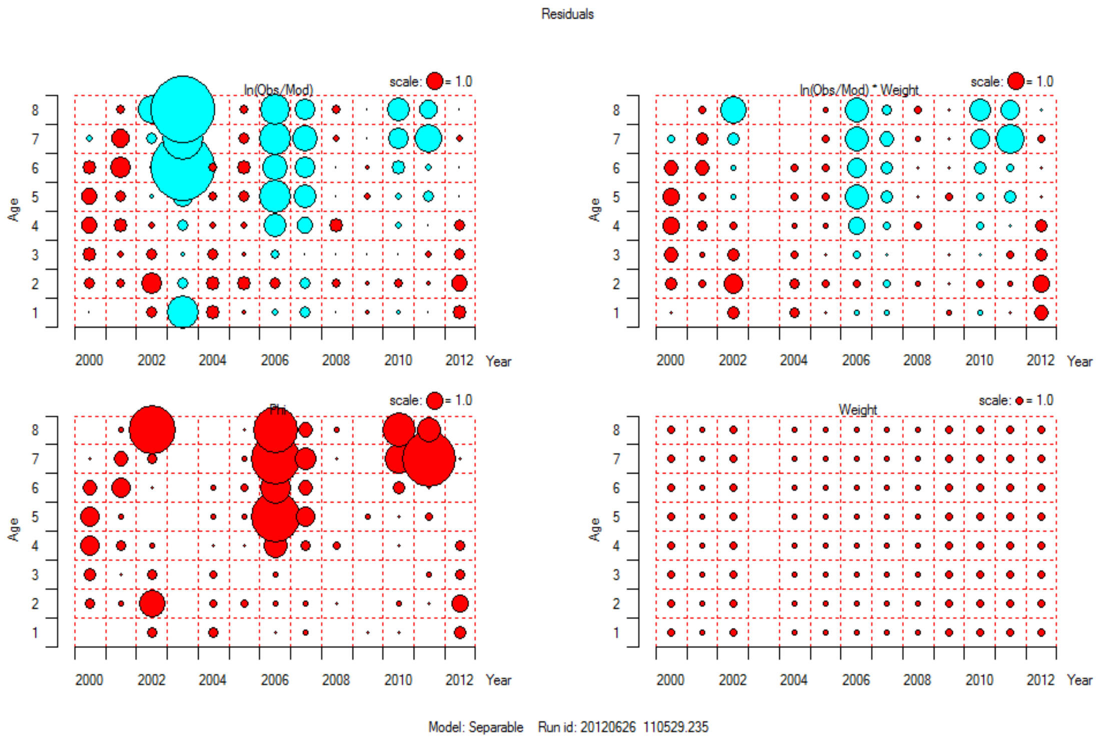

Figure 5.6.4.2. Residuals of the TASACS assessment for the commercial survey.

Residuals in all subsequent simulations for the Bay of Biscay and including the other regions were the same in any scenario because the same age structure and tuning fleets were used despite different amount of landings between areas.

Outputs (Figure 5.6.4.3) suggest a fishing mortality at very low level (0.06) in comparison to the assumption made for natural mortality M=0.33 . The decrease of SSB from 400 kt in 2010 to 125 kt in 2012 is in line with the decrease observed by acoustic during the PELGAS survey. This standard run is the reference simulation for the next simulations including the other areas. This run does not show substantial retrospective patterns (Figure 5.6.4.4).

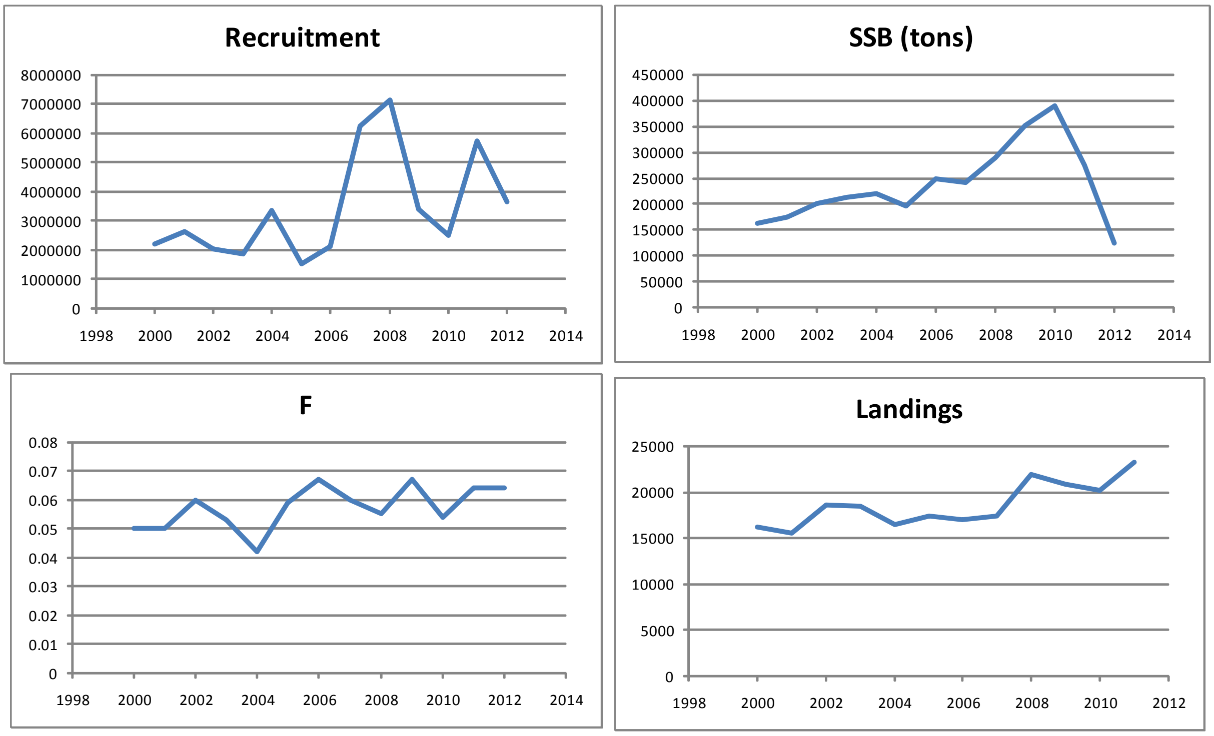

Figure 5.6.4.3. Summary output plots from the TASACS run for the Bay of Biscay.

Figure 5.6.4.4. Retrospective plots from the TASACS run for the Bay of Biscay.

b) Extension to the Celtic Seas and English Channel.

Due to the lack of age-structured data in Subarea VII, it was proposed to assume that the data from the Bay of Biscay could be extended to Subarea VII. This is a strong assumption because fisheries and environmental conditions are known to be different therefore the actual population in VII is likely to be different than in the Bay of Biscay. Landings in Subarea VII (Celtic Seas and English Channel) show a downward trend (Figure 5.6.4.5).

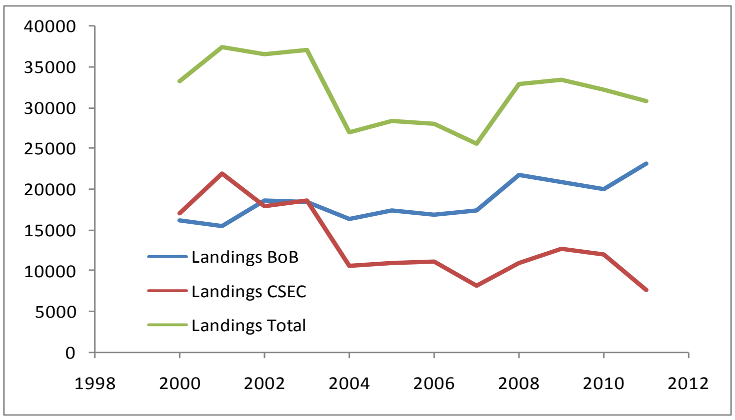

Figure 5.6.4.5. Trends in landings in the Bay of Biscay (BoB), Division VII (CSEC) and total.

Several runs have been considered. In addition to the standard (Bay of Biscay) run, a "Global" run based on the total landings in the stock unit was performed. SSB for the global run (Figure 5.6.4.6) does not seem realistic because the biomass in the final year is very close to the one for the Bay of Biscay. Recruits are also in lower number than the estimates for the Bay of Biscay (Figure 5.6.4.7).

Another approach was to consider separately a run for the Bay of Biscay and another one for Subarea VII. The sums of SSB and recruits are in substantially different than for the Bay of Biscay in that case. These runs highlights some issues with the survey catchability as the PELGAS survey only cover the Bay of Biscay.

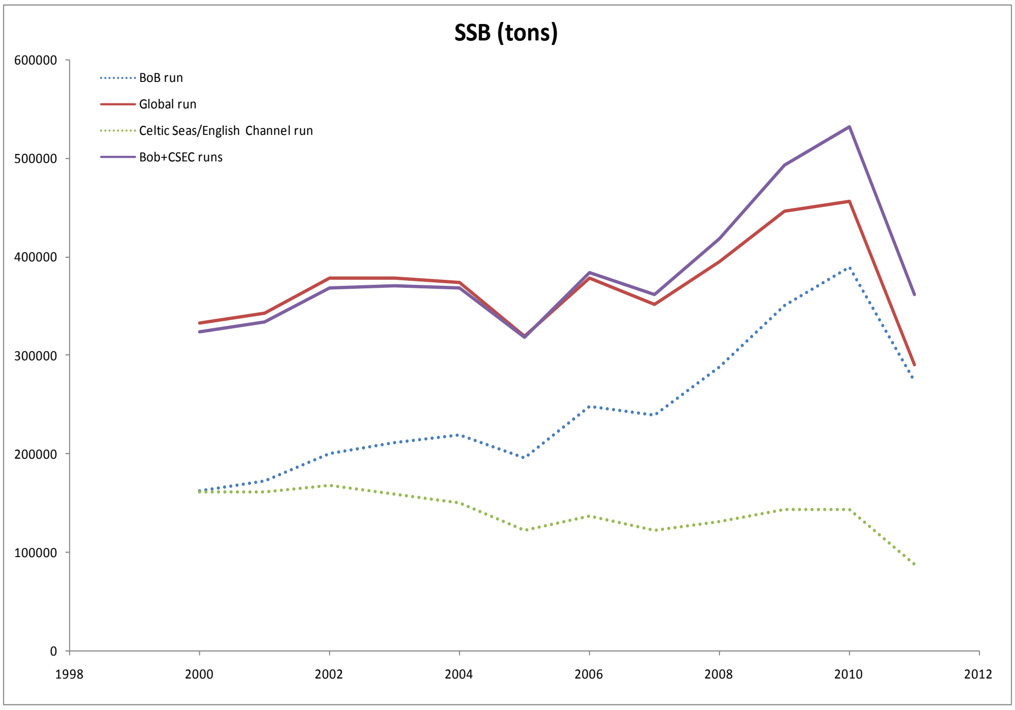

Figure 5.6.4.6. Estimate of SSB for the Bay of Biscay (BoB), Division VII (CSEC), global run and combined areas.

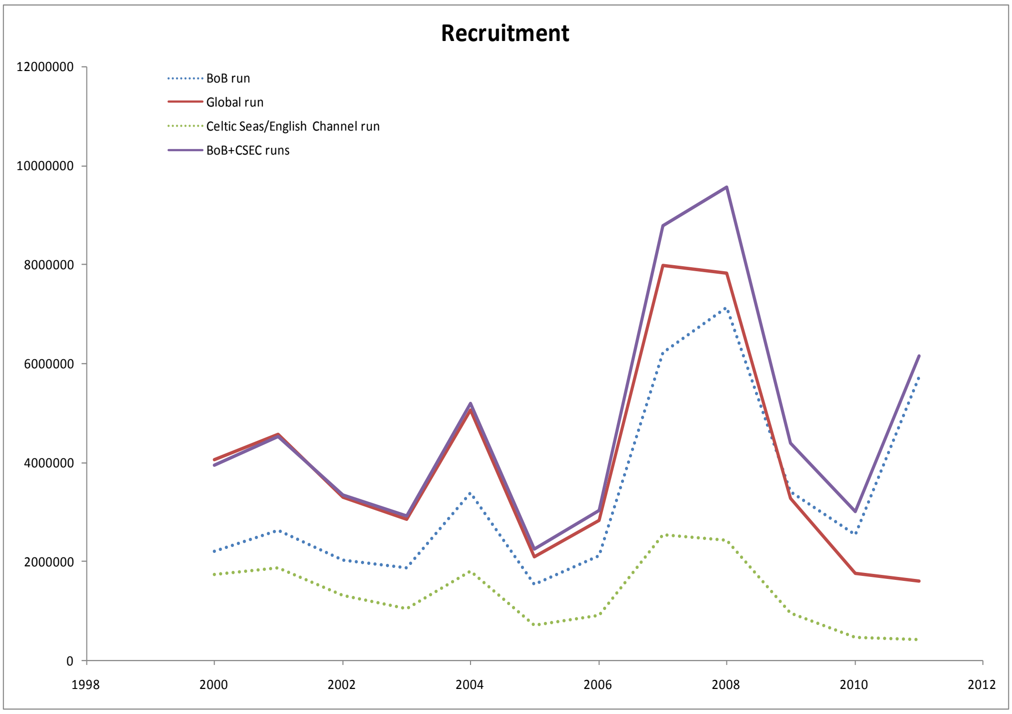

Figure 5.6.4.7. Estimate of recruits for the Bay of Biscay (BoB), Division VII (CSEC), global run and combined areas.

c) Sensitivity to catchability assumption

The previous runs have considered a catchability set to 1 but because of the extension of the run to Subarea VII, it is necessary to reconsider the impact of this value to this assessment. Various runs were made with Q set from 0.2 to 1.0. Q appears here only as a scaling factor for SSB, recruits, F using the Bay of Biscay dataset (Figures 5.6.4.8–5.6.4.10). Higher SSB and recruits levels are achieved at lower Q. Fishing mortality is also lower for lower Q. In any cases, Q is simply here a scaling factor and does not impact the fitting of the model to existing data. Therefore it is not possible to conclude of which value of Q to adopt in order to combine the Bay of Biscay data to the northern component of the stock.

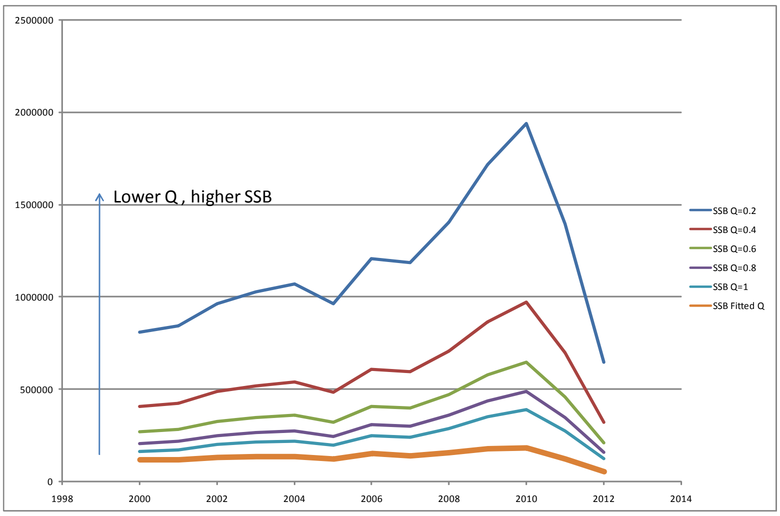

Figure 5.6.4.8. Effects of catchability over SSB estimates using the TASACS model.

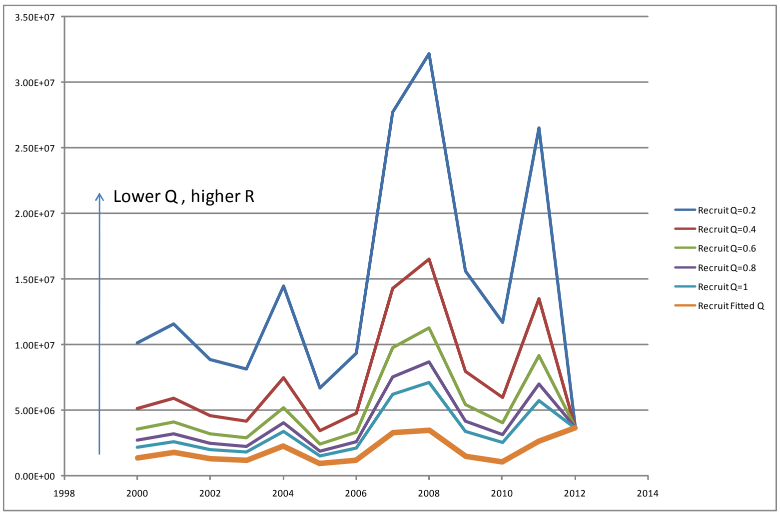

Figure 5.6.4.9. Effects of catchability over recruits estimates using the TASACS model.

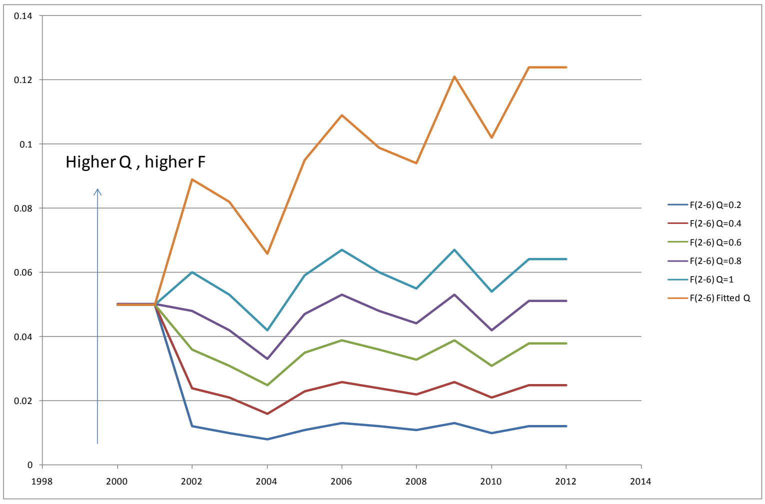

Figure 5.6.4.10. Effects of catchability over fishing mortality estimates using the TASACS model.

d) Conclusion

The TASACS model results were often difficult to follow and comprehend due to lack of clarity in the model assumptions. For example, the estimated value for recruitment in the terminal year remained constant over different models evaluated (e.g. when a profile over survey selectivity was conducted). The time-series was extremely short for conducting an assessment since models typically require contrast in the data in order to provide reasonable estimates. In particular the model may have difficulty estimating the population scale and hence fishing mortalities without making assumptions about the available survey data.

5.6.4.2 Catch curves and yield per recruit analysis

Catch curves were evaluated as a simple alternative from the fishery and survey age composition data to gain some idea of total mortality (Figures 5.6.4.11–5.4.6.12). Those figures show that more noise comes from the survey because of the lower number of individuals sampled. The range of value for total mortality goes from nearly 0 to 1. For the last years, this value has been between 0.3 and 0.5. Considering an assumption that natural mortality is 0.33, the fishing mortality appears to be low but its value is unknown. Total mortality-at-age was estimated based on the age-structure obtained from commercial fleets (Figure 5.6.4.13). Exception for the last year classes (6–8 years old) which range is wide due to the low number of fishes sampled, for most ages, the magnitude of the variation of total mortality is between 0 and 1.

This approach allowed inference on average fishing mortality although it is necessary to make an assumption on the value of natural mortality. Subsequently, yield per recruit analysis could potentially give some indication of appropriate levels of fishing mortality (Figure 5.4.6.14).

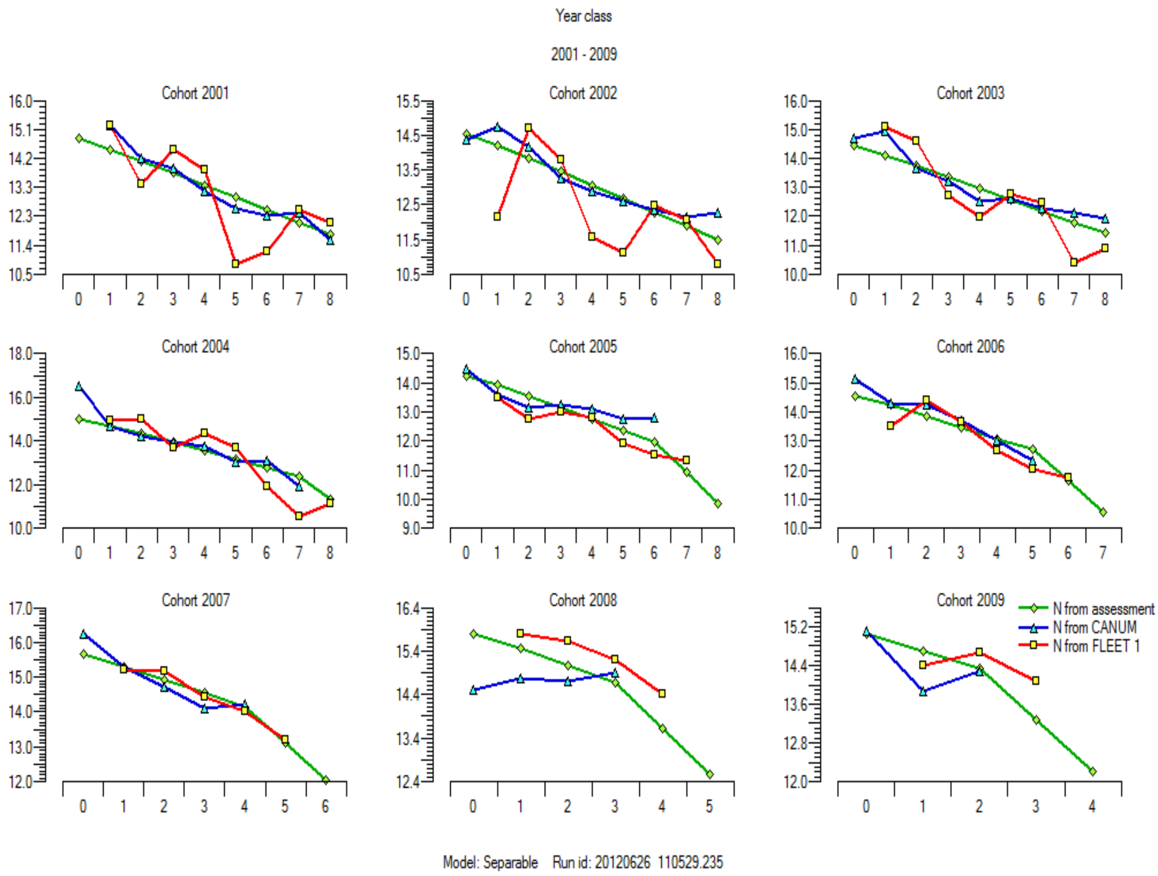

Figure 5.4.6.11. Catch curve from commercial data (blue line), PELGAS (red line), model fit (green line).

Figure 5.4.6.12. Total fishing mortality based on the PELGAS survey or commercial fleets.

Figure 5.4.6.13. Total fishing mortality-at-age based on commercial fleets (top to bottom ages 1–3, 4–5, 6–8).

Two yield-per-recruit (Figures 5.4.6.14–5.4.6.15) analyses were performed using the YPR software from NOAA NMFS based on data from two age ranges (Ages 1–8 and 0–9). Summary table are in Tables 5.4.6.1 and 5.4.6.2. $F_{0.1}$ is estimated to be 0.33 or 0.45 depending on the run. This is in the same range than for the total mortality assuming M=0.33. Therefore, the current fishing mortality appears to be below $F_{0.1}$.

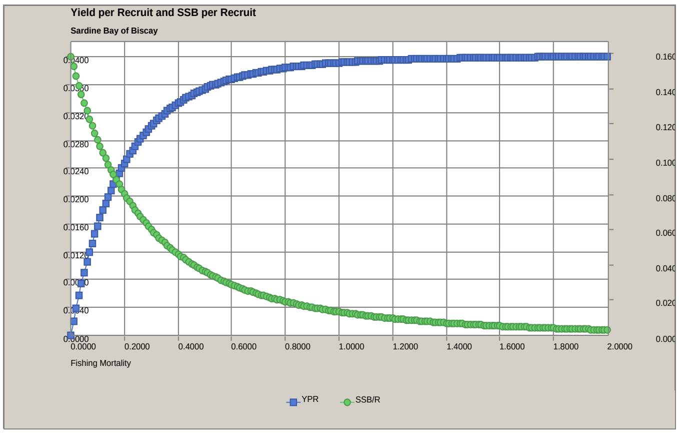

Figure 5.4.6.14. Yield per recruit analysis based on datasets for ages 1–8.

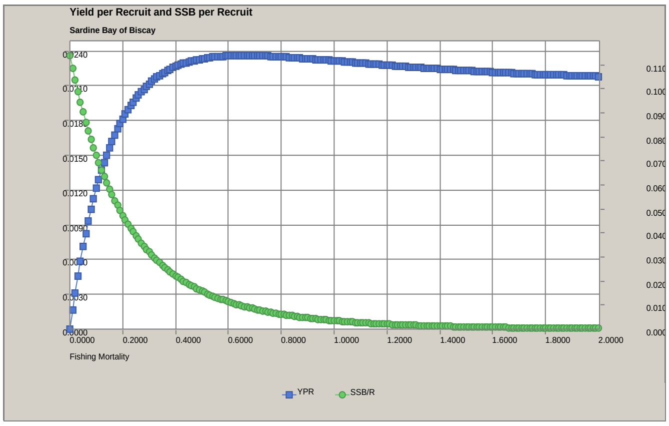

Figure 5.4.6.15. Yield per recruit analysis based on datasets for ages 0–9.

Table 5.4.6.1. Summary table for yield per recruit analysis based on datasets for ages 1–8.

Reference Point	F	Yield per Recruit	SSB per Recruit	Total Biomass per	Mean Age	Mean Generatio Time	Expected Spawning
F Zero	0.00000	0.00000	0.15834	0.20501	2.94299	3.74818	2.01696
F-01	0.45110	0.03456	0.04067	0.09001	1.82919	2.43306	0.62749
F-Max	N/A						
F at 40 %MSP	0.28170	0.02928	0.06335	0.11442	2.12504	2.81879	0.91711

Table 5.4.6.2. Summary table for yield per recruit analysis based on datasets for ages 0–9.

Reference Point	F	Yield per Recruit	SSB per Recruit	Total Biomass per	Mean Age	Mean Generatio Time	Expected Spawning
F Zero	0.00000	0.00000	0.11383	0.17049	2.07105	3.74818	1.45004
F-01	0.32920	0.02171	0.02874	0.07806	1.04761	2.69878	0.42407
F-Max	0.66030	0.02360	0.00943	0.04992	0.58979	2.09125	0.15544
F at 40 %MSP	0.20980	0.01854	0.04554	0.09859	1.32688	3.01997	0.63973

5.6.4.3 AMAK

Subsequent to the benchmark meetings, an alternative age-structured model was applied for contrast and to gain further insights on the data and potential sensitivities of model assumptions. The application used is an ADMB model (and an extension of the AMAK model from NOAA: http://nft.nefsc.noaa.gov/). Fishery and survey were compiled into aggregated biomass and proportions-at-age. Parameters estimated include the recruitment in each year, annual fishing mortality rates, selectivity (for a pre-set number of ages) and depending on configuration, additional parameters allowed changes in selectivity over time. Results from this approach provide an alternative way to judge the data and goodness of fit (Figures 5.6.4.1 and 5.6.4.2). Survey catchability was estimated (with a diffuse prior with a mean a 1.0) to be about 1.6 indicating that stock estimates from the model were smaller than those from the survey. Spawning biomass was estimated to be highly uncertain but increasing over the short time from of the assessment (Figure 5.6.4.3). The age specific natural mortality used for sardine in the Iberian region was used (Figure 5.6.4.4).

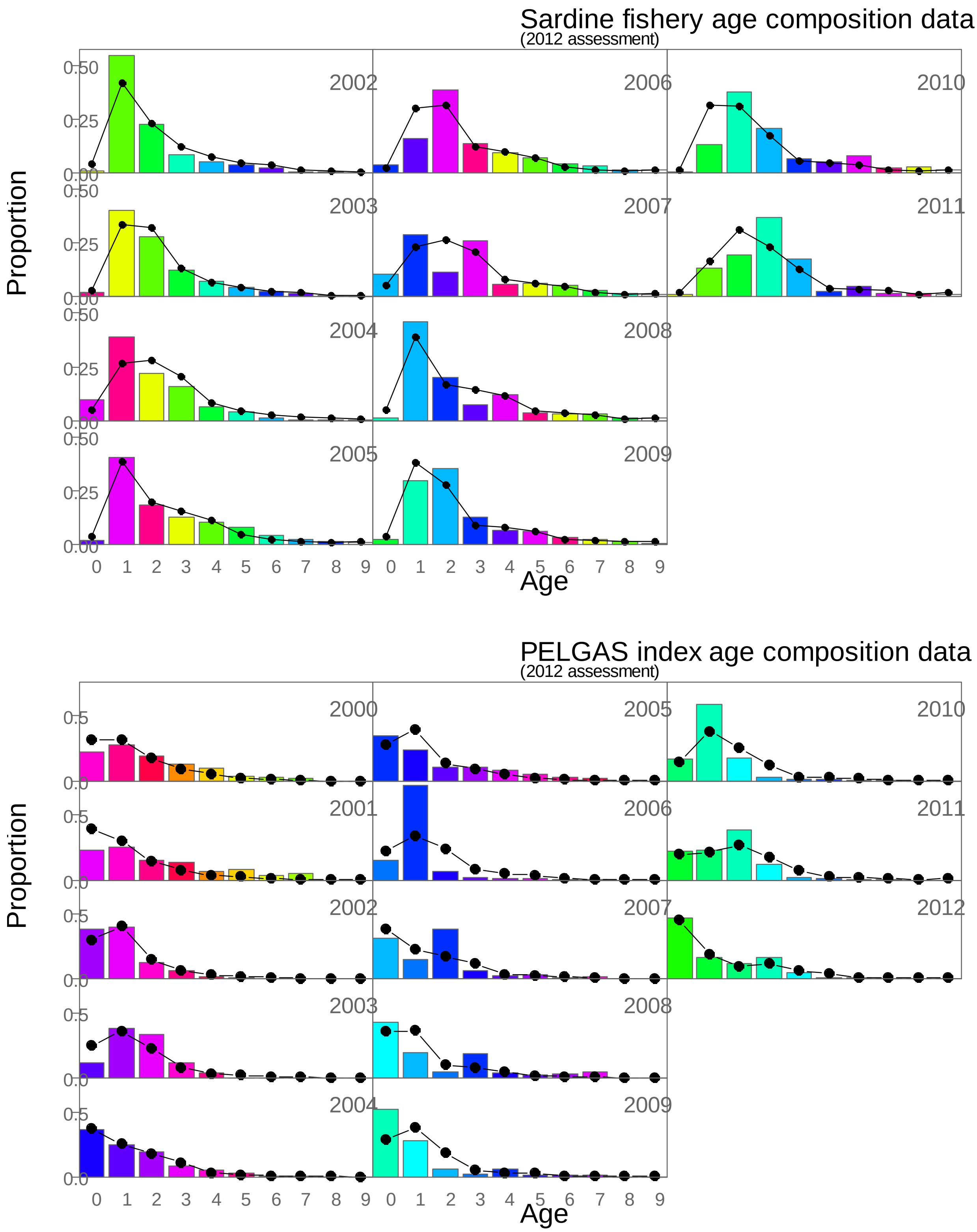

Figure 5.6.4.1. Example fit to available fishery (top) and survey (bottom) age composition data. The different colour bars represent data on cohorts through time whereas the dotted lines are the model fits.

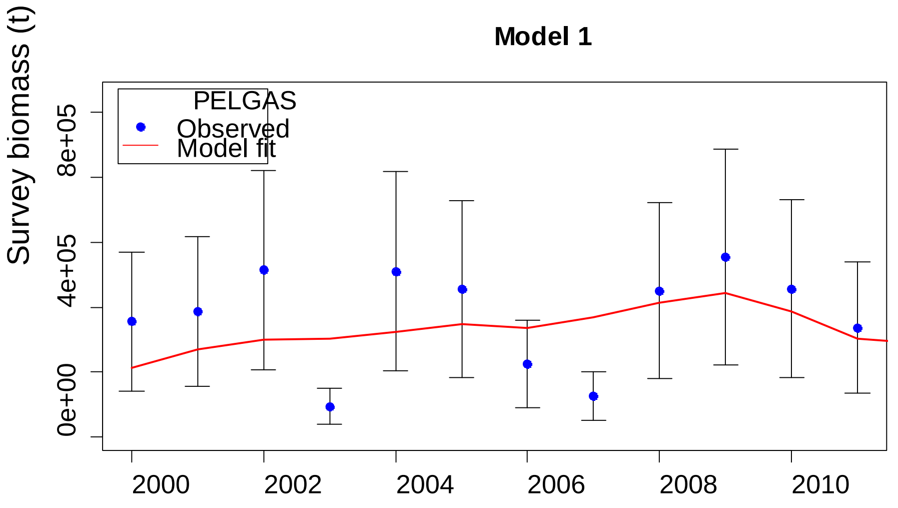

Figure 5.6.4.2. Example results of fit to different indices used in the model. Error bars represent the uncertainty specified as input to the model.

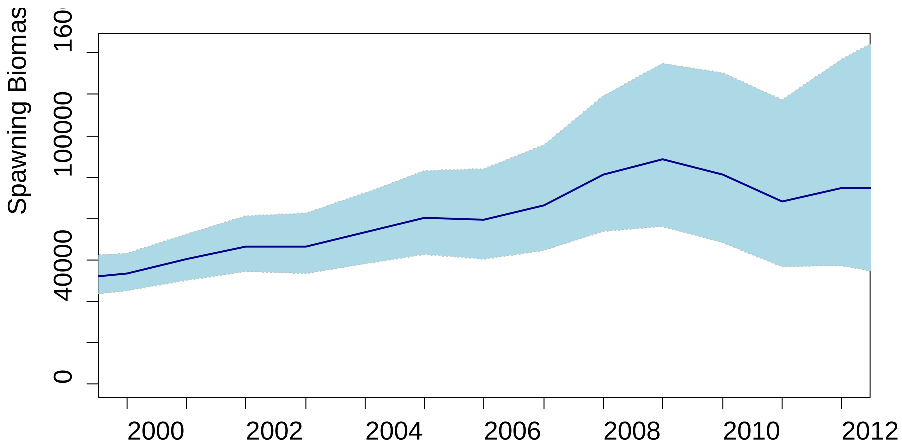

Figure 5.6.4.3. Estimated female spawning biomass for sardine from the AMAK model.

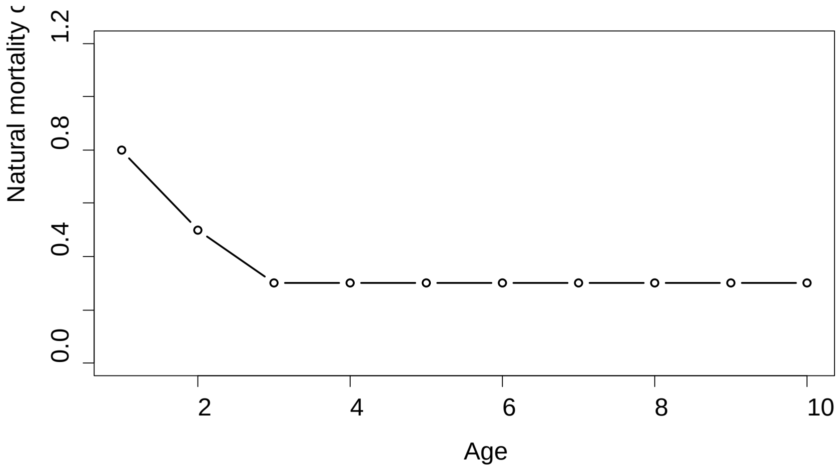

Figure 5.6.4.4. Input natural mortality-at-age used for the AMAK model configuration.

5.6.4.4 Conclusions on assessment models

The exploratory assessment runs with TASACS and AMAK are informative and suggest low exploitation rates. Additionally, catch curve analysis was presented. The models suffer from lack of input data and are sensitive to assumptions made without sufficient tuning data to validate them. Therefore, the use of assessment models will be explored further, but these are not yet considered sufficiently quality assured to serve as a basis for advice.

WKPELA concludes that there are insufficient data to inform models. Information available does give indications about the stock status which can be the basis for datalimited stock advice.

Bay of Biscay

1) Biomass trends can be found in PELGAS and DEPM survey results;
2) Stock structure (recruitment information) can be found in trends in size structure from commercial catches and PELGAS and DEPM surveys.

Celtic Seas and English Channel

1) Because no information is available on stock structure from existing pelagic surveys, only landings can be used. Some length structure information is available from demersal surveys (IBTS) but the number of individuals caught is generally low.

Because of the short-lived nature of the sardine stock, recent levels in relation to long-term averages could give an indication of the need for management action. Indicators such as successive recruitment failure can give input for short-term advice. Input from the fisheries can also be used. These indicators are available from the current commercial and PELGAS survey age-structure datasets.

5.7 Short-term projections

Due to the lack of proper analytical assessment, no projection can be done for this stock.

5.8 Appropriate reference points (MSY)

Due to the lack of data and proper analytical assessment, it is impossible to set any proper reference point. One additional problem is the regional heterogeneity of the available information. Treating the stock as whole can be problematic for the time being as this would imply assuming the situation in the most known area (Bay of Biscay) is the same in the Celtic Seas and English Channel which is unlikely because of different environmental conditions and fishing practices. Any attempt to set reference points should take account of this by consolidating the available datasets for area where they are insufficient and/or by dividing the stock in the three main areas and by setting some regional reference points.

5.9 Future research and data requirements

The possibility of successfully carrying out an analytical assessment for this stock involves dealing with two main issues:

- Having more years of age-structured data for the time-series of the sardine in the Bay of Biscay from both commercial sampling and surveys. The current level of sampling is sufficient and this problem should be self-solved with a few additional years;

- Collecting a sufficient amount of data and knowledge for the fisheries operating in the Celtic Seas and English Channel. In those areas, no analytical assessment will be possible without a robust data collection programme. This involves at least building time-series of length distribution of landings and discards per fleet in those areas and collecting information and effort on the fishing fleets in those two areas. Information from surveys is needed to get biomass trend information.

Regarding stock identity, further efforts should be made to clarify the sardine population structure in the stock area as well as the potential exchanges between Bay of Biscay and the Iberian sardine stock in order to take account of any dynamics that may exist between those regions.

5.10 External reviewers comments

Comments by reviewers were taken up in the report.

5.11 Sources

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Annex 2: Recommendations

Recommendation	Where/who (Contact person from WKPELA)	To – group
WKPELA set up a database to store historical assessment input data at least down to the level by stock (NSAS, WBSS), area (Division IV and IIIaN/IIIaS, SD 22, SD 23 and SD 24), fleet (A, C, D, E), age groups (= WRs) 0–8+ and year (1991–now) to ensure quality of the input data of the assessment. WKPELA encourages HAWG to continue the population of the database.	4.3; Data quality -	HAWG
Further work is needed to quantify the amount of mixing of WBSSH and CBH in areas SD22–24 and SD25. To verify and improve the quality of assignment of stock identity, novel genetic methods should be additionally applied (Limborg *et al*., 2012).	4.5; Migration patterns - Tomas Gröhsler	??
Improving areal coverage of sampling of catches for WBSS herring. In order to get a solid base for estimation of the removals by the fishery, it is of utmost importance that all parts of the distribution area and the fishery herein are covered by the biological sampling. Though the sampling coverage has improved the past years and at present covers the entire distribution area and follows the spatial and temporal distribution of the catches, there is still room for improvement; the sampling in recent periods very poorly covers the area IVaE. Thus it is highly recommended that the sampling intensity in Subdivision IVaE and eastern parts of IVb is substantially increased.	4.5.1; Catch sampling for size-at-age and stock identity - Lotte Worsøe Clausen	PGCCDBS
In the assessment for anchovy in the bay of Biscay the potential inclusion the CUFES index into future assessments was postponed until WGACEGG provides WGHANSA with the following: - a complete servies (two years are lacking) and, more importantly, - a verified index series that is supported by WGACEGG as a reliable index of anchovy egg production	3.6.2; New index from CUFES egg data from acoustic survey - Leire Ibaibarriaga	WGACEGG
For future improvement of the assessment for anchovy in the Bay of Biscay improved data on environmental conditions (all over the year) should be made available to try to link with the larval survival and recruitment.	3.5; Ecosystem drivers - Andres Uriarte	??
For future improvement of the assessment for anchovy in the Bay of Biscay the estimation of discards on the pelagic trawlers should be completed and survival experiments after slipping of anchovy (in both Spanish and French purse-seiners fishery) might be considered.	3.3; WKACCU scorecard - Erwan Duhamel	PGCCDBS
For improvement of the assessment possibilities of sardine in Subareas VII and VIII, improved data collection on catch sampling, etc is needed, as well as better survey coverage.	5 - Lionel Pawlowski	PGCCDBS

Annex 3: Discussion on the assessment model for Bay of Biscay anchovy after WKPELA

At the beginning of the benchmark workshop the assessment model proposed for the Bay of Biscay anchovy stock was the CBBM (Ibaibarriaga *et al*., 2011). The list of issues to be addressed during the benchmark workshop was: (a) natural mortality rates, (b) DEPM survey catchability and (c) the use of the JUVENA index in the assessment. During the benchmark a new issue was added to the list: the possibility of fixing the variance of the observation equations. The initial CBBM model proposal estimated the variance-related parameters of the observation equations. However, the DEPM and acoustic methods provide not only spawning biomass estimates but also the corresponding coefficient of variation (CV).

WKPELA studied the possibility of incorporating these estimates as fixed values in the observation equations. The variance related parameters of the observation equations of the age 1 proportion from the surveys and the catch were also fixed. This had the effect of increasing the magnitude of the Pearson residuals but also of greatly reducing the width of the final SSB posterior distributions (the fewer parameters estimated, the smaller the uncertainty). During the benchmark this option was considered as the most appropriate one as it was using the uncertainty estimates from the surveys for weighting the observations provided by each survey per year.

Right after the benchmark meeting an additional model run providing a compromise between both approaches was proposed. This model consisted in splitting the variance of the SSB observation equations from the surveys as the sum of the variances obtained from the surveys (sampling error changing from year to year and fixed according to the survey results) and the residual variance (constant parameter across years estimated from the model). The rest of the variance related parameters of the observation equations were estimated as in the initial CBBM proposal.

Results of the new run compared with the WKPELA outcome

The recruitments and fishing mortality rates by semester for the three approaches:

a) initial proposal with variances estimated;

b) WKPELA setting with variance related parameters fixed; and

c) proposal after the meeting with variances of SSB observation equations from the surveys split into fixed and estimated variances.

are compared in Figure 1. In general proposal c) after the meeting gives very similar results to the initial proposal a) (Table 1). The main difference is on the estimated ψ_{depm} and ψ_{ac}. When splitting the variances, the resulting medians of ψ_{depm} and ψ_{ac} are larger. However the SSB series remain basically the same. The substantial difference is obtained for option b), in which the variance related parameters of the observation equations are fixed. In this case there are changes in some years and the uncertainty is greatly reduced (Figure 2).

The Pearson residuals for the case proposed after the meeting in which the variance of the SSB observation equations from the surveys is the sum of the variances obtained from the surveys and the residual variance are shown in Figure 3. In general residuals are smaller than the case in which the variance related parameters are fixed.

Figure 4 shows the retrospective analysis of SSB for option a) (in which the variance of the SSB observation equations from the surveys is the sum of the variances obtained from the surveys and the residual variance). The SSB changes from 1992 to 2002 are smaller than the case in which the variance related parameters are fixed. From 2006 to 2010 the SSB estimates are revised upwards as more years are added.

Considerations

After the meeting the benchmark workshop could not reach an agreement on the best approach by correspondence.

On the one hand, the possibility of considering the sum of variances was considered an improvement due to the smaller residuals. In addition, the obtained probability estimates were considered to be more realistic and to reflect better the uncertainty in the spawning biomass estimates. The wide probability intervals in the last two years are considered a good reflection of the discrepancies between the surveys in 2012.

On the other hand, it was felt that the increased perception of uncertainty in the last years will influence the advice forecast which was not looked into. It might be difficult to explain to outsiders what the main drivers are of changes to the model. An additional problem is the increased the retrospective patterns with SSB being underestimated by the last year in most cases (Figure 5; Table 2). Stakeholder and fishermen have been sensitive to that in the past because each revision (and increase) of the SSB meant to them they could have fished more (as the projection from the LTMP are a direct function of the SSB). When SSB is low, their perception is the model is biased downward. This problem was one of the points to review with the former model. This also highlights the point that any catch option projection might be properly evaluated to take account of the effect of those uncertainties and bias.

The external reviewers considered this new proposal (sum of variances) an improvement since the new results better capture the uncertainty in estimates of annual spawning biomass, fishing mortality, etc. The precision of annual estimates of population size and fishing mortality will be pretty uncertain, considering we are dealing with a short-lived, fast-growing species. At that, our observations informing these attributes are only relative biomass indices and catch (in biomass) for two age groups (recruits or those older). The external reviewers therefore propose that this rather than the final model we obtained during the meeting be the basis of management advice.

Due to the lack of consensus, the benchmark workshop could not reach agreement by correspondence.

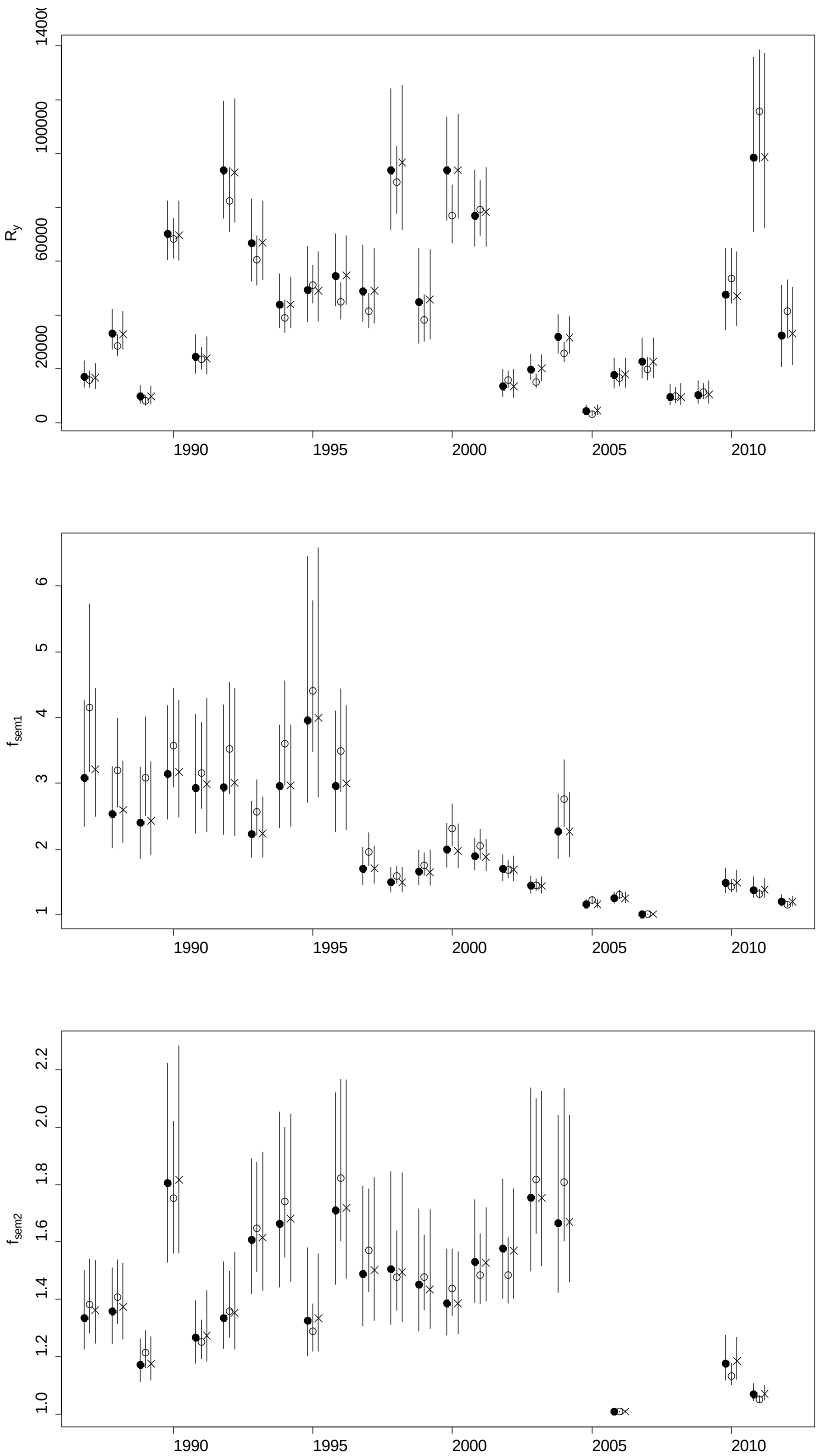


Figure 1. From top to bottom comparison of recruitment, fishing mortality in the first and in the second semester when the variances of the observation equations are estimated (bullet), fixed (open circle) and split as the sum of sampling error and residual variance (cross).

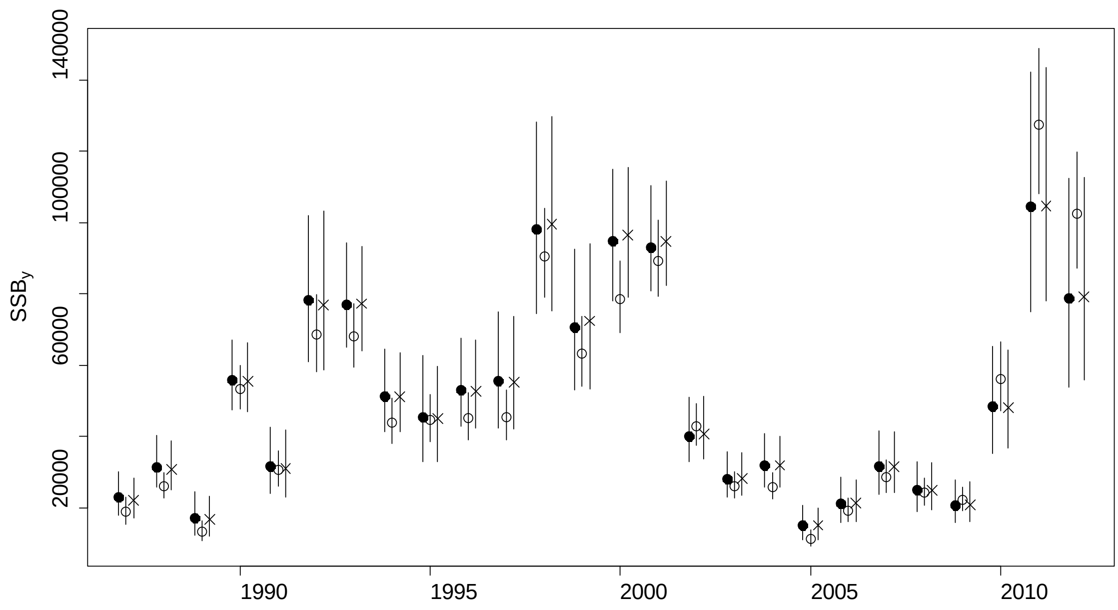


Figure 2. Comparison of spawning biomass when the variances of the observation equations are estimated (bullet), fixed (open circle) and split as the sum of sampling error and residual variance (cross).

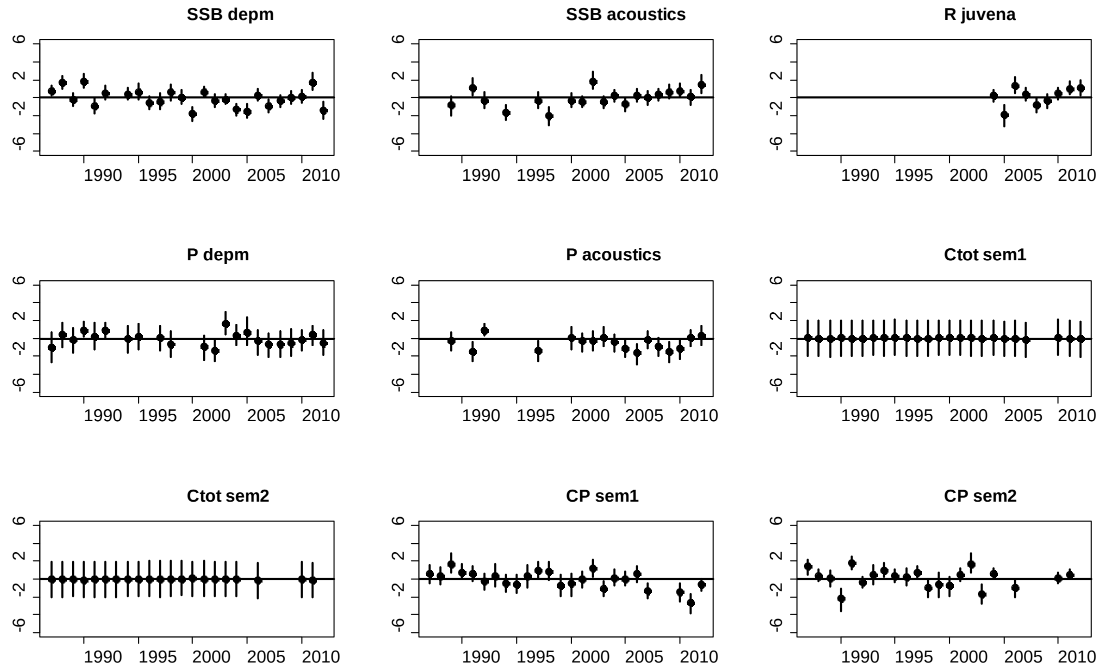


Figure 3. Pearson residuals when variance related parameters from the observation equations are split as the sum of sampling error and residual variance.

Figure 4. Retrospective analysis of spawning biomass from the CBBM when variance related parameters from the observation equations are split as the sum of sampling error and residual variance.

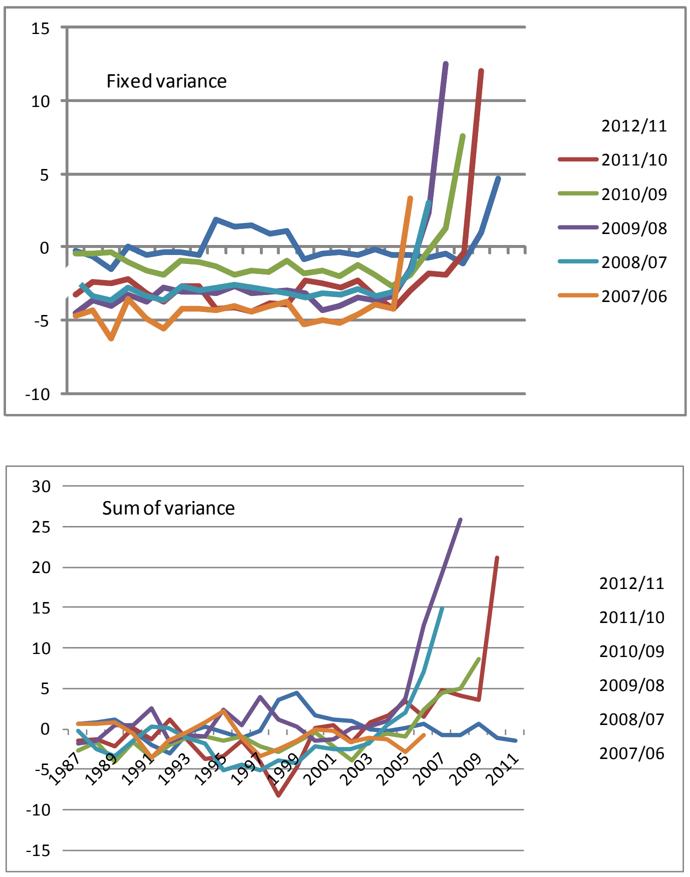


Figure 5. Relative variation of SSB from a retrospective analysis for a given assessment year and the year before.

Table 1. Posterior quantiles for the CBBM depending on various approaches regarding the variances of the observation equations.

	VARIANCES ESTIM			VARIANCES FIXED			VARIANCES FIXED + ESTIM		
	WITHOUT JUVENA			WITH JUVENA			WITH JUVENA		
	DEPM relative			DEPM relative			DEPM relative		
	$M_1 = 0.8$ and $M_{2+} = 1.2$			$M_1 = 0.8$ and $M_{2+} = 1.2$			$M_1 = 0.8$ and $M_{2+} = 1.2$		
Parameter	5%	50%	95%	5%	50%	95%	5%	50%	95%
q_{depm}	0.502	0.626	0.759	0.597	0.673	0.757	0.505	0.617	0.753
q_{ac}	1.034	1.296	1.606	1.265	1.426	1.602	1.053	1.296	1.606
q_{juv}	1.511	2.562	4.031	1.707	2.671	3.975	1.529	2.542	3.991
ψ_{depm}	2.982	5.151	8.386				3.400	6.542	12.071
ψ_{ac}	3.177	6.280	11.491				3.448	7.122	14.621
ψ_{juv}	0.609	1.513	3.194	0.770	1.959	3.998	0.591	1.499	3.250
ξ_{depm}	3.194	3.989	4.922				3.202	3.974	4.963
ξ_{ac}	2.703	3.393	4.182				2.686	3.376	4.071
ξ_{catch}	2.393	2.843	3.242				2.387	2.841	3.252
B_0	17 466	22 471	29 144	14 750	17 854	21 742	16 764	21 982	27 723
μ_R	10.060	10.390	10.701	9.981	10.310	10.640	10.050	10.380	10.700
ψ_R	0.718	1.170	1.793	0.703	1.128	1.707	0.727	1.163	1.805
$s(sem_1, 1)$	0.401	0.484	0.577	0.413	0.463	0.518	0.398	0.482	0.580
$s(sem_2, 1)$	1.022	1.287	1.631	1.224	1.432	1.691	1.004	1.271	1.591
G_1	0.454	0.523	0.594	0.493	0.564	0.641	0.451	0.521	0.594
G_{2+}	0.163	0.225	0.296	0.214	0.283	0.364	0.157	0.225	0.294
ψ_G	19.380	29.685	43.881	15.590	25.185	37.951	19.760	29.820	43.000

Table 2. Variation of SSB for a given year between the year when it was a final year estimate (assessment year y) and as it was estimated in 2012.

fixed var

Year y	assess2012	final SSB assessed on that year y	%
2006	19108	20149	-5.2
2007	28545	27880	2.4
2008	24319	21874	11.2
2009	22202	20967	5.9
2010	55992	49499	13.1
2011	127552	121815	4.7
2012	102569	102569	0

Sum of variance

y	assess2012	final SSB assessed on that year y	%
2006	21389	17045	25.5
2007	31413	21141	48.6
2008	24802	18173	36.5
2009	20801	18374	13.2
2010	48037	40114	19.8
2011	104729	106311	-1.5
2012	79144	79144	0

Annex 4: Stock Annexes

Stock Annex: Bay of Biscay Anchovy (Subarea VIII)

Stock	Bay of Biscay Anchovy (Subarea VIII)
Working Group	WGHANSA (Working Group on the Assessment of Southern Horse Mackerel, Anchovy and Sardine)
Date	February 2013
Revised at	WKPELA 2013
Authors	G. Boyra, E. Duhamel, L. Ibaibarriaga, J. Massé, L. Pawlowski, M. Santos and A. Uriarte.

A. General

A.1. Stock definition

The Anchovy (*Engraulis encrasicolus* L) inhabiting Subarea VIII (Bay of Biscay) is considered to be isolated from a small population in the English Channel and from the populations in western Iberia (Division IXa) (Magoulas *et al*., 2006; Zarraonaindia *et al*., 2012). Morfometrics and meristic studies suggest some heterogeneity at least in morphotipes (Prouzet and Metuzals, 1994; Junquera and Pérez-Gandaras, 1993). Along the North of Spain (in Division VIIIc) Junquera and Pérez-Gandaras (1993) had already reported significant morphological differences in anchovies between Galicia, Asturias, and the Basque Country, and recently Borrell *et al*. (2012) have pointed out that there is some genetic isolation of anchovies in the middle west side of this division from the eastern one. In addition, some genetic heterogeneity, based on proteins *allocime loci*, have been found between the Garonne spawning regions and southern regions in the Bay of Biscay (Adour and Cantabrian shores) (Sanz *et al*., 2008). Despite the evidences for some heterogeneity and perhaps subpopulation in parts of the Bay of Biscay (western Cantabria), there are ample evidences that the major part of the population inhabits the Eastern and northern parts of the Bay of Biscay and show rather homogenous recruitment pulses and have a rather well understood common spatial dynamics throughout the year (Uriarte *et al*., 1996). This leads ICES to consider that the anchovy in this area should be dealt as a single stock for assessment and management.

A.2. Fishery

The fisheries were closed from July 2005 to December 2009 due to poor condition of the stock. It was reopened in January 2010 with a TAC of 7000 t. The fisheries for anchovy are targeted by purse-seiners and pelagic trawlers. The Spanish and French fleets fishing for anchovy in Subarea VIII are spatially and temporally quite well separated. The Spanish fleet (purse-seine fleet) operates mainly in Divisions VIIIc and VIIIb in spring, while the French fleet (mainly pelagic trawlers) operates in Division VIIIa in summer and autumn and in Division VIIIb in winter and summer. A small fleet of French purse-seiners operates in the south of the Bay of Biscay (VIIIb) in spring and in the north (VIIIa) during the autumn. An overview of the history of the fishery until the mid-nineties and its spatial behaviour is found in Junquera (1986) and Uriarte *et al.* (1996) and for more recent perspective see ICES (2007, 2008) or STECF (2008) for the international fishery, Uriarte *et al.* (2008); Villamor *et al.* (2008), for the Spanish fishery and Duhamel (2004) and Vermard *et al.* (2008) for the French pelagic trawler. According to information provided by the SWWRAC in 2009 during the closure of the fishery the fleet size operating on anchovy decreased and the fleets redeployed their effort towards other small pelagic species (57%) and tuna (29%).

A.3. Ecosystem aspects

Anchovy is a prey species for other pelagic and demersal species in the Bay of Biscay, and also for cetaceans and birds (Goñi *et al*., 2011a,b; López-López *et al*., 2012). In addition to predator interactions on adults, in recent years major attention is being paid to the role that intraguild predation may have in affecting the survival of early life stages (Irigoien and Ross, 2011), and for this anchovy the potential influence of sardine predating on anchovy eggs has been evidenced (Bachiller *et al*., submitted).

The recruitment depends strongly on environmental factors. Recently ICES WGSPEC (ICES, 2012) has reviewed the role that environmental factors may have on determining the success of recruitment. Two environmental recruitment indices have been considered during the last ten years: i) Borja's *et al.* (1998) index, which is an upwelling index, and ii) Allain's *et al.* (2001) index, which is a combination of upwelling and stratification breakdown. Allain's model was reviewed by Huret and Petitgas (WD 2007, ICES 2008) including a) the previous "upwelling" index, plus a new "stratification" index according to a new hydrodynamic model and b) an adult spatial indicator. The role of the Eastern Atlantic pattern in relation to the Upwelling index and the recruitment of anchovy have also been recently pointed out (Borja *et al.*, 2008). Other approaches based on coupling spawning habitat with hydrodynamic and production models are being tried for this anchovy population with promising results (Allain *et al.*, 2007). From the latter studies the issue of much drifting (induced by the Upwelling) of the anchovy eggs and larval out of the shelf is controversial among scientists (Borja *et al*., 1996; 1998; Uriarte, 2001; Allain *et al*., 2001; 2007; Irigoien, 2007; 2008).

Recent research for identifying and monitoring limiting factors of anchovy recruitment in the Bay of Biscay was made by Petitgas (2011). Indices of physical features were estimated (river plumes, gyres, stratification, fronts) as well as indices of larval dispersal, primary production and temperature. Indices of spawning aggregations derived from fisheries survey data were also estimated. Results showed that the larval period was where many indices responded, confirming that it is a critical period. The limiting factors changed across the series, confirming the multiple nature of the determinism of recruitment.

Fernandes *et al*. (2010) presents an alternative to attempt to relate environmental indices with recruitment by means of linear models. They use machine-learning techniques to obtain the probability of having a recruitment discretized into low, medium and high classes depending on environmental variables. The proposed methodology consists of performing supervised predictors discretization, carrying out supervised predictors selection and learning a 'naive Bayes' classifier. The approach can be applied to a dataset where the values of the recruitment have been discretized by the end-user, or the recruitment discretization can be part of the proposed model-building process in a bootstrap scheme. Environmental variables seem to explain a significant part of the observed variability of the small pelagics but not more than 50% of it (at least from the available indicators), so that there is space for looking for other supplementary variables driving recruitment for these species. The significance and reliability of all these indices is considered still insufficient for their consideration alone in the provision of management advice. But they are considered valuable information accompanying the forecasts given from recruitment surveys such as JUVENA. It is certainly useful their consideration for further improvements.

B. Data

B.1. Commercial catches

Annual Landings are available since 1940. Discards are not measured and hence not included in the assessment, but nowadays they are considered not relevant for the two fleets. In the past (late eighties and early nineties for the French Pelagic trawlers and sixties and seventies for the Spanish Purse seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified.

B.2. Biological

- Catches-at-length and catches-at-age are known since 1984 for Spain and since 1987 for France. They are obtained by applying to the monthly Length distributions half year or quarterly ALKs (and when possible monthly ALKs, as for the Spanish fishery in spring). Biological sampling of the catches has been generally sufficient, except for 2000 and 2001, when an increase of the sampling effort seemed useful to have a better knowledge of the age structure of the catches during the second semester in the North of the Bay of Biscay. Complete age composition and mean weight-at-age on half year basis, were reported in ICES.
- Age reading is considered accurate.

  The most recent cross reading exchanges and workshop took place in 2009 WKARA (ICES CM 2009/ACOM:43). The overall level of agreement and precision in anchovy age reading determinations seemed to be satisfactory: Most of the anchovy otoliths were well classified by most of the readers during the exchange (with an average agreement of 88.8% and a CV of 12.9%). CV was minimum at age 0 and increased slightly with age while the percentage of agreement decreased with age (with Percentage of agreement with the modal ages of 100%, 83%, 91% and 63% respective to ages 0, 1, 2 and 3). The most expert readers who are in charge of the largest fraction of the international catches showed higher agreements than the rest of readers.

- In former workshops between Spain and France which took place in 2005 and 2006 respectively (Uriarte *et al.*, 2006 and 2007). The overall level of agreement and precision in anchovy age reading determinations was also satisfactory: Most of the anchovy otoliths were well classified by most of the readers during the 2006 workshop (with an average agreement of 92.7% and a CV of 9.2%). CVs were on average smaller than 15% for any age, although individual CVs for ages or readers might be 30–35%. Anchovies are mature at their 1st year of life.
- Growth in weight and length are well known from surveys and from the monitoring of the fishery (Uriarte *et al.*, 1996).
- Natural mortality is fixed at 0.8 for age 1 and at 1.2 for older individuals. This parameter is considered to vary between years, but it is assumed to be constant for the assessment of the stock.
- In the CBBM assessment model the parameters G_1 and G_{2+} representing the annual intrinsic growth of the population by age class are assumed constant along years and are estimated based on the weight-at-age data.

B.3. Surveys

The population is monitored by the two annual surveys carried out in spring on the spawning stock, namely, the Daily Egg Production Method (since 1987 with a gap in 1993) (Santiago and Sanz, 1992; Motos *et al.*, 2005; Santos *et al.*, 2011) and the Acoustics surveys (regularly since 1989, although surveys were also conducted in 1983, 1984 and some in the seventies) (Massé, 1988; 1994; 1996). Both surveys provide spawning biomass (this equals total stock biomass since all anchovies are mature in spring) and population-at-age estimates. The surveys have shown pronounced interannual variability of biomass according to the pulse of recruitments, since one year old anchovies can conform up to more than 75% of the spawning population. Spawning area and biomass are positive and closely related, revealing expansion of the area occupied by the population when SSB increases (Uriarte *et al.*, 1996; Somarakis *et al.*, 2004).

The spring surveys provide population estimates by the middle of the year, when about half of the annual catches have been already taken; and provide very little information about the anchovy population in the next year, since the bulk of it will consist of one year old anchovies being born at the time the surveys take place. Since 2003 an autumn acoustic survey (JUVENA) is conducted yearly. The main objective of this survey is estimating the anchovy juvenile abundance in order to forecast the strength of the recruitment that will enter the fishery the next year.

B.3.1 Anchovy Daily Egg Production Method

B.3.1.1 The DEPM model

The anchovy spawning–stock biomass estimate is derived according to Parker (1980) and Stauffer and Picquelle (1980) from the ratio between daily production of eggs in the sea and the daily specific fecundity of the adult population:

$$SSB = P_{tot} / DF = \frac{P_0 \cdot A+}{k \cdot R \cdot F \cdot S / W} \qquad \text{Equation 1}$$

Where,

SSB = Spawning–stock biomass in metric tons

P_{tot} = Total daily egg production in the sampled area

P_0 = daily egg production per surface unit in the sampled area

A+ = Spawning area, in sampling units

DF = Daily specific fecundity. $DF = \frac{k \cdot R \cdot F \cdot S}{W}$

W = Average weight of mature females in grams,

R = Sex ratio, fraction of population that are mature females, by weight.

F = Batch fecundity, numbers of eggs spawned per mature females per batch

S = Fraction of mature females spawning per day

k = Conversion factor from gram to metric tons (10^6)

An estimate of an approximate variance and bias for the biomass estimator derived using the *delta* method (Seber, 1982, *in* Parker 1985.) was also developed by the latter authors.

Population estimates of numbers-at-age are derived as follows:

$$N_a = N \cdot E_a = \frac{SSB}{W_t} \cdot E_a \qquad \text{Equation 2}$$

Where,

N_a = Population estimate of numbers-at-age *a*.

N = Total spawning–stock estimate in numbers. $N = \frac{SSB}{W_t}$

SSB = spawning–stock biomass estimate.

W_t = average weight of anchovies in the population.

E_a = Relative frequency (in numbers) of age *a* in the population.

Wt and Ea are obtained from the average of the mean weight and the percentages by ages across the anchovy samples from the survey (see the adult parameter section below).

Variance estimate of the anchovy stock in numbers-at-age and total is derived applying the delta method.

B.3.1.2 Collection of plankton samples

Every year the area covered to collect the plankton samples is the southeast of the Bay of Biscay which corresponds to the main spawning area and spawning season of anchovy.

Predetermined distribution of stations is shown in Figure B.3.1.2.1. The strategy of egg sampling is as follow: a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found (Motos, 1994). Stations are located every three miles along 15-mile-apart transects perpendicular to the coast. The sampling strategy is adaptive. When the egg abundances found are relatively high, additional transects separated by 7.5 nm are completed.

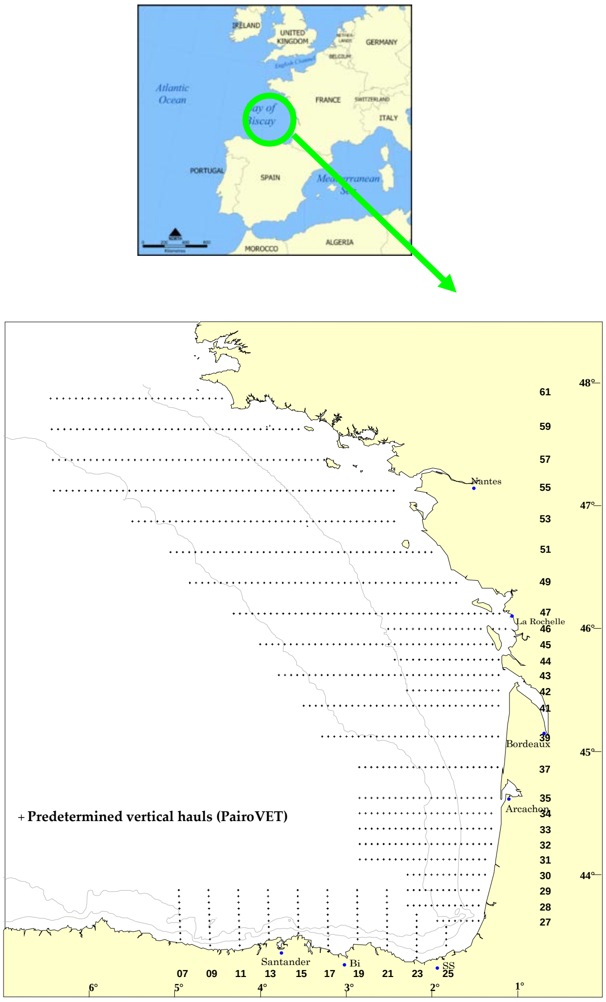


Figure B.3.1.2.1. Predetermined stations of the vertical hauls (PairoVET) that could be performed during the survey.

At each station a vertical plankton haul is performed using a PairoVET net (Pair of Vertical Egg Tow, Smith *et al.*, 1985 in Lasker, 1985) with a net mesh size of 150 µm for a total retention of the anchovy eggs under all likely conditions. The net is lowered to a maximum depth of 100 m or 5 m above the bottom in shallower waters. After allowing ten seconds at the maximum depth for stabilisation, the net is retrieved to the surface at a speed of 1 m s-1. A 45 kg depressor is used to allow for correctly deploying the net. "G.O. 2030" flowmeters are used to detect sequential clogging of the net during a series of tows.

Immediately after the haul, the net is washed and the samples obtained are fixed in formaldehyde 4% buffered with sodium tetra borate in seawater. After six hours of fixing, anchovy, sardine and other eggs species are identified, sorted out and counted on board. Afterwards, in the laboratory, a percentage of the samples are checked to assess the quality of the sorting made at sea. According to that, a portion of the samples are sorted again to ensure no eggs were left in the sample. In the laboratory, anchovy eggs are classified into morphological stages (Moser and Alshtrom, 1985).

The Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al.*, 1997) is used to record the eggs found at 3 m depth with a net mesh size of 350 µm. The samples obtained are immediately checked under the microscope so that the presence/absence of anchovy eggs is detected in real time. When anchovy eggs are not found in six consecutive CUFES samples in the oceanic area transect is abandoned. The CUFES system has a CTD to record simultaneously temperature and salinity at 3 m depth, a flowmeter to measure the volume of the filtered water, a fluorimeter and a GPS (Geographical Position System) to provide sampling position and time. All these data are registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software.

During the survey, the anchovy, sardine and other eggs are recorded per PairoVET station and the area where anchovy eggs occurred is quantified. The spawning area is delimited with the outer zero anchovy egg stations. It contains some inner zero egg stations embedded on it (Picquelle and Stauffer, 1985). Following the systematic central sampling scheme (Cochran, 1977) each station is located in the centre of a rectangle. Egg abundance found at a particular station is assumed to represent the abundance in the whole rectangle. The area represented by each station is measured. A standard station has a surface of 45 squared nautical miles (154 km^2) = 3 (distance between two consecutive stations) x 15 (distance between two consecutive transects) nautical miles. Since sampling is adaptive, station area changed according to sampling intensity and the cut of the coast.

Sample depth, temperature, salinity and fluorescence profiles are obtained in every station using a CTD RBR-XR420 coupled to the PairoVET. In addition, surface temperature and salinity are recorded in each station with a manual termosalinometer WTW LF197. Moreover current data are obtained all along the survey with an ADCP (Acoustic Doppler Current Profiles). In some point determinate previously to the survey, water is filtered from the surface to obtain chlorophyll samples to calibrate the chlorophyll data.

The historical maps of anchovy egg distribution obtained with PairoVET are shown in Figure B.3.1.2.2.

B.3.1.3 Collection of adult samples

In 1987 and 1988 the samples were obtained from commercial purse-seines and the adult sampling was opportunistic. From years 1989 to 2005 the adult samples were obtained both from commercial purse-seines and a research vessel with pelagic trawl so the adult sampling was both opportunistic and directed. Since 2006 the samples are obtained from a research vessel with pelagic trawl. Samples from the purse-seines were not available due to the closure of the fishery. Since the reopening of the fisheries in March 2010 the commercial purse-seines are providing again samples for the analysis apart from the ones obtained from the research vessels.

The research vessel pelagic trawler covers the same area as the plankton vessel. When the plankton vessel encountered areas with anchovy eggs, the pelagic trawler is directed to those areas to fish. In each haul 100 individuals of each species are measured. Immediately after fishing, anchovy is sorted from the bulk of the catch and a sample of two Kg is selected at random. A minimum of one kg or 60 anchovies are weighted, measured and sexed and from the mature females the gonads of 25 non-hydrated females (NHF) are preserved. If the target of 25 NHF is not completed ten more anchovies are taken at random and process in the same manner. Sampling is stopped when 120 anchovies have to be sexed to achieve the target of 25 NHF. Otoliths are extracted on board and read in the laboratory to obtain the age composition per sample. In case samples are obtained from the purse-seines, a sample of two kg is selected from the fishing and is directly kept in 4% formaldehyde. Afterwards, in the laboratory the samples are process in the same manner as explained above.

B.3.1.4 Total daily egg production estimates

When all the anchovy eggs are sorted and staged, it is possible to estimate the total daily egg production (P_{tot}). This is calculated as the product between the daily egg production (P_0) and the spawning area (SA):

$$P_{tot} = P_0\, SA \qquad (1)$$

A standard sampling station represents a surface of 45 nm² (i.e. 154 km²). Since the sampling was adaptive, area per station changes according to the sampling intensity and the cut of the coast. The total area is calculated as the sum of the area represented by each station. The spawning area (SA) is delimited with the outer zero anchovy egg stations but it can contain some inner zero stations embedded. The spawning area is computed as the sum of the area represented by the stations within the spawning area.

The daily egg production per area unit (P_0) was estimated together with the daily mortality rate (Z) from a general exponential decay mortality model of the form:

$$P_{i,j} = P_0 \exp\left(-Z\, a_{i,j}\right), \qquad (2)$$

where Pi,j and ai,j denote respectively the number of eggs per unit area in cohort j in station i and their corresponding mean age. Let the density of eggs in cohort j in station i, Pi,j, be the ratio between the number of eggs Ni,j and the effective sea area sampled Ri (i.e. $P_{i,j} = N_{i,j} / R_i$). The model was written as a generalised linear model (GLM, McCullagh and Nelder, 1989; ICES, 2004) with logarithmic link function:

$$\log\left(E[N_{i,j}]\right) = \log(R_i) + \log\left(P_0\right) - Z\, a_{i,j}\ , \qquad (3)$$

where the number of eggs of daily cohort *j* in station *i* (N_{ij}) was assumed to follow a negative binomial distribution. The logarithm of the effective sea surface area sampled ($\log(R_i)$) was an offset accounting for differences in the sea surface area sampled and the logarithm of the daily egg production $\log(P_0)$ and the daily mortality Z rates were the parameters to be estimated.

The eggs collected at sea and sorted into morphological stages had to be transformed into daily cohort frequencies and their mean age calculated in order to fit the above model. For that purpose the Bayesian ageing method described in ICES (2004), Stratoudakis *et al.*, (2006) and Bernal *et al.*, (2011) was used. This ageing method is based on the probability density function (pdf) of the age of an egg *f(age | stage, temp)*, which is constructed as:

$$f(age \mid stage, temp) \propto f(stage \mid age, temp)\, f(age) \qquad (4)$$

The first term f(stage | age, temp) is the pdf of stages given age and temperature. It represents the temperature dependent egg development, which is obtained by fitting a multinomial model like extended continuation ratio models (Agresti, 1990) to data from temperature dependent incubation experiments (Ibaibarriaga *et al.*, 2007; Bernal *et al.*, 2008). The second term is the prior distribution of age. *A priori* the probability of an egg that was sampled at time τ of having an age is the product of the probability of an egg being spawned at time τ - age and the probability of that egg surviving since then (exp(-Z age)):

$$f(age) \propto f(spawn = \tau - age)\exp(-Z\ age) \qquad (5)$$

The pdf of spawning time f(spawn= τ - age) allows refining the ageing process for species with spawning synchronicity that spawn at approximately certain times of the day (Lo, 1985a; Bernal *et al*., 2001). Anchovy spawning time was assumed to be normally distributed with mean at 23:00 h GMT and standard deviation of 1.25 (ICES, 2004). The peak of the spawning time was also used to define the age limits for each daily cohort (spawning time peak plus and minus 12 hours). Details on how the number of eggs in each cohort and the corresponding mean age are computed from the pdf of age are given in Bernal *et al*. (2011). The incubation temperature considered was the one obtained from the CTD at 10 m in the way up.

Given that this ageing process depends on the daily mortality rate which is unknown, an iterative algorithm in which the ageing and the model fitting are repeated until convergence of the Z estimates was used (Bernal *et al*., 2001; ICES, 2004; Stratoudakis *et al*., 2006). The procedure is as follows:

Step 1. Assume an initial mortality rate value;

Step 2. Using the current estimates of mortality calculate the daily cohort frequencies and their mean age;

Step 3. Fit the GLM and estimate the daily egg production and mortality rates. Update the mortality rate estimate;

Step 4. Repeat steps 1–3 until the estimate of mortality converged (i.e. the difference between the old and updated mortality estimates was smaller than 0.0001).

Incomplete cohorts, either because the bulk of spawning for the day was not over at the time of sampling, or because the cohort was so old that its constituent eggs had started to hatch in substantial numbers, were removed in order to avoid any possible bias. At each station, younger cohorts were dropped if they were sampled before twice the spawning peak width after the spawning peak and older cohorts were dropped if their mean age plus twice the spawning peak width was over the critical age at which less than 99% eggs were expected to be still unhatched. In addition, cohorts in which hatching has started are excluded: Upper limit is set at the age in which 99% of the eggs are unhatched, having developed at the 50 quantile of the incubation temperature.

Once the final model estimates were obtained the coefficient of variation of P_0 was calculated from the standard error of the model intercept (log(P0)) (Seber, 1982) and the coefficient of variation of Z was obtained directly from the model estimates.

The analysis was conducted in R (www.r-project.org). The "MASS" library was used for fitting the GLM with negative binomial distribution and the "egg" library (http://sourceforge.net/projects/ichthyoanalysis/) for the ageing and the iterative algorithm.

B3.1.5 Adult parameters and daily fecundity estimates

The DF estimate for the WGHANSA in June is obtained as a mean of the historical DF. Two weeks after arriving from the survey the adult parameters are not processed yet, uniquely the anchovies are weighted, measured, sexed and the otoliths are extracted, consequently Daly Fecundity is preliminarily borrowed from the past historical series. Afterwards in the ICES WGACEGG in November the complete DEPM with all the adult parameters estimates is presented and approved. This occurred since 2005 when the advice started demanding SSB estimates in June.

From the whole set of adult samples gathered during the survey, a subset is chosen for final processing with the criterion of collection within ±5 days of the egg sampling in the same particular area. In the last years the samples were collected within the same day as the egg sampling. These samples are used to obtain adult parameters to estimate the Daily Fecundity, i.e. batch fecundity, spawning fraction, average female weight and sex ratio. These adult parameters are estimated for November as follows:

Sex Ratio (R): Given the large variability among samples of the sex ratio and taking into account that for most of the years when the DEPM has been applied to this population the final estimate has come out to be not significantly different from 50% for each sex (in numbers), since 1994 the proportion of mature females per sample is being assumed to be equal to 1:1 in numbers. This leads to adopt as R the value of the average sample ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

Total weight of hydrated females is corrected for the increase of weight due to hydration. Data on gonad-free-weight (Wgf) and correspondent total weight (W) of non-hydrated females is fitted by a linear regression model. Gonad-free-weight of hydrated anchovies is then transformed to total weight by applying the following equation:

$$W = -a + b * W_{gf}$$

For the **Batch fecundity (F)** estimates i.e. number of eggs laid per batch and female, the hydrated egg method was followed (Hunter *et al*., 1985). The number of hydrated oocytes in gonads of a set of hydrated females is counted. This number is deduced from a subsampling of the hydrated ovary: Three pieces of approximately 50 mg are removed from different parts of each ovary, weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Sanz and Uriarte (1989) showed that three tissue samples per ovary are adequate to get good precision in the final batch fecundity estimate and the location of subsamples within the ovary do not affect it. Finally the number of hydrated oocytes in the subsample is raised to the total gonad of the female according to the ratio between the weights of the gonad and the weight subsampled.

A linear regression between female weight and batch fecundity is established for the subset of hydrated females and used to calculate the batch fecundity of all mature females. The average of the batch fecundity estimates for the females of each sample as derived from the gonad free weight; eggs per batch relationship is then used as the sample estimate of batch fecundity.

Moreover, an analysis is conducted to verify if there are differences in the batch fecundity between different strata if strata are defined to estimate SSB.

To estimate **Spawning Frequency (S)**, i.e. the proportion of females spawning per day, a new spawning frequency estimates were obtained applying the new classification for oocyte and POFs stage of Alday *et al*. (2008) and the procedures described in Uriarte *et al*. (2012). The degeneration of postovulatory follicles (POFs) in time and at different temperatures was studied for the Bay of Biscay anchovy by Alday *et al*. (2008). For this purpose a key of seven POF stages, solely defined on the basis of their histological degeneration characteristics, was applied (Alday *et al*., 2008; 2010). The novelty of this procedure is that it separates staging of POFs from their ageing process. The ovaries, taken from several captivity experiments and field samples, were classified in this way. There was close agreement in the succession of POF stages after spawning between the experiment and the field samples. The first four stages of POF occurred in less than 24 h, and by the end of the first day the POFs were mainly in Stage V. Stages VI and VII showed their highest occurrence during the first and second half of the second day after spawning, respectively. Full resorption of POFs was achieved in 55–60 h. For the range of temperatures examined (13–19˚C), little effect of temperature on the degeneration of POF was noticed.

The procedure to assign mature females to spawning classes was improved by incorporating all the knowledge on oocyte maturation and degeneration of POFs in a matrix system which defines the probabilities of females with those histological indicators belonging to pre- or post-spawning cohort according to the time of capture (Uriarte *et al*., 2012).

Finally, the selected estimator is the mean of S (day 0) and S (day 1). Corrections of sample estimates +/-five hours around peak spawning time (23:00 hours) were applied according to the formulas in Uriarte *et al*. (op. cit.) for an average S of 0.39.

For the years with S estimates which could not be reviewed by the time of WKPELA 2013 (2006, 1989, 1988 and 1987), but have their own estimates of the other reproductive parameters, the average of the historical series (1990–2012) of new S was considered. For the years which did not have any adult reproductive parameters, 1996, 1999 and 2000, the average Daily Fecundity (DF) estimate across the historical series (1990–20012) was adopted (of about 98.5 eggs gram-1 day-1).

Mean and variance of the adult parameters are estimated following equations for cluster sampling (as suggested by Picquelle and Stauffer, 1985):

$$Y = \frac{\sum_{i=1}^{n} M_i \, y_i}{\sum_{i=1}^{n} M_i} \qquad \text{Equation 6}$$

$$Var(Y) = \frac{\sum_{i=1}^{n} M_i^{2} (y_i - Y)^2}{\overline{M}^2 \, n(n-1)} \qquad \text{Equation 7}$$

Where,

Y_i is an estimate of whatever adult parameter from sample *i* and M_i is the size of the cluster corresponding to sample *i*. occasionally a station produced a very small catch, resulting in a small subsample size. To reflect the actual size of the station and its lower reliability, small samples were given less weight in the estimate. For the estimation of W, F and S, a weighting factor was used, which equalled to one when the number of mature females in station *i* (M_i) was 20 or greater and it equalled to $M_i/20$ otherwise. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to total weight of the sample divided by 800 g, otherwise it was set equal to one. In summary for the estimation of the parameters of the Daily Fecundity we are using a threshold-weighting factor (TWF) under the assumption of homogeneous fecundity parameters within each stratum.

B.3.1.6 SSB estimates

In WGHANSA during June the spawning–stock biomass is preliminary estimated as the ratio between the total egg production (P_{tot}) and Daily Fecundity (DF) estimated as the mean of the historical series and its variance is computed using the Delta method (Seber, 1982):

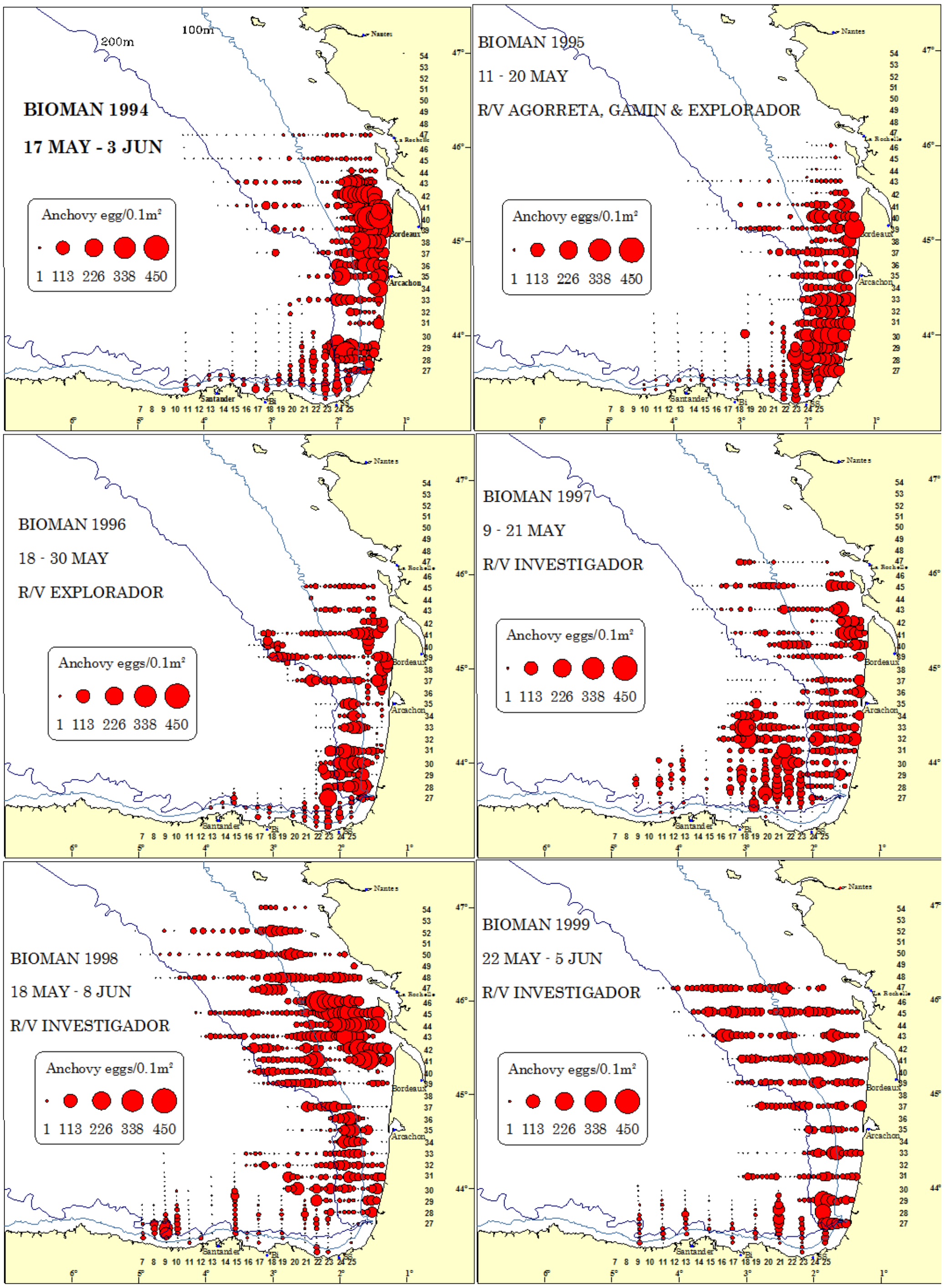
$$V\hat{a}r[SSB] = \frac{V\hat{a}r[Ptot]}{DF^2} + \frac{P_{tot}^{\ 2} V\hat{a}r[DF]}{DF^4}$$

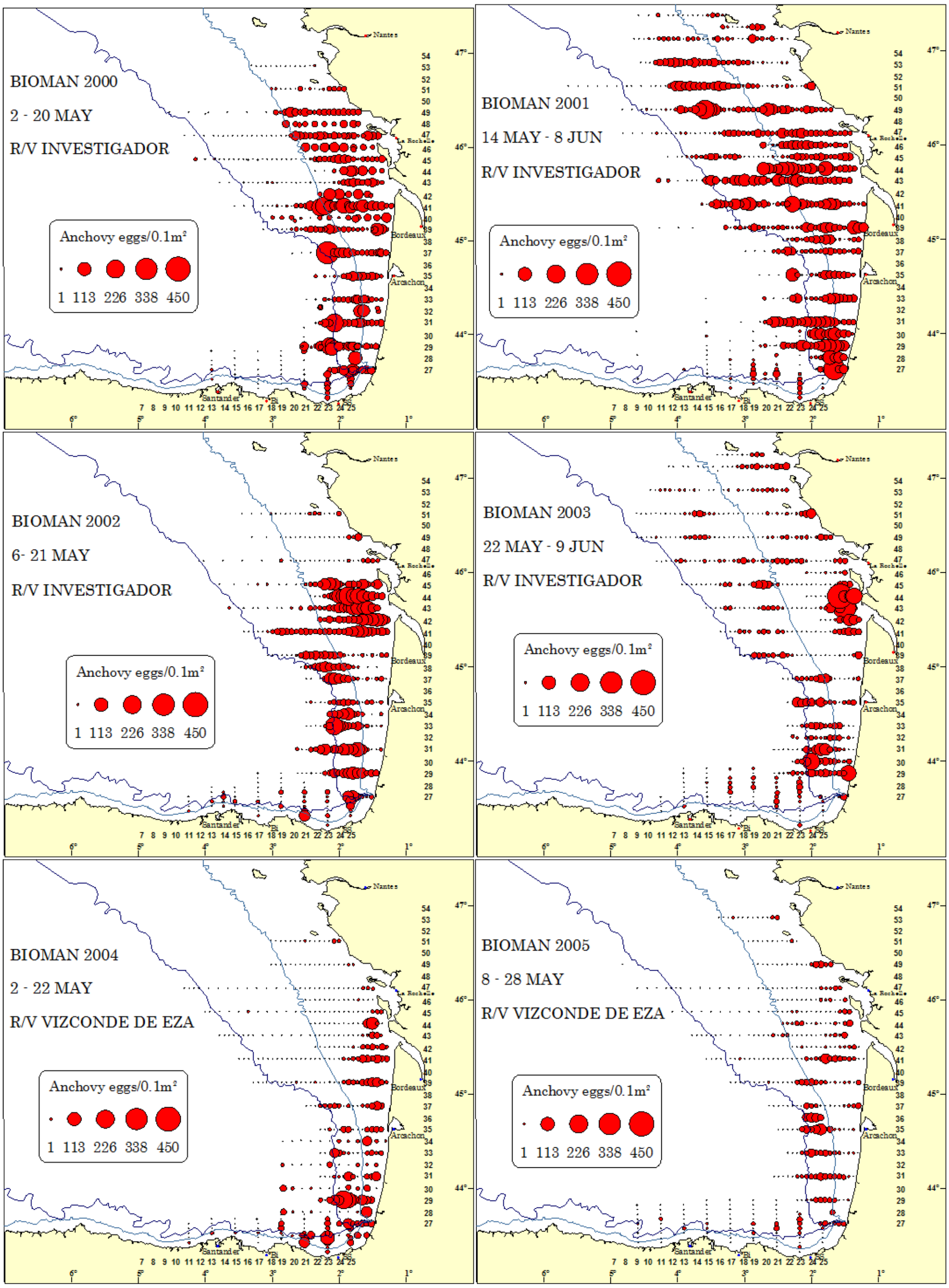
The definitive SSB estimate with all the adult parameters is presented and approved at WGACEGG during November.

B.3.1.7 Numbers-at-age

For the purposes of producing population-at-age estimates, the age readings based on otoliths from the adult samples collected are available. Estimates of anchovy mean weights and proportions-at-age in the adult population are computed as a weighted average of the mean weight and age composition per samples where the weights are proportional to the population (in numbers) in each stratum considered. These weighting factors are proportional to the egg abundance per stratum divided by the numbers of samples in the stratum and the mean weight of anchovy per sample. Weighting factors were allocated according to the relative egg abundance and to the amount of samples in the strata defined for the proposed of the estimation of the numbers-at-age. These strata are defined each year depending on the distribution of the adult samples i.e. size, weight, age and the distribution of the anchovy eggs.

Mean and variance of the adult parameters of the population in numbers-at-age and the population length distribution (total weight, proportion by ages and length distribution) are estimated following equations 6 and 7 for cluster sampling.


200m
100m
BIOMAN 1994
17 MAY - 3 JUN
Anchovy egg/0.1m²
1 113 226 338 450
BIOMAN 1995
11 - 20 MAY
R/V AGORRETA, GAMIN & EXPLORADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1996
18 - 30 MAY
R/V EXPLORADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1997
9 - 21 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1998
18 MAY - 8 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 1999
22 MAY - 5 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
La Rochelle
Bordeaux
Arcachon
Santander


BIOMAN 2000
2 - 20 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2001
14 MAY - 8 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2002
6- 21 MAY
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2003
22 MAY - 9 JUN
R/V INVESTIGADOR
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2004
2 - 22 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
BIOMAN 2005
8 - 28 MAY
R/V VIZCONDE DE EZA
Anchovy eggs/0.1m²
1 113 226 338 450
Nantes
Bordeaux
Arcachon
Santander

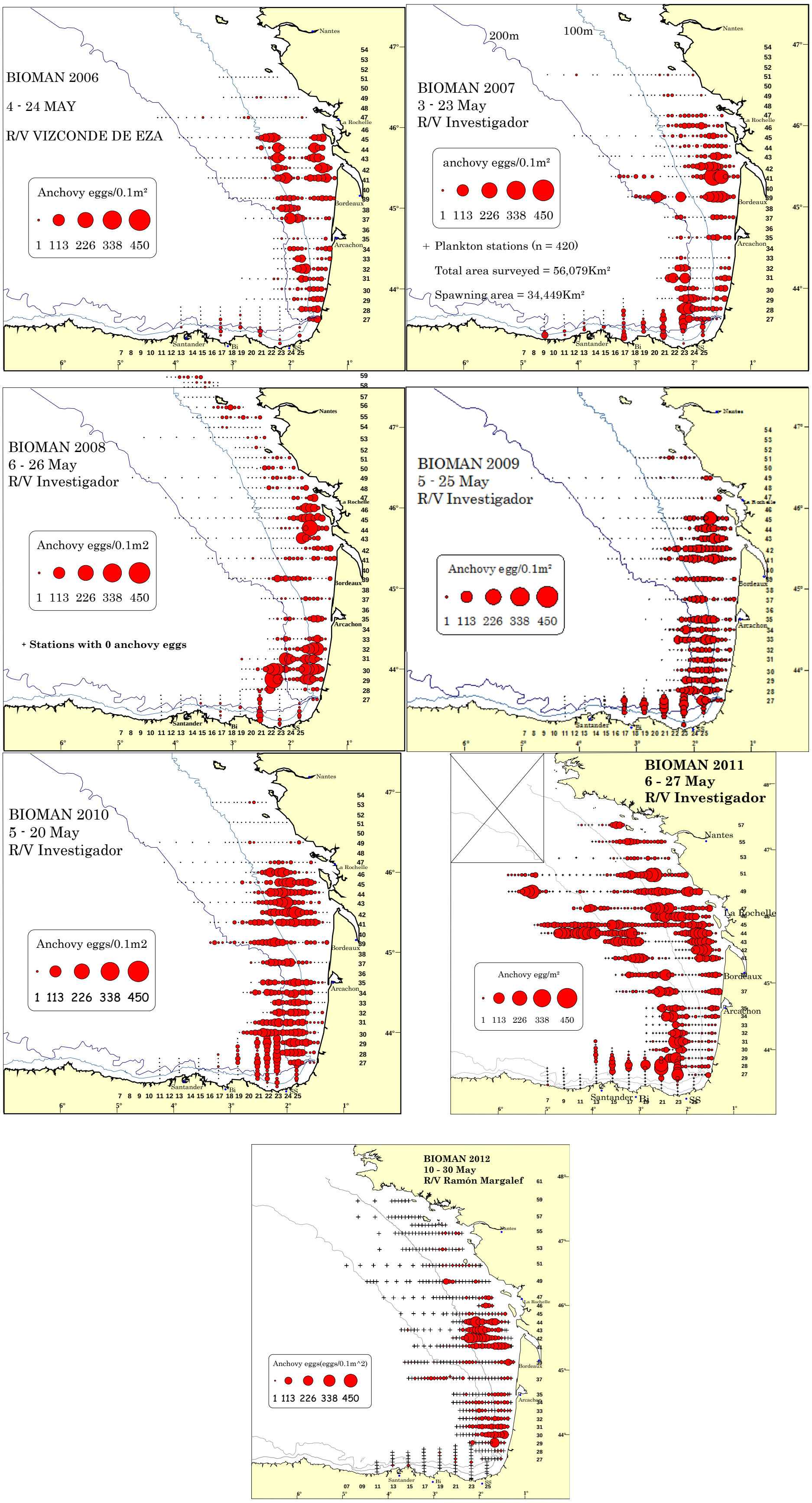


Figure B.3.1.2.2. Anchovy egg distribution from 1998 to 2012.The circles represent the anchovy egg abundance /0.1m² encountered in each plankton station.

B.3.2. Anchovy acoustic indices

Acoustic surveys are carried out every year in the Bay of Biscay in spring on board the French research vessel Thalassa. The objective of PELGAS surveys is to study the abundance and distribution of pelagic fish in the Bay of Biscay. The main target species is anchovy but it will be considered in a multispecific context as species located in the centre of ecosystem.

These surveys are connected with Ifremer programmes on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. These surveys must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain (PELACUS) and Portugal (PELAGO) in order to have most of the potential area to be covered from Gibraltar to Brest with the same protocol for sampling strategy. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

B.3.2.1. Method and sampling strategy

In the frame of an ecosystemic approach, the pelagic ecosystem is characterized at each trophic level. In this objective, to assess an optimum horizontal and vertical description of the area, two types of actions are combined:

- Continuous acquisition by storing acoustic data from five different frequencies and pumping seawater under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler); and
- Discrete sampling at stations (by trawls, plankton nets, CTD). Satellite imagery (temperature and sea colour) and modelisation are also used before and during the cruise to recognise the main physical and biological structures and to improve the sampling strategy.

Concurrently, a visual counting and identification of cetaceans and of birds (from board) is carried out in order to characterise the top predators of the pelagic ecosystem.

The strategy was the identical to previous surveys (2000 to 2009):

- Acoustic data were collected along systematic parallel transects perpendicular to the French coast (Figure B3.2.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was one mile and the transects were uniformly spaced by 12 nautical miles covering the continental shelf from 20 m depth to the shelf break.
- Acoustic data were collected only during the day because of pelagic fish behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer for the echosounder between the surface and 8 m depth.

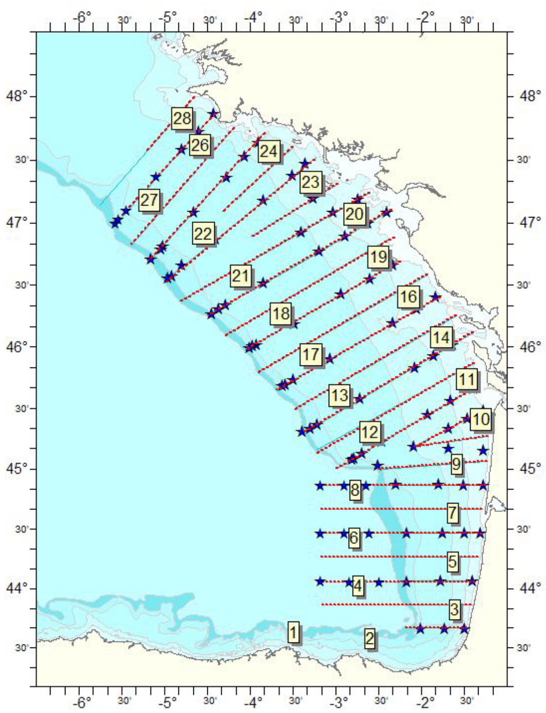


Figure B 3.2.1.1. Acoustic transects and stations during PELGAS surveys since 2000.

Two echosounders are usually used during surveys (SIMRAD EK60 for vertical echosounding and SIMRAD ME70 multibeam echosounder for a 3D approach since 2009). Energies and samples provided by split beam transducers (six frequencies EK60, 18, 38, 70, 120, 200 and 333 kHz), and multibeam echosounder were simultaneously visualised, stored using the MOVIES+ software and at the same standard HAC format.

The calibration method is the same that the one described for the previous years (see WD 2001) with a tungsten sphere hanged up 20 m below the transducer and is generally performed at anchorage in front of Machichaco Cap or in the Douarnenez Bay, at the west side of Brittany, in optimum meteorological conditions.

Acoustic data are collected by Thalassa along the totality of the daylight route from which about 2000 nautical miles on one way transect are usable for assessment. Fish are measured on board (for all species) and otoliths (for anchovy and sardine) are collected for age determinations.

B.3.2.2. Echoes scrutinizing

Most of the acoustic data along the transects are processed and scrutinised during the survey and are generally available one week after the end of the survey (Figure 2.2.1). Acoustic energies (Sa) are cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into several categories of echotraces according to the year fish (species) structures.

Some categories are standard such as:

D1 – energies attributed to mackerel, horse mackerel, blue whiting, divers demersal fish, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10 m height layer close to the bottom.

D2 – energies attributed to anchovy, sprat, sardine corresponding to the usual echotraces observed in this area since more than 15 years, constituted by schools well designed, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal areas and sometime more offshore.

D3 – energies attributed to blue whiting and myctophids offshore, just closed to the shelf break.

D4 – energies attributed to sardine, mackerel or anchovy corresponding to small and dense echoes, very close to the surface.

D6 – energies attributed to a mix, usually between 50 and 100 m depth when D1 and D2 were not separable.

Some particular categories are usually specifically designed according to several identifications during the survey (when Thalassa and/or commercial vessels hauls are available), such as:

D7 – energies attributed exclusively to sardine (big and very dense schools).

D5 – energies attributed to small horse mackerel only when they are gathered in very dense schools; this category is usually used for typical echoes which occur along particular surveys. In the case of 2010, it was used to gather energies which occurred all along the transects in the. northern platform where a continuous cover of mainly blue whiting was observed.

B.3.2.3. Data processing

The global area is split into several strata where coherent communities are observed (species associations) in order to minimise the variability due to the variable mixing of species. For each stratum, a mean energy is calculated for each type of echoes and the area measured. A mean haul for the strata is calculated to get the proportion of species into the strata. This is obtained by estimating the average of species proportions weighted by the energy surrounding haul positions. Energies are therefore converted into biomass by applying catch ratio, length distributions and TS relationships. The calculation procedure for biomass estimate and variance is described in Petitgas *et al.*, 2003.

The TS relationships used since 2000 are still the same and as following:

Sardine, anchovy and sprat:	TS = 20 Log L – 71.2
Horse mackerel:	TS = 20 Log L – 68.7
Blue whiting:	TS = 20 Log L – 67.0
Mackerel:	TS = 20 Log L – 86.0

The mean abundance per species in a stratum (tons m.n.$^{-2}$) is calculated as:

$$M_e(k)=\sum_D \bar{s}_A(D,k)\bar{X}_e(D,k)$$

and total biomass (tons) by: $B_e=\sum_k A(k)Me(k)$

where,

k: strata index

D: echo type

e: species

S_A: Average S_A (NASC) in the strata (m2/n.mi.2)

X_e: species proportion coefficient (weighted by energy around each haul) (tons m^{-2})

A: area of the strata (m.n.^{2})

Then variance estimate is:

$$Var.M_e(k)=\sum_D \bar{s}_A^2(D,k)Var[X_e(D,k)]/n.cha(k)+\overline{X}_e^2\,\mathrm{var}[s_A(D,k)]/n.esu(D,k)$$

$$Var.B_e=\sum_k A^2(k)Var.Me(k)$$

$$cv=\sqrt{Var.Be}/Be$$

At the end, density in numbers and biomass by length and age are calculated for each species in each ESDU according to the nearest haul length composition. These numbers and biomass are weighted by the biomass in each stratum and data are used for spatial distributions by length and age.

The detailed protocol for these surveys (strategy and processing) is described in Annex 6 of the WGACEGG Report in 2009.

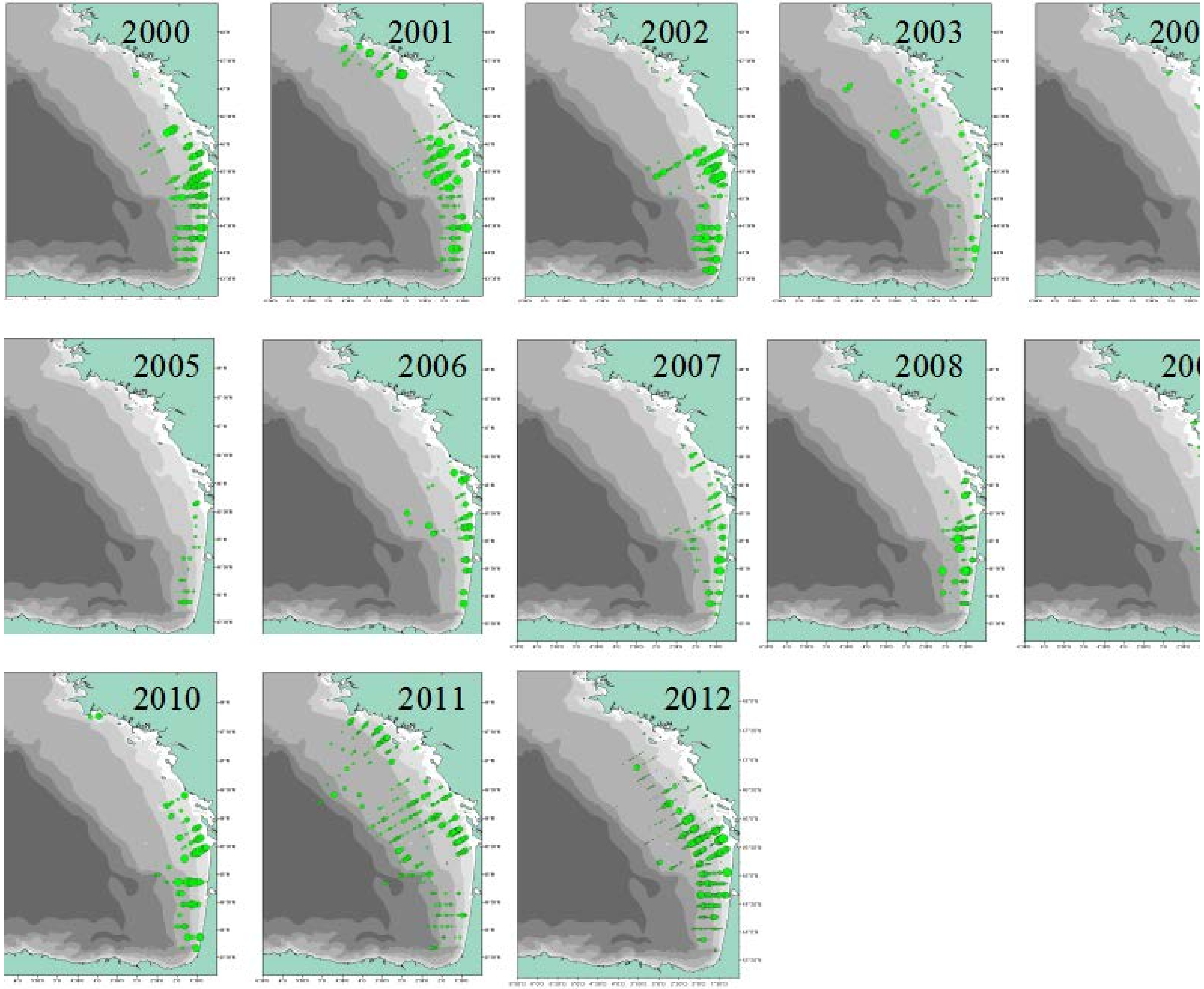


Figure B 3.2.1. Back-scattered energies (SA) registered for anchovy during PELGAS surveys since 2000.

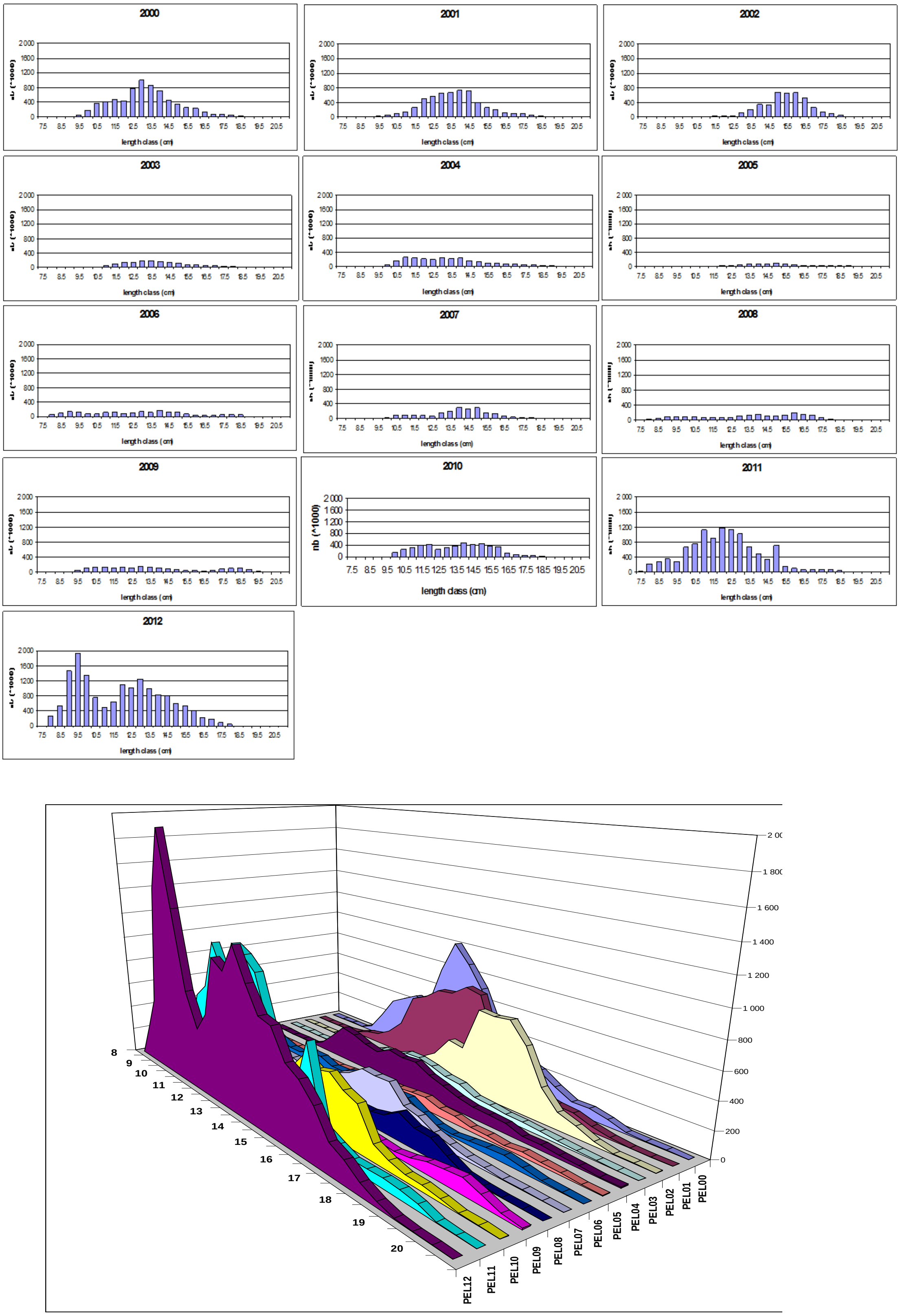


Figure B 3.2.2. Length composition of adults of anchovy as estimated by acoustics since 2000 during PELGAS surveys.

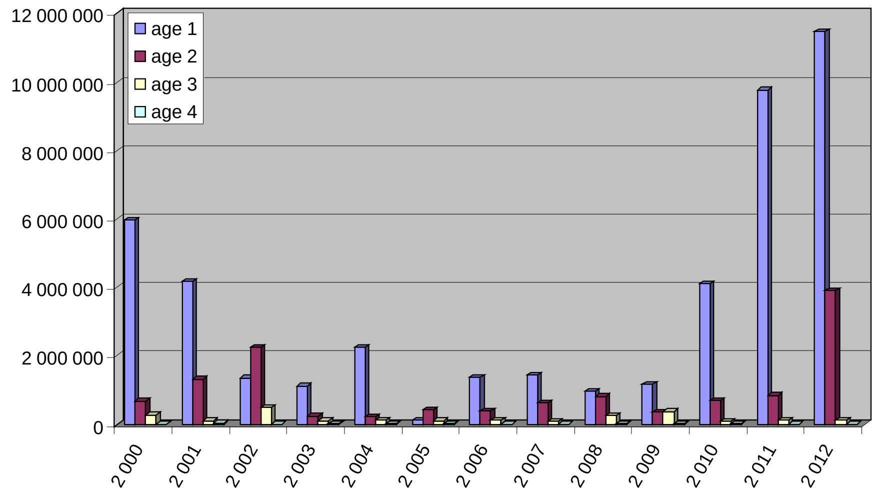


Figure B 3.2.3. Age composition of adults of anchovy as estimated by acoustics since 2000 during PELGAS surveys.

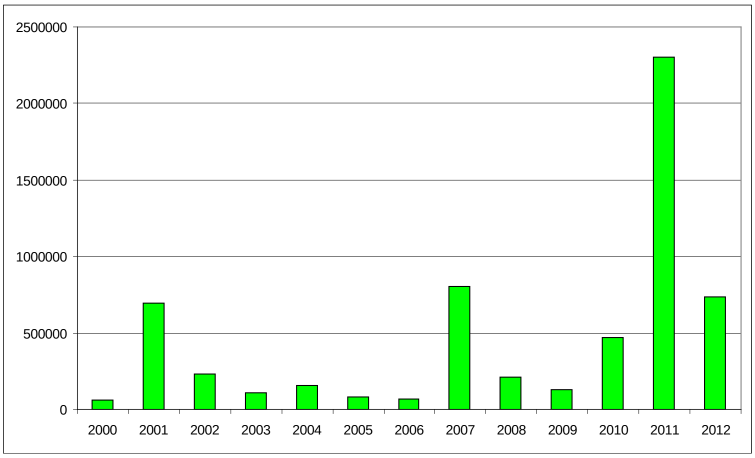


Figure B 3.2.4. Number of eggs observed during PELGAS surveys with CUFES from 2000 to 2010.

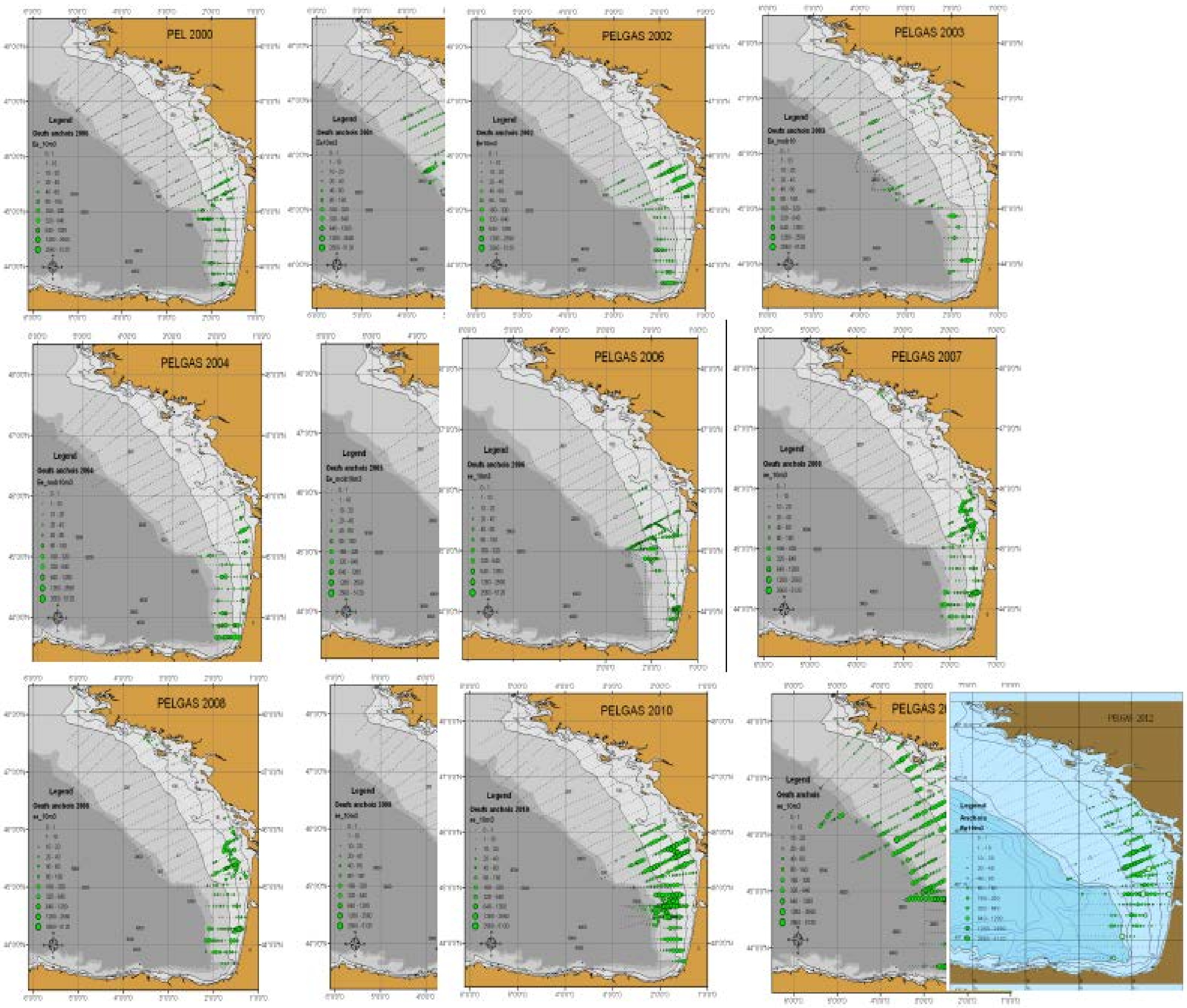


Figure B 3.2.5. Distribution of anchovy eggs observed with CUFES during PELGAS surveys from 2000 to 2012 (number for 10m³).

B.3.4 Autumn survey JUVENA on juvenile anchovy

Since year 2003, there is an acoustic survey to estimate abundance of juvenile anchovy (JUVENA) every September–October, with the long-term objective of forecasting the strength of the anchovy recruitment which will enter the fishery the next year (ICES 2008–2011 WGACEGG reports, Boyra, submitted). The survey was conducted by AZTI from 2003 to 2009, and is coordinated between AZTI and IEO since year 2010. The IEO conducted a parallel acoustic survey on anchovy, PELACUS10, from 2006 to 2009. Both surveys were merged in year 2010 in a joint JUVENA AZTI-IEO survey coordinated in ICES WGACEGG. This survey is expected to provide further insights on the recruitment process and additional knowledge on the biology and ecology of the juveniles.

The recruitment prediction capability of the survey has been tested by comparing the biomass estimates of juveniles and the next year's age-1 recruits for a wide range of recruitment values, and has been confirmed by the significant ($p<0.001$) positive correlations between them.

B.3.4.1 Sampling strategy

The JUVENA surveys were carried out annually between September and October in the Bay of Biscay. In these months the juveniles have grown enough to be visible to the echosounders (allowing the tuna fishing fleet to target them as live bait) and normally occupy large outer and off shelf areas in front of the Cantabric and west French coasts (Uriarte *et al*., 2001; Cort *et al*., 1976; Martin, 1976). Acoustic sampling was performed during the day because at this time of year juveniles usually aggregate in schools in the upper layers of the water column during the day, and can be distinguished from plankton structures (Uriarte *et al*., 2001; Cort *et al*., 1976). The sampling was carried out following a regular grid formed by transects arranged perpendicular to the coast (Figure B.3.4.1), spaced at 17.5 n.mi. (from 2003 to 2005) or 15 n.mi. (2006 onwards) to ensure their independence (Carrera *et al*., 2006). Sampling started in the Cantabrian Sea, going from west to east, and then moved to the north to cover the waters in front of the French coast. It is important to conduct the survey in the precise temporal window that extends from mid-August to mid-October, which is not too early, so juveniles have sufficiently grown and hence can be detected and caught, and not too late, so they have not yet abandoned the offshore grounds towards the coasts.

The survey covered the entire expected spatial distribution of juvenile anchovy in these months of the year, from offshore areas well beyond the continental shelf to very coastal waters, because the spatial process of anchovy juvenile recruitment occurs from offshore areas towards the coast during autumn (Uriarte *et al*., 2001). This exploration area can vary from year to year and is potentially large. Consequently, considerable effort was made to achieve the broadest possible coverage of the area by using an adaptive sampling strategy. In this strategy, the boundaries of the sampling area were defined according to the findings of each survey and the parallel information obtained from the commercial fishing fleet, which uses juvenile anchovy as live bait for tuna fishing. Along the Spanish and French coastlines, the minimum limits of the sampling area were set at 5°W and 46°N respectively. According to previous information on juvenile distribution, this area was expected to contain the vast majority of the juvenile anchovy abundance (Uriarte *et al*., 2001; Carrera *et al*., 2006; Cort *et al*., 1976). For practical reasons, a maximum surveying area was set within the limits 6°W and 48°N. Between these limits, the actual along-coastline boundaries were set each year at the points where there was a clear decrease in abundance or, if possible, a transect in which juvenile anchovy were not detected. The length of the transects extended from about the 20 m to at least the 1000 m isobaths, and, according to the adaptive scheme of the survey, if the detections continued they were enlarged offshore to 4 n.mi. beyond the last detection of an anchovy school. In addition, the information from the commercial live bait tuna fishery collected before and during each survey was taken into account when decisions about the sampling strategy were made during the surveys. As a result of this sampling scheme, the years with a larger abundance of anchovy required a larger sampling coverage.

In the period from 2003 to 2004, the area was sampled with a single commercial purse-seiner subcontracted for the survey and equipped with scientific echosounders. In 2005 a second purse-seiner was added to the survey to provide extra fishing operations, and in 2006 a pelagic trawler with complete acoustic equipment, the R/V Emma Bardán, replaced the second purse-seiner.

B.3.4.2 Data acquisition

The acoustic equipment included Simrad EK60 split-beam echosounders (Kongsberg Simrad AS, Kongsberg, Norway) of 38 and 120 kHz from 2003 to 2006, plus a 200 kHz transducer from 2007 (Table 2). The transducers were installed looking vertically downwards, at about 2.5 m depth, at the end of a tube attached to the side of the vessel in the case of the commercial fishing vessels and on the vessel hull in the case of the research vessel. The transducers were calibrated using standard procedures (Foote, 1987).

The water column was sampled acoustically to a depth of 200 m. Catches from the fishing hauls and echotrace characteristics were used to identify fish species and determine the population size structure. Purse-seining was used to collect samples up to 2005 and then this was combined with pelagic trawls from 2006 onwards. To improve species identification in the first three surveys when only purse-seiners were available, additional night fishing operations were performed by focusing bright light on the water to attract the fish from surrounding waters. In 2006 pelagic trawling was included in the surveys, which made it possible to fish at greater depths than the purse-seine range (50 m maximum). The purse-seiners generally covered the coastal areas and the waters off the shelf where juveniles occupy the surface waters and are accessible to the purse-seine fishing range. The pelagic trawler covered the intermediate shelf regions where it may be necessary to sample at all depth layers. In addition, when deep, anchovy like aggregations were detected by the purse-seiners, the pelagic trawler temporally left its coverage area to carry out additional fishing operations in these areas.

For the years when pelagic trawling was carried out in the surveys (2006 onwards) we have assessed the fraction of juvenile biomass observed deeper than 45 m below the surface. This assessment was restricted to the areas over the shelf because pure aggregations of juveniles off the shelf were all above 45 m depth. This was done in order to determine by how much the limited vertical fishing range of purse-seines could have affected the detection and estimates of juvenile biomass in the years 2003–2005, when only this fishing gear was available, and to eventually correct the potential underestimation of the juvenile biomass detected over the shelf in those years.

B.3.4.3 Intercalibration of acoustic data between vessels

Since the 2006 survey, when the acoustic sampling was split between two vessels, intercalibration exercises between the two vessels were routinely carried out each year based on the intercalibration methodology described by Simmonds and MacLennan (2005). The intercalibration process consisted in comparing the echo integration of the bottom echo in areas with a smoothly variable bottom (visible as overlapping transects in Figure B.3.4.1). A minimum distance of 30 n.mi. was covered simultaneously by the two vessels for these exercises (Figure B.3.4.1). The NASC values (Maclennan *et al.*, 2002) obtained by the layer echo integration of both the water column and bottom echos obtained by the two vessels were compared to detect recording biases or other potential problems.

B.3.4.4 Abundance estimates

Echograms were examined visually with the aid of the catch species composition to identify positive anchovy layers. Noise from bubbles, double echoes, and, when necessary, plankton were removed from the echograms. Acoustic data were processed in the positive strata by layer echo integration using an ESDU (Echo integration Sampling Distance Unit) of 0.1 n.mi. with the Movies+ software (Ifremer, France). Echoes were thresholded to -60 dB and integrated into six depth channels: 7.5–15 m, 15–25 m, 25–35 m, 35–45 m, 45–70 m and 70–120 m (no anchovies were found below 120 m depth).

Generally, only the 38 kHz data were echo integrated using the TS-length relationships agreed in ICES WGACEGG for the main species (ICES, 2006; Table B.3.4.1). Each fishing haul was classified into species. A random sample of each species was measured to determine the length–frequency distribution of the different species in 0.5 cm classes for the smaller species (anchovy and sardine) and one cm classes for the rest. Complete biological sampling of anchovy was performed to analyse age, size and the size–weight ratio. The hauls were grouped by strata of homogeneous species and size composition. The species and size composition of each homogeneous stratum were obtained by averaging the composition (in numbers) of the individual hauls contained in the stratum weighted to the acoustic density in the vicinity (2 n.mi. diameter). This species and size composition of each stratum was used to obtain the mixed species echo integrator conversion factor (Simmonds and Maclennan, 2005) for converting the NASC values of each ESDU into numbers of each species. However, although the methodology involved estimating multiple species, the survey strategy was focused strongly on juvenile anchovy and only the positive areas for anchovy were processed. Therefore, only estimates of this species were considered reliable and thus produced.

The procedure is as follows:

Each fish species has a different acoustic response, defined by its scattering cross section that measures the amount of the acoustic energy incident to the target that is scattered backwards. This scattering cross section depends upon specie *i* and the size of the target *j*, according to:

$$\sigma_{ij} = 10^{TS_j/10} = 10^{\{(a_i + b_i \log L_j)/10\}}$$

Here, L_j represents the size class, and the constants a_i and b_i are determined empirically for each species. For anchovy, we have used the following TS to length relationship:

$$TS_j = -72.6 + 20\log L_j$$

The composition by size and species of each homogeneous stratum is obtained by averaging the composition of the individual hauls contained in the stratum, being the contribution of each haul weighted to the acoustic energy found in its vicinity (2 nm of diameter). Thus, given a homogeneous stratum with M hauls, if E_k is the mean acoustic energy in the vicinity of the haul k, w_i, the proportion of species i in the total capture of the stratum, is calculated as follows:

$$w_i = \sum_j w_{ij} = \sum_j \left(\frac{\sum_{k=1}^{M} \left(q_{ijk} \cdot E_k \big/ Q_k \right)}{\sum_{k=1}^{M} E_k} \right).$$

Being q_{ijk} the quantity (in mass) of species i and length j in the haul k; and Q_k, the total quantity of any species and size in the haul k.

In order to distinguish their own contribution, anchovy juveniles and adults were separated and treated as different species. Thus, the proportion of anchovy in the hauls of each stratum (w_{ij}) was multiplied by a age-length key to separate the proportion of adults and juveniles. Then, separated w_i were obtained for each.

Inside each homogeneous stratum, we calculated a mean scattering cross section for each species, by means of the size distribution of such specie obtained in the hauls of the stratum:

$$\langle \sigma_i \rangle = \frac{\sum_j w_{ij} \sigma_{ij}}{w_i}.$$

Let s_A be the calibration-corrected, echo-integrated energy by ESDU (0.1 nautical mile). The mean energy in each homogeneous stratum, $E_m = < s_A >$, is divided in terms of the size-species composition of the haul of the stratum. Thus, the energy for each species, E_i, is calculated as:

$$E_i = \frac{w_i \langle \sigma_i \rangle E_m}{\left(\sum_i w_i \langle \sigma_i \rangle \right)}$$

Here, the term inside the parenthesis sums over all the species in the stratum. Finally, the number of individuals F_i of each species is calculated as:

$$F_i = H \cdot l \frac{E_i}{\langle \sigma_i \rangle}$$

Where l is the length of the transect or semi-transect under the influence of the stratum and H is the distance between transect (about 15 nm.). To convert the number of juveniles to biomass, the size-length ratio obtained in each stratum is applied to obtain the average weight of the juveniles in the stratum:

$$< W_i > = a \cdot < L_i >^b$$

Thus, the biomass is obtained by multiplying F_i times $< W_i >$.

Anchovy juveniles (age=0) and adults (age ≥ 1) were separated and treated as different species. To separate juveniles from adults, the length frequency distribution of anchovy by haul was multiplied by a corresponding age-length key. The key was determined every year for three broad areas: the pure juvenile area, the mixed juvenile area (with a mix of juveniles and adults), and the Garonne area (also a mixed area but here adult anchovy were usually smaller than in the other areas).

B.3.4.5 Recruitment predictive capability

The annual biomass estimates for anchovy juveniles were compared with the estimates of anchovy recruitment the following year. The recruitment is the biomass of age-1 anchovy in January of the following year, estimated according to the ICES assessment using a Bayesian model with inputs from catches and biomass estimates of two spring surveys: an acoustic one (PELGAS), conducted by Ifremer, and a survey based on DEPM (BIOMAN), conducted by AZTI (ICES, 2011). Up to 2012, The Spearman rank correlation between the JUVENA series and the assessment estimates of recruitment at age 1 is 0.81, which is statistically significant with p-value=0.01, and the Pearson correlation is 0.94, which is statistically significant with p-value=0.000163. In addition, JUVENA's juvenile abundance index shows also statistically significant (Pearson's) correlations with the series of recruit estimates provided independently by each of the spring surveys (R=0.94 P(R=0)=0.000 for DEPM and R=0.89 P(R=0)=0.001 for Acoustics). WGHANSA (2012) considered that the JUVENA acoustic index of juveniles is a valid indicator of the strength of the incoming recruitment and hence useful for improving the forecast of the population and potentially its assessment.

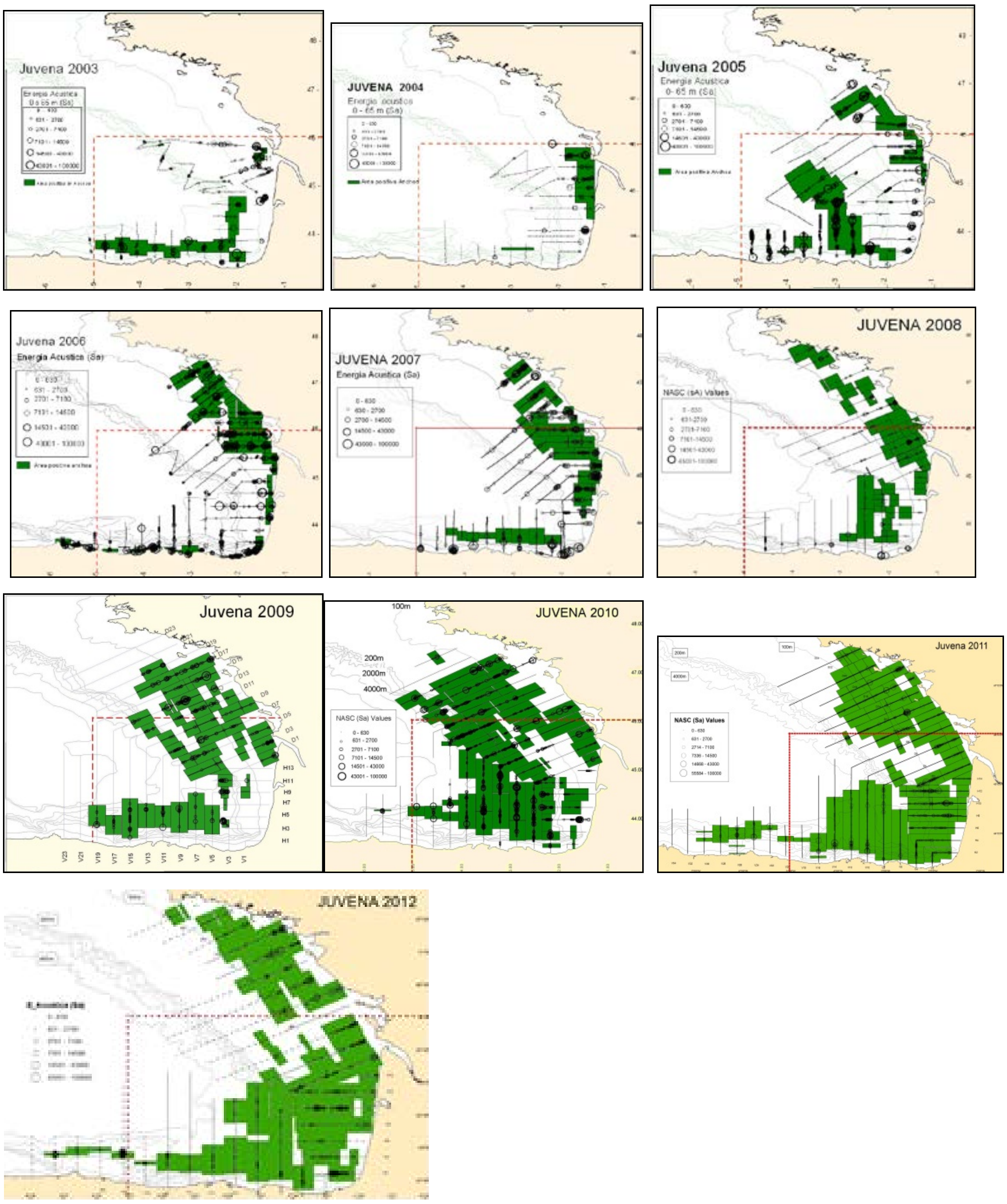


Figure B.3.4.1. Positive area of presence of anchovy and total acoustic energy echo-integrated (from all the species) for the ten years of surveys. The area delimited by the dashed line is the minimum or standard area used for inter annual comparison.

Table B.3.4.1. Vessels and equipment.

			VESSEL 1	VESSEL 2
Vessel	name		Variable*	Emma Bardán
	Length (m)		30–35	27
	Side (m)		8	7
	Draft (m)		3.5–4	3.5
	Acoustic installation		side perch	hull
Acoustic Equipment	Transducer frequencies (kHz)		38,120, (200)**	38,120,200
	Power (for 38, 120, 200 kHz) (W)		1200, 250, (210)**	1200, 250, 210
	Pulse duration (10^{-6}s)		1024	1024 (except in 2006: 256)
	Ping interval (s)		0.25–0.5	
Target Strength (b_{20})***	*Engraulis encrasicolus* *Sardina pilchardurs* *Sprattus sprattus*	-72.6 dB	Degnbol *et al.* (1985)	
	Trachurus trachurus *Trachurus mediterraneus* *Scomber japonicas*	-68.7 dB	ICES (2006)	
	Scomber scombrus	-88 dB	Clay and Castonway (1996)	
	Jellyfish (mean TS)	-81.7 dB	Average TS for jellyfish species in Simmonds and Maclennan (2005)	
Fishing gear****	Pelagic trawl	nº of doors		2
		vert opening		15
		Mesh size (mm)		4
	Purse-seine	Depth	75	
		Perimeter	400	
		Mesh size	4	

(*Vessel names: Divino Jesus de Praga (2003), Nuevo Erreñezubi (2004), Mater Bi (2005), Gure Aita Joxe (2005, 2008), Itsas Lagunak (2006, 2007, 2009, 2010, 2011, Ramón Margalef (2012)). **The 200 kHz transducer has been available onboard purse-seiners since 2007. ***TS of the mean pelagic species. The TS is obtained according to the relationship TS = b20 - 20log(L), where L is the standard length of the fish in cm. ****The fishing gear of RV Ramon Margalef in 2012 was a pelagic trawl identical to the Emma Bardan one.

B.4 Commercial cpue

According to literature, cpue indices have been considered as not reliable indicators of abundance for small pelagic fishes (Ulltang, 1980, Csirke 1988, Pitcher 1995, Mackinson *et al.* 1997). Current series of cpue available for the Spanish Purse seine are not considered of utility for the monitoring of the fishery (Uriarte *et al.*, 2008).

B.5 Other relevant data

Members of the South Western Waters Regional Advisory Council (SWWRAC) participated in the benchmark workshop process for the Bay of Biscay anchovy stock. They provided their opinion relative to the anchovy assessment (SWW RAC Opinion 69, 22 November 2012) and participated to WKPELA, their input being reflected in the report.

C. Stock assessment method

There are two points in time where an assessment can be given for this stock. In June when SSB is estimated based on the most recent spring surveys information. In December when the assessment can incorporate the most recent juvenile abundance index from JUVENA, the catches in the second semester and any other updated data. In the former the assessment goes up to June, whereas in the latter the assessment covers the whole year up to December.

C.1 June assessment

Model used:

The assessment for the Bay of Biscay anchovy population is a Bayesian two-stage biomass-based model (CBBM) (Ibaibarriaga *et al.*, 2011), where the population dynamics are described in terms of biomass with two distinct age groups, recruits or fish aged 1 year, and fish that are 2 or more years old. The biomass changes exponentially with time according to intrinsic growth, natural mortality and fishing mortality rates. Growth and natural mortality are separated processes that are assumed constant along time but distinct across age groups (recruits and older individuals). Fishing is treated as a continuous process in time separated by semester. The first semester fishery consists mainly of the Spanish purse-seine fishery operating in spring, and the second semester fishery primarily relates to the French fleet. Furthermore, fishing mortality by semester is separable into age and year effects.

The observation equations consist of:

- log-normally distributed spawning–stock biomass from the acoustics and DEPM surveys, where the biomass observed is scaled to the true population biomass by the catchability coefficient of each of the surveys.
- the beta distributed age 1 biomass proportion from the acoustics and DEPM surveys, with mean given by the true age 1 biomass proportion in the population.
- log-normally distributed juvenile abundance index from the JUVENA surveys, where the abundance index observed in year (y-1) is scaled to the true recruitment (age 1 biomass in January of year y) by the catchability coefficient of the survey.
- log-normally distributed total catch by semester.
- beta distributed age 1 biomass proportion in the catch by semester.
- normally distributed growth rates by ages.

The unknown parameters are the initial biomass, the mean and the precision of the recruitment process in log scale, the surveys catchabilities, the parameters affecting the precision of the survey and catch observation equations, the year and age components of the fishing mortality by semester, the annual intrinsic growth rates by age, the precision of the observation equations for growth and the annual natural mortality rates by age.

Inference on the unknowns is made using Markov Chain Monte Carlo (MCMC).

<u>Software used:</u>

The model is implemented in BUGS (www.mrc-bsu.cam.ac.uk/bugs/). The WinBUGS development interface was used to reduce run times. The assessment is run from R (www.r-project.org) using the package R2WinBUGS.

<u>Model Options chosen:</u>

- Catchability of the DEPM and acoustic SSB estimates and of the juvenile abundance indexare estimated. DEPM and acoustic surveys are assumed to provide unbiased proportion of age 1 biomass estimates in the stock.
- Natural mortality rates are fixed at M_1=0.8 and M_{2+}=1.2.
- The precisions of the observation equations of biomass from the DEPM and acoustic surveys are fixed (not estimated) according to the coefficients of variation from the survey each year. Other variance related parameters of the observation equations of the DEPM and acoustic surveys and of the catch observation equations by semester are also fixed.

The set of priors as defined in Ibaibarriaga *et al.*, 2011 are used. The length of the MCMC run, the burn-in period (removal of the first draws to avoid dependency on the initial values) and the thinning to diminish autocorrelation should be enough to ensure convergence and obtain a representative joint posterior distribution of the parameters.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year. Yes/No
Caton	Catch in tonnes by semesters	1987–latest year	1 to 2+	Yes
Canum	Catch-at-age in numbers by semesters	1987–latest year	1 & 2+	Yes
Weca	Weight-at-age in the commercial catch by semesters	1987–latest year	1 to 2+	Yes
Mprop	Proportion of natural mortality before spawning	Not applicable		
Fprop	Proportion of fishing mortality before spawning	Not applicable		
Matprop	Proportion mature-at-age	Not applicable		
Natmor	Natural mortality M_1=0.8 and M_{2+}=1.2	1987–latest year	1 to 2+	No
G	Intrinsic growth rate	1987–latest year	1 to 2+	Yes

Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	DEPM SSB spring series	1987–latest year (with gap in 1993)	
Tuning fleet 2	Acoustic SSB spring series	1989–latest year (with gaps)	
Tuning fleet 3	DEPM P1 (B1/SSB) spring series	1987–latest year (with gaps)	
Tuning fleet 4	Acoustic P1 (B1/SSB) spring series	1989–latest year (with gaps)	
Tuning fleet 5	Juvenile abundance index from JUVENA autumn survey	2003–latest year	Recruitment

Prior distributions of the parameters:

The current prior distributions (see table below) are described and justified in Ibaibarriaga *et al.* (2011).

Parameter	Hyperparameter	Median (90% probability interval)
q_{surv}	$\mu_{q_{\text{surv}}} = 0$ $\psi_{q_{\text{surv}}} = 2$	1 (0.3, 3.2)
ψ_{surv}	$a_{\psi_{\text{surv}}} = 0.9$ $b_{\psi_{\text{surv}}} = 0.02$	29.8 (1.7, 139.9)
ξ_{surv}	$\mu_{\xi_{\text{surv}}} = 5$ $\psi_{\xi_{\text{surv}}} = 0.2$	5 (1.3, 8.7)
ξ_{catch}	$\mu_{\xi_{\text{catch}}} = 5$ $\psi_{\xi_{\text{catch}}} = 0.2$	5 (1.3, 8.7)
B_0	$\mu_{B_0} = 10.3$ $\psi_{B_0} = 1.0$	29 733 (5 740, 154 022)
μ_R	$\mu_{\mu_R} = 9.8$ $\psi_{\mu_R} = 1.0$	9.8 (8.2, 11.4)
ψ_R	$a_{\psi_R} = 2$ $b_{\psi_R} = 3$	0.6 (0.1, 1.6)
$s(\text{sem}_j, 1)$	$a_s = 0$ $b_s = 2$	1.0 (0.1, 1.9)
$f(\text{sem}_j, y)$	$\mu_f = -0.9$ $\psi_f = 1$	0.4 (0.1, 2.1)
M_a	$\mu_{\log(M)} = 0.2$ $\psi_{\log(M)} = 5$	1.2 (0.6, 2.5)
G_a	$\mu_{\log(G)} = -0.7$ $\psi_{\log(G)} = 2$	0.5 (0.2, 1.6)
ψ_G	$a_{\psi_G} = 1.5$ $b_{\psi_G} = 0.1$	11.8 (1.8, 39.1)

C.2 December assessment:

The assessment conducted in June can be updated using the same settings in December once the results from the JUVENA survey and the catch levels during the second semester are available. The definitive DEPM estimates which are obtained after the full processing of the adult samples is completed by November can be incorporated in this update. It must be taken into account that only preliminary estimates of the total catch in the first and the second semesters and of the age structure of the catch during the first semester of the interim year Y would be available in December.

D. Short-term projection

The forecast can be given either based on the June or on the December assessment. In June, there is no indication on next year recruitment, so the forecast is based on an assumed scenario constructed from past recruitments. In December the forecast can be based on the next year recruitment distribution derived from the December assessment (which will be informed ultimately by the JUVENA anchovy juvenile index).

D.1 June forecast:

<u>Model used:</u>

The CBBM model (Ibaibarriaga *et al.* 2011) used for the assessment of the stock is used to project the population one year forward from the current state and to analyse the probability of the population in the next year of being below the biological reference point B_{lim} under a recruitment scenario based on the past recruitment-series and under alternative exploitation levels for the second half of the current year and the first half of next year. Exploitation can be given either in terms of fishing mortality or in terms of catches.

The predictive distribution of recruitment at age 1 (in mass) in January next year is defined as a mixture of the past series of posterior distributions of recruitments as follows:

$$R_{2008} = \sum_{y=1987}^{2007} w_y \; p(R_y | \cdot \,) \; ,$$

where $p(R_y | \cdot)$ denotes the posterior distribution of recruitment in year y and w_y are the weights of the mixture distribution, such that $\sum w_y = 1$. When no information about incoming recruitment is available all the years are equally weighted, resulting in an undetermined recruitment scenario. This is the typical situation in June.

Software used:

The projections are implemented in R (www.r-project.org), using ad hoc script for the anchovy model.

Projection period:

One year ahead from the spawning period (15th May) in the last assessment year.

Initial stock size:

Posterior distribution of SSB in the last assessment year

Maturity: NA

F and M before spawning: NA

Weight-at-age in the stock: NA

Weight-at-age in the catch: NA

Intrinsic growth rate (G):

Intrinsic growth rates are assumed distinct by age groups and their posterior distribution from the assessment is used.

Natural mortality rate (M):

Assumed constant same as in the assessment (M_1=0.8 and M_{2+}=1.2)

Exploitation pattern:

Alternative options for the year effect of fishing mortality by semester are tested. The age effects of the fishing mortality by semester are taken from the posterior distribution from the assessment.

Intermediate year assumptions: NA

Stock–recruitment model used:

No implicit S/R model is used. Recruitment is sampled from the posterior distributions of past series recruitments. The default recruitment scenario in June is the undetermined case, where all past years are equally likely. However, if there are other reliable indications available, different recruitment scenarios could be constructed by giving different weights to the past series recruitments.

Procedures used for splitting projected catches: NA

D.2 December forecast

The method for the short-term projections based on the December assessment is the same as the ones based on the June assessment, the main difference being that the next year recuitment distribution is obtained directly from the assessment. This recruitment distribution is mainly obtained by the latest JUVENA juvenile abundance index and the parameters of the JUVENA observation equations estimated from the model. Therefore, if the latest juvenile abundance index is high/low, the recruitment distribution are centered around high/low values. The December assessment provides estimates of the fishing mortality in the second semester in the interim year and the December short-term projections allow for exploring catch options for the first semester of the following year. For the current management calendar, where the TAC is set from July to June next year, the December short-term projections could be used to adjust the TAC accordingly for the first semester until a new assessment in June.

E. Medium-term projections

No medium-term projections are applied to this fishery for the provision of advice by ICES.

F. Long-term projections

No long-term projections are applied to this fishery for the provision of advice by ICES. Long-term projections (ten years ahead) were run by STECF in 2008 to set the basis of a management plan on anchovy to the EC. This work was based in other assessment models and assumptions. Thus, the biomass estimates obtained with the new methods are not valid to inform the harvest control rules in the draft management plan proposal of this stock. The long-term management plan proposal should be revised accordingly.

G. Biological reference points

A stock–recruitment relationship is not explicitly used. B_{lim} is defined by WKPELA as B_{loss} (minimum estimated biomass which still produced a substantial recruitment) based on the posterior median of the 1987 SSB. This value is also approximately the median of the SSB levels comprised between the 2003 and the 2005 levels (years: 1987/1989/2003/2005/2006/2008/2009), a range of SSB where low recruitments occurred more often than medium or high recruitments. Therefore, the probability of suffering impaired recruitment under these levels is high, as expected from the B_{lim} definition.

	Type	Value	Technical basis
MSY	MSY $B_{trigger}$	Not defined	
Approach	F_{MSY}	Not defined	
	B_{lim}	19 000 t	B_{loss} (minimum estimated biomass which still produced a substantial recruitment)
Precautionary	B_{pa}	Not defined	
Approach	F_{lim}	Not defined	
	F_{pa}	Not defined	

H. Other issues

None.

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Stock Annex: Herring WBSS

Stock	Western Baltic Spring spawning herring (WBSS)
Working Group	Herring Assessment Working Group for the Area South of 62ºN
Date	19.02.2013
Authors	L.Worsøe Clausen, V. Bartolino, H. Mosegaard, T. Gröhsler, P. Polte

A. General

A.1. Stock definition and biology

Stocks

Most herring populations are migratory and often congregate on common feeding and wintering grounds where aggregations may consist of mixtures of individuals from several populations. Thus herring spawning components uphold significant levels of reproductive isolation, possibly affected by selective differences among spawning and/or larval habitats (Limborg *et al.*, 2012). Genetic stratification is likely maintained by mechanisms of natal homing, larval retention and natural selection (Gaggiotti *et al.*, 2009). In the Western Baltic tagging and genetic studies suggest that three to four more or less well-described stock components, that either spawn and use the area as nursery or migrate through it: Rügen herring (abbreviated RHS), local (autumn) spawning Fehmarn herring, herring from the Kattegat and Inner Danish waters, and potentially other Western Baltic herring stocks, each of which have different contributions to the fishery and ecosystem. The RHS are assumed to make up the majority of the western Baltic Sea herring in the area (ICES, 2010) and the stock spawn around the Geifswalder Bodden, mainly in March–May, but with some autumn spawning also (e.g. Nielsen *et al.*, 2001; Bekkevold *et al.*, 2007).The other herring populations occurring in the area are found in many of the bays in the area, where at least Kiel, Møn, Schlei, Flensburg, Fåborg, and Fehmarn have been reported as spawning sites for these apparently less abundant herring stocks. Thus the WBSS stock has a complex mixture of different herring populations predominantly spawning during spring, but also local spring-, autumn- and winter spawning stock components. The exact proportions of these stocks are hitherto unknown; however, they are observed in the area to some degree and could potentially be important parts of the total amount of herring available for the fishery.

Given a complex stage-dependent migration pattern, the different components mix during part of the year (Figure 1) and most likely experience different fishing pressures but are assessed and managed as one unit.

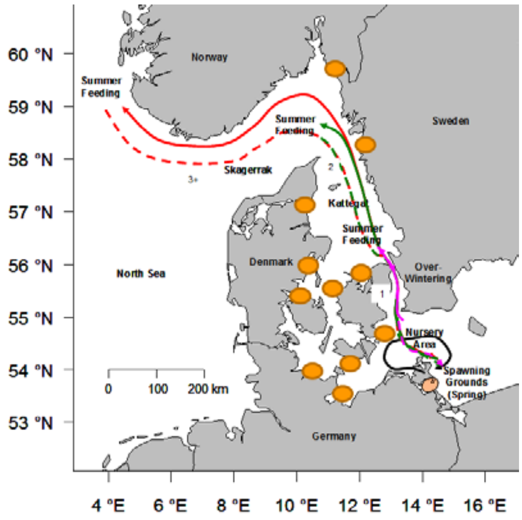


Figure 1. General migration patterns of the WBSS; the numbers indicates the age-dependent migration pattern; the yellow circles indicate local spawning populations (redrawn from M. Payne).

The majority of 2+ ringers migrate out of the area during the 2nd quarter of the year, through the Sound and Belt Sea and propagate into the western part of the Skagerrak and the eastern North Sea to feed (Payne *et al.*, 2009). The extent of the migration is age dependent, where the younger individuals migrates up into Kattegat and Skagerrak and the older fish migrate all the way out into the eastern North Sea. Towards the end of summer the herring aggregate in the eastern Skagerrak and Kattegat before they migrate to the main wintering areas in the southern part of the Kattegat, the Sound and the Western Baltic (ICES, 1991; Nielsen *et al.*, 2001). The extent of the migration is season dependent and variable over time (Clausen *et al.*, 2006).

These distribution patterns had yet to be fully quantified, however, they have been examined in a recent study of the temporal and spatial coverage of all available data in terms of current biological understanding of stock components, their distribution in the Western Baltic and IIIa using combined information from fisheries catches and International surveys in the Western Baltic Sea (including the Sound) and Kattegat, Skagerrak over the past decade. The major migration routes indicated by the temporal-spatial distribution of the herring stock components over time shows for the largest herring stock (the Rügen herring) an outmigration from the spawning sites during April–June through all Belts. This migration is not performed in large dense schools; these form during the summer feeding in Skagerrak and Kattegat. The school formation is retained during the overwintering, which mainly occurs in the Southern Kattegat and the Sound.

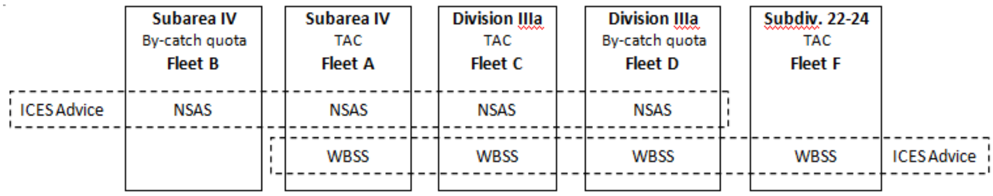
The fishery on WBSS takes place in the eastern North Sea, Division IIIa and the Western Baltic. In these areas the stock complex mixes with another large herring stock complex; the North Sea Autumn Spawners (NSAS). All spring-spawning herring in the eastern part of the North Sea (IVa&b east), Skagerrak (Subdivision 20), Kattegat (Subdivision 21) and the Western Baltic (Subdivisions 22, 23 and 24) are treated as one stock despite the local stock diversity. Given the mixing with the NSAS, the ICES Herring assessment Working Group (HAWG) make use of biological samples routinely collected to estimate the stock composition of the annual catches. The analysis of stock composition in commercial samples for stock assessment and management purposes of the herring populations in the North Sea and adjacent areas has been routine since the beginning of the 1990s. Recent development of the stock identification methodology has opened for a monitoring of the local stock components beyond the general spawning components of spring-autumn-and winter spawners; however this is not part of the routine treatment of herring catches yet.

The current definition of the Western Baltic herring stock of spring, autumn and winter spawners as a single management unit appears to have been operational in the past, despite potential changes in the relative strengths of the different spawning components and in their relative importance during collapse and recovery.

Methods for stock separation

Background

ICES advises on catch options by fleet for the entire distribution of WBSS and NSAS herring stocks separately. However, the fisheries are managed by areas covering the geographical distribution of the stocks (see the following text diagram).



The method for separation of the herring stock components in the catches has developed over the past decade. Prior to 1996, the splitting key between NSAS and WBSS herring used by ICES was calculated from a sample-based mean vertebral count. This uses a cut off algorithm for calculating the proportion of western Baltic spring-spawning herring (WBSS) in a sample as:

MIN(1,MAX(0,(VSsample-55.8)/(56.5–55.8)))

where VSsample is the sample mean vertebrae count and assuming a population mean VS of 55.8 for WBSS and 56.5 for NSAS. This method is still being used to split samples of Norwegian catches from the transfer area in IVa East.

In the period from 1996 to 2001 splitting keys were constructed using information from a combination of vertebrae count and otolith microstructure (OM) methods (ICES, 2001). From 2001 and onwards, the splitting keys have been constructed solely using the otolith microstructure method which uses visual inspection of season-specific daily increment patterns from the larval origin of the otolith, with the exception of the splitting key made for the mixture area in Subdivision IVa East, where vertebrae counts currently is the only method used to split the mixed-stock (Mosegaard and Madsen, 1996; ICES, 2004; Clausen *et al.*, 2007).

Otolith shape analysis has been used to discriminate between populations for a variety of species and for herring this approach has had increasing success with development of imaging techniques and statistical methods. Both temporal and geographical separation of populations gives rise to variation in the shape of otoliths (Messieh, 1972; Lombarte and Lleonart, 1993; Arellano *et al.*, 1995). These variations may suggest differences in the environmental conditions of the dominant habitats of populations within a species. However both genetic and environmental influences have been reported as important in determining otolith shape (Cardinale *et al.*, 2004). Using Fourier Series Shape Analysis on otoliths from Alaskan and Northwest Atlantic herring, Bird *et al.* (1986) showed that otolith shape reflects population differences as well as differences between year classes of the same population. Sagittal otoliths have certain morphological features that are laid down early in the ontogeny of the fish (Gago, 1993), and measurements of internal otolith shape in adult herring has proven a powerful tool for stock discrimination (Burke *et al.*, 2008).

Image analysis software (MATLAB) has been developed to automatically extract otolith contour curves and calculate 60x4 Elliptic Fourier Coefficients from one or two herring sagittal otoliths per image in batches with more than 1000 images.

From 2009 and on otolith shape analysis has been used as a supplementary method to increase sample size for estimating stock proportions of NSAS and WBSS in the mixing areas of Division IIIa. For each assessment year individual population identity has been established by OM visual inspection and used as a baseline for assignment of shape characteristics to the involved stock components. A baseline of about 800–1200 otoliths with known hatch type has then been used as calibration in an age-structured discriminant analysis where additionally 3000–4000 otolith shapes have been assigned to one of the two hatch types using a combination of shape Elliptic Fourier Coefficients, otolith metrics, fish metrics, length, weight and maturity as well as longitude–latitude and seasonal parameters.

Validation

The purpose of classifying individual spawning type is to estimate proportions of the two major stock components by age in catches and surveys from the different areas and seasons. Combining OM with otolith shape and fish meristic characters in a discriminant analysis approach will increase precision of the estimated stock proportions if errors in estimated proportions are low. Validation of the shape and meristic based methodology may be performed using samples of known spawning type (from OM analysis) and classifying subsets by shape/meristics to test for bias and variation in estimated proportions.

OM and otolith shape data from the 2010 HAWG were used as a typical example of the procedure for estimating proportions of hatch type representing North Sea autumn and winter spawners and western Baltic spring spawners in the samples. The data were disaggregated into age groups 0, 1, 2 and 3+ and individuals of known autumn/winter or spring hatched types were used to assign the corresponding shape parameters and fish metrics from the same individuals by cross-validated nonparametric nearest neighbour discriminant analysis.

The accuracy of individual assignment of 1279 otoliths into known hatch type varied somewhat among hatch types and ages (2%–100%) but exhibited an overall error rate of 15.7% (see Table 4.1.1). However, more importantly, the average absolute error of the proportions of WBSS was only 2%, indicating a reasonably robust method for upscaling the baseline to the larger production sample.

		assigned to type		known type	estimated	deviasion		% error in	
Age group	known type	WBSS	NSAS	number	number	Individ. assignm.	prop.	Individ. assignm.	prop.
0	WBSS	34	13	47	44	13	3	27.7%	-6.4%
	NSAS	10	145	155	158	10	3	8.2%	1.9%
1	WBSS	188	72	260	254	72	6	27.7%	-2.3%
	NSAS	66	204	270	276	66	6	26.1%	2.2%
2	WBSS	288	14	302	305	14	3	4.6%	1.0%
	NSAS	17	3	20	17	17	3	82.4%	-15.0%
3+	WBSS	216	4	220	221	4	1	1.8%	0.5%
	NSAS	5	0	5	4	5	1	100.0%	-20.0%
		824	**455**	**1279**	**1279**	**201**	**26**	**15.7%**	**2.0%**

Table 4.1.1. Stock assignment data from 2009 commercial samples of herring in Division IIIa.

A.2. Fishery

Fleet definitions

The fleet definitions used since 1998 for the fishery in Division IIIa are:

- **Fleet C**: directed fishery for herring in which trawlers (with 32 mm minimum mesh size) and purse seiners participate.
- **Fleet D**: All fisheries in which trawlers (with mesh sizes less than 32 mm) and small purse seiners, fishing for sprat along the Swedish coast and in the Swedish fjords, participate. For most of the landings taken by this fleet, herring is landed as bycatch.

Danish and Swedish bycatches of herring from the sprat, Norway pout and blue-whiting fisheries are included in fleet D.

In Subdivisions 22–24 most of the catches are taken in a directed fishery for herring and some as bycatch in a directed sprat fishery. All landings from Subdivisions 22–24 are treated as one fleet.

The fishery

The Western Baltic herring fishery is a multinational fishery that seasonally targets herring in the eastern parts of the North Sea (Eastern IVa,b), the Skagerrak and Kattegat (Division IIIa) and Western Baltic (SD 22–24). The main fleets come from Denmark, Sweden, Norway and Germany, while Poland has a minor fishing activity in the area. After 1996 the fishery is roughly concentrated in the first and the third quarter of the year, whereas earlier the fishery was more spread over the year since it constituted a substantial part of the 16 mm industrial fishery.

The fishery is regulated according to an area TAC (herring catches in the IIIa and SD 22–24), but the assessment and fisheries advice is stock based (Western Baltic spring spawning herring (WBSS) to which estimates of potential WBSS catches from the neighbouring area of the eastern North Sea are added.

The fishery for human consumption has mostly single-species catches, although in recent years some mackerel bycatch can have occurred in the trawl fishery for herring. Discarding in the herring fishery in the eastern North Sea is low, with 2–4% discarded by weight (van Helmond and Overzee, 2011). In Division IIIa and SD 22–24 discarding is considered negligible because all sizes are equally valuable and hence there are no incentives for highgrading since hence.

The bycatch of sea mammals and birds is low enough to be below detection levels based on observer programmes (ICES, 2011a). At present there is a very limited industrial fishery in Division IIIa and hence a limited bycatch of juvenile herring. Further, herring bycatch quota is allocated in both the North Sea and Area IIIa. The sprat fishery in SD 22–24 operates with a certain degree of herring bycatch which is closely monitored and counted against the sprat quota (up to 8% herring allowed).

A.3. Ecosystem aspects

Herring is presumably the key pelagic species in the IIIa and Western Baltic and is thus considered to have major impact as prey and predator to most other fish stocks in that area.

Although knowledge on crucial variables affecting larval herring survival increased since the latest stock collapse in the 1970s, the understanding of particular mechanisms of early herring life-history mortalities is still a major task of fishery science in the North Atlantic Ocean. Dominant drivers of larval survival and year-class strength of recruitment are considered to be linked to oceanographic dispersal, sea temperatures and food availability in the critical phase when larvae start feeding actively. However, research on larval herring survival dynamics indicates that driving variables might not only vary at the population level and by region of spawning but also by larval developmental stage Since WBSS herring relies on inshore, transitional waters for spawning and larval retention, the suit of environmental variables driving reproduction success potentially differs from other North Atlantic stocks recruiting from coastal shelf spawning areas. The suite of variables driving early ontogenetic development and major survival bottlenecks is subject of ongoing research.

Rügen herring is considered a significant component of WBSSH. Results on time-series analysis of larval herring growth and survival dynamics indicate that distinct hatching cohorts contribute differently to the number of 1+winter ring (wr) recruits in the overall western Baltic Sea. The abundances of the earliest larval stage (5–9 mm TL) explains 62% of the variability of later stage larval abundance and 61% of the variability of surviving (1+ group) juveniles. This indicates important pre-hatching survival bottlenecks associated with spawning and egg development. Furthermore, findings demonstrate that hatching cohorts occurring later during the spawning season contribute most to the surviving year class whereas earlier hatching cohorts do not result in significant growth and survival. This could be explained by limited food supply at hatching prior to spring plankton blooms, indicating an additional bottleneck at the critical period when larvae start feeding.

Availability of suitable prey at the critical period after yolk consumption is generally considered the predominant survival bottleneck in larval fish ecology. However, analyses of zooplankton prey abundance in strong vs. weak year classes did not reveal significant food limitation in the eutrophic waters of Greifswald Bay. However, besides prey abundance larval growth and survival might also be affected by the nutritional quality of prey. Comparative results on essential fatty acid contents of larvae and prey from two different spawning grounds showed no significant differences of larval growth conditions in Kiel Canal and Greifswald Bay. The food quality, however, was found to be generally important for larval growth. Accordingly, even when prey availability is plentiful in mixed, natural feeding conditions, larval growth is affected by nutritional value of prey.

Along the inshore–offshore gradients of Western Baltic watersheds, transitional waters, such as bays, lagoons and estuaries seem to represent significant areas for herring reproduction as i) important spawning grounds and ii) retention of early development stages. It still remains a major challenge to quantify the role of small scale drivers and stressors for overall recruitment strength. The rationale in hypothesizing cascading scale effects is supported by current WBSSH recruitment time-series and the relationship of indices derived on differing spatial scales. The regular correspondence of the regional larval index (4.6.2) with recruitment patterns of WBSSH stock implies a relation between larger scale recruitment success and regional survival bottlenecks. On the other hand the N20 time-series provides a sound background to test the magnitudes of regional effects on the overall WBSSH stock.

The pelagic fisheries on herring claim to be some of the "cleanest" fisheries in terms of bycatch, disturbance of the seabed and discarding (ICES, 2010). Pelagic fish interact with other components of the ecosystem, including demersal fish, zooplankton and other predators (sea mammals, elasmobranchs and seabirds). Thus a fishery on pelagic fish may impact on these other components via second order interactions. There is a paucity of knowledge of these interactions, and the inherent complexity in the system makes quantifying the impact of fisheries very difficult. As such the discard ban is not believed to make any changes in the fishery or fishing pattern.

Another potential impact of the Western Baltic herring fishery is the removal of fish that could provide other "ecosystem services." The ecosystem needs a biomass of herring to graze the plankton and act as prey for other organisms. If herring biomass is very low other species, such as sandeel, may replace its role or the system may shift in a more dramatic way. There is, however, no recent research on the multispecies interactions in the foodweb in which the WBSS interact.

B. Data

B.1. Commercial catch

Misreporting of commercial catches induces bias on the estimated fishing mortality and stock size. The potential of such a bias should be taken into account when decisions on reference points and long-term management plans are taken. Misreporting is not only a question of landing species under a different name but can also be a result of reporting catch in a different area than the catches took place. Area misreporting has probably taken place in IIIa and the adjacent North Sea, where catches from the North Sea have been reported in IIIa. The reason for this misreporting has been due to the size differences of herring in the two areas, where the optimal sized herring were caught in the North Sea but reported as taken from IIIa.

Misreporting is understood to have taken place for the Danish catches during the period from 1997 to 2008. The Danish reported landings have been corrected for this misreporting each year in the period 2002–2009 based on information from the industry, week-by-week evaluation of the fishing trips, and since 2004 by using VMS data.

All Norwegian herring catches in IIIa between 1995–2001 are understood to have been taken in the North Sea and this was corrected for. However, since 2008 management has allowed optional transfers (flexibility in terms of where to take the IIIa TAC), where part of the TAC in IIIa legally could be caught in the North Sea.

It is unclear to what extent Swedish catches reported in IIIa in period 1991–2008 have been reported to the correct area. Similar to Denmark it is suspected that some North Sea catches have been reported as IIIa catches. For the period post-2008 misreporting in Danish and Swedish fishery has been judged unlikely primarily due to new regulations prohibiting the vessels to fish in two management areas in one trip; the flexibility in where to take the IIIa TAC (North Sea or IIIa) is also thought to decrease the incitement for area misreporting.

Conclusively, the past area misreporting has been corrected for year-by-year and thus the catch matrix applied in the assessment can be considered as accurate as possible.

There is at present no information about the relevance of local herring populations in relation to the fisheries and their possible influence on the stock assessment. Recent studies on the genetic differentiation among spawning aggregations in the Skagerrak suggests a potential high representation of these local spawning stocks (Bekkevold *et al.*, 2005). Other results suggest that at least the mature proportion of the different stock components shares migration patterns and feeding areas (Ruzzante *et al.*, 2006; van Deurs and Ramkaer, 2007).

B.2. Biological parameters for assessment

Mean weights-at-age in the catch in the 1st quarter were used as stock weights.

In order to check if this is a valid assumption and represents the actual weights in the stock, the index was compared to the average weights in the catch by age during the whole year. The relationship followed the expected pattern where the weight of the younger age classes in the catch are somewhat higher than in the stock as these are taken as an average over the whole year allowing for growth. From age class 4 the relation between weight in catch and weight in stock followed a 1:1 line as expected. Thus the use of weight in the catch in quarter 1 is a sound indicator for the weight in the stock and does not give a biased representation of the stock.

The proportion of F and M before spawning was assumed constant. F-prop was set to be 0.1 and M-prop 0.25 for all age groups.

Natural mortality was assumed constant at 0.2 for all years and 2+ ringers. A predation mortality of 0.1 and 0.2 was added to the 0 and 1 ringers, which resulted in an increase in their natural mortality to 0.3 and 0.5, respectively (Table 3.6.4). The estimates of predation mortality were derived as a mean for the years 1977–1995 from the Baltic MSVPA (ICES 1997/J:2).

The maturity ogive was assumed constant between years:

W-RINGS	0	1	2	3	4	5	6	7	8+
Maturity	**0.00**	**0.00**	**0.20**	**0.75**	**0.90**	**1.00**	**1.00**	**1.00**	**1.00**

Catch sampling for size-at-age and stock identity.

In terms of method reliability, the issue of sampling for biological data for the splitting between NSAS and WBSS is an important factor; without a robust and appropriate sampling strategy, the basis for the splitting is somewhat impaired. When sampling commercial catches for the biological composition concerning the proportions of the two herring stocks, it is crucial that the sampling scheme and coverage mirrors the actual distribution of the fishery. The sampling coverage compared to the reported catches by ICES rectangle over the period 2002–2011 is shown in Figure 4.7.1.1

It is apparent that catches concentrate in the northwestern part of Area IIIa, while sampling intensity is highest in the northeastern area.

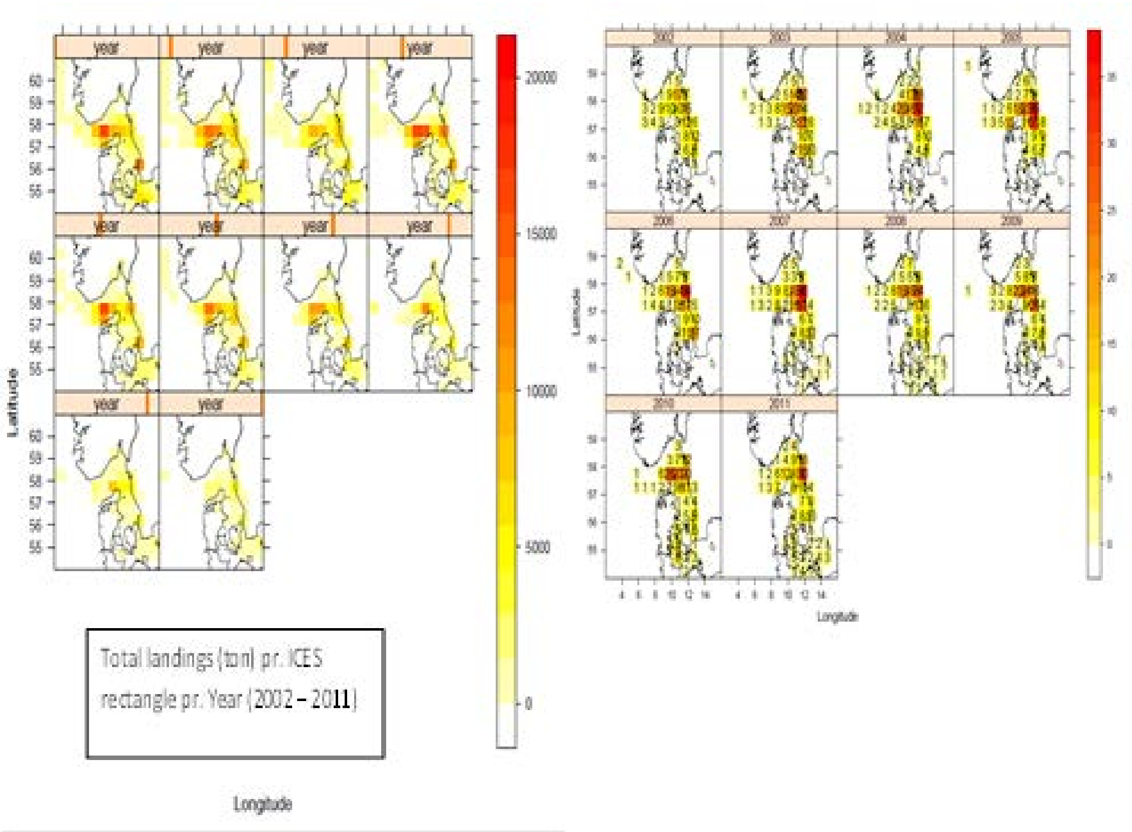
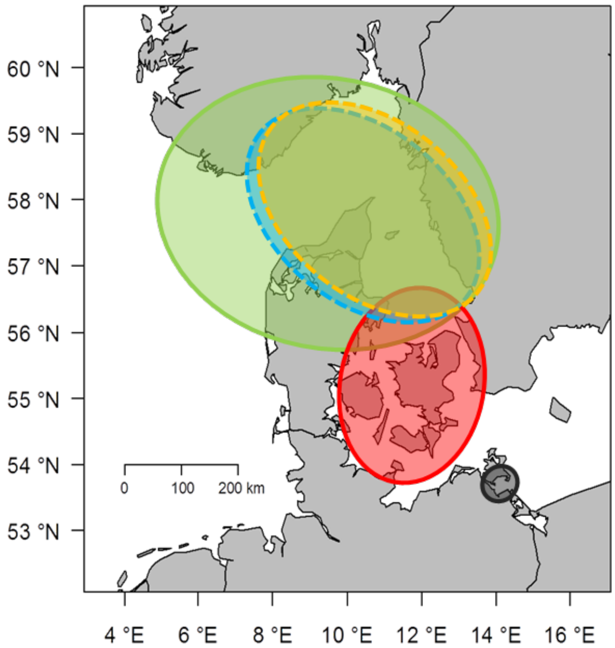


Figure 4.7.1.1. Number of samples by rectangle (right panel) and average landings in tonnes per year by ICES rectangle (left panel) over the period 2002–2011.

In order to get a solid base for estimation of the removals by the fishery, it is of utmost importance that all parts of the distribution area and the fishery herein are covered by the biological sampling. Though the sampling coverage has improved the past years and at present covers the entire distribution area and follows the spatial and temporal distribution of the catches, there is still room for improvement; the sampling in recent periods very poorly covers the Area IVaE (Figure 4.7.1.1). Thus it is highly recommended that the sampling intensity in Subdivision IVaE and eastern parts of IVb is substantially increased.

B.3. Surveys

The WBSS stock has several survey indices available as tuning indices for the assessment (Figure 4.7.2.1). During the benchmark process, an objective selection of survey datasets for inclusion in the stock assessment was performed. In essence, any dataset included should increase the net amount of information, adding more signal than noise. The signal-to-noise ratio in a survey depends on both the noise level and the magnitude of the underlying signal itself (i.e. for a given constant noise level, signals that vary slightly will always be harder to detect than those that vary widely). For example, sample size, survey design, spatial coverage (including how well the spatial distribution of the stock is captured), and consistency of performance can all contribute significant amounts of noise to survey data. In the following the available surveys are described shortly as well as their status as tuning indices.



Survey name	Method	Season	Time-series	Ages	Colour code
GERAS	Acoustic	October	1991-2011	0 to 8	
HERAS	Acoustic	June/July	1991-2013	0 to 8+	
IBTS Q1	Bottom trawl	February/March	1991-2014	1 to 4	
IBTS Q3	Bottom trawl	September	1991-2015	1 to 4	
N20	Larvae sampling	September	1992-2011	0	

Figure 4.7.2.1. Spatial and temporal survey coverage of the WBSS herring stock complex.

GERAS

The GERman Acoustic Survey (GERAS) has since 1993 included the Subdivisions 21 (Southern Kattegat, 41G0–42G2) to 24 as a part of BIAS (Baltic International Acoustic Survey). The survey is being carried out on the German R/V 'Solea' in October (GERAS). Further details of GERAS can be found in ICES reports from the Working Group of International Pelagic Surveys (WGIPS) and Baltic International Fish Survey Working Group (WGBIFS). The survey design and the specific settings of the hydroacoustic equipment follow the guidelines of the 'Manual for the Baltic International Acoustic Surveys (BIAS)', which is part of the WGBIFS report (ICES, 2012).

Recent results of GERAS indicated that in SD 24, which is part of the WBSSH management area, a considerable fraction of CBH is present and correspondingly erroneously allocated to WBSSH stock indices. Accordingly, a Stock Separation Function (SF) based on growth parameters was established to identify the fraction of CBH in the WBSSH area and applied to survey data from the German Acoustic Survey GERAS from 2005–2011. Results showed a distinct fraction of CBH in SD 24 and indicated that applying the SF greatly improved both abundance and biomass indices for WBSSH (WD 01: Gröhsler, Oeberst and Schaber).

WKPELA 2013 thoroughly compared the performance of the GERAS with and without the CBH component and as a result, the GERAS without the CBH component is applied in the assessment (ICES, 2013).

In order to analyse the external consistency between GERAS and the non-larvae surveys, the pairwise correlations of index time-series between all combinations surveys and for each age class respectively in order to analyse to what extent surveys indicate the same development in herring abundance over time. GERAS displayed high external consistency with IBTS-Q1 for age-3 and for the larval survey when correlating the larvae-index in year i with age class 1 in year i+1 and age class 2 in year i+2, etc.

Thus conclusively; both versions of the GERAS are suitable as indices for the WBSS, however, if judging solely on the internal consistency, the 'new' version appear better fit than the version including the CBH.

HERAS

The ICES Coordinated acoustic surveys for herring in the North Sea, Skagerrak and Kattegat gives an index of numbers-at-age for 1–9+-ringers, mean weights-at-age in the stock and proportions mature-at-age. This index has been used in assessments of NSAS since 1994 with the time-series data extending back to 1989. Over the years the survey has been extended to cover Division IIIa to include the overlapping western Baltic spring-spawning stock, the whole of VIa (North) and since 2008 the whole Malin Shelf. By carrying out the coordinated survey at the same time from the Kattegat to Donegal, all herring in these areas are covered simultaneously, reducing uncertainty due to area boundaries as well as providing input indices to three distinct stocks. The surveys are coordinated under the ICES Working Group for International Pelagic Surveys (WGIPS) and full technical details of the survey can be found in the latest WGIPS report (e.g. ICES, 2012).

The internal consistency of HERAS was analysed following the same procedure as applied for GERAS.

As shown in Figure B.3.1, HERAS displayed high internal consistency for ages 3–6, but no internal consistency for ages 1–3.

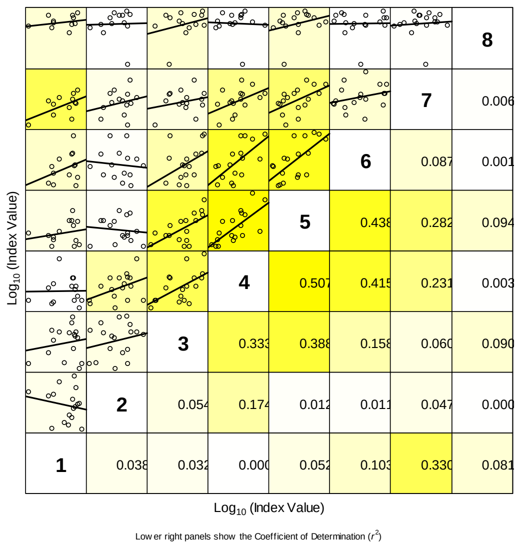


Figure B.3.1. Correlation coefficient diagram for acoustic survey by cohort.

The external consistency between HERAS and the non-larvae surveys was analysed following the same procedure as described for GERAS above. HERAS showed a relatively high consistency with IBTS-Q3 for age-4.

Conclusively; the HERAS index consistently provides age-disaggregated information on WBSS herring. There is a strong internal consistency when tracking cohorts as obtained from the acoustic survey time-series and it correlates with other indices on the older age groups. Thus the time-series derived from the acoustic survey from 1996 to the present is regarded as a relatively good and precise indicator for abundance -at-age. **HERAS is used as one of the tuning indices in the assessment.**

IBTS Q1 and Q3

The International Bottom Trawl Survey (IBTS) in Division IIIa is part of the IBTS surveys in the North Sea. The survey started out as the International Young Herring Survey (IYHS) in 1966 with the objective of obtaining annual recruitment indices for the combined North Sea herring populations (Heessen *et al.*, 1997). It has been carried out every year since. The survey is considered fully standardized from 1983 onwards, when it became known as the International Bottom Trawl Survey (IBTS). Examination of the catch data from the 1st quarter IBTS showed that these surveys also gave indications of the abundances of the adult stages of herring, and subsequently the catches have been used for estimating 2–5+ ringer abundances. The surveys are carried out in 1st quarter (February) and in 3rd quarter (August–September). During the HAWG 2002 the IBTS survey data (both quarter) were revised from 1991 to 2002 and was deemed unfit as indices for the WBSS, however, as part of the WKPELA benchmark the suitability of these indices were re-evaluated.

The internal consistency of both surveys was analysed following the procedure described for GERAS, and in general the internal consistency in the two IBTS time-series was less than for the acoustic surveys. Overall consistency was highest among older fish and in IBTS-Q1 (Figure B.3.2).

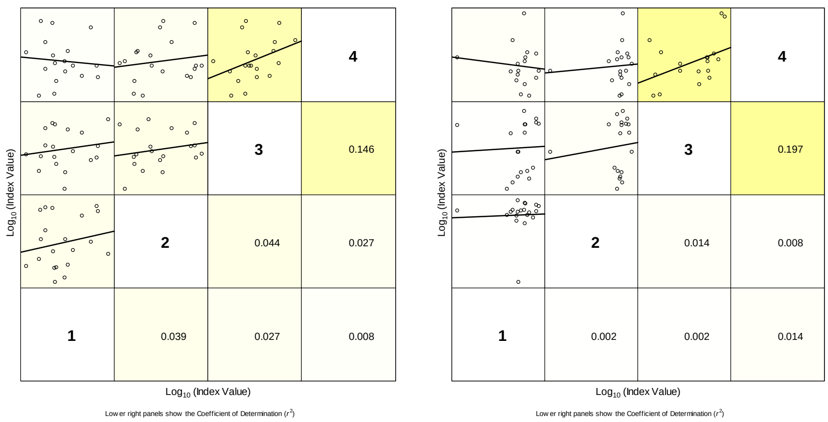


Figure B.3.2. Correlation coefficient diagram for IBTS Q1 (left panel) and IBTS Q3 (right panel) survey by cohort.

The external consistency between the IBTS surveys and the non-larvae surveys was analysed following the same procedure as described for GERAS above. The external consistency between HERAS and IBTS-Q3 for age-4 and between IBTS-Q1 and IBTS-Q3 for age 1 was relatively high. Therefore, **IBTS Q1 and Q3 are used as indices in the assessment.**

N20

The inshore waters of Strelasund/Greifswalder Bodden (ICES SD 24) are considered the main spawning area of Ruegen herring which represents a significant component of the WBSS stock. The German Institute of Baltic Sea Fisheries (TI-OF), Rostock, monitors the density of herring larvae as a vector of recruitment success since 1977 within the frame work of the Ruegen Herring Larvae Survey (RHLS). N20 delivers a unique high-resolution dataset on larval herring growth and survival dynamics in the Western Baltic Sea (see WD 09; Oeberst *et al*., 2009 for detailed description).

In 2006 the rationale and methodology of the survey has been reviewed twice by external scientists (Dickey-Collas and Nash, 2006; Dickey-Collas and Nash, 2011) and the conclusions of this process was that the survey design of the RHLS was greatly improved and efforts were made to test many of the underlying assumptions (ICES, 2013, WD 09). The data collected provide an important baseline for detailed investigation of spawning- and recruitment ecology of WBSS herring stocks. As a fishery-independent indicator of stock development, the recruitment index is incorporated into the ICES Herring Assessment Working Group (HAWG) advice since 2007 as the only 0-group recruitment index for the assessment of WBSS herring.

The consistency/ability of the N20 to match the recruitment of the WBSS stock was analysed by correlating the larvae-index in year i with age class 1 in year i+1 and age class 2 in year i+2, etc. Figure B.3.3 shows the consistency between the N20 and the 'New GerAS' which proved to be the survey fitting the N20 best. The index from the Larvae survey is externally highly consistent with GERAS age 1 (best for the new time-series) and to some extent with age 0 in the same survey. Therefore, **the N20 is used as index in the assessment.**

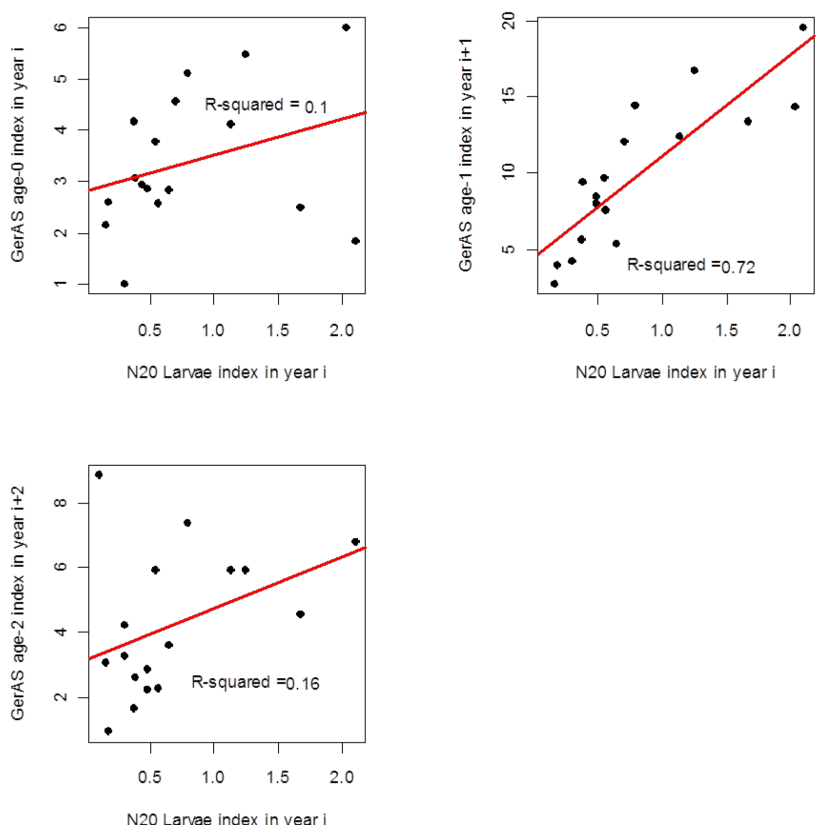
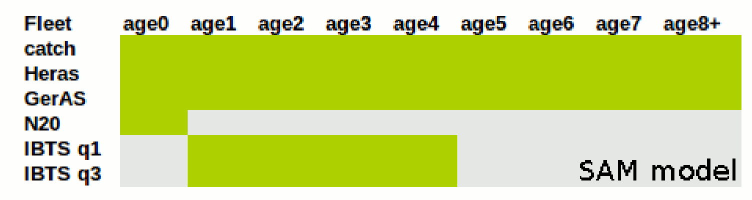


Figure B.3.3. Correlation coefficient diagram for N20 with the 'New GerAS' Survey by age group.

Conclusively, the survey indices used in the assessment are the following:



B.4. Commercial cpue

None.

B.5. Other relevant data

None.

C. Assessment: data and method

Model used: State–space model SAM

Software used: SAM (via web-interface https://www.stockassessment.org)

Model Options chosen:

Minimum age: 0

Maximum age: 8+

Coupled ages of fishing mortality states: 0,1,2,3,4,5,6,7+

Correlated random walk on F

Coupled ages of HERAS catchability: 1,2,3,4,5,6,7+

Coupled ages of GerAS catchability: 0,1,2,3,4,5,6,7+

Coupled ages of IBTS q1 catchability: 1,2,3,4

Coupled ages of IBTS q3 catchability: 1,2,3,4

Coupled ages of F variance: 0,1,2+

Coupled ages of logN variance: 0,1+

Coupled ages of catch observation variance: 0,1,2+

Coupled ages of HERAS observation variance: 1,2,3–6,7+

Coupled ages of GerAS observation variance: 0–3,4–5,6+

Coupled ages of IBTS q1 observation variance: 1–4

Coupled ages of IBTS q3 observation variance: 1–2,3–4

FBAR age: 3–6

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Canum	Catch-at-age in numbers	1991–last data year	0–8+	Yes
Weca	Weight-at-age in the commercial catch	1991–last data year	0–8+	Yes
West	Weight-at-age of the spawning stock at spawning time.	1991–last data year	0–8+	Yes, assumed as the Mw in the catch first quarter
Mprop	Proportion of natural mortality before spawning	1991–last data year	0–8+	No, set to 0.25 for all ages in all years
Fprop	Proportion of fishing mortality before spawning	1991–last data year	0–8+	No, set to 0.1 for all ages in all years
Matprop	Proportion mature-at-age	1991–last data year	0–8+	No, constant for all years
Natmor	Natural mortality	1991–last data year	0–8+	No, constant for all years

Presently used Tuning data:

Type	Name	Year range	Age range
Tuning fleet 1	Danish part of HERAS in Division IIIa	1991–last year data Except 1999	1–8+
Tuning fleet 2	German part of BIAS in SDs 22–24	1994–last year data Except 2001	0–8+
Tuning fleet 3	N20 larval survey, Greifswalder Botten	1992–last year data	0
Tuning fleet 4	IBTS quarter 1	1991–last year data	1–4
Tuning fleet 5	IBTS quarter 3	1991–last year data	1–4

D. Short-term projection

Model used: Age structured

Software used: Rscript (integrated in the SAM web-interface https://www.stockassessment.org)

Initial age structure of the stock for the intermediate year: SAM estimates of survivors (except age0 and age1)

Recruitment (age0): Geometric mean of the recruitment over the five years previous to the assessment year

Age1: calculated by simple exponential decay [$N_{1,t+1} = N_{0,t} \cdot e^{-(F_0+M_0)}$] assuming the same geometric mean recruitment in the year of the assessment

Natural mortality: The same constant vector used for all years in the assessment

Maturity: The same constant vector used for all years in the assessment

F and M before spawning: The same values used for all the years in the assessment

Weight-at-age in the stock: Average weight of the last three years

Weight-at-age in the catch: Average weight of the last three years

Exploitation pattern (selectivity): Average selection pattern of the last three years

Intermediate year assumptions: Catch constraint with the following assumptions:

In case an optional transfer of quota between IIIa and the North Sea is agreed by managers, the Pelagic RAC will provide HAWG with an estimate of the proportion of the TAC for IIIa that will be fished in the North Sea in the assessment year. This estimate will be provided at least two weeks before the working group meeting. If this information is not available, then the proportion of the TAC not taken in IIIa will be assumed to be the average of the most recent three years for which data are available (including only those years where an optional transfer was applied).

The proportion of the Norwegian quota in Division IIIa that is assumed to be caught as NSAS in Subarea IV will be assumed to be the same as last year, and subtracted from the TAC for the C-fleet in Division IIIa.

The fractions of the catch by fleet to the above reduced total TAC in the assessment year is the same as in the previous year.

The proportion of WBSS in the catches in by fleet are assumed equal to the previous year.

Stock–recruitment model used: None

Procedures used for splitting projected catches: Projected catches are for WBSS herring only, therefore no splitting is needed.

E. Medium-term projections

No medium-term projections are carried out for this stock.

F. Long-term projections

No long-term projections are carried out for this stock.

G. Biological reference points

New precautionary biomass reference points were defined at WKPELA 2013. MSY reference points may be revised at HAWG 2013.

	TYPE	VALUE	TECHNICAL BASIS
MSY	MSY $B_{trigger}$	110 000 t	Based on management plan development and the lowest observed SSB in the 2008 assessment.
Approach	F_{MSY}	0.25	Management plan evaluations (ICES, 2008).
	B_{lim}	90 000 t	B_{lim} = B_{loss}, the 2011 estimate, estimated in 2012.
Precautionary	B_{pa}	110 000 t	95% confidence interval of the last year’s estimate.
Approach	F_{lim}	Not defined	
	F_{pa}	Not defined	

H. Other issues

None.

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Stock Annex: Sardine Subarea VII and VIIIabd

Stock	Sardine Subarea VII + VIIIabd
Working Group	WGHANSA
Date	4th to 8th of February, 2013
Revised at	WKPELA
Authors	E. Duhamel, L. Ibaibarriaga, J. Massé, L. Pawlowski, M. Santos and A. Uriarte.

A. General

A.1. Stock definition

European sardine (*Sardine pilchardus* Walbaum, 1792) has a wide distribution extending in the Northeast Atlantic from the Celtic Sea and North Sea in the north to Mauritania in the south. Populations of Madeira, the Azores and the Canary Islands are at the western limit of the distribution (Parrish *et al*., 1989). Sardine is also found in the Mediterranean and the Black Seas. Changing environmental conditions affect sardine distribution, with fish having been found as far south as Senegal during episodes of low water temperature (Corten and van Kamp, 1996; Binet *et al*., 1998).

Sardine in Celtic Seas (VIIabcfgjk), English Channel (VIId, VIIe, VIIh) and in Bay of Biscay (VIIIabd) are considered to belong to the same stock from a genetic point of view. Therefore, the sardine stock in VIIIabd and VII can be considered as a single stock unit but it is important to note that there should be some distinction within the stock structure to take account of some regional differences between fisheries as there are some locally important fisheries operating in some area.

The availability of data strongly differs between the northern (Celtic Seas, English Channel) and the southern component (Bay of Biscay). Additionally, each area presents different historical exploitation patterns. Therefore analysis and management advice between the areas may differ, even if the advice covers the whole stock.

A.2. Fishery

There are currently no management measures implemented for this stock. The fisheries appear to be regulated by market price. Some fisheries (e.g. French fleets in the Bay of Biscay) have set their own local management in order to sustain correct market prices which imply targeting fish of certain sizes and limit to the total amount of catch. The absence of TAC is currently not seen as a problem for the management of those fisheries as the demand of sardine is considered to be low.

Divisions VIIIabd (Bay of Biscay)

An update of the French and Spanish catch dataseries in Divisions VIIIa and VIIIb (from 1983 and 1996 for France and Spain, respectively) including 2011 catches was presented to this benchmark. Spanish catches are taken by purse seines from the Basque Country operating only in Division VIIIb. Spanish landings peaked in 1998 and 1999 with almost 8 thousand tonnes but have decreased until 2010 to below 1 thousand tonnes. The Spanish fishery takes place mainly during March and April and in the fourth quarter of the year.

French catches have increased along the series, with values ranging from 4400 tonnes in 1983 to 23 000 tonnes in 2011 (Figure A.2.1). A total of 90% of the catches are taken by purse seiners while the remaining 10% is reported by pelagic trawlers (mainly pair trawlers). A substantial part of the French catches originates in Divisions VIIh and VIIe, but these catches have been assigned to Division VIIIa due to their very concentrated location at the boundary between VIIIa, VIIh and VIIe.

Spanish catches were unusually high prior 1989 where a strong drop occurs. The reason of this drop is unknown and likely to be related to some data aggregation issues which make any uses of landings prior this year uncertain.

Both purse seiners and pelagic trawlers target sardine in French waters. Average vessel length is about 18 m. Purse seiners operate mainly in coastal areas (<10 nautical miles) while trawlers are allowed to fish within 3 nautical miles from the coast. Both pair trawlers and purse seiners operate close to their base harbour when targeting sardine. The highest catches are taken in the summer months. Almost all the catches are taken in southwest Brittany.

While French catches in Divisions VIIIa and VIIIb are constituted by fish of a wide range of sizes with a peak at 20 cm length, sardine taken by Spanish vessels show a narrower range of sizes but with a peak at similar length size.

The Bay of Biscay sardine fisheries overlaps with VIIe and VIIh (statistical rectangle 25E4, 25E5). Catches in those rectangles are assumed to be of sardine from Bay of Biscay. Therefore landings in Bay of Biscay and English Channel are corrected to take account of this phenomenon by adding the catches in those rectangles to the Bay of Biscay landings time-series.

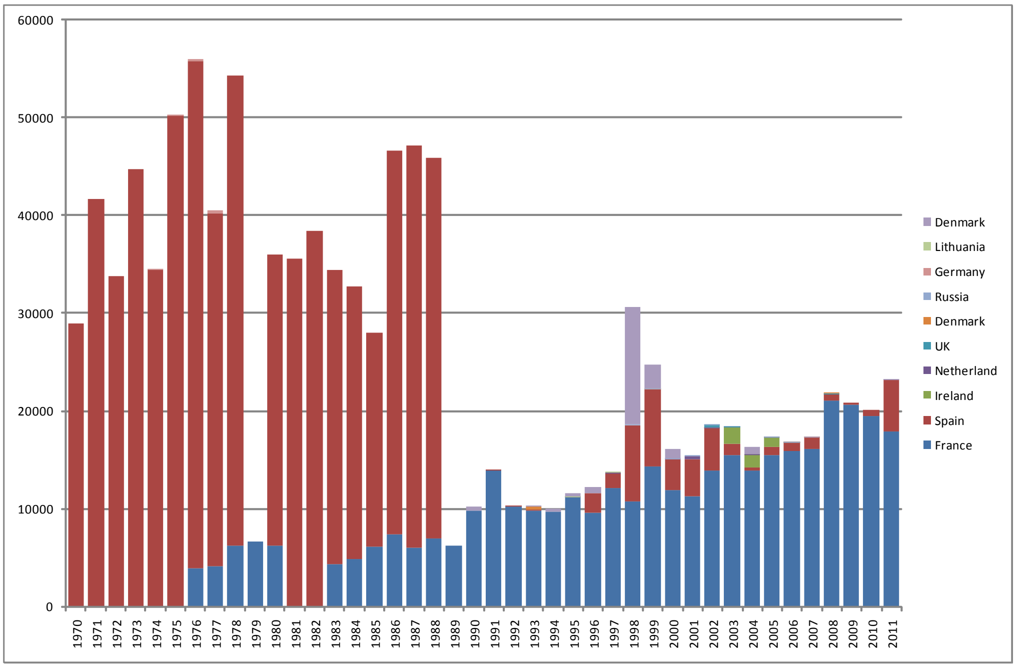


Figure A.2.1. Historical time-series of landings of sardine per country in the Bay of Biscay.

Subareas VIIdeh (English Channel and VIIh)

Most of the catches are concentrated close to or in the English Channel (VIId, VIIe, VIIh) with major landings from France and Netherlands, other catches being taken by England and Wales. Little information was available from other countries operating in that subarea. Catches have substantially oscillated with time and between countries from 25 000 to less than 2000 tons. This region has been harvested substantially in the past by various fleets (Figure A.2.2) from various countries that are no longer operating in those waters. The peak of fishing activity was in the early 1990s at around 25 000 tons. Over the last decades, the landings have been between nearly 5000 to 11 000 tons with no particular trends. The English Channel is after Bay of Biscay the second fishing area for sardine.

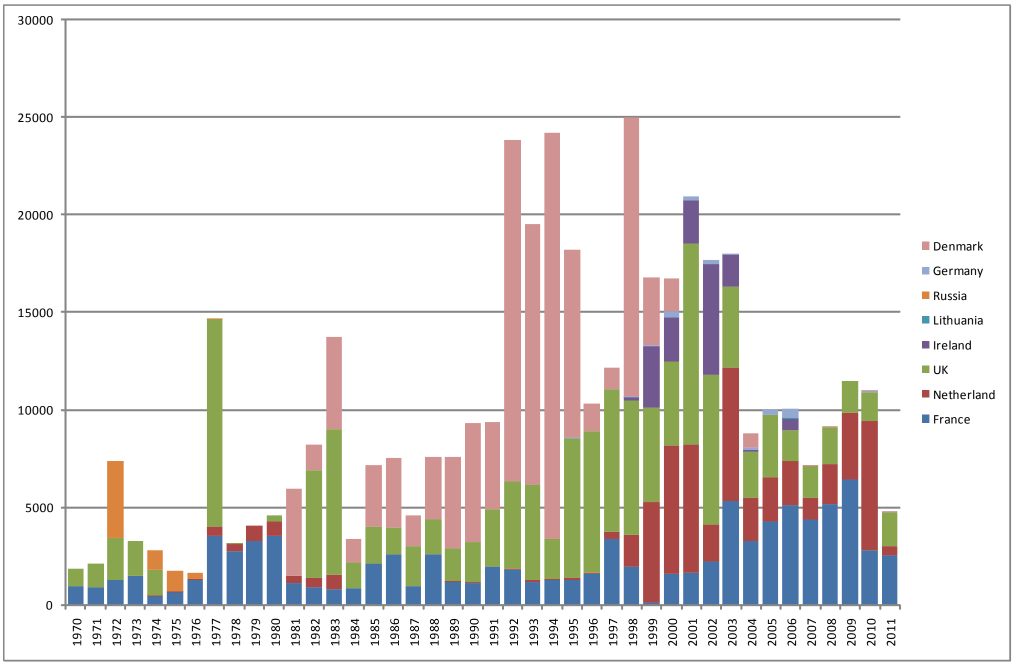


Figure A.2.2. Historical time-series of landings of sardine per country in the English Channel and VIIh.

As mentioned for the Bay of Biscay, catches in rectangles 25E4, 25E5 are removed from the official landings and added to the catches in the Bay of Biscay to take account of the mixing at the borders of Division VIIIa and VIIh and VIIe.

Subareas VIIabcfgjk (Celtic Seas)

Catches in this area are very low.

A.3. Ecosystem aspects

Sardine is prey of a range of fish and marine mammal species which take advantage of its schooling behaviour and availability. Sardine has been found to be important in the diet of common dolphins (*Delphinus delphis*) in Galicia (NW Spain) (Santos *et al.*, 2004), Portugal (Silva, 2003) and the Atlantic French coast (Meynier, 2004). Recent studies of consumption of common dolphins in Galician (Santos *et al.*, 2011) waters give figures ranging from almost 6000 tons to more than 9000 tons of sardine, which represents a rather small proportion of the combined Spanish and Portuguese annual landings of sardine from ICES Areas VIIIc and IXa (6–7%).There are also other species feeding on sardine, although to a lesser extent, such as: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), and white-sided dolphin (*Lagenorhynchus acutus*) (e.g. Santos *et al.*, 2007).

B. Data

B.1. Commercial catches

Landings data have been available for since 1950 on various aggregation levels. Data are considered to be accurate for all countries starting 1989 within the whole area. Discards were measured only in 2012 and were low based on the French Observers at sea program in the Bay of Biscay and hence not included in the assessment. In the past (late eighties and early nineties for the French Pelagic trawlers and sixties and seventies for the Spanish Purse seine fleet) they seemed to be more relevant (according to disputes among fishermen), but were never quantified. Length distribution of discards are also available from Netherlands in the English Channel for 2011.

B.2. Biological

- Catches-at-length and catches-at-age are known since 1984 for Spain and since 2002 for France in the Bay of Biscay. Because of the availability of the datasets only the period starting in 2000 is used. They are obtained by applying to the monthly Length distributions half year or quarterly ALKs. Biological sampling of the catches has been generally sufficient, and useful to have a better knowledge of the age structure of the catches during the second semester in the North of the Bay of Biscay. Complete age composition and mean weight-at-age on half year basis, were each year reported in ICES (WGHANSA report, ICES 2012).
- Age reading is considered accurate. The most recent cross reading exchanges and workshop between Spain and France (but other countries, too) took place in 2011 (WKARAS report, ICES 2011). The overall level of agreement and precision in sardine of the Bay of Biscay age reading determinations seems to be satisfactory: Most of the sardine otoliths were well classified by most of the readers during the 2011 workshop (with an average agreement 75% and a CV of 14%).
- Sardines are mature in their 1st year of life.
- Growth in weight and length are routinely obtained from surveys and from the monitoring of the fishery.
- Natural mortality is fixed at 0.33 based on the assessment for sardine in VIIIc and IXa. This parameter is considered to vary between years and ages, but it is assumed to be constant for the assessment of the stock.

B.3. Surveys

Relevant surveys are available for the Bay of Biscay only. Some sardines are caught during the various demersal surveys (e.g FR-IBTS) occuring each year in the Celtic Seas, Bay of Biscay and English Channel but those catches are not substantial enough to be considered as indicators of the stock status.

Some abundance indices are available every year for the Bay of Biscay through two spring surveys based on acoustic surveys (PELGAS) and DEPM (Daily egg production method - BIOMAN).

The population present in the Bay of Biscay is monitored by the two annual surveys carried out in spring on the spawning stock, namely, the Daily Egg Production Method and the Acoustics surveys (regularly since 1989, although surveys were also conducted in 1983, 1984 and some in the seventies) (Massé, 1988; 1994; 1996). Both surveys provide spawning biomass and population-at-age estimates.

This survey based monitoring system provides population estimates by the middle of the year, when a small part of the annual catches have been already taken.

B.3.1. Sardine acoustic indices (PELGAS survey)

Acoustic surveys are carried out every year in the Bay of Biscay in spring on board the French research vessel Thalassa since 1997. The objective of PELGAS surveys is to study the abundance and distribution of pelagic fish in the Bay of Biscay.

These surveys are connected with Ifremer programmes on data collection for monitoring and management of fisheries and ecosystemic approach for fisheries. This task is formally included in the first priorities defined by the Commission regulation EU N° 199/2008 of 06 November 2008 establishing the minimum and extended Community programmes for the collection of data in the fisheries sector and laying down detailed rules for the application of Council Regulation (EC) No 1543/2000. These surveys must be considered in the frame of the Ifremer fisheries ecology action "resources variability" which is the French contribution to the international Globec programme. It is planned with Spain and Portugal in order to have most of the potential area to be covered from Gibraltar to Brest with the same protocol for sampling strategy. Data are available for the ICES working groups WGHANSA, WGWIDE and WGACEGG.

In 2003, survey data are considered less reliable because of unusual environmental conditions linked to the heat wave over Europe. Results this year were considered not representative of the true status of the stock.

B.3.1.1. PELGAS Method and sampling strategy

In the frame of an ecosystemic approach, the pelagic ecosystem is characterised at each trophic level. In this objective, to assess an optimum horizontal and vertical description of the area, two types of actions are combined:

- Continuous acquisition by storing acoustic data from five different frequencies and pumping seawater under the surface in order to evaluate the number of fish eggs using a CUFES system (Continuous Under-water Fish Eggs Sampler); and
- Discrete sampling at stations (by trawls, plankton nets, CTD). Satellite imagery (temperature and sea colour) and modelisation will be also used before and during the cruise to recognise the main physical and biological structures and to improve the sampling strategy. Concurrently, a visual counting and identification of cetaceans and birds (from board) is carried out in order to characterise the higher level predators of the pelagic ecosystem.

Satellite imagery (temperature and sea colour) and modelisation are also used before and during the cruise to recognise the main physical and biological structures and to improve the sampling strategy.

The strategy of the survey is the same for the whole series (since 2000).

- Acoustic data were collected along systematic parallel transects perpendicular to the French coast (Figure B.3.1.1). The length of the ESDU (Elementary Sampling Distance Unit) was 1 mile and the transects were uniformly spaced by 12 nautical miles covering the continental shelf from 20 m depth to the shelf break.

- Acoustic data were collected only during the day because of pelagic fish behaviour in this area. These species are usually dispersed very close to the surface during the night and so "disappear" in the blind layer for the echo sounder between the surface and 8 m depth.

Two echo-sounders are usually used during surveys (SIMRAD EK60 for vertical echo-sounding and MARPORT on the pelagic trawl). Since 2009 the SIMRAD ME70 is used for multibeam visualisation. Energies and samples provided by split beam transducers (six frequencies EK60, 18, 38, 70, 120, 200 and 333 kHz), simple beam (MARPORT) and multibeam echosounder were simultaneously visualised, stored using the MOVIES+ software and at the same standard HAC format.

The calibration method is the same that the one described for the previous years (see W.D. 2001) with a tungsten sphere hanged up 20 m below the transducer and is generally performed at anchorage in front of Machichaco Cap or in the Douarnenez Bay, on the west side of Brittany, in optimal meteorological conditions.

Acoustic data are collected by Thalassa along the totality of the daylight route from which about 2000 nautical miles on one way transect are usable for assessment. Fish are measured on board (for all species) and otoliths (for anchovy and sardine) are collected for age determinations.

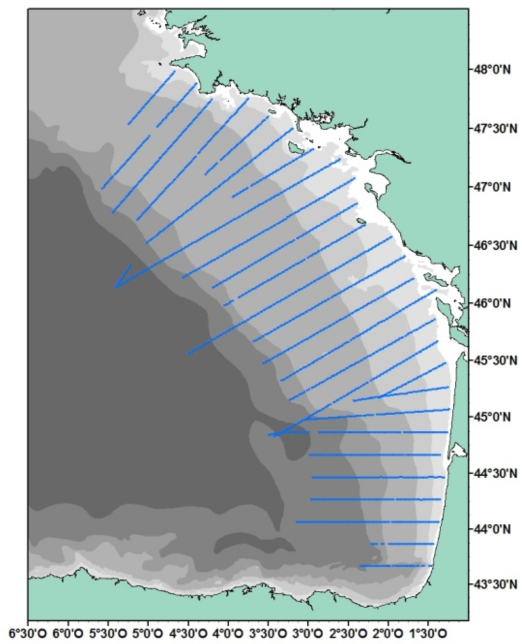


Figure B.3.1.1. The acoustic transects network of the PELGAS survey.

B.3.1.2. Echoes scrutinizing

Most of the acoustic data along the transects are processed and scrutinised during the survey and are generally available one week after the end of the survey. Acoustic energies (Sa) are cleaned by sorting only fish energies (excluding bottom echoes, parasites, plankton, etc.) and classified into several categories of echotraces according to the year fish (species) structures.

D1 – energies attributed to mackerel, horse mackerel, blue whiting, various demersal fish, corresponding to cloudy schools or layers (sometimes small dispersed points) close to the bottom or of small drops in a 10 m height layer close to the bottom.

D2 – energies attributed to anchovy, sprat, sardine and herring corresponding to the usual echo-traces observed in this area since more than 15 years, constituted by schools well defined, mainly situated between the bottom and 50 meters above. These echoes are typical of clupeids in coastal areas and sometimes more offshore.

D3 – energies attributed to blue whiting, myctophids and boarfish offshore, just closed to the shelf-break and on the platform in the north.

D4 – energies attributed to sardine, mackerel and anchovy corresponding to small and dense echoes, very close to the surface.

D8 – energies attributed exclusively to sardine (big and very dense schools).

B.3.1.3. Data processing

The global area is split into several strata where coherent communities are observed (species associations) in order to minimise the variability due to the variable mixing of species. For each stratum, a mean energy is calculated for each type of echoes and the area measured. A mean haul for the strata is calculated to get the proportion of species into the strata. This is obtained by estimating the average of species proportions weighted by the energy surrounding haul positions. Energies are therefore converted into biomass by applying catch ratio, length distributions and TS relationships. The calculation procedure for biomass estimate and variance is described in Petitgas *et al.*, 2003.

The TS relationships used since 2000 are still the same and as following:

Sardine, anchovy & sprat: TS = 20 Log L – 71.2

Horse mackerel: TS = 20 Log L – 68.7

Blue whiting: TS = 20 Log L – 67.0

Mackerel: TS = 20 Log L – 86.0

The mean abundance per species in a stratum (tons m.n.$^{-2}$) is calculated as:

$$M_e(k)=\sum_D \overline{s}_A(D,k)\overline{X}_e(D,k)$$

and total biomass (tons) by: $B_e=\sum_k A(k)Me(k)$

where,

k : strata index

D : echo type

e : species

S$_A$: Average S_A (NASC) in the strata (m2/n.mi.2)

X$_e$: species proportion coefficient (weighted by energy around each haul) (tons m^{-2})

A : area of the strata (m.n.[2])

Then variance estimate is:

$$Var.M_e(k)=\sum_D \bar{s}_A^{\,2}(D,k)Var[X_e(D,k)]/n.cha(k)+\overline{X}_e^{\,2}\,\mathrm{var}[s_A(D,k)]/n.esu(D,k)$$

$$Var.B_e=\sum_k A^2(k)Var.Me(k)$$

$$cv=\sqrt{Var.Be}/Be$$

At the end, density in numbers and biomass by length and age are calculated for each species in each ESDU according to the nearest haul length composition. These numbers and biomass are weighted by the biomass in each stratum and data are used for spatial distributions by length and age.

The detailed protocol for these surveys (strategy and processing) is described in Annex 6 of WGACEGG report (ICES 2009).

B.3.2 Anchovy Daily Egg Production Method (BIOMAN Survey)

B.3.2.1 the DEPM model

The sardine spawning–stock biomass estimates is derived according to Parker (1980) and Stauffer and Picquelle (1980) from the ratio between daily production of eggs in the sea and the daily specific fecundity of the adult population:

$$SSB = P_{tot}/DF = \frac{P_0 \cdot A+}{k \cdot R \cdot F \cdot S/W}$$

Equation 1

Where,

SSB = Spawning–stock biomass in metric tons

P_{tot} = Total daily egg production in the sampled area

P_0 = daily egg production per surface unit in the sampled area

A+ = Spawning area, in sampling units

DF = Daily specific fecundity. $DF = \dfrac{k \cdot R \cdot F \cdot S}{W}$

W = Average weight of mature females in grams,

R = Sex ratio, fraction of population that are mature females, by weight.

F = Batch fecundity, numbers of eggs spawned per mature females per batch

S = Fraction of mature females spawning per day

k = Conversion factor from gram to metric tons (10^6)

An estimate of an approximate variance and bias for the biomass estimator derived using the *delta* method (Seber, 1982, *in* Stauffer and Picquelle, *op. cit.*) was also developed by the latter authors.

Population estimates of numbers-at-age are derived as follows:

$$N_a = N \cdot E_a = \frac{SSB}{W_t} \cdot E_a$$

Equation 2

Where,

Na = Population estimate of numbers-at-age *a*.

N = Total spawning–stock estimate in numbers. $N = \frac{SSB}{W_t}$

SSB = spawning–stock biomass estimate.

Wt = average weight of anchovies in the population.

Ea = Relative frequency (in numbers) of age *a* in the population.

Variance estimate of the sardine stock in numbers-at-age and total is derived applying the delta method.

B.3.2.2 Collection of plankton samples

Every year the area covered to collect the plankton samples is the southeast of the Bay of Biscay taking in advance the anchovy survey in the Bay of Biscay.

Predetermined distribution of stations is shown in Figure B.3.1.2.1. The strategy of egg sampling is as follow: a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance found (Motos, 1994). Stations are located every 3 miles along 15-mile-apart transects perpendicular to the

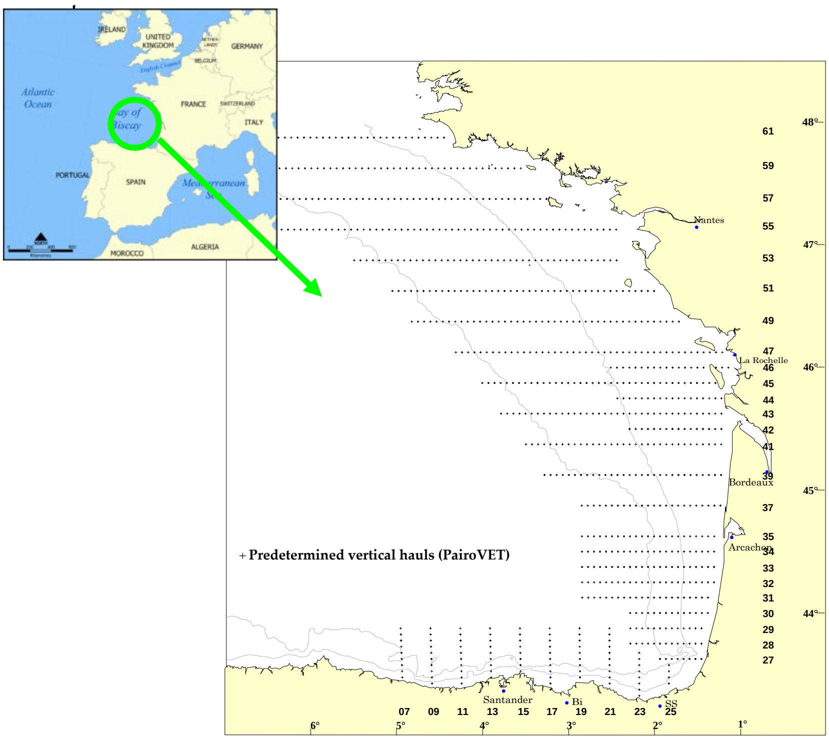


Figure B.3.1.2.1. Predetermined stations of the vertical hauls (PairoVET) that could be performed during the survey.

At each station a vertical plankton haul is performed using a PairoVET net (Pair of Vertical Egg Tow, Smith *et al*., 1985 in Lasker, 1985) with a net mesh size of 150 µm for a total retention of the sardine eggs under all likely conditions. The net is lowered to a maximum depth of 100 m or 5 m above the bottom in shallower waters. After allowing 10 seconds at the maximum depth for stabilisation, the net is retrieved to the surface at a speed of 1 m s-1. A 45 kg depressor is used to allow for correctly deploying the net. "G.O. 2030" flowmeters are used to detect sequential clogging of the net during a series of tows.

Immediately after the haul, the net is washed and the samples obtained are fixed in formaldehyde 4% buffered with sodium tetra borate in seawater. After six hours of fixing, anchovy, sardine and other eggs species are identified, sorted out and count on board. Afterwards, in the laboratory, a percentage of the samples are checked to assess the quality of the sorting made at sea. According to that, a portion of the samples are sorted again to ensure no eggs were left in the sample. In the laboratory, sardine eggs are classified into morphological stages (adapted from Gamulin and Hure, 1955).

The Continuous Underway Fish Egg Sampler (CUFES, Checkley *et al*., 1997) is used to record the eggs found at 3 m depth with a net mesh size of 350 µm. The CUFES system has a CTD to record simultaneously temperature and salinity at 3 m depth, a flowmeter to measure the volume of the filtered water, a fluorimeter and a GPS (Geographical Position System) to provide sampling position and time. All these data are registered at real time using the integrated EDAS (Environmental Data Acquisition System) with custom software.

During the survey, the anchovy, sardine and other eggs are recorded per PairoVET station and the area where sardine eggs occurred is quantified. Following the systematic central sampling scheme (Cochran, 1977) each station is located in the centre of a rectangle. Egg Abundance found at a particular station is assumed to represent the abundance in the whole rectangle. The area represented by each station is measured. A standard station has a surface of 45 squared nautical miles (154 km^2) = 3 (distance between two consecutive stations) x 15 (distance between two consecutive transects) nautical miles. Since sampling is adaptive, station area changed according to sampling intensity and the cut of the coast.

Sample depth, temperature, salinity and fluorescence profiles are obtained in every station using a CTD RBR-XR420 coupled to the PairoVET. In addition, surface temperature and salinity is recorded in each station with a manual termosalinometer WTW LF197.Moreover current data are obtained all along the survey with an ADCP (Acoustic Doppler Current Profiles). In some point determinate previously to the survey, water is filtered from the surface to obtain chlorophyll samples to calibrate the chlorophyll data.

B.3.2.3 Collection of adult samples

Since 2008 each three years adults are being obtained from a research vessel with pelagic trawl taking in advance the anchovy survey.

The research vessel pelagic trawler covers the same area as the plankton vessel. When the plankton vessel encountered areas with sardine eggs, the pelagic trawler is directed to those areas to fish. In each haul 100 individuals of each species are measure. Immediately after fishing, sardine is sorted from the bulk of the catch and a sample is selected at random. A minimum of 60 anchovies are weighted, measured and sexed and from the mature females the gonads of 25 non-hydrated females (NHF) are preserved. If the target of 25 NHF is not completed 10 more anchovies are taken at random and process in the same manner. Sampling is stopped when 120 anchovies have to be sexed to achieve the target of 25 NHF. Otoliths are extracted on board and read in the laboratory to obtain the age composition per sample.

B.3.2.4 Total daily egg production estimates

Since 1999 the sardine eggs were counted but only were staged in years 1999, 2002, 2008 and 2011.

In years without egg stages it was considered the total abundances of eggs defined as the sum along all the stations of the sardine eggs in each station multiplied by the area each station represents.

In years when sardine eggs are sorted and staged (1999, 2002, 2008 and 2011), it is possible to estimate total daily egg production (P_{tot}). This is calculated as the product between the daily egg production (P_0) and the spawning area (SA).

$$P_{tot} = P_0 \, SA$$

A standard sampling station represents a surface of 45 nm^2 (i.e. 154 km^2). Since the sampling was adaptive, area per station changes according to the sampling intensity and the cut of the coast. The total area is calculated as the sum of the area represented by each station. The spawning area (SA) is delimited with the outer zero sardine egg stations but it can contain some inner zero stations embedded. The spawning area is computed as the sum of the area represented by the stations within the spawning area.

The daily egg production per area unit (P0) was estimated together with the daily mortality rate (Z) from a general exponential decay mortality model of the form:

(2) $$P_{i,j} = P_0 \exp\left(-Z \, a_{i,j}\right),$$

where Pi,j and ai,j denote respectively the number of eggs per unit area in cohort j in station i and their corresponding mean age. Let the density of eggs in cohort j in station i, Pi,j, be the ratio between the number of eggs Ni,j and the effective sea area sampled Ri (i.e. $P_{i,j} = N_{i,j} / R_i$). The model was written as a generalised linear model (GLM, McCullagh and Nelder, 1989; ICES, 2004) with logarithmic link function:

(3) $$\log\left(E[N_{i,j}]\right) = \log(R_i) + \log\left(P_0\right) - Z \, a_{i,j},$$

where the number of eggs of daily cohort *j* in station *i* (N_{ij}) was assumed to follow a negative binomial distribution. The logarithm of the effective sea surface area sampled ($\log(R_i)$) was an offset accounting for differences in the sea surface area sampled and the logarithm of the daily egg production $\log(P_0)$ and the daily mortality Z rates were the parameters to be estimated.

The eggs collected at sea and sorted into morphological stages had to be transformed into daily cohort frequencies and their mean age calculated in order to fit the above model. For that purpose the Bayesian ageing method described in ICES (2004), Stratoudakis *et al.*, (2006) and Bernal *et al.*, (2011) was used. This ageing method is based on the probability density function (pdf) of the age of an egg *f(age | stage, temp)*, which is constructed as:

(4) $$f(age \mid stage, temp) \propto f(stage \mid age, temp)\, f(age).$$

The first term f(stage | age, temp) is the pdf of stages given age and temperature. It represents the temperature dependent egg development, which is obtained by fitting a multinomial model like extended continuation ratio models (Agresti, 1990) to data from temperature dependent incubation experiments (Ibaibarriaga *et al*., 2007, Bernal *et al*., 2008). The second term is the prior distribution of age. A priori the probability of an egg that was sampled at time τ of having an age is the product of the probability of an egg being spawned at time τ - age and the probability of that egg surviving since then (exp(-Z age)):

(5) $$f(age) \propto f(spawn = \tau - age)\exp(-Z\ age)$$.

The pdf of spawning time f(spawn= τ - age) allows refining the ageing process for species with spawning synchronicity that spawn at approximately certain times of the day (Lo, 1985a; Bernal *et al*., 2001). Sardine spawning time was assumed to be normally distributed with mean at 21:00h GMT and standard deviation of 3 (ICES, 2004). The peak of the spawning time was also used to define the age limits for each daily cohort (spawning time peak plus and minus 15 hours). Details on how the number of eggs in each cohort and the corresponding mean age are computed from the pdf of age are given in Bernal *et al*. (2011). The incubation temperature considered was the one obtained from the CTD at 10 m in the way up.

Given that this ageing process depends on the daily mortality rate which is unknown, an iterative algorithm in which the ageing and the model fitting are repeated until convergence of the Z estimates was used (Bernal *et al*., 2001; ICES, 2004; Stratoudakis *et al*., 2006). The procedure is as follows:

Step 1. Assume an initial mortality rate value;

Step 2. Using the current estimates of mortality calculate the daily cohort frequencies and their mean age;

Step 3. Fit the GLM and estimate the daily egg production and mortality rates. Update the mortality rate estimate;

Step 4. Repeat steps (1)–(3) until the estimate of mortality converged (i.e. the difference between the old and updated mortality estimates was smaller than 0.0001).

Incomplete cohorts, either because the bulk of spawning for the day was not over at the time of sampling, or because the cohort was so old that its constituent eggs had started to hatch in substantial numbers, were removed in order to avoid any possible bias. At each station, younger cohorts were dropped if they were sampled before twice the spawning peak width after the spawning peak and older cohorts were dropped if their mean age plus twice the spawning peak width was over the critical age at which less than 99% eggs were expected to be still unhatched. Once the final model estimates were obtained the coefficient of variation of P0 was given by the standard error of the model intercept (log(P0)) (Seber, 1982) and the coefficient of variation of Z was obtained directly from the model estimates.

The analysis was conducted in R (www.r-project.org). The "MASS" library was used for fitting the GLM with negative binomial distribution and the "egg" library (http://sourceforge.net/projects/ichthyoanalysis/) for the ageing and the iterative algorithm.

B3.2.5 Adult parameters, daily fecundity and SSB estimates

In 2008 and 2011 adult samples were collected within the same day as the egg sampling. These samples are used to obtain adult parameters to estimate the daily fecundity, i.e. batch fecundity, spawning fraction, average female weight and sex ratio.

These adult parameters are estimates as follows:

Sex Ratio (R): It is calculate as the average sample ratio between the average female weight and the sum of the average female and male weights of the anchovies in each of the samples.

Total weight of hydrated females is corrected for the increase of weight due to hydration. Data on gonad-free-weight (Wgf) and correspondent total weight (W) of nonhydrated females is fitted by a linear regression model. Gonad-free-weight of hydrated anchovies is then transformed to total weight by applying the following equation:

$$W = -a + b * W_{gf}$$

For the **Batch fecundity (F)** estimates i.e. number of eggs laid per batch and female, the hydrated egg method was followed (Hunter et al, 1985). The number of hydrated oocytes in gonads of a set of hydrated females is counted. This number is deduced from a sub-sampling of the hydrated ovary: Three pieces of approximately 50 mg are removed from different parts of each ovary, weighted with precision of 0.1 mg and the number of hydrated oocytes counted. Sanz and Uriarte (1989) showed that three tissue samples per ovary are adequate to get good precision in the final batch fecundity estimate and the location of sub-samples within the ovary do not affect it. Finally the number of hydrated oocytes in the subsample is raised to the total gonad of the female according to the ratio between the weights of the gonad and the weight subsampled.

A linear regression between female weight and batch fecundity is established for the subset of hydrated females and used to calculate the batch fecundity of all mature females. The average of the batch fecundity estimates for the females of each sample as derived from the gonad free weight–eggs per batch relationship is then used as the sample estimate of batch fecundity.

Moreover, an analysis is conducted to verify if there are differences in the batch fecundity if strata are defined to estimate SSB.

To estimate **Spawning Frequency (S)**, i.e. the proportion of females spawning per day, was estimated from the incidence of postovulatory follicles 1 and 2 day old in the gonads of mature females (Hunter and Macewicz, 1985) (the number of females with Day-0 POF was corrected by the average number of females with Day-1 or Day-2 POF).

Mean and variance of the adult parameters are estimated following equations for cluster sampling (as suggested by Picquelle and Stauffer, 1985):

Equation 3
$$Y = \frac{\sum_{i=1}^{n} M_i \, y_i}{\sum_{i=1}^{n} M_i}$$

Equation 4
$$Var(Y) = \frac{\sum_{i=1}^{n} M_i^{2} (y_i - Y)^2}{\overline{M}^{2} \, n(n-1)}$$

Where,

Y_i is an estimate of whatever adult parameter from sample *i* and M_i is the size of the cluster corresponding to sample *i*. occasionally a station produced a very small catch, resulting in a small sub-sample size. To reflect the actual size of the station and its lower reliability, small samples were given less weight in the estimate. For the estimation of W, F and S, a weighting factor was used, which equalled to 1 when the number of mature females in station *i* (M_i) was 20 or greater and it equalled to $M_i/20$ otherwise. In the case of R when the total weight of the sample was less than 800 g then the weighting factor was equal to total weight of the sample divided by 800 g, otherwise it was set equal to 1. In summary for the estimation of the parameters of the Daily Fecundity we are using a threshold-weighting factor (TWF) under the assumption of homogeneous fecundity parameters within each stratum.

The Spawning–Stock Biomass is estimates as the ratio between the total egg production (P_{tot}) and Daily Fecundity (DF).

B3.2.6 Egg abundance estimates 1999–2012

Table B3.2.6.1. Sardine egg abundances in the Bay of Biscay from 1999 to 2012.

Ab.tot.Sp is the sum along all the stations of the sardine eggs in each station multiplied by the area each station represents. Pos.area is the positive area for sardine; tot area is the total area surveyed; %pos area is the percentage the positive area represents in relation to the total area and Ptot is the total egg production.

Year	Ab.tot_Sp	pos area	tot area	% pos area	Ab.tot/pos.area	Ptot(egg/day)
1999	**1.3E+12**	26,679	59,193	45	5.0E+07	7.8E+11
2000	**5.0E+12**	40,139	52,212	77	1.2E+08	
2001	**9.2E+11**	14,547	51,629	28	6.3E+07	
2002	**8.3E+12**	39,112	50,951	77	2.1E+08	4.4.E+12
2003	**2.8E+12**	22,878	47,927	48	1.2E+08	
2004	**9.2E+12**	37,289	49,446	75	2.5E+08	
2005	**1.1E+13**	38,979	50,202	78	2.8E+08	
2006	**3.8E+12**	23,376	45,413	51	1.6E+08	
2007	**2.3E+12**	16,710	45,499	37	1.4E+08	
2008	**9.4E+12**	20,235	46,501	44	4.6E+08	6.0.E+12
2009	**7.53E+12**	34,746	60,733	57	2.2E+08	
2010	**1.06.E+13**	36,361	61,940	59	2.9E+08	
2011	**4.50.E+12**	22,851	98,405	23	2.0E+08	available
2012	**5.68E+12**	20,054	80,381	25	2.8E+08	

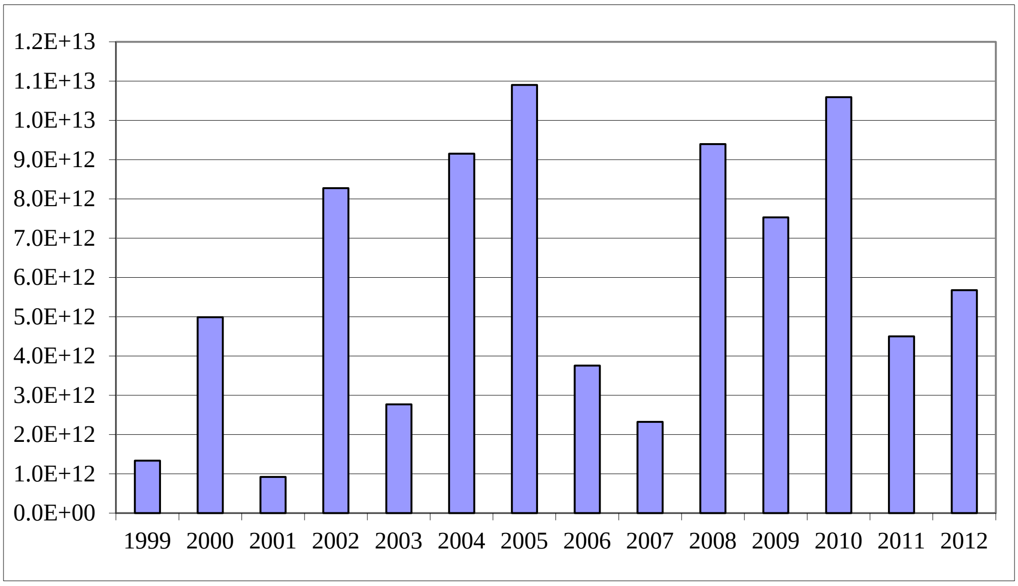
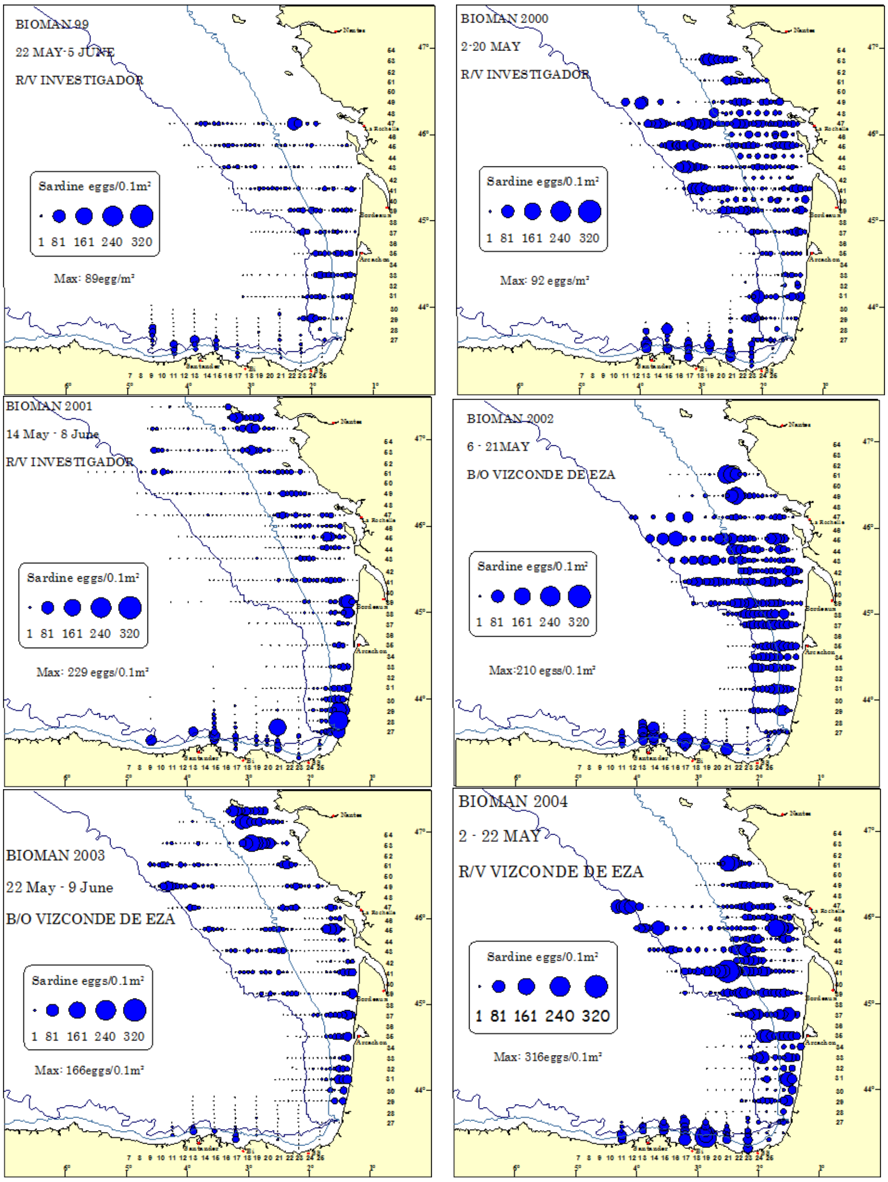
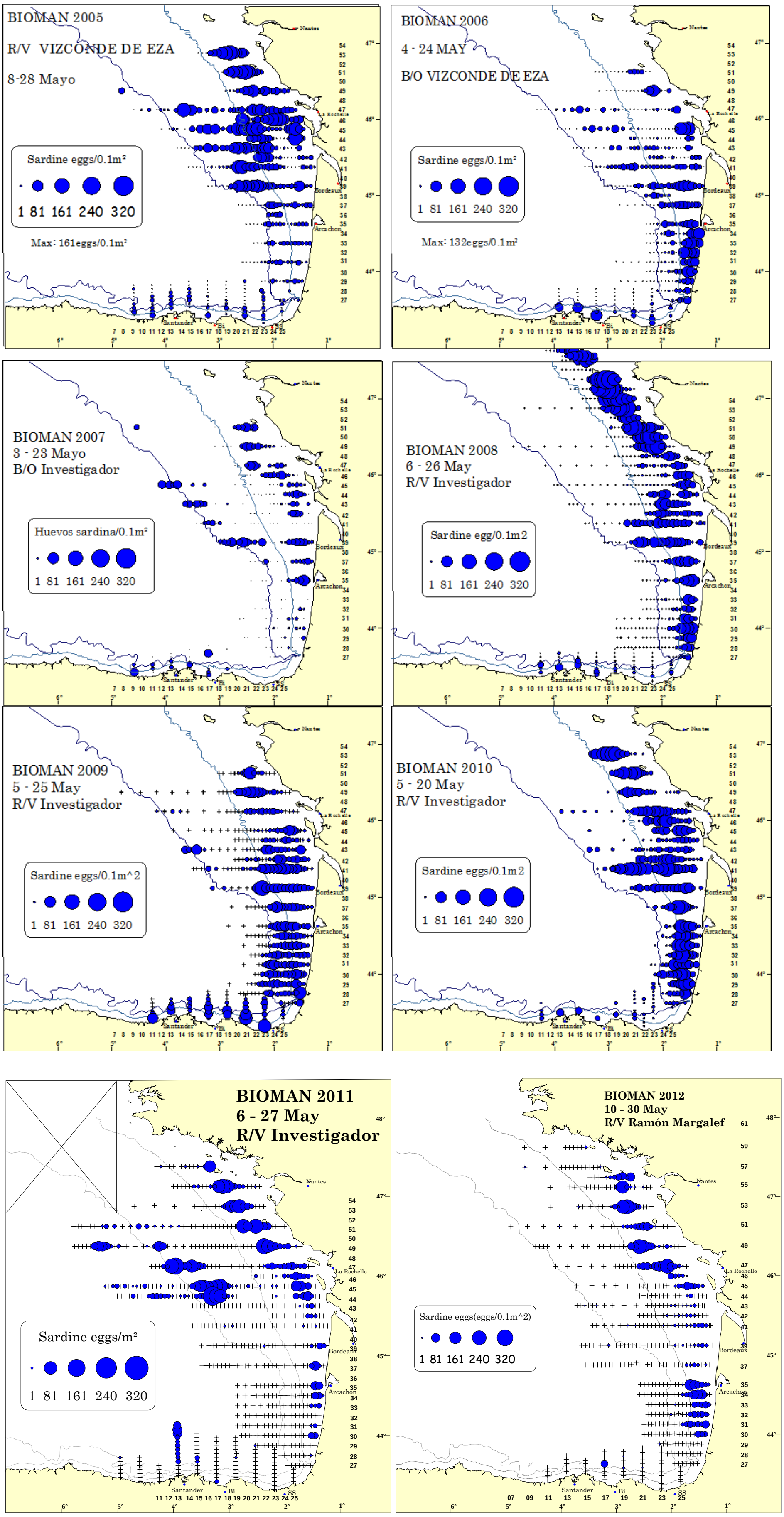


Figure B3.2.6.1. Total sardine egg abundance estimates from 1999 to 2012 in the Bay of Biscay.

B.3.2.7 Historical series DEPM and acoustic surveys




BIOMAN 2005
R/V VIZCONDE DE EZA
8-28 Mayo
Sardine eggs/0.1m²
1 81 161 240 320
Max: 161eggs/0.1m²
BIOMAN 2006
4 - 24 MAY
B/O VIZCONDE DE EZA
Sardine eggs/0.1m²
1 81 161 240 320
Max: 132eggs/0.1m²
BIOMAN 2007
3 - 23 Mayo
B/O Investigador
Huevos sardina/0.1m²
1 81 161 240 320
BIOMAN 2008
6 - 26 May
R/V Investigador
Sardine egg/0.1m2
1 81 161 240 320
BIOMAN 2009
5 - 25 May
R/V Investigador
Sardine eggs/0.1m^2
1 81 161 240 320
BIOMAN 2010
5 - 20 May
R/V Investigador
Sardine eggs/0.1m2
1 81 161 240 320
BIOMAN 2011
6 - 27 May
R/V Investigador
Sardine eggs/m²
1 81 161 240 320
BIOMAN 2012
10 - 30 May
R/V Ramón Margalef
Sardine eggs(eggs/0.1m^2)
1 81 161 240 320
Nantes
La Rochelle
Bordeaux
Arcachon
Santander

B. 3.3 Sardine Daily Egg Production Method (SAREVA Survey) in the inner of the Bay of Biscay

B.3.3.1 Introduction

The Daily Egg Production Method (DEPM) is a well-established methodology to assess the spawning biomass (SSB) of fish species with indeterminate fecundity. The Sardine DEPM is based on the equation (Picquelle and Stauffer, 1985; Lasker, 1985):

$$SSB = \frac{Area^{+} * P0 * W}{F * S * R}$$

Where

P_0: Daily egg production (eggs/m^2/day)

Area $^+$: Spawning area

W: Average weight of mature females in grams

F: Batch fecundity, number of eggs spawned per mature female per batch

S: Spawning fraction, fraction of mature females spawning per day

R: Sex Ratio is the fraction of the mature population that are females by weight.

The Daily Egg Production Method (DEPM) for sardine has been applied by Instituto Español de Oceanografía (IEO) to estimate the spawning–stock biomass of the North Atlanto-Iberian sardine stock since 1988 (García *et al*., 1992) and then repeated in 1990, 1997, 1999, 2002, 2005, 2008 and 2011. From 2000 onwards the surveys have been planned and conducted within the framework of ICES, on a triennial basis. Spring surveys for the application of the DEPM, consisting of ichthyoplankton, adults and hydrographic sampling, and since 1997 the sampling area was extended in order to reach the 45 degrees latitude North, covering the region from the northwestern (border Minho River), north Iberian Peninsula (north Spanish Atlantic and Cantabrian waters, ICES Division IXa North and VIIIc) and the inner part of the Bay of Biscay (from 42 ºN to 45°N, ICES Division VIIIb).

This section provides a description of the sampling, laboratory analysis and estimation procedures used to obtain the sardine spawning–stock biomass estimate for the application of DEPM conducted by IEO from 1997 to present in the inner of the Bay of Biscay (ICES Division VIIIb). Since 2002 extra effort was put in place in order to standardize methodologies for surveying, laboratorial and data analyses. These objectives were possible due to methodological developments and effective coordination undertaken first by the SGSBSA (ICES 2002–2004) and later by the WGACEGG (Stratoudakis *et al*., 2004; Stratoudakis *et al*., 2006; ICES, 2009; ICES, 2010; ICES, 2011).

Estimations for area delimitation (surveyed & spawning), egg ageing, mortality and model fitting for egg production (P_0) are presented. Results from adults fishing sampling are showed and parameters from the mature fraction of the population (mean females weight, sex ratio, batch fecundity and spawning fraction) are calculated. Estimates were based on procedures and software adapted and developed during the WKRESTIM 2009 and modifications carried out subsequently for the revision of the sardine DEPM historical series (1988–2011) in Divisions IXa and VIIIc.

Sardine DEPM estimates in the inner of the Bay of Biscay (the inner part of Divisions VIIIb until 45˚N) from 1997 until 2011, were presented in ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX

(WGACEGG) last November of 2012, in order to be considered as a contribution for the ICES WKPELA 2013 meeting for sardine in Subarea VII and Divisions VIIIa, b, d.

B.3.3.2 Methodology

B.3.3.2.1 Surveying

From 1997, six DEPM surveys were carried out by IEO (1997, 1999, 2002, 2005, 2008 and 2011). The Spanish surveys were undertaken using two vessels, RV Cornide de Saavedra for plankton sampling mainly and RV Thalassa to carry out the fishing hauls (in 2008 and 2011 some fishing hauls were carried out on RV Cornide de Saavedra). The surveys were designed to obtain en adequate spatial and temporal coverage during the spawning peak of sardine in the area. Due to the bad weather, in 2005 was not possible to complete the plankton sampling coverage, so no data for this year is presented in this work.

Plankton sampling

The main egg sampler for the DEPM is the PairoVET net that collects eggs through the water column at point stations. The PairoVET sampler (=double CalVET) includes two nets (Ø 25cm) with 150 µm mesh size; sampling covered the water column from bottom, or 100 m (beyond the 100 isobath) depth, to the surface. Vertical plankton hauls were carried out following a pre-defined grid (Figure 3.3.2.1.1) of sampling stations along transects perpendicular to the coast and spaced 8 miles from 2005 onwards. The inshore limit of the transects is determined by bottom depth (as close to shore as possible) while the offshore extension was decided adaptively, based on the presence of eggs and covering the extension of the platform to the 200 m isobath.

From 2002, the Continuous Underway Fish Egg Sampler (CUFES) was used as an auxiliary egg sampler, helping in defining the offshore extension of the transects and to modify adaptively the intensity of CalVET sampling. The outer limit of a transect was reached when two consecutive CUFES samples were negative beyond the 200 m depth.

From 1997 to 2005, a CTD (Sea Bird-25) profile (Temperature and Salinity) was carried out in each CalVET station. From 2008 to 2011 the Sea Bird-25 was used in each transect head and in alternate stations along the transects, meanwhile a CTD (Sea Bird-37) was coupled to the CalVET sampler. General Oceanics Flowmeters were used to record the towing length and estimate the sampled water volume (assuming a filtration efficiency of 100%).

After hauling, nets are washed from the outside with seawater under pressure and plankton samples from the two nets are preserved in formalin at 4% in distilled water and the two samples from each net stored in separate containers. Samples for one net are then sorted, and sardine, anchovy and other eggs are identified and counted. The total numbers of eggs from both plankton samplers, CalVET and CUFES, were counted onboard in order to obtain a preliminary data of sardine egg abundance and distribution.

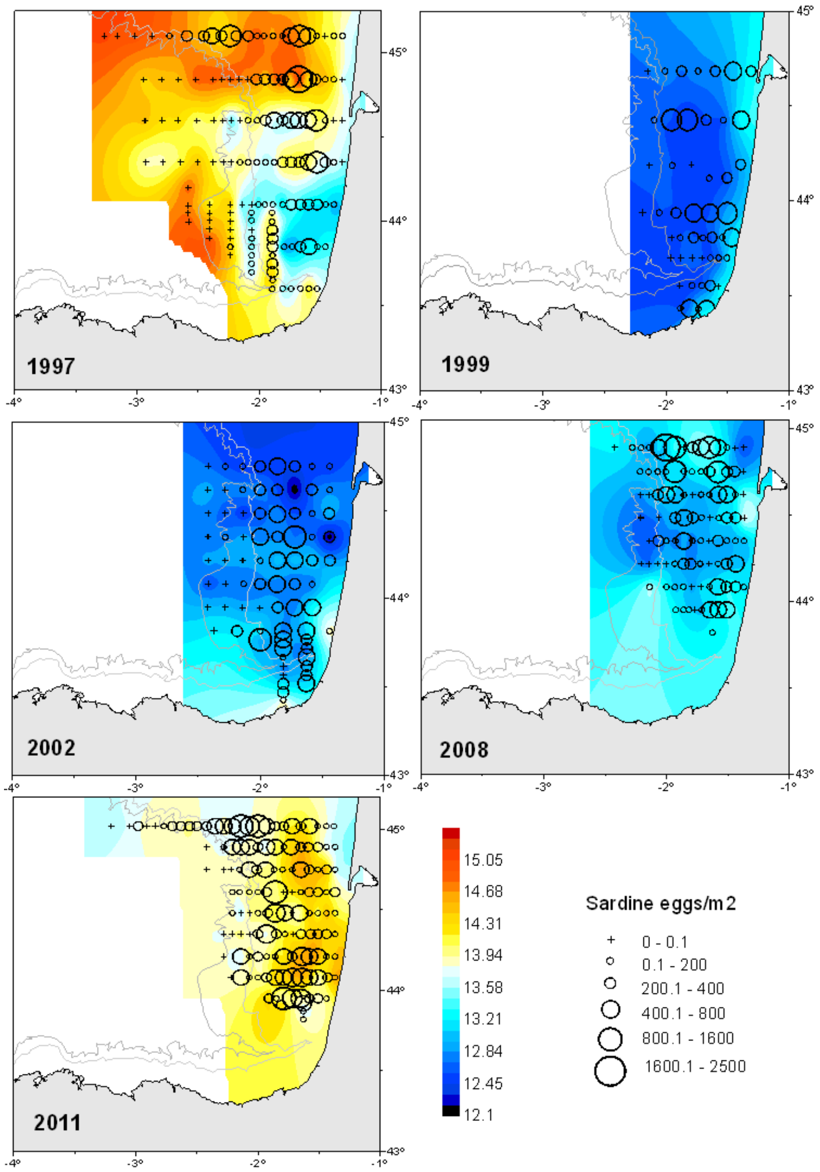


Figure 3.3.2.1.1. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. Sardine egg distribution (eggs/m² from PairoVET sampler) and SST (ºC) by year.

Adult fish surveying

Fishing hauls were conducted by pelagic trawling following sardine schools detection by the echosounder (for RV Thalassa). The number of samples and its spatial distribution was organized to ensure good and homogeneous coverage of the survey area (Figure 3.3.2.1.2) in order to obtain a representation of the sardine population.

Onboard the RV, and for each haul, a minimum of 60 sardines were randomly selected and biologically sampled. These could also be complemented by additional fish in order to achieve a minimum of 30 females per haul for histology, and/or to obtain extra hydrated females for the fecundity estimations. The biological sampling was always carried out in fresh material, and ovaries were immediately collected and preserved in a formaldehyde buffered solution (4% diluted in distilled water) for posterior histological processing and analysis at the laboratory. Moreover, otoliths were extracted on board to obtain the age composition per sample in the laboratory.

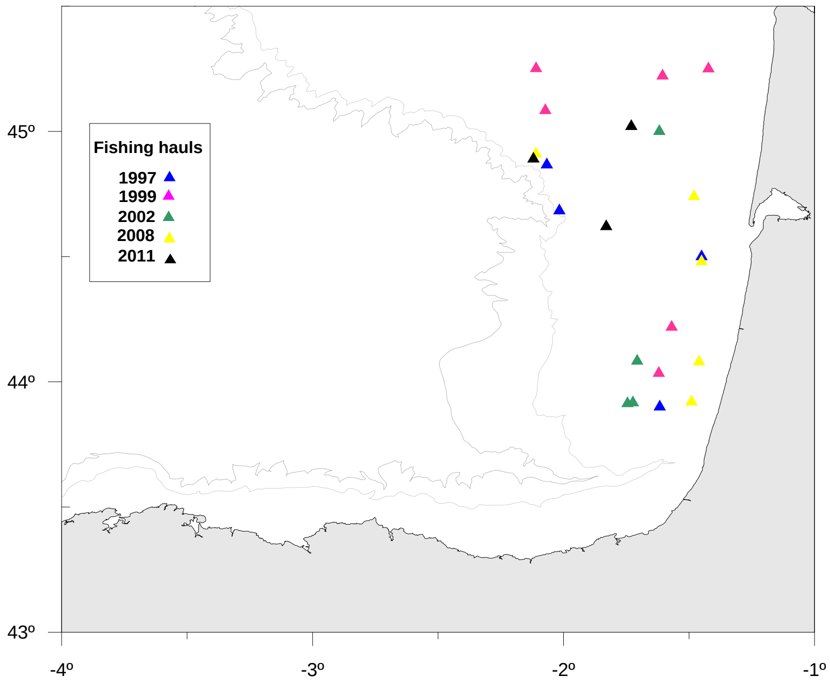


Figure 3.3.2.1.2. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. Spatial distribution of the positive fishing hauls by year.

B.3.3.2.2. Laboratorial analysis

Plankton samples

In the laboratory, all sardine eggs were sorted from PairoVET samples. The eggs from the vertical hauls (one net) were all counted and staged according to the eleven stages of development classification (adapted from Gamulin and Hure, 1955). Samples for the second net are used for plankton biomass quantification.

Adult fish samples

The preserved ovaries were weighted in laboratory and the obtained weights corrected by a conversion factor (between fresh and formaldehyde fixed material) established previously. These ovaries were processed for histology, first, they were embedded in resin (paraffin before 2005), the histological sections were stained with haematoxylin and eosin, and then the slides examined and scored for their maturity state, POF presence and age assignment (Hunter and Macewicz, 1985; Pérez *et al.*, 1992a; Ganias *et al.*, 2007). Prior to fecundity estimation, hydrated ovaries were also processed histologically in order to check for POF presence and thus avoid underestimating fecundity (Pérez *et al.*, 1992b). The individual batch fecundity was then measured, by means of the gravimetric method applied to the hydrated oocytes, on 1–3 whole mount subsamples per ovary, weighting on average 50–150 mg (Hunter *et al.*, 1985).

B.3.3.2.3 Data analysis

Databases with date, time, position, bottom depth and other variables registered during the sampling on board and in the laboratory, were merged in a common standardised dataset (eggs and adults data separately) and include all surveys undertaken in the period from 1997 to 2011. The dataset for eggs and adults include minor corrections (e.g. wrong geographical coordinates, duplicated points, ovary and total weights data, etc.), that were observed as mistakes in a first exploration data. All estimations and statistical analysis were performed using the R software (www.r-projet.org).

Egg data

Calculations for area delimitation, egg ageing and model fitting for egg production (P_0) estimation were carried out using the R packages (*geofun, eggsplore and shachar*) available within the open source project *ichthyoanalysis* (http://sourceforge.net/projects/ichthyoanalysis). Some routines of the R packages used were updated since the 2008 versions.

The coastline and depth contour were imported from the GEBCO coastline, transformed into spatial objects to be used with the statistical software R. The limits of the survey area (sampled) and positive area (area with eggs), both offshore and coastal, were estimated using the library geofun, which mainly use the spatial analysis functionality provided by spatstat. To define the precision of the poligons to be selected, a 600x600 resolution was used in the spatstat function (spatstat.options(npixel=c(600,600)).

To find the geographical limits of sampled and positive areas the findlimits.fun function was used. The procedure includes an automated routine using neighbourhood distance, in km, between stations (minimum distance in ratio represented by each station). The routine thus generates circles around each sampling point and uses the intercepts between circles to define the sampling area. To estimate the limits of the sampled area, the argument dist was set to 15 km (findlimits.fun (data, dist = 15, plot = "limits")) and all the sampled stations were used in the analysis.

The limits of the spawning area (positive area) were obtained using only those stations with eggs, the diameter of the circles was the same referred above (15 km) allowing embedment of negative stations fully surrounded by positive stations. After this initial delimitation of positive area, the function erode.owin (with diameter = 10 km) was used to reduce the external limits of the positive area, in order to limit the amount of negative (offshore) stations included in the positive area. With this trimming only the negative stations on the borders are excluded from the positive areas. The stations within that domain are flagged as positive and thereafter used in the analyses. Both the survey and total areas were afterwards corrected to avoid extrapolation to the coast, by computing the intercept between the areas estimated as above and the area delimited by the coastline.

To avoid high and low extremes values detected in the area represented by each sampled station, the parameter "area.range" was forced to the minimum and maximum values of 25 and 175 respectively (the extreme values usually occur on the borders of the survey area and therefore do not affect the estimation of the positive area). The area.range parameter was included in the estimate.sea.area function during the present analyses to avoid over estimation of the areas on the borders of the survey limits. The range 25–175 was selected to be a mean interval suitable for all the surveys, according to the distance between transect and stations (that varied in the initial years; from 2002 onwards it was fixed to be 8 nm between transects and 3 or 6 nm between stations, along transects).

The area represented by each station within the survey limits is estimated by a dirichlet tessellation of the survey stations, using the survey limits as estimated above. The positive area is the sum of the areas of the individual stations included in the positive area (including also the negative stations embed in the positive area).

The model of egg development with temperature was derived from the incubation experiment data available within the *sardata* R library. Egg ageing was achieved by a multinomial Bayesian approach described by Bernal *et al*. (2008) and using *in situ* SST.

depm.control function from *egg* package, controls some constants for DEPM as the assumption of spawning peak, the proportion of eggs that must still be unhatched (i.e. not transformed to larvae) at "2*sig" past the last cohort mean age (how.complete) and the distribution of the daily spawning cycle. For the present analyses the distribution of the daily spawning cycle was assumed as a normal (Gaussian) distribution, with a peak at 21:00 h GMT and a standard deviation of 3 h. (spawning period from 21-6 h to 21+6 hours). It is assumed that 0 time is at midnight and days are 24 hours long.

The upper age cutting limit was determined using a maximum age for the entire area considered and it is not dependent on the individual stations (upper.age=F). Older cohorts are dropped if their mean age plus 2* st-dev hours is over the critical age at which less than 5% of the eggs are expected to be still unhatched (how.complete=95%). The lower age cutting excluded the first cohort of stations in which the sampling time is included within the daily spawning period (lower.age=T).

The exponential model: $E[P] = P0\ e^{-Z\ age}$ was fitted as a Generalized Linear Model (GLM) with negative binomial distribution and log link. For 1999 survey a model without mortality was applied since an estimate for mortality led to non-coherent mortality. Weights proportional to the relative area represented by each station (estimated using the dirichlet tessellation and divided by the mean area represented by a station) were used to account for increased sampling in areas of expected high egg densities.

Finally, the total egg production is calculated multiplying the daily egg production ratio (eggs per m^2 and day) by the positive area (in m^2).

$Ptot = P0 * A+$

Fish data

The adult parameters estimated for each fishing haul considered only the mature fraction of the population (determined by the fish macroscopic maturity data) and was based on the biological data collected from surveys. For the present estimations, a minimum sample criterion (n = 30) was introduced: a few hauls containing less than 30 fish sampled were excluded from the mean and variance calculations.

Before the estimation of the mean female weight per haul (W), the individual total weight (Wt) of the hydrated females was corrected by a linear regression between the total weight of non-hydrated females and their corresponding gonad-free weight (Wnov). The sex ratio (R) in weight per haul was obtained as the quotient between the total weight of females on the total weight of males and females.

The fraction of females spawning per day (S) was determined, for each haul, as the average number of females with Day-1 or Day-2 POF, divided by the total number of mature females (the number of females with Day-0 POF was corrected by the average number of females with Day-1 or Day-2 POF, and the hydrated females were not included).

In 1999 no histology samples were available to estimate spawning fraction (S) and a non-parametric bootstrap approach was performed using mean spawning fraction by each haul obtained along the all series and considering a single haul as the basic sampling unit. Hauls were resampling with replacement from the original dataset, leading to a new, artificial sample that was then used to estimate S parameter. By repeating this procedure an adequate number of times (1000 in this application), we obtained an empirical probability distribution for the S parameter.

The expected individual batch fecundity (Fexp) for all mature females (hydrated and non-hydrated) was estimated by modelling the individual batch fecundity observed (Fobs) in the sampled hydrated females and their gonad-free weight (Wnov) by a GLM (with a negative binomial error distribution and an identity link). In 1999, 2002 and 2008, no hydrated o very few hydrated females were collected off the Inner of the Bay of Biscay (no one in 1999 and 2002, and n = 3 in 2008). For these years, F was modelled polling data from the inner Bay of Biscay and North Spanish coast, but F estimates were nevertheless calculated for the two areas separately.

The mean and variance of the adult parameters for all the samples collected was then obtained using the methodology from Picquelle and Stauffer, 1985 (weighted means and variances).

Spawning–stock biomass (SSB)

Spawning–stock biomass (SSB) is obtained based on the equation proposed by Picquelle and Stauffer (1985):

$$SSB = \frac{Area^{+} * P0 * W}{F * S * R}$$

For the calculation of the coefficient of variation, variance is estimated using the Delta method (Seber, 1982), in which the squared CV of the product of several parameters is equal to the sum of their squared CVs:

$$CV(B)^2 = CV(P)^2 + CV(W)^2 + CV(R)^2 + CV(F)^2 + CV(S)^2.$$

B.3.3.3 Results

Eggs

Total transects and PairoVET stations that were sampled along the years are summarised on Table 3.3.3.1. In 1997 and 2011 the number of samples performed was higher than others years and 1999 was the year with less stations sampled. The percentage of stations with sardine eggs was higher than 63% for all years and has been increasing from the first survey (1997) until the last one (2011), reaching 85% in 2011. In total 6667 were sorted, staged and counted for the vertical tows in the area studied, of which 2764 were caught in 2011, around 1100 in 1997, 2002 and 2008, and 586 in 1999. The highest egg abundances per haul were 2332.1 (eggs/m^2) and 2321.7 (eggs/m^2) reached in 2008 and 2011 respectively. The lowest egg abundance per haul was 1185.4 (eggs/m^2) in 1999 and with values ranged from 1185.5 to 1669.6 (eggs/m^2) for 2002 and 1997 respectively.

Table 3.3.3.1. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. General sampling for eggs.

SURVEY EGGS	1997	1999	2002	2008	2011
R/V	Cornide de Saavedra				
Date	27/03–02/04	03/04–05/04	06/04–12/04	20/04–24/04	09/04–15/04
Transects	12	11	10	8	10
PairoVET stations	140	48	75	97	134
Positive stations	89 (63.6)	37 (77.1)	55 (73.3)	74 (76.3)	114 (85.1)
Tot. Eggs	1123	586	1090	1104	2764
Max eggs/m^2	1669.6	1185.4	1220.1	2332.1	2321.7
Temp (°C) min/mean/max	12.8/14.1/15.3	12.5/12.7/13.3	12.1/12.9/13.9	12.6/13.1/13.9	13/14/14.7
CUFES stations	-	-	130	95	137
Positive CUFES stat.	-	-	88(67.7)	84 (88.4)	124 (90.5)
Tot. Eggs CUFES	-	-	7108	13837	39798
Max eggs/m^3	-	-	83.6	215.5	97.3

For all the surveys, 99.2% of the sardine eggs have been classified into eleven stages according to the degree of embryonic development. It has been found sardine eggs in all the described stages (except stage I in 1999 and 2002). The most abundant development stages were II, V and VI. Very few eggs of stage I and XI (right after and before the spawning and hatching respectively) were found along the series.

Sardine egg distribution, obtained from the PairoVET sampler, for the whole area is presented in Figure 3.3.2.1.1. Almost the entire shelf (from coast to slope) was occupied by sardine eggs. For some years (1997, 2008 and 2011), two areas of spots with higher density occurred along the coast and offshore, namely in waters along the end of the continental slope (200 m depth), meanwhile some zones of weaker density in the distribution were observed between both, coast and offshore waters.

The oceanographic setting during the period of the surveys for the region was showed in Figure 3.3.2.1.1 and Table 3.3.3.1. Minimum, mean and maximum measured SST ranged from 12.1 to 15.3°C. The highest temperature values were observed in 1997 and 2011; meanwhile the lowest one was registered in 2002.

The estimates of both surveyed and spawning area, mortality, daily egg production and total egg production are given in Table 3.3.3.2.

The largest area sampled was reached in 1997, covering a total of 20 149 km^2 (Table 3.3.3.2), while the smallest one was 6793 km^2 in 1999. The spawning area was quite similar in 1997 and 2011 (12 755 km^2 and 12 400 km^2 respectively), smaller in 2002 and 2008 (9154 km^2 and 8167 km^2) and the lowest value was obtained in 1999 (5724 km2). The percentage of spawning area over the sampling area was all the years greater than 60%, reaching the 80% in 1999, 2008 and 2011.

Table 3.3.3.2. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. Summary of the results for eggs.

PARAMETER	YEAR				
Eggs	**1997**	**1999**	**2002**	**2008**	**2011**
Survey area (Km²)	20 149	6793	11 888	10 187	14 091
Positive area (Km²) (%)	12 755(63)	5724(84)	9154(77)	8167(80)	12 400(88)
Z (hour⁻¹)(CV%)	-0.012(41)	-0.006(89)	-0.022(18)	-0.019(26)	-0.018(22)
Max age (hours)	66.8	81.6	81.6	78.6	68.8
Daily mortality rate (%)	25.3	13.7	41.7	37.3	35.6
P0 (eggs/m²/day)(CV%)	136.6(20)	78.7(13)	182.3(19)	171.4(23)	219.1(16)
P0 tot (eggs/day) (x10¹²) (CV%)	1.74(20)	0.45(13)	1.67(18)	1.4(23)	2.72(16)

Mortality values for the period between 2002 and 2011 are much higher than for the 1997 values. Mortality calculated for each one of the years surveyed (except 1999) shows negative and significantly different from zero values and was considered acceptable for egg production estimation. For 1999 survey a model without mortality was applied since an estimate for mortality led to non-coherent (positive) mortality.

Daily egg production per m² (eggs/m²/day) in 2011 (219) is the highest in the series, meanwhile the lowest (78.7) corresponds to 1999. Total egg production (eggs/day) estimated by year is shown in Figure 3.3.3.1 and ranged between 0.45×10^{12} (1999) to 2.72×10^{12} (2011). Total egg production in 2011 was almost two times higher than 1997, 2002 and 2008 estimated.

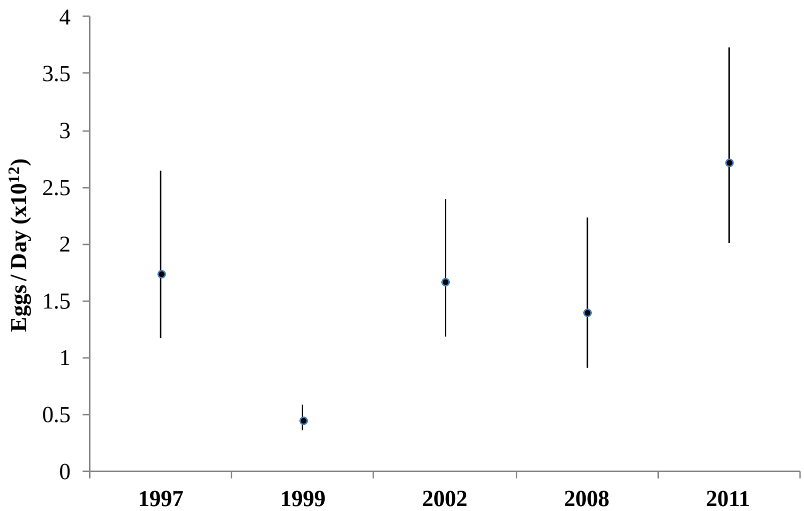


Figure 3.3.3.1. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. Time-series of total egg production (eggs/day x 10¹²) estimates. Vertical lines indicate confidence intervals.

Adults

On the whole DEPM series, 22 fishing hauls which caught sardines were performed during the surveys using pelagic trawling (Figure 3.3.2.1.2). The fishing effort and its spatial distribution were made to guarantee good and homogeneous level of sampling for the survey area.

In total, almost 1759 sardines were sampled (Table 3.3.3.3) and more than 500 ovaries were collected, preserved and analysed histologically. On the whole, a total of 749 otoliths were removed for age determination in 1999, 2002, 2008 and 2011. A total of 71 hydrated females were caught for batch fecundity estimation, although ovaries from hydrated females caught in 1999 (12) and 2002 (2) were not preserved for histological analysis on the laboratory and not number of oocytes was obtained to estimate batch fecundity.

Table 3.3.3.3. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. General sampling for adults.

SURVEY ADULTS	1997	1999	2002	2008	2011
R/V	Thalassa	Thalassa	Thalassa	Thalassa/ Cornide de Saavedra	Cornide de Saavedra
Number positive hauls	4	6	4	5	3
Date	29/03–31/03	06/03–10/03	29/03–31/03	21/04–24/04	13/04–15/04
Time range			07:00–20:00		
Total sardine sampled	239	516	199	503	302
Total males	104	241	106	280	150
Total females (% Mature)	135 (100)	271 (98)	93 (100)	223 (100)	152 (100)
Length range (mm)	180–255	123–260	152–244	154–250	175–243
Weight range (g)	45–144	13–152	23–104	25–114	41–102
Oocyte stage ovaries	68	50	20	164	127
Hydrated females (Batch fecundity)	42	12		3	14
Females for spawning	68		20	161	124
Otoliths	NA	328	195	97	129
Ages Range		1–10	1–8	1–9	1–9

Length and age distribution of sardine is showed in Figure 3.3.3.2. Sardine shows a bimodal length distribution in 1999 and 2008, with the first mode about 15 and 17 cm respectively and the second about 21 and 20 cm. In 1999 the size range is the wider for the whole historical series, with a minimum of size measured of 12.3 cm and a maximum of 26 cm. The age structure of the sampled population is different by year, and it must be noticed that the number of individuals, especially between 1 and 3 ages were really important in all years which otholits were collected.

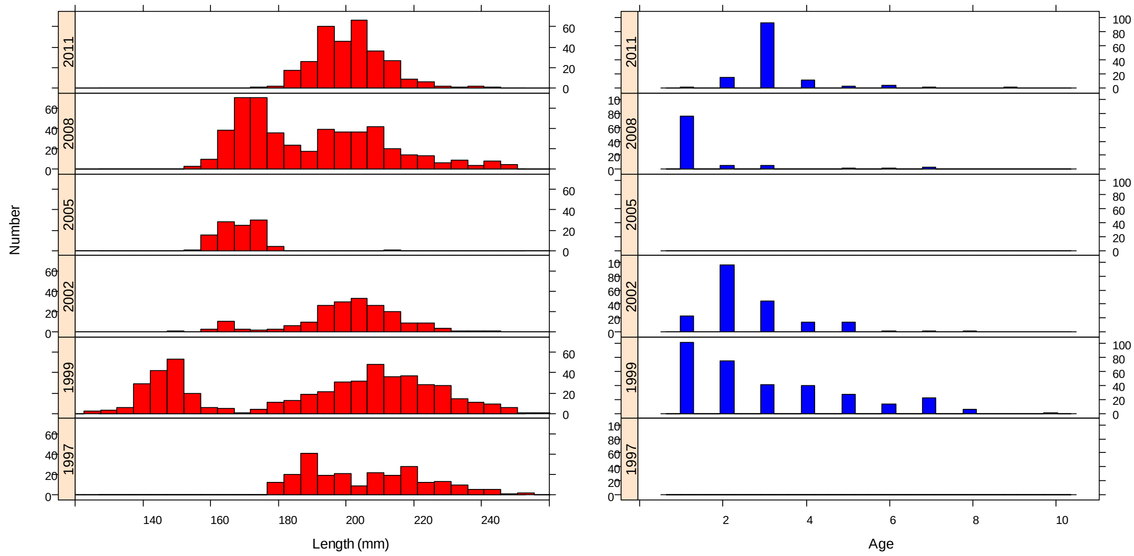


Figure 3.3.3.2. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. Length (mm) and age distribution of sardine by year. No otoliths for age reading were available in 1997.

Final estimates of the mean female weight (W), batch fecundity (F), sex ratio (R), spawning frequency (S) and spawning–stock biomass (SSB) with their CVs are given in Table 3.3.3.4.

Table 3.3.3.4. Sardine DEPM IEO surveys in the inner of the Bay of Biscay. Summary of the results for eggs, adults and SSB estimates.

PARAMETER	YEAR				
Eggs	**1997**	**1999**	**2002**	**2008**	**2011**
Positive area (Km^2) (%)	12 755(63)	5724(84)	9154(77)	8167(80)	12 400(88)
Z (hour^{-1})(CV%)	-0.012(41)	-0.006(89)	-0.022(18)	-0.019(26)	-0.018(22)
P0 (eggs/m2/day)(CV%)	136.6(20)	78.7(13)	182.3(19)	171.4(23)	219.1(16)
P0 tot (eggs/day) (x10^{12}) (CV%)	1.74(20)	0.45(13)	1.67(18)	1.4(23)	2.72(16)
Adults					
Female Weight (g) (CV%)	74.5(11.8)	63.6(12.7)	62.9(5.6)	55.4(11.1)	61.3(9)
Batch Fecundity (CV%)	32 269(17)	32704(45)	24577	15849(29)	30 383(4)
Sex Ratio (CV%)	0.508(8.1)	0.535(10.7)	0.492(22.9)	0.483(8.9)	0.51(19.6)
Spawning Fraction (CV%)	0.131(9.7)	0.124(15.4)	0.143	0.137(24.4)	0.066(49.2)
Spawning Biomass (tons) (CV%)	**60 332(31)**	**13 200(52)**	**60 720**	**73 942(47)**	**162 930(55)**

The minimum mean weights by haul were observed in 1999 and the maximum 1997. Mean female weight (W) was similar for 1999, 2002 and 2011(63.6, 62.9 and 61.3, respectively) and considerably higher in 1997 (74.5). Mean females weights in 2008 survey present the lowest value of the historical series (38.1). Concerning sex ratio estimates, mean values are quite homogeneous across the whole surveys.

Considering that few hydrated females (n=3) were collected in 2008 and no hydrated females were available in 1999 and 2002, the data from these three years were pooled with data from North Atlantic Spanish coast, for the modelling of batch fecundity. Mean batch fecundity estimate (F) was considerably lower (15849 number of oocytes, 286 oocytes/gr) in 2008 according to the mean female weight estimated. On the contrary the first two surveys (1997 and 1999) presented the highest estimates (32 269, 433 oocytes/gr and 32 704, 514 oocytes/gr) of the historical series, though similar to the one obtained for the 2011 (30 383, 495 oocytes/gr) survey. In particular, for 2002, although mean female weight was similar to the ones obtained during the 1999 and 2011 surveys, batch fecundity estimate was reduced to 24 577 (390 oocytes/gr) when compared to the values obtained these years.

Bootstrapped estimate of spawning fraction for 1999 was 0.124. Mean Spawning fraction estimate for 2011 survey was among the lowest (0.066) of the time-series. For the remaining surveyed years the values are generally quite high and homogeneous (between 0.124 and 0.137).

SSB estimate

The whole survey-series DEPM-based SSB estimate is showed in Table 3.3.3.4. SSB in 2011 is the highest estimate of the time-series (162 930 tons), while 1999 is among the lowest of the time-series (13 200 tons). In 1997 and 2002 estimates are comparable (60 332 and 60 720 tons respectively) and in 2008 an increase in relation to the previous surveyed years was found (73 942 tons).

The lowest and highest SSB estimates found in 1999 and 2011 respectively are related to the egg production. Egg production estimate in the 1999 survey is the lowest of the time-series, probably due to the egg survey period has not covered the amount of spawning peak activity. By the contrary the large egg production estimate in 2011 is sustained by a combination of high egg production density (in eggs per day per square meter) and large spawning area. Moreover, the contribution of the lowest spawning fraction value (0.066) estimated in 2011 on the equation applied to estimate SSB, has largely increased the SSB value.

The estimates presented from DEPM application in the inner of the Bay of Biscay, are *a priori* considered provisionally. The way to obtain batch fecundity estimates for 1999, 2002 and 2008, modelling together with data from the North Atlantic Spanish coast, prevents to consider these preliminary results as definitely ones. Moreover, to solve the unreliable egg mortality estimated in 1999 an aggregated model similar to that used by Bernal *et al.*, 2011, could be tried. All these issues require further analysis in terms of implications for the best estimation procedures and reliability of the results.

B.4. Commercial cpue

According to literature, cpue indices have been considered as not reliable indicators of abundance for small pelagic fishes (Ulltang, 1980; Csirke, 1988; Pitcher, 1995; Mackinson *et al.*, 1997). Commercial catch per unit of effort data are available at various levels of aggregation (subarea/gear/years) from official data, but these are not considered indicative of stock trends (see also information from the industry, below).

B.5. Other relevant data

Interviews with the French fishing industry operating in the Bay of Biscay highlighted a potential displacement of the stock further north. This could partly explain the increase of activity in the Celtic Sea over the last decade. According to fishermen, the main driver of the Bay of Biscay fishery is the market. Many fishers could catch more sardine as regards sardine availability, but this would not be suitable due to poor levels of prices. Thus, the industry data should not directly be put in relation to variation of sardine abundance.

C. Assessment-data and method

From the modelling point of view, the lack of sampling, survey, biological information in the English Channel and Celtic Seas in contrast to the richness of the datasets available for the Bay of Biscay does not allow the use of a single assessment method for the whole area. Therefore, for practical reasons related to the availability of data between the English Channel, Celtic Seas and Bay of Biscay, it was decided to divide this stock into two "data" regions: VIIIabd and VII.

The following indicators are considered relevant for the description of the stock in the different regions:

Subdivision VIIIabd

1) Trends in the Pelgas survey index;
2) Trends in the DEPM survey index.

Subdivision VII

3) Trends in size (age?) distribution in catches (to be built up).

D. Short-term projection

No short-term projection method is currently set for this stock.

E. Medium-term projections

No medium-term projection method is currently set for this stock.

F. Long-term projections

No long-term projection method is currently set for this stock.

G. Biological reference points

No reference points are currently set for this stock. Given the differences of availability of data between the Celtic Seas, Bay of Biscay and English Channel, any set reference should take account of this or some regional reference points should be set accordingly.

Given the current lack of assessment, advices could be based on other indicators such as successive recruitment failure. These indicators are available from the current commercial and survey datasets.

H. Other issues

While the stock is considered to spread over Celtic Seas (VIIabcfjk), Bay of Biscay (VIIIabd) and English Channel (VIIdeh), the critical lack of information in Celtic Seas and English Channel impairs the possibility of assessing this stock for the whole area.

H.1. Historical overview of previous assessment methods

2013 is the first year ICES is requested to give advice for sardine in VIIIabd and VII. In previous years, exploratory assessments using TASACS were carried out during the working group on horse mackerel, anchovy and sardine (WGHANSA). Cohort tracking analyses have also been conducted this year.

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Annex 5: Working documents

Anchovy working documents

WKPELA 2013 – WD 1

Quick study on sardine and anchovy discards

E. Duhamel – IFREMER Lorient

This is a quick overview of the data collected in the French discard sampling program concerning anchovy and sardine.

Only pelagic trawlers targeting small pelagic fish (single + pair trawlers) are taken into account here. Purse seiners are not taken into account because this fisheries is known not to discard.

Data are available only for 2012, which was the first time an observation program on french pelagic trawlers was executed with a relative good seasonal representativity.

The data presented are preliminary and allow just to have an idea on the amount of discards on pelagic trawlers. It is supposed to vary highly from one year to an other.

Sampling program

The fishing trips sampled target small pelagics, not only anchovy or sardine.

Å Fishing hauls sampled :

Type of trawler	Target \ quarter	Q1	Q2	Q3	Q4
Single	Mackerel	**4**	0	0	0
Single	Anchovy	0	0	**8**	**5**
Single	Horse mackerel	0	0	0	**1**
Pair	Anchovy	0	**60**	**14**	**3**
Pair	Horse mackerel	0	0	**2**	0
Pair	Sardine	0	**4**	0	0

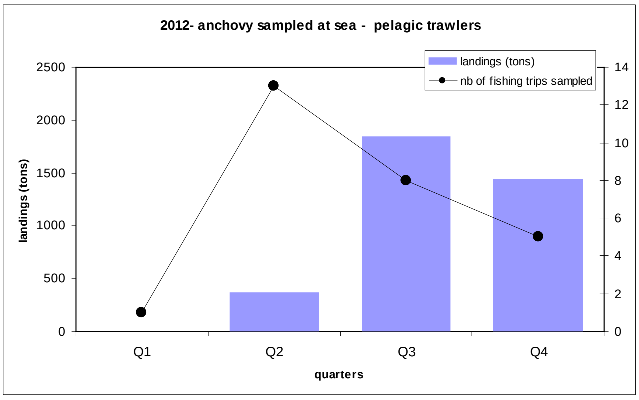
Results

Anchovy

Å 27 fishing trips sampled along the year

Å No real problem to go onboard during the season of anchovy

Å Small problem of representativity of samples:



The second quarter is relatively over-sampled compared to quarter 3 and 4, which is when the majority of the landings took place.

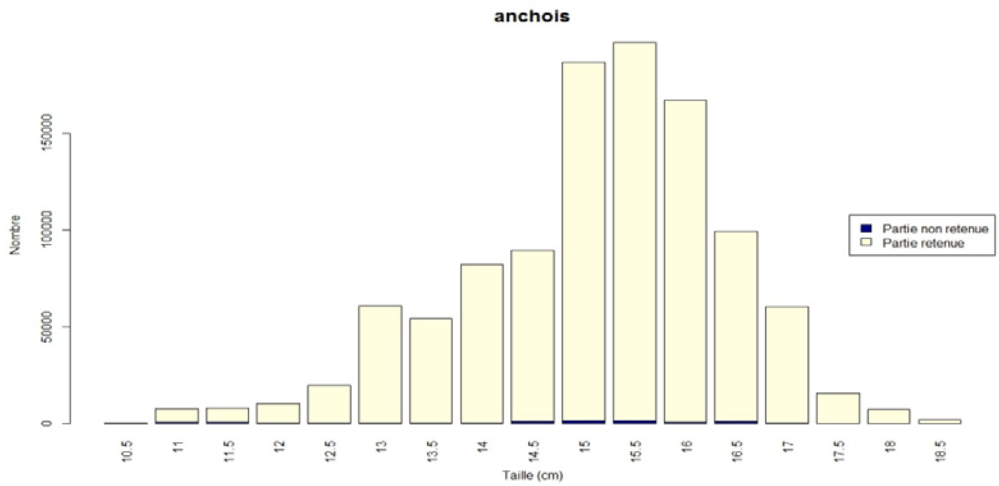


Figure 2 – Anchovy catch length frequency in French pelagic trawlers sampled during all quarters in 2012, split between the part kept on board (cream) and the part discarded (dark blue).

Anchovy discards in the French pelagic trawler fishery are 2.34 % in numbers (anchovy discards / total anchovy catch for this fishery).

Sardine

In France, 15 to 20 ktons of sardine landed per year, of which 90 to 95 % by purse seiners (targeting large sardines in the Bay of Biscay, no discards) and 5 to 10 % by pelagic trawlers (targeting the smaller individuals).

Discarding is recorded on French pelagic trawlers targeting small pelagics, not only sardine (only 2 fishing trips sampled when sardine was the target – 4 trawl hauls). The main part of trawlers targeting sardine didn't agree to have observers on board.

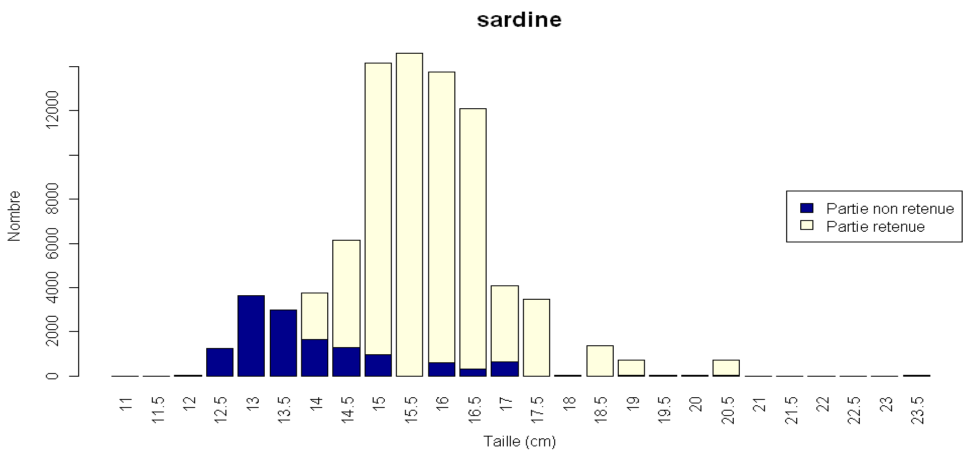


Figure 3 – Sardine catch length frequency in French pelagic trawlers sampled during quarter 2 in 2012, split between the part kept on board (cream) and the part discarded (dark blue).

Sardine discards in the French pelagic trawler fishery are 16.5 % in numbers (sardine discarded / total sardine catch of this fishery).

Working document to WKPELA 2013, 4-8 February 2013, Copenhagen (Denmark)

Assessment of the Bay of Biscay anchovy using CBBM

by

Ibaibarriaga, L. and Uriarte, A.

1. Introduction

Currently the Bay of Biscay anchovy is assessed using the two-stage Bayesian biomass-based model (BBM) described in Ibaibarriaga et al. (2008) following the stock annex agreed in last benchmark workshop (ICES 2009). This model is statistically sound and its framework allows incorporating uncertainty both in the assessed state of the stock and the subsequent short term projections. However the model makes some assumptions that might not be fully adequate for this stock. On the one hand growth and natural mortality are accounted for in a unique parameter g that is constant across ages and years, which might be an oversimplification. On the other hand the assessment is scaled by the assumption that the spawning stock biomass (SSB) obtained with the Daily Egg Production Method (DEPM) is an absolute index. The latest revision of this index led to a reduction of former estimates and makes this assumption hardly sustainable for a few years for which the recorded catch levels may contradict the estimates of SSB. This assumption is therefore subject to revision. Furthermore, a retrospective analysis suggests that in the last years there might be a systematic upwards correction of the final SSB medians derived from the assessment model as subsequent years are added. Therefore, these issues should be addressed either extending this model or exploring alternative model formulations.

Ibaibarriaga et al. (2011) presented an extension of the BBM, called in what follows CBBM. This model tried to overcome some of these issues and explored whether commercial catch data (including the absence of catches during the fishery closure years) can provide useful information for the assessment of the stock. The CBBM follows the same principles as the BBM: the population dynamics are described in terms of biomass, with the population divided in two age classes (recruits and older fish). The model is cast in a Bayesian state-space framework, with process error incorporated in the recruitment process, and inference is conducted using Markov chain Monte Carlo (MCMC) methods. However, in CBBM fishing is treated as a continuous process, separable into age and year effects by semester, and observed total catch and age 1 biomass proportion in the catch are incorporated through observation equations in each semester, whereas in BBM catches are just treated as instantaneous removals from the population. In addition, in CBBM intrinsic growth and natural mortality, which in BBM were encapsulated by a single parameter, are now disaggregated by process (i.e. growth and natural mortality) and age class. Incorporating observation equations based on the annual average weights-at-age of the fish in the stock allows precise estimation of the growth rates, and inference on the rates of natural mortality can then be examined in detail.

This working document explores the use of CBBM for the assessment of the Bay of Biscay anchovy stock using data from 1987 to 2012. First the model is described and then different assumptions on survey's catchability and natural mortality are tested. Finally, a retrospective analysis for each case is conducted.

2. Methods

2.1. State equations

Let $B(t, y, a)$ denote the biomass of age a at time instant t ($0 \leq t \leq 1$) in year y (where age class $a+$ denotes individuals aged a and older). Recruitment in year y refers to age 1 biomass at the start of the year and is assumed to be lognormally distributed with mean μ_R and precision (inverse of variance) ψ_R for the log of recruitment, i.e.

$$\log(R_y) = \log(B(0, y, 1)) \sim \text{Normal}\left(\mu_R, \frac{1}{\psi_R}\right).$$

Biomass at age a ($a = 1,2+$) evolves during semester j ($j = 1,2$) as follows:

$$B(t, y, a) = B\left(b_{\text{sem}_j}, y, a\right) \exp\left\{\left(G_a - M_a - f(\text{sem}_j, y) s(\text{sem}_j, a)\right)\left(t - b_{\text{sem}_j}\right)\right\}$$

where t is a time-point during the semester, b_{sem_j} denotes the beginning of the semester, G_a and M_a are the intrinsic growth and natural mortality rates at age, and $f(\text{sem}_j, y)$ and $s(\text{sem}_j, a)$ represent the year and age factors of the fishing mortality rate in that semester.

Two monitoring surveys, an acoustic one and a DEPM, take place at time t_{surv}. For modelling purposes, it is assumed that both surveys take place on 15 May each year ($t_{\text{surv}} = 0.375$). Then biomass of ages 1 and 2+ at survey time will be

$$B(t_{\text{surv}}, y, 1) = R_y \exp\{(G_1 - M_1 - f(\text{sem}_1, y) s(\text{sem}_1, 1)) t_{\text{surv}}\},$$
$$B(t_{\text{surv}}, y, 2+) = B(0, y, 2+) \exp\{(G_{2+} - M_{2+} - f(\text{sem}_1, y) s(\text{sem}_1, 2+)) t_{\text{surv}}\},$$

where $B(0, y, 2+)$ is the biomass surviving from the previous year, which may be computed as:

$$B(0, y, 2+) = \sum_{a=1,2+} B(t_{\text{surv}}, y-1, a) \exp\{(G_a - M_a)(1 - t_{\text{surv}}) - f(\text{sem}_1, y-1) s(\text{sem}_1, a)(0.5 - t_{\text{surv}}) - f(\text{sem}_2, y-1) s(\text{sem}_2, a) 0.5\}.$$

The total biomass at the time of the survey is the sum of the two age groups:

$$B(t_{\text{surv}}, y, 1+) = \sum_{a=1,2+} B(t_{\text{surv}}, y, a),$$

and the age 1 biomass proportion is given by

$BP(t_{\text{surv}}, y) = B(t_{\text{surv}}, y, 1)/B(t_{\text{surv}}, y, 1+)$.

According to the Baranov catch equation, the catch at age a (in biomass) in semester j of year y is

$$C(\text{sem}_j, y, a) = B\left(b_{\text{sem}_j}, y, a\right)\frac{f(\text{sem}_j, y)s(\text{sem}_j, a)}{M_a - G_a + f(\text{sem}_j, y)s(\text{sem}_j, a)}$$
$$\left\{1 - \exp\left\{\left(G_a - M_a - f(\text{sem}_j, y)s(\text{sem}_j, a)\right)0.5\right\}\right\} .$$

The total catch is the sum of the two age classes:

$C(\text{sem}_j, y, 1+) = \sum_{a=1,2+} C(\text{sem}_j, y, a)$,

and the age 1 biomass proportion in the catch is

$CP(\text{sem}_j, y) = C(\text{sem}_j, y, 1)/C(\text{sem}_j, y, 1+)$.

2.2. Observation equations

The observation equations for the survey biomass indices $B(t_{\text{surv}}, y, 1+)$ and age 1 biomass proportion $BP(t_{\text{surv}}, y)$ are:

$$\log(B_{\text{surv}}(t_{\text{surv}}, y, 1+)) \sim \text{Normal}\left(\log(q_{\text{surv}}) + \log\left(B(t_{\text{surv}}, y, 1+)\right), \frac{1}{\psi_{\text{surv}}}\right),$$
$$BP_{\text{surv}}(t_{\text{surv}}, y) \sim \text{Beta}\left(e^{\xi_{\text{surv}}} BP(t_{\text{surv}}, y), e^{\xi_{\text{surv}}}(1 - BP(t_{\text{surv}}, y))\right),$$

where for each survey surv = depm, ac (DEPM and acoustics), q_{surv} denotes catchability, ψ_{surv} is the precision, and ξ_{surv} is related to the variance of the observation equation for the age 1 biomass proportion. In particular, the variance of $BP_{\text{surv}}(t_{\text{surv}}, y)$ is given by $\left(1 + e^{\xi_{\text{surv}}}\right)^{-1} BP(t_{\text{surv}}, y)\left(1 - BP(t_{\text{surv}}, y)\right)$.

The total catches observed by semester $C_{\text{obs}}(\text{sem}_j, y, 1+)$ are assumed to be lognormally distributed with the mean given by the actual catches (on a log-scale) according to the model and precision ψ_{catch}:

$$\log\left(C_{\text{obs}}(\text{sem}_j, y, 1+)\right) \sim \text{Normal}\left(\log\left(C(\text{sem}_j, y, 1+)\right), \frac{1}{\psi_{\text{catch}}}\right) .$$

The observation equation for the age 1 biomass proportion in the catch (CP) is taken as:

$$CP_{\text{obs}}(\text{sem}_j, y) \sim \text{Beta}\left(e^{\xi_{\text{catch}}} CP(\text{sem}_j, y), e^{\xi_{\text{catch}}}\left(1 - CP(\text{sem}_j, y)\right)\right),$$

where ξ_{catch} is a parameter related to the variance of the observation equation.

In addition, the stock weights-at-age estimated from the surveys are used to include observation equations for the intrinsic growth parameter G_a, as follows:

$$G_{obs}(y,a) \sim \text{Normal}\left(G_a, \frac{1}{\psi_G}\right),$$

for $a = 1,2+$, where $G_{obs}(y,a) = \log(w_{y+1,a+1}/w_{y,a})$ is the logarithm of the weights-at-age ratio estimated from surveys in consecutive years. Basically, ages 1, 2, and 3+ are observed in the surveys, and the observations for the growth parameter at age 2+ are computed from the weights at ages 2 and 3+, using an average weighted by abundance at age.

All the observation equations are assumed to be independent of each other, as well as independent across years $y = 1, \ldots, Y$, age groups $a = 1,2+$, semester $j = 1,2$, and surveys surv = depm,ac.

2.3. Parameters and prior distributions

The unknown parameters are the initial biomass, $B_0 = B(0,1,2+)$, defined as the age 2+ biomass at the start of the first year ($t = 0, y = 1, a = 2+$), the average log-recruitment level, μ_R, the precision of the normal process for log-recruitment, ψ_R, the surveys catchabilities, q_{depm} and q_{ac}, the parameters affecting the precision of the observation equations, ψ_{depm}, ψ_{ac}, ξ_{depm}, ξ_{ac} and ξ_{catch}, the year and age components of the fishing mortality by semester, $f(\text{sem}_j, y)$ and $s(\text{sem}_j, a)$ for $j = 1,2$ and $a = 1,2+$, the annual intrinsic growth rates by age, G_a for $a = 1,2+$, the precision of the observation equations for growth, ψ_G, and the annual natural mortality rates by age, M_a for $a = 1,2+$. Fishing mortality is the product of $f(\text{sem}_j, y)$ and $s(\text{sem}_j, a)$, so it is not possible to estimate the absolute value of each factor separately as these parameters only intervene in product form in all equations. To resolve this issue, the 2+ age-class selection parameters have been fixed to 1, i.e. $s(\text{sem}_j, 2+) = 1$ for both semesters. Therefore, $f(\text{sem}_j, y)$ corresponds to the fishing mortality of the 2+ age class and $s(\text{sem}_j, 1)$ to the fishing mortality of age 1 with respect to that of age 2+. No discards or catch underreporting are expected for this stock, and the recorded total landings are assumed to be very close to the actual stock catches. Hence, the parameter ψ_{catch} is fixed at 400 in the total catch observation equation, which corresponds to a 5% CV for observed catch in original (non-logged) scale.

In a Bayesian context, a prior distribution has to be elicited for all unknown parameters. It is assumed that all are independent a priori, so that the joint prior distribution is the product of the individual prior distributions, which are chosen to be

$$\log(q_{\text{surv}}) \sim \text{Normal}\left(\mu_{q_{\text{surv}}}, 1/\psi_{q_{\text{surv}}}\right) \text{ for surv} = \text{depm, ac}$$
$$\psi_{\text{surv}} \sim \text{Gamma}\left(a_{\psi_{\text{surv}}}, b_{\psi_{\text{surv}}}\right) \text{ for surv} = \text{depm, ac}$$
$$\xi_{\text{surv}} \sim \text{Normal}\left(\mu_{\xi_{\text{surv}}}, 1/\psi_{\xi_{\text{surv}}}\right) \text{ for surv} = \text{depm, ac}$$
$$\xi_{\text{catch}} \sim \text{Normal}\left(\mu_{\xi_{\text{catch}}}, 1/\psi_{\xi_{\text{catch}}}\right)$$
$$\log\left(f(\text{sem}_j, y)\right) \sim \text{Normal}\left(\mu_f, 1/\psi_f\right) \text{ for j} = 1,2 \text{ and y} = 1, \ldots, \text{Y}$$
$$s(\text{sem}_j, 1) \sim \text{Unif}(a_s, b_s) \text{ for } j = 1,2$$

$$\log(B_0) \sim \text{Normal}\left(\mu_{B_0}, 1/\psi_{B_0}\right)$$
$$\mu_R \sim \text{Normal}\left(\mu_{\mu_R}, 1/\psi_{\mu_R}\right)$$
$$\psi_R \sim \text{Gamma}\left(a_{\psi_R}, b_{\psi_R}\right)$$
$$\log(G_a) \sim \text{Normal}\left(\mu_{\log(G)}, 1/\psi_{\log(G)}\right) \text{ for } a = 1{,}2+$$
$$\psi_G \sim \text{Gamma}\left(a_{\psi_G}, b_{\psi_G}\right)$$
$$\log(M_a) \sim \text{Normal}\left(\mu_{\log(M)}, 1/\psi_{\log(M)}\right) \text{ for } a = 1{,}2+.$$

The hyperparameters of the prior distributions and corresponding medians and 90% probability intervals for the parameters are listed in Table 1.

2.4. Inference

From Bayes' theorem, the joint posterior probability density function (pdf) of the unknowns is proportional to the product of the pdf's of observations, states and priors. Markov chain Monte Carlo (MCMC) techniques (Gilks et al. 1996) were used to sample from the posterior distribution. The implementation was done using the software BUGS (Bayesian inference Using Gibbs). The WinBUGS development interface reduced run times by about a factor of 20 with respect to directly using the standard WinBUGS software. Analysis of the results was conducted in R. In particular, inspection of the MCMC draws used the package CODA (convergence diagnostics and output analysis).

3. Results

Six different inference settings were explored, depending on whether the DEPM survey was assumed to provide an absolute or a relative abundance index ($q_{\text{depm}} = 1$ or estimated) and on whether the rates of natural mortality by age were assumed known and equal by ages ($M_1 = M_{2+} = 1.2$) or known distinct by ages ($M_1 = 0.5$ and $M_{2+} = 1.5$) or unknown (M_1 and M_{2+} estimated).

The results presented here are based on MCMC runs of 1,100,000 iterations with burn-in period of 100,000 (i.e. first 100,000 iterations discarded) and thinning interval of 200 (i.e. 1 out of 200 iterations kept) with random starting values sampled from the prior distributions. Mixing of the chains was slow because of high correlation between the parameters. Chain behaviour was examined by visually inspecting traces, cumulative plots, and autocorrelation functions.

When the DEPM is taken as absolute, the posterior medians of the catchability of the acoustic index is about 1.4 when $M_1 = M_{2+} = 1.2$, 1.6 when $M_1 = 0.5$ and $M_{2+} = 1.5$ and 1.9 when M_1 and M_{2+} are estimated (Table 2). When the DEPM is taken as relative, its catchability is below 1. The catchability of the DEPM and acoustic surveys are respectively 0.5 and 1.1 when $M_1 = M_{2+} = 1.2$, 0.6 and 1.3 when $M_1 = 0.5$ and $M_{2+} = 1.5$ and 0.8 and 1.6 when M_1 and M_{2+} are estimated (Table 3).

The precision of the DEPM and acoustic surveys, the initial biomass, the annual recruitments and the year effects of the fishing mortality also change depending on the assumptions on the DEPM survey catchability. When the DEPM is taken as relative the initial biomass and the annual recruitments are larger and the year effects of the fishing mortality by semester are lower than when the DEPM is taken as absolute (Figure 1 and Figure 2). For the cases when M_1 and M_{2+} are fixed the precision of the surveys are larger when DEPM is taken as relative. Other parameters like the selectivity at age by semester are almost the same regardless the DEPM survey catchability assumption. The selectivity at age 1 is lower in the first semester than in the second one (0.4-05 and 1.3-1.5 approximately). All this results in larger biomass estimates when the DEPM is taken as relative than when the DEPM is taken as absolute (Figure 3).

Natural mortality is estimated at 0.7 and 0.84 for age 1 and age 2+ respectively when the DEPM is taken as absolute and at 0.82 and 0.86 when the DEPM is taken as relative. In terms of biomass, the lower biomass levels are obtained when $M_1$and M_{2+} are estimated whereas the larger biomass levels are obtained when $M_1 = M_{2+} = 1.2$. In any case the trends in R and SSB for the different assumptions regarding natural mortality and DEPM catchability are the same.

Pearson residuals under different model setting do not show major clear trends. However for the cases the DEPM is takes as absolute, the residuals of the DEPM SSB were mostly negative either for natural mortality fixed ($M_1 = M_{2+} = 1.2$ or M_1=0.5 and M_{2+}=1.5) (Figure 4a,b), although the free estimation of M lead to a better fitting of the SSB (Figure 4.c). On the other hand, for the case when DEPM is taken as a relative index if the natural mortality is fixed the fitting to the SSB from both surveys seems satisfactory but there is negative pattern in the proportions at age 1 in mass in recent years for both surveys. This pattern is partially improved when the natural mortality is fixed at distinct values by age ($\mathrm{M}_1 = 0.5$ and $\mathrm{M}_{2+} = 1.5$) or it is estimated (Figure 5).

The retrospective analysis when the DEPM is taken as relative under the different natural mortality assumptions are shown in Figure 4. When the natural mortality rates are fixed (either constant across ages or not) there seems to be an upwards revision of the SSB values when new years are included. This pattern disappears when the natural mortality rates are estimated. However, when the natural mortality rates are estimated there is a change in the age 2+ natural mortality rate from around 1.2 when the assessment is until 2002 to 0.9 when the assessment is until 2011 Figure 5.

4. Discussion and Conclusions

The selection of the assumed catchability by surveys and the natural mortality by age should be based on the general fit achieved and the extend of overcoming any retrospective pattern.

Our analysis shows that:

a) the fixed pattern of M1+=1.2 produces a worse fit of the observations than those allowing changing M1+ across ages. In general a negative pattern of proportions at age 1 in mass is observed for the two surveys particularly in the period 2005-1010 when little fishery was taking place. This simply means that in the absence of fishing a younger age structure would be expected than the one observed for the selected M1+. This in general tends to demand either a smaller constant M1+ or a different pattern of M by ages. In general estimation of natural mortality leads to smaller M1 and M2+ than 1.2 for all ages, and this suggests that former assumption on M1+=1.2 was an overestimate, and that M may change with age. This result was true independently of the way DEPM SSB is dealt in the analysis.

b) Adopting the DEPM as absolute led to negative residuals of most of the DEPM SSB estimates, both for the fixed M1+=1.2 or for fixed M at age pattern, althogth estimating M at age led to a better fitting. This lead to conclude that taking the DEPM as absolute may be contradictory with observations, unless M is let to be estimated freely. Therefore the new downwards revised DEPM estimates could be correct and not contradictory with catches for estimated natural mortality values.

c) For the DEPM taken as relative and M changing across ages, there were apparently little differences in the fitting of the observation between the M by ages fixed or being estimated (figures 5, pearson residuals). This is certainly due to the fact thatM_1 and M_{2+} are heavily corelated (see text table below) and hence they are not easily estimated separately.

	logqdepm	logqac	logM1	logM2
logqdepm	1.0000000	0.5437118	-0.1861770	-0.1606419
logqac	0.5437118	1.0000000	-0.1374372	-0.1855203
logM1	-0.1861770	-0.1374372	1.0000000	-0.7389643
logM2	-0.1606419	-0.1855203	-0.7389643	1.0000000

This means that there can be a wide range of plausible values of suitable M_1 and M_{2+} (i.e. leading to a rather similar good fitting) over which little contrast is obtained in the current set of data inputs. Additional information should therefore be used to make the best selection among alternative patterns of natural mortality at age. This external aid can come from the scatter plot of covariation between M1 and M2, between the ANVOA analysis of natural mortalities by ages (Uriarte and Ibaibarriaga 2013WD) or from age structured analysis up to age 3 (such as SICA- Uriarte et al. 2010).

d) the M pattern which shows the lesser retrospective pattern is that where M at age is estimated. These results departures remarkably from the estimates from ANOVA on the age structure of the surveys up to age 3 (in Uriarte & Ibaibarriaga 2013 WD), where larger differences between M1 and M2+ are inferred.
Final election of the natural mortality pattern should be conditioned to broader perspective on the fishing mortality pattern, such as looking at the shape of the M1 and M2 covariation which may allow selecting a better pair of M1 and M2+ closer to the ANOVA estimates and to the current best estimates based on free estimation of M1 and M2+ (which show little retrospective pattern).

5. References

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Uriarte A., P. L. Ibaibarriaga P. Abaunza, L. Pawlosky, J. Massé, P.Petitgas, M.Santos. D. Skagen, 2010: Assessing natural mortality of anchovy from surveys' population and biomass estimates. ICES CM 2010/C:12

Table 1: Hyperparameters specifying the prior distribution and corresponding medians and 90% central probability intervals for the model parameters. For semester- or age- specific parameters, the prior distributions are assumed to be the same for both semesters or ages.

	Hyperparameters	Median (90% P.I.)
q_{surv}	$\mu_{q_{\text{surv}}} = 0 \;\; \psi_{q_{\text{surv}}} = 2$	1 (0.3, 3.2)
ψ_{surv}	$a_{\psi_{\text{surv}}} = 0.9 \;\; b_{\psi_{\text{surv}}} = 0.02$	29.8 (1.7, 139.9)
ξ_{surv}	$\mu_{\xi_{\text{surv}}} = 5 \;\; \psi_{\xi_{\text{surv}}} = 0.2$	5 (1.3, 8.7)
ξ_{catch}	$\mu_{\xi_{\text{cacth}}} = 5 \;\; \psi_{\xi_{\text{catch}}} = 0.2$	5 (1.3, 8.7)
B_0	$\mu_{B_0} = 10.3 \;\; \psi_{B_0} = 1.0$	29733 t (5740, 154022)
μ_R	$\mu_{\mu_R} = 9.8 \;\; \psi_{\mu_R} = 1.0$	9.8 (8.2, 11.4)
ψ_R	$a_{\psi_R} = 2.0 \;\; b_{\psi_R} = 3.0$	0.6 (0.1, 1.6)
$s(\text{sem}_j, 1)$	$a_s = 0 \;\; b_s = 2.0$	1.0 (0.1, 1.9)
$f(\text{sem}_j, y)$	$\mu_f = -0.9 \;\; \psi_f = 1$	0.4 (0.1, 2.1)
M_a	$\mu_{\log(M)} = 0.2 \;\; \psi_{\log(M)} = 5$	1.2 (0.6, 2.5)
G_a	$\mu_{\log(G)} = -0.7 \;\; \psi_{\log(G)} = 2$	0.5 (0.2, 1.6)
ψ_G	$a_{\psi_G} = 1.5 \;\; b_{\psi_G} = 0.1$	11.8 (1.8, 39.1)

Table 2: Posterior quantiles under different assumptions regarding natural mortality when the DEPM survey catchability is fixed to 1.

	DEPM absolute								
	$M_1 = M_{2+} = 1.2$			$M_1 = 0.5$ and $M_{2+} = 1.5$			M_1 and M_{2+} estimated		
Parameter	5%	50%	95%	5%	50%	95%	5%	50%	95%
q_{depm}									
q_{ac}	1.098	1.394	1.808	1.264	1.601	2.012	1.552	1.895	2.333
ψ_{depm}	1.453	2.638	4.762	1.892	3.621	6.375	3.236	5.554	9.013
ψ_{ac}	1.972	3.981	7.639	2.524	5.035	9.414	2.856	5.442	9.816
ξ_{depm}	2.976	4.082	5.761	3.183	4.471	6.115	3.268	4.115	5.226
ξ_{ac}	2.343	3.155	3.926	2.627	3.340	3.995	2.941	3.719	4.496
ξ_{catch}	2.315	2.772	3.283	2.373	2.798	3.256	2.483	2.909	3.382
B_0	15994	21699	28001	17730	22697	28854	13306	16933	20974
μ_R	10.120	10.480	10.810	9.768	10.090	10.420	9.665	10.020	10.370
ψ_R	0.663	1.076	1.666	0.705	1.152	1.751	0.630	1.014	1.562
$s(\text{sem}_1, 1)$	0.360	0.436	0.540	0.454	0.539	0.644	0.430	0.517	0.622
$s(\text{sem}_2, 1)$	1.029	1.313	1.655	0.847	1.088	1.370	1.181	1.593	1.945
M_1							0.421	0.681	1.008
M_{2+}							0.614	0.840	1.089
G_1	0.514	0.595	0.690	0.486	0.560	0.639	0.427	0.498	0.567
G_{2+}	0.221	0.310	0.413	0.186	0.252	0.329	0.126	0.189	0.257
ψ_G	12.480	21.760	35.232	16.800	27.235	40.611	20.730	31.290	44.731

Table 3: Posterior quantiles under different assumptions regarding natural mortality when the DEPM survey catchability is estimated.

	DEPM relative								
	$M_1 = M_{2+} = 1.2$			$M_1 = 0.5$ and $M_{2+} = 1.5$			M_1 and M_{2+} estimated		
Parameter	5%	50%	95%	5%	50%	95%	5%	50%	95%
q_{depm}	0.416	0.517	0.637	0.507	0.638	0.782	0.613	0.757	0.941
q_{ac}	0.856	1.087	1.376	1.035	1.302	1.636	1.261	1.586	2.030
ψ_{depm}	3.035	5.328	8.928	2.565	4.500	7.368	3.282	5.688	9.086
ψ_{ac}	2.624	5.136	9.445	3.029	5.869	11.180	3.050	5.816	10.231
ξ_{depm}	2.845	3.636	4.600	3.271	4.143	5.456	3.098	3.972	4.815
ξ_{ac}	2.320	3.035	3.762	2.656	3.355	4.040	2.901	3.709	4.647
ξ_{catch}	2.390	2.804	3.274	2.415	2.833	3.273	2.454	2.901	3.348
B_0	17239	24588	33190	18845	24343	31571	13836	18106	23624
μ_R	10.370	10.710	11.040	9.937	10.260	10.580	9.815	10.200	10.590
ψ_R	0.736	1.209	1.891	0.757	1.240	1.897	0.678	1.080	1.651
$s(\mathrm{sem}_1, 1)$	0.347	0.418	0.506	0.446	0.529	0.635	0.403	0.497	0.615
$s(\mathrm{sem}_2, 1)$	0.995	1.290	1.655	0.871	1.103	1.363	1.191	1.585	1.944
M_1							0.484	0.821	1.189
M_{2+}							0.624	0.863	1.169
G_1	0.478	0.553	0.632	0.456	0.526	0.595	0.424	0.495	0.564
G_{2+}	0.187	0.259	0.342	0.165	0.228	0.298	0.130	0.189	0.255
ψ_G	16.949	26.905	40.111	19.229	29.800	42.984	20.440	31.125	44.403

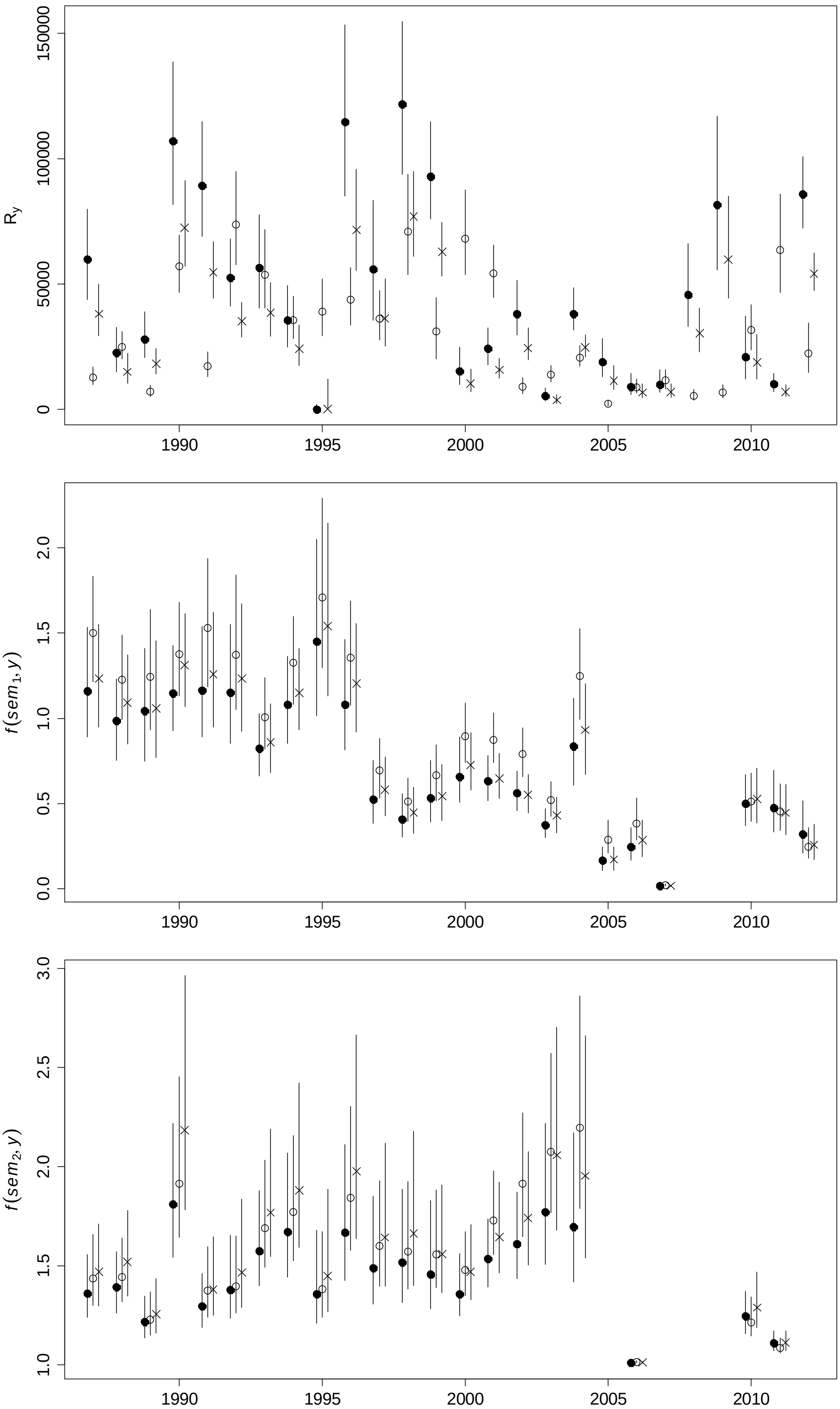


Figure 1: Posterior median and 90% probability intervals of recruitment in tonnes (top), age 2+ fishing mortality in the first (middle) and second (bottom) semesters, under different assumptions on natural mortality (solid bullet when natural mortality is fixed at 1.2, open circle when natural mortality is estimated and cross when natural mortality is mixed at distinct value by age) when the DEPM is taken as absolute.

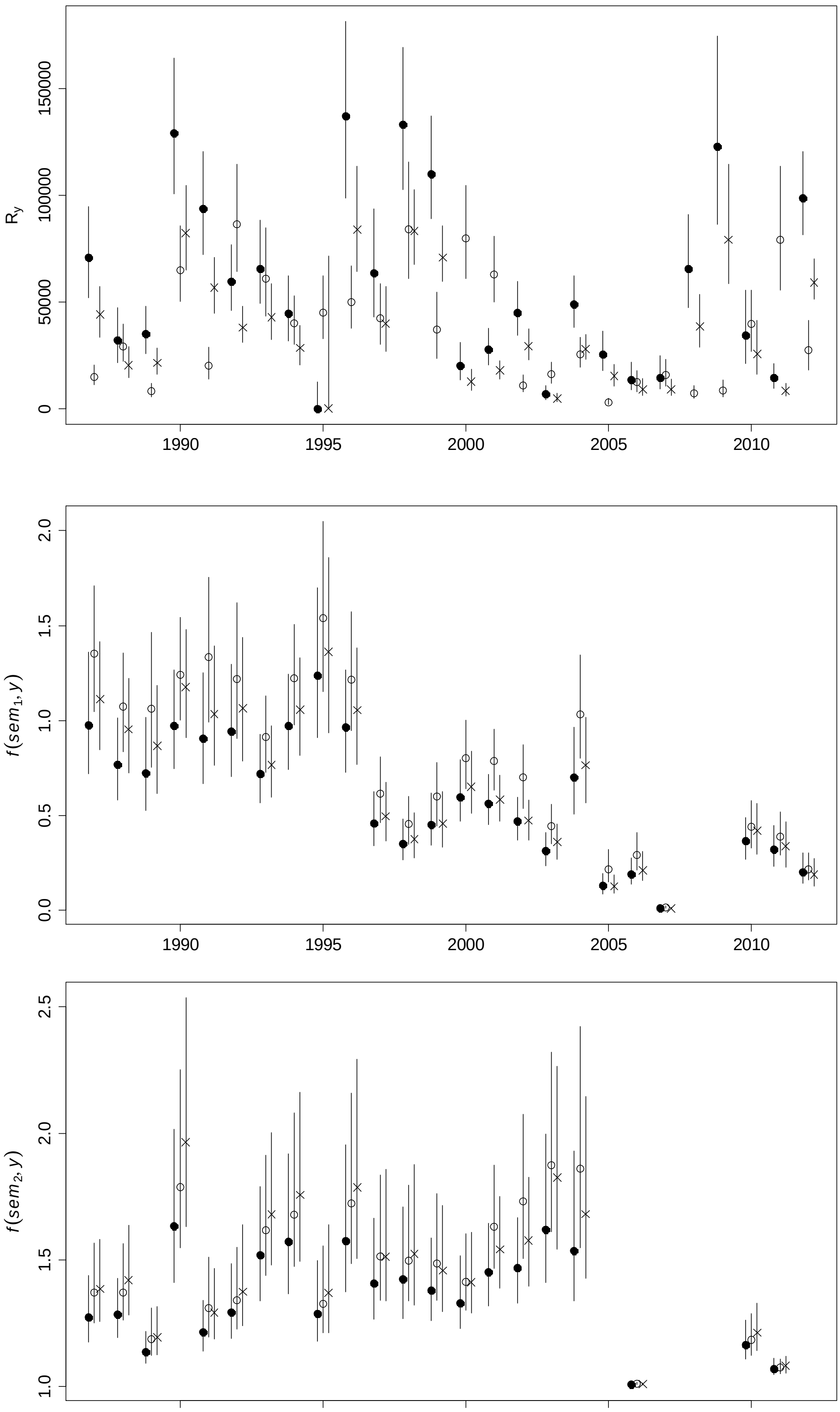


Figure 2: Posterior median and 90% probability intervals of recruitment in tonnes (top), age 2+ fishing mortality in the first (middle) and second (bottom) semesters, under different assumptions on natural mortality (solid bullet when natural mortality is fixed at 1.2, open circle when natural mortality is estimated and cross when natural mortality is mixed at distinct value by age) when the DEPM is taken as relative.

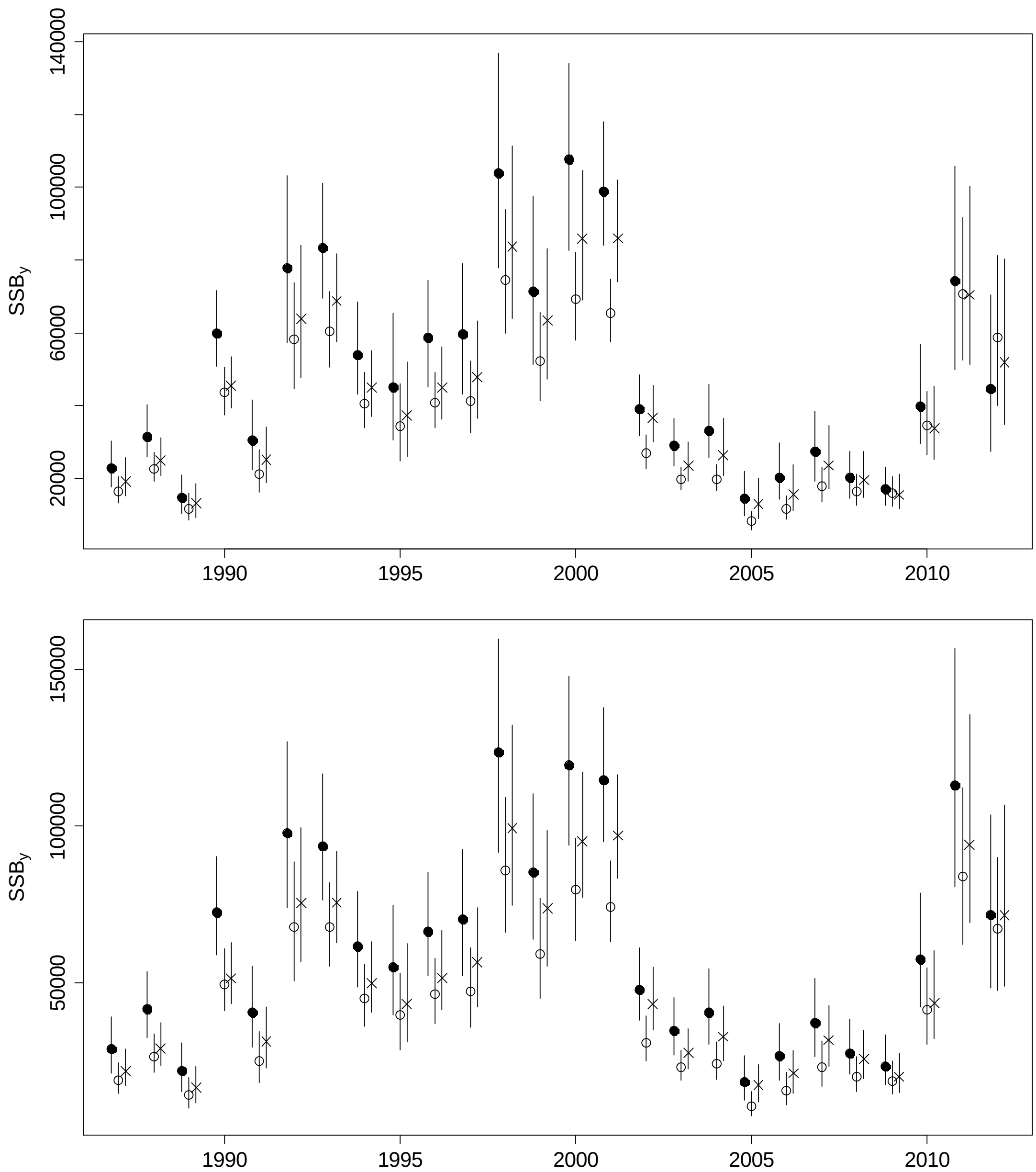
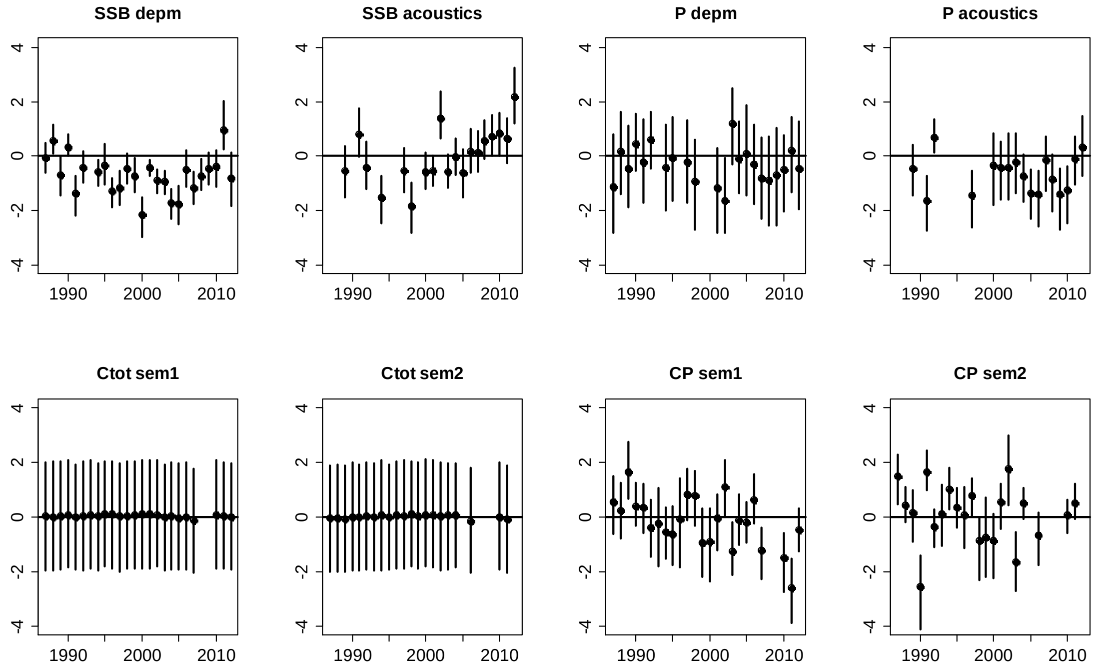


Figure 3: Posterior distributions of the total biomass (in tonnes) at survey time under different assumptions about natural mortality (solid bullet when natural mortality is fixed at 1.2, open circle when natural mortality is estimated and cross when natural mortality is mixed at distinct value by age). Top and bottom panels correspond to DEPM taken as absolute and relative, respectively.

a)



b)

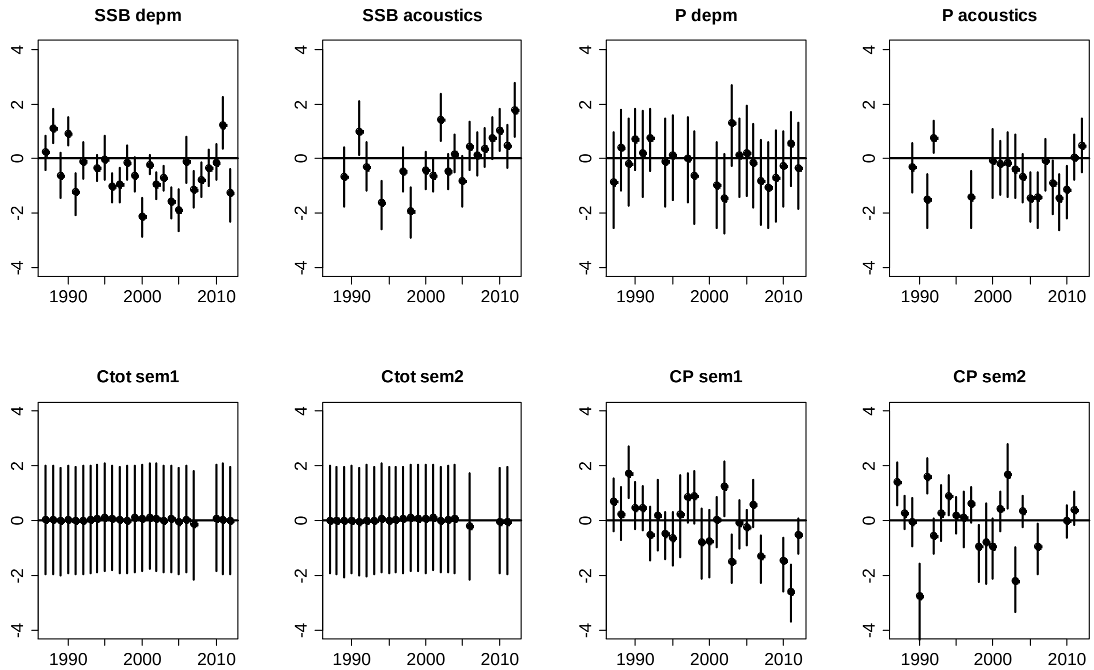


Figure 4: Posterior median (bullet) and 95% probability intervals (vertical segment) of Pearson residuals of each of the observed time series (DEPM and acoustic biomass indices in tonnes, DEPM and acoustic age 1 biomass proportions, total catches in tonnes observed by semester and age 1 biomass proportion in the catch by semester) for the three different cases of natural mortality at age and taking the DEPM index as absolute. The horizontal solid line is located at zero. Panel a – for the case of fixed M1+=1.2, Panel 2 for the M1=0.5 and M1+=1.5, and panel c when M at age are estimated.

c)

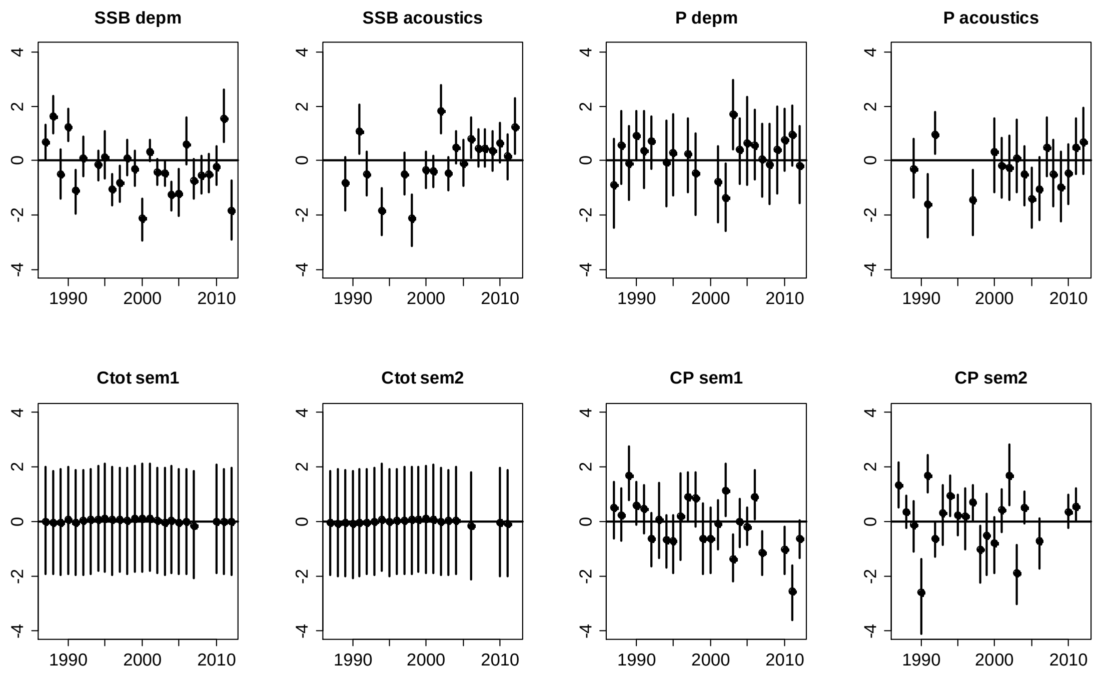
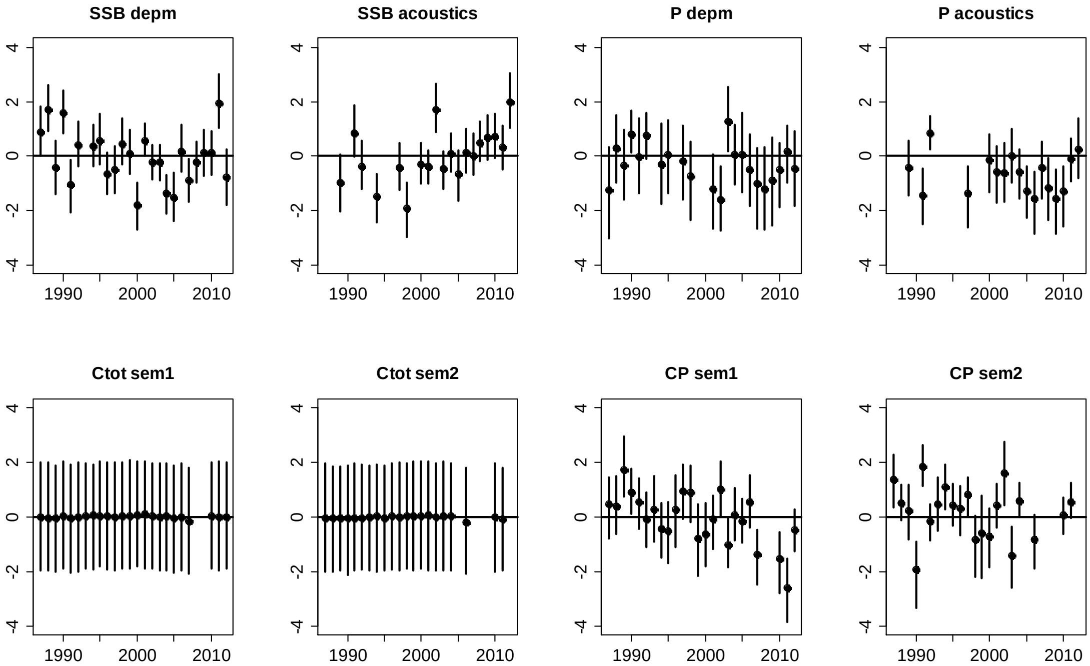


Figure 4 (cont) : Posterior median (bullet) and 95% probability intervals (vertical segment) of Pearson residuals of each of the observed time series (DEPM and acoustic biomass indices in tonnes, DEPM and acoustic age 1 biomass proportions, total catches in tonnes observed by semester and age 1 biomass proportion in the catch by semester) for the three different cases of natural mortality at age and taking the DEPM index as absolute. The horizontal solid line is located at zero. Panel a – for the case of fixed M1+=1.2, Panel 2 for the M1=0.5 and M1+=1.5, and panel c when M at age are estimated.

a)



b)

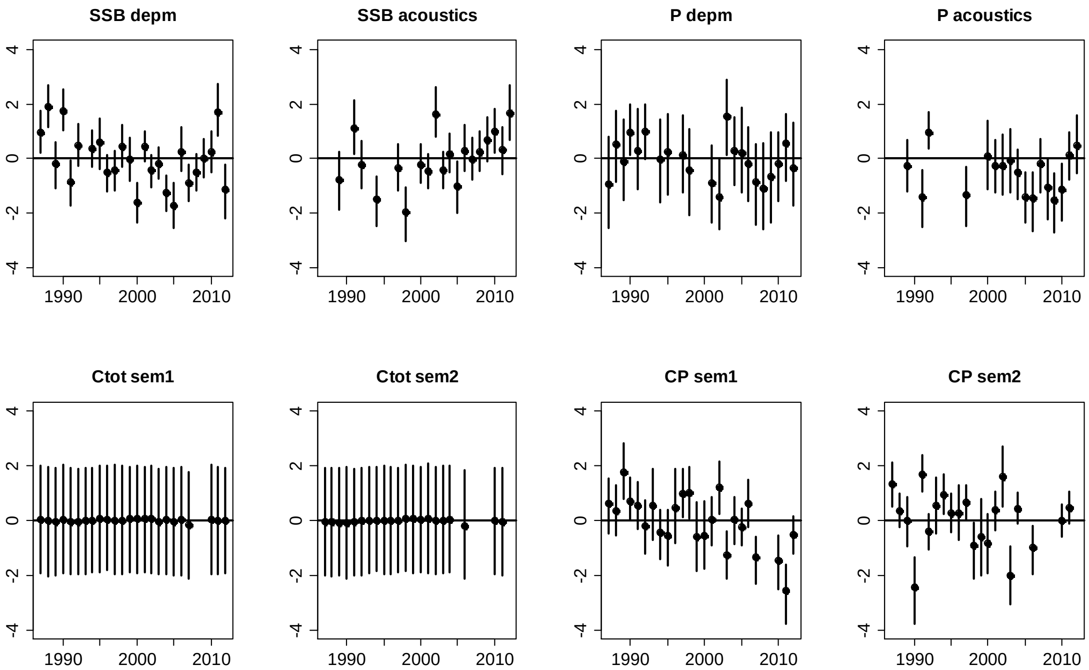


Figure 5: Posterior median (bullet) and 95% probability intervals (vertical segment) of Pearson residuals of each of the observed time series (DEPM and acoustic biomass indices in tonnes, DEPM and acoustic age 1 biomass proportions, total catches in tonnes observed by semester and age 1 biomass proportion in the catch by semester) for the three different cases of natural mortality at age and taking DEPM index relative. The horizontal solid line is located at zero. . Panel a – for the case of fixed M1+=1.2, Panel 2 for the M1=0.5 and M1+=1.5, and panel c when M at age are estimated.

c)

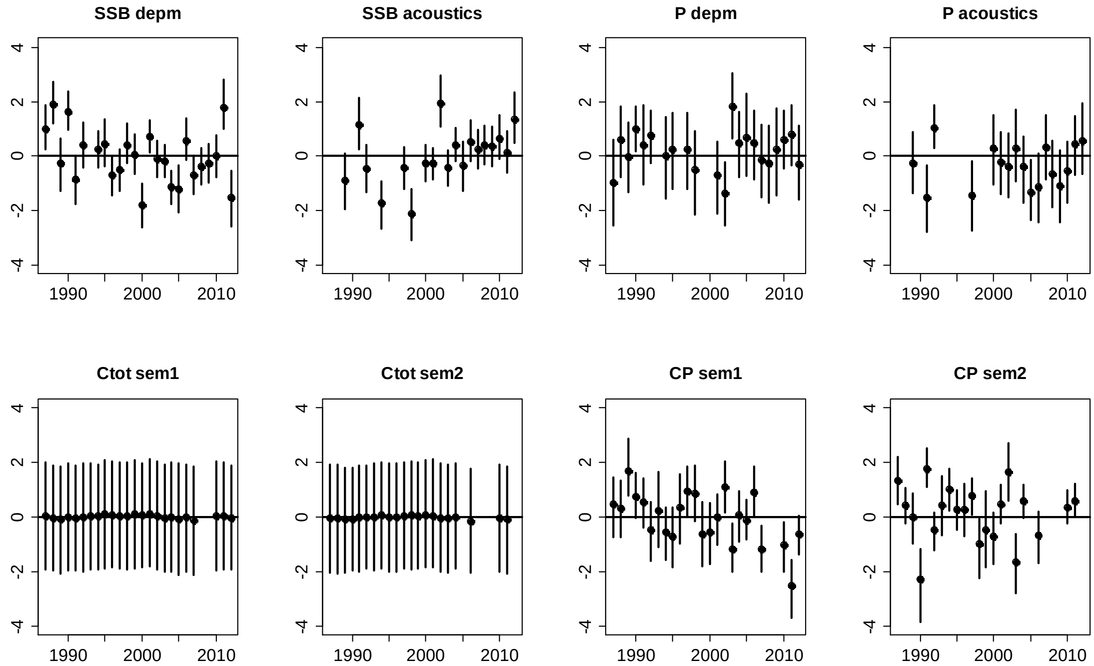
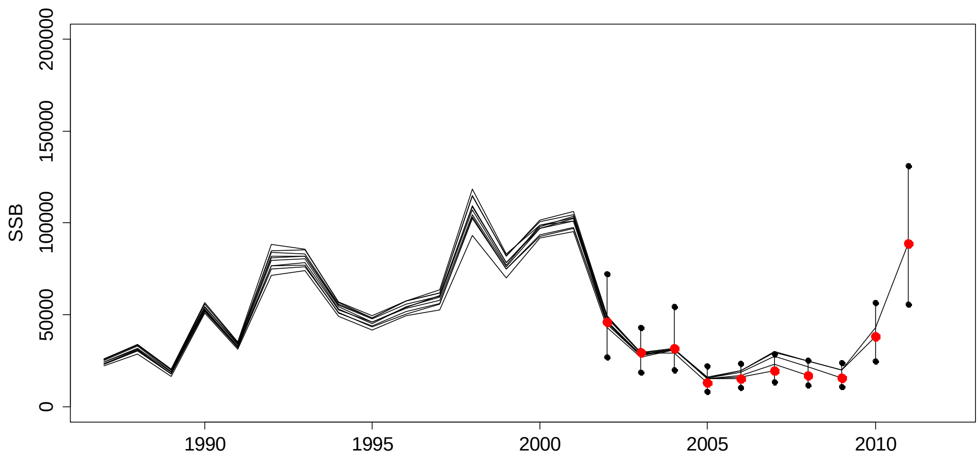
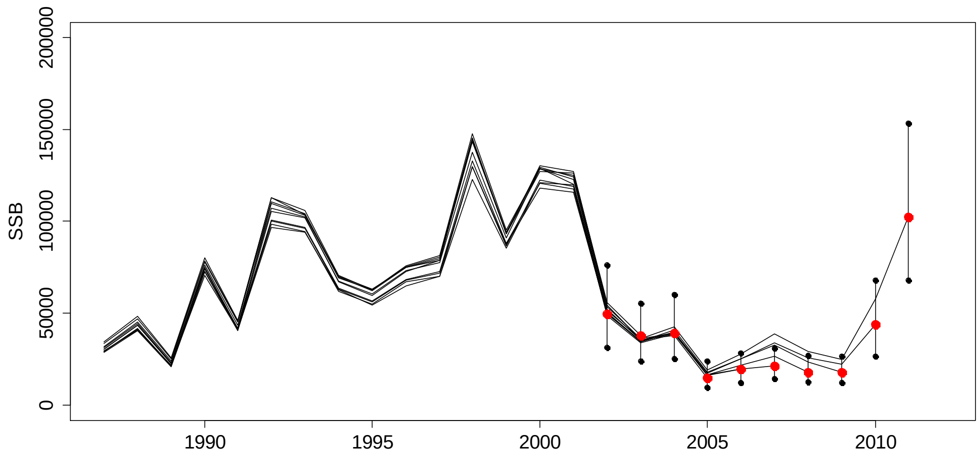


Figure 5 (cont…): Posterior median (bullet) and 95% probability intervals (vertical segment) of Pearson residuals of each of the observed time series (DEPM and acoustic biomass indices in tonnes, DEPM and acoustic age 1 biomass proportions, total catches in tonnes observed by semester and age 1 biomass proportion in the catch by semester) for the three different cases of natural mortality at age and taking DEPM index relative. The horizontal solid line is located at zero. . Panel a – for the case of fixed M1+=1.2, Panel 2 for the M1=0.5 and M1+=1.5, and panel c when M at age are estimated.





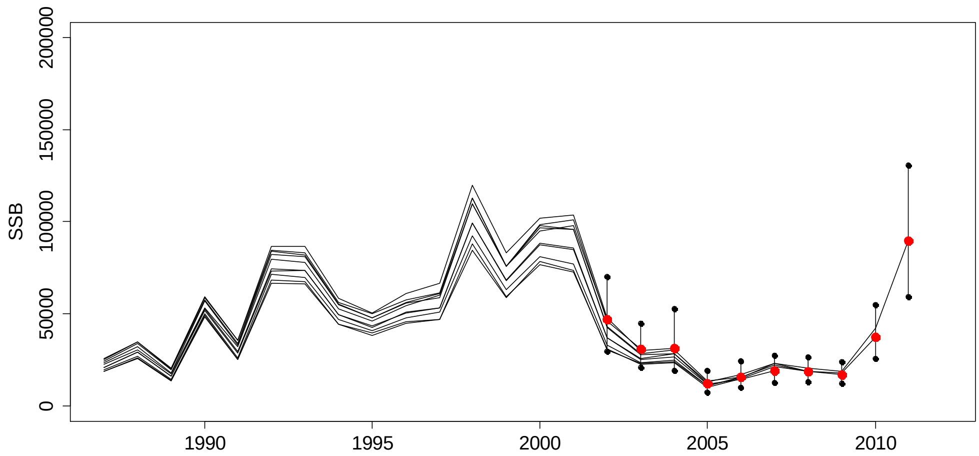


Figure 4: Retrospective analysis when DEPM is taken as relative and Mage considered. From top to bottom M fixed at distinct values by age, M fixed and constant across ages and M estimated.

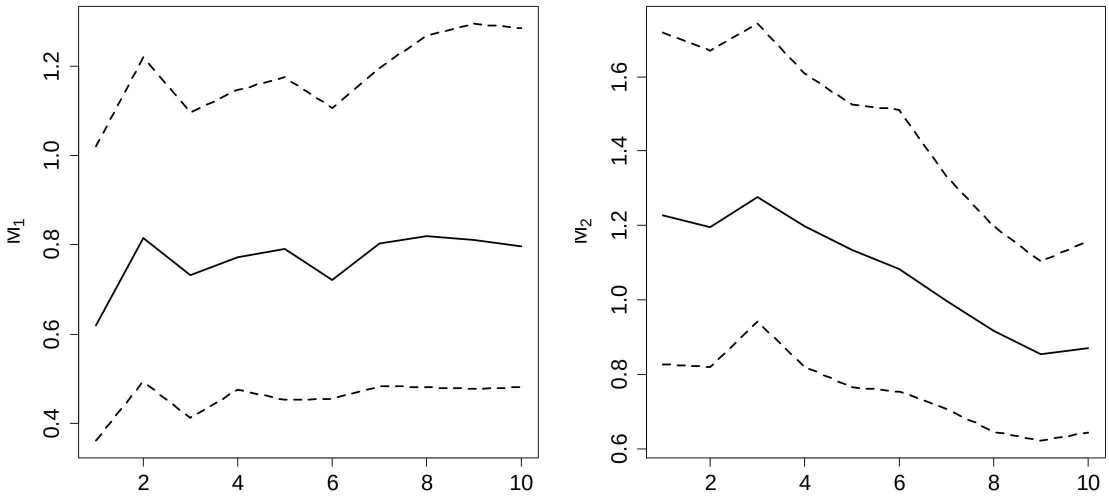


Figure 5: Retrospective pattern of natural mortality rates at age when the DEPM is taken as relative and the mortality rates are estimated.

Working document to WKPELA 2013, 4-8 February 2013, Copenhagen (Denmark)

Is there an upward revision of the assessed biomass from year to year?

by

Ibaibarriaga, L., Santos, M. and Uriarte, A.

1. Introduction

In November 2012 the South Western Waters Regional Advisory Committee (SWW RAC) publishes a document with the major issues they considered should be addressed on the next benchmark regarding the assessment methodology for anchovy in the Bay of Biscay (SWW RAC 2012). The first issue of concern was the consistently positive back-calculations of the biomass from year to year. Since 2008 the assessment methodology is the same from year to year (see the stock annex agreed in the last anchovy benchmark workshop (ICES 2009). Then, for these years there are two possible explanations for this pattern. On the one hand the data used in the assessment change from year to year. For instance, the biomass and age structured indices in the last year from the Daily Egg production Method (DEPM) are preliminary in June, when the assessment is conducted. On the other hand, there might be a retrospective pattern in the model that systematically underestimates the population biomass in the last assessment years.

In this working document we study this pattern in detail. First we analyse the changes in the assessment methodology and data, with a special focus on whether the preliminary DEPM estimates in June are systematically corrected upwards. Then, we study the retrospective pattern based on the last assessment's data (ICES 2012). Finally, conclusions of the work are summarised.

2. Methods

2.1. Revision of the historical ICES assessments

First the historical ICES assessments were revised and the methodology and data changes from assessment to assessment were tracked.

One of the main indices in the anchovy assessment comes from the Daily Egg production Method (DEPM), which consists on estimating the spawning stock biomass (SSB) as the ratio between the total daily egg production and the total daily fecundity. The DEPM survey for anchovy in Biscay is carried out in May (Santos et al. 2011), and since 2005 there is a demand for having the DEPM results available in June when the assessment of the stock is conducted. However, by that time the adult samples for the estimation of the total daily fecundity are not fully processed. The stock annex (ICES 2009) establishes that the daily fecundity is estimated as an average of the past historical series (63.39 egg/ g per day). As a result the SSB and the age structured indices from the DEPM used for the assessment in June are preliminary. The final and definitive estimates are provided to Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG) in November and are used in the next assessment working group (WGHANSA) in June of the following year.

The preliminary and definitive DEPM SSB and age 1 biomass proportion indices are reviewed in order to check whether the preliminary estimates are systematically corrected upwards. The differences between the preliminary and definitive estimates are quantified in relative and absolute terms.

2.2. Retrospective pattern

The Bay of Biscay anchovy is assessed yearly using the two-stage biomass-based model BBM (Ibaibarriaga et al. 2008, ICES 2009). The population dynamics are described in terms of biomass with two distinct age groups, recruits or fish aged 1 year, and fish that are 2 or more years old. The biomass decreases exponentially on time by a factor g accounting for intrinsic rates of growth (G) and natural mortality (M) which are assumed year- and age-invariant. Two periods are distinguished within each year. The first begins on 1 January, when it is assumed that age incrementing occurs and age 1 recruit enter the exploitable population, and runs to the date when the monitoring research surveys (acoustics and DEPM) take place. The second period covers the rest of the year (from 15th May to 31st December). Catch is assumed to be taken instantaneously within each of these periods. The model can be cast into a Bayesian state-space model framework where inference on the unknowns is done using Markov Chain Monte Carlo (MCMC). The final assessment is based on DEPM as an absolute index of SSB and the g parameter fixed at 0.68.

The retrospective analysis was based on the same data (1987-2012) as used in the last assessment carried out in June 2012 (ICES 2012). Starting from 2012, one year was removed each time and the assessment was repeated under the settings described on the stock annex (ICES 2009). Special focus was on the last year assessed biomass, on which the current LTMP proposal is based to set the TAC for this stock.

3. Results

The biomass estimates from the historical assessments conducted by ICES are shown in Table 1. Up to 2005 the Bay of Biscay anchovy stock was assessed by the Integrated Catch at age Analysis (ICA, Patterson and Melvin 1996). In 2006 the stock was first assessed using a preliminary version of the BBM, explaining the differences between 2005 and the rest of years. In 2008 the BBM version used by ICES was the same as in Ibaibarriaga et al. (2008) and in 2009 this model was accepted in the Benchmark Workshop (ICES 2009).

From 2005 to 2007 the working group took place at the beginning of September and the DEPM estimates were usually the definitive ones. However in these years due to the fishery collapse intermediate STECF meetings where the preliminary estimates were used took place. In 2008 the ICES assessment working group for anchovy in the Bay of Biscay was moved to June and started to give advice from July to June next year. Therefore from 2008 to 2012 the last year DEPM estimates and the first period catch data used by the ICES assessment working group in June had been preliminary and have been revised the year after. The comparison between the preliminary and definitive SSB and age 1 biomass proportions used in the BBM is shown in Table 2. The major relative changes are in the SSB with an average of 0.09 in comparison with the -0.01 average relative change for the age 1 biomass proportion. The only year when the SSB was reviewed downwards (-0.13) is 2009 and larger SSB upwards revision (+0.22) corresponded to 2006. However, this doesn’t seem to be enough to explain the changes observed in Table 1.

The retrospective analysis of the BBM using the definitive input data available for the last ICES assessment is shown in Figure 1, Figure 2 and Figure 3. The first two figures show the SSB estimates when one year is removed at a time. The final year estimates are highlighted in red. In most of the years the last year’s SSB estimates increase when subsequent years are included. The exceptions are 1998, 2003, 2004 and 2011. However, except in 2000, the final year’s SSB probability intervals always contain the SSB estimates of the assessment conducted in 2012 (Figure 1). On the contrary the last assessment’s SSB probability intervals do not always contain the SSB estimated in previous years (Figure 2). From 2004 to 2010 the lower limit of the interval is very close to the SSB estimates from previous years (Figure 2). From an assessment perspective the most important quality control is the one shown by Figure 1as it says that the first assessment does include within its confidence interval the final most accurate estimate which will be obtained next years. However if a consistent pattern exists in Figure 1 then an improvement of the current assessment is desirable.

The median and the 95% probability intervals of the rest of the BBM parameters from the retrospective analysis are shown in Figure 3. The catchability of the acoustic SSB index shows an increasing trend. On the contrary, the average recruitment in log scale decreases. Regarding the precision of the surveys, the precision of the DEPM SSB indices decreases, whereas the precision of the acoustics SSB increases slightly when the last years are included.

4. Conclusions

- There is a correction upwards of 3% (on average) from year to year in the SSB estimates of the ICES historical assessments.
- The preliminary DEPM SSB estimates available in June are reviewed upwards in November by about 9% on average. But this does not explain the pattern observed in the historical assessments.
- In the retrospective analysis the last year’s SSB estimates increase when subsequent years are included. However, except in 2000, the final year’s SSB probability intervals always contain the SSB estimates of the assessment conducted in 2012. The rest parameters also change depending on the years included in the assessment.
- The results of the retrospective analysis show a pattern which is not as pronounced as in other stocks. Further, it must be taken into account that the first assessment does include within its probability interval the final most

accurate estimate which will be obtained the following years. However, given the implications of the changes in the last year's biomass in terms of management an improvement of the assessment that minimises these effects is desirable.

5. References

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Table 1: Biomass estimates from the historical assessment conducted in ICES.

		Year												
		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Assessment Year	2012	21860	35700	17280	64825	30230	100900	98410	61060	52580	59490	50990	75130	75340
	2011	21940	35720	17250	65110	30495	103700	97780	60760	52030	59510	50500	74120	76365
	2010	22325	36110	17590	65780	30150	98315	96030	58380	45945	60260	50460	74230	76470
	2009	22900	37290	18820	66840	31065	103900	97095	59530	49695	60040	49190	71575	76610
	2008	22651	37147	18642	66186	30429	100214	97267	59760	49920	60500	50204	74076	75436
	2007	22911	38011	19246	67640	32089	102672	99454	61372	53232	60194	51677	75722	74174
	2006	23144	38446	19690	67847	31971	101234	99112	61027	52977	60646	51771	76004	74218
	2005	66228	42095	25423	52298	30224	70602	82103	53047	43315	39927	44617	93098	75333

		Year												
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Assessment Year	2012	120600	100400	37170	34910	43660	19690	31455	42390	31010	25475	54180	104200	68180
	2011	120000	100400	37180	34490	42490	18800	29825	40530	29820	24550	52280	98450	
	2010	117900	99380	36770	33430	40120	17110	27190	37080	27235	22000	51350		
	2009	117400	99380	36870	33045	39440	16650	26180	35980	26240	21270			
	2008	116958	98870	36551	32573	38440	15962	24560	32989	24101				
	2007	116561	100153	36567	31133	37140	15177	23457	29873					
	2006	113625	100397	36712	30727	36600	14826	22304						
	2005	89883	88142	49190	19836	29526	9200							

Table 2: Comparison between the preliminary and definitive DEPM SSB and P1 estimates.

	Preliminary (June)		Definitive (November)	
Year	SSB (t)	P1	SSB (t)	P1
2005	7422	0.3195	8002	0.258
2006	16820	0.6774	21436	0.703
2007	25309	0.6112	25973	0.617
2008	24712	0.2908	25377	0.299
2009	27994	0.3709	24846	0.374
2010	36627	0.8136	42979	0.785
2011	138069	0.8067	172223	0.816
2012	36200	0.3074	41742	0.334

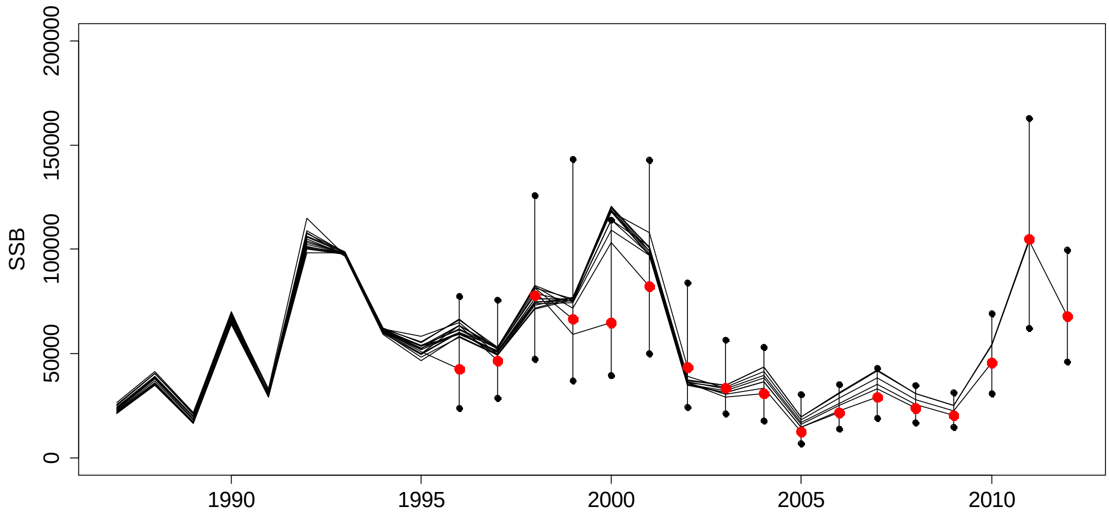

Figure 1: Retrospective pattern; Yearly estimates with their confidence intervals compared with the most recent assessment (obtained in 2012)

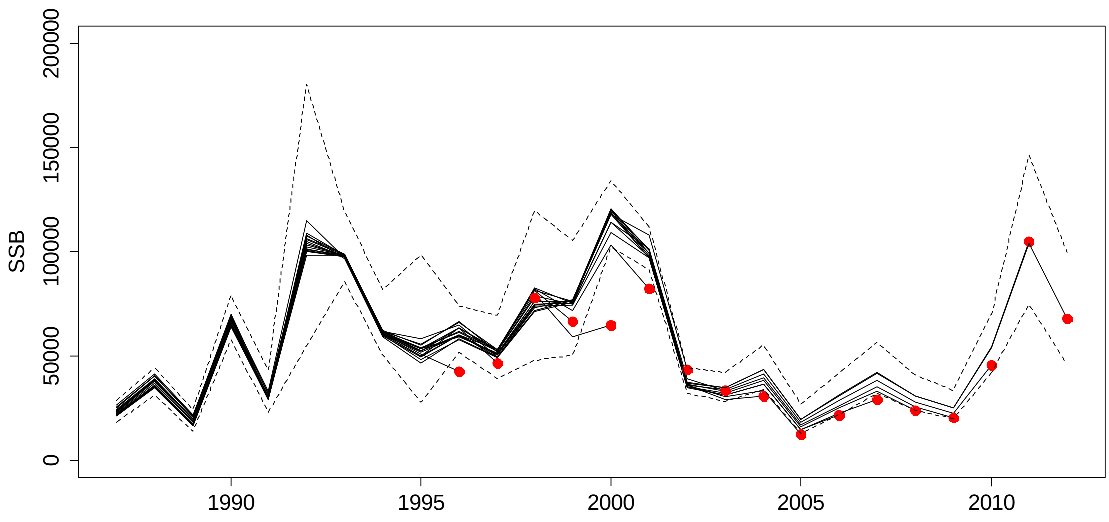

Figure 2: Retrospective pattern; Most recent assessment with its confidence intervals (dotted lines) compared with the medians of the previous years' assessments.

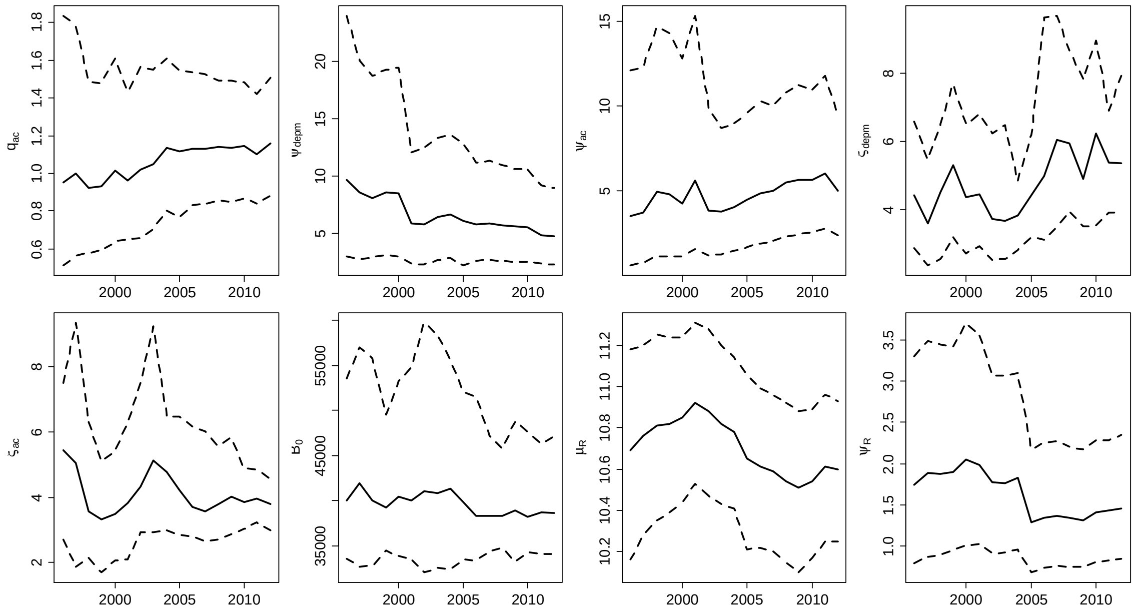

Figure 3: Retrospective of all the rest of parameters.

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Coherence between Egg and Acoustic survey estimates (Bay of Biscay anchovy)

Pierre Petitgas – IFREMER – EMH Nantes – France

In the Bay of Biscay anchovy abundance is estimated by acoustics (PELGAS series of Ifremer) and DEPM (BIOMAN series of Azti). The egg survey provides an estimate of total daily egg production (Ptot: # eggs d^{-1}) and the acoustic survey an estimate of spawning biomass (B, tones).

In the DEPM (e.g., Stradoudakis et al., 2006) the egg production (Ptot) is converted into spawning biomass (B, tonnes) by dividing Ptot by the daily fecundity (DF: # eggs d^{-1} g^{-1}). DF can be estimated from sampling adult fish and after analysis of the ovaries. We have DF=S BF SF / w, where S is the sex ratio, BF the average batch fecundity of a female (# eggs d^{-1}), SF the spawning fraction (fraction of females spawning per day) and w the average female weight (g). This procedure is used by Azti in addition to the egg survey BIOMAN. While all parameters are estimated in each year, the value for SF used is the average SF prior to 2004 (because of a change in the procedure to estimate SF).

But there is another possibility to estimate DF, taking advantage of the fact that we have an egg survey providing Ptot estimates and an acoustic survey providing Biomass (B) estimates. We may simply access to DF by the ratio Ptot/B. Because the two indices Ptot and B are linked through DF, the coherence between the egg and the acoustic surveys BIOMAN and PELGAS can be investigated.

The daily egg production Ptot depends on the spawning biomass (B) and the daily fecundity (DF). DF depends on environmental and trophic conditions, which determine individual fish fecundity (e.g., Motos et al., 1996). Daily egg production (Ptot) and spawning biomass (B) are linearly related. The slope of the linear regression is a (direct) estimate of the average DF over the series. Large residuals in a particular year around the regression line could indicate either a major discrepancy between survey estimates (e.g., one survey not accessing well the resource in that year) or dramatic environmental conditions affecting DF in that particular year. Residuals can thus be used to alert on potential discrepancies between survey estimates providing that they are not explained by environmental conditions potentially affecting DF.

The Ptot of the BIOMAN surveys was linearly regressed on the Biomass of the acoustic survey PELGAS (Fig. 1). The value of the slope was: DF= 33.83 eggs g^{-1}.

To characterize environmental conditions we used hydrological indices computed on the CTD profiles that were collected during the PELGAS survey in each year. In each year, CTD casts are performed on a pseudo regular grid covering the entire French of the Bay of Biscay where spawning occurs predominantly. From the CTD profiles we considered the following indices (detailed in Huret et al., 2013): surface (5m) and bottom temperature, surface and bottom salinity, potential energy deficit to characterize stratification, equivalent fresh water height to characterize river plumes, surface and integrated fluorescence. The residuals were linearly regressed on each of the hydrological indices, one at a time. Regressions selected showed an R-squared > 0.35 and a p-value < 0.1.

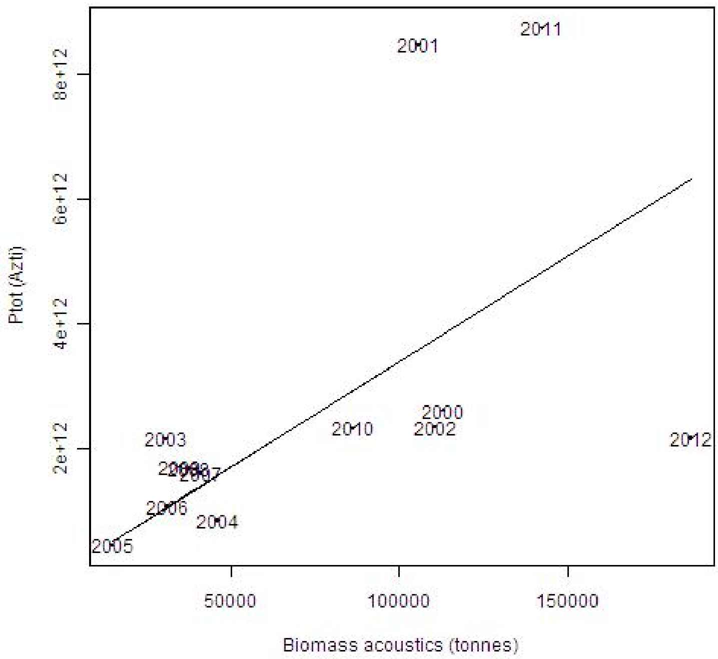

Fig. 1: Relationship between total daily egg production Ptot as estimated from BIOMAN surveys and spawning biomass as estimated from PELGAS surveys. The regression line is forced to pass by the origin. Slope= DF= 33.83 eggs g^{-1}. R-squared= 0.66.

Years 2001, 2011 and 2012 show largest residuals (Fig. 1). In 2012 the BIOMAN egg production estimate is lower than expected relative to the acoustic estimate while in 2001 and 2011 it was higher. The residuals correlated well with surface temperature (ts) and the index of water column stratification (deficit of potential energy, dep) (Figs. 2 and 3). In these figures the large residuals for years 2001, 2011 and 2012 stay unexplained by the hydrological indices and can thus be attributed to major discrepancies between the BIOMAN egg production and PELGAS biomass survey estimates. It is noteworthy that in most years, the 2 survey estimates are in agreement with coherent relation to the environment. The discrepancies in the three years 2001, 2011 and 2012 have until now stayed unexplained.

When survey estimates disagree in particular years, one may consider the survey indices as less reliable than for the years showing agreement. Therefore, a weighting depending on the coherence between survey estimates could be worth investigating as input to the ICES assessment model.

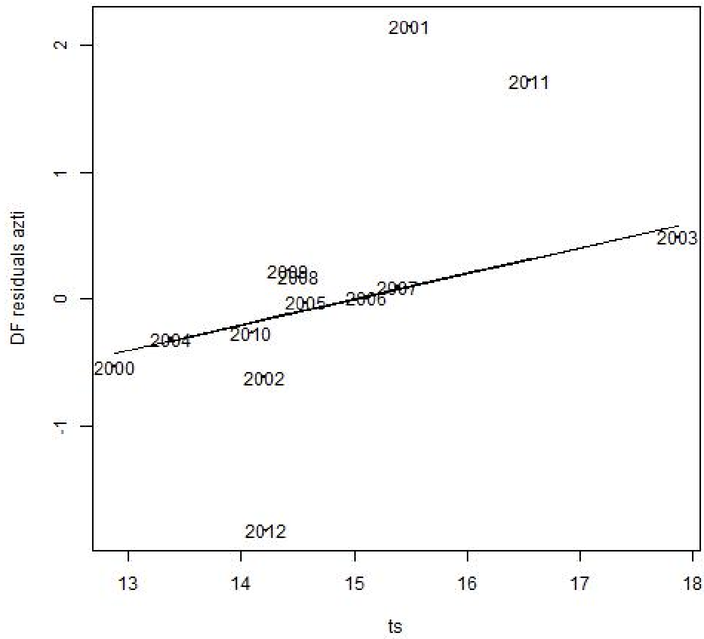

Fig. 2: Variation of the (standardized) residuals on Fig. 1 with surface temperature (ts). The regressionline is calculated without the large residuals in years 2001, 2011, 2012.

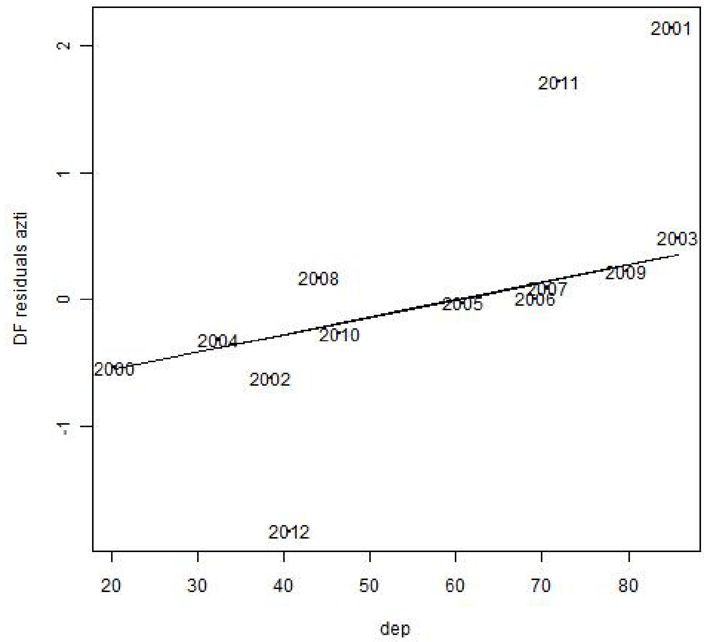

Fig. 3: Variation of the (standardized) residuals on Fig. 1 with deficit of potential energy (dep). The regression line is calculated without the large residuals in years 2001, 2011, 2012.

Further, during the PELGAS surveys the subsurface fish egg pump CUFES (Checkley et al. 1997) is operated contiuously along the acoustic transects thus resulting in an additional egg survey covering the entire French of the Bay of Biscay (Petitgas et al., 2009). The subsurface

CUFES egg concentrations (# eggs m-3) are converted to vertically integrated egg abundances (# eggs m-2) using a vertical model (Petitgas et al., 2006; 2009; Gatti, 2012). Here we used the latest version of the model (Gatti, 2012). The analysis procedure results in the estimation of Ptot using CUFES. A similar analysis as the one performed previously can be done by replacing the Ptot series of BIOMAN by the Ptot series of CUFES. Largest residuals are not exactly for the same years (Fig..4) with in particular a high positive residual for CUFES in 2007. In contrast with the BIOMAN survey series, Ptot and B are here in better agreement in 2012.

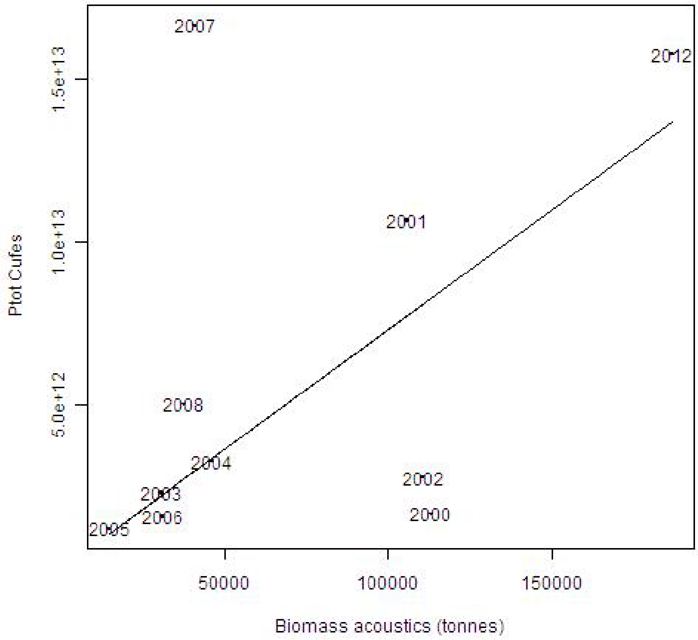

Fig. 4: Relationship between total daily egg production Ptot as estimated from BIOMAN surveys and spawning biomass as estimated from PELGAS surveys. The regression line is forced to pass by the origin. Slope= DF= 73.30 eggs g-1. R-squared=0.60.

WGACEGG considered promising the results so far and useful for the cross analysis of surveys (DEPM and acoustic) estimates. The potential for inclusion of the Ptot Cufes index as a new tunning abundance index for the assessment of anchovy is suggested to WKPELA 2013.. In effect, when survey estimates agree, the uncertainty is low. But when there are large unexplained discrepancies, the uncertainty is high even if each estimate is precise. Therefore the interest to use several indices so as to access better to the uncertainty.

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DEPM revision and implications in the current assessment

by

Santos, M., Ibaibarriaga, L. and Uriarte, A.

1. Introduction

For the Bay of Biscay anchovy the Daily Egg Production Method (DEPM; Lasker, 1985) is used to monitor the population on an annual basis since 1987 (Santiago and Sanz 1992, Motos et al. 2005). Resulting spawning stock biomass (SSB) and numbers at age estimates have been used as observations, together with the acoustic survey and the catch data, for the integral assessment of the stock. In particular the DEPM has been considered to provide an absolute index of abundance.

In 2008 a new method for classifying the postovulatory follicles was presented (Alday et al. 2008, 2010). This lead to new spawning frequency (S) estimates (Uriarte et al. 2012). This revision resulted in females spawning every 2 or 3 days (i.e. S between 0.33 and 0.5 with an average of 0.4 on average), instead of every 3 or 5 days (i.e S between 0.2 and 0.33) as perceived previously (Motos et al 1996). Given that the spawning frequency is one of the parameters required in the DEPM, the new spawning frequency estimates implied lower SSB (ICES 2011). This was already pointed out in the last assessments of the stock where the need for revising and updating the time series from the DEPM was highlighted (ICES 2009, 2012).

The methods for estimating the total daily egg production have been also under development in the last years. New methodology, such as generalised linear models (GLM), new criteria for cutting the tails, the incorporation of CUFES as an auxiliary sampler in the egg surveys have been incorporated gradually to routine applications of the DEPM. However, these methods have not been used to provide a complete updated of the time series of total daily egg production.

Further, population at age estimates from the DEPM are also available, which have been reported in previous years, but which need be revised accordingly to the revision of the adult parameters and regionalised biomass estimates.

This working document presents the revision of the SSB and population at age estimates according to the new available methods for spawning frequency and total daily egg production for the whole time series since 1987. Then, the implications for the assessment in comparison with the last ICES assessment based on the two stage biomass based model are studied.

2. Methods

2.1. Revision of the DEPM time series

The Daily Egg Production method (DEPM; Lasker 1985) estimates the Spawning Stock Biomass (SSB) as follows:

$$SSB = \frac{Daily\_Egg\_production}{Daily\_Fecundity} = k \frac{A \cdot E0}{R' \cdot S' \cdot (F'/W'_f)} = k \frac{A \cdot E0 \cdot W'_f}{R' \cdot S' \cdot F'} , \quad (1)$$

where ***A*** refers to the spawning area, $\boldsymbol{E_0}$ to the daily egg production per unit area (in other papers called P_0), ***R´*** is the sex ratio in mass, ***S´*** is the spawning fraction, or the fraction of mature females spawning per day, ***F´*** is the batch fecundity or number of eggs released daily per spawning females and $\boldsymbol{W'_f}$ refers to the mean weight of mature females.

For the application of the DEPM, concurrent egg and adult sampling are conducted every year (except in 1993) along the accepted spawning area of this stock at peak spawning time (May-June). See Figure 1 as an example of typical surveys.

For the egg sampling a systematic central sampling scheme with random origin and sampling intensity depending on the egg abundance is applied (Motos 1994). Stations are situated at intervals of 3 nm along 15 nm apart transects perpendicular to the coast. At each station a vertical plankton haul is performed using a PairoVET net (Pair of Vertical Egg Tow, Smith et al. 1985) with a net mesh size of 150 µm for a total retention of the anchovy eggs under all likely conditions.

The adult sampling over the spawning area is obtained for most of the years either by direct fishing from the egg sampling vessel (as in 1991 and 1992) or by collaboration with a French parallel acoustic survey (1994, 1997, 1998, 2001). This sampling is complemented with opportunistic samples collected from the commercial fleet operating in the area. Samples of two kg are selected at random from each haul. A minimum of one kg or 60 anchovies are weighted, measured and sexed and from the mature females the gonads of 25 non-hydrated females (NHF) are preserved for histological examination to determine the spawning fraction. Otoliths are extracted on board and read in the laboratory to obtain the age composition per sample.

The survey is aimed to get estimates of realised spawning area, egg production, fecundity, population biomass and age composition. The standard methods followed in the application of the DEPM method are detailed in Motos (1994) and Somarakis et al. (2004).

From the egg surveys the eggs collected at sea after fixation in formaldehyde, are sorted and classified into embryo development stages, which are used to obtain their most likely age in hours.

The daily egg production per area unit (P_0) is estimated together with the daily mortality rate (Z) from a general exponential decay mortality model of the form:

$$P_{i,j} = P_0 \exp\left(-Z\, a_{i,j}\right), \quad (2)$$

where $P_{i,j}$ and $a_{i,j}$ denote respectively the number of eggs per unit area in cohort j in station i and their corresponding mean age.

Since 2007 the egg ageing is done using the Bayesian method described in ICES (2004), Stratoudakis et al. (2006) and Bernal et al. (2011) and the egg mortality model is fitted as a generalised linear model (GLM, McCullagh and Nelder, 1989; ICES, 2004). Let the density of eggs in cohort j in station i, $P_{i,j}$, be the ratio between the number of eggs $N_{i,j}$ and the effective sea area sampled R_i (i.e. $P_{i,j} = N_{i,j} / R_i$). Then, model (2) can be written as:

$$\log\left(E[N_{i,j}]\right) = \log(R_i) + \log\left(P_0\right) - Z\, a_{i,j} \;, \quad (3)$$

where the number of eggs of daily cohort j in station i (N_{ij}) is assumed to follow a negative binomial distribution with logarithmic link function. The logarithm of the effective sea surface area sampled ($\log(R_i)$) is an offset accounting for differences in the sea surface area sampled and the logarithm of the daily egg production $\log(P_0)$ and the daily mortality Z rates are the parameters to be estimated.

Regarding the adult parameters, in the past spawning frequency (S) was derived from the average proportion of the day_1 past spawning cohort (Sanz et al. 1992; Motos 1996), averaged with POFs of day_2 since 2004. As oversampling of day_0 spawners at night (between 20:00 h and 04:00 hours) was noticed (Santiago and Sanz 1992; Motos 1996), and sampling at the beginning of the series used to take place mostly at night, the day_0 cohort was discarded from the estimation of S. Examination of the state of POF degeneration and the assignment of POF ages was directly done by an expert judgement in a single step following the descriptions of Hunter and Macewicz (1985). This resulted in a mean S of 0.25 (ranging from 0.17 to 0.33) in May and early June, during the DEPM surveys (Somarakis et al. 2004).

Recently, a validation of POF degeneration stages with time was made available for this population (Alday et al. 2008, 2010), indicating a faster degeneration process of POFs than previously estimated. This study suggested that the spawning fraction could be higher than formerly estimated. This demanded a revision of the basis for ageing POFs, i.e. allocating them to spawning cohorts, as well as a revision of the estimators used for spawning fraction, including here an evaluation of whether day_0 spawning cohort could be included in estimates of S. Such a revision was made by Uriarte et al. (2012), which showed that the mean joint incidence of day_0 and day_1 cohorts, S(0+1), was practically an unbiased estimator and slightly more precise than the traditional S(1) corrected estimator. This resulted in females spawning every 2 or 3 days (i.e. S between 0.33 and 0.5 with an average of 0.4).

Following all these improvements in methodology a full revision of the DEPM series was mandatory and here follows the way the revision was implemented:

a) New estimates of the P_0, Z and Ptot 1989-2012, based on a GLM with an external cutting at the 50% of the incubation temperature of eggs of each survey. For the years where egg data classified into stages were not available (1987, 1988) then the original total daily egg production (Ptot) estimates were left unchanged. This does not imply any major disturbance as the GLM and external cutting of the 50% does imply only very minor revisions of the former Ptot estimates (as shown in results).

b) New spawning frequency estimates were obtained after application of the new histological examination of gonads for oocyte and POFs stage classification of Alday et al. (2008) and the procedures described in Uriarte et al. (2012). The selected estimator was the mean of S(day 0) and S(day 1), i.e. S(0+1). Corrections of sample estimates +/- 5 hours around daily peak spawning time (at 23:00 hours) were applied according to the formulas in Uriarte et al (op. cit.) for an average S of 0.39. The relative correction factors within that period are in any case smaller than 3% of the actual sample estimates.

For the years with S estimates which could not be reviewed (2006, 1989, 1988 and 1987), but have their own estimates of the other reproductive parameters, old S was replaced by the average new S of the historical series 1990-2012. For the years which did not have any adult reproductive parameters, 1996, 1999 and 2000, the average Daily Fecundity (DF) estimate across the historical series 1990-20012 was adopted (of about 98.5 eggs $gram^{-1}$ day^{-1}).

c) The spatial principles (stratification schemes) adopted for all the new estimates respected the stratification scheme adopted originally by the authors of the respective surveys. As result of this, stratified estimates were obtained for the years 1990, 1991, 1992, 1994, 1997 and 1998, while for all other years Ptot and reproductive parameters and population at age estimates corresponded with a pool area processing.

For the pool area processing adult parameters were weighted according to a number proportional to the fraction of the spawning biomass represented by each sample and the parameters of the population in numbers were weighted by the former weighting factors divided by the mean of anchovies per sample.

The SSB was estimated as the ratio between the total daily egg production and the daily fecundity. The corresponding coefficient of variation was calculated using the delta method. Numbers at age were also re-evaluated as in the original implementations, but corresponding to the revised biomass estimates.

2.2. Implications for the assessment of the stock

The assessment conducted in the ICES Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA; ICES 2012) in June 2012 was updated using the new time series of DEPM. The assessment was based on the two-stage biomass-based model (Ibaibarriaga et al. 2008, ICES 2009) with the DEPM SSB as an absolute index and the parameter g accounting for growth and natural mortality considered constant across ages and years.

In addition, the implications of changing the model assumptions for the DEPM survey catchability ($q_{\text{depm}} = 1$ or estimated) and for the g parameter ($g = 0.68$ or estimated) were also explored. The model was fitted to the new DEPM time series for the following cases:

- DEPM SSB absolute and g fixed.
- DEPM SSB relative and g fixed.
- DEPM SSB absolute and g estimated.
- DEPM SSB relative and g estimated.

3. Results

3.1. Revision of the DEPM time series

The new total daily egg production and daily mortality estimates are given in

ICES. 2011. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG), 21–25 November 2011, Barcelona, Spain. ICES CM 2011/SSGESST:20. 157 pp.

Motos, L., 1994. Estimación de la biomasa desovante de la población de anchoa del Golfo de Vizcaya Engraulis encrasicolus a partir de su producción de huevos. Bases metodológicas y aplicación. Ph. D. thesis UPV/EHU, Leioa.

Motos, L. 1996. Reproductive biology and fecundity of the Bay of Biscay anchovy population (Engraulis encrasicolus L.) Sci. Mar. 60 (suppl. 2), 195-207.

Motos, L., Uriarte, A., Prouzet, P., Santos, M., Alvarez, P., Sagarminaga, Y., 2005. Assessing the Bay of Biscay anchovy population by DEPM: a review 1989–2001. In: Castro, L.R., P. Freón, C. D. van der Lingen and A. Uriarte, editors, Report of the SPACC Meeting on Small Pelagic Fish Spawning Habitat Dynamics and the Daily Egg Production Method (DEPM). GLOBEC Report 22, xiv, pp. 88-90.

Santiago, J., Sanz, A., 1992. Egg production estimates of the Bay of Biscay anchovy, Engraulis encrasicolus (L.), spawning stock in 1987 and 1988. Bol. Inst. Esp. Oceanogr. 8, 225-230.

Santos, M. Uriarte, A. and L. Ibaibarriaga, 2012: Spawning Stock Biomass estimates of Bay of Biscay anchovy (Engraulis encrasicolus, L.) in 2012 applying the DEPM. Working Document to the ICES WGACEGG, 26 - 30 November 2012 at Fuengirola (Spain)

Sanz A., L.Motos & A. Uriarte, 1989: Daily Fecundity of the Bay of Biscay Anchovy Population in 1987. ICES CM 1989/H:42

Sanz, A., Motos L., Uriarte, A, 1992. Daily fecundity of the Bay of Biscay anchovy, Engraulis encrasicolus (L.), population in 1987. Bol. Inst. Esp. Oceanogr. 8, 203-214.
Santos et al. 2012

Somarakis, S., Palomera, I., García, A., Quintanilla, L., Koutsikopoulos, C., Uriarte, A., Motos, L., 2004. Daily egg production of anchovy in European waters. ICES J. Mar. Sci. 61, 944-958.

Uriarte A., Alday A., Santos M, and Motos L., 2012: A re-evaluation of the spawning fraction estimation procedures for Bay of Biscay anchovy, a species with short interspawning intervals. Fisheries Research. 117–118: 96–111 (doi: 10.1016/j.fishres.2011.03.002)

Table 1 and Figure 2. Differences are minima between the old and the new revised series of Ptot. During the implementation of the GLM some ad hoc decisions were required as in year 1992 the egg mortality rate had incorrect sign and in the GLM it was fixed at 0.27 (mean of the new historical series). For some of the other years the total daily egg mortality was non-significant. As said before the total daily egg production estimates in 1987 and 1988 could not be recalculated according to the new methodology as the stage classified data were not available.

The parameters from the adult sampling are given in Table 2. The only noticeable changing arises from the revision of the spawning frequency (Figure 3). New S is on average about 57% higher than the former estimates.

The population in percentage and in numbers at age are in Table 3 and the changes are minima as expected (Figure 4). The relative age composition (% by ages) in 1987-1989 was kept equal to the original estimates, as the original data were not available.

The old and new time series of SSB are shown in **¡Error! No se encuentra el origen de la referencia.** New estimates go parallel to the old one, showing similar year to year fluctuations of the SSB (Figure 5), but on average new SSB estimates are around 0.66 the old estimates (so 33% smaller). The major driver of this correction is due to the upward revision of the spawning frequency, as the changes of Ptot are relatively small.

The new series of SSB estimates, along with the old SSB series, will be passed to the ICES Benchmark WKPELA for consideration. The new series can be considered as the one complying with the usual standard implementation of the method (with P0 based on common GLM fitting across stations and DF on the analysis of reproductive parameters from adult fish caught at the fishing stations following to the most reliable biological information on POFs degeneration and S estimation procedures.

3.2. Implications for the assessment

The new DEPM time series were used to update the last ICES assessment based on the two-stage biomass-based model. Model parameters other than annual recruitment estimates are compared in Table 4. With the new DEPM time series, the catchability of the acoustic survey is larger and the precision of the DEPM SSB estimates has decreased significantly. Given that the revision of the DEPM SSB series was downwards, the initial biomass and the average recruitment are lower with the revised time series. As a result, the time series of recruitment (age 1 in mass –tonnes- at the beginning of the year) and SSB are lower, the larger differences corresponding to the nineties (Figure 6).

The Pearson residuals of the assessment model when the new DEPM series are used are shown in Figure 7. The residuals for the DEPM SSB are mostly negative indicating that the assumptions on DEPM catchability might not be appropriate any more.

Therefore, assumptions on the DEPM survey catchability and on the g parameter were revisited. Posterior median and 95% probability intervals of the model parameters for these four cases are shown in Table 5 and Figure 8. Regardless the catchability of the DEPM SSB index, the recruitment values are larger and the surveys catchability parameters are lower when g is fixed at 0.68. When the DEPM SSB is considered as a relative index, its catchability parameter is estimated to be around 0.5 and the catchability of acoustics is around 1 when g is fixed and around 1.2 when g is estimated.

4. Conclusions

- DEPM revised downwards.
- This implies that the assessment goes downwards.
- The assumption of DEPM providing an absolute index might not be adequate.
- However, there is lack of identifiability. If both catchabilities are to be estimates, need to make assumptions on M or add more data for model fitting.

5. References

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Somarakis, S., Palomera, I., García, A., Quintanilla, L., Koutsikopoulos, C., Uriarte, A., Motos, L., 2004. Daily egg production of anchovy in European waters. ICES J. Mar. Sci. 61, 944-958.

Uriarte A., Alday A., Santos M, and Motos L., 2012: A re-evaluation of the spawning fraction estimation procedures for Bay of Biscay anchovy, a species with short interspawning intervals. Fisheries Research. 117–118: 96–111 (doi: 10.1016/j.fishres.2011.03.002)

Table 1: Time series of total daily egg production and mortality rates from the DEPM.

Year	Spawn area	Ptot	cv(Ptot)	P0	cv(P0)	Z	cv(Z)
1989	17,070	8.85.E+11	0.2748	51.86	0.2748	-0.30	-0.5357
1990	47,231	4.79.E+12	0.1470	101.48	0.1470	-0.49	-0.1816
1991	22,430	1.34.E+12	0.2595	59.53	0.2595	-0.23	-0.7303
1992	52,736	4.49.E+12	0.1886	85.05	0.1886	0.01	9.6543
1994	46,909	4.44.E+12	0.1542	94.73	0.1542	-0.23	-0.3357
1995	32,108	4.06.E+12	0.1521	126.34	0.1521	-0.34	-0.1770
1996	29,074	2.57.E+12	0.1469	88.53	0.1469	-0.30	-0.2366
1997	47,214	2.77.E+12	0.1187	58.62	0.1187	-0.23	-0.2398
1998	75,971	8.41.E+12	0.1153	110.64	0.1153	-0.42	-0.1640
1999	49,709	4.52.E+12	0.1164	90.96	0.1164	-0.16	-0.4976
2000	37,916	2.79.E+12	0.1198	73.53	0.1198	-0.15	-0.4065
2001	72,022	7.57.E+12	0.1150	105.06	0.1150	-0.37	-0.1954
2002	35,268	2.27.E+12	0.1427	64.43	0.1427	-0.17	-0.3822
2003	42,915	2.20.E+12	0.1687	51.35	0.1687	-0.35	-0.3156
2004	20,364	8.61.E+11	0.0923	42.26	0.0923	-0.24	-0.1279
2005	27,863	4.48.E+11	0.1752	16.08	0.1752	-0.18	-0.4728
2006	24,614	1.12.E+12	0.2070	45.53	0.2070	-0.24	-0.4434
2007	34,449	1.25.E+12	0.1702	36.26	0.1702	-0.08	-1.0504
2008	33,502	1.74.E+12	0.1959	51.96	0.1959	-0.32	-0.3472
2009	28,214	1.53.E+12	0.1299	54.39	0.1299	-0.22	-0.2899
2010	37,517	2.22.E+12	0.1217	59.12	0.1217	-0.33	-0.1578
2011	69,094	9.56.E+12	0.1291	138.37	0.1291	-0.36	-0.2380
2012	38,974	2.09.E+12	0.1837	53.68	0.1837	-0.17	-0.5145

Table 2: Time series of adult parameters from the DEPM

Year	Actual dates	Main Month	DEP	R'	S. New	F	Wf	Daily Fec.	SSB
1987	2 - 7 June	June	2.20E+12	0.540	0.395	15,904	33.81	100.22	**21,942.6**
1988	21 - 28 May	May	5.01E+12	0.520	0.395	15,783	29.23	110.78	**45,230.0**
1989	10 - 21 May	May	8.85E+11	0.541	0.395	12977	29.63	93.41	**9,477.1**
1990	4 - 15 May	May	4.69E+12	0.548	0.347	6,617	18.846	63.81	**74,371.1**
1991	16May-07Jun	May	1.42E+12	0.544	0.396	12,137	23.119	107.60	**13,294.9**
1992	16May-13Jun	May	6.66E+12	0.547	0.398	9,688	18.508	111.57	**60,331.7**
1993	No Survey								
1994	17 May-3June.	May	3.95E+12	0.550	0.384	11,236	22.524	104.90	**37,777.2**
1995	11 - 25 May	May	4.06E+12	0.530	0.397	13,038	24.62	111.59	**36,432.4**
1996	18 - 30 May	May	2.57E+12					98.44	**26,148.5**
1997	9 - 21 May	May	2.52E+12	0.530	0.390	8,019	18.573	87.59	**29,021.5**
1998	18 May - 8 June	May	8.03E+12	0.560	0.395	8,819	18.70	104.31	**77,642.6**
1999	22 May - 5 June	May-Jun	4.52E+12					98.44	**45,931.5**
2000	2- 20 May	May	2.79E+12					98.44	**28,320.9**
2001	14-May - 8 June	May-Jun	7.57E+12	0.531	0.409	11,195	24.27	100.11	**75,826.4**
2002	6 - 21 May	May	2.27E+12	0.539	0.401	16,426	35.08	101.29	**22,461.7**
2003	22 may-9Jun	May-Jun	2.20E+12	0.536	0.414	14,591	23.65	137.04	**16,108.5**
2004	2 may- 17 May	May	8.61E+11	0.540	0.380	8,871	24.13	75.46	**11,495.9**
2005	8 may- 28 may	May	4.48E+11	0.551	0.427	12,094	30.40	93.68	**4,831.9**
2006	4-24 May	May	1.12E+12	0.537	0.395	9,046	25.46	75.36	**14,872.0**
2007	3-23 May	May	1.25E+12	0.536	0.399	11,897	26.56	95.93	**13,059.9**
2008	6-26 may	May	1.74E+12	0.541	0.496	14,692	29.15	135.22	**12,898.2**
2009	5-25 may	May	1.53E+12	0.565	0.428	14,097	28.45	119.99	**12,831.6**
2010	5-20 may	May	2.22E+12	0.533	0.342	8,353	21.27	71.57	**31,277.4**
2011	6-28 may	May	9.56E+12	0.553	0.346	6,990	18.86	71.00	**135,732.0**
2012	10-29 may	May	2.09E+12	0.530	0.351	8,901	20.92	79.16	**26,663.5**

Table 3: Time series of population at age estimates from the DEPM.

Year	SSB	W (g)	Tot Population	Page 1%	Page 2%	Page 3%	Numage 1	Numage 2	Numage 3	SSBage 1	Bage1%
1987	21,942.6	26.57	825.77	0.5810	0.2932	0.1258	479.81	242.10	103.86	10,636.9	48.5%
1988	45,230.0	23.55	1920.48	0.8781	0.0964	0.0254	1686.43	185.23	48.82	37,813.0	83.6%
1989	9,477.1	25.53	371.19	0.5234	0.4383	0.0383	194.28	162.69	14.22	4,127.5	43.6%
1990	74,371.1	16.12	4617.70	0.9759	0.0206	0.0034	4,506.9	95.1	12.2	71,142.5	95.7%
1991	13,294.9	19.91	670.67	0.7037	0.2915	0.0047	473.7	193.8	3.2	7,820.7	58.8%
1992	60,331.7	15.36	3986.46	0.9648	0.0327	0.0025	3,849.5	127.0	10.0	56,202.0	93.2%
1993	No Survey										
1994	37,777.2	19.92	1904.65	0.7164	0.2702	0.0134	1,370.3	508.9	25.5	23,739.4	62.8%
1995	36,432.4	20.74	1763.60	0.8525	0.1254	0.0221	1,507.2	218.1	38.3	28,416.4	78.0%
1996	26,148.5									0.0	
1997	29,021.5	13.99	2096.18	0.8539	0.1422	0.0040	1,798.1	290.1	8.1	21,098.4	72.7%
1998	77,642.6	15.80	4963.92	0.8782	0.1138	0.0080	4,368.7	555.7	39.7	60,344.0	77.7%
1999	45,931.5										
2000	28,320.9										
2001	75,826.4	20.33	3761.06	0.7021	0.2738	0.0242	2,658.1	1,013.6	89.5	45,779.1	60.4%
2002	22,461.7	29.67	759.87	0.2695	0.6009	0.1297	207.2	454.7	98.0	4,330.4	19.3%
2003	16,108.5	18.38	880.87	0.8069	0.1390	0.0541	712.8	121.3	47.2	11,400.9	70.8%
2004	11,495.9	18.44	632.31	0.8780	0.0949	0.0271	557.5	58.0	16.8	9,120.7	79.3%
2005	4,831.9	25.76	188.41	0.3676	0.6079	0.0245	69.9	114.0	4.5	1,438.7	29.8%
2006	14,872.0	18.17	818.37	0.8220	0.1350	0.0430	672.69	110.52	35.15	10,451.2	70.3%
2007	13,059.9	19.30	682.07	0.7022	0.2593	0.0385	480.0	175.6	26.6	7,946.3	60.8%
2008	12,898.2	23.26	559.41	0.4286	0.5062	0.0652	242.2	280.9	36.2	3,940.4	30.5%
2009	12,831.6	19.62	659.31	0.6405	0.1895	0.1660	424.7	124.4	107.6	5,460.1	42.6%
2010	31,277.4	17.94	1756.12	0.8664	0.1266	0.0070	1,522.5	221.4	12.2	25,543.3	81.7%
2011	135,732.0	14.36	9556.20	0.8931	0.1045	0.0024	8,546.8	986.7	22.7	112,202.2	82.7%
2012	26,663.5	15.76	1733.33	0.4956	0.4871	0.0174	880.7	822.5	30.1	8,882.4	33.3%

Table 4: Comparison of the ICES assessment with the old and new DEPM time series. Posterior median and 95% probability intervals for the model parameters.

	OLD DEPM (ICES 2012)			NEW DEPM		
	2.50%	Median	97.50%	2.50%	Median	97.50%
q_{ac}	0.884	1.158	1.505	0.990	1.313	1.719
ψ_{depm}	2.343	4.752	8.948	1.093	2.233	4.216
ψ_{ac}	2.364	5.016	9.528	2.630	5.606	10.691
ξ_{depm}	3.912	5.367	7.908	4.351	5.869	8.173
ξ_{ac}	2.982	3.784	4.565	2.742	3.547	4.271
μ_R	10.250	10.600	10.930	10.160	10.520	10.870
ψ_R	0.843	1.453	2.353	0.816	1.399	2.257
B_0	34090	38570	47070	33310	36890	42230

Table 5: Comparison for the assessment model under different assumptions regarding the catchability of the surveys and the estimation of the g parameter when the new DEPM time series are used.

	g FIXED						g ESTIMATED					
	DEPM ABSOLUTE			DEPM RELATIVE			DEPM ABSOLUTE			DEPM RELATIVE		
	2.50%	Median	97.50%	2.50%	Median	97.50%	2.50%	Median	97.50%	2.50%	Median	97.50%
q_{depm}				0.351	0.489	0.653				0.383	0.559	0.818
q_{ac}	0.990	1.313	1.719	0.717	1.003	1.357	1.275	1.703	2.201	0.793	1.162	1.769
ψ_{depm}	1.093	2.233	4.216	2.014	3.995	7.092	1.969	4.100	7.466	2.187	4.315	8.003
ψ_{ac}	2.630	5.606	10.691	2.741	5.944	11.740	2.878	6.423	12.151	2.772	5.916	11.750
ξ_{depm}	4.351	5.869	8.173	3.415	4.438	6.656	3.157	4.522	7.638	2.763	4.420	7.819
ξ_{ac}	2.742	3.547	4.271	2.859	3.837	4.895	3.054	4.077	7.652	2.804	3.898	6.350
g							0.390	0.498	0.627	0.478	0.615	0.734
μ_R	10.160	10.520	10.870	10.330	10.700	11.080	9.816	10.220	10.620	10.050	10.540	11.000
ψ_R	0.816	1.399	2.257	0.843	1.456	2.349	0.724	1.232	1.988	0.795	1.372	2.216
B_0	33310	36890	42230	33760	39920	54620	23240	29140	35620	26880	35975	54320

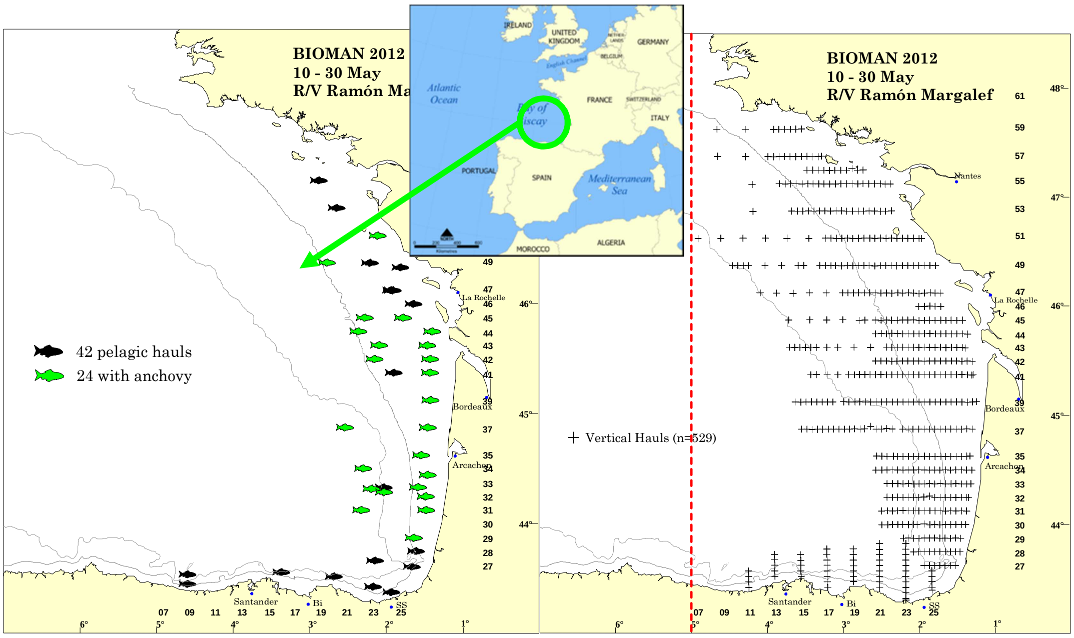

Figure 1: Adult fishing hauls and plankton stations during BIOMAN 2012, in May (from Santos et al. 2012).

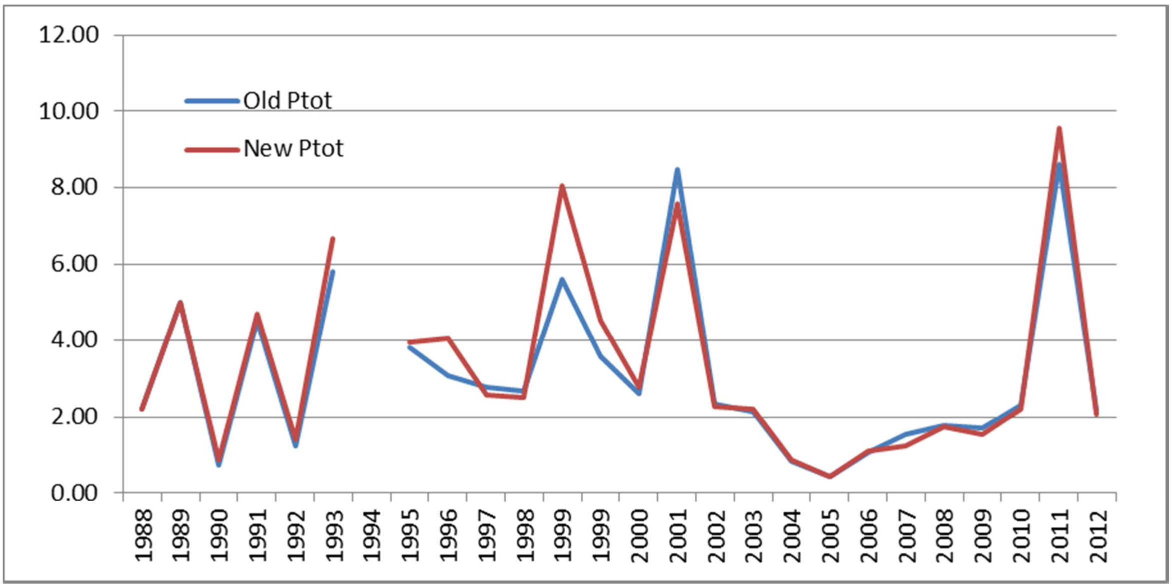

Figure 2: Comparison of the Original Total Egg Production series (Old Ptot) and current revised series (new Ptot).

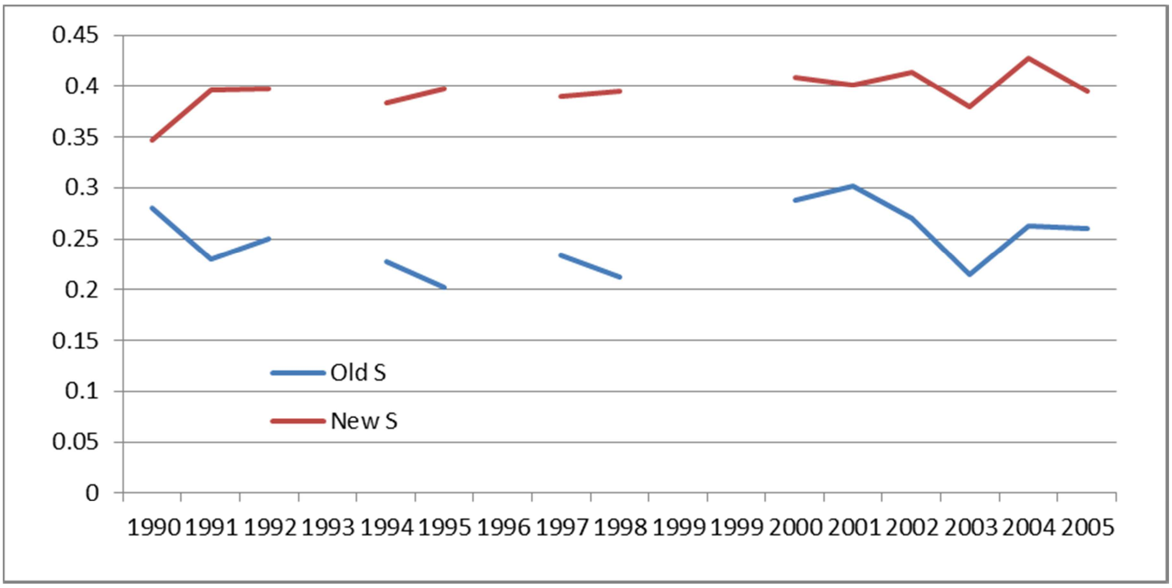

Figure 3: Comparison of the Original Spawning Frequency Series (Old S) and current revised S series (new S).

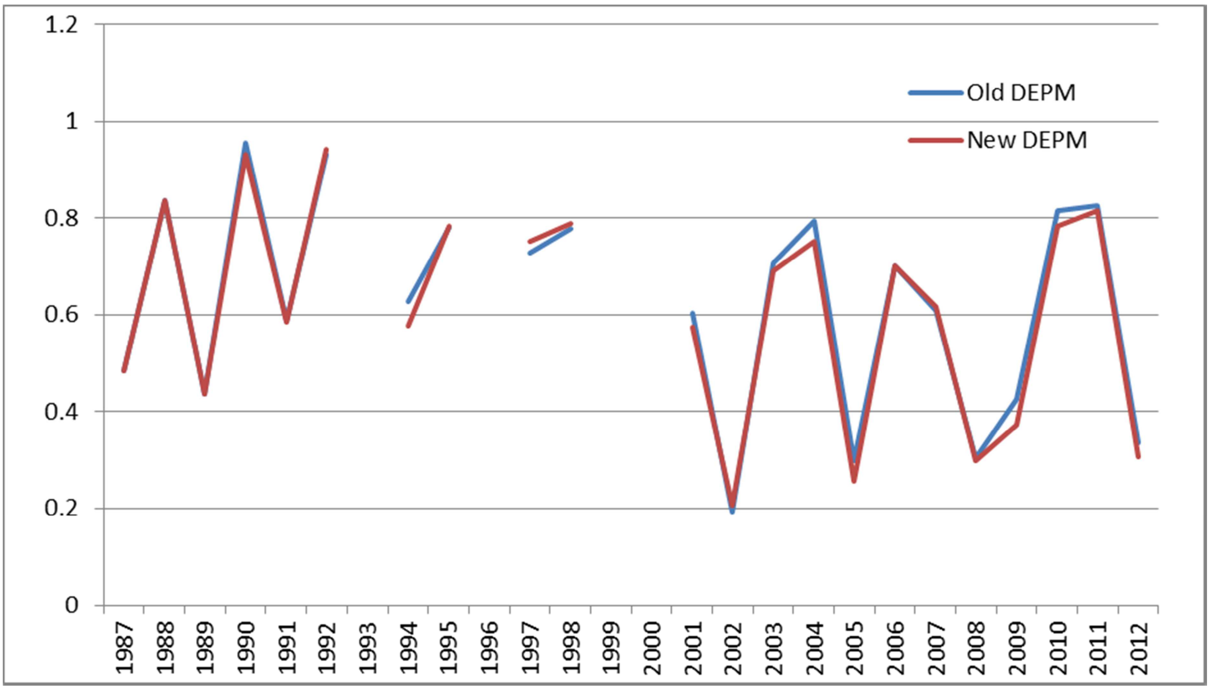

Figure 4: Comparison of the Original Proportion at age 1 in mass (Old DEPM) and current revised Proportion at age 1 in mass series (new DEPM).

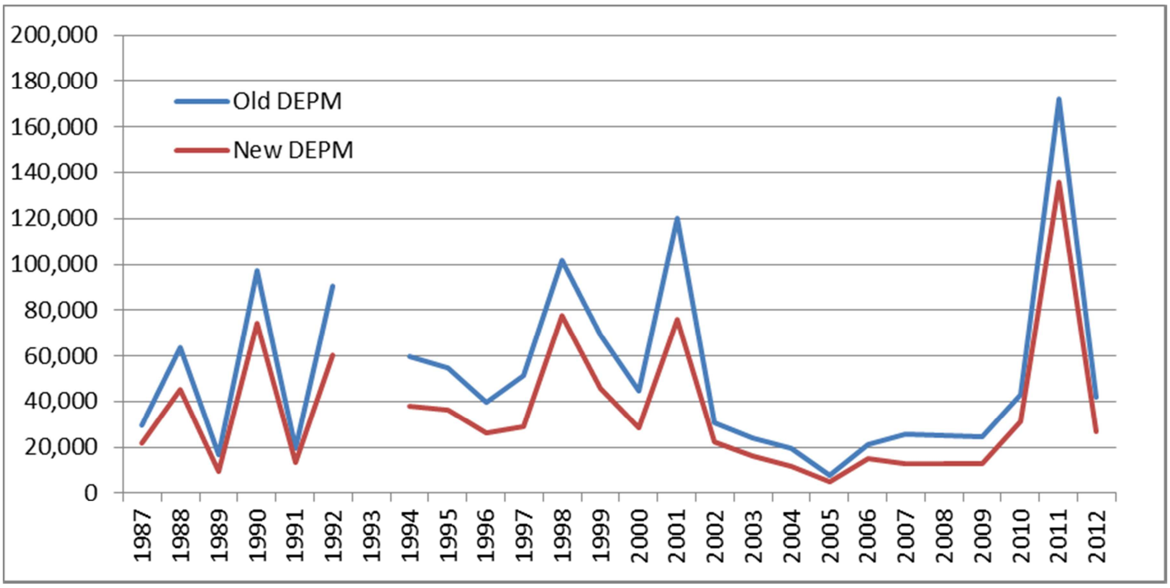

Figure 5: Comparison of the Original Total Spawning Biomass series (Old DEPM) and current revised Biomas series (new DEPM).

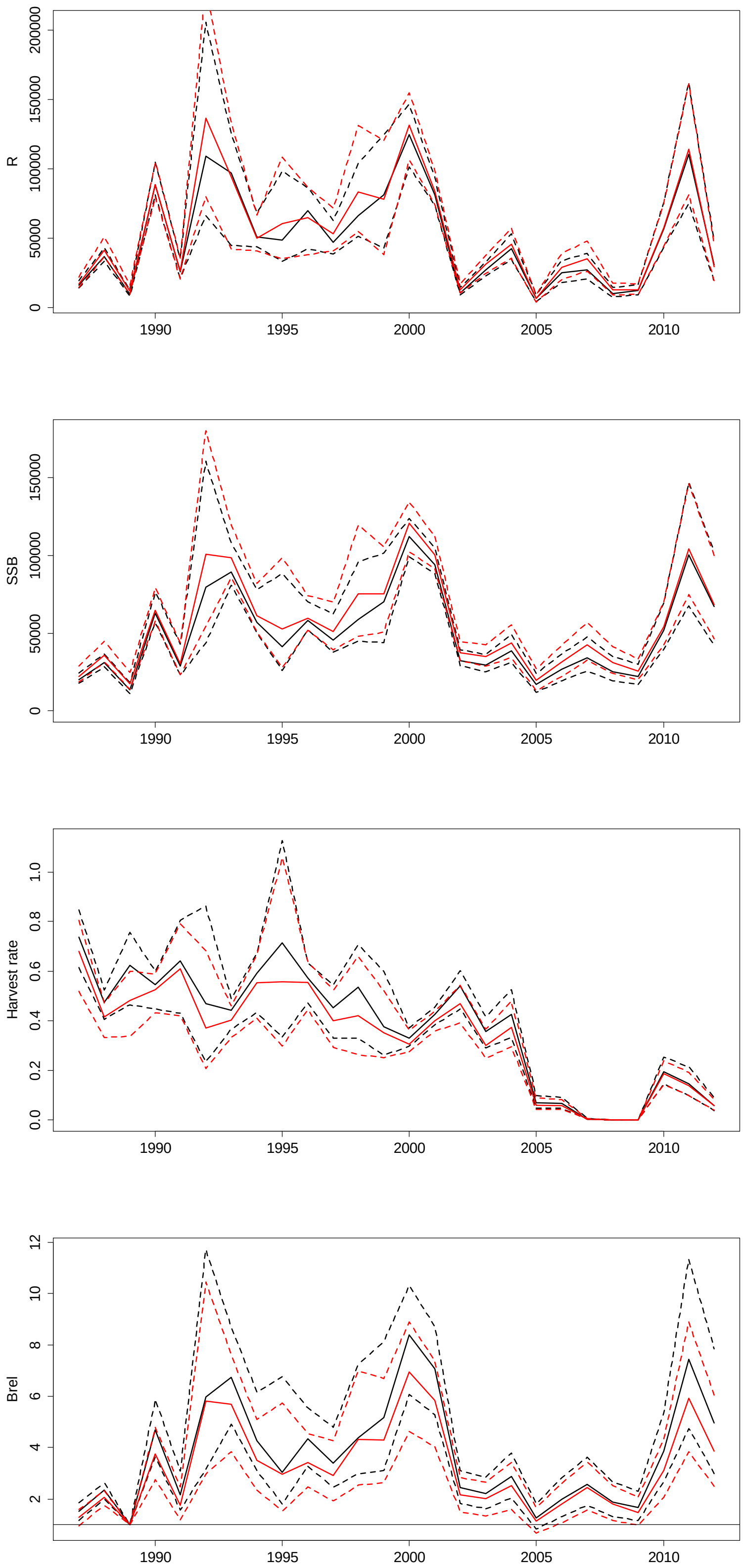

Figure 6: From top to bottom comparison between recruitment (tonnes), SSB (tonnes), harvest rate and relative biomass when the old (in red) and updated (in black) time series of SSB from the DEPM are used in the current assessment model.

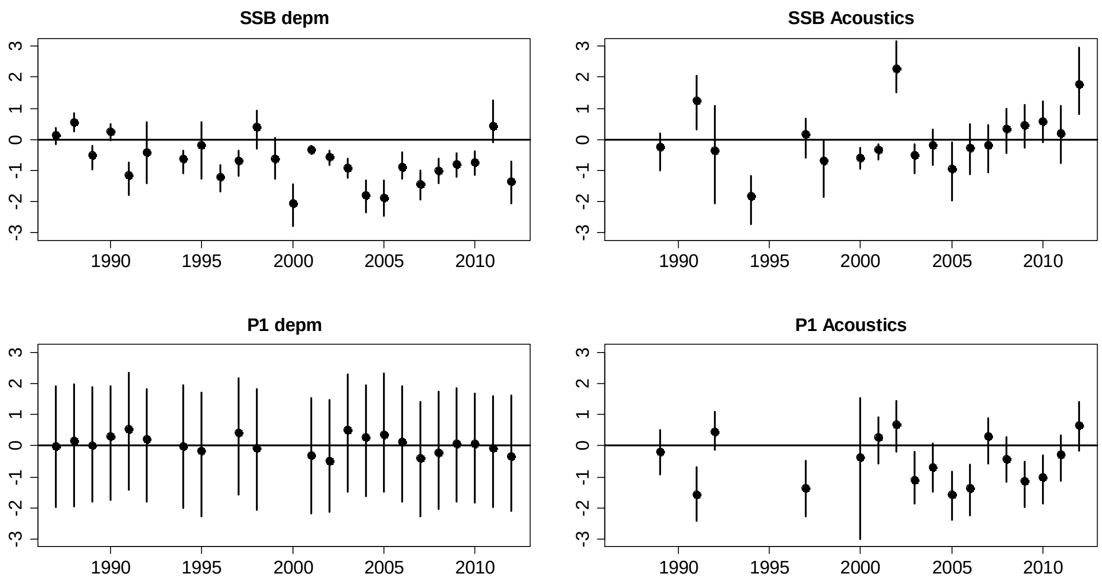

Figure 7: Pearson residuals for the current assessment model for Bay of Biscay anchovy when the new DEPM new time series are used.

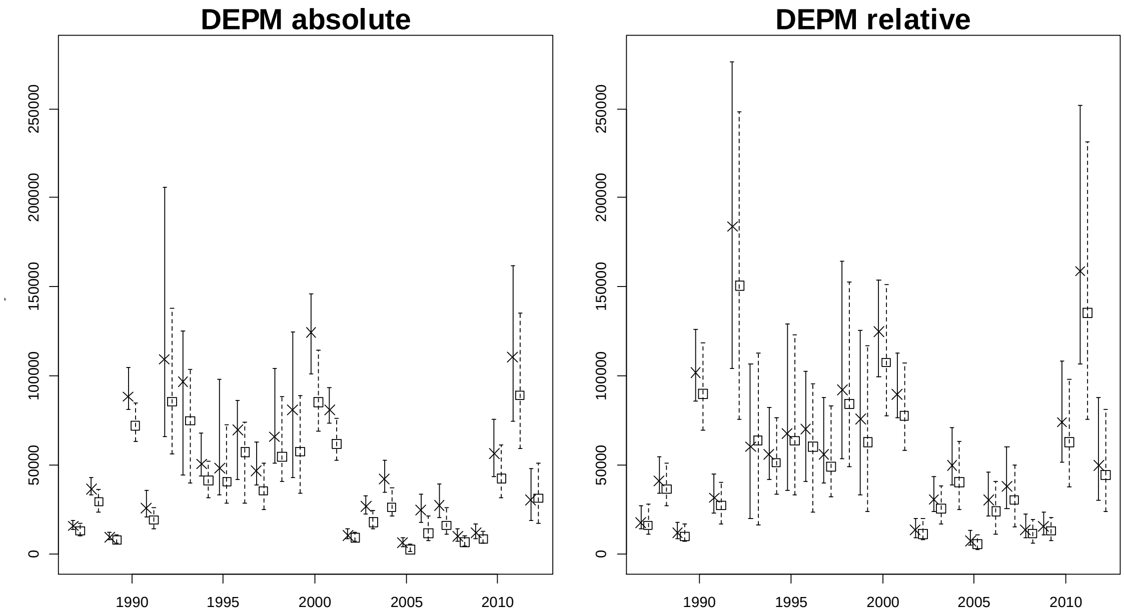

Figure 8: Recruitment (tonnes) when the new DEPM time series are used for DEPM absolute (left) and relative (right) under different assumptions for the g parameter (cross and solid line when g is fixed at 0.68 and open square and dashed line when it is estimated).

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ASSESSING NATURAL MORTALITY OF ANCHOVY DIRECTLY FROM SURVEYS' POPULATION ESTIMATES

Partial Update of the ICES CM 2010/C:12

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Abstract:
In ordinary catch at age models, natural mortality conditions and determines the catchabilities at age obtained for the surveys which tune the assessments. For the same reason, inferring the Natural mortality of a fish stock from surveys' estimates, require some assumption of the survey catchabilities at age. The anchovy fishery in the Bay of Biscay has been closed since 2005 up to 2010, due to low biomass levels. In the mean time, and since 1989, the population has been directly monitored by two independent surveys, acoustic and egg (DEPM) surveys, which supplied the basic information for the assessment of this stock carried out by ICES. The closure of the fishery supposes a major contrast on total mortality levels affecting the population in comparison with the former period of exploitation, suitable to get estimates of Natural and Fishing mortalities, under the assumption of no major changes in M occurring between both periods. Log linear models and a seasonal integrate catch at age analysis were tuned to the fishery and two series of surveys under the assumption of constant catchabilities across ages for the two surveys' population estimates. The analysis of the period 1987-2012, searching for a single and constant natural mortality at age, results in an M around 0.8-0.9. But there is a firm evidence that natural mortality at ages 2 and older (M2+) is markedly higher than at age 1 (M1) a likely indication of senescent mortality, a possibility suggested since a long time for this type of short living species. M1 may lay somewhere between 0.7 and 0.9 whilst M2+ can be around 1.5 - 1.75, depending on the concrete set of data being used for the linear models (either the whole data or a subset of it).
Keywords: Anchovy; Natural mortality, M at age, Integrate assessment.

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1. Introduction

Natural mortality (M) is a key parameter scaling the outcomes from any assessment concerning population and biomass levels. Despite its relevance, it often has to be assumed due to the difficulties to estimate it separately from the fishing mortality (F) (Cotter et al. 2004). Even in cases when a direct monitoring of the population is made by research survey, the distinction between M and F is hard to be made unless the catchability of the survey is known or assumed. In the absence of proper estimates, natural mortality can be estimated indirectly from meta analysis of M from a wide range fish species of different growth dynamics and environmental conditions (Pauly 1980, Gislason et al.2010). Certainly, the best method to estimate natural mortality is analysing two periods of high contrast in the level of fishing mortality (i.e. fishing effort). The difference in the total mortality should be proportional to the change in effort between these two periods allowing to split fishing from natural mortality (Gulland 1983, Vetter 1988, Sinclair 2001, Wang et al. 2009).

The life history of fishes suggest that natural mortality will change throughout the successive life stages from very high values in the egg larval and juvenile stages to medium or low values across its mature life span until an increasing natural mortality in senescence. Several models have been proposed to represent this pattern at age of the natural mortality (Chen and Watanabe 1988, Caddy 1991, 1996, Abella 1997). Short lived species, as engraulidae, sandeels or capelin have usually natural mortalities higher than 0.6 in their adult phase (Gislason et al. 2010) and for them the senescence increase of M is particularly expected to be noticeable (Beverton 1963). In some cases, as for sandeels, this increasing M with age has been suggested (Cook 2004) and an extreme case is that of capelin showing massive mortalities after their first spawning. The major difficulty in evidencing changing natural mortalities with age is the confusion between differential catchability (and availability) phenomena with natural mortality patterns at age (Caddy 1991, Vetter 1988).

The Bay of Biscay anchovy is a short living species, rarely over passing its third year of life, which is yearly monitored by two independent surveys: an acoustic survey (Pelgas series –Ifremer-) and a Daily Egg Production Method (DEPM Bioman series –AZTI-). Both surveys supply biomass and population at age estimates, which constitute the basic information for the assessment of this stock carried out by ICES. This stock was assessed until 2004 by ICA (Integrated Catch at age Analysis, Patterson and Melvin 1996) (ICES 2005), being subsequently assessed by a Bayesian two stage biomass model (Ibaibarriaga et al. 2008). In both cases natural mortality was assumed to be constant across ages and years and fixed at 1.2. This value was inferred from the direct estimates of the population at age by the DEPM, under the assumption of unbiased absolute estimates of the population, and accounting for the catch removals (Prouzet et al. 1999 Uriarte 1996). While the Bayesian two stage biomass model assumes constant catchabilty at age of surveys, ICA calculated catchabilties at age for the surveys if demanded. When both surveys were assumed to give relative indices of abundance, then their respective catchabilities at age were 50% higher for age 2 than for ages 1 or 3 (ICES 2005); this is a result hard to accept given the sufficient surveys coverage of the spatial distribution of the stock. Certainly an alternative explanation of that result could be due to a differential mortality at age of anchovies.

The closure of the anchovy fishery in the Bay of Biscay between 2005 and 2010, due to low biomass levels, provided a unique occasion to check the actual level of natural mortality and the potential for a pattern of changing natural mortality at age. The closure of the fishery supposes a major contrast on total mortality levels affecting the population in comparison with the former period of exploitation, suitable to get estimates of natural and fishing mortalities, under the assumption of no major changes in M occurring between both periods.

In this paper we apply several methods to estimate the natural mortality values of anchovy in the Bay of Biscay . We first perform a direct analysis (by linear models) of the total mortalities between successive survey estimates of the population in numbers at age and analyse the changes between the period prior and after the closure of the fishery. Next, the natural mortality is estimated by regression of the total mortality on an indicator proportional to F derived from the ratio of the catches over the average survey estimates of abundance. Finally an integrate catch at age analysis with a seasonal separable model of fishing mortality is applied to the analysis of the fishery in order to see what levels of natural mortality optimise the assessment, under the assumption of no differential catchability at age affecting the surveys.

2. Material and Methods

3.

2.1.Data

Population at age estimates are available from the acoustic and DEPM surveys that are carried out in May at mid spawning period. These estimates are split in either three (1,2 and 3+) or two age groups (1and 2+). DEPM surveys, since 1987 and acoustic surveys since 2000 report population at ages 1, 2 and 3+ (with 3+ referring to three year old and older anchovies), whilst previous years of acoustic estimates report the population at ages 1 and 2+ (with 2+ referring to 2 year old or older fishes) (in 1989, 1991&92 and in 1997, Table 1). Let $U_{a,y,s}$ denote the number of individuals at age a in year y estimated from survey s. For each survey and from every pair of consecutive population at age estimates, total mortality at age a in year y from survey s, $Z_{a,y,s}$ estimates were derived for the ages 1 (from age 1 to 2), 1+ (from ages 1+ to 2+) and 2+ (from ages 2+ to 3+) as the log of the ratio of successive age classes in consecutive surveys (Table 2).

$$\ln\left[\frac{U_{a,y}}{U_{a+1,y+1}}\right] = \ln\left[\frac{N_{a,y}\cdot Q_{a,s}\cdot \exp(\varepsilon_{s,y})}{N_{a+1,y+1}\cdot Q_{a+1,s}\cdot \exp(\varepsilon_{s,y+1})}\right] = Z_{a,y} + \ln\left[\frac{Q_{a,s}}{Q_{a+1,s}}\right] + \varepsilon_s = F_{a,y} + M_{a,y} + \ln\left[\frac{Q_{a,s}}{Q_{a+1,s}}\right] + \varepsilon_s$$

$$\hat{Z}_{a,y,s} = \ln\left[\frac{U_{a,y,s}}{U_{a+1,y+1,s}}\right] = F_{a,y} + M_{a,y} + \ln\left[\frac{Q_{a,s}}{Q_{a+1,s}}\right] + \varepsilon_{y,s} \qquad \text{equation 1}$$

Notice from the above expression that the ratio of successive abundance indices of the same cohort will be equal to the total mortality Z only if the catchabilities of the successive age classes are equal. This is the first assumption we explicitly make in this study. In addition the larger the observation errors the poorer the estimates of Z will be. The second assumption made in the analysis is that the errors of the observations made by the surveys are log normal and of equal magnitude for both surveys (the requirement of homocedasticity for the ANOVA performed later).

Mean Z_{1+} estimates should provide an overall estimate of Z common to all ages, being roughly closer to the Z by age of the most abundant age classes (in this case of Z at age 1), whilst Z_1 and Z_{2+} should provide indications of the level of total mortality for the one year old and older fishes respectively. Notice that changes in the Z between these two age groups for the period when the fishery was open can be due either to changes in the fishing mortality or in the level of natural mortality, provided the surveys do not show any differential catchability at age. However for the recent period when the fishery has been closed, Z equals M for all ages and any change in Z should be indicative of changes in M with age.

It should be noted that as surveys are made at mid spawning time, these Z estimates refer to the mortality occurring between successive spawning periods and not over the official year calendar.

In order to make use of the whole set of data for the estimation of M through a linear model, an indicator of the fishing intensity for each year was estimated as the ratio of the catches between surveys and the mean abundance of the cohort between surveys. This follows from the catch equation:

$$C_{a,y} = F_{a,y} \cdot \overline{N}_{a,y} = F_{a,y} \cdot \frac{N_{a,y}}{Z_{a,y}} \cdot \left(1 - e^{-Z_{a,y}}\right) \Rightarrow$$

$$F_{a,y} = \frac{C_{a,y}}{\overline{N}_{a,y}} == \frac{C_{a,y}}{N_{a,y,s} \cdot \left(1 - e^{-Z_{a,y,s}}\right) / Z_{a,y,s}} = \frac{C_{a,y}}{U_{a,y,s} \cdot \left(1 - e^{-Z_{a,y,s}}\right) / Z_{a,y,s}} \cdot Q_{a,s} = RC \cdot f \qquad \text{Equation 2}$$

Where f is a coefficient of proportionality of the relative catches (*RC*) to F, which equals $Q_{a,s}$ the catchability coefficient when the mean abundance is known without error from the surveys. Notice that in order to make $N_{a,y}$ (the numbers at the beginning of the period) equal to the mean abundance in the period the required factor is $(1-exp(-Z_{a,y}))/Z_{a,y}$. This is a factor ranging between 0 and 1 and usually around 0.5. One inconvenience of this approach is that the fitted Z will appear in the independent covariate (RC). As a sensitivity analysis, alternative formulations of RC were made and essayed in this paper, as:

$$RCSurvey = \frac{C_{a,y}}{U_{a,y,s} \cdot \left(1 - e^{-Z_{a,y,s}}\right) / Z_{a,y,s}} \qquad \text{Equation 3}$$

$$RCSurvey2 = \frac{C_{a,y}}{\left(U_{a,y,s} + U_{a+1,y+1,s}\right) / 2} \qquad \text{Equation 4}$$

$$RCjoint = \frac{C_{a,y}}{\left[(U_{a,y,s=A} + U_{a,y,s=DEPM}) / 2\right] \cdot \left(1 - e^{-Z_{a,y,*}}\right) / Z_{a,y,*}} \qquad \text{Equation 5}$$

$$RCjoint2 = \frac{C_{a,y}}{\sum_{s} \left(U_{a,y,s} + U_{a+1,y+1,s}\right) / 4} \qquad \text{Equation 6}$$

The second estimator takes as mean population the mean of the abundances provided by every survey at the beginning and the end of the period (i.e. the estimates of the cohort provided by the survey in year y and y+1).

The third estimator of RC tries to supply a single indicator of fishing intensity for each year based on both surveys estimates of the abundance at the beginning of the period and their mean *Z* ($Z_{a,y,*} = \left(Z_{a,y,A} + Z_{a,y,DEPM}\right)/2$) for the period, therefore we restrict the analysis to the years when both surveys were carried out in parallel.

The fourth estimator also supplies a single indicator of fishing intensity for each year by taking the average population as that provided by both surveys estimates of the abundance at the beginning and at the end of the Z estimate period. Here again the analysis will be restricted to the years when both surveys were carried out in parallel at the beginning and at the end of the Z period.

In all cases, the catches considered are those comprised between May 15 of year *y* and May 15 of year *y+1*, for the ages a and a+1 in each respective year. Original Catches at age (in numbers) with their mean weights are reported by seasons in ICES until the closure of the fishey in 2005 (ICES 2005) and more recently in WGHANSA report (ICES2012).

2.2 Methods

a) Analysis of Variance of Total mortality (ANOVA)

We first test the consistency of the Z estimates by surveys across years for all ages

$$\hat{Z}_{a,y,s} = Year_y + Survey_s + [Old_a] + \varepsilon_{s,y} \qquad \text{(Models A1)}$$

With ***Year*** and ***Survey*** being taken as factors and $\boldsymbol{Old_a}$ which appears only for the joint analysis of *Z1* and *Z2* is a factor reflecting whether the *Z* analysed corresponds to the age group 1 (*Old* =0) or 2+ (*Old* =1).

Next, we tested the effect of closure on the overall levels of *Z* and by ages.

$$\hat{Z}_{a,y,s} = \bar{Z} + Fishing_i + Survey_s + [Old_a] + Interactions + \varepsilon_{a,y,s} \qquad \text{(Models A2)}$$

With ***Fishing*** indicating a period with fishing (***Fishing*** =1) or without fishing (***Fishing*** =0). ***Survey*** is a factor indicating they type of survey generating *Z* (DEPM=0 or Acoustics=1). And ***Old*** being a factor reflecting the age Z refers to, which it is put in brackets as it only appears when Z_1 and Z_{2+} are being analysed together, but not when dealing with Z_{1+} Interactions are the potential first order and second order interactions of the former variables, which were initially checked.

Finally $\varepsilon_{a,y,s}$ is assumed to be a normal random variable $N(0,\sigma)$ common for all ages, years and surveys.

b) Linear models of total mortality based on regression on the fishing intensity (relative catches) to obtain estimates of natural mortality.

Here the following model will be statistically tested for the different potential significant coefficients:

$$\hat{Z}_{a,y,s} = \ln\left[\frac{U_{a,y,s}}{U_{a+1,y+1,s}}\right] = M_{a,y,s} + F_{a,y,s} + \varepsilon_{a,y} = M + [Old_a] + f_s \cdot RC_y + Survey + Interactions + \varepsilon_{a,y,s}$$

(Models B1)

With ***M*** being the intercept, or natural mortality at age 1 (M1) or for all ages together (M1+) depending on the subset of data being analysed.
Old is a dummy variable being 0 for age 1 and 1 for age 2+, this term will indicate the increase of natural mortality for fishes of age 2+ relative to the natural mortality for age 1 (M1). It is put in brackets as it only appears when Z_1 and Z_{2+} are being analysed together, but not when dealing with Z_{1+}
RC accounts for the Relative Catches between surveys of the respective age *a* in year *y*. And its coefficient ***f*** accounts for proportionality of ***RC*** to *F*
Survey is a dummy variable being 0 for DEPM and 1 for Acoustics, and this term will reflect any potential effect of the acoustic survey relative to the DEPM on the estimates of Z.
Interactions are the potential first order and second order interactions of the former variables, which were initially checked.
Notice however that for our Z estimates from surveys we required the assumption of catchability constant across ages and therefore second or third order interaction relative to the slope changing by age should not be significant. Second the intercepts reflecting M are population parameters which should be similarly estimated by the surveys if they both have constant catchabilities across ages, this means that if the intercepts would change by surveys that would imply that at least one of the surveys (if not both) has changing catchability by age.

4. Results

a) Analysis of Z by ANOVA (Models A):

Raw data are shown in Table1. During the fishing closure 2005-2009 Z estimates were lower than during periods with fishing. Table 2 shows that estimates of Z do not differ statistically between surveys across the whole period of analysis (Models A1) for all ages pooled together (Z1+) (Table 2a); but there might be some differences between surveys as result from the analysis of Z by ages (at alpha 0.026 -Table 2b). However the analysis of potential differences between surveys is delayed to the analysis of Models B.

All Z estimates in the closure period were significantly lower than in years with fishery for both surveys (ANOVAs in Table 3a for Z1+, Model A2), as displayed in Figure 1 and shown in Table 4 (pooling both surveys together). Some differences again may appear by surveys for the Z by ages (table 4a) but for both ages Z in the closure period were lower than in the fishing periods (table 4c, d & e) and Figure 1 b and c.

Older anchovies (age 2+) show higher mortalities than recruits (of age 1) (Tables 1 and 4c). Examining the individual results by surveys in Table 1b, this is clear for the DEPM survey, but for acoustics this is less evident during the fishing periods than for the closure period.

b) Linear models of Total mortality based on regression on the fishing intensity

We first take as reference the indicator of fishing intensity RCSurvey2 to show the information global and on survey by survey basis, and then we check the sensitivity to other Relative Catches estimators; but paying special attention to the single joint estimate from the two surveys obtained by the RCJoint2 estimator of RC which should absorb much of noisy variability in the individual survey estimates. In addition all models have been fitted again after removing the contribution of Zs for high values of RC (above 0.8, as they become too influyent on the slope and the intercept estimates), negative values Zs (i.e Increase instead of decreasing rates) and of the 2011 Z values because of the strong discrepancy among the surveys in 2012, which has shown to have a remarkable effect on the intercept values as will shown later on.

Significant relationships of total mortality (Z1+) on the relative catches between surveys were found (Table 5 for RCSurvey2 and Figure 2); neither the slopes nor the intercepts did significantly change between surveys. The common intercept of that model gives the estimate of Natural Mortality for all ages together (M1+) at about 1.13 with a CV of 15%. By surveys, the DEPM would estimate an M1+ of about 1.23 (S.e.=0.287) and the acoustics to and M1+ of 0.812 (S.e.=0.259) (Table 5c, Figure 2a), although these differences are not statistically significant as shown in Table 5.
The final fitting and that obtained after removing of the Z values corresponding with RC>0.8 and Year=2011 can be seen in Figure 2b and 2c. The results of M1+ for all the RC estimators and with all the data or after removing of the Z values corresponding with RC>0.8 and Year=2011 are summarised in Table 10a.

By ages, Z for ages 1 and 2+ also showed significant relationships with the relative catches (RCSurvey2) taken between surveys (Table 6) and for neither the intercepts nor the slopes did significantly change by surveys, although in some cases as the one shown in Table 6 for the RCSurvey2 the second order interaction was significant between the 1% 5% alpha levels. However according to our assumption the intercept was always removed from the analysis and subsequently all other interaction for RC cases become not significant. All the final retained models indicated significant differences in the intercepts by ages (by Old covariate). For the case of RCSurvey2, the results pointed out an M1=0.96 and M2=1.735, with a CV around

18% (Table 6c and Figure 3). The estimates by surveys making of RCSurvey2 resulted in M1 of 1 and 0.82 with M2+ of 2 and 1.47 for the Acoustic and DEPM surveys respectively (table 7 and 8 and Figures 4 and 5). We found that the marginal significance of the second order interaction might come from the potential differences in the slopes by age for the acoustics which has a P=0.025, however we proceed our analysis under the assumption of equal catchabilities across ages as the differences seem more to be due to random noise than to a credible patter (see Figure 5).

The combination of both surveys into a single estimate of the Natural mortality at age (intercepts) is presented in detail for RCJoint2 in Table 9 and Figure 6. Natural Mortalities of M1=0.83 (CV=24%) and M2=1.75 (CV=18%) were found but after omission of the untruthful data those values become M1=0.72 (CV=27%) and M2=1.64 (CV=17%).

Results for Z and M by ages for all RC estimators are summarised in Table 10b

5. Discussion

The closure of the fishery produced a significant reduction on the Z levels estimates from surveys. At the closure time (2005-2009) Total Mortality M1+ was around 0.8 (CV=) while by ages M1 was about 0.45 and M2+=1.6. Among the 5 years of closure, the 2005 resulted in a contradictory negative mortalities being estimated by both surveys (positive generation of individuals) indicating that either the estimates of 2005 were too low or the 2006 too high. By substracting the 2005 and 2006 estimates the means for the remaining three years of closure **(2007-2009) (n= 6 = 3 Years * 2 Surveys) yields M1+=0.87 (S.e.=0.25, CV=29%) M1=0.65 (S.e.=0.27, CV=41%) and M2+=1.63 (S.e.=0.30, CV=18%).**
It can be debatable whether the negative values should or not be removed from the analysis, but for a short series of years as the closure period this is probably convenient. On the hand the values for M1 obtained with all data were a priori to be too low for a short living species as anchovy, whilst the reduced set of data points towards higher values for M1.

In order to increase the data basis to estimate M we decided to follow the Log linear models including an indicator of fishing intensity as the slope of Z. In such analysis the inclusion of all year of data was debatable, i.e. the negative values?, the 2011 divergent results from surveys and the years with very high RC values too influent on the intercepts when inducing obvious departuring from the observations of Z made under low fishing intensity (and hence close to natural mortality conditions).
Removing 2011 made that the information from both surveys not statistically distinguishable for any RC estimator and assured that the slopes were not statistically different among ages (i.e. catchability was flat) at least at the 1% alpha level (even though for acoustic they stayed invariantly with a P around 5% - but as for this survey the slope on all RCs for age 2 was always negative and hence meaningless, i.e. noisy, it follows that the assumption of constant slopes across ages was required to include the acoustic data in the analysis which always acceptable at the alpha level of 1% -see footnote)[1]
By considering that too high RC (above 1) are increasingly unrealistic (for the hard of producing such fishing impact), we should suspect that those values may be misleading

[1] Results for Acoustic RCSurvey first interaction OLD*RC (P=0.0427) For RCSurvey2 ,P=0.0373, For RCJoint P=0.055 and For RCJoint2 P=0.0445. Notice that the slope on all RCs for age 2 was always negative and hence meaningless, i.e. noisy. From it follows that the assumption of constant slopes across ages was required to include the acoustic data in the analysis. Hence the constant catchability assumption should be adopted to analyse the data in a meaningfull way. ////////
Results for NDEPM RCSurvey first interaction OLD*RC (P=0.2945), For RCSurvey2 ,P=0.8380, For RCJoint P=0.3975 and For RCJoint2 P=0.3744.In any case for the DEPM they were not significant already without removing 2011 results

probably due to too low biomass estimates by the survey in that year. This give justification to removing values with RC>0.8 as we did. In general removing these values made the fitting of the intercepts closer to the observations of Z around the origin (see figures 3-6).
More debatable is the need to refuse making use of the negative Z values: if they were due to abnormal error estimates in the surveys then probably two consecutive estimates should be removed unless there is a good information pointing out which year is the wrong one. IN addition consecutive years may somewhat balance each other. Would we require the same analysis just omitting the RC>0.8?

Despite some sensitivity to the actual RC estimators, Global Natural Mortality (M1+) was between 0.9 and 1 when all data were used together, in consonance with the direct mean estimates during the closure period. For the DEPM the total fitting points to a M1+ around 1.23 which matches with the former assumption of NatMort for this population at 1.2 (as it was calculated in the nineties on the basis of this survey.

All the analysis of Z by ages showed that M1 is around 0.8 or 0.95 when the whole set of data is analysed together. However the fitting of the data seems visually to overestimate the Intercept as it lets below quite many of the observations at very low fishing intensity (at very low RC values – Figures 3, 4 and 5). In order to improve visually such fitting the analysis was restricted to estimates corresponding to Z>0, RC<0.8 and omitting year 2011. However the improvement was not achieved for RCSurvey2 (Figures 3, 4 and 5) and M1 was not reduced (table 6), except for the DEPM survey (resulting in an M1 DEPM=0.88, Table 7). So the selection of removals can be questioned. The analysis by surveys with (RCSurvey2) showed for all the data that DEPM might indicate some higher have values of NatMor, however the restriction of the analysis denied this possibility, reducing the M1 of the DEPM while increasing that of the Acoustic (table 10b), so no clear single estimate could be obtained from the two surveys.
Regarding the level of natural Mortality at ages 2 and older (M2+) al the analysis suggest that M2+ is significantly far higher than M1, with a difference ranging from about 0.5 to 1 depending upon the concrete RC being used and/or the set of data analysed. The RCSurvey2 analysis on survey by survey basis agreed pointing towards M2 values around 1.5.

However the best synthetic estimate from both surveys together is expected to arise from the use of RCJoint2 as indicator of fishing intensity as it confronts under the same RC values the yearly Z estimates of the two surveys. This indicator did not have RC values higher than 0.8. This joint estimate suggest M1 around 0.82 and M2+ around 1.7. This values reduced, after removing year 2011 and Z<0 to M1 around 0.72 (CV=27%) and to M2+ around 1.6 (CV=17) (Tables 9 and 10). Such removal did visually improve the fitting (Figure 6). **Bearing in mind that surveys did not show any significant differences in their Z estimates as a function of RCJoint2, and that the latter was the best suited joint indicator of fishing mortality (less subjet to individual noisy results) the later estimates of NatMort are probably the best synthetic estimates which can be obtained from both surveys together. This estimates are a bit higher but very similar to the raw mean estimates obtained during the closure period of the fishery.**
As it can be argued that year 2011 or Z<0 should not be withdrawn from the analysis we see that the the second best estimate will correspond with the one given by the analysis of all data together which results in M1= 0.83 (CV=20%) and M2+=1.75 (CV=30%). These potential selections are not statistically different but the second differs more from the raw estimates during the fishing closure.

It can be questioned what was the advantage of including a linear model of Z on RC for the estimation of the natural mortality from the intercepts. The major advantage of the linear model analysis is that the power of the contrast of the differences in NatMort between ages is largely enhanced. Second, part of the individual errors in the estimates during the short closure period can be filtered by the information in the remaining set of years expanding the contrast in the data. Some information about the catchabilities of the surveys can be inferred from the slopes of the fitted model and particularly the assumption of constant catchability of survey across ages can not be rejected (as the slope across ages was not significantly difference for both surveys together (the second order interaction-except for RCSurvey2)[2] as on the analysis on survey by survey basis – see footnote 1).

Regarding the catchabilities of the Surveys; The use of the whole set of data provide slopes below 1, suggesting some understimates of the indexes of abundances from the surveys. However the reduction of the series of year to be analysed leads to slopes in majority above 1. All these results are rather noisy with CV around 35% or more not different from a slope=1. These results therefore have no clear indication of the surveys to over estimate or to underestimate the actual abundance at sea.

Our estimates of NatMort refer to the period between two consecutive population estimates, i.e. from mid may to mid may next of the next year. The assessment however applies M by calendar year. In order to accommodate our results to the request of the calendar year for M in the current assessment models, we have applied temptatively the following approach, intermediate between the different results shown above: M1=0.5 and M2=1.5. This imply for M1 between successive survey estimates of 0.875 (= (7.5*0.5 + 4.5*1.5)/12) and of M2+ of 1.5. These inter Surveys Mortalities at age 1 and 2+ are rather similar to those resulting from the use of RCSurvey2 after removing data (RC>0.8 & Z>0 & Year=2011), jointly or on survey by survey basis.

Final considerations:

The closure of the anchovy fishery allows estimating an average rate of natural mortality for all ages (M1+) around 0.87 (actual mean 2007-2009 with CV=29%) or around 0.88-0.78 (based on linear model on RCJoint2 estimates with total data with the subset of data respectively). The analysis therefore suggest lower M1+ values than the former estimates of 1.2 for the Bay of Biscay anchovy which had been deduced under the assumption of the DEPM providing unbiased estimates of the absolute level of the population (and verified again in this paper). For the same level of total mortalities Z, this result implies fishing mortalities higher than formerly assessed, i.e. higher impact of the fishery on the stock.

The analysis also provides evidence that the level of natural mortality is higher for the ages 2+ than for age 1, a result always significant and insensitive to the concrete RC estimator used for the analysis. The analysis certainly depends upon the assumption of no differential catchabilty by ages in the surveys and this has been verified by the GLM modelling here.

These results suggest therefore that Natural Mortality may increase with age for anchovy, particularly after its second spawning, being anchovy an intermediate small pelagic fish between capelin (which die after it first spawning) and sardines or sprats. This finding is similar to the one shown for sandeels (Cook 2004) and in line with the expectation of increasing mortality at senescence for the short living species (Beverton 1963, Caddy 1991).

One caveat of all these analysis is the relative noisy results obtained. The r2 of the regression models are at best around 50% o lower, with high standard errors (of about 0.5). Part of it should be due to observation errors from surveys and errors in the RC estimates, but in addition another source of variability can be due to inter-annual variability in natural mortality

[2] Second order interactions all data: RCJoint2 P=0.2257, RCJoint P= 0.1635, RCSurvey2=0.0321, and removing year 2011 it remained at P= 0.0331. Finally for RCSurvey P=0.0558.

according to different predation and so on. This analysis can not discriminate among these source of variability but inter-annual variability in Natural mortality was already pointed out for this stock (Prouzet et al. 1999) and they are expected to happen for all stocks (Vetter, 1988, Cook 2004, Gislason 2010). Even more the higher the natural mortality the higher the variability of M should be.

By comparison with Uriarte et el. (ICES CM 2010) there has been a general increase in the levels of M estimates, partly due to the changes in the series of DEPM being analysed but also to the addition of a couple of points to the series. Current results still support the idea of making use of models assuming flat catchability at age in surveys. Such models (as the implementation of SICA in Uriarte et al 2010) optimum fittings for M1 values lower than 0.8 and M2+ around 1.15; i.e. quite parallel pattern of natural mortality at age as that shown by the linear models above although lower for M2 than our results here. SICA has not been updated by the time being for WKPELA 2013.

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Table 1: Direct Population in numbers at age estimates.(a) and derived total mortality values by age groups (b). The fishery has been closed since July 2005 (just with very small catches in 2006).

a)

Year\ ages	1	2	3 +	Year\ ages	1	2 & 2 +	3+
1987	479.81	242.10	103.86	1987			
1988	1686.43	185.23	48.82	1988			
1989	194.28	162.69	14.22	1989	400.0	**405.0**	
1990	4,506.9	95.1	12.2	1990			
1991	473.7	193.8	3.2	1991	1873.0	**1300.0**	
1992	3,849.5	127.0	10.0	1992	9072.0	**270.0**	
1993				1993			
1994	1,370.3	508.9	25.5	1994			
1995	1,507.2	218.1	38.3	1995			
1996				1996			
1997	1,798.1	290.1	8.1	1997	2481.0	**870.0**	
1998	4,368.7	555.7	39.7	1998			
1999				1999			
2000				2000	5965.3	682.6	281.3
2001	2,658.1	1,013.6	89.5	2001	4169.7	1325.7	141.1
2002	207.2	454.7	98.0	2002	1354.2	2253.5	500.6
2003	712.8	121.3	47.2	2003	1120.8	239.0	114.9
2004	557.5	58.0	16.8	2004	2248.6	226.2	126.0
2005	69.9	114.0	4.5	2005	131.2	421.7	110.2
2006	672.69	110.52	35.15	2006	1365.1	394.5	111.4
2007	480.0	175.6	26.6	2007	1437.0	632.0	101.2
2008	242.2	280.9	36.2	2008	961.3	811.5	266.0
2009	424.7	124.4	107.6	2009	1174.5	348.0	402.9
2010	1,522.5	221.4	12.2	2010	4102.7	701.7	97.6
2011	8,546.8	986.7	22.7	2011	9771.2	851.3	116.3
2012	880.7	822.5	30.1	2012	22417.2	5648.3	182.9

b) Total mortality values for different age groups and by surveys

New DEPM survey series

Year\ ages	Z (1-2)	Z(1+ 2+)	Z(2+ 3+)
1987	0.95	1.26	1.96
1988	2.34	2.38	2.80
1989	0.71	1.24	2.68
1990	3.15	3.15	3.53
1991	1.32	1.59	2.98
1992			
1993			
1994	1.84	2.01	2.64
1995			
1996			
1997	1.17	1.26	2.02
1998			
1999			
2000			
2001	1.77	1.92	2.42
2002	0.54	1.51	2.46
2003	2.51	2.47	2.31
2004	1.59	1.67	2.80
2005	-0.46	0.26	1.22
2006	1.34	1.40	1.70
2007	0.54	0.77	1.72
2008	0.67	0.88	1.08
2009	0.65	1.03	2.94
2010	0.43	0.55	2.33
2011	2.34	2.42	3.51

Acoustic Survey complete serie up to 3+

Year\ ages	Z (1-2)	Z(1+ 2+)	Z(2+ 3+)
1987			
1988			
1989			
1990			
1991		2.46	
1992			
1993			
1994			
1995			
1996			
1997			
1998			
1999			
2000	1.50	1.55	1.92
2001	0.62	0.72	1.08
2002	1.73	2.45	3.18
2003	1.60	1.43	1.03
2004	1.67	1.59	1.16
2005	-1.10	0.27	1.56
2006	0.77	0.94	1.61
2007	0.57	0.70	1.01
2008	1.02	1.00	0.98
2009	0.52	0.88	2.04
2010	1.57	1.62	1.93
2011	0.55	0.61	1.67

New DEPM series

	Z (1-2)	Z(1+ 2+)	Z(2+ 3+)
N	18	18	18
Z (1987-2004)	1.63	1.86	2.60
CV	49%	33%	17%
M (2005-2009)	**0.55**	**0.87**	**1.73**
CV	118%	48%	42%
Z (1987-2011)	1.30	1.55	2.33
CV	70%	46%	29%

ACOUSTIC Surveys

	Z (1-2)	Z(1+ 2+)	Z(2+ 3+)
	12	13	12
Mean Z (1987-2004)	1.43	1.70	1.67
	32%	39%	55%
Mean M (2005-2009)	**0.35**	**0.76**	**1.44**
	236%	39%	31%
mean Z (1987-2011)	0.89	1.27	1.56
	96%	56%	44%

Table2: Analysis of Variance for total Z (Z1+) (a) and for Z by ages (Z1 and Z2+) (b)

a) Analysis of Variance for total Z (Z1+) - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Year	10.7522	18	0.597344	1.53	0.2370
B:Survey	0.138017	1	0.138017	0.35	0.5638
RESIDUAL	4.28668	11	0.389698		

b) Analysis of Variance for Z by Ages (Z1 and Z2+) - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Year	18.6841	18	1.03801	2.62	0.0059
B:OLD	12.9921	1	12.9921	32.75	0.0000
C:Survey	2.1252	1	2.1252	5.36	0.0260
RESIDUAL	15.4706	39	0.396682		

Table 3: Anovas testing the effect of the fishing closures for Z1+ and Means

a) Analysis of Variance for overall Z (Z1+) - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Fishing?	5.09017	1	5.09017	14.33	0.0007
B:Survey	0.308373	1	0.308373	0.87	0.3595
RESIDUAL	9.9487	28	0.355311		
TOTAL (CORRECTED)	15.703	30			

c) Table of Means for Z (Z1+) by Fishing
with 95.0 percent LSD intervals

Fishing	Count	Mean	(pooled s)	Lower limit	Upper limit
N	10	0.811	0.188067	0.539018	1.08298
Y	21	1.70762	0.129779	1.51993	1.8953
Total	31	1.41839			

Table 4: Anovas testing the effect of the fishing closures for Z1 and Z2+ and Means.

a) Anova for Z by ages (Z1 and Z2+): Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Fishing	8.25305	1	8.25305	18.17	0.0001
B:OLD	11.2361	1	11.2361	24.73	0.0000
C:Survey	2.32725	1	2.32725	5.12	0.0278
INTERACTIONS					
AB	0.558443	1	0.558443	1.23	0.2727
AC	0.416427	1	0.416427	0.92	0.3428
BC	0.46108	1	0.46108	1.01	0.3184
ABC	0.275143	1	0.275143	0.61	0.4400
RESIDUAL	23.6248	52	0.454323		
TOTAL (CORRECTED)	52.1689	59			

b) Anova for Z by ages (Z1 and Z2+): Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A:Fishing	8.75124	1	8.75124	19.29	0.0001
B:OLD	12.9921	1	12.9921	28.64	0.0000
C:Survey	3.20606	1	3.20606	7.07	0.0102
RESIDUAL	25.4035	56	0.453634		
TOTAL (CORRECTED)	52.1689	59			

c) 95.0% confidence intervals for coefficient estimates (Z)

Parameter		Estimate	Standard Error	Lower Limit	Upper Limit	V.I.F.
Fishing						
N	20	1.0175	0.150604	0.715802	1.3192	
Y	40	1.83622	0.10984	1.61619	2.05626	
OLD						
0	30	0.961528	0.127464	0.706186	1.21687	
1	30	1.8922	0.127464	1.63685	2.14754	
Survey						
Acoustic	24	1.18844	0.138357	0.911276	1.4656	
NDEPM	36	1.66528	0.119653	1.42559	1.90498	
GRAND MEAN	60	1.42686				

d) Z at age 1 (Z1): Table of Means for Z by Fishing
with 95.0 percent LSD intervals

Fishing	Count	Mean	Stnd. error (pooled s)	Lower limit	Upper limit
N	10	0.447	0.230055	0.113778	0.780222
Y	20	1.495	0.162674	1.25938	1.73062
Total	30	1.14567			

e) Z at ages 2 and older (Z2+): Table of Means for Z by Fishing
with 95.0 percent LSD intervals

Fishing	Count	Mean	Stnd. error (pooled s)	Lower limit	Upper limit
N	10	1.588	0.219241	1.27044	1.90556
Y	20	2.3205	0.155027	2.09595	2.54505
Total	30	2.07633			

Table 5: Fitting the total Mortality for the whole population Z (Z1+) as a function of Relative catches index (ModelB1): a) First test of the complete model and b) Retained model after consecutive omission of non significant coefficients.

a) Comparison of Regression lines First test of the complete model fo Z (Z1+): Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.811511	0.295551	2.74575	0.0106
Rcsurvey2	2.72178	1.42818	1.90578	0.0674
Survey=NDEPM	0.422524	0.397673	1.06249	0.2974
Rcsurvey2*Survey=NDE	-2.13491	1.48434	-1.43829	0.1618

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	3.29983	3	1.09994	2.39	0.0903
Residual	12.4032	27	0.459377		
Total (Corr.)	15.703	30			

b) Comparison of Regression lines Final model for Total Z (Z1+) Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1.1348	0.175053	6.48259	0.0000
Rcsurvey2	0.761452	0.337358	2.2571	0.0317

c)Estimates by surveys

Acoustic Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.811511	0.258796	3.13572	0.0095
RCSurvey2	2.72178	1.25056	2.17645	0.0522

NDEPM Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1.23404	0.286611	4.30561	0.0005
RCSurvey2	0.586871	0.435672	1.34705	0.1967

Table 6: Fitting the total Mortality at ages (Z1 and Z2+) as a function of Relative catches index (RCSurvey2) (ModelB1): a) First test of the complete model and b) Intermediate model and c)Retained model after consecutive omission of all non significant coefficients at α=5%.

a) Comparison of Regression lines First test of the complete model fo Z by ages
Analysis of Variance for Z

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	24.0111	7	3.43016	6.33	0.0000
Residual	28.1578	52	0.541496		
Total (Corr.)	52.1689	59			

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
OLD	7.97561	1	7.97561	14.73	0.0003
RCSurvey2	2.06307	1	2.06307	3.81	0.0563
Survey	1.69372	1	1.69372	3.13	0.0828
OLD*Survey	0.330532	1	0.330532	0.61	0.4382
OLD*RCSurvey2	2.24998	1	2.24998	4.16	0.0466
Survey*RCSurvey2	0.707895	1	0.707895	1.31	0.2581
OLD*Survey*RCSurvey2	2.62753	1	2.62753	4.85	0.0321
Residual	28.1578	52	0.541496		
Total (corrected)	52.1689	59			

b) Intermediate Linear model for Z by ages: Analysis of Variance for Z

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
OLD	5.55936	1	5.55936	9.57	0.0032
RCSurvey2	0.737279	1	0.737279	1.27	0.2650
Survey	1.01144	1	1.01144	1.74	0.1926
OLD*Survey	0.392827	1	0.392827	0.68	0.4146
OLD*RCSurvey2	0.00941464	1	0.00941464	0.02	0.8992
Survey*RCSurvey2	0.0190537	1	0.0190537	0.03	0.8570
Residual	30.7853	53	0.580855		
Total (corrected)	52.1689	59			

c) Final retained model for Z by age : Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.89551	0.156843	5.70959	0.0000
RCSurvey2	0.678731	0.201237	3.3728	0.0013
OLD=1	0.839243	0.197313	4.25336	0.0001

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	19.51	2	9.755	17.03	0.0000
Residual	32.6589	57	0.572964		
Total (Corr.)	52.1689	59			

c) Estimates of the Final retained model for Z by age after removal of the values RCSurvey2>0.8 & Z<0 & Year=2011:

Parameter	Estimate	Standard Error	Lower Limit	Upper Limit
CONSTANT	0.966181	0.181125	0.600113	1.33225
RCSurvey2	1.25622	0.44083	0.365266	2.14717
OLD=1	0.516399	0.198272	0.115676	0.917123

Table 7: Fitting the total Mortality at ages (Z1 and Z2+) by surveys as a function of Relative catches index (RCSurvey2) (ModelB1) for the DEPM: a) First test of the complete model for DEPM and b) Final retained model for DEPM with parameters after consecutive omission of all non significant coefficients at α=5%.

a) Comparison of Regression lines of Z by ages for the DEPM on RCSurvey2, Initial complete test of Model B1:

Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1.11194	0.29716	3.74189	0.0007
RCSurvey2	0.358514	0.445327	0.805058	0.4267
OLD=1	0.895773	0.40472	2.21331	0.0341
RCSurvey2*OLD=1	0.182997	0.529331	0.345713	0.7318

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	13.3486	3	4.44954	7.33	0.0007
Residual	19.4313	32	0.607228		
Total (Corr.)	32.7799	35			

R-Squared = 40.722 percent R-Squared (adjusted for d.f.) = 35.1646 percent

Standard Error of Est. = 0.779248

b) Final retained model for Z by age for DEPM: Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	1.044	0.219898	4.74765	0.0000
RCSurvey2	0.488038	0.237495	2.05494	0.0479
OLD=1	1.0019	0.260188	3.8507	0.0005

c) Final retained model for Z by age for DEPM after removal of the values RCSurvey2>0.8 & Z<0 & Year=2011

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.88512	0.296624	2.98398	0.0076
RCSurvey2	1.50868	0.607353	2.48402	0.0225
OLD=1	0.641461	0.29389	2.18265	0.0418

Table 8: Fitting the total Mortality at ages (Z1 and Z2+) by surveys as a function of Relative catches index (RCSurvey2) (ModelB1) for the Acoustics survey: a) First test of the complete model for Acoustic and b) Final retained model for Acoustic with parameters after consecutive omission of all non significant coefficients at α=5%. And c) Final model after removals of values RCSurvey2>0.8 & Z<0 & Year=2011

a) Comparison of Regression lines of Z by ages for the Acoustic on RCSurvey2, Initial complete test of Model B1:
Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.364656	0.293179	1.2438	0.2280
RCSurvey2	4.0833	1.65481	2.46754	0.0228
OLD=1	1.35371	0.398914	3.3935	0.0029
RCSurvey2*OLD=1	-4.7211	1.94741	-2.42429	0.0249

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	5.64042	3	1.88014	4.31	0.0169
Residual	8.72651	20	0.436326		
Total (Corr.)	14.3669	23			

R-Squared = 39.2598 percent R-Squared (adjusted for d.f.) = 30.1487 percent
Standard Error of Est. = 0.660549

b) Final retained model for Z by age for Acoustic: Multiple Regression Analysis
Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.823416	0.248576	3.31253	0.0033
RCSurvey2	0.674352	0.968425	0.696339	0.4939
OLD=1	0.649717	0.303607	2.13999	0.0443

c) Final retained model for Z by age for Acoustic after removal of the values RCSurvey2>0.8 & Z<0 & Year=2011

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.823416	0.248576	3.31253	0.0033
RCSurvey2	0.674352	0.968425	0.696339	0.4939
OLD=1	0.649717	0.303607	2.13999	0.0443

Table 9: Fitting the total Mortality at ages (Z1 and Z2+) by surveys as a function of Relative catches index (RCJoint2) (ModelB1) to both surveys: a) First test of the complete model and b) Intermediate and c) Final retained model with parameters after consecutive omission of all non significant coefficients at α=5%. And d) Final model after removals of values RCJoint2>0.8 & Z<0 & Year=2011

a) Comparison of Regression lines First test of the complete model fo Z by ages

Analysis of Variance for Z

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	18.295	7	2.61357	4.77	0.0006
Residual	20.8205	38	0.547907		
Total (Corr.)	39.1155	45			

Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
OLD	10.1464	1	10.1464	18.52	0.0001
Survey	0.803272	1	0.803272	1.47	0.2334
RCJoint2	2.59671	1	2.59671	4.74	0.0358
OLD*Survey	0.00158839	1	0.00158839	0.00	0.9573
OLD*RCJoint2	2.16642	1	2.16642	3.95	0.0540
Survey*RCJoint2	0.0163296	1	0.0163296	0.03	0.8639
OLD*Survey*RCJoint2	0.830947	1	0.830947	1.52	0.2257
Residual	20.8205	38	0.547907		
Total (corrected)	39.1155	45			

b) Intermediate Linear model for Z by ages: Analysis of Variance for Z

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
OLD	9.96692	1	9.96692	17.95	0.0001
Survey	0.581953	1	0.581953	1.05	0.3122
RCJoint2	2.3262	1	2.3262	4.19	0.0474
OLD*Survey	0.73802	1	0.73802	1.33	0.2559
OLD*RCJoint2	1.91252	1	1.91252	3.44	0.0710
Survey*RCJoint2	0.199468	1	0.199468	0.36	0.5524
Residual	21.6514	39	0.555164		
Total (corrected)	39.1155	45			

c)Final retained model for Z by age for both surveys:

Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.826036	0.195677	4.22142	0.0001
RCJoint2	0.815706	0.528367	1.54382	0.1300
OLD=1	0.920856	0.235171	3.91569	0.0003

d) Final retained model for Z by age for Acoustic after removal of the values RCJoint2>0.8 & Z<0 & Year=2011

Multiple Regression Analysis

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	0.723139	0.192956	3.74768	0.0007
RCJoint2	1.75814	0.594771	2.95599	0.0057
OLD=1	0.91617	0.204991	4.46932	0.0001

Table 10: Global summary of all results:

a) Global Mortality Z1+ to 2+ and M1+
b) Estimates of Z by ages Z1 to 2 and Z2+ to 3+

a) Global Mortality Z1+ to 2+ Analysis and estimates of M1+

CASE Z1+ 2+					NDEPM	Acoustic
					RCsurvey2	**RCsurvey2**
N	31	31	26	24	18	
ALL DATA CASE	**Rcsurvey**	**RCsurvey2**	**RCJoint**	**RCJoint2**	Estimate	Estimate
CONSTANT (= M1+)	**1.063**	**1.135**	**0.874**	**0.877**	**1.234**	**0.812**
Standard Error	0.165	0.175	0.170	0.183	0.287	0.259
CV	16%	15%	19%	21%	23%	32%
RC slope coefficient	**0.763**	**0.761**	**1.418**	**1.647**	**0.587**	**2.722**
Standard Error	0.254	0.337	0.437	0.538	0.436	1.251
CV	33%	44%	31%	33%	74%	46%
R-Squared	24%	15%	30%	30%	10%	30%
Standard Error of Est.	0.643	0.679	0.564	0.591	0.730	0.593
Slpes by Surveys						
Acoustic	**2.643**	**2.722**	**1.665**	**1.675**		
DEPM	**0.660**	**0.587**	**1.190**	**1.620**		

Removing data (RC>0.8 & Year=2011)				
N	22	25	24	22
AFTER REMOVALS	**Rcsurvey**	**RCsurvey2**	**RCJoint**	**RCJoint2**
CONSTANT (= M1+)	**0.843**	**0.909**	**0.776**	**0.778**
Standard Error	0.176	0.201	0.159	0.173
CV	21%	22%	21%	22%
RC slope coefficient	**1.443**	**1.669**	**1.586**	**1.834**
Standard Error	0.477	0.546	0.394	0.489
CV	33%	33%	25%	27%

Table 10. b) Analysis of the Estimates of Z by ages Z1 to 2 and Z2+ to 3+ And M1 and M2+:

ALL DATA SET

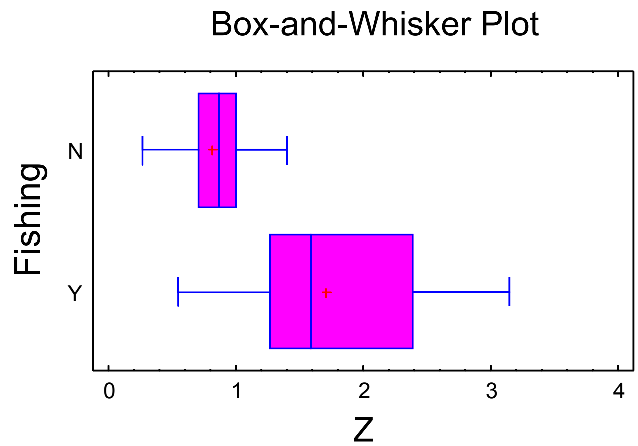
N	60	60	50	46	NDEPM	Acoustic
RC estimator	**Rcsurvey**	**RCsurvey2**	**RCJoint**	**RCJoint2**	**RCsurvey2**	**RCsurvey2**
Parameter	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
CONSTANT (= M1)	**0.928**	**0.896**	**0.807**	**0.826**	**1.044**	**0.823**
Standard Error	0.145	0.157	0.180	0.196	0.220	0.249
CV	16%	18%	22%	24%	21%	30%
OLD (addition for M2+)	**0.773**	**0.839**	**0.927**	**0.921**	**1.002**	**0.650**
Standard Error	0.194	0.197	0.218	0.235	0.260	0.304
CV	25%	24%	24%	26%	26%	47%
M2+	**1.701**	**1.735**	**1.734**	**1.747**	**2.046**	**1.473**
Standard Error	0.242	0.252	0.283	0.306	0.341	0.392
CV	14%	15%	16%	18%	17%	27%
RC slope coefficient	**0.496**	**0.679**	**0.685**	**0.816**	**0.488**	**0.674**
Standard Error	0.125	0.201	0.370	0.528	0.237	0.968
CV	25%	30%	54%	65%	49%	144%
R-Squared	41%	37%	35%	31%	38%	38%
Standard Error of Est.	0.734	0.757	0.761	0.793	0.767	0.767

Removing data (RC>0.8 & Z>0 & Year=2011)

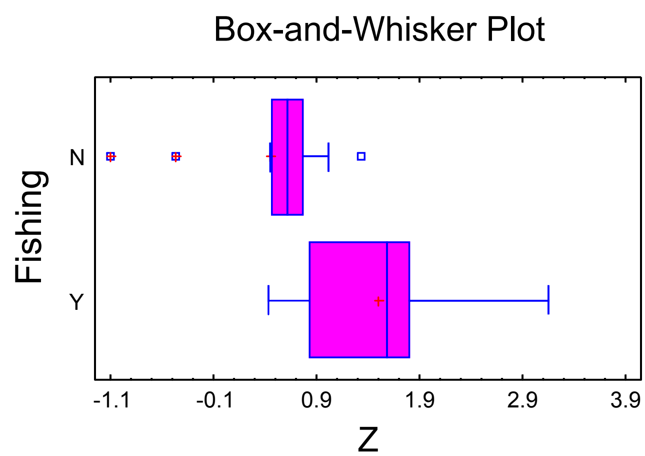
					NDEPM	Acoustic
N	39	43	39	36	22	21
RC estimator	**Rcsurvey**	**RCsurvey2**	**RCJoint**	**RCJoint2**	**RCsurvey2**	**RCsurvey2**
Parameter	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
CONSTANT (= M1)	**0.921**	**0.966**	**0.703**	**0.723**	**0.885**	**1.120**
Standard Error	0.170	0.181	0.177	0.193	0.297	0.233
CV	18%	19%	25%	27%	34%	21%
OLD (addition for M2+)	**0.534**	**0.516**	**0.913**	**0.916**	**0.641**	**0.433**
Standard Error	0.188	0.198	0.187	0.205	0.294	0.270
CV	35%	38%	20%	22%	46%	62%
M2+	**1.456**	**1.483**	**1.616**	**1.639**	**1.527**	**1.553**
Standard Error	0.254	0.269	0.257	0.282	0.418	0.357
CV	17%	18%	16%	17%	27%	23%
RC slope coefficient	**0.931**	**1.256**	**1.370**	**1.758**	**1.509**	**0.204**
Standard Error	0.364	0.441	0.427	0.595	0.607	0.830
CV	39%	35%	31%	34%	40%	407%
R-Squared	28%	28%	45%	42%	37%	13%
Standard Error of Est.	0.588	0.649	0.426	0.596	0.689	0.613

Figure 1: Box and Whisker Plot for Z by ages (pooling survey's estimates).
N= No Fishing period. Y= Fishing period

a) Overall Z (Z1+):



b) Z at age 1 (Z1):



c) Z at ages 2 and older (Z2+):

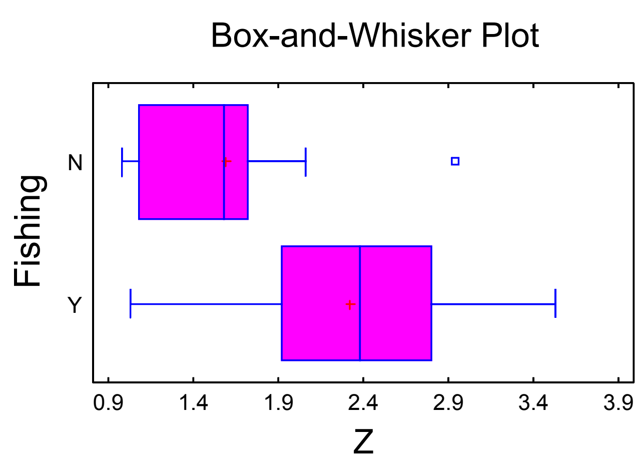
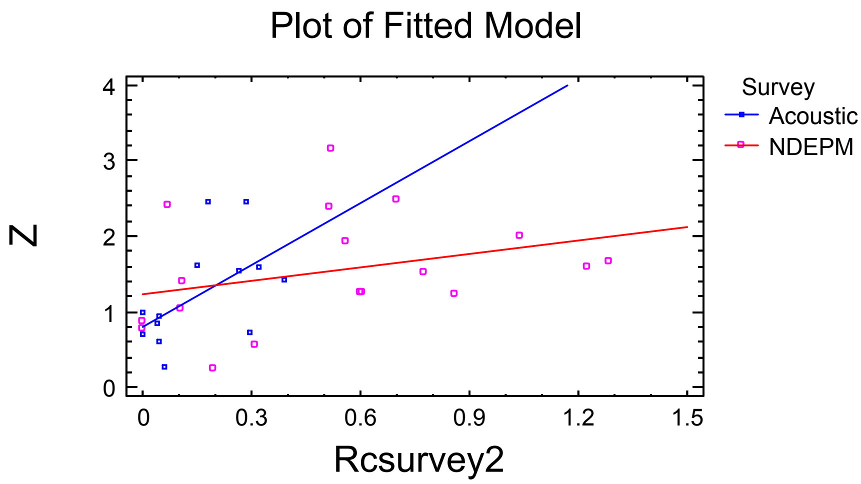
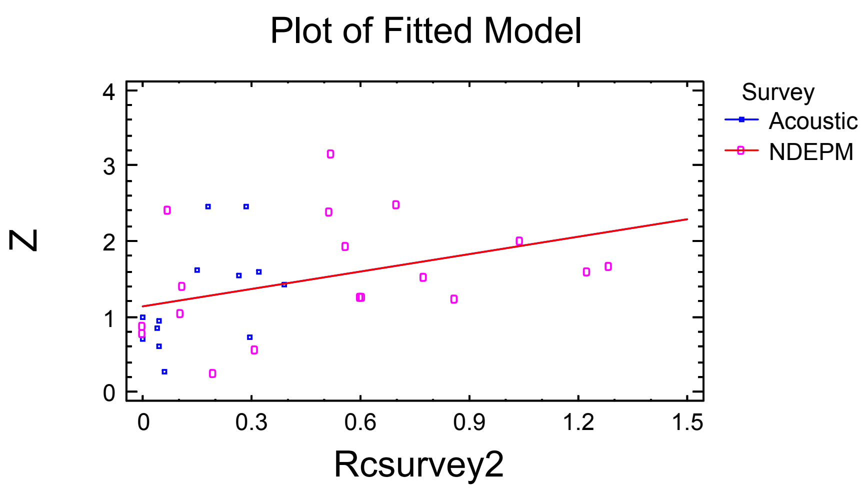


Figure 2: Total Z estimates (Z1+) (Model B1) on RCsurvey2

a) Fitting of the Original Model B1



b) Final adjusted model B1 for total Z (Z1+)



c) Fitted model after removing values with RC>0.8 and Year=2011

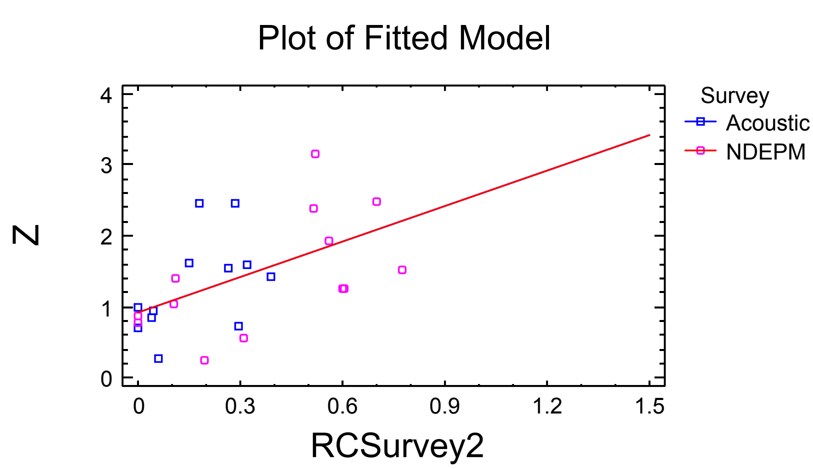
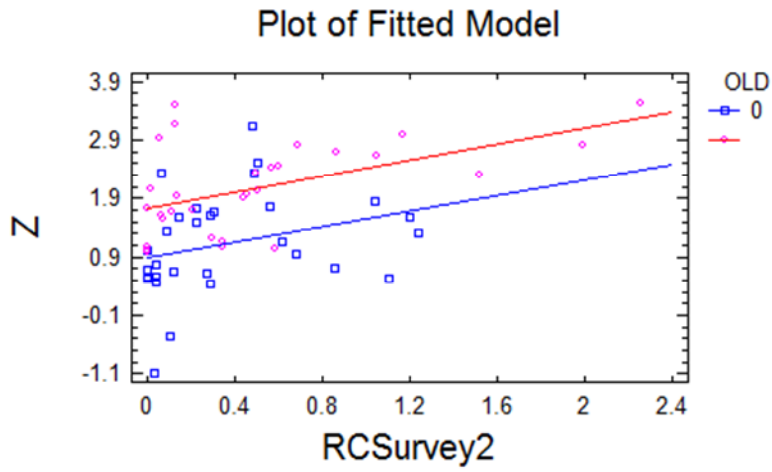
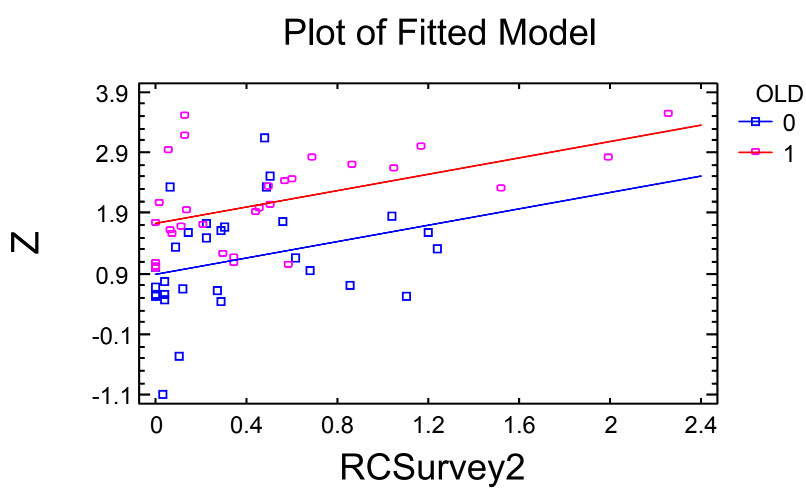


Figure 3: Initial and Final fitted models for the Z by ages as a function of the relative catches between surveys (RCSurvey2).

a) Initial Model



b) Fitted model



c) Fitted model after removing values with RC>0.8 Z<0 and Year=2011

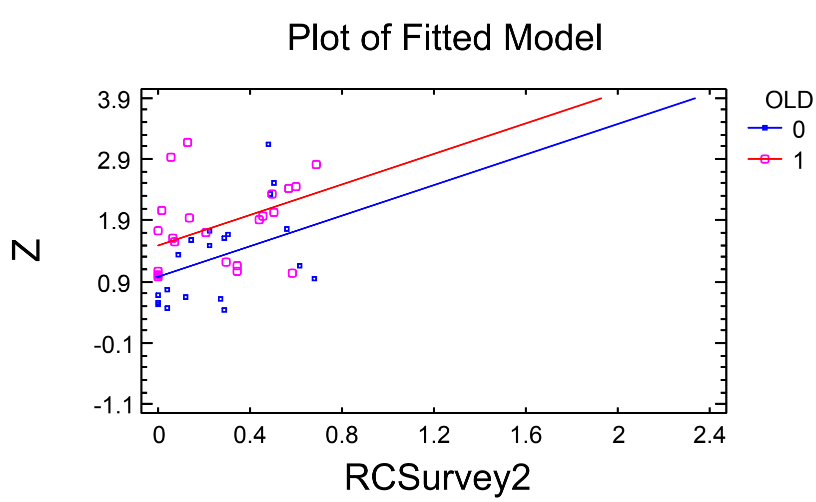
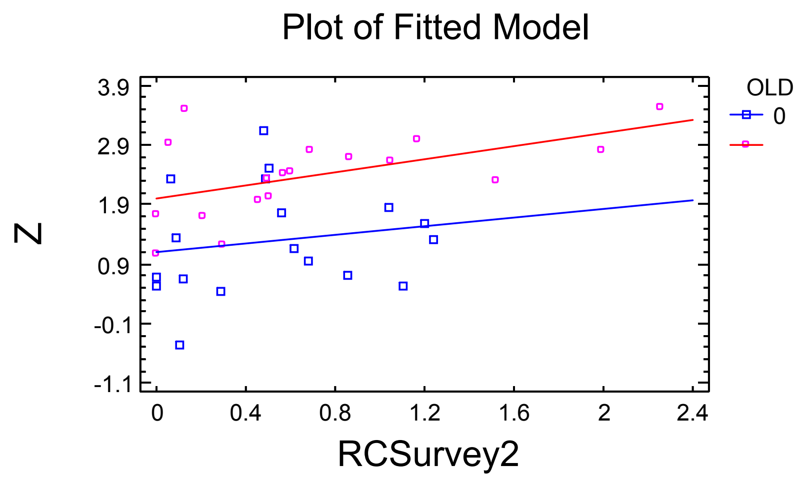
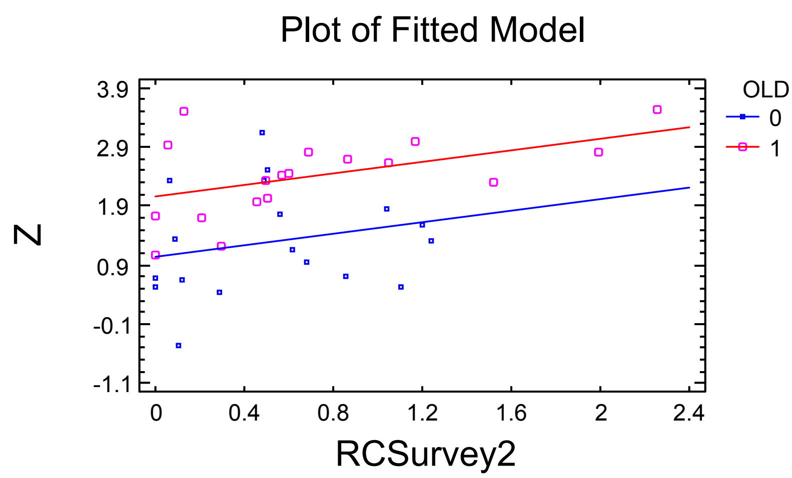


Figure 4: Initial and Final fitted models for the Z by ages for the DEPM as a function of the relative catches between surveys.

d) Initial Model



e) Fitted model



b) After removal of the values with RC>0.8 Z<0 and Year=2011

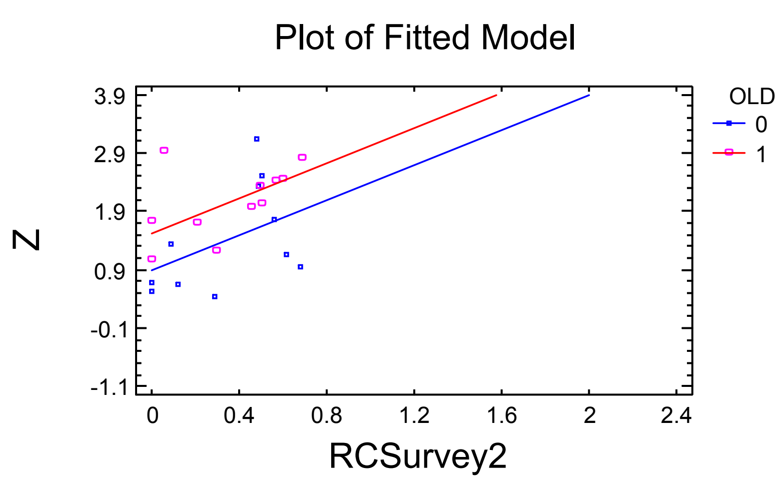
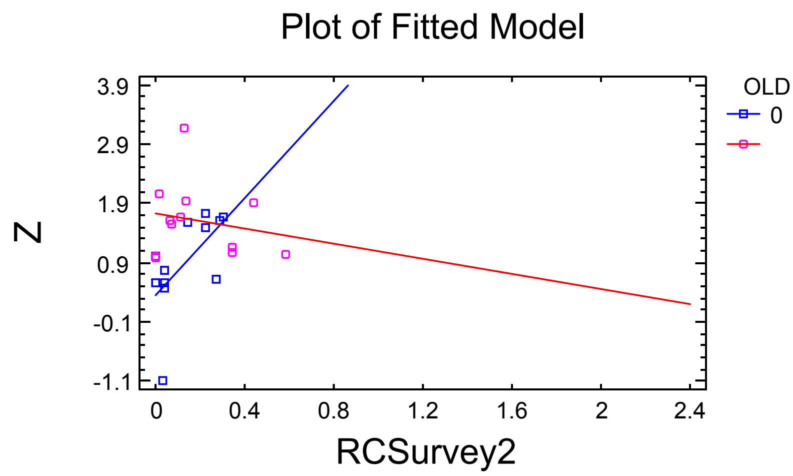
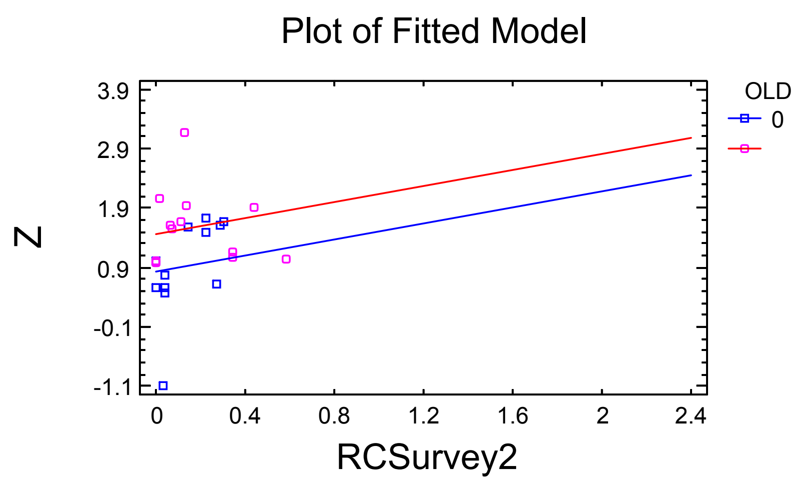


Figure 5: Initial and Final fitted models for the Z by ages for the Acoustic as a function of the relative catches between surveys.

a) Initial Model



b) Fitted model



c) Final Model after removal of the values with RC>0.8 Z<0 and Year=2011

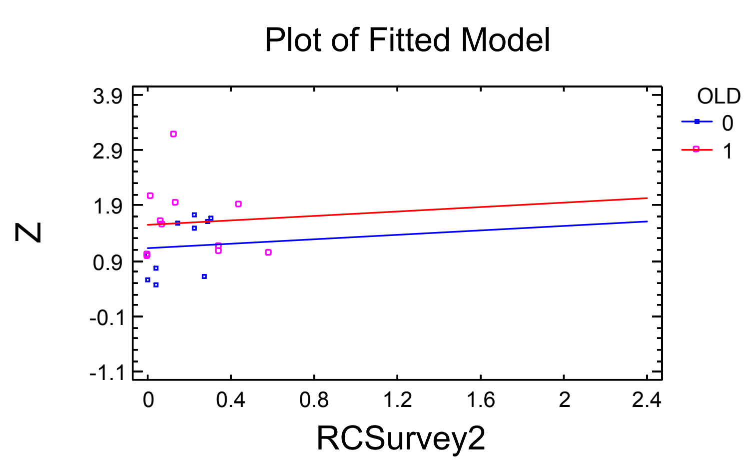
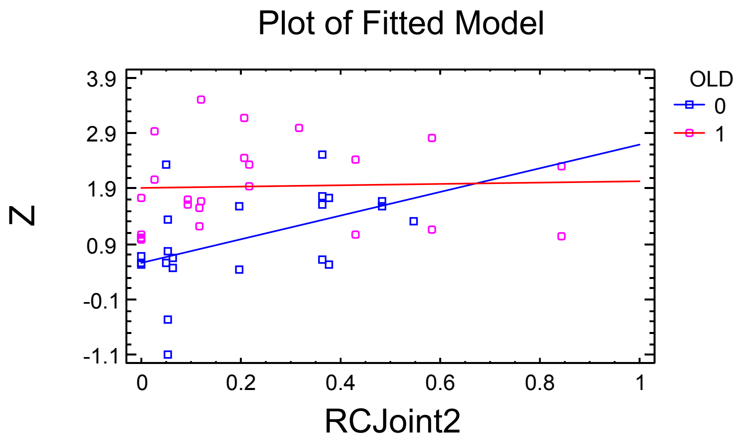
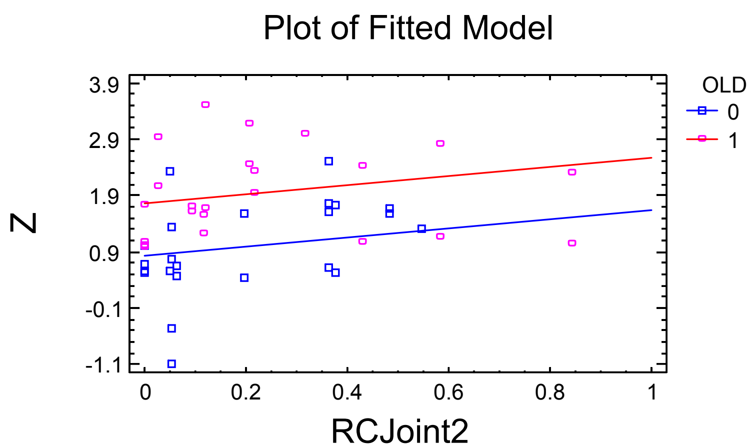


Figure 6: Initial and Final fitted models for the Z by ages as a function of the relative catches between surveys (RCJoint2).

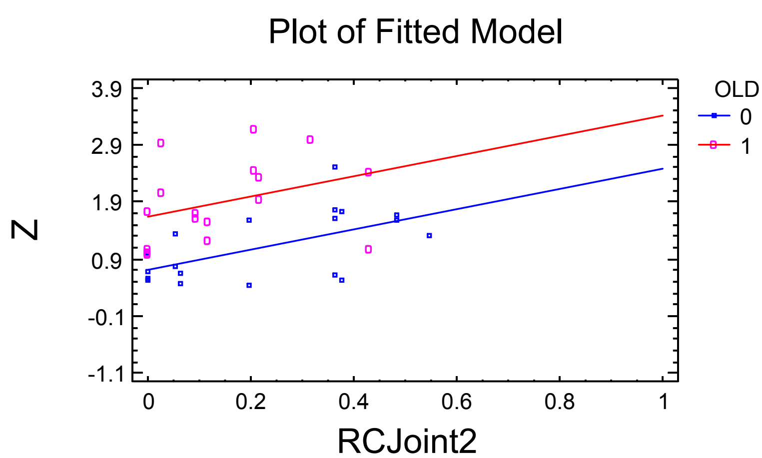
a) Initial Model



b) Fitted model



c) Fitted model after removing values with RC>0.8 Z<0 and Year=2011



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Working document to WKPELA 2013, 4-8 February 2013, Copenhagen (Denmark)

Potential use of the JUVENA survey for the assessment and forecast of the anchovy population in the Bay of Biscay

by

A. Uriarte, L. Ibaibarriaga and G. Boyra

Abstract

Since 2003 an autumn acoustic survey called JUVENA has been conducted annually to estimate the abundance of the juvenile anchovy. This working document reviews the evaluation of the JUVENA juvenile abundance index as an indicator of recruitment strength and summarises previous work on the potential use of this index for management purposes. In addition three different ways of producing population forecast based on the JUVENA index are detailed: Use of JUVENA only for forecasting purposes (external to the assessment); Use of JUVENA in the assessment and for forecasting purposes after the June assessment; Use of JUVENA in the assessment and for forecasting purposes after a November update assessment, all of them with the example of the forecast for 2013. All the procedures presented make use of the same predictive model, a log-linear model between this juvenile abundance index and the recruitment at age 1 next year as estimated in the assessment, which has proven to be so far the best fitted model in terms of the coefficient of determination (R^2 = 87%), certainly above the minimum level necessary to improve the provision of management advice. Recruitment forecasts based on the log-linear model have shown a reasonable good performance over the last three years. The inclusion of JUVENA as a tool to forecast the population in next year, should serve to either review the TAC set currently from July to June according to the tendency of the forecasted population, or to generate an advice for a TAC going from January to December, both according to different catch options in the management year. Certainly, this new advice would be generated in November, once the results from the survey become available.

1. Introduction

One of the major sources of uncertainty when managing small pelagic fish is the level of next incoming recruitment, which is highly variable and dependent on environmental conditions. This is usually addressed either trying to reduce the uncertainty when forecasting recruitment or promoting the development of management procedures robust to that uncertainty (Barange et al. 2009). Both approaches have been tried for the Bay of Biscay anchovy. On the one hand, several methods relating recruitment with various environmental indices have been developed (Allain et al. 2001, Borja et al.

2008, Borja et al. 1998, Fernandes et al. 2010, Huret et al. 2007). However, their low reliability has prevented their actual use with management purposes. On the other hand, the long term management plan for this stock proposed by the European Commission (EC) in 2009 (COM 2009) was selected with the aim of being robust to the unknown level of recruitment entering the population in January. According to the harvest control rule (HCR), in that proposal, the Total Allowable Catch (TAC) is set from June to July next year based on the spawning stock biomass estimate available in June, once the recruits have been fully incorporated into the spawning population.

Since 2003, an autumn juvenile acoustic survey called JUVENA (Boyra et al. 2012) has been conducted annually. The main objective of the survey is to estimate the juvenile abundance in order to provide an index of recruitment for the following year. JUVENA survey and its results are reported and discussed annually in the ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG) (ICES 2010). In the last years the survey methodology has been consolidated and the protocol has been endorsed by WGACEGG. Given the strong relationships between JUVENA index and next coming recruitments, since June 2010 ICES recognizes the possibility to review its June advice on anchovy once indications of the next incoming recruitment become available from the autumn acoustic survey. Such possibility has not been triggered yet.

In this working document we summarise the relationship between JUVENA index and the recruitment estimates in the respective following years. The reliability of the index is also analysed by reviewing the recruitment forecasts made in the past (2009-2012) based on the JUVENA index and its relationship with next year recruitment. Then, we discuss the following potential uses of the JUVENA series to improve the assessment and management advice of this stock::

a) Use JUVENA only for forecasting purposes based on a model fitted to the past series of JUVENA and next year recruitments.
b) Include JUVENA as a recruitment index in the assessment conducted in June. Once the results from JUVENA are available in November forecast the population one year forward according to the parameters relating JUVENA and recruitment as estimated in the June assessment.
c) Include JUVENA as a recruitment index in the assessment conducted in November. The assessment would automatically provide an estimate of next year recruitment, so that different catch options could be tested.

Finally, some considerations on the management of anchovy resulting from the incorporation of JUVENA are put forward for discussion.

2. Relationship between JUVENA juvenile abundance index and next year recruitment

The times series of the JUVENA anchovy juveniles abundance index and the estimates of recruitment (median values of age 1 biomass in January as estimated by the Bayesian two-stage biomass-based assessment model -BBM) from the last ICES assessment in 2012 (ICES 2012) are compared in Figure 1. The high estimate of anchovy juveniles in JUVENA2010 was followed by strong anchovy recruitment at age 1 in 2011. In addition, the low juvenile abundance indices of 2004, 2007 and 2008 are associated with the lowest recruitments estimated by the assessment since 2003.

The relationship between the JUVENA's juvenile abundance index and the recruitment next year (age 1 biomass in January,) has been statistically significant since 2009. The Spearman rank correlation between the JUVENA series and the assessment estimates of recruitment at age 1 is 0.81, which is statistically significant with p-value=0.01, and the Pearson correlation is 0.94, which is statistically significant with p-value=0.000163. The coefficient of determination of the linear model is 87% which is above the minimums required (around 50%) for recruitment indicators to suppose an improvement in case of using it for the provision of management advice (De Oliveira and Butterworth 2005, De Oliveira et al. 2005). Furthermore, the juvenile index of abundance provided by JUVENA series has a significant positive relationships with the direct estimates of recruitment at age 1 provided by the spring surveys (DEPM and acoustics), with coefficient of correlation of 0.94 and 0.89 for the DEPM and Acoustic estimates respectively and probabilities around 0.001 of such relationship being due to random (Figure 2).

Nowadays, among several simple candidate models the best fitting of the ICES recruitment assessment and the juvenile abundance index is achieved with a log-linear model (Table 1). The model is significant (p-value= 1.6E-04) with R^2=0.89% (Figure 3 and Table 2). Therefore WGHANSA (2012) considered that the JUVENA acoustic index of juveniles is a valid indicator of the strength of the incoming recruitment and hence useful for improving the forecast of the population and potentially its assessment and determined that the best use of this survey index should be established in the framework of the next benchmark for the stock (WKPELA) in February 2013.

3. Revision of past forecasts of recruitment based on the JUVENA series

Since 2009, once the results from the JUVENA survey were available in November, a forecast of next year recruitment was provided based on the model fitted to past series of JUVENA and recruitment similar to the one described in the previous section. Table 3 summarises the basis of those predictions and the forecasted recruitment with their probability intervals, *versus* the ICES estimates of those recruitments from the assessment in 2012. The ICES estimates of recruitment are always contained within the 95% prediction intervals from the JUVENA survey and the specified fitted model.

4. Use of JUVENA only for forecasting purposes

Currently the short term projections of the Bay of Biscay anchovy are based on the procedure described in Ibaibarriaga et al. (2008). Given that at the time of ICES delivering its advice in June there is no indication of recruitment, the short term projections of the anchovy population conducted by WGHANSA assume an undetermined recruitment scenario for next year, in which any of the past recruitments of the population are equally likely. This leads to a wide probability density function for recruitment and biomass of next year.

However, once the JUVENA juvenile abundance index is available in November a predictive distribution of recruitment can be constructed based on the log-linear regression model fitted to the past series of juvenile abundance index from the autumn acoustic JUVENA survey and recruitment in the following year. This distribution, while incorporating the uncertainty in the prediction, provides a more realistic and narrower scenario than the undetermined recruitment scenario and could be used to update the projections conducted by WGHANSA in June. In particular this approach has been used routinely since 2009 on the projections performed for the Spanish government and its performance has been reviewed in the former section.

Example: Prediction of the 2013 recruitment at age1

Applying the log-linear model between the juvenile abundance index and the biomass at age 1 in January next year (Figure 3) to the juvenile abundance estimates in autumn 2012 by JUVENA, the recruitment (biomass at age 1 in January) in 2013 would be around 41,100 t, with 95% prediction interval between 7,000 and 103,400 t (Figure 4, Table 4).

From the posterior biomass from the 2012 ICES assessment corresponding to May 2012 and the assumed or forecasted recruitment at age 1 in January 2013 (Figure 4), the population is projected forward in the short term (1 year) for different catch options from July 2012 to June 2013, using the same projection procedure as the one used by ICES (ICES, 2012; Ibaibarriaga et al., 2008). For this exercise, catches during the second semester in 2012 are assumed to be the 30% of the catches between July 2012 and June 2013 (although actual values can probably currently be incorporated). The rest of the catches are carried out during the first semester of 2013, from which the 58% (historical mean 1987-2004) are realized before mid-May, moment when the forecasted biomass is assessed for the evaluation of stock status at spawning time.

The median biomass and the probability of biomass being below B_{lim} in May 2013 are shown in Table 4 and Figures 5 and 6, in comparison with the undetermined recruitment scenario used in June 2012 by ICES. In the June forecast, catches larger than 28,000 t between June 2012 and July 2013 led to risks above 5% of the biomass in May 2013 of being below B_{lim}, with a median biomass of 53,000 t or lower depending upon actual catches. The risk of the biomass being below B_{lim} in May 2013 for the agreed TAC of 20,700 t would have been lower than 2%. According to the JUVENA based prediction all the catch levels evaluated (and up to 45,000 t) would imply risks lower than 5% of falling below B_{lim} in May 2013, with median biomass levels in May 2013 above 40,000 t., The risk of the biomass being below B_{lim} in May 2013 for the TAC established of 20,700 t would be lower than 0.5%.

5. Use of JUVENA for assessment and forecasting purposes

The JUVENA acoustic index of juvenile abundance could be included in the assessment in a straightforward manner parallel to the way the DEPM and acoustic spring surveys are included in the Bayesian assessment, but with the particularity of only tunning the abundance of a single age group (recruits age 1 in January next year). Therefore catchability and variance parameters of the survey will refer only to age 1. For an assessment carried out in June JUVENA series would comprise all the available indexes up to the year previous to the assessment. For an assessment carried out in November JUVENA series would comprise all the available indexes up to interim year of the assessment, incorporating thus in the output the expected recruitment at age 1 the following year Y+1.

Here below we describe the ways the forecast would be carried out conditioned to a June or November assessment in the context of the Bayesian assessments proposed for the evaluation of the anchovy:

5.1. Use of JUVENA for assessment and forecasting purposes from a June assessment.

The JUVENA juvenile abundance index can be included as a relative index of recruitment in the assessment model in Ibaibarriaga et al. (2011). Table 5 and Figure 6 show the comparison of CBBM when DEPM is taken as relative and M_1 and M_{2+} are estimated depending on whether JUVENA is included as a relative index or not. The major difference between both comes from the estimated natural mortality rates and recruitment series. When JUVENA is not included M_1 is lower than M_{2+}, whereas when JUVENA is included M_1 is larger than M_{2+}. This leads to slightly larger recruitment values when JUVENA is included in the assessment. The catchability of the JUVENA survey and its precision are estimated around 3.1 and 1.7 respectively.

From the posterior distributions of the parameters estimated in this model and once the results of the new JUVENA survey are available in November, the analysis could be completed to obtain an estimate of next year recruitment. This would allow analysing the effect of different fishing mortalities on the resulting distributions while incorporating uncertainty

5.2. Use of JUVENA for assessment and forecasting purposes from a November assessment.

As an alternative, an update assessment could be conducted once JUVENA index would become available in November. This assessment would include the catches up to the end of the year, the JUVENA index for the last year and any revision of the spring cruise results (as for instance expected for the DEPM). Such assessment will result in the population of survivors plus recruits in year Y+1. This would allow testing different catch options on the projected population and calculating the probability of the population falling below B_{lim} and/or any other statistic of interest.

6. Comment to the options open by the inclusion of JUVENA in the assessment and forecast of the population for the improvement of the advice.

Not including JUVENA in the assessment to make only use of it in the forecast has the appealing of independency of predictors from the assessment (i.e of the independent X variable vs the dependent variable Y in the fitted predictive model).

However it is arguable that for the past (at least) the juvenile abundance index can help in better assessing the past status of the population. Particularly for years like 2013 where major discrepancies between the two spring surveys arise between their SSB estimates.

Once inputted in the assessment the differences between the two projecting options (one making use of the June assessment or the other updating the assessment with inclusion of the autumn JUVENA index of the interim year Y) should be minimal. The obvious advantage of running an assessment in November is that the final (definitive) estimates of the DEPM and actual catches in the interim year can be taken into account for the projection of the next coming year. So the assessment and forecast of the population in January Y+1 will be somewhat improved (refined more precise) compared to the other options.

Nevertheless, the inclusion of JUVENA will allow evaluating the risk of the fishery operating for a range of catches option during, not only the first half of the year, but throughout entire year Y+1. This opens the possibility of making use of such prediction not only for updating a TAC set from July to June, but also to set TAC on the natural calendar year from January to December, a possibility already considered when developing the actual draft LTMP. As such, in the impact assessment accompanying the regulation proposal for the long-term management plan of the stock, it is stated that "DG MARE supports the views expressed by the SWWRAC and believes that the results of the autumn recruitment survey should be incorporated into the decision-making process to ensure that TAC set in early winter takes into account the natural mortality exerted on the newly recruits during the rest of the season and thus, can predict the available biomass for the next year. The proposal for a long-term plan would set the rule whereby fishing would be permitted from July of year N to June of the year N+1 depending on the biomass available in June, which is estimated following the spring scientific research trips. Once the JUVENA survey of juvenile fish commences, the TAC would once again be set every year, for a calendar year (from January to December)." Certainly in this new framework the spring surveys should serve to correct (if necessary) any major deviation from the projected population to actually occurring one and perceived by the surveys in the spring of Y+1.

The election of using JUVENA for just updating the TACs set from July to June or to revert to the TAC on natural calendar year, should depend on the comparison on the performance indicators for the two calendar management strategies along with their potential revisions at middle of the management year in terms for instance of the average attainable catches for a given allowable level of biological risk or of the frequency of requiring interim mid-year revision, according to the rules set to trigger such revision. Although such evaluation it is not the objective of this WD, the authors presumed that the needs for revisions will be less frequent for the TACs set in a natural calendar year than for the ones going from July to June, because the latter is set blind to the incoming recruitment while the former is not. However, moving from the current HCR of the draft management plan to a HCR setting TAC from January to December, based on the JUVENA recruitment index, requires a revaluation of the risk levels associated to different harvest rates in order to define the best harvest rate in agreement with the management objectives for this fishery. This re-evaluation could be carried out either by the STCEF or, if requested, by ICES.

Finally it is worth mentioning that it is not clear on what basis the TACs set according to the HCRs of the current draft management plan could be updated in December other that in the frame of the PA approach, because the HCR was developed to be robust to uncertainties in recruitment (i.e. without any information of the incoming recruitment). Revision of such TAC was not part of the HCR MSE loop and hence would de facto change the HCR and its properties. Therefore it would require some re-evaluation even if the suggested revisions in January will lead it to be more secure.

7. References

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Table 2:
Multiplicative (Log lineal) model fitted to the relationship
between Juveniles (Age 0) and Recruits at age 1 in January next year.

Regression Analysis - Multiplicative model: Y = a*X^b

Dependent variable: RecruitsAge1
Independent variable: JuvenilesAge0

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	4.79817	0.745334	6.43761	0.0004
Slope	0.490987	0.0667797	7.35233	0.0002

NOTE: intercept = ln(a)

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	5.48244	1	5.48244	54.06	0.0002
Residual	0.70994	7	0.10142		
Total (Corr.)	6.19238	8			

Correlation Coefficient = 0.940932
R-squared = 88.5353 percent
R-squared (adjusted for d.f.) = 86.8974 percent
Standard Error of Est. = 0.318465

Table 3: Past performance of the JUVENA index when forecasting next year recruitment.

JUVENA survey Year	Sources reference	for prediction Fitted Model	Original forecast Prediction for Y+1	Original 95% Lower limit	Original 95% Upper Limit	ICES most recent Assessment Recr. Y+1
2009	Uriarte et al. 2009	Linear	45345	7126	83564	57370
2010	Uriarte et al. 2010	Log-Linear	81000	31200	207700	113900
2011	Ibaibarriaga et al. 2011	Log-Linear	53000	27000	103400	29280
2012	This WD (see below)	Log-Linear	41,100	7000	103400	????

Table 4: Median recruitment in mass in January 2012, median biomass in May 2013 and probability of biomass in May 2013 of being below Blim depending on the catch between July 2012 and June 2013 and on the assumed recruitment scenario.

	MEDIAN RECRUITMENT IN 2013	
	Undetermined (1987-2012)	JUVENA 2012
	45600	41100

	MEDIAN BIOMASS IN 2012	
CATCH (July 2012 - June 2013)	Undetermined (1987-2012)	JUVENA 2012
0	69457	66210
5000	66566	63319
10000	63675	60428
15000	60784	57537
20000	57893	54646
20700	57488	54241
25000	55002	51755
30000	52111	48864
35000	49220	45973
40000	46329	43082
45000	43437	40191
50000	40546	37299

	PROBABILITY OF BIOMASS IN MAY 2012 BEING BELOW B_{lim}	
CATCH (July 2012 - June 2013)	Undetermined (1987-2012)	JUVENA 2012
0	0.0000	0.0000
5000	0.0000	0.0000
10000	0.0020	0.0000
15000	0.0060	0.0000
20000	0.0140	0.0000
20700	0.0160	0.0000
25000	0.0330	0.0010
30000	0.0600	0.0040
35000	0.0950	0.0090
40000	0.1330	0.0200
45000	0.1760	0.0410
50000	0.2220	0.0790

Table 5:Comparison of CBBM assessment depending on whether JUVENA index is included or not for the case when the DEPM is taken as relative and natural mortality rates are estimated.

	WITHOUT JUVENA			WITH JUVENA		
Parameter	5%	50%	95%	5%	50%	95%
q_{depm}	0.613	0.757	0.941	0.600	0.754	0.934
q_{ac}	1.261	1.586	2.030	1.243	1.576	1.997
				1.852	3.161	5.114
ψ_{depm}	3.282	5.688	9.086	3.291	5.635	9.115
ψ_{ac}	3.050	5.816	10.231	3.117	5.907	10.351
				0.693	1.750	3.678
ξ_{depm}	3.098	3.972	4.815	3.336	4.170	5.450
ξ_{ac}	2.901	3.709	4.647	2.999	3.849	4.658
ξ_{catch}	2.454	2.901	3.348	2.426	2.881	3.321
B_0	13836	18106	23624	14029	18215	23156
μ_R	9.815	10.200	10.590	9.837	10.220	10.610
ψ_R	0.678	1.080	1.651	0.646	1.050	1.625
$s(\text{sem}_1, 1)$	0.403	0.497	0.615	0.395	0.486	0.597
$s(\text{sem}_2, 1)$	1.191	1.585	1.944	1.232	1.592	1.937
M_1	0.484	0.821	1.189	0.484	0.860	1.256
M_{2+}	0.624	0.863	1.169	0.605	0.837	1.132
G_1	0.424	0.495	0.564	0.426	0.494	0.562
G_{2+}	0.130	0.189	0.255	0.127	0.189	0.259
ψ_G	20.440	31.125	44.403	20.610	31.045	44.751

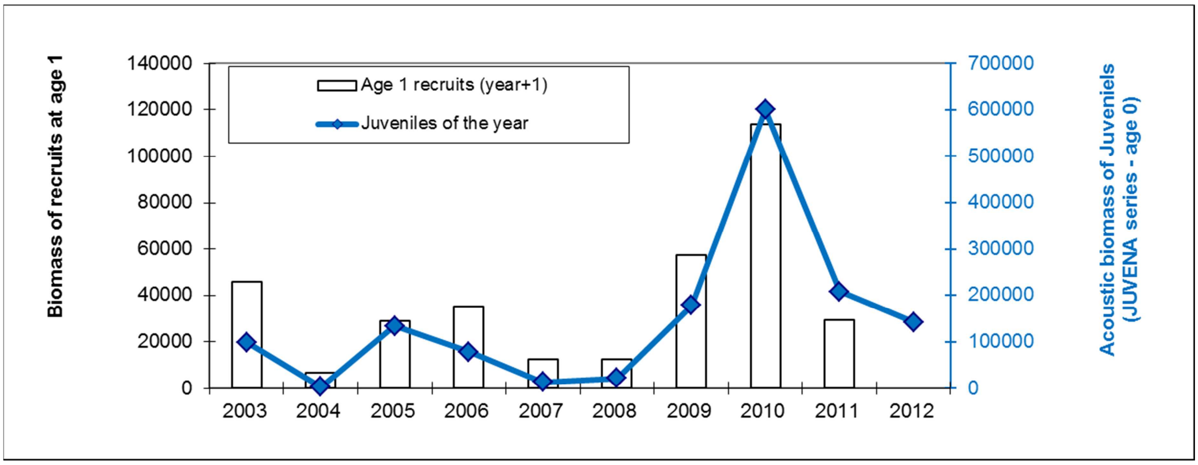

Figure 1: Times series of the JUVENA anchovy juveniles abundance index (blue line) and of the recruitment (median of the age 1 biomass at the beginning of the next year) as estimated by the 2012 ICES assessment (ICES 2012).

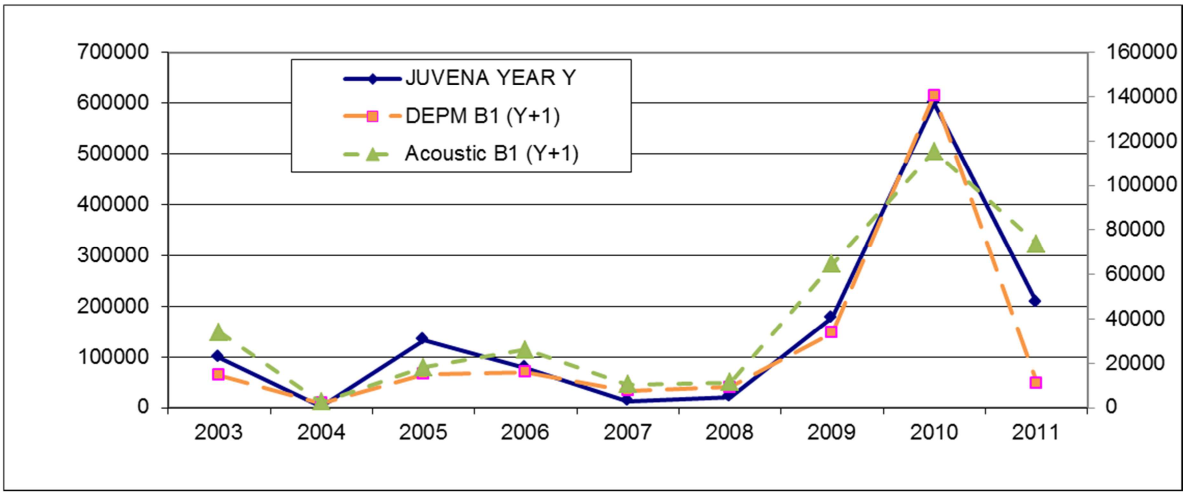

Figure 2: Times series of the JUVENA anchovy juveniles abundance index (blue line) and of the recruitment at age 1 during the Acoustic and DEPM surveys in May of the following years.

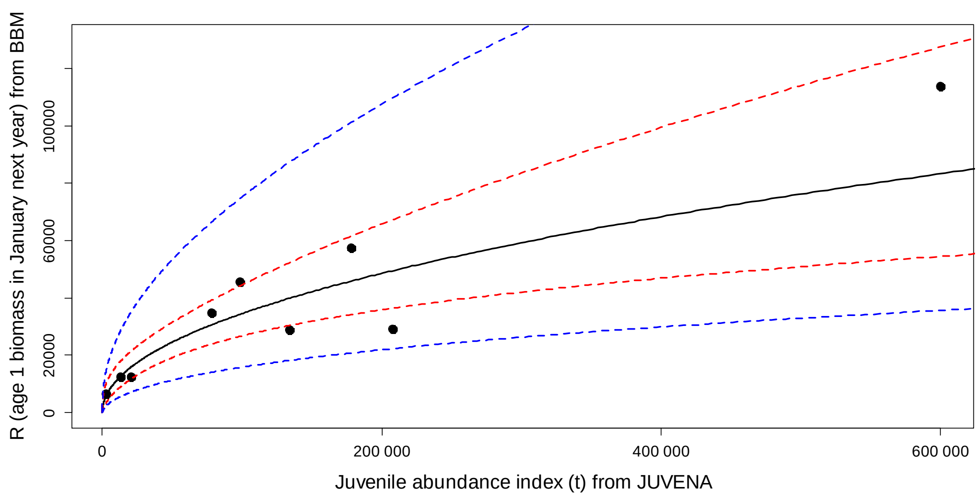

Figure 3: Log linear model fitted to the recruitment (median of the age 1 biomass at the beginning of the next year, y-axis) as estimated by ICES IN 2012 and the juvenile abundance index from the JUVENA surveys (x-axis, in tones). The bullets represent the estimated points of Recruitment by ICES in year Y+1 corresponding to the JUVENA juvenile index from 2003 to 2011. The solid black line is the fitted model, whereas the red and blue dashed lines are the 95% confidence and prediction intervals. Taken from WGHANSA (ICES 2012)

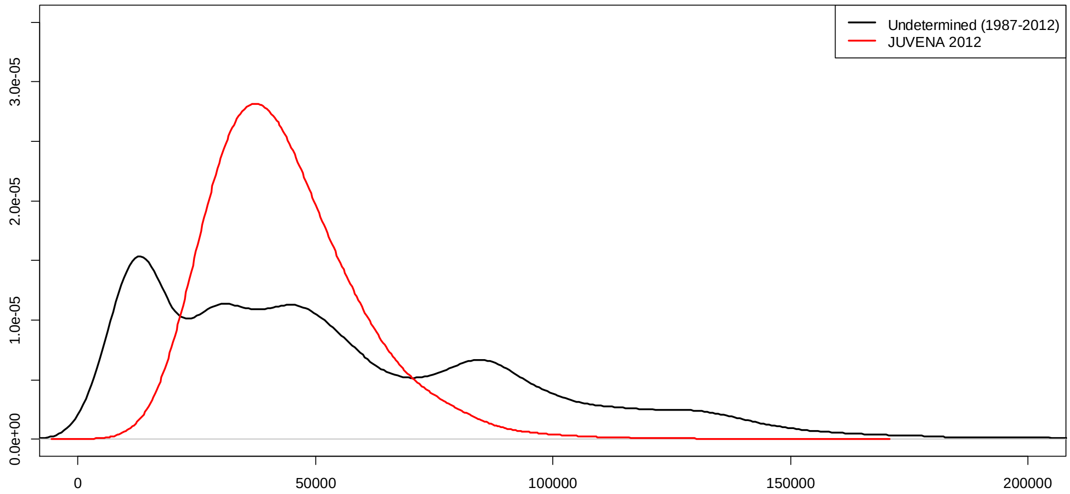

Figure 4: Probability density distributions for the recruitment at age 1 in January 2013, according to the undertermined and log lineal model forecasted recruitment levels

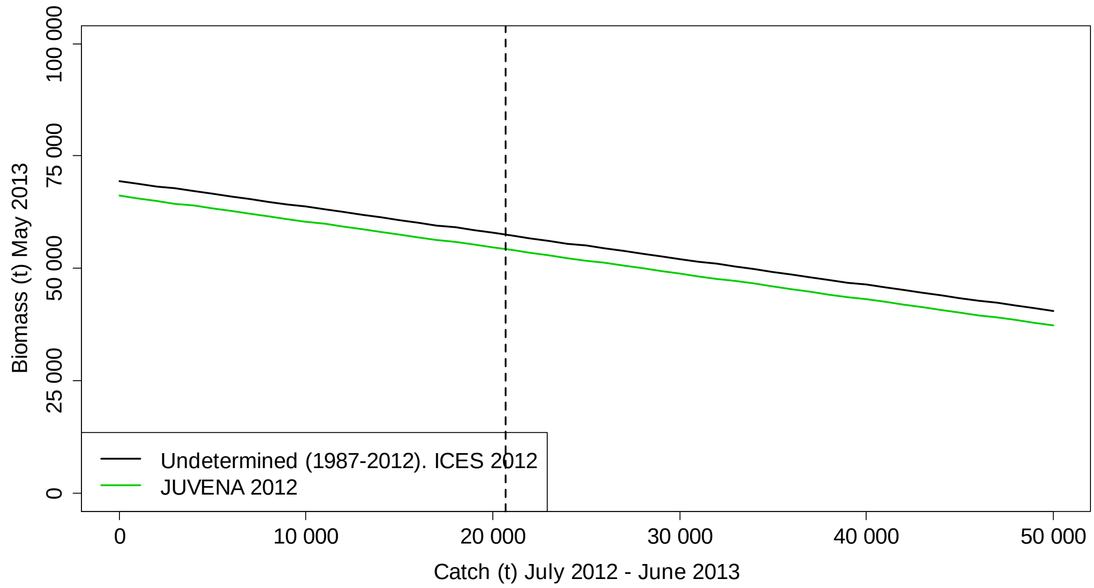

Figure 5: Median biomass in May 2013 (y-axis) depending on the catch between July 2012 and June 2013 (x-axis). Each line corresponds to a recruitment scenario. The vertical black dashed line corresponds with the TAC set for this fishery for this July-June period.

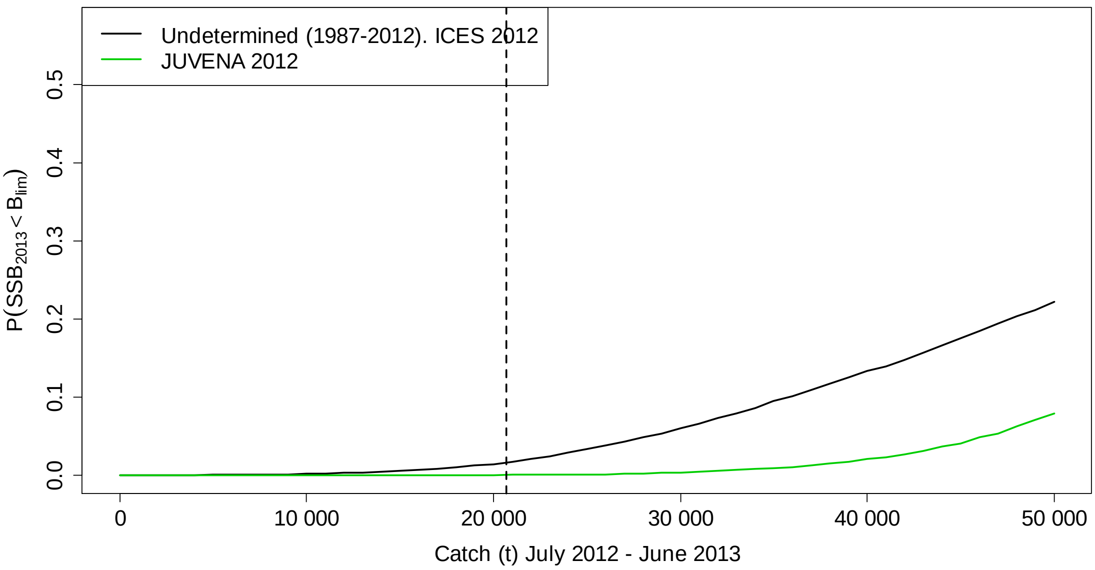

Figure 6: Probability of biomass in May 2013 of being below Blim (y-axis) depending on the catch between July 2012 and June 2013 (x-axis). Each line corresponds to a recruitment scenario. The vertical black dashed line corresponds with the TAC set for this fishery for this July-June period.

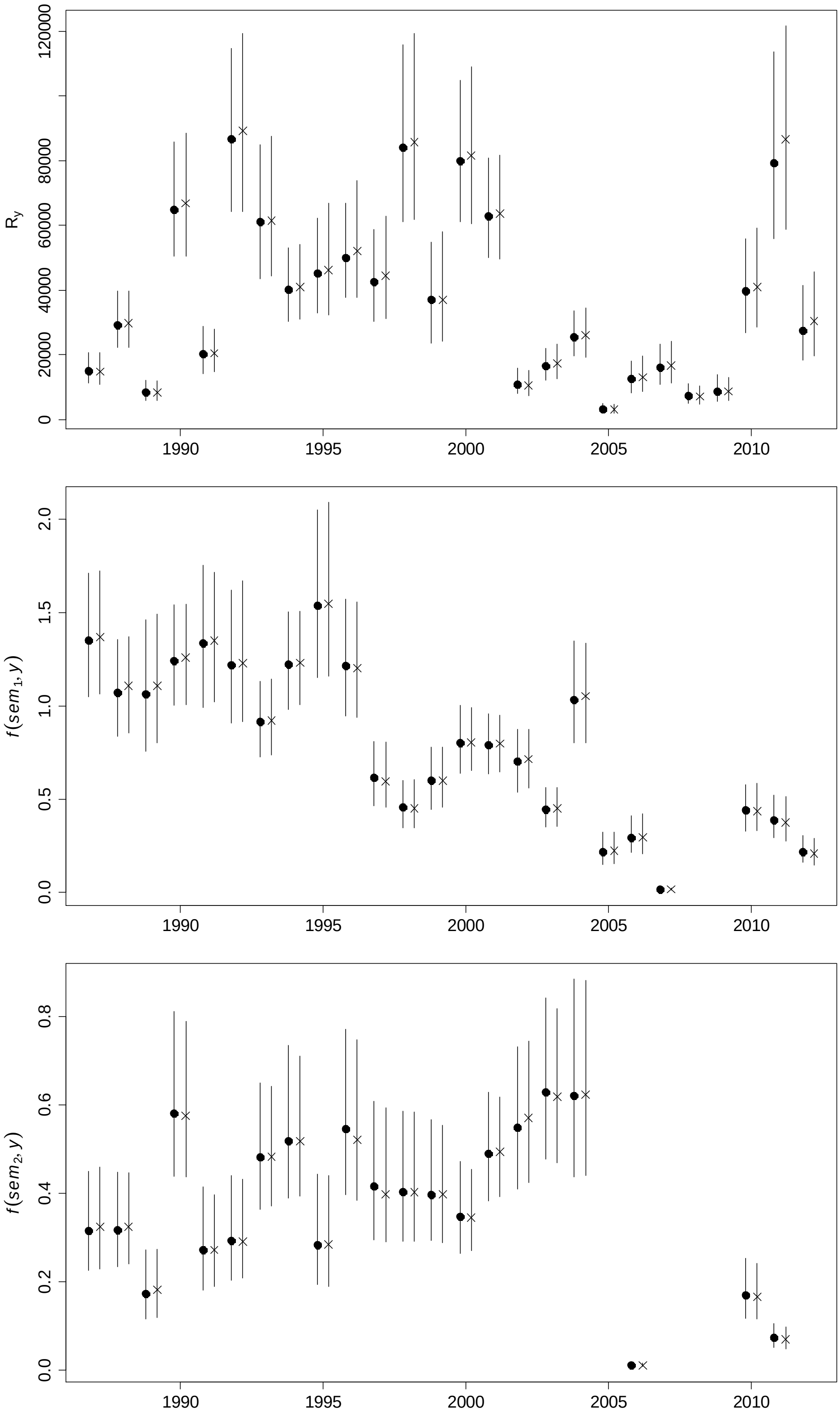

Figure 7: Comparison of posterior probability intervals for recruitment and fishing mortality by semester when JUVENA is not included (bullet) and it is included (cross) in the assessment with the CBBM.

Herring working documents

WD 1 Implementation of the Stock Separation Function (SF) within GERAS in 2005-2011

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Abstract

In the Baltic Sea, herring stocks are surveyed and managed according to a spatial separation that is based on ICES subdivisions. In the western Baltic, the distribution areas of two stocks, the Western Baltic Spring Spawning Herring (WBSSH) and the Central Baltic Herring (CBH) overlap. Survey results indicated that in SD 24, which is part of the WBSSH management area, a considerable fraction of CBH is present and correspondingly erroneously allocated to WBSSH stock indices. Accordingly, a Stock Separation Function (SF) based on growth parameters was established to identify the fraction of CBH in the WBSSH area and applied to survey data from the German Acoustic Survey GERAS from 2005-2011. Results showed a distinct fraction of CBH in SD 24 and indicated that applying the SF greatly improved both abundance and biomass indices for WBSSH.

1 Introduction

In the western Baltic, the distribution areas of two different herring stocks, the Western Baltic Spring Spawning Herring (WBSSH) and the Central Baltic Herring (CBH) overlap. Stock assessment for Baltic herring so far is based on indices generated on a spatial separation of both stocks according to ICES subdivisions. Generally, herring monitored and sampled in ICES subdivisions 21-24 are allocated to the WBSSH stock. Overall, the CBH stock is characterized by a lower weight at age and an overall “ailing” appearance as compared to the WBSSH. The abundance and biomass index generated from the German 2010 autumn acoustic herring survey data showed an uncharacteristic decrease in weight with increasing age, together with lower mean weights at age. Additionally, peak abundances in some age groups indicated strong previous year classes, which had not been detected in previous surveys. This was mainly evident in ICES SD 24. This indicated that in parts of the survey area, a stronger mixing and contribution of CBH took place. To assess the degree of contribution of CBH to the abundance and biomass index generated for WBSSH from catch data in the survey area, a method was required to separate both stocks according to measures readily available from survey data and to consecutively remove the CBH fraction from survey results. As a separation according to e.g. genetic analyses etc. was not applicable due to a lack of data and as other measures as e.g. eye diameter proved too inaccurate for a reliable separation, another measure was required. Thus, a separation function (SF) based on growth parameters was established. Generally, CBH show a lower weight at age than WBSSH. Thus, based on Bertalanffy growth parameters of both WBSSH and CBH, a SF was established and applied to survey data to indentify and quantify the fraction of CBH.

2 Method

The stock separation function (SF) was applied to herring sampled in ICES SD 24 during the German Acoustic Survey (GERAS) as part of the ICES coordinated Baltic International Autumn Acoustic Survey (BIAS) in 2005-2011. In this period, lower and decreasing mean weights at age were most obvious in this area, indicating a mixing of WBSSH and CBH stocks.

The SF was derived from comparing Bertalanffy growth parameters of both WBSSH and CBH. Accordingly, a herring can be allocated to either WBSSH or CBH if its length (in cm) at age A_M (in months) is above or below the separator length (SF, in cm):

$$SF = 25.3962\ \text{cm}\ \times (1 - e^{\left(-0.385 \times \left(\frac{A_M}{12}\right) - 0.262\right)})$$

A detailed description of the SF as well as details on derivation and baseline samples for the identification of growth parameters etc. is given in a Working Document presented to ICES HAWG (Gröhsler et al. 2012).

After estimation of a new abundance index for the survey period, the applicability of the SF as well as the quality of the newly generated index were tested by assessing the correlation of abundance indices of consecutive year classes over the survey period.

3 Results

An application of the SF to survey data from 2005-2011 led to an overall reduction of both numbers and biomass of WBSSH since 2005, indicating a stronger contribution of CBH to the index in recent years (Fig. 1, Table 1). Removal of the CBH fraction from herring survey indices in SD 24 resulted in biomass reductions of ca. 6-8% before 2008 and 13-17% afterwards with corresponding reductions in numbers of 5-6% and 6-11% respectively. Overall, the decrease in biomass was more pronounced than the decrease in abundance. The unexplained peak in 3 year old herring as observed in 2010, together with an unrealistic decrease in mean weight at age vanished after removing CBH from survey data (Fig. 2).

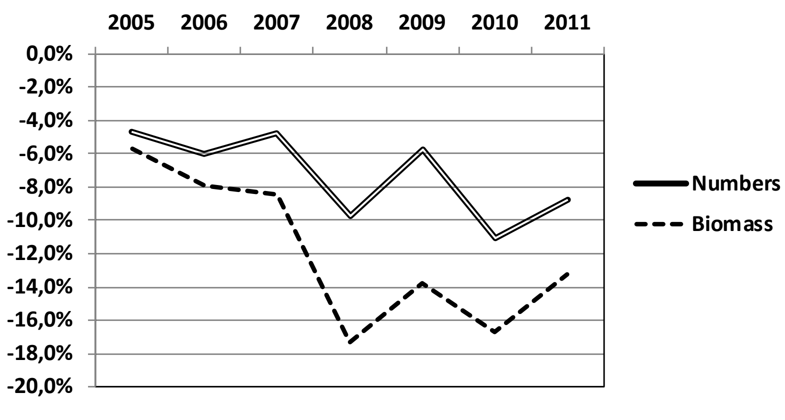

Figure 1: Relative changes in abundance and biomass of Western Baltic Spring Spawning Herring in ICES Subdivisions 21-24 (2005-2011) after application of the stock separation function to the abundance and biomass index generated from German survey data.

Table 1: Abundance and biomass as well as mean weight of both Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in ICES Subdivisions 21-24 in 2005-2011. Changes in abundance and biomass of WBSSH after removal of CBH are indicated in the far right column.

	Numbers (millions)			Mean weight (g)			Biomass (t)			Original Biomass	Change in (%)	
Year	WBSSH	CBH	Total*	WBSSH	CBH	Total	WBSSH	CBH	Total	incl. CBH (t)	Biomass	Numbers
2005	5.033,12	245,99	5.279,11	39,0	39,4	39,1	196.503	9.696	206.199	208.300	-5,7%	-4,7%
2006	6.150,78	392,33	6.543,11	36,5	43,0	36,9	224.665	16.884	241.548	243.900	-7,9%	-6,0%
2007	3.676,53	182,47	3.859,00	27,7	45,7	28,5	101.668	8.346	110.014	111.000	-8,4%	-4,7%
2008	3.109,31	335,36	3.444,67	31,4	49,2	33,1	97.588	16.516	114.104	118.000	-17,3%	-9,7%
2009	3.265,06	199,65	3.464,71	17,2	40,6	18,5	56.048	8.110	64.158	65.000	-13,8%	-5,8%
2010	5.896,59	731,51	6.628,10	26,1	39,0	27,5	153.646	28.558	182.204	184.400	-16,7%	-11,0%
2011	4.975,68	477,52	5.453,20	35,8	51,1	37,2	178.320	24.413	202.733	205.600	-13,3%	-8,8%

* Orignal Index

A "quality check" of the data that included comparing abundance indices of consecutive year classes before and after the application of the SF showed a far better correlation of corresponding abundances throughout the year classes after removal of Central Baltic Herring from the indices (Figures 3 & 4).

4 Conclusions

The application of a stock separation function based on herring growth parameters to survey data from the western Baltic is feasible to separate different stock fractions. Accordingly, after the application of the SF, a variable but seemingly increasing degree of mixing of Western Baltic Spring Spawning Herring and Central Baltic Herring was evident in recent years in an area that for assessment purposes is allocated to WBSSH. Removal of the CBH fraction from German survey results used to generate an abundance and biomass index for WBSSH in ICES Subdivisions 21-24 led to an overall yearly reduction in biomass of up to 17% while a corresponding reduction in abundance only in one year exceeded 10%. However, the indices generated after exclusion of CBH seemed far more reliable as this led to the removal of unexplained/unobserved strong year classes and unrealistic mean weights at age in WBSSH. It is recommended to apply the SF to future survey data for an improvement of survey indices used in WBSSH stock assessment.

5 References

*Gröhsler, T., Oeberst, R., Schaber, M. Casini, M., Chervonstev, V., Wyszyński, M. (2012). Mixing of Western Baltic Spring Spawning and Central Baltic Herring (*Clupea harengus*) Stocks – Implications and consequences for stock assessment. Working document for the ICES

- "Herring Assessment Working Group for the Area South of 62° N (HAWG)", 13.-22.03.2012, Copenhagen (WD 06).
- "Baltic International Fish Survey Working Group (WGBIFS)", 26.-**30**.03.2012, Kaliningrad, Russia.
- "Baltic Fisheries Assessment Working Group (WGBFAS)", 12.-19.04.2012, Copenhagen (WD 4)

In: Report of the Baltic International Fish Survey Working Group (WGBIFS). ICES CM 2012 /SSGESST: 02, Annex 9: 376-398,

Report of the Baltic Fisheries Assessment Working Group (WGBFAS). ICES CM 2012/ACOM:10, Annex 16: 749-772.

* this WD has been prepared as a manuscript and was submitted to the ICES Journal of Marine Science (Current status: accepted/resubmit after revision).

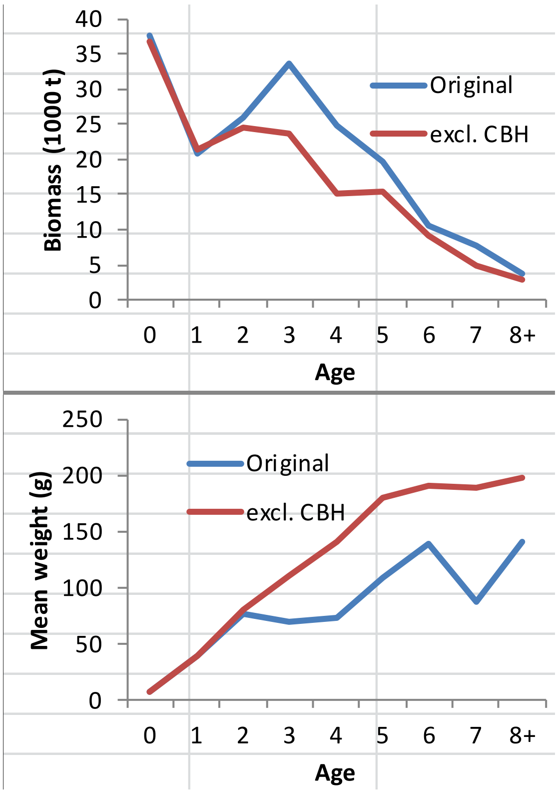

Figure 2: Biomass index (upper panel) and mean weight at age (lower panel) of herring as derived from survey data in 2010 (GERAS, BIAS) in the western Baltic (SD 21-24) prior to and after application of Stock Separation Function and removal of the Central Baltic Herring fraction.

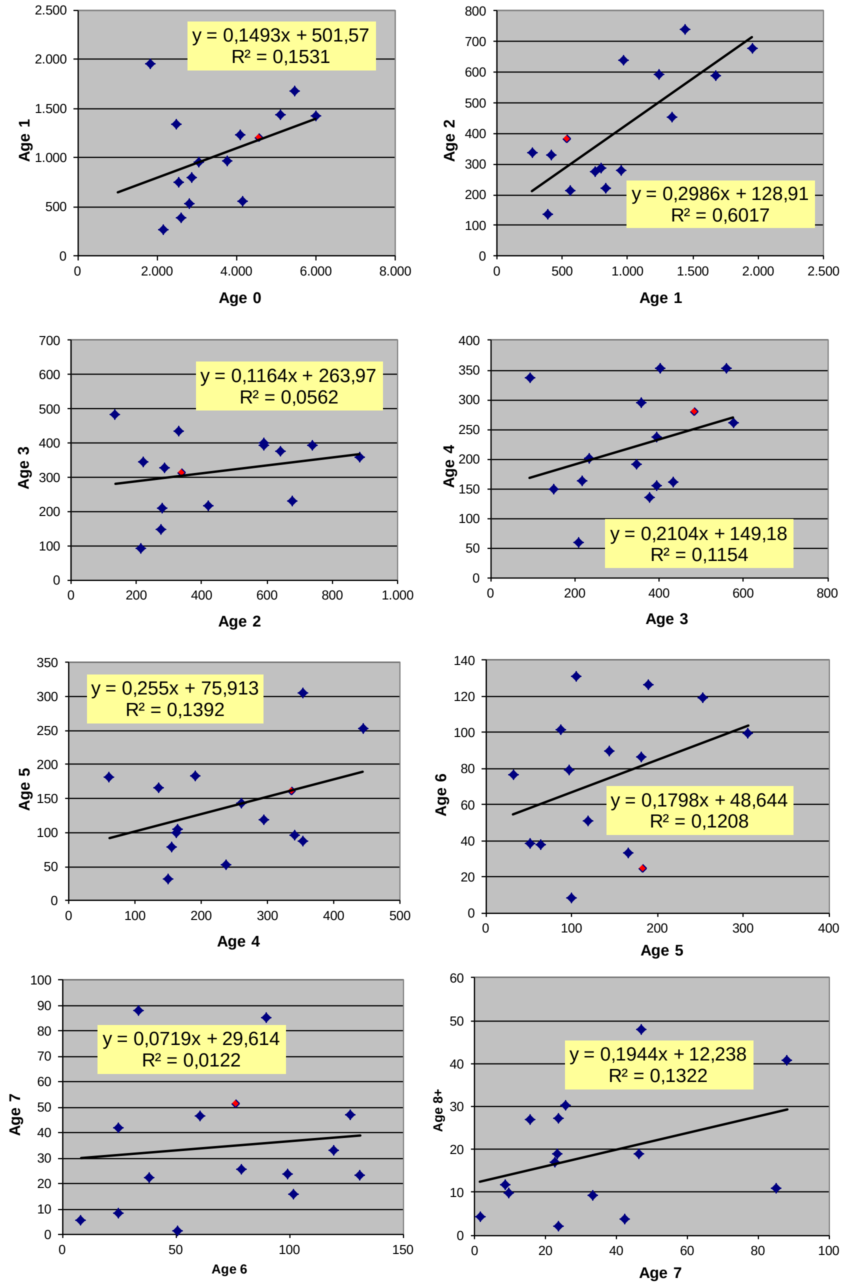

Figure 3: Pair-wise (consecutive winter rings/ages) comparison of age based original abundance indices for Western Baltic Spring Spawning herring 1994-2011.

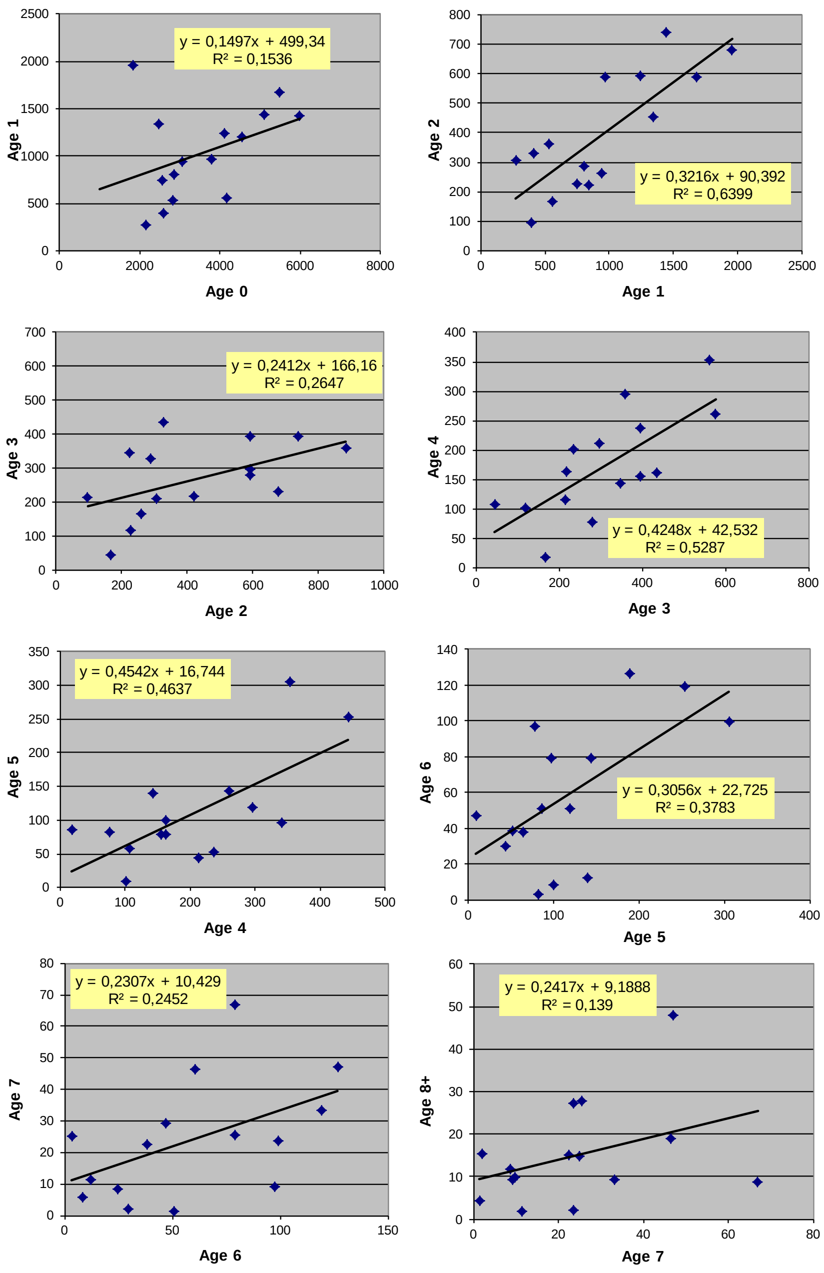

Figure 4: Pair-wise (consecutive winter rings/ages) comparison of age based abundance indices for Western Baltic Spring Spawning herring 1994-2011 after application of the Stock Separation Function in SD 24 survey results and removing of the Central Baltic Herring fraction from 2005-2011.

WD 2 Applicability of the Stock Separation Function (SF) on the first period of GERAS in 1994-2004

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Abstract

To assign herring individuals to either Western Baltic Spring Spawning Herring (WBSSH) or Central Baltic Herring (CBH), a stock separation function (SF) based on different growth patterns of both stocks was derived from survey and commercial data from 2005 to 2010 (for details see WD Gröhsler, Oeberst and Schaber). Length and age data from the German Autumn Acoustic Survey (GERAS) sampled in Subdivision (SD) 21 and 23 between 1994 and 2004 were used to estimate the parameters of the Bertalanffy growth function (BGF) in order evaluate the existing SF. The analyses showed a slight shift of the parameters and a change of growth within this period. Therefore, the SF cannot be extrapolated to the period between 1994 and 2004. An application of the SF to the period 1994-2004 would result in an overestimation of the fraction of CBH. Possible changes in age reading procedures did not determine changing growth parameters. It is needed to estimate a separate SF for the period between 1994 and 2004.

Introduction

A separation function (SF) for assigning individual herring to WBSSH or CBH (for details see WD 01: Gröhsler, Oeberst and Schaber) was applied to estimate the fraction of WBSSH during GERAS between 1994 and 2010. The analyses of the consistency of the stock indices by age showed that the coefficient of determination (R^2) of the linear regression between the indices of the same year class in subsequent years ($N(y+1,t+1) = a + b * (y,t)$) increased after excluding CBH between 2005 and 2011 based on SF. This is in contrast to the extrapolation of the separation function to 1994 to 2004, which resulted in a significant decrease of the R^2 values. This decrease was most pronounced in 1994.

The aim of this study was to evaluate the cause of the overall decrease of the R^2 values by analysing the parameters of the Bertalanffy growth function for the earlier period of GERAS in 1994 till 2004.

Material and Methods

Yearly based parameters of the BGF were estimated from age and length data of herring captured in SD 21 and 23 in 1994 -2010 in order to evaluate the existing separation function (SF) (WD Gröhsler, Oeberst and Schaber).

Results

The estimates of L_∞ and k of the BGF showed clear trends from 1994 to 2010 (Fig. 1a and 1b). L_∞ was lower in 2005 to 2010 compared to the former period. In contrast, k values were larger in 2008-2010 compared to 1994-2007, with a positive trend. L_∞ and k of the different years were highly correlated (Fig. 2). The linear relation indicated an increase of the mean length of young herring (increasing k) resulting in a decrease of L_∞ and vice versa.

The mean length of age groups showed different developments between 1994 and 2004 (Fig. 3). A slightly negative trend was observed for the length at age 0. In contrast to this, a positive trend was observed for mean lengths of age group 1 to 6. The opposite development of mean length at age resulted in an increase of the annual growth of young herring (age group 0 to age group 1, etc., Fig. 4). The mean annual growth at ages 4 and 5 decreased in the same period. The development of both the parameters of the BGF and mean length at age clearly indicated that the extrapolation of the separation function based on the period 2005 to 2010 to the earlier period 1994-2004 would result in biased estimates of the proportion of CBH and WBSSH. The smaller length at ages 2 to 6 between 1994 and 2004 would lead to an overestimation of the proportion of CBH in the years before 2005.

Discussion

The observed different parameters of the BGF for the period 1994-2004 could have different causes. The change of the growth of WBSSH between 1994 and 2004 compared to the later period 2005-2010 could be caused by the decreasing stock size at that time, which possibly led to a change in predation pressure by cod. Such a development corresponds with the observed increase of the annual growth of age group 1 to 6 and increasing k. In addition, the number of large herring decreased which influence the estimates of L_∞.

Different ageing of herring during the early period could also explain these observed changes in growth. In 1995 and 1998, ICES held two workshops where the ageing of herring was compared between different readers (ICES 2005, 2008). The participation in these workshops could have had some influence on the ageing procedure later on.

To evaluate possible changes of the ageing procedure in German readers, the relative length frequencies of herring sampled by rectangles during GERAS were compared to the theoretical relative length frequencies (for further details on the method see Oeberst, 2000). The theoretical relative length frequency was estimated by means of the mean length at age and the standard deviation of the mean length at age assuming that the length frequency of an age group is normally distributed.

Figure 5 and 6 give examples of the observed length frequencies and the corresponding theoretical length distribution by rectangles in 1994, 2009 and 2010. Only ICES rectangles including more than 5 age groups were selected for illustration.

The theoretical length distributions agreed well with the observed length frequencies in general. Changes of the frequencies due to the variability of the strength of age group 0 and 1 were well described by the theoretical length frequency. This agreement indicates that the ageing of herring with age group 0 and 1 was not influenced by systematic errors of ageing (see Rectangle 39G4 in 2009). In 2009 larger differences are apparent in Rectangle 39G4. The peaks of the length frequency of herring larger than 18 cm were not well fitted by the theoretical length. However, the comparisons did not indicate any systematic change in the agreement between the length frequencies and the theoretical length distributions in the years 1994 to 2010. It can therefore be concluded that the change of L_∞ and k in 1994 to 2010 is not significantly determined by a change in ageing procedures of the German readers.

Conclusions

- SF based on the period between 2005 and 2010 cannot be extrapolated to the earlier period of the years 1994-2004 due to different growth parameters in these years.
- The use of the SF for the period 1994-2004 would result in an overestimation of CBH
- Possible changes in age reading procedures did not determine changing growth parameters. It is needed to estimate a separate SF for the period between 1994 and 2004.

References

ICES. 2005. Report from the Herring Age Reading Workshop in the Archipelago Research Institute, the island of Seili, Finland, on 6–9 June, 2005: http://www.ices.dk/reports/acfm/pgccdbs/her.agewk2005.pdf

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Oeberst, R. 2000. An universal cost function for the optimisation of the number of age readings and length measurements for Age-Length-Key-Tables (ALKT). Arch. Fish. Mar. Res. 48(1), 2000: 43-60

Figures

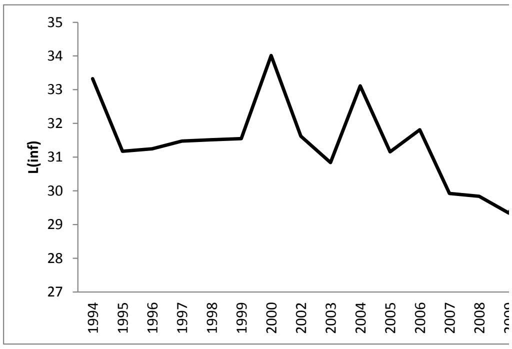


Figure 1a: Development of L_{∞} in 1994- 2010

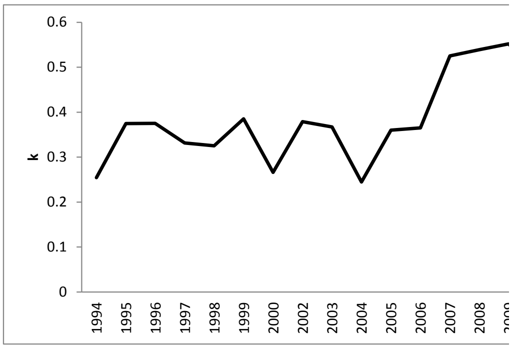


Figure 1b: Development of k in 1994-2010

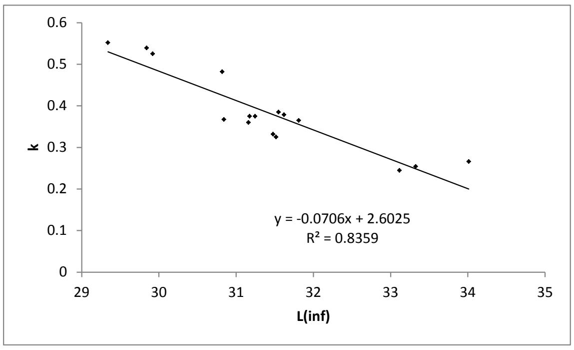


Figure 2: Relation between L_{∞} and k of yearly BGF in 1994-2010.

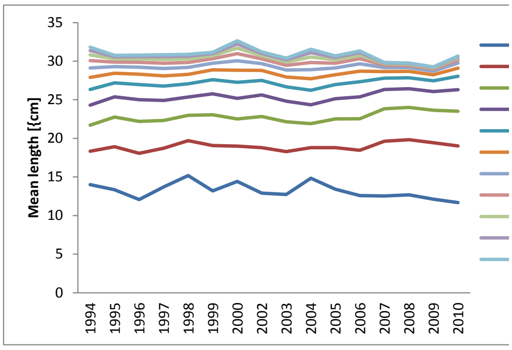


Figure 3: Development of mean length a stage of WBSSH in SD 21 and SD 23 in 1994-2010

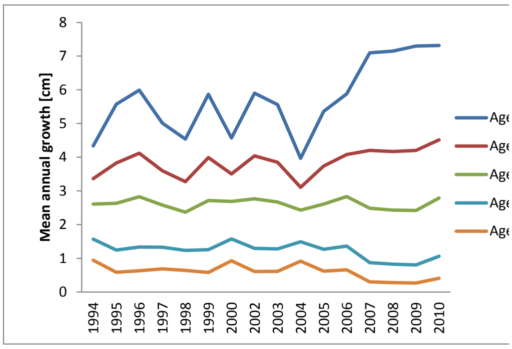
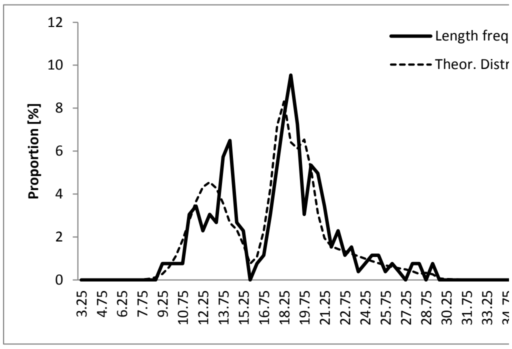
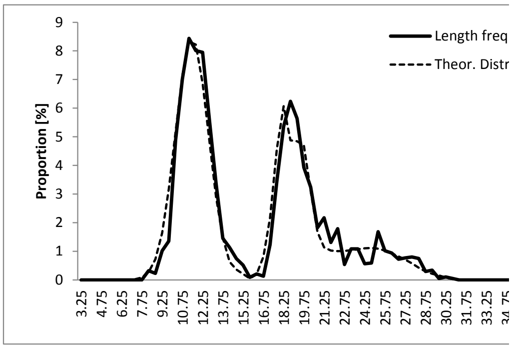


Figure 4: Development of the mean yearly growth of herring at age in 1994-2010

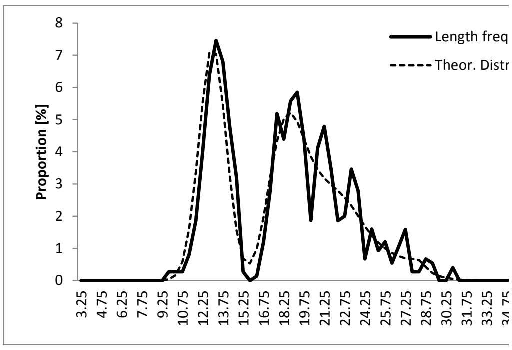


Rectangle 38G4 in 1994

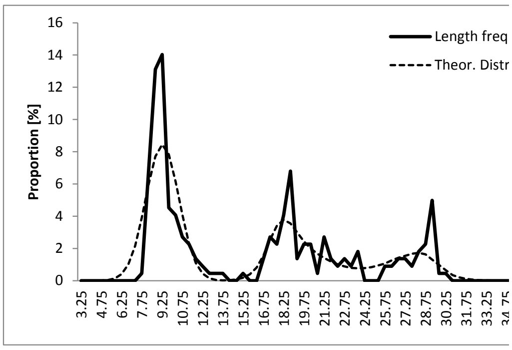


Rectangle 39G3 in 1994

Figure 5: Observed and theoretical length distribution of herring in different rectangles in 1994 (GERAS)



Rectangle 39G4 in 2009



Rectangle 37G3 in 2010

Figure 6: Observed and theoretical length distribution of herring in different rectangles in 2009 and 2010 (GERAS)

WD 3 Implementation of the Stock Separation Function (SF) on German commercial landings

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Abstract

Western Baltic Spring Spawning Herring constitute an important species in the German commercial fisheries in ICES Subdivisions (SD) 22 and 24. As shown from data sampled in German acoustic surveys (GERAS) in ICES SD 21-24, a varying but distinct fraction of herring in SD 24 belong to the Central Baltic Herring stock. Therefore, a Stock Separation Function that was established from survey data was employed to identify the fraction of Central Baltic Herring in German commercial herring landings from SD 22 and 24 in the years 2005-2011. Results showed a rather low share of CBH in landings from all métiers but indicated that the actual degree of mixing might be underrepresented in commercial landings as German commercial fisheries target pre-spawning and spawning aggregations of WBSSH.

1 Introduction

In the western Baltic, the distribution areas of two different herring stocks, the Western Baltic Spring Spawning Herring (WBSSH) and the Central Baltic Herring (CBH) overlap. Stock assessment for Baltic herring so far is based on indices generated on a spatial separation of both stocks according to ICES Subdivisions. Generally, herring monitored and sampled in ICES SD 21-24 are allocated to the WBSSH stock. However, especially in the border regions of the assessment areas, significant mixing of both WBSSH and CBH occurs.

To assess the degree of contribution of CBH to the abundance and biomass index generated for WBSSH from scientific catch data in the survey area, a method was established to separate both stocks according to measures readily available from survey data and to consecutively remove the CBH fraction from survey results. Based on Bertalanffy growth parameters of WBSSH and CBH, a Stock Separation Function (SF) was established and applied to survey data to indentify and quantify the fraction of CBH (Gröhsler et al., 2012). Results showed that especially in ICES SD 24 a distinct fraction of WBSSH biomass and abundance could be allocated to Central Baltic Herring.

Herring, i.e. WBSSH, constitute an important species in the German commercial fisheries in ICES SD 22 and 24. The overall share of German herring landings from these subdivisions is about 24-36% of the total herring landings (Fig. 1, Table 1). To assess the fraction of CBH in German commercial landings, the Stock Separation Function established from survey and commercial catch data was applied to German landings data from Subdivisions 22 and 24 from the years 2005-2011.

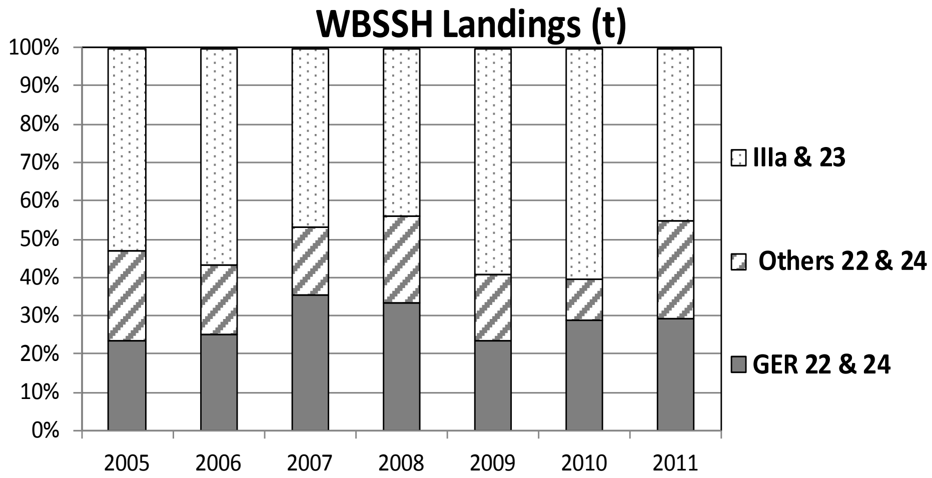

Figure 1: Relative contribution of German commercial herring landings (in t) to overall herring landings in ICES area IIIa and Subdivisions 22-24 in the years 2005-2011.

Table 1: Commercial (Germany and others) herring landings (t) in ICES area IIIa and Subdivisions 22-24 from 2005-2011.

Year	GER 22 & 24	Others 22 & 24	IIIa & 23	TOTAL
2005	21.040	20.483	46.883	88.406
2006	22.870	16.512	51.167	90.549
2007	24.583	12.095	32.319	68.997
2008	22.832	15.716	29.936	68.484
2009	15.981	11.428	39.853	67.262
2010	12.239	4.595	25.381	42.214
2011	8.187	7.072	12.513	27.772

2 Method

The stock separation function (SF) was derived from comparing Bertalanffy growth parameters of both WBSSH and CBH. Accordingly, a herring can be allocated to either WBSSH or CBH if its length (in cm) at age A_M (in months) is above or below the separator length (SF, in cm):

$$SF = 25.3962 \text{ cm } \times (1 - e^{\left(-0.385 \times \left(\frac{A_M}{12}\right) - 0.262\right)})$$

A detailed description of the SF as well as details on derivation and baseline samples for the identification of growth parameters etc. is given in Gröhsler et al. (2012).

The SF was applied to herring from German commercial landings from ICES SD 22 and 24, from where an important fraction of German commercial herring landings origins. In SD 22, the major part of commercial catches (total: ~ 2000 t per year) were conducted with trawl nets, with gillnet and trapnet contributing to a lesser extent (Fig. 2, Table 2). In SD 24, trawl catches constituted about 50% of total herring catches (7000 – 22 000 t, Fig. 3, Table 3). The rest of commercial landings in SD 24 also origin from gillnets, and to a small extent trapnets.

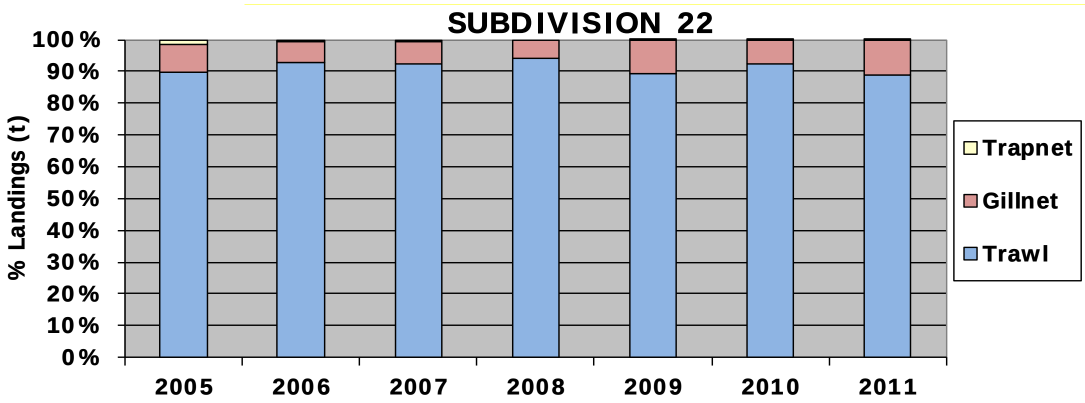

Figure 2: Relative contribution of different gear types in total German commercial herring catches in ICES SD 22 in the years 2005-2011.

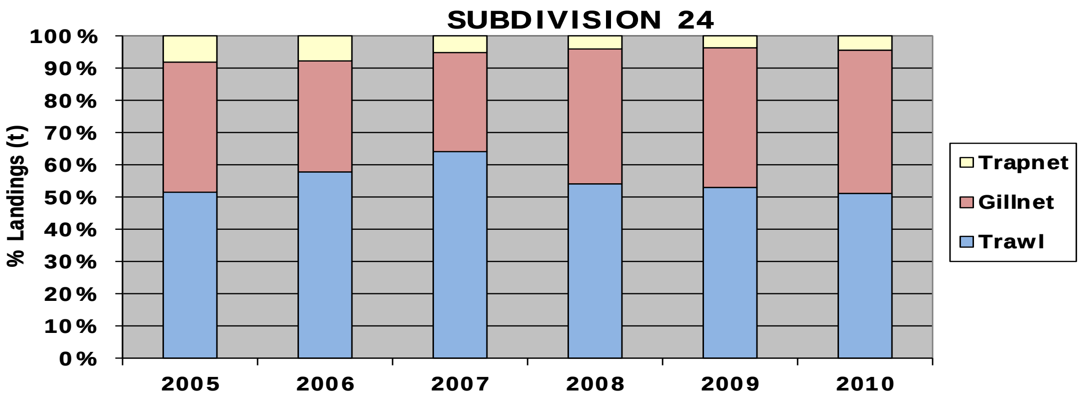

Figure 3: Relative contribution of different gear types in total German commercial herring catches in ICES SD 24 in the years 2005-2011.

Table 2: German commercial herring catches (t) in ICES SD 22 in the years 2005-2011 according to gear type.

(t)	Trawl	Gillnet	Trapnet	Total
2005	1.700,627	162,795	29,312	1.892,734
2006	2.977,731	215,366	14,372	3.207,469
2007	1.922,914	139,321	16,395	2.078,630
2008	2.086,175	124,471	0,000	2.210,646
2009	1.436,082	171,106	0,910	1.608,098
2010	1.565,826	125,609	3,381	1.694,816
2011	1.040,724	124,015	3,073	1.167,812

Table 3: German commercial herring catches (t) in ICES SD 24 in the years 2005-2011 according to gear type.

(t)	Trawl	Gillnet	Trapnet	Total
2005	9.863,481	7.761,212	1.522,218	19.146,911
2006	11.393,038	6.744,164	1.525,095	19.662,297
2007	14.449,006	6.937,814	1.117,411	22.504,231
2008	11.196,706	8.636,140	789,005	20.621,851
2009	7.617,179	6.232,206	523,088	14.372,473
2010	5.415,716	4.679,209	448,801	10.543,726
2011	3.654,547	3.177,875	186,600	7.019,022

3 Results

According to Subdivision, quarter of year and gear type employed, distinct differences in Central Baltic Herring proportions were evident. Overall, the catch levels in trapnets (numbers caught) and accordingly the number of samples were low in both SD 22 and 24. The share of CBH in these catches according to numbers caught was generally low with only two exceptions in 2005 (SD 24) and 2011 (SD 22) when the CBH fraction was 16% and 14% respectively (Figures 4 & 5).

German gillnet catches in SD 22 and 24 consisted almost exclusively of WBSSH. The share of CBH was negligible both in SD 22 and SD 24, with a highest overall share of 1.9% in 2009 in SD 24/Q4 (Figures 6 & 7).

In German trawl catches, the share of CBH (in numbers) was highest in both SD 22 and SD 24. Overall, the level was in the order of less than 5% in most years but in some years reached levels of 12-24% (Figures 8 & 9).

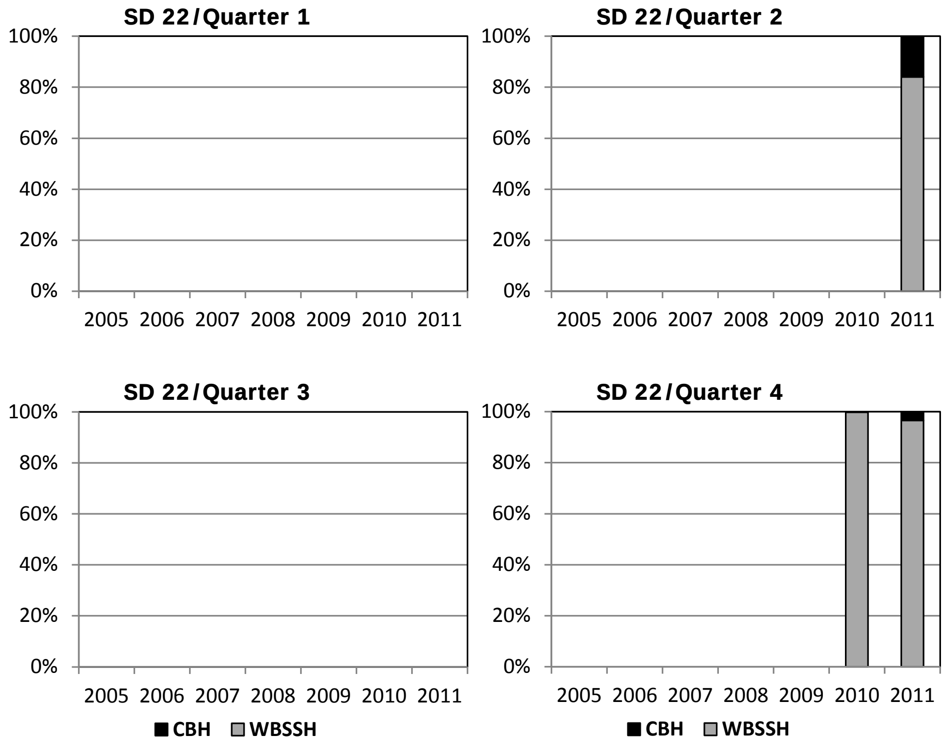

Figure 4: Herring (*Clupea harengus*) in the German trapnet fishery in SD 22. Quarterly catch composition 2005-2011 showing fractions of Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in the catches.

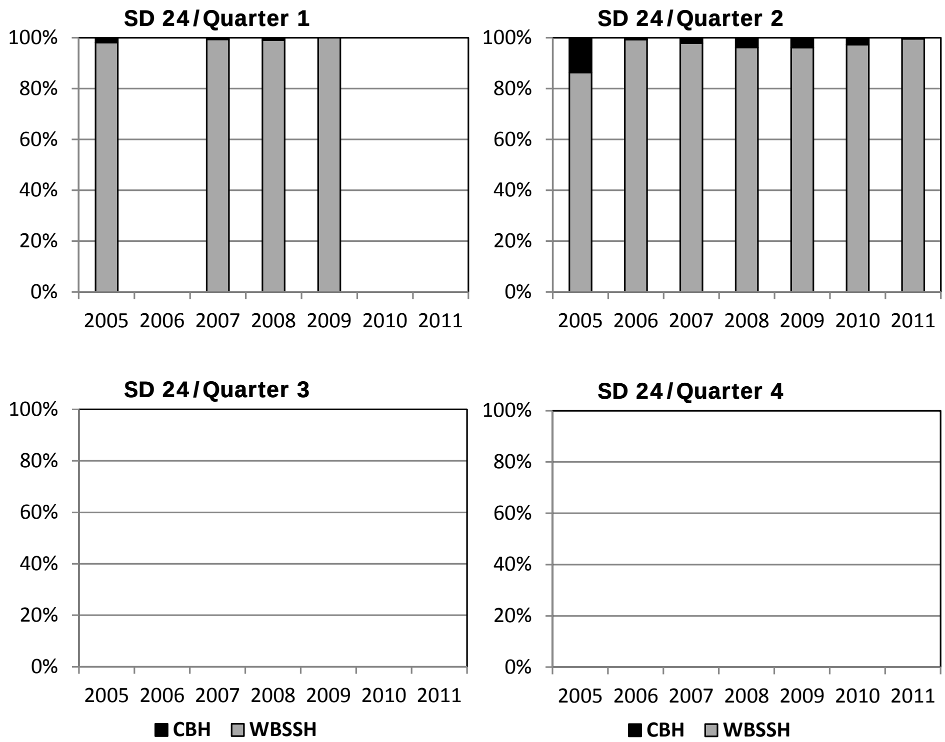

Figure 5: Herring (*Clupea harengus*) in the German trapnet fishery in SD 24. Quarterly catch composition 2005-2011 showing fractions of Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in the catches.

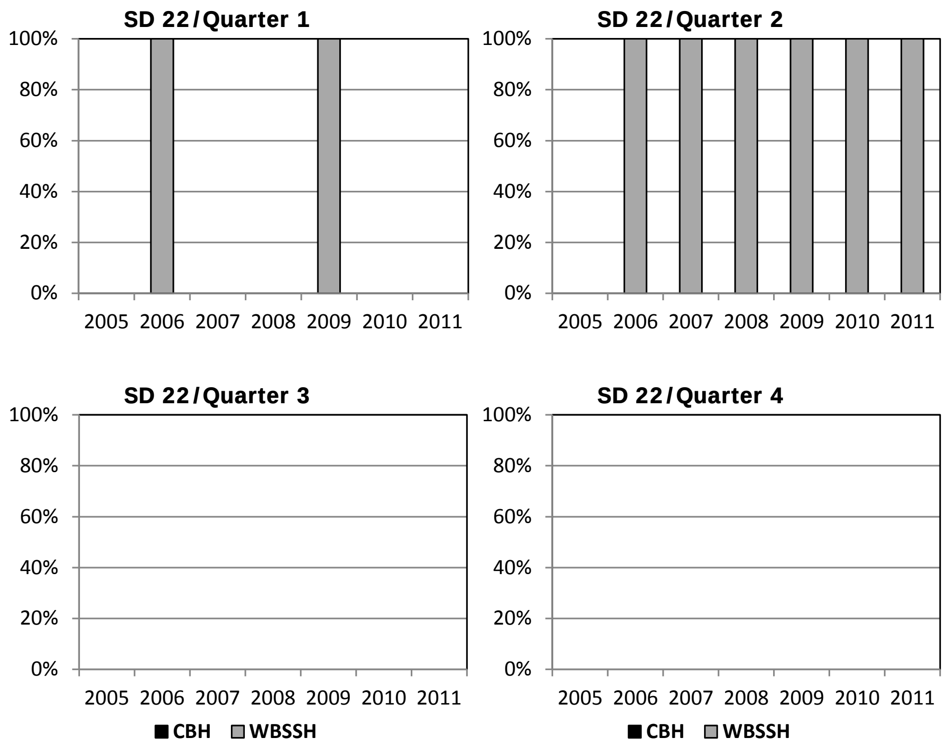

Figure 6: Herring (*Clupea harengus*) in the German gillnet fishery in SD 22. Quarterly catch composition 2005-2011 showing fractions of Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in the catches.

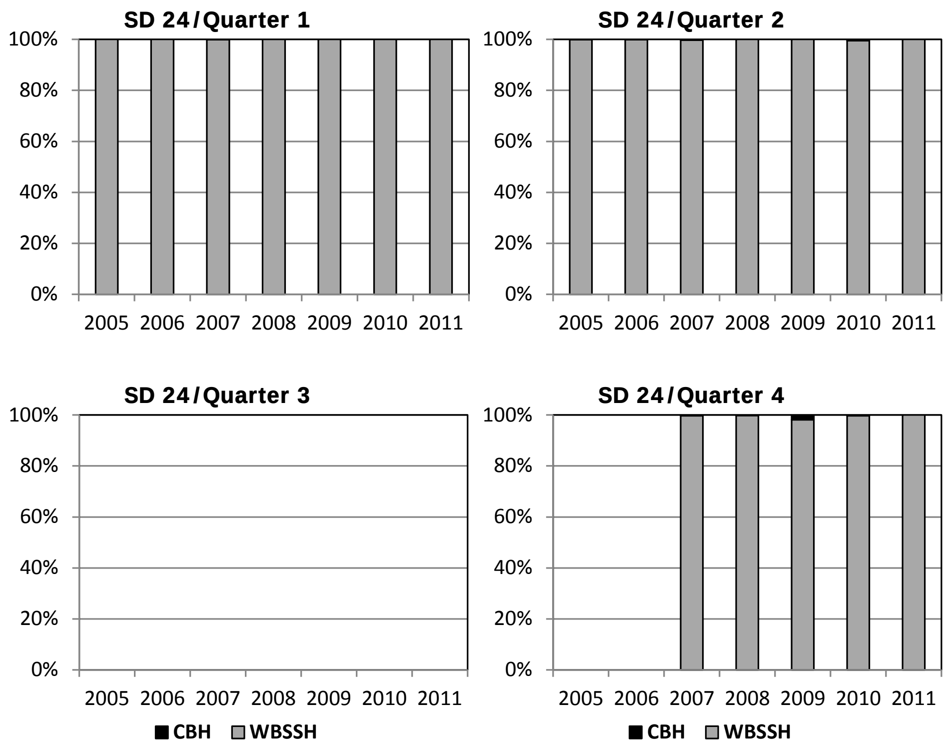

Figure 7: Herring (*Clupea harengus*) in the German gillnet fishery in SD 24. Quarterly catch composition 2005-2011 showing fractions of Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in the catches.

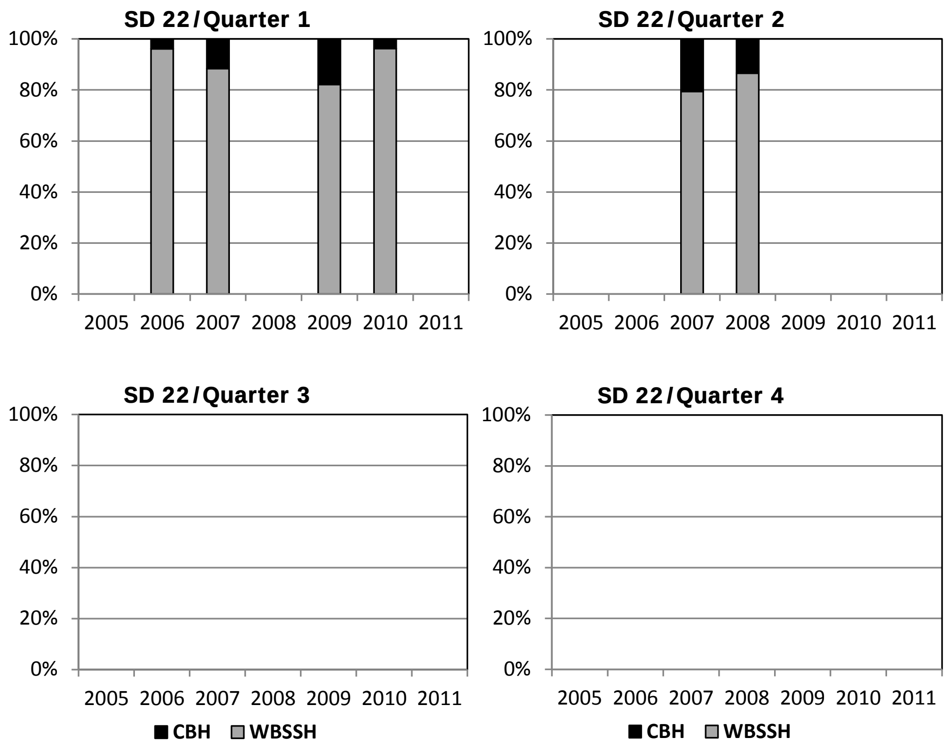

Figure 8: Herring (*Clupea harengus*) in the German trawl fishery in SD 22. Quarterly catch composition 2005-2011 showing fractions of Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in the catches.

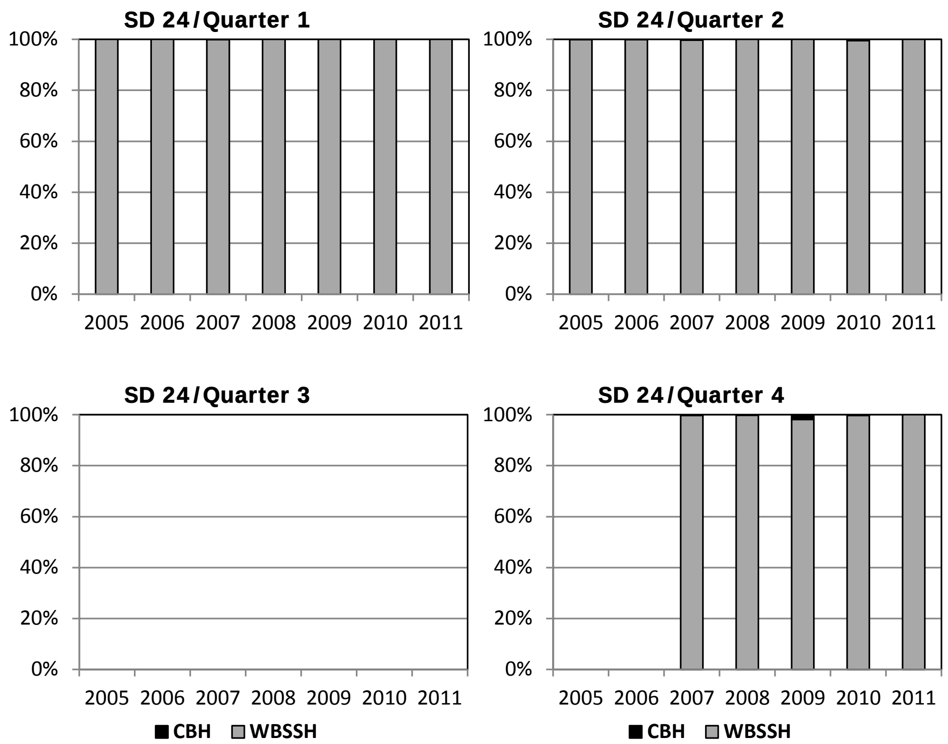

Figure 9: Herring (*Clupea harengus*) in the German trawl fishery in SD 24. Quarterly catch composition 2005-2011 showing fractions of Western Baltic Spring Spawning Herring (WBSSH) and Central Baltic Herring (CBH) in the catches.

4 Conclusion

An application of the stock separation function to German commercial herring catch data in ICES SD 22 and SD 24 reveals varying fractions of Central Baltic Herring in the catches. Overall, the highest share of CBH was found in trawl samples, whereas in trapnet samples only a minor fraction of CBH was identified. Gillnet samples almost exclusively consisted of Western Baltic Spring Spawning Herring. The overall share of CBH in German landings in SD 22 and 24 was comparatively low during the sampling period 2005-2011. If the same share of CBH is assumed in Polish, Swedish and Danish landings, the degree of mixing and its impact on assessment input data could be assumed as being of rather low concern. However, it has to be mentioned that the German fishery is mostly targeting pre-spawning (Q4) and spawning (Q1 and Q2) concentrations of WBSSH in SD 22 and 24. Corresponding catch data thus possibly do not reveal the actual degree of mixing.

5 References

*Gröhsler, T., Oeberst, R., Schaber, M. Casini, M., Chervonstev, V., Wyszyński, M. (2012). Mixing of Western Baltic Spring Spawning and Central Baltic Herring (*Clupea harengus*) Stocks – Implications and consequences for stock assessment. Working document for the ICES

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- “Baltic International Fish Survey Working Group (WGBIFS)”, 26.-30.03.2012, Kaliningrad, Russia.
- “Baltic Fisheries Assessment Working Group (WGBFAS)”, 12.-19.04.2012, Copenhagen (WD 4)

In: Report of the Baltic International Fish Survey Working Group (WGBIFS). ICES CM 2012 /SSGESST: 02, Annex 9: 376-398,

Report of the Baltic Fisheries Assessment Working Group (WGBFAS). ICES CM 2012/ACOM:10, Annex 16: 749-772.

* this WD has been prepared as a manuscript and was submitted to the ICES Journal of Marine Science (Current status: accepted/resubmit after revision).

WD 3b Analysis of the proportions of herring smaller than the proposed length at age separation function (SF) in the Baltic Sea.

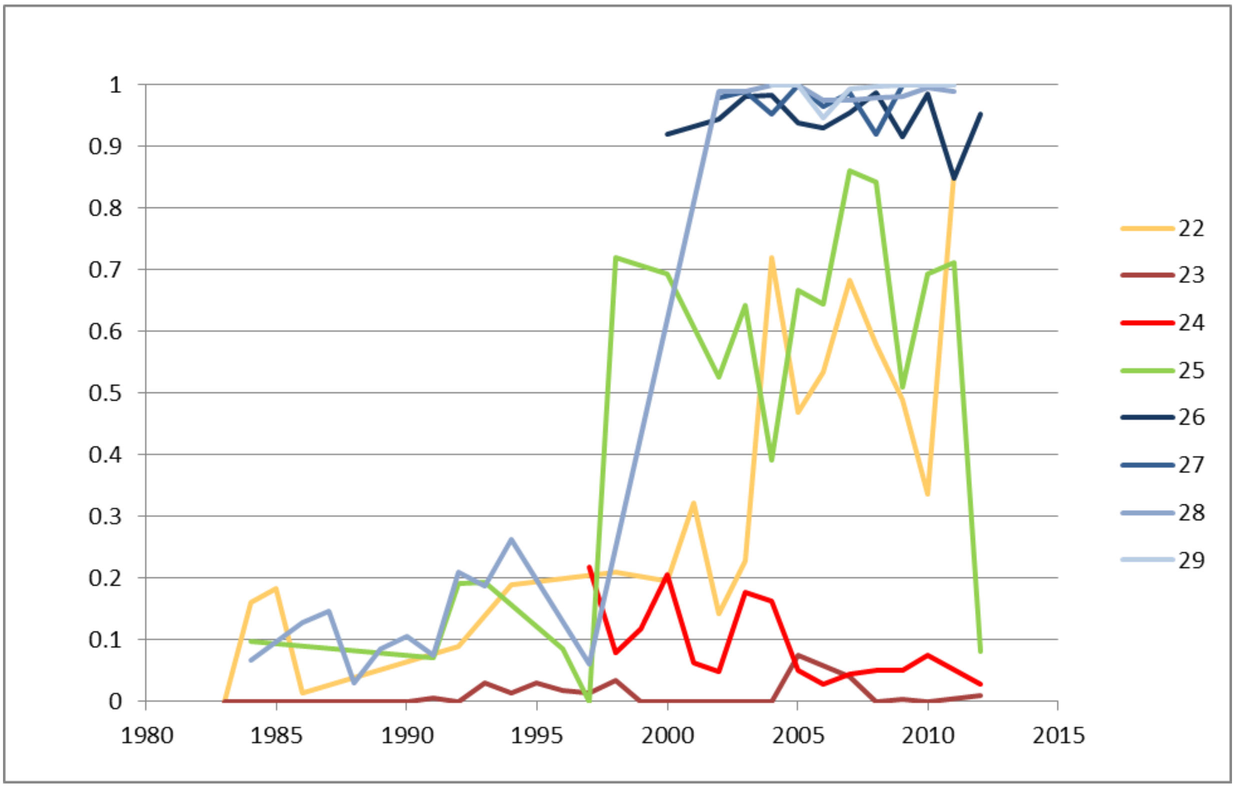
H. Mosegaard, DTU-Aqua

Danish samples of herring from commercial catches from the Baltic Sea taken in the period 1983-2012 were analysed with regards to length at age in relation to Subdivision.

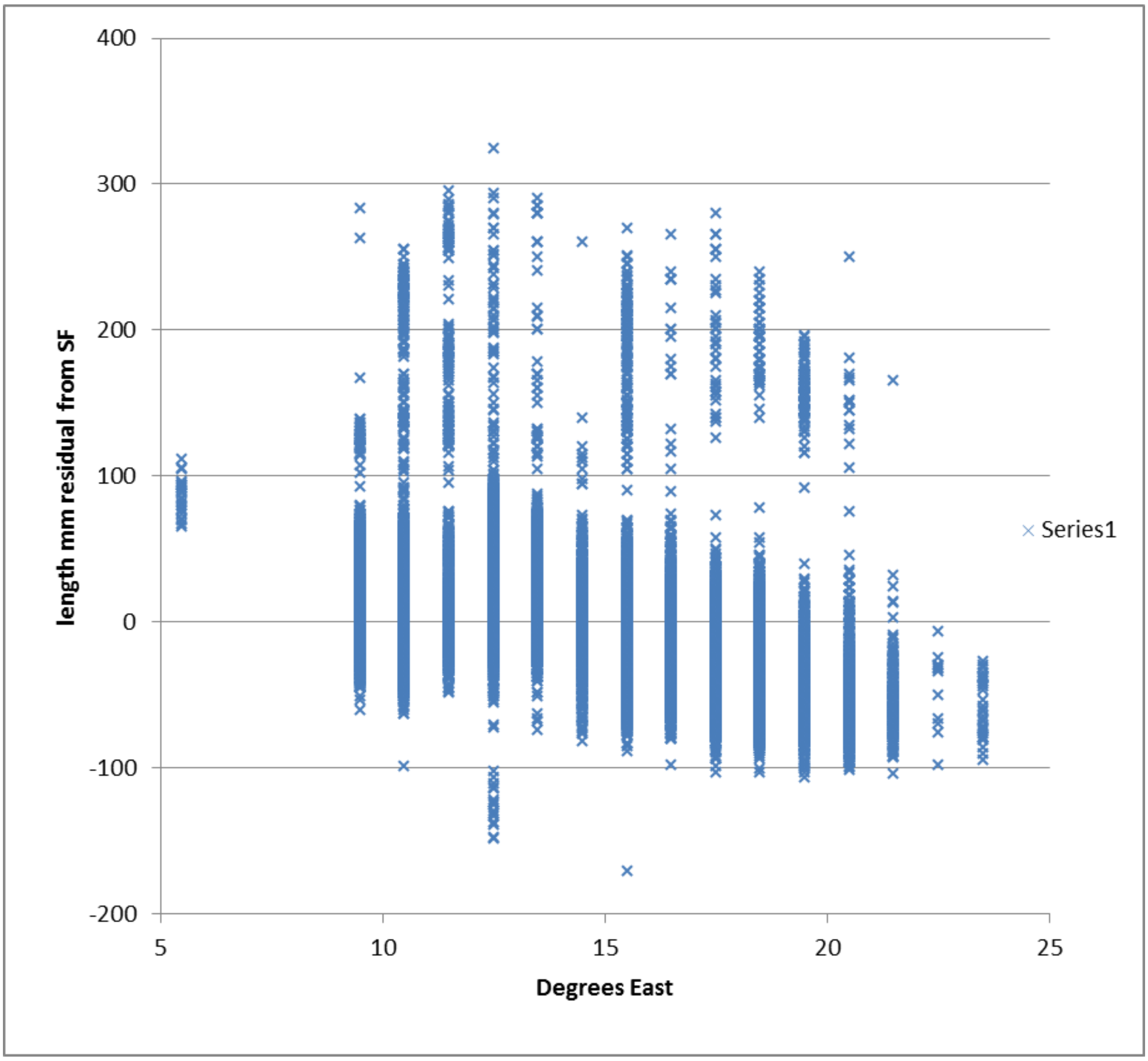
A separation function $\mathbf{SF_{new} = 25.3962*(1-e^{(-0.385*(age*12+T)/12-0.262)})}$ based on a vBG approach (Gröhsler et al. 2012) was applied to the data and individuals were split into two growth types slow growers <SF and fast growers >=SF.
After screening for outliers about 36,000 individual observations from samples of Danish commercial catches were available from the period 1983-2012.

A plot of proportion herring <SF by year and Subdivision shows an unexplained increase in proportion of slow growers after 1997 for SD25 and SD26, and a similar shift for SD22 after 2003. Further a shift back in 2012 was observed in SD25.

For the subdivision 24 where a small proportion of slow growing herring has been observed in the acoustic surveys in later years, a proportion varying between 3% and 22% in the commercial fishery can be seen between 1997 and 2012.

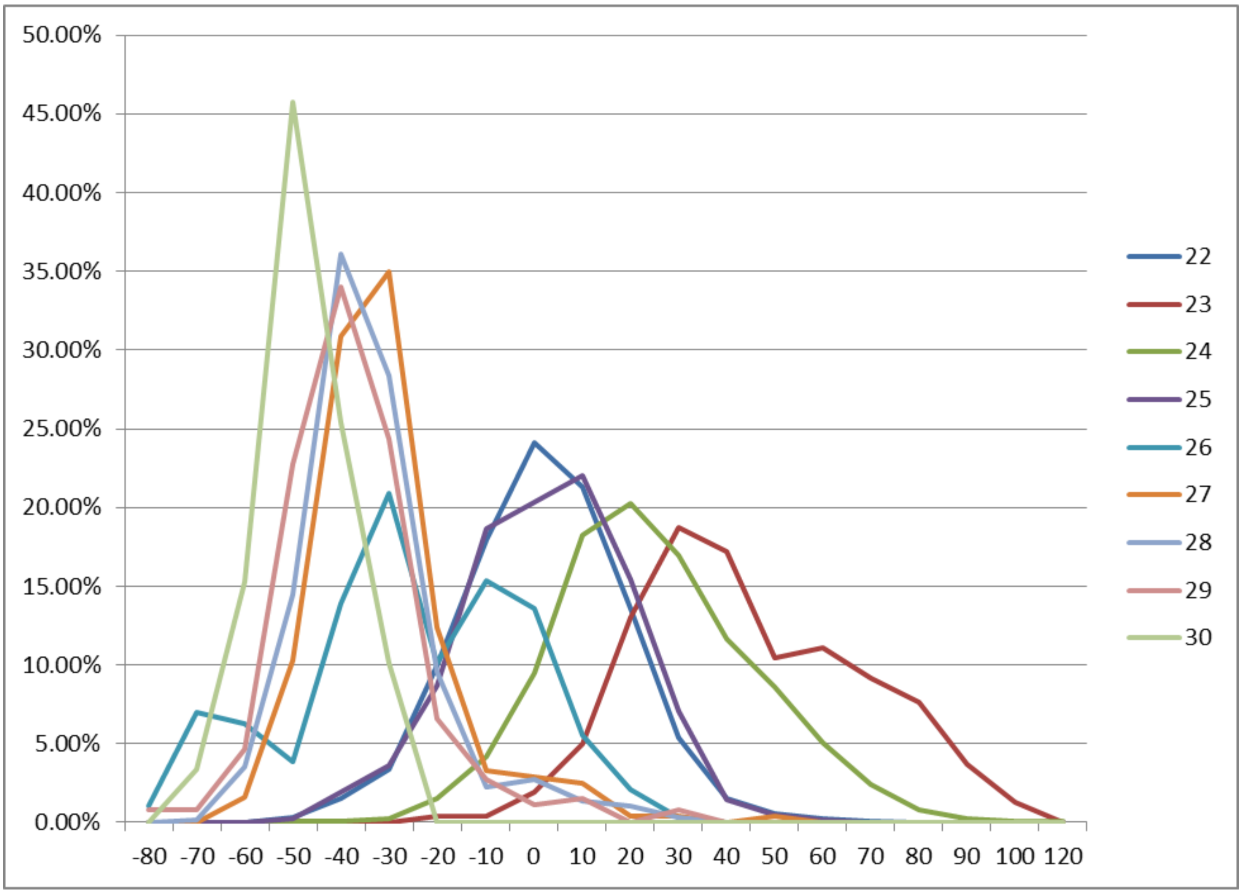


The two identified growth groups were plotted as length residuals from the separation function versus the average Easterly position of the ICES rectangle sampled. There is an apparent tendency of slower growing herring with increasing Easterly position. However there is also a bimodal distribution within most of the geographical entities.

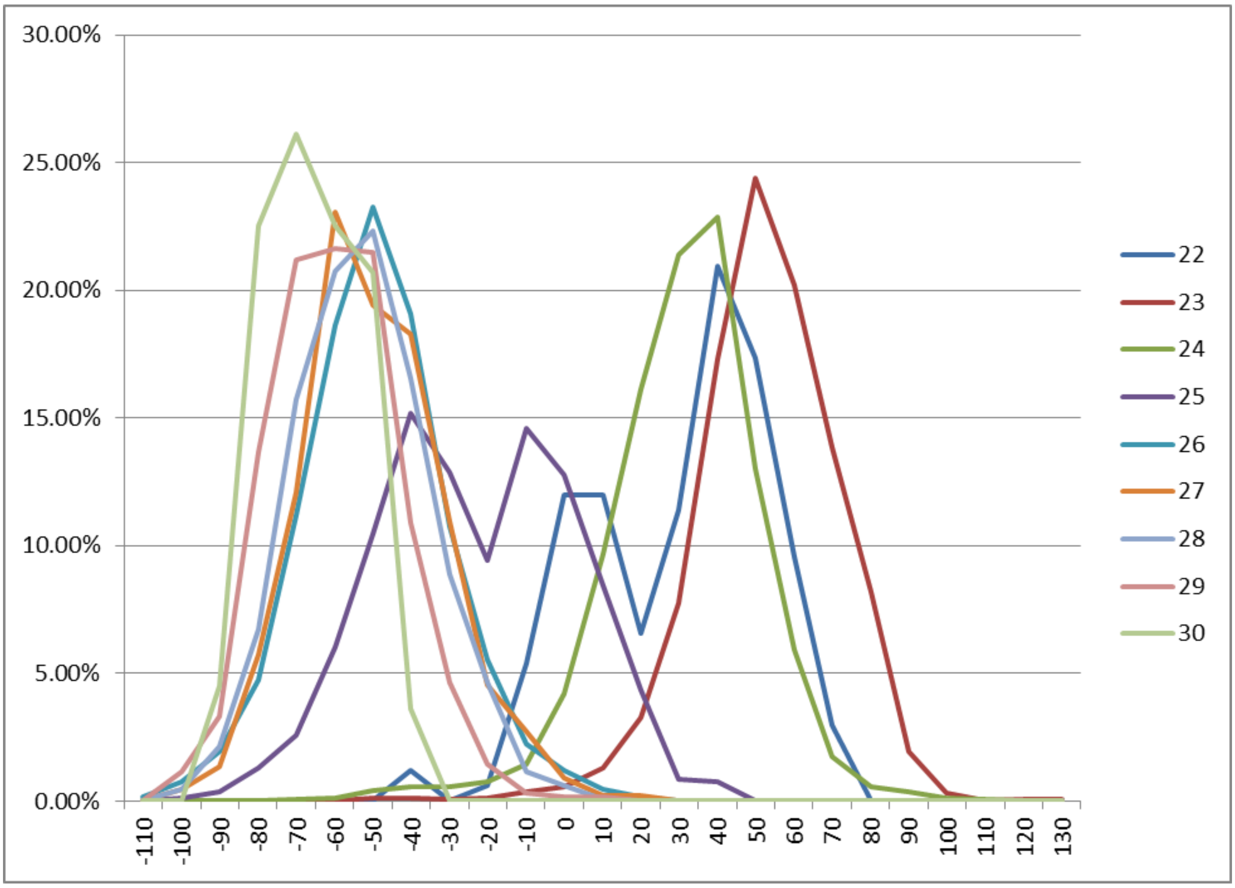


SF residuals plotted versus an East – West distribution of samples.

When data are limited to the period 1998-2011, and frequencies of increasing SF residuals are plotted for the different subdivisions a clear picture of the growth type distribution emerges.



Juvenile herring (1-2 group) frequency distributions of SF residuals.



Adult herring (3+ group) frequency distributions of SF residuals.

Further, information on infestation rates of Anisakis parasites from later years were compared to the growth type assignment.

The results of the parasite loadings support the hypothesis that herring from the Eastern Subdivisions (>SD25) and generally herring of the slow growing type do not perform migrations to the higher salinities in the Skagerrak and North Sea. Further, infestation rates increase with age for the more Western Subdivisions (Table 1), indicating both increasing migration distances and cumulative age effects.

Table 1. Infestation rates of herring from Danish samples 2008-2012 from scientific cruises and commercial catches combined

Years	2008-2012			number analysed	
SubDivision	Age range	<=SF	>SF	N (<=SF)	N(>SF)
22	1	0%	0%	116	125
22	2	0%	1%	1	88
22	3 _ 5	0%	14%	2	7
22	6 _ 9	0%	0%	1	1
23	1	0%	4%	22	261
23	2	0%	24%	8	349
23	3 _ 5	8%	68%	13	689
23	6 _ 9	0%	90%	3	187
23	10 _ 19		100%	0	11
24	1	0%	7%	12	246
24	2	0%	13%	12	272
24	3 _ 5	2%	55%	53	573
24	6 _ 9	0%	90%	21	135
24	10 _ 19	0%	82%	1	11
25	1	0%	0%	99	143
25	2	0%	3%	85	101
25	3 _ 5	0%	37%	470	404
25	6 _ 9	0%	24%	444	246
25	10 _ 19	0%	5%	29	59
26	1	0%	0%	12	4
26	2	0%	0%	16	14
26	3 _ 5	0%	0%	146	16
26	6 _ 9	1%	0%	167	13
26	10 _ 19	0%	0%	14	2
28	1	0%	0%	2	1
28	2	0%		24	0
28	3 _ 5	2%		60	0
28	6 _ 9	3%		30	0
29	1	0%		2	0
29	2	0%	0%	11	1
29	3 _ 5	0%		75	0
29	6 _ 9	0%		42	0
29	10 _ 19	0%		3	0
32	1	0%		1	0
32	2	0%		4	0
32	3 _ 5	0%		10	0
32	6 _ 9	0%		1	0

Conclusions: SD23, the Sound between Denmark and Sweden exhibits the collection of fastest growers for both juvenile and adult herring, and there appears to be only minor overlap with Eastern SDs (27-32) in length at age.

In SD24 there is a shift to a slightly smaller size at age compared to SD23, but the distribution has a similar shape. Trawl fishing in SD23 is prohibited and gillnet fishers may target the largest herring the schools. For both juveniles and adults there is some overlap with Eastern SDs (27-32) in length at age.

SD25 and SD22 constitute intermediate size distributions over similar shape and with a very similar size distribution for juveniles. And the Anisakis infestations from SD25 indicate migrations of the fastest growing group to the Skagerrak and the North Sea.

However there is also a very large overlap of SD25 herring with SD26 for the slowest growers and with SD24 for the fastest growers. Without further knowledge about within SD stock structure or between SD migration patterns this is a major problem in determining the appropriate stock limits of WBSS.

Danish impact on to total catch rates is low with 14% and 2% of the TACs in SD22-24 and SD25-29+32 respectively, however there are indications of similar intermediate size distributions from Polish and Swedish commercial landings (Oeberst et al 2013 WD).

Gröhsler, T., Oeberst, R., Schaber, M. Casini, M., Chervonstev, V., Wyszyński, M. 2012. Mixing of Western Baltic Spring Spawning and Central Baltic Herring (Clupea harengus) Stocks – Implications and consequences for stock assessment (2012). Working document for the ICES.

Oeberst R., Gröhsler T. and Schaber M. 2013. Investigations on quality of Stock Separation Function (SF). Working Document 4 WKPELA 2013

WD 4 Investigations on quality of Stock Separation Function (SF)

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Abstract

Three methods were evaluated to assess the quality of a stock separation function (SF) derived for identifying the fraction of CBH in western Baltic subdivisions 22-24. Length distributions of GERAS in SD 24 were split up into normally distributed length components. The effect of ageing errors related to the overlap of the length distribution of the same age group of both stocks based on simulated data were studied. The length ranges age groups of herring captured during acoustic surveys and in the commercial fishery were compared with the expected data. Additionally, effects of ageing errors originating from an overlap of length distributions of the same age groups of both stocks were studied based on simulation data. Furthermore, length ranges of different age groups of herring captured during acoustic surveys and in commercial fisheries were compared with the expected results from simulation data. Analyses of the length frequencies indicated that CBH can be identified from length distributions, but the estimates are uncertain due to the high fluctuation of the length frequencies within small length ranges and the strong overlap of the length frequencies of age group 2+ of CBH. The simulated data showed that ageing errors are important for age groups 1 and 2. Especially important are underestimations of the age of CBH and overestimation of the age of WBSSH. The length ranges of age groups support the results of SF in most cases. Unexpected results were observed in SD 25 which are partly determined by ageing errors.

Introduction

Atlantic herring (*Clupea harengus* L.) constitute an important fraction of catches in the European commercial fisheries. The management of herring fish stocks includes the definition of either management- or distribution area, respectively. Due to the migratory behavior of older herring characterized by extended migrations between feeding and spawning areas, the static stock boundaries used for management can hereby lead to problems in the assessment.

In the Baltic Sea, several herring stocks are surveyed and managed separately. The distribution area of the most westerly located Western Baltic Spring Spawning herring (WBSSH) stock covers the Skagerrak/Kattegat (ICES Division IIIa) and ICES Subdivisions (SDs) 22-24. The main spawning area of WBSSH is considered to be the Greifswalder Bodden at Rügen Island (ICES CM 1998/H:1). Herring caught in Division IIIa also comprises a stock component of the North Sea Autumn Spawning herring (NSASH) distributed in adjacent North Sea areas. The separation of NSASH and WBSSH in Division IIIa within the assessment process is presently based on vertebrae counts and otolith microstructure analysis (ICES CM 2011/ACOM:06).

The areas of the southern and central Baltic Sea (SDs 25-29, 32 excluding the Gulf of Riga) are on the other hand inhabited by the Central Baltic Herring (CBH) stock. Stock separation for assessment purposes so far has been based on ICES Subdivisions with herring originating from SDs 22-24 being by definition allocated to WBSSH and specimens from SDs 25-32 to CBH

Gröhsler et al. (2012) developed a separation function (SF) to assign individuals to one of the both Baltic herring stocks. The SF was developed based on the different growth function of both herring stocks and involves the parameters length, month of capture and age of individuals. The method was used to quantify the mixing of both herring stocks during the acoustic surveys BASS and BIAS in parts of the Baltic Sea and during the commercial fishery in SD 22, 24 and 25.

The expected uncertainty of the SF can be assessed if the residuals of the Bertalanffy growth function BGF are normally distributed with a mean of zero and a standard error of SE. Then it can be inferred that the length of ~ 97.5 % of all specimens of CBH is smaller than

BGF(CBH) + 2 * SE(CBH) (broken line in Figure 10). That means ~2.5 % of individuals of CBH will be assigned to WBSSH. For an age of more than 34 months the proportion of false assignments is lower because of the distance between the two curves. Similar conclusions are possible for individuals of WBSSH because ~ 97.5 % of the length of all specimens of WBSSH is larger than BGF(WBSSH) + 2 * SE(WBSSH) (line in Figure 10). The proportion of false assigned individuals of 3 % is slightly underestimated for age group 3 to 6 because the standard deviation of the length of these age groups is larger than the SE of BGF. In addition, the positive kurtosis of the residuals of the BGF of both stocks as well as the right skewed residuals of the BGF of CBH will result in a slightly higher proportion of false assignment. On the other hand, the proportion of false assigned individuals of 3 % is slightly overestimated for older herring because the standard deviation of the length of these age groups is smaller than the SE of the BGF's.
In addition, the infection of herring with *Anisakis simplex* was used to assess the quality of the SF.

The life cycle of *Anisakis simplex* in the Norwegian Deep was described by Klimpel et al. (2004). They showed that euphausiids, constituting an important prey for herring, are the first obligatory intermediate host of L3 larvae of *A. simplex*. These euphausiids do not occur in the Baltic Sea. Therefore, only herring which migrate to the North Sea or Danish Straits can, by feeding on euphausiids, become infested by *A. simplex* (Podolska et al. 1997). Yearly migration from the spawning grounds in the shallow waters of the Baltic Sea to the feeding grounds in the Skagerrak and North Sea are described for Western Baltic Spring Spawning herring (WBSSH) older than 2 years (Biester, 1979). Therefore, the occurrence of *A. simplex* can at least for older herring be used as an indicator for the migration pattern of WBSSH in the Baltic Sea. Highest prevalence of *A. simplex* was observed in SD 22 and SD 24 by Lang et al. (1990). The prevalence of *A. simplex* infested herring captured east of Bornholm decreases from west to east (Lubieniecki, 1972, Grabda, 1974, Lang, 1988, Podolska et al., 1997, Podolska et al. 2006 and Rodiuk and Shukhgalter, 1997). A strong seasonal development of the prevalence was observed in all areas of the Baltic Sea with a minimum between June and September. In addition, a positive correlation was found between the length and age of herring and the proportion of infested herring. Data from 1975 until 1988 showed that less than 10 % of age group 2 herring and between 5 % and 40 % of age group 3 herring were infested by *A. simplex* (Lang et al., 1990). The probability that individuals of age group 0 and 1 of WBSSH are infested by *A. simplex* is low because these young herring stay close to the nursery areas in SD 22 and SD 24 (ICES 2012 c; Oeberst et al. 2009).
The infestation rate of herring with *A. simplex* confirms the SF and its assignment of WBSSH and CBH. Only a low fraction of herring which were assigned to CBH based on the SF were infested by *A. simplex*. The precision level of the two methods used to separate WBSSH and CBH varies considerably. Not all WBSSH are infested with *A. simplex*. In consequence the infestation rate with *A. simplex* underestimates the proportion of WBSSH in the samples. It is recommended to use the SF to separate WBSSH and CBH in the Baltic Sea.
The SF uses the parameters length, month of capture and age of individuals. Length is commonly determined to 0.5 cm below with high accuracy and the month of capture is also available with high precision. In contrast, ageing of herring is of lower accuracy as shown by ICES study groups and workshops in 1998, 2001, 2005 and 2008 where the ageing of different readers was compared. The workshop in 2008 with 9 participants stated that "The opinion of the Baltic herring age reading experts at the Workshop was that the achieved levels of agreement and coefficient of variation correspond to desirable levels in age determination of Baltic herring. However, for younger age groups (1-3 old herring) agreement of 95–100% would be necessary and achievable. "

The aim of this study is to analyse factors which affect the quality of the SF and to assess the quality of the SF based on simulations where errors of ageing were taken into account and based on the length frequencies of age groups of acoustic surveys and commercial samples.

Material and Methods

Different methods were applied to assess the quality of the SF.

Overlap of the length distributions of age groups of WBSSH and CBH

The occurrence of CBH in SD 24 can produce small peaks in the length frequencies of herring captured during acoustic surveys due to the different growth of both herring stocks. Length frequencies of herring from SD 24 as observed during GERAS were separated into nine normally distributed length components. For each component (k) the number of individuals (N(k)), the mean length (M(k)) and the standard deviation of the length (S(k)) were estimated. For the estimation of the parameters were only restricted than the means of the normally distributed components were less than a defined length (M(1) < 17, M(2) < 20, M(3) < 24, M(4) < 25, M(5) < 30, M(6) < 30, M(7) < 31, M(8) < 32, and M(9) < 33). The parameters of the normally distributed components were varied to minimize the sum of squares between observed and estimated length frequencies. A comparison of the observed length distribution, LD, and the back-calculated theoretical length distribution, tLD, was used to evaluate the quality of ageing. tLD was estimated by means of the mean length at age, M(a), of age group a, the standard deviation of the length distribution of age group, S(a) and the number of individuals of the age group, N(a), assuming that the length of age groups is normally distributed (Oeberst, 2000).

Simulation of errors in ageing to assess the effect concerning the quality of assignment of herring to WBSSH and CBH

Length of herring was simulated for a given age (in months) based on the parameters of the BGF. The length of an individual was determined by means of the expected mean length according to the BGF and age in months in combination of a normally distributed error with the standard error (SE) of the BGF. Each simulated individual was assigned to one of the both herring stocks by means of the SF. In each case 5000 individuals of WBSSH and CBH were simulated to estimate the proportion of right and false assignments. Different proportions of ageing errors were applied to determine the effect of the errors concerning the quality of the assignment of individuals based on SF. The proportion of false age individuals was described by

p_{-2} proportion of individuals with an age of two years less than the true age

p_{-1} proportion of individuals with an age of one year less than the true age

p proportion of individuals with true age

p_{+1} proportion of individuals with an age of one year more than the true age

p_{+2} proportion of individuals with an age of two years more than the true age

with $p_{-2} + p_{-1} + p + p_{+1} + p_{+2} = 1$.

Ageing errors of more than 2 years less or more were not taken into account. The errors of ageing were the same for both stocks. Following versions of ageing errors were applied:

Version	p_{-2}	p_{-1}	p	p_{+1}	p_{+2}
A	0	0	1	0	0
B	0.02	0.05	0.82	0.09	0.02
C	0.05	0.010	0.70	0.10	0.05
D	0.00	0.00	0.00	1	0.00

Version A describes the situation if ageing of herring is exact. The deviation from the true age according to age reading workshop in 2008 (ICES, 2008) was applied in version B. Ageing of 14 readers were compared during the workshop. Version C was used to evaluate the effects of higher uncertainty of ageing. Version D was illustrates the effect of a systematic shift of ageing in CBH. It was assumed that age of all herring of CBH and WBSSH was overestimated by one year.

Data used for the determination of the SF and the quantification of the mixing of herring stocks were also used for the assessment of the quality of the SF. Data were provided by Germany, Latvia, Poland and Sweden and comprised total length, weight and age. An overview of data incorporated in analyses is given in Table 1. Herring data from the Baltic Acoustic Spring

Survey (BASS), which is mainly conducted to deliver stock indices for the sprat stock in the Baltic Sea (SDs 22-32), were also included in the present analysis.

Analyses of the length ranges of herring age groups captured during acoustic surveys and commercial fishery

Data of total length, weight and age were provided by Germany, Latvia, Poland and Sweden to determine the SF (Gröhsler et al. 2012) and to quantify the mixing of herring stocks (Tab. 1). A stratified age-length sampling strategy is used by Germany, Latvia and Poland in order to combine an age-length-key with the mean length distribution per stratum. This strategy follows the guidelines given in the "Manual of the Baltic International Autumn Acoustic Survey (BIAS)" (ICES, 2011/SSGESST:05). In Sweden, proportions per age groups are directly estimated from random sampling of herring for determination of age. Length frequencies of sampled herring by year and age group were compared with the expected mean length of WBSSH and CBH.

Results

Overlap of the length distributions of age groups of WBSSH and CBH

A comparison of the observed length distribution, LD, and the back-calculated theoretical length distribution, tLD, is difficult for Baltic herring because the LD of the age groups 0 to 6 of CBH overlap with the length distributions of age groups 0 to 3 of WBSSH (Fig. 1). The length distributions of age group 0 to 3 of WBSSH are presented in Figure 1 by black lines where the thickness of the lines increases with increasing age. The mean length at age was estimated by means of the BGF (2005 – 2010) in October (Gröhsler et al. 2012). The standard deviation of age groups corresponded with the standard deviation of the BGF and was constant for all age groups. N(a) was defined with 100 individuals for all age groups. In addition the LD of age groups 0 to 6 of CBH is presented as red lines with different line structures. M(a) of CBH were estimated by means of the BGF of CBH in October, the standard deviation of LD corresponded with the standard deviation of the BGF, and the N(a) was chosen with 50 to allow clear distinction of the LD of WBSSH and CBH. The figure illustrates the overlap of the different age groups of WBSSH and CBH between 10 cm and 24 cm. The main length range of age group 0 of WBSSH (9 cm to 14 cm) is overlaid with the length range of age groups 0 to 2 of CBH, and the main length range of age group 1 of WBSSH is overlaid with the length ranges of age groups 3 + of CBH. This overlay can produce strong fluctuation in the length frequencies of neighboring length intervals. The influence of CBH was low for the length distributions of age groups 3+ of WBSSH.

Length frequencies of herring in SD 24 during GERAS were separated into nine normally distributed length components. The length frequencies strongly fluctuated within short length ranges (Fig. 2 to 4 as example) that were less evident in the length frequencies of Herring in SD 23. In many cases, components were estimated with very small estimates of standard deviation (S(k)) of length indicating a small peak in the length frequencies (Tab. 3). In addition, S(k) values were significantly smaller than the standard deviation of the length of age groups by means of BGF. Small S(k) values of neighbouring length components with small distance between the means of the components can be caused by random variations of the length frequencies. In many cases the mean length of the components (M(k)) were close to expected mean length of age groups estimated by BGF (see different colours). Beside these components, additional normally distributed components were identified with a mean length which differed from the expected mean length. It can be assumed that parts of these components represent herring of CBH like M(k) = 11.7 cm in 1994, M(k) = 10.7 cm in 1995 or M(k) = 11.9 cm in 1998. However, the results of the applied method are uncertain due to the high fluctuation of the length frequencies sampled during the GERAS in combination with the strong overlap of the length distributions of age groups 2+ of CBH and the length distributions of the age groups 1 to 3 of WBSSH.

Simulation of errors in ageing to assess the validity of assignment of herring to WBSSH and CBH

The assignment of individuals to one of the both stocks based on the SF showed a low proportion of misclassification if it is assumed that ageing is true (Version A). About 5 % of age group 1 of both herring stocks was misclassified (Tab. 2) due to an overlap of the values $BGF_{WBSSH} – 2 * SE_{WBSSH}$ and $BGF_{CBH} + 2 * SE_{CBH}$ (see Gröhsler et al. 2012, Figure 10). For herring older than 2 years, a misclassification of less than 2 % can be expected.

The length distributions of age groups 1 to 4 of WBSSH and CBH are given in Figure 5 (left column). Besides the length frequencies, the expected mean lengths of WBSSH and of CBH are given. In addition the estimate of SF is presented. Herring with lengths smaller than the estimate of SF are assigned to CBH while larger individuals are assigned to WBSSH. However, also if ageing is true, some individuals of CBH and WBSSH were assigned to the other stock because low proportions of the individuals of WBSSH had lengths less than of the separator length SF, and low proportions of CBH individuals had lengths larger or equal to SF. The corresponding proportion was low for age group 1 and decreased with increasing age. The overall effect is low if the abundance of both stocks is equal, because individuals of CBH are assigned to WBSSH and vice versa. The proportion of misclassification slightly increases if one stock is dominant in the area. This effect is low for herring older than 1 year.

The overlap of the length frequencies of WBSSH and CBH of the same age group increased with ageing errors. The random errors of ageing according to the estimates of the age reading workshop in 2008 (ICES, 2008, Version B) resulted in a high proportion of WBSSH age group 1 which was assigned to CBH (Figure 5, second column). The proportion of misclassification due to ageing errors of CBH was lower compared with WBSSH. The proportion of misclassification decreased with increasing age.

The increase of ageing errors (Version C) resulted in an increasing proportion of misclassification. Again, the proportion of misclassification was higher for WBSSH and decreased with increasing age.

A systematic shift in ageing of 1 year (Version D) resulted in a significant underestimation of the proportion of CBH because the length of only a low proportion of herring was smaller than the estimate of SF. The effect of systematic error in ageing decreased with increasing age and was small for herring of age group 4.

Analyses of the length ranges of herring age groups captured during acoustic surveys and commercial fishery

Length distributions of age groups 1 to 6 by year of the German BIAS in SD 21 and SD 23 are given in Figure 6. These data were used to estimate the BGF of WBSSH herring stocks. Besides the number of aged herring by length, the expected mean lengths of WBSSH and of CBH per age group are presented. In addition, the value of SF for the same age is presented. Only low numbers of herring with a length of less than SF were observed in all age groups. A small number of herring larger than SF was observed during German BASS in SD 27 to 29 (Fig. 7). The length range of age group 1 herring was smaller than the mean length based on BGF. This discrepancy was not found for older herring. Length frequencies of herring captured during Swedish BIAS in SD 27 corresponded with estimates of German BASS. The modal values of the sum of length distributions were close to the expected mean length of CBH. Similar distribution patterns were observed during Swedish BIAS in SD 28. The data of German BIAS in SD 21 and SD 23 and the data of German BASS in SD 22 to SD 27 as well as the Swedish data in SD 27 and SD 28 (BIAS) illustrate the bimodal length distribution of herring in these areas. Length distributions of herring sampled during Latvian BASS and BIAS in SD 26 support the bimodal length distribution of herring with exception of age group 1 during BIAS (Fig. 8). The length of this age group was larger than the separator length SF in most cases. In contrast to this, herring of age group 2 were smaller than SF in most cases. The length ranges of both age groups were similar suggesting that herring did not grow from age group 1 to 2. The extreme low lengths of herring captured during Latvian BASS in 2010 can only be explained by uncertainty in ageing.

Bimodal length frequencies of age group 2 to 4 were found in German catches between March and May (Fig. 9). The two length ranges could clearly be assigned to WBSSH and CBH based on SF. This bimodal structure was not found for age group 1 although the length ranges of WBSSH and CBH were covered. The distribution pattern between March and May varied. The results suggest intensive mixing of age group 1 herring of both stocks in this area.

Length distributions of herring captured during BIAS in SD by Germany and in SD 25 by Poland and Sweden suggest that individuals of both herring stocks occurred (Fig. 10). Herring in SD 24 was dominated by WBSSH with increasing amount of CBH with increasing age. An opposite development of the corresponding proportions was observed in SD 25 with increasing age. The proportion of CBH increased with increasing age. Age group 1 was dominated by herring with lengths larger than SF and age group 4 by herring smaller than SF. This development continued in ages older than 4 years (not shown).

The proportion of WBSSH and CBH by age groups in the Swedish commercial fishery in SD 25 were similar to the data of Swedish BIAS in the same area (Fig. 11). Age group 1 was dominated by herring larger than SF and age group 6 was dominated by herring smaller than SF. The Swedish data in spring and autumn suggested that similar fractions of WBSSH and CBH occurred.

Different results were found based on the data of Polish commercial fishery in April and October (Fig. 12). Only a small proportion of herring was smaller than SF for age group 3+. The proportion slightly increased with increasing age. A special situation was observed in 2006. Then, the length of age group 1 varied between 11.75 cm and 28.75 cm and did not change with increasing age, indicating problems in ageing. In contrast to this, the length range increased from age group 1 to age group 3 in the other years.

Discussion

The separation function is an easy to apply method for assigning herring individuals to one of the both stocks. Required data are regular samples from commercial fisheries and acoustic surveys. However, annually evaluation of the growth is required. Results of the investigation of infection rates of herring by *Anisakis simplex* support the validity of the SF. A validation of the SF by another method can improve the acceptance of estimates that are based on the SF.

The identification of CBH from length distributions is difficult due to an overlap of the length distributions of older CBH with the length distributions of young WBSSH. In addition, small random errors in the length frequencies strongly affect the estimates of the proportions of age groups by stock between 15 cm and 25 cm (see Fig. 1).

The separation function is based on length and age to assign herring individuals to either WBSSH or CBH. The method requires stable growth of both herring stocks and is sensible against problems in ageing of herring. Simulations showed that SF is especially sensitive for an underestimation of the age of CBH and an overestimation of the age of WBSSH. The effect of false ageing is more important for younger herring and the proportion of misclassification decreases with increasing age due to the low growth of older herring. Therefore, intercalibration experiments of age reading between the countries working in the same area and repeated ageing within the institutes should be realized on a regular basis.

In addition, changes in growth of WBSSH or CBH can also result in increasing misclassification. Therefore, a yearly evaluation of the growth is required for the application of the method.

The model assumes the occurrence of two herring stocks in the Baltic Sea. SF was estimated based on herring captured in SD 21 and 23 as well as in SD 27 – 29. Length distributions in the same areas and those in SD 26 based on Latvian acoustic surveys support the usability of the proposed method. The bimodal length frequencies in the German commercial fishery support the approach because the two separate length ranges can be assigned to both herring stocks.

The interpretation of results from SD 25 is difficult. The length ranges of Swedish commercial data are small compared to the total length range of herring between SD 21 and SD 28. In addition, a shift of herring from WBSSH to CBH with increasing age is suggested based on SF. Larger length ranges of age groups were observed in the samples of Swedish BIAS in SD 25, with higher fractions of CBH in youngest herring and a decreasing proportion of WBSSH with increasing age. The strong differences of age group 1 are probably determined by the differences of the mesh sizes used in the commercial fishery and during BIAS, where the catchability of smaller herring is higher. In addition, the migration pattern to the spawning grounds is of lower importance for age group 2 and 3 due to the lower fraction of spawning individuals. The proportion of maturing WBSSH is estimated to 20 % and 75 % for age group 2 and 3, respectively (ICES 2012a) while it is 70 % and 90 % for the same age groups in CBH, respectively (ICES, 2012b). Smaller fractions of WBSSH in older age groups in the commercial fishery were influenced by the migration of herring to the spawning places with high probability.

Results of Polish data samples during BIAS in SD 25 correspond with data from Sweden. Minima of the length frequencies correspond with the estimates of SF. In contrast to this, the length ranges of age groups of the samples from the Polish commercial fishery significantly differed and indicated the absence or low proportions of CBH in the catches. However, the length ranges of the age groups differ from the length ranges of the same age groups in the Swedish commercial fishery in the same SD and indicate problems in ageing (see age group 1 and other age groups).

The occurrence of different herring stocks was shown in SD 25. WBSSH also spawn in the western part of the Polish coast (Aro, 1989) and were also observed around Bornholm island during feeding. The same area is used by spring-spawning coastal herring with expansion of the spawning area to the coast of Latvia (Aro, 1989). These herring cover SD 25 and SD 26 during feeding. In the same area, herring infested with *Anisakis simplex* was observed (Podolska et al. 2006, Rodjuk, 2007) during the spawning season indicating a mixture of spring-spawning coastal herring and WBSSH. On the other hand, spawning of herring was described along the Swedish coast (spring-spawning open-sea herring, Aro,1989). Individuals of this stock also use SD 25 and SD 26 for feeding. Based on this observation, a mixture of different herring stocks can be observed in SD 25 during BIAS. The results of the acoustic surveys of Sweden in SD 27 and SD 28 as well as the data of Latvian BASS and BIAS in SD 26 suggest that spring-spawning open-sea herring and the spring spawning coastal herring have similar growth and that individuals of these stocks can be discriminated from WBSSH by means of the SF.

The L_∞ parameters of BGF estimated for herring in SD 25 (Gröhsler et al. 2012 a, Table 8, Popiel, 1958) were between the estimates of WBSSH and CBH for 2005 to 2010 (Gröhsler et al. 2012). These differences can be determined by different reasons like faster growth of CBH in SD 25 due to variations in temperature, the occurrence of prey etc. or the mixing of both stocks in the sample. Spring-spawning coastal herring migrate from the spawning grounds to the feeding grounds in the central parts of SD 25 and SD 26, mixing with herring from different stocks (Aro, 1989). An increasing growth of herring in SD 25 will produce signals in the length-age relations of these individuals. After feeding, the herring migrate back to the spawning grounds in SD 25 and 26. Consequently, the signal of different growth becomes also evident in SD 26. Similar signals of different growth can also be expected for spring-spawning open-sea herring which spawn at the Swedish coast. However, such a signal was not observed in the data of Latvian BASS and BIAS in SD 26 and in the data of Swedish BIAS.

Conclusion

Increasing ageing errors result in an increasing misclassification of age group 1 herring to WBSSH and CBH based on SF (Version A to C). The effect decreases with increasing age. The proportion of misclassification decreases with increasing age. The proportion of CBH is overestimated due to random ageing errors if the abundance of both stocks of the age group is equal. Differences of the abundance of both stocks results in variable effects of ageing errors. Systematic ageing errors have strong effects concerning the assignment quality of the SF.

The length frequencies used in the base line samples from different areas correspond with the expected length ranges of both herring stocks. The use of a SF is supported by the results of Latvian acoustic surveys in SD 26 and by the samples of the German commercial fishery in SD 24. Results of BIAS in SD 24 and SD 25 indicate variable mixing of both stocks with changing fractions with increasing age. The data of Polish and Swedish commercial samples showed similar changes of the fraction of both stocks with increasing age. Polish data also showed that the results are sensible against problems in ageing.

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Tables

Table 1 Individual herring data and data sources included in the present study. Note that also herring data from the Baltic Acoustic Spring Survey mainly targeting sprat to provide an index for the sprat stock in the Baltic Sea (SDs 22-32) were included. BASS – Baltic Acoustic Spring Survey, BIAS – Baltic International Acoustic Autumn Survey, CF – Commercial fishery.

Country	Data Source	Years	Quarter	SD	Numbers			
					Age 0	Age 1-2	Age 3+	Total
Germany	BASS	2005-2010	2	24	0	731	971	1,702
				25	0	879	1,769	2,648
				26	0	184	684	873
				27	0	277	581	858
				28	0	166	390	556
				29	0	58	76	134
	BIAS	2005-2010	4	21	990	875	93	1,958
				22	1,199	402	59	1,660
				23	525	1,365	1,442	3,332
				24	0	1,072	1,527	2,599
	CF	2005-2011	1, 2	22	0	556	1,048	1,604
			1, 2, 4	24	163	2,643	16,028	18,834
Latvia	BASS	2005-2008	2	26N	0	43	855	898
	BIAS	2005-2010	4	26N	21	0	2,199	2,200
Poland	BIAS	2006-2010	4	25	439	515	1,446	2,400
	CF	2006-2010	2	25	500	757	1,899	3,156
Sweden	BIAS	2005-2010	4	25	1,086	1,376	3,772	6,234
				26	0	29	150	179
				27	690	1,674	2,134	4,498

				28	164	489	1,768	2,421
	CF	2006-2010	1-4	25	3	1,009	4,116	5,128
Total	Total	Total	Total	Total	5,780	15,100	43,012	63,892

A stratified age-length sampling strategy is used by Germany, Latvia and Poland in order to combine an age-length-key with the mean length distribution per stratum. This strategy follows the guidelines given in the "Manual of the Baltic International Autumn Acoustic Survey (BIAS)" (ICES, 2011/SSGESST:05). In Sweden, proportions per age groups are directly estimated from random commercial sampling of herring for determination of age.

Table 2: Proportion of right and false assignment of individuals of WBSSH and CBH based on 5000 simulated herring by age group, age in month for October and herring stock

			Stock: WBSSH		Stock: CBH	
Age in year	Error of ageing	Age in month	Assignment to WBSSH [%]	Assignment to CBH [%]	Assignment to WBSSH [%]	Assignment to CBH [%]
1	0	22	94.9	5.1	5.4	94.6
2	0	34	98.4	1.6	1.5	98.5
3	0	46	99.0	1.0	0.7	99.3
4	0	58	99.2	0.8	0.6	99.4
5	0	70	99.4	0.6	0.4	99.6
6	0	82	99.5	0.5	0.3	99.7
7	0	94	99.5	0.5	0.4	99.6
8	0	106	99.3	0.7	0.3	99.7
9	0	118	99.4	0.6	0.4	99.6
10	0	130	99.4	0.6	0.6	99.4

Table 3: The number of individuals (N), the mean length (M) and the standard deviation of length (S) of the normally distributed components, sorted according M, of herring captured in SD 24 during GERAS (left panel) and expected mean length based on annual BGF of WBSSH by age group (right panel). The different colours indicate the mean length of age group 0 to 2 based on BGF and the corresponding mean length of components. Length components with S values < 0.4 are marked with red colour.

Detected normally distributed length components sorted by M

	Comp	1	2	3	4	5	6	7	8
1994	N	863.5	257.0	433.0	145.5	242.6	92.0	106.7	0.0
	M	11.7	14.5	18.9	20.5	21.1	25.7	27.3	32.0
	S	1.1	0.7	0.8	1.9	1.3	1.6	2.3	2.7
1995	N	443.2	197.3	356.3	448.8	39.0	252.4	16.4	20.7
	M	10.7	11.8	13.2	18.5	21.3	23.1	26.7	28.1
	S	0.6	0.8	1.4	1.0	0.0	1.7	0.1	0.2
1996	N	418.0	278.6	231.9	34.5	31.2	81.2	13.8	232.0
	M	11.8	16.9	18.6	20.1	21.2	22.1	23.8	25.7
	S	1.3	0.7	0.9	0.4	0.0	0.6	0.0	2.3
1997	N	820.5	356.2	67.9	2.0	209.3	67.5	27.1	13.7
	M	11.6	18.1	19.9	20.0	21.7	25.2	27.9	30.0
	S	1.5	0.8	0.5	0.9	1.4	1.5	0.9	1.5
1998	N	913.1	0.0	84.4	131.5	1.1	51.9	139.3	36.5
	M	11.9	13.8	17.3	19.5	19.9	21.5	23.8	27.2
	S	0.7	2.2	1.5	1.7	2.2	2.2	1.0	1.1
1999	N	2.6	909.3	18.3	208.4	124.2	30.9	55.7	73.3
	M	4.5	12.3	16.8	18.3	21.5	23.7	25.4	26.8
	S	1.1	1.3	0.0	0.8	1.3	0.3	0.8	2.0
2000	N	0.8	220.2	115.5	0.0	18.3	265.9	262.9	157.9
	M	0.0	12.2	14.8	16.6	17.7	18.7	22.0	26.6
	S	1.4	0.9	0.8	0.0	0.1	0.8	1.2	2.0
2002	N	554.0	373.5	88.7	160.5	101.8	165.5	77.8	17.8
	M	10.4	12.2	18.3	22.6	24.0	26.1	27.2	27.3
	S	0.7	1.2	0.8	1.0	1.8	1.3	2.1	2.1
2003	N	122.6	668.6	114.6	161.3	154.5	128.2	80.7	242.7
	M	9.7	10.4	12.4	12.8	14.3	17.9	18.3	22.9
	S	0.1	0.7	0.4	0.0	1.1	0.6	0.7	3.0
2004	N	14.6	372.6	66.5	267.8	76.1	22.7	342.5	191.4
	M	10.0	10.3	12.1	12.4	13.6	16.7	17.8	22.4
	S	0.1	0.9	0.0	0.3	0.6	0.1	1.2	1.7

Mean length based on annual BGF by age group

1	2	3	4	
14.01	18.34	21.71	24.31	26.3
2.00	2.00	2.00	2.00	2.0
13.36	18.93	22.75	25.39	27.1
2.16	2.16	2.16	2.16	2.1
12.08	18.08	22.19	25.02	26.9
2.16	2.16	2.16	2.16	2.1
13.72	18.73	22.33	24.91	26.7
1.99	1.99	1.99	1.99	1.9
15.17	19.71	22.99	25.35	27.0
2.04	2.04	2.04	2.04	2.0
13.19	19.06	23.05	25.77	27.6
1.76	1.76	1.76	1.76	1.7
14.43	19	22.51	25.2	27.2
1.54	1.54	1.54	1.54	1.5
12.9	18.8	22.84	25.61	27.5
1.98	1.98	1.98	1.98	1.9
12.74	18.3	22.15	24.82	26.6
1.57	1.57	1.57	1.57	1.5
14.84	18.8	21.91	24.34	26.2
1.96	1.96	1.96	1.96	1.9

Figures

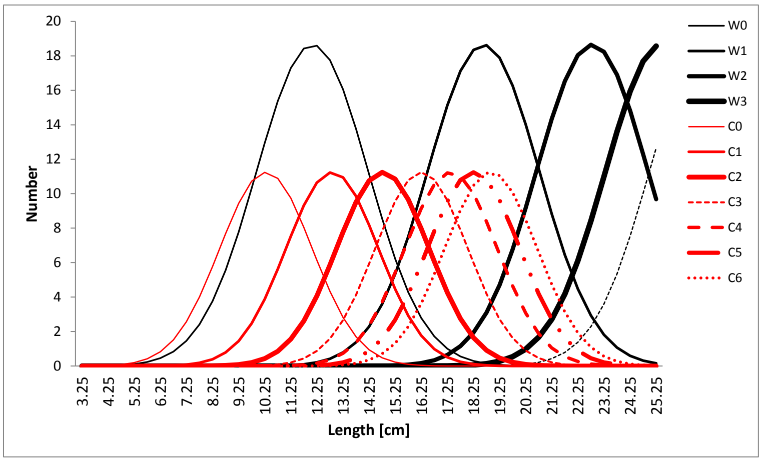
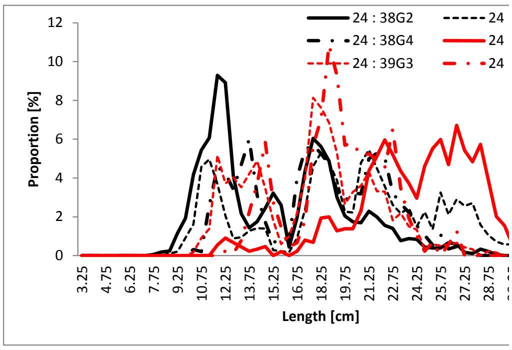


Figure 1: Length distributions of age groups 0 to 3 of WBSSH (W0 .. W3) and age groups 0 to 6 (C0 .. C6) of CBH in October. The mean length of age groups were estimated based on the mean BGF between 2005 and 2010 by stock. The standard deviation corresponds with the standrd devaiation of the BGF and the number of individuals were chosen with 100 for all age groups.



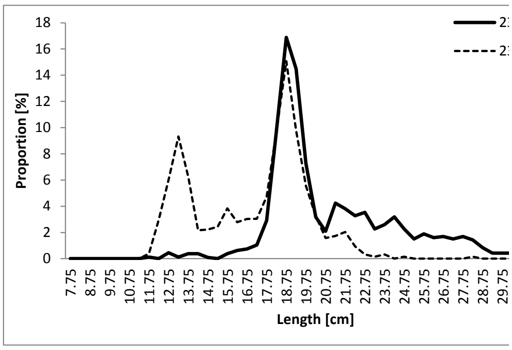
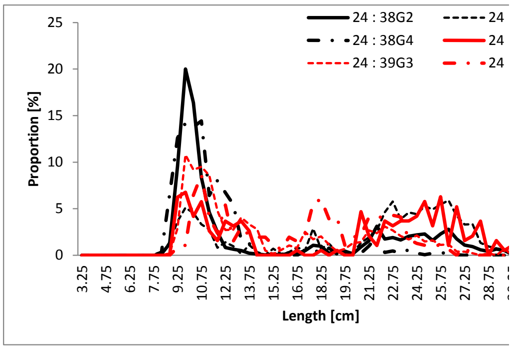


Figure 2: Relative length frequencies of herring captured during GERAS in 2000 by rectangles of SD 24 (left panel) and for SD 23 (right panel).



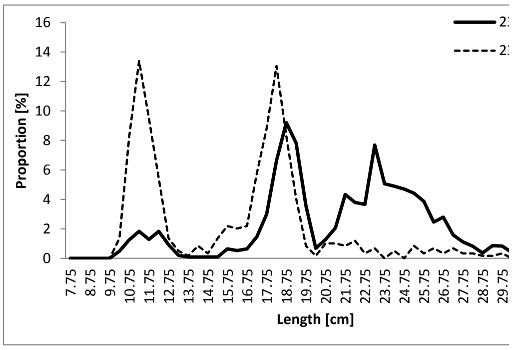


Figure 3: Relative length frequencies of herring captured during GERAS in 2002 by rectangles of SD 24 (left panel) and for SD 23 (right panel).

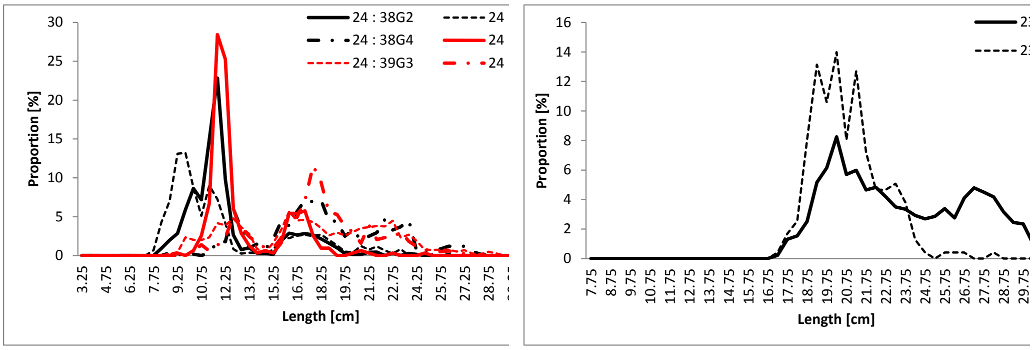


Figure 4: Relative length frequencies of herring captured during GERAS in 2004 by rectangles of SD 24 (left panel) and for SD 23 (right panel).

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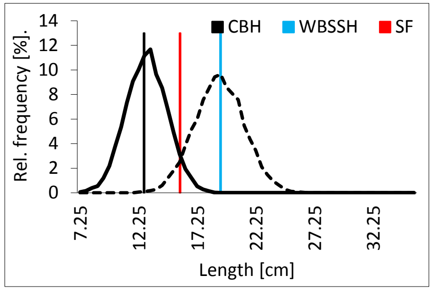
<td>
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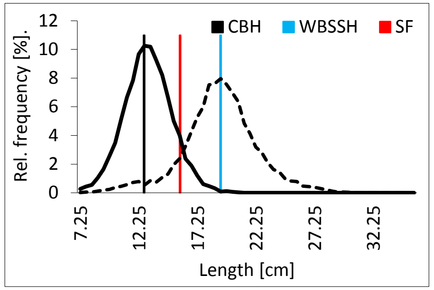
<td>
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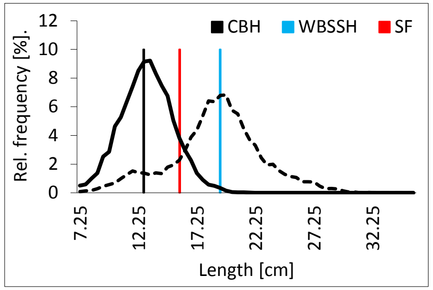
<td>
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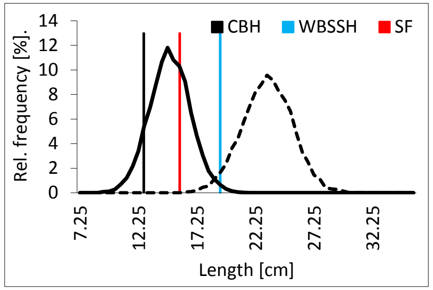
<td>
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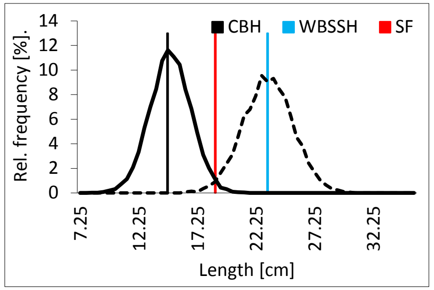
<td>
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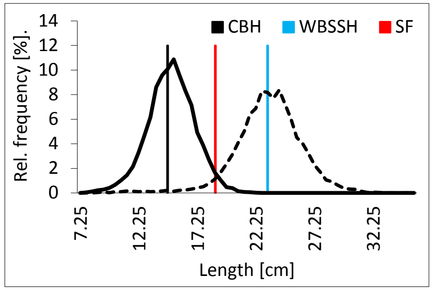
<td>
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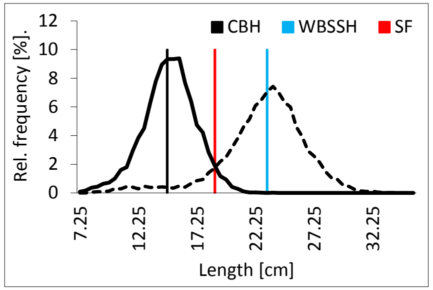
<td>
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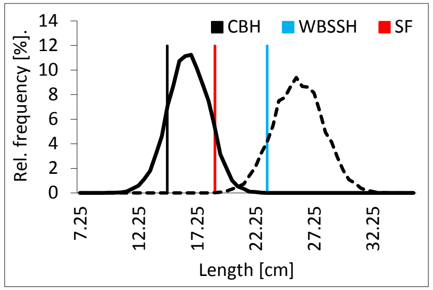
<td>
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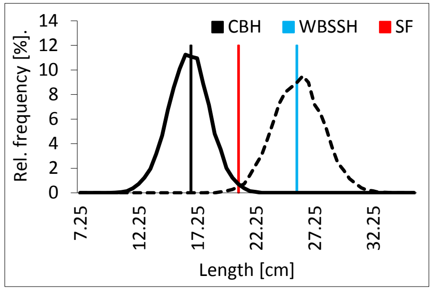
<td>
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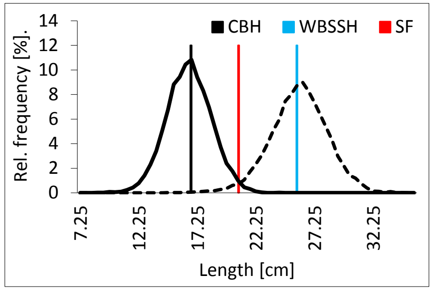
<td>
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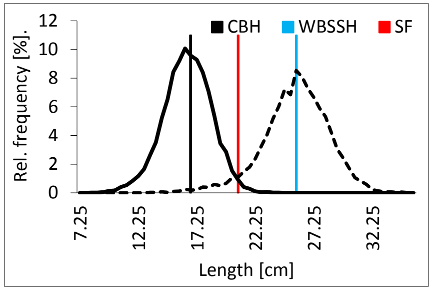
<td>
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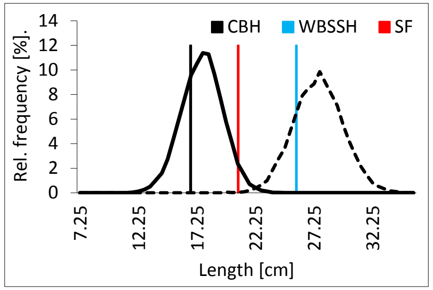
<td>
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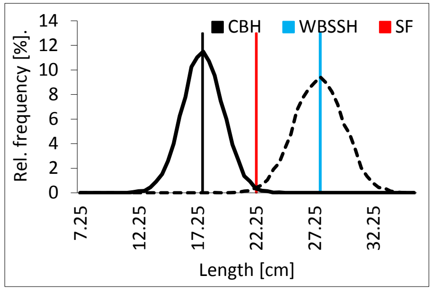
<td>
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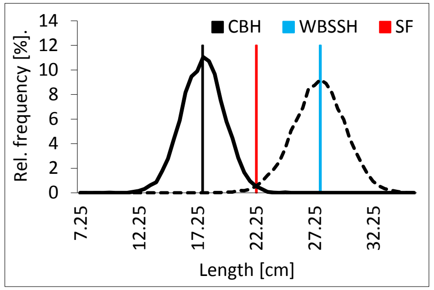
<td>
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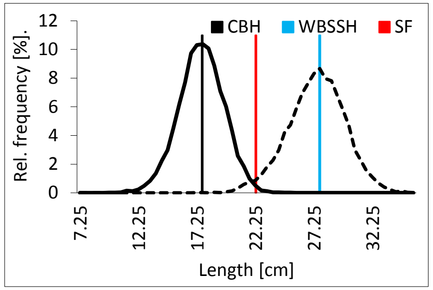
<td>
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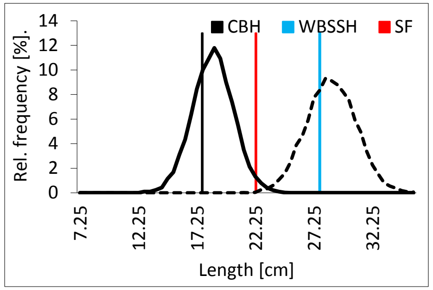
<td>
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Figure 5: Length frequencies of both herring stocks in October (line: CBH, dotted line: WBSSH) by age and version of errors of ageing (see Tab. 2). The bars present the mean length of WBSSH (blue), CBH (black) and SF (red). Version A describes the length distribution if ageing is correct, Version B uses the mean error of ageing of the ICES workshop (2008) and Version C uses symmetric errors of ageing larger than Version B and Version D describes the effect of systematic shift of ageing by +1 year.

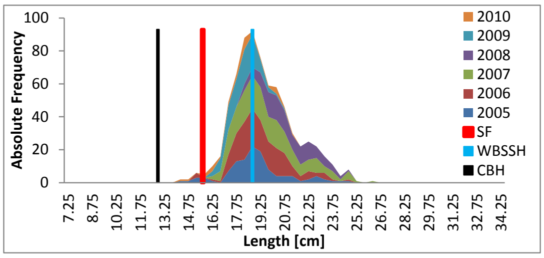
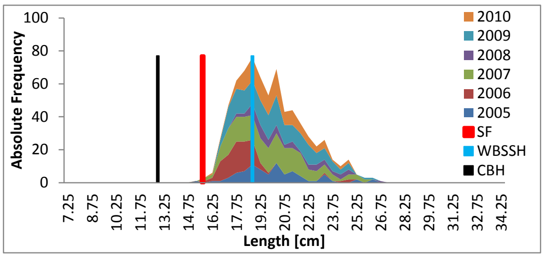
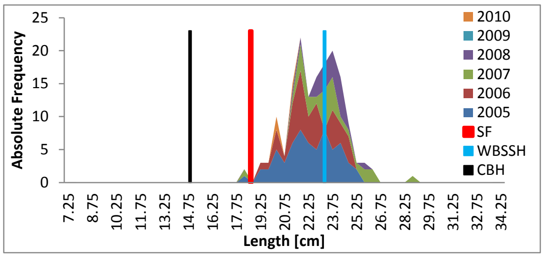
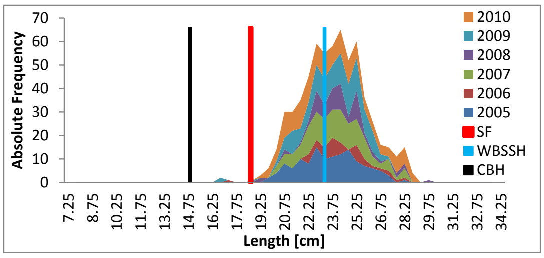
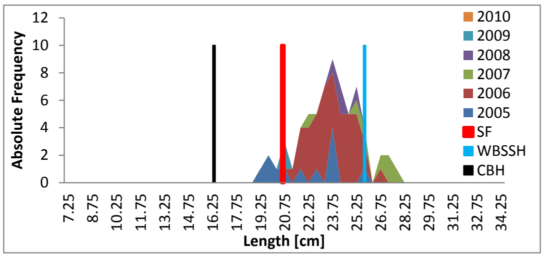
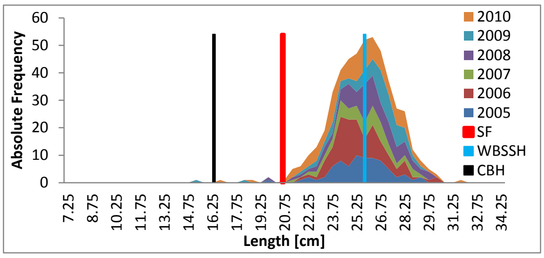
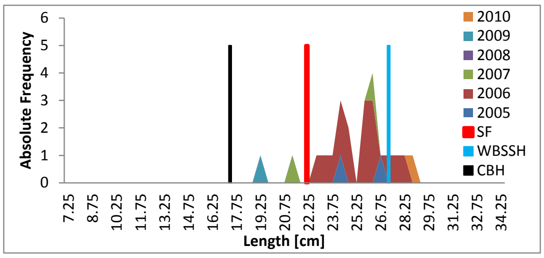
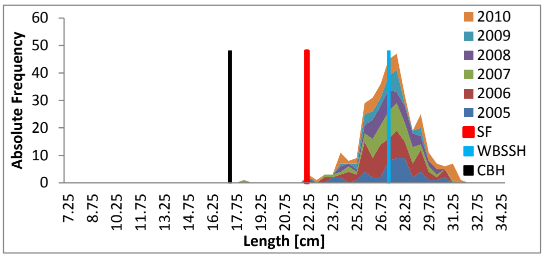
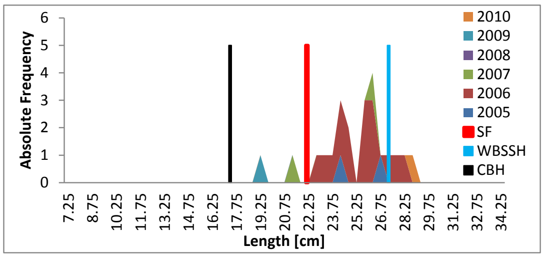
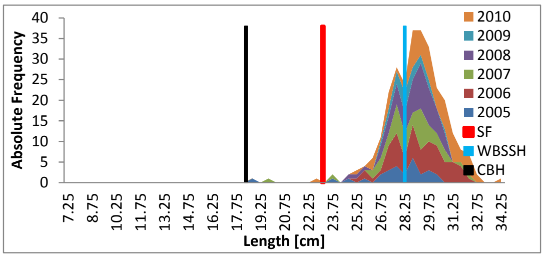
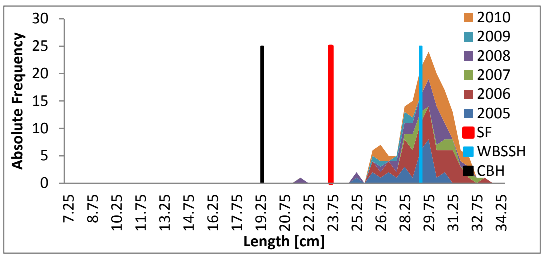
Age group	German BIAS in SD 21	German BIAS in SD 23
1		
2		
3		
4		
5		
6		

Figure 6: Length frequencies of age group1 to 6 of German BIAS in SD 21 and SD 23 by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

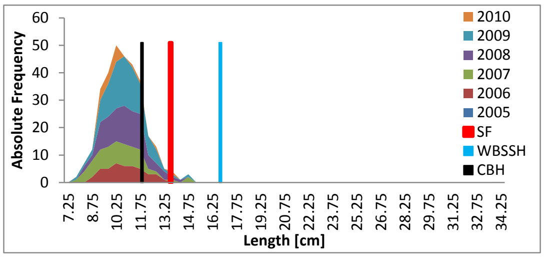
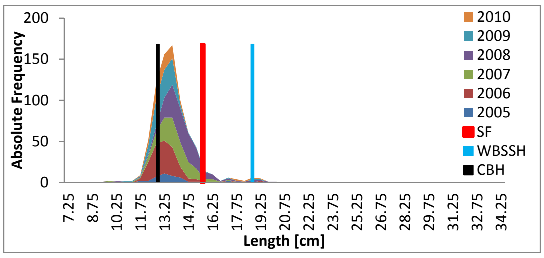
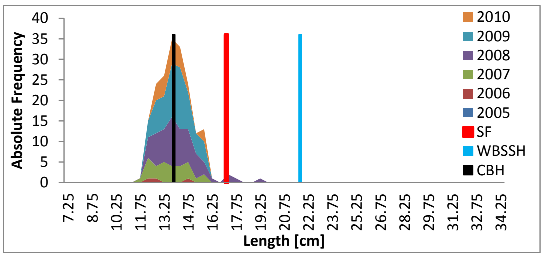
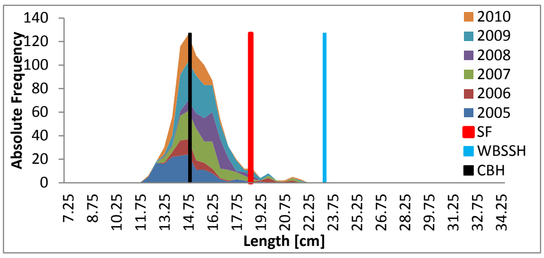
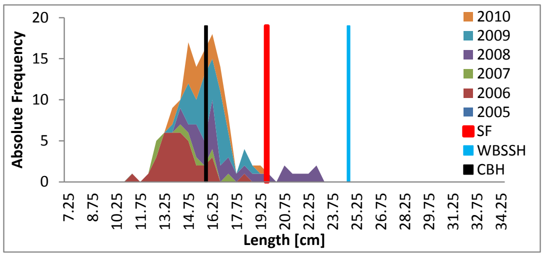
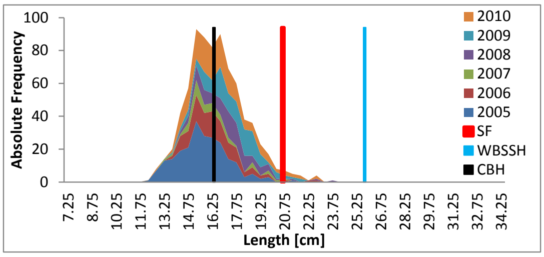
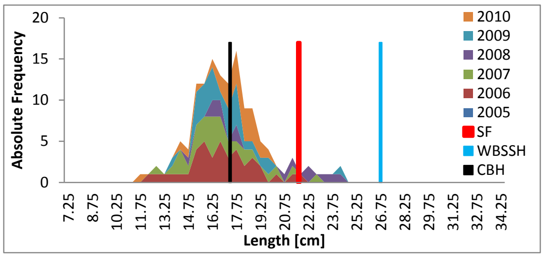
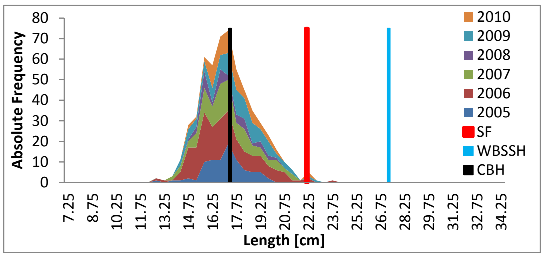
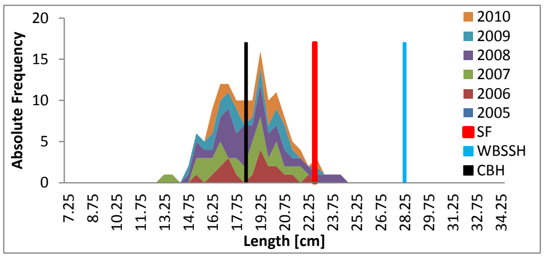
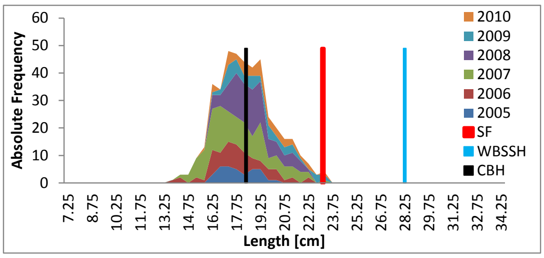
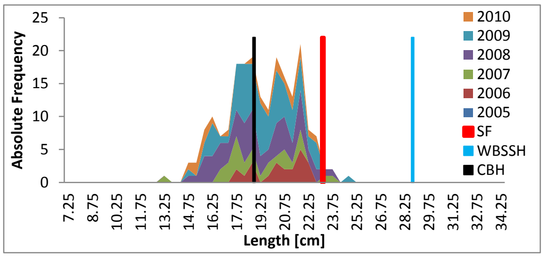
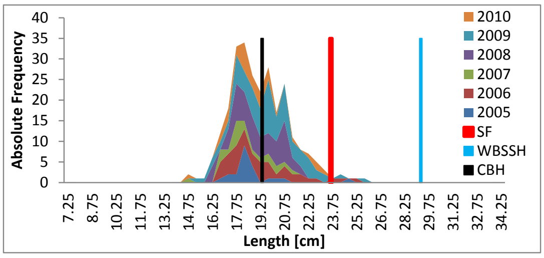
Age group	German BASS in SD 27+	Swedish BIAS in SD 27
1		
2		
3		
4		
5		
6		

Figure 7: Length frequencies of age group1 to 6 of German BASS in SD 27+ and Swedish BIAS in SD 27 by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

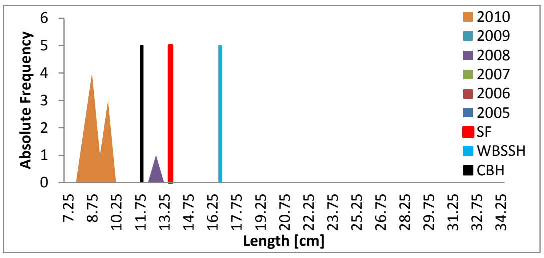
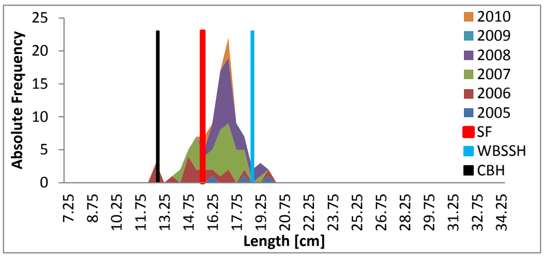
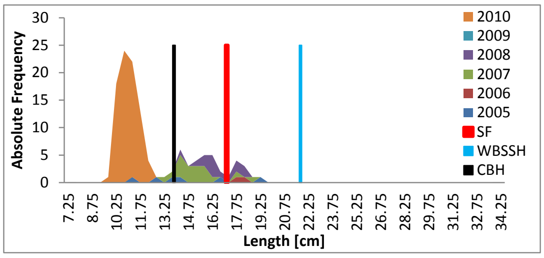
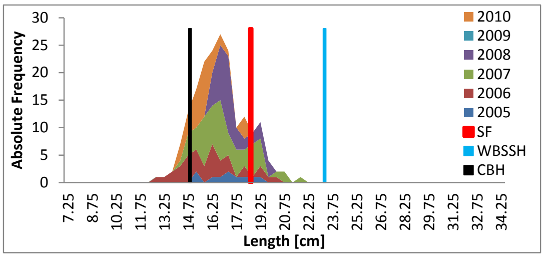
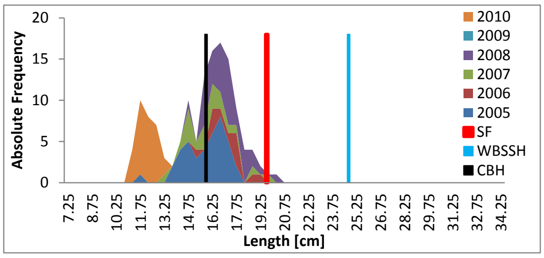
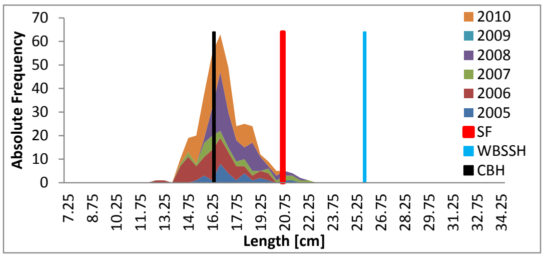
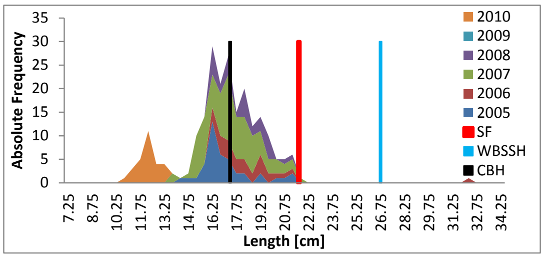
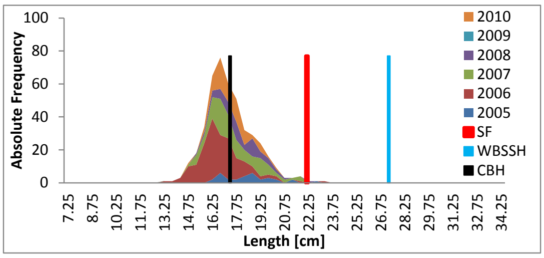
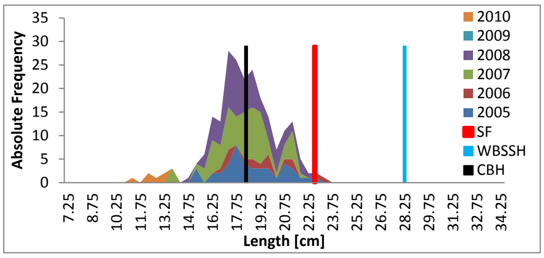
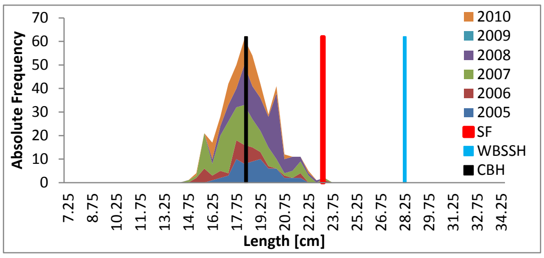
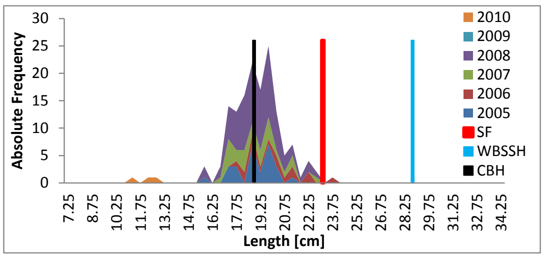
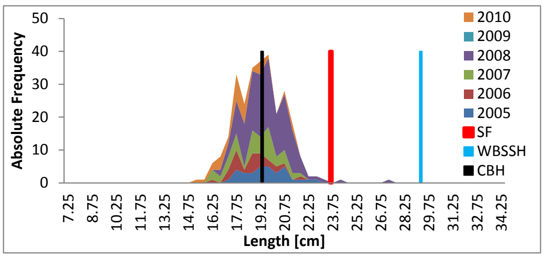
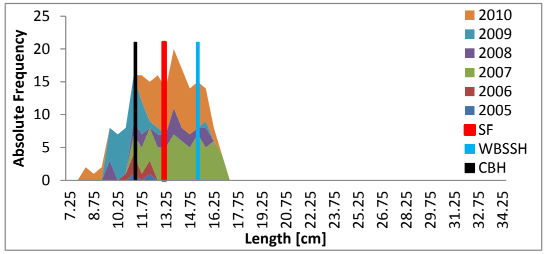
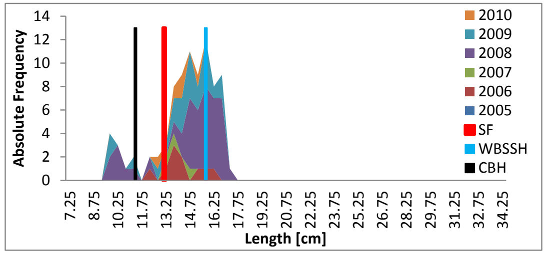
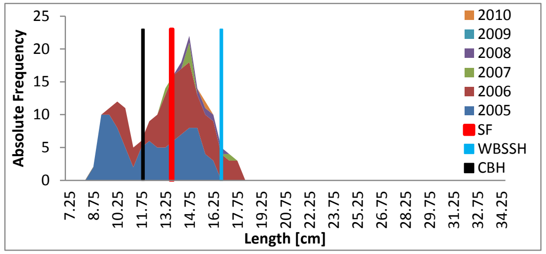
Age group	Latvian BASS in SD 26	Latvian BIAS in SD 26
1		
2		
3		
4		
5		
6		

Figure 8: Length frequencies of age group1 to 6 of Latvian BASS and BIAS in SD 26 by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

<table>
<tr><th>Age group</th><th>German catch in SD 24 in March</th><th>German catch in SD 24 in April</th><th>German catch in SD 24 in May</th></tr>
<tr><td>1</td>
<td></td>
<td></td>
<td></td></tr>
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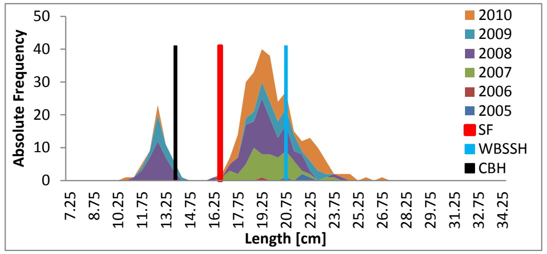
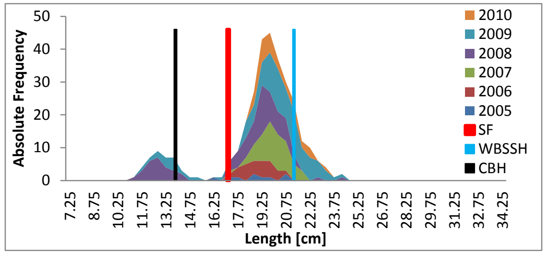
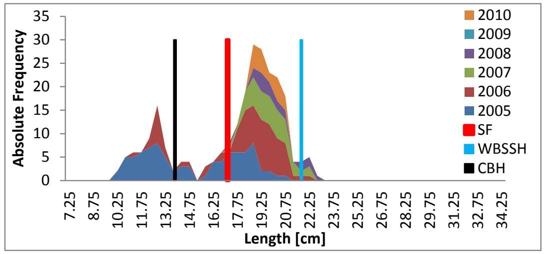
<td></td>
<td></td>
<td></td></tr>
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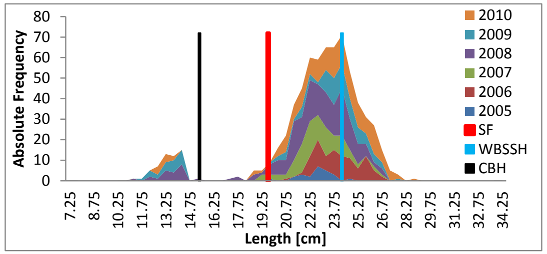
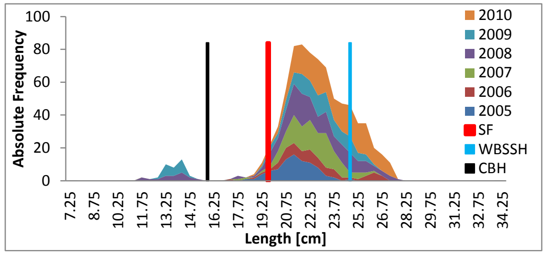
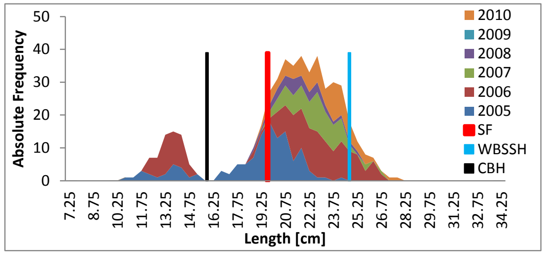
<td></td>
<td></td>
<td></td></tr>
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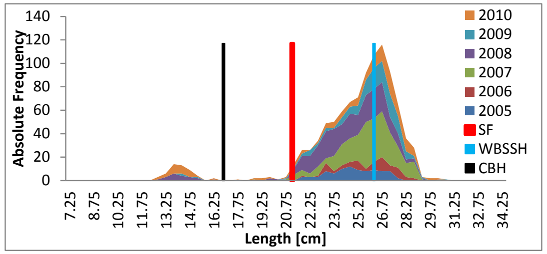
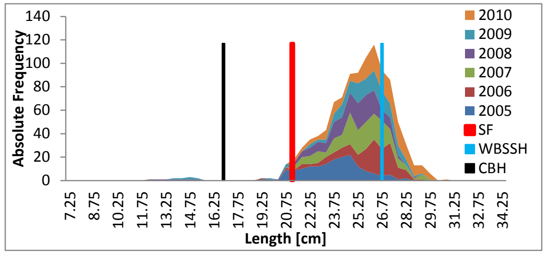
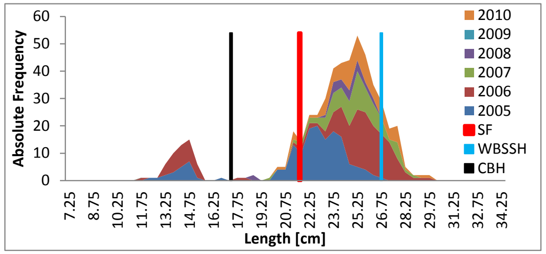
<td></td>
<td></td>
<td></td></tr>
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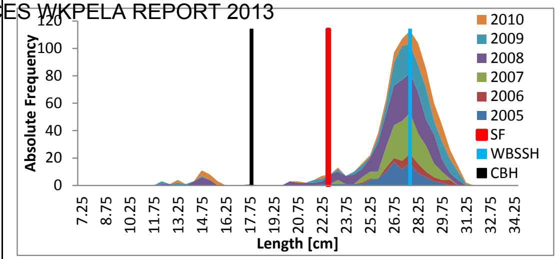
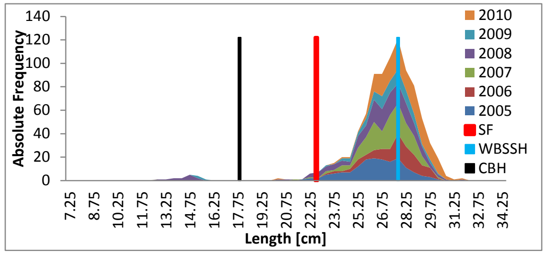
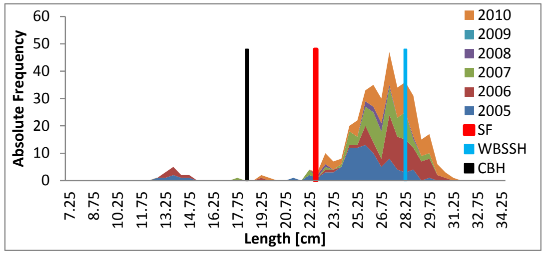
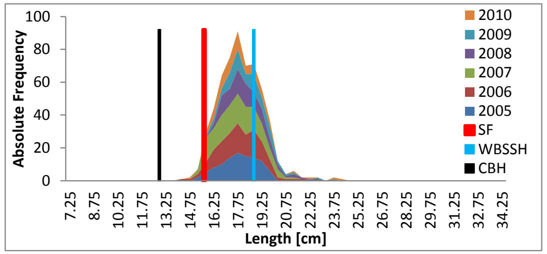
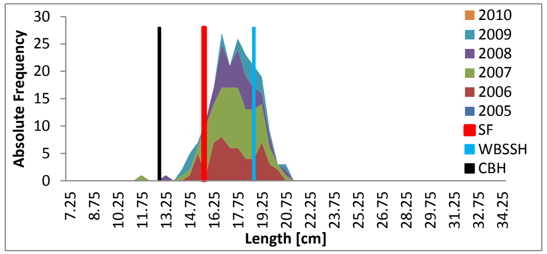
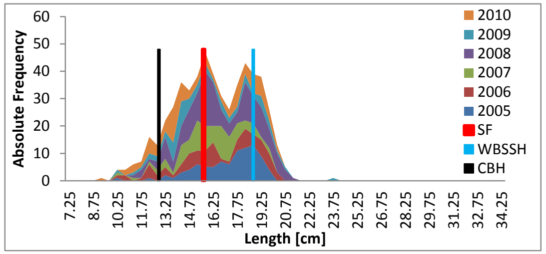
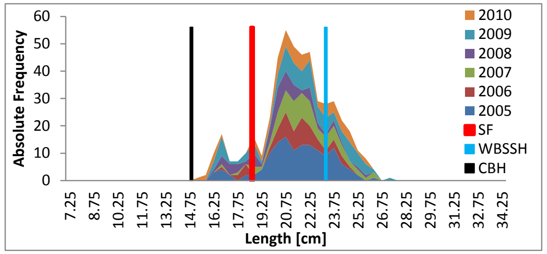
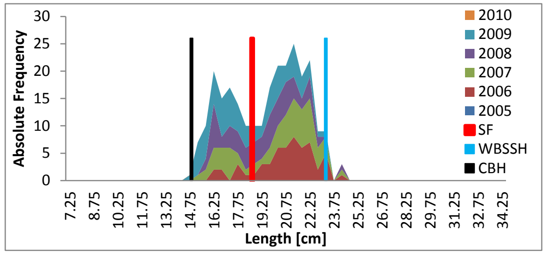
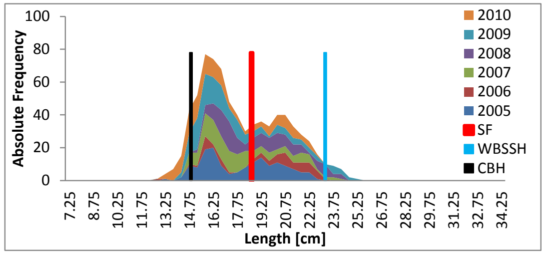
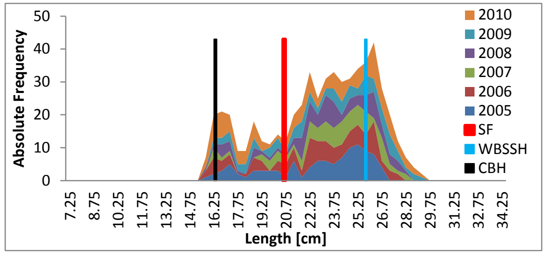
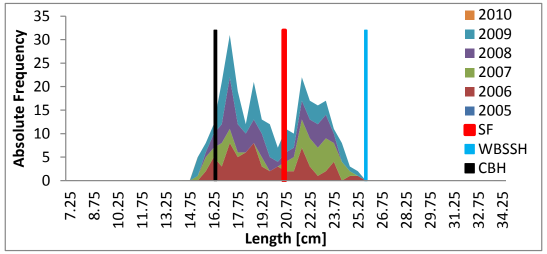
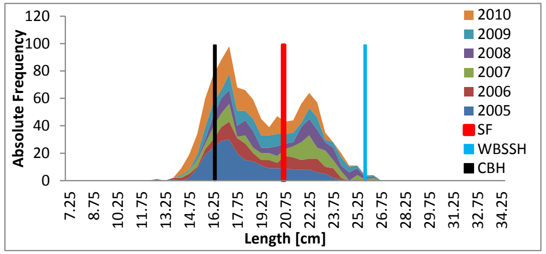
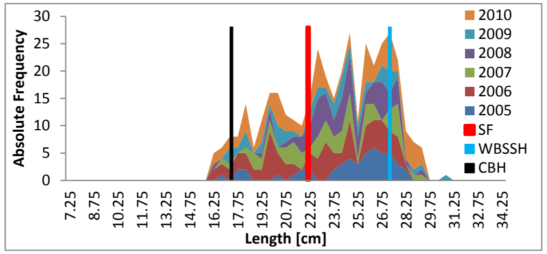
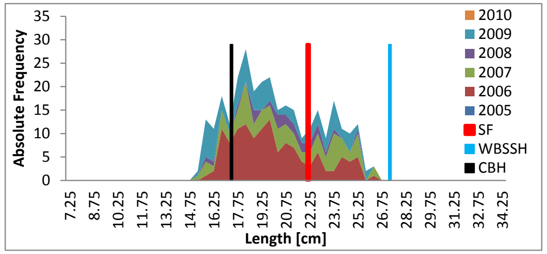
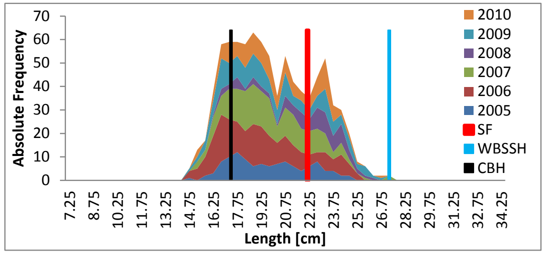
5			

Figure 9: Length frequencies of age groups 1 to 5 of herring sampled in German commercial catches in SD 24 in March to May by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

Age group	German BIAS in SD 24	Polish BIAS in SD 25	Swedish BIAS in SD 25
1			
2			
3			
4			

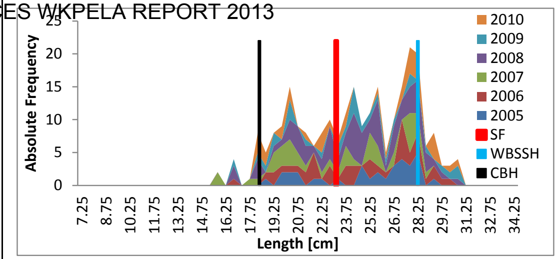
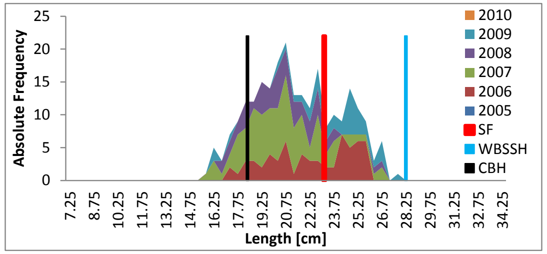
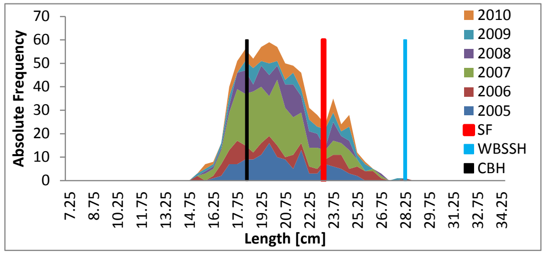
5			

Figure 10: Length frequencies of age groups 1 to 5 of herring sampled during German, Polish and Swedish BIAS in SD 25 by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

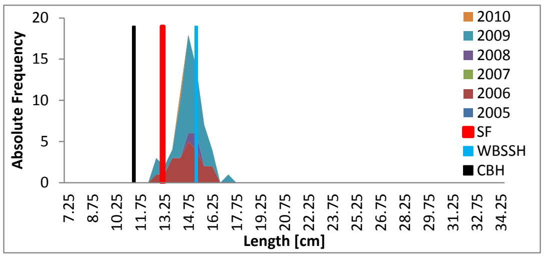
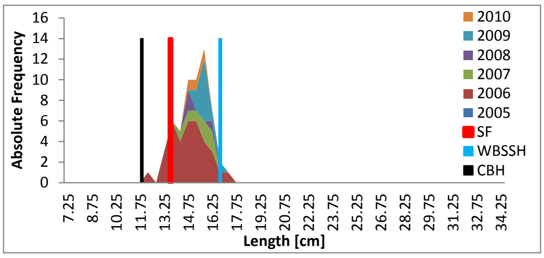
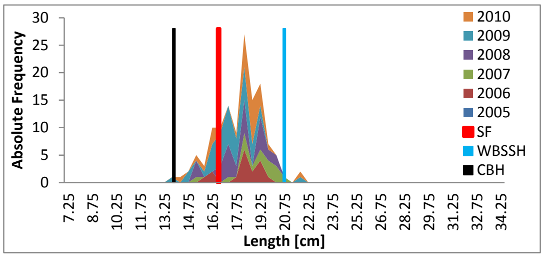
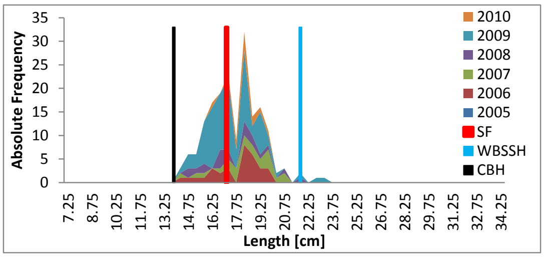
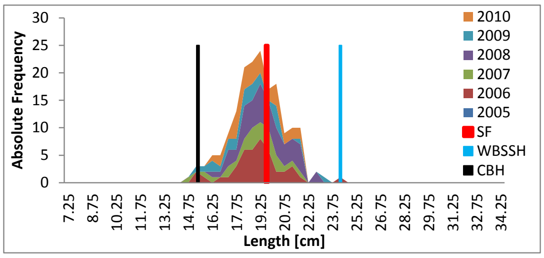
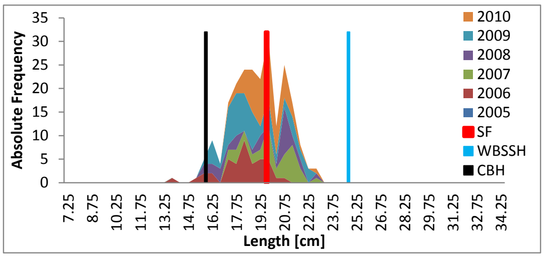
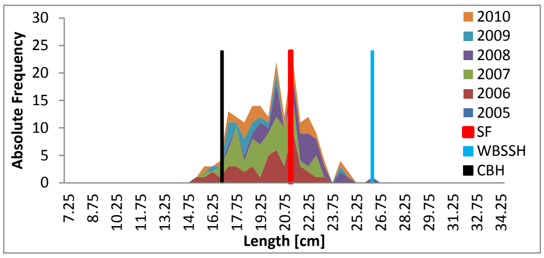
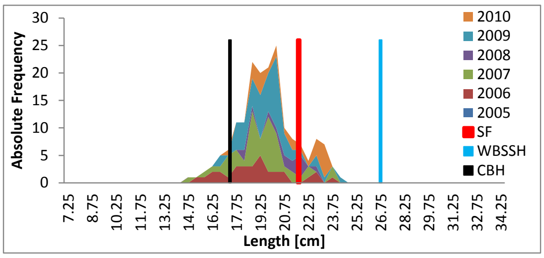
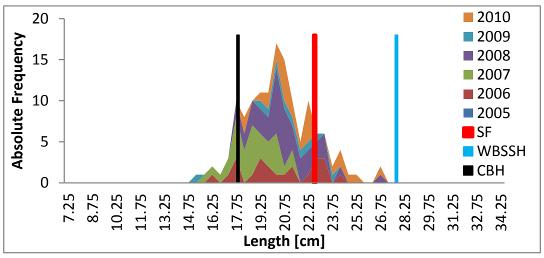
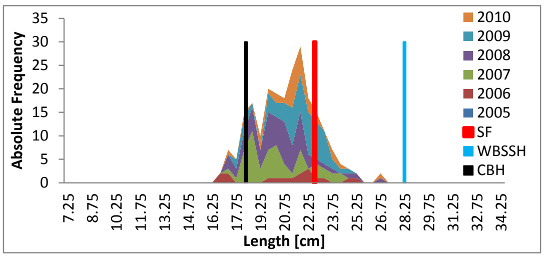
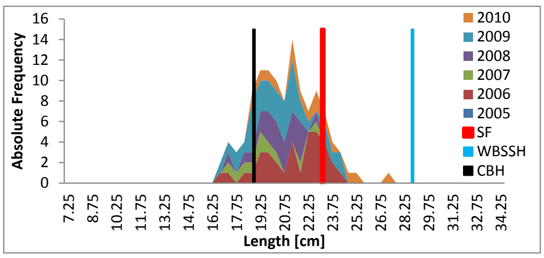
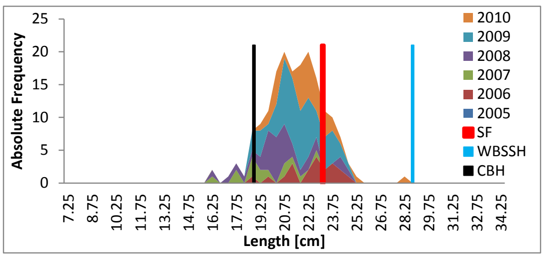
Age group	Swedish catch in SD 25 in March	Swedish catch in SD 25 in May
1		
2		
3		
4		
5		
6		

Figure 11: Length frequencies of age groups 1 to 6 of herring sampled in Swedish commercial catches in SD 25 in March and May by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

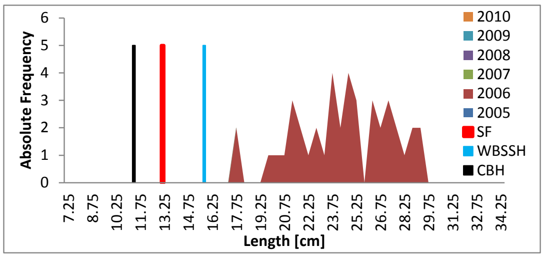
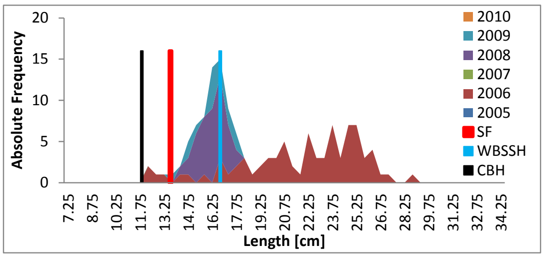
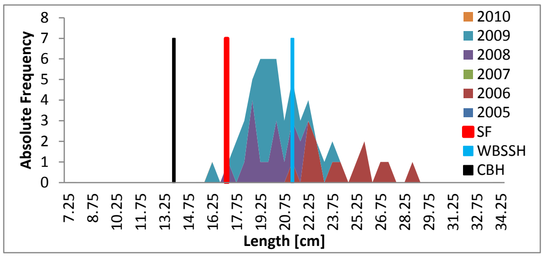
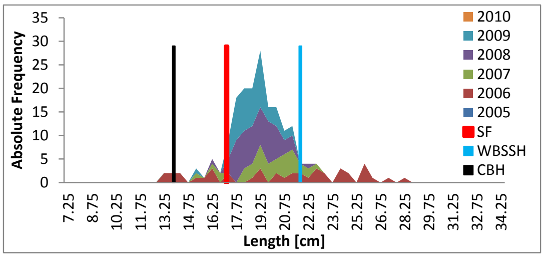
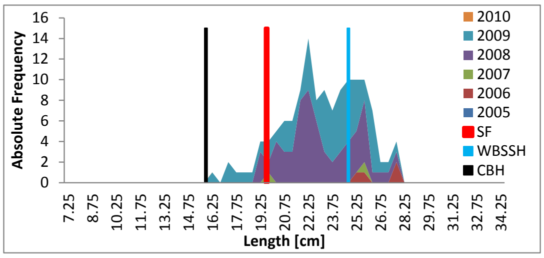
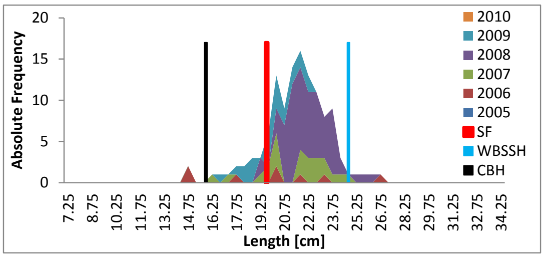
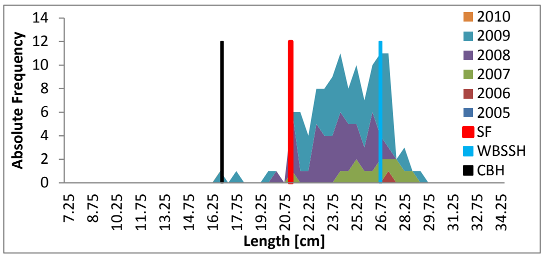
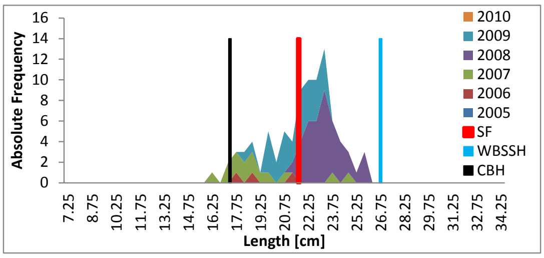
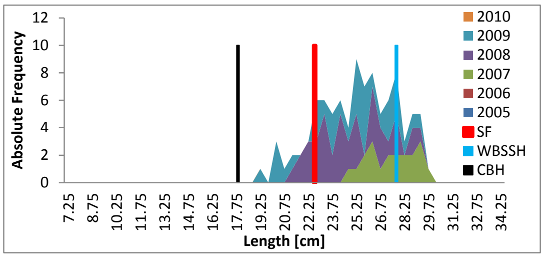
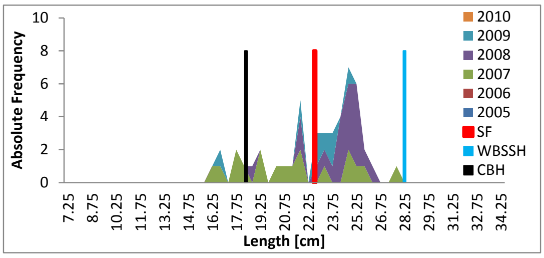
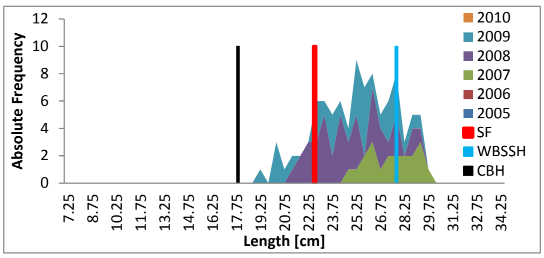
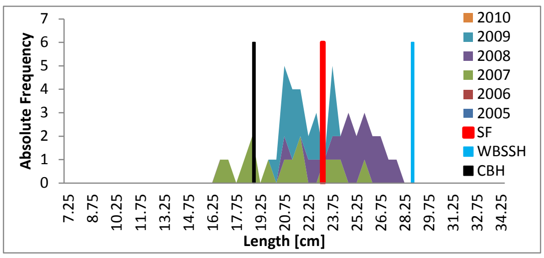
Age group	Polish catch in SD 25 in April	Polish catch in SD 25 in May
1		
2		
3		
4		
5		
6		

Figure 12: Length frequencies of age groups 1 to 6 of herring sampled in Polish commercial catches in SD 25 in April and May by years (different color) and the mean length of CBH (black bar), of WBSSH (blue bar) and SF (red bar).

WD 5 Assessment Input database

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Abstract

Old assessment input files were used and cross-checked with the output of the corresponding old and the latest HAWG report, respectively to compile a historic database on assessment input data (CANUM, WECA, WEST, CATON) for **WBSSH**. The data were aggregated in following units: winter rings/age groups (0, 1, 2, 3, 4, 5, 6, 7 and 8+, not relevant for CATON), stock (NSAS, WBSS), area (IV, IIIaN, IIIaS, 22, 23, 24), fleet (A, C, D, F) and year (1991-now). The current database status is as follows: 1991-1995: some data; 1996-1999: no data at all; 2000: ok; 2001: It was somehow possible to reconstruct the data, but data have still to be checked; 2002-2005: ok; 2006: Do not exactly match up related to the presently used data of CATON, WECA and WEST; 2007: 1000 t missing (CATON), differences in CANUM and WECA; 2008: CATON, WECA and WEST due to the changes in the German landings and 2009-2011: ok.

It seems that the presently used input values for the years 1991-1999/2000 were updated in one go during the HAWG meeting in 2004. These corresponding updated input files were not available when compiling the data-base.

1 Introduction

The assessment input data for WBSSH are compiled year by year by the stock coordinator. The basis for the compilation procedure consists of national input data, which are submitted by area (SD 20-24), fleet (A, C, D, F), fishing gear (trawl, gillnet, trapnet) and year. These data are then summarized to produce the overall assess-ment input data of the total stock as CATON, CANUM, WECA, WEST etc. The intermediate international data (by area, fleet, etc.) of the current year are available in the corresponding HAWG report but they are presently not stored in any database. The goal of the preset work was to initiate a database to store historical assessment input data at least down to the level by stock (NSAS, WBSS), area (Division IV and IIIaN/IIIaS, SD 22, SD 23 and SD 24), fleet (A, C, D, E), age groups (= WRs) 0-8+ and year (1991-now).

2 Method

Old input files were used and cross-checked with the output of the:

- corresponding old HAWG reports and
- latest HAWG report.

Contents of the database include the following type of data sets:

- CANUM (Catch at age in numbers),
- WECA (Mean weight at age),
- WEST (Mean weight at age in the stock),
- CATON (Total landings = SOP).

Resolution of these data reached the following levels:

- Stock (NSAS, WBSS),
- Area (IV, IIIaN, IIIaS, 22, 23, 24),
- Fleet (A, C, D, F),
- Age groups (WRs) 0-8+,
- Year (1991-now).

3 Results

It seems that the present values for 1991-1999/2000? were somehow updated in one go during the HAWG meet-ing in 2004. These old input files are not available at present.

Catch in numbers at age/WR (CANUM, in millions) by stock, area and fleet for the years 1991-2011 are given in Table 1.

Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011 are given in Table 2.

Mean weight at age/WR in the stock (WEST, in grams) for the years 2001-2011, which equals Quarter 1 overall estimates, are given in Table 3.

Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012 are given in Table 4.

The database currently has the following status:

- 1991-1995: some data
- 1996-1999: no data at all
- 2000: ok?
- 2001: It was somehow possible to reconstruct the data; should be checked!
- 2002-2005: ok
- 2006: Do not exactly match up related to the presently used CATON, WECA and WEST
- 2007: 1000 t missing (CATON), differences in CANUM, WECA?
- 2008: I updated the CATON, WECA and WEST due to the changes in the German landings
- 2009-2011: ok

Table 1 Catch in Numbers at age/WR (CANUM, in millions) by stock, area, and fleet for the years 1991-2011.

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Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+	TOTAL
1991	WBSS	IV	A	0.000	0.000	6.700	15.100	18.000	9.100	3.100	0.800	0.300	53.100
1991	NSAS	IIIaN	C										0.000
1991	NSAS	IIIaN	D										0.000
1991	NSAS	IIIaN	C, D	367.300	541.140	194.406	49.007	7.045	4.690	1.099	0.363	0.147	1165.198
1991	NSAS	IIIaS	C										0.000
1991	NSAS	IIIaS	D										0.000
1991	NSAS	IIIaS	C, D	309.804	207.130	103.879	3.424	0.682	0.459	0.045	0.003	0.003	625.430
1991	WBSS	IIIaN	C										0.000
1991	WBSS	IIIaN	D										0.000
1991	WBSS	IIIaN	C, D	0.000	19.260	120.794	194.493	109.955	69.710	15.601	5.537	2.153	537.502
1991	WBSS	IIIaS	C										0.000
1991	WBSS	IIIaS	D										0.000
1991	WBSS	IIIaS	C, D	99.996	138.170	255.421	185.176	39.018	33.541	3.155	0.997	0.697	756.170
1991	WBSS	IIIa	C, D	99.996	157.430	376.215	379.668	148.973	103.251	18.756	6.534	2.850	1293.673
1991	WBSS	22	F										0.000
1991	WBSS	23	F										0.000
1991	WBSS	24	F										0.000
1991	WBSS	22-24	F	18.962	668.539	158.331	169.662	112.794	65.135	24.631	5.907	1.782	1225.743
1991	WBSS	TOTAL	A, C, D, F	118.958	825.969	541.246	564.430	279.767	177.486	46.487	13.241	4.933	2572.516
1992	WBSS	IV	A	0.000	0.000	0.300	9.900	11.100	8.400	8.600	2.500	1.300	42.100
1992	NSAS	IIIaN	C										0.000
1992	NSAS	IIIaN	D										0.000
1992	NSAS	IIIaN	C, D	1710.330	1055.007	173.480	21.192	9.637	6.235	2.638	0.936	0.386	2979.842
1992	NSAS	IIIaS	C										0.000
1992	NSAS	IIIaS	D										0.000
1992	NSAS	IIIaS	C, D	588.100	353.776	46.796	0.924	0.750	0.355	0.236	0.074	0.030	991.041
1992	WBSS	IIIaN	C										0.000
1992	WBSS	IIIaN	D										0.000
1992	WBSS	IIIaN	C, D	0.000	50.403	161.420	89.768	91.803	48.885	35.092	12.154	5.224	494.748
1992	WBSS	IIIaS	C										0.000
1992	WBSS	IIIaS	D										0.000
1992	WBSS	IIIaS	C, D	109.080	195.594	160.134	74.356	51.570	21.045	12.134	3.256	2.010	629.179
1992	WBSS	IIIa	C, D	109.080	245.997	321.554	164.124	143.373	69.930	47.225	15.410	7.234	1123.927
1992	WBSS	22	F										0.000
1992	WBSS	23	F										0.000
1992	WBSS	24	F										0.000
1992	WBSS	22-24	F	36.010	210.710	280.770	190.840	179.520	104.870	84.010	34.750	14.040	1135.520
1992	WBSS	TOTAL	A, C, D, F	145.090	456.707	602.624	364.864	333.993	183.200	139.835	52.660	22.574	2301.547
1993	WBSS	IV	A	0.000	0.000	4.200	10.800	12.300	8.400	5.900	4.700	2.700	49.000
1993	NSAS	IIIaN	C										0.000
1993	NSAS	IIIaN	D										0.000
1993	NSAS	IIIaN	C, D	2297.910	1429.852	194.046	26.017	7.395	3.473	2.626	2.118	0.635	3964.070
1993	NSAS	IIIaS	C										0.000
1993	NSAS	IIIaS	D										0.000
1993	NSAS	IIIaS	C, D	497.538	602.671	43.575	0.495	0.286	0.170	0.086	0.041	0.021	1144.882
1993	WBSS	IIIaN	C										0.000
1993	WBSS	IIIaN	D										0.000
1993	WBSS	IIIaN	C, D	0.000	103.529	186.474	165.403	61.925	38.517	28.154	13.102	4.406	601.510
1993	WBSS	IIIaS	C										0.000
1993	WBSS	IIIaS	D										0.000
1993	WBSS	IIIaS	C, D	161.252	267.969	125.145	42.845	19.854	12.510	6.914	3.909	1.119	641.518
1993	WBSS	IIIa	C, D	161.252	371.497	311.620	208.248	81.780	51.027	35.068	17.012	5.525	1243.027
1993	WBSS	22	F										0.000
1993	WBSS	23	F										0.000
1993	WBSS	24	F										0.000
1993	WBSS	22-24	F	44.850	159.210	180.130	196.060	166.870	151.070	61.800	42.210	16.310	1018.510
1993	WBSS	TOTAL	A, C, D, F	206.102	530.707	495.950	415.108	260.950	210.497	102.768	63.922	24.535	2310.537
1994	WBSS	IV	A	0.000	0.000	8.800	28.200	16.300	11.000	8.600	3.400	3.900	80.200
1994	NSAS	IIIaN	C										0.000
1994	NSAS	IIIaN	D										0.000
1994	NSAS	IIIaN	C, D	413.670	804.338	161.657	25.583	5.449	2.661	1.369	0.340	0.148	1415.214
1994	NSAS	IIIaS	C										0.000
1994	NSAS	IIIaS	D										0.000
1994	NSAS	IIIaS	C, D	67.938	282.203	39.753	1.327	0.558	0.237	0.185	0.037	0.024	392.264
1994	WBSS	IIIaN	C										0.000
1994	WBSS	IIIaN	D										0.000
1994	WBSS	IIIaN	C, D	0.000	26.302	152.333	120.857	89.781	52.279	27.392	7.350	2.852	479.146
1994	WBSS	IIIaS	C										0.000
1994	WBSS	IIIaS	D										0.000
1994	WBSS	IIIaS	C, D	60.622	126.807	100.007	72.583	24.892	14.023	8.405	3.643	1.866	412.846
1994	WBSS	IIIa	C, D	60.622	153.108	252.340	193.440	114.673	66.302	35.796	10.994	4.718	891.992
1994	WBSS	22	F										0.000
1994	WBSS	23	F										0.000
1994	WBSS	24	F										0.000
1994	WBSS	22-24	F	202.580	96.290	103.840	161.010	136.060	90.840	74.020	35.110	24.470	924.220
1994	WBSS	TOTAL	A, C, D, F	263.202	249.398	364.980	382.650	267.033	168.142	118.416	49.504	33.088	1896.412

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Table 1 **Catch in Numbers at age/WR (CANUM, in millions) by stock, area, and fleet for the years 1991-2011.**

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+	TOTAL
1995	WBSS	IV	A	0.000	0.000	22.400	11.000	14.900	4.000	2.900	1.900	0.700	57.800
1995	NSAS	IIIaN	C										0.000
1995	NSAS	IIIaN	D										0.000
1995	NSAS	IIIaN	C, D	1079.908	743.380	138.128	12.737	2.959	0.901	0.502	0.307	0.218	1979.039
1995	NSAS	IIIaS	C										0.000
1995	NSAS	IIIaS	D										0.000
1995	NSAS	IIIaS	C, D	64.632	445.867	23.379	0.578	0.503	0.199	0.123	0.056	0.050	535.387
1995	WBSS	IIIaN	C										0.000
1995	WBSS	IIIaN	D										0.000
1995	WBSS	IIIaN	C, D	0.000	58.112	123.374	85.472	60.283	19.157	13.184	9.026	3.990	372.598
1995	WBSS	IIIaS	C										0.000
1995	WBSS	IIIaS	D										0.000
1995	WBSS	IIIaS	C, D	50.312	244.393	72.035	33.172	33.712	12.171	7.684	3.689	3.002	460.170
1995	WBSS	IIIa	C, D	50.312	302.506	195.408	118.644	93.994	31.328	20.869	12.716	6.992	832.768
1995	WBSS	22	F										0.000
1995	WBSS	23	F										0.000
1995	WBSS	24	F										0.000
1995	WBSS	22-24	F	490.990	1358.177	233.950	128.879	104.012	53.569	38.818	20.873	13.224	2442.491
1995	WBSS	TOTAL	A, C, D, F	541.302	1660.683	451.758	258.522	212.907	88.896	62.587	35.488	20.915	3333.059
1996	WBSS	IV	A										0.000
1996	NSAS	IIIaN	C										0.000
1996	NSAS	IIIaN	D										0.000
1996	NSAS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	NSAS	IIIaS	C										0.000
1996	NSAS	IIIaS	D										0.000
1996	NSAS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	WBSS	IIIaN	C										0.000
1996	WBSS	IIIaN	D										0.000
1996	WBSS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	WBSS	IIIaS	C										0.000
1996	WBSS	IIIaS	D										0.000
1996	WBSS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	WBSS	IIIa	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	WBSS	22	F										0.000
1996	WBSS	23	F										0.000
1996	WBSS	24	F										0.000
1996	WBSS	22-24	F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	WBSS	TOTAL	A, C, D, F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	WBSS	IV	A										0.000
1997	NSAS	IIIaN	C										0.000
1997	NSAS	IIIaN	D										0.000
1997	NSAS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	NSAS	IIIaS	C										0.000
1997	NSAS	IIIaS	D										0.000
1997	NSAS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	WBSS	IIIaN	C										0.000
1997	WBSS	IIIaN	D										0.000
1997	WBSS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	WBSS	IIIaS	C										0.000
1997	WBSS	IIIaS	D										0.000
1997	WBSS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	WBSS	IIIa	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	WBSS	22	F	164.330	529.490	58.000	6.600	2.840	3.840	3.200	1.600	1.600	771.500
1997	WBSS	23	F	21.427	6.218	5.605	2.229	0.571	0.351	0.411	0.281	0.350	37.443
1997	WBSS	24	F	165.070	59.482	67.018	88.029	41.717	24.774	30.652	17.229	19.182	513.152
1997	WBSS	22-24	F	350.828	595.190	130.623	96.858	45.128	28.964	34.263	19.109	21.132	1322.095
1997	WBSS	TOTAL	A, C, D, F	350.828	595.190	130.623	96.858	45.128	28.964	34.263	19.109	21.132	1322.095
1998	WBSS	IV	A										0.000
1998	NSAS	IIIaN	C										0.000
1998	NSAS	IIIaN	D										0.000
1998	NSAS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	NSAS	IIIaS	C										0.000
1998	NSAS	IIIaS	D										0.000
1998	NSAS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	WBSS	IIIaN	C										0.000
1998	WBSS	IIIaN	D										0.000
1998	WBSS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	WBSS	IIIaS	C										0.000
1998	WBSS	IIIaS	D										0.000
1998	WBSS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	WBSS	IIIa	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	WBSS	22	F										0.000
1998	WBSS	23	F										0.000
1998	WBSS	24	F										0.000
1998	WBSS	22-24	F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	WBSS	TOTAL	A, C, D, F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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Table 1 Catch in Numbers at age/WR (CANUM, in millions) by stock, area, and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+	TOTAL
1999	WBSS	IV	A										0.000
1999	NSAS	IIIaN	C										0.000
1999	NSAS	IIIaN	D										0.000
1999	NSAS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	NSAS	IIIaS	C										0.000
1999	NSAS	IIIaS	D										0.000
1999	NSAS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	WBSS	IIIaN	C										0.000
1999	WBSS	IIIaN	D										0.000
1999	WBSS	IIIaN	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	WBSS	IIIaS	C										0.000
1999	WBSS	IIIaS	D										0.000
1999	WBSS	IIIaS	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	WBSS	IIIa	C, D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	WBSS	22	F										0.000
1999	WBSS	23	F										0.000
1999	WBSS	24	F										0.000
1999	WBSS	22-24	F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	WBSS	TOTAL	A, C, D, F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	WBSS	IV	A	0.000	0.000	8.161	9.752	10.223	5.660	2.466	0.605	0.778	37.644
2000	NSAS	IIIaN	C	56.485	300.793	79.719	15.542	19.467	7.317	2.889	0.280	0.051	482.543
2000	NSAS	IIIaN	D	86.079	248.348	9.750	0.489	3.027	0.061	0.345	0.322		348.421
2000	NSAS	IIIaN	C, D	142.563	549.141	89.469	16.031	22.494	7.378	3.234	0.602	0.051	830.964
2000	NSAS	IIIaS	C	6.612	184.571	26.105	5.815	0.320	0.148	0.026		0.017	223.614
2000	NSAS	IIIaS	D	87.005	250.549	0.052	0.011	0.005		0.001		0.001	337.623
2000	NSAS	IIIaS	C, D	93.616	435.120	26.156	5.826	0.325	0.148	0.026	0.000	0.018	561.237
2000	WBSS	IIIaN	C	56.111	29.789	121.719	66.885	50.176	17.736	6.163	0.943	0.675	350.197
2000	WBSS	IIIaN	D	30.088	6.662	13.316	4.972	0.514	0.149	0.082	0.018		55.801
2000	WBSS	IIIaN	C, D	86.198	36.451	135.035	71.857	50.690	17.886	6.246	0.961	0.675	405.998
2000	WBSS	IIIaS	C	3.071	179.790	173.033	32.175	5.490	2.625	1.147	0.035	0.097	397.463
2000	WBSS	IIIaS	D	28.393	102.675	0.572	0.061	0.042	0.006	0.004		0.010	131.763
2000	WBSS	IIIaS	C, D	31.464	282.465	173.605	32.236	5.532	2.631	1.152	0.035	0.107	529.226
2000	WBSS	IIIa	C, D	117.662	318.916	308.640	104.093	56.222	20.517	7.397	0.996	0.782	935.224
2000	WBSS	22	F	4.905	373.948	97.561	2.604	7.346	5.173	2.830	2.476	4.580	501.422
2000	WBSS	23	F	0.146	2.572	2.327	2.808	2.565	1.070	0.351	0.220	0.004	12.064
2000	WBSS	24	F	32.698	239.801	94.412	81.319	67.865	46.721	26.875	9.733	4.707	604.132
2000	WBSS	22-24	F	37.749	616.321	194.300	86.731	77.777	52.964	30.056	12.428	9.291	1117.618
2000	WBSS	TOTAL	A, C, D, F	155.411	935.237	511.100	200.575	144.221	79.141	39.920	14.030	10.851	2090.487
2001	WBSS	IV	A	0.000	0.454	11.344	10.224	6.123	7.151	2.664	1.556	0.410	39.927
2001	NSAS	IIIaN	C	2.972	156.966	65.606	8.350	0.936	0.118	0.439	0.018	0.009	235.415
2001	NSAS	IIIaN	D	421.156	111.584	2.858	0.371	0.007	0.004	0.013	0.010	0.013	536.016
2001	NSAS	IIIaN	C, D	424.127	268.551	68.465	8.722	0.942	0.122	0.452	0.028	0.022	771.432
2001	NSAS	IIIaS	C	13.111	180.244	65.306	6.078	0.287	0.081				265.108
2001	NSAS	IIIaS	D	370.515	108.076	6.230	0.138						484.958
2001	NSAS	IIIaS	C, D	383.626	288.320	71.535	6.216	0.287	0.081	0.000	0.000	0.000	750.066
2001	WBSS	IIIaN	C	0.318	9.072	57.666	55.353	16.414	10.511	5.657	1.590	0.824	157.407
2001	WBSS	IIIaN	D	45.124	8.873	2.209	2.153	0.580	0.374	1.157	0.932	1.126	62.528
2001	WBSS	IIIaN	C, D	45.442	17.945	59.876	57.506	16.994	10.885	6.815	2.523	1.950	219.935
2001	WBSS	IIIaS	C	2.606	13.407	127.165	42.243	8.810	1.548	0.322	0.082	0.057	196.240
2001	WBSS	IIIaS	D	73.635	4.822	9.717	1.103	0.131	0.086	0.039	0.006	0.004	89.543
2001	WBSS	IIIaS	C, D	76.241	18.229	136.882	43.346	8.941	1.634	0.361	0.088	0.061	285.783
2001	WBSS	IIIa	C, D	121.683	36.174	196.758	100.852	25.935	12.519	7.176	2.610	2.011	505.718
2001	WBSS	22	F	622.431	334.102	106.773	35.098	5.571	0.567				1104.542
2001	WBSS	23	F			3.429	3.875	0.690	0.297	0.193		0.030	8.514
2001	WBSS	24	F	12.200	164.077	173.043	108.628	69.635	46.942	28.550	13.928	4.158	621.162
2001	WBSS	22-24	F	634.631	498.179	283.245	147.601	75.897	47.807	28.743	13.928	4.188	1734.218
2001	WBSS	TOTAL	A, C, D, F	756.314	534.806	491.347	258.678	107.955	67.477	38.583	18.094	6.610	2279.863
2002	WBSS	IV	A	0.000	0.000	7.589	14.825	10.583	3.349	2.877	0.969	0.620	40.812
2002	NSAS	IIIaN	C	6.163	184.368	51.034	4.659	0.687	0.156	0.115	0.048	0.023	247.254
2002	NSAS	IIIaN	D	184.247	134.012	5.131	0.533	0.053	0.005	0.005		0.002	323.987
2002	NSAS	IIIaN	C, D	190.410	318.380	56.165	5.193	0.740	0.162	0.120	0.048	0.024	571.241
2002	NSAS	IIIaS	C	4.000	16.587	0.497	0.436						21.520
2002	NSAS	IIIaS	D	284.088	27.598	0.026							311.712
2002	NSAS	IIIaS	C, D	288.088	44.185	0.522	0.436	0.000	0.000	0.000	0.000	0.000	333.232
2002	WBSS	IIIaN	C	1.207	57.911	50.557	56.554	22.682	4.846	3.355	1.384	0.710	199.206
2002	WBSS	IIIaN	D	68.427	35.075	0.776	1.707	1.742	0.169	0.160		0.053	108.109
2002	WBSS	IIIaN	C, D	69.634	92.986	51.334	58.261	24.424	5.014	3.514	1.384	0.763	307.315
2002	WBSS	IIIaS	C		50.831	83.403	61.512	18.086	3.687	1.088	0.075	0.636	219.316
2002	WBSS	IIIaS	D		433.877	25.939							459.816
2002	WBSS	IIIaS	C, D	0.000	484.708	109.342	61.512	18.086	3.687	1.088	0.075	0.636	679.132
2002	WBSS	IIIa	C, D	69.634	577.694	160.675	119.773	42.510	8.701	4.602	1.459	1.399	986.447
2002	WBSS	22	F	75.241	39.868	8.449	10.938	8.712	4.634	5.465	1.382	0.533	155.222
2002	WBSS	23	F		1.727	5.773	4.871	1.910	0.401	0.256	0.105	0.043	15.086
2002	WBSS	24	F	5.396	39.841	99.353	170.905	108.570	40.076	25.332	9.927	5.734	505.134
2002	WBSS	22-24	F	80.637	81.436	113.576	186.714	119.192	45.110	31.053	11.414	6.310	675.442

continued **4/6**

Table 1 Catch in Numbers at age/WR (CANUM, in millions) by stock, area, and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+	TOTAL
2003	WBSS	IV	A	0.000	0.000	0.030	3.130	5.992	3.502	1.167	1.305	0.605	15.732
2003	NSAS	IIIaN	C	0.169	97.036	100.222	10.426	14.714	1.608	1.006	1.223	0.174	226.579
2003	NSAS	IIIaN	D	15.307	61.096	30.368	0.398	0.129	0.013	0.066	0.006	0.001	107.383
2003	NSAS	IIIaN	C, D	15.475	158.133	130.590	10.824	14.843	1.621	1.073	1.229	0.175	333.962
2003	NSAS	IIIaS	C	1.752	70.448	41.838	1.940	1.270	0.170	0.048	0.003	0.003	117.471
2003	NSAS	IIIaS	D	4.348	216.412	9.881	0.273	0.094	0.001	0.000	0.000	0.002	231.011
2003	NSAS	IIIaS	C, D	6.100	286.860	51.719	2.213	1.364	0.170	0.048	0.003	0.005	348.482
2003	WBSS	IIIaN	C	0.023	7.229	88.171	31.939	32.492	11.762	2.849	2.477	0.717	177.658
2003	WBSS	IIIaN	D	2.041	2.092	15.215	1.702	1.367	0.721	0.251	0.212	0.069	23.670
2003	WBSS	IIIaN	C, D	2.063	9.320	103.386	33.641	33.859	12.483	3.100	2.689	0.786	201.328
2003	WBSS	IIIaS	C	4.681	20.770	67.007	25.574	22.147	4.663	1.578	0.308	0.334	147.063
2003	WBSS	IIIaS	D	45.370	32.929	12.103	3.108	2.373	0.822	0.414	0.051	0.089	97.259
2003	WBSS	IIIaS	C, D	50.051	53.699	79.109	28.682	24.521	5.485	1.992	0.359	0.424	244.322
2003	WBSS	IIIa	C, D	52.114	63.019	182.495	62.323	58.380	17.968	5.093	3.049	1.210	445.651
2003	WBSS	22	F	0.111	17.218	14.818	17.431	13.545	5.981	1.034	1.034	0.024	71.196
2003	WBSS	23	F		2.681	2.657	1.865	4.480	2.163	0.179	0.028	0.100	14.153
2003	WBSS	24	F	1.264	43.958	64.855	76.502	107.034	74.034	21.645	12.036	6.882	408.210
2003	WBSS	22-24	F	1.374	63.857	82.330	95.798	125.060	82.178	22.858	13.098	7.006	493.559
2003	WBSS	TOTAL	A, C, D, F	53.489	126.876	264.855	161.251	189.432	103.648	29.117	17.452	8.820	954.941
2004	WBSS	IV	A	0.000	0.000	15.140	27.898	3.520	4.110	1.002	0.456	0.146	52.271
2004	NSAS	IIIaN	C	11.123	5.313	57.494	9.193	4.391	8.575	1.596	1.857	0.849	100.392
2004	NSAS	IIIaN	D	24.099	39.225	51.175	8.030	1.596	1.028	0.222	0.107	0.017	125.500
2004	NSAS	IIIaN	C, D	35.223	44.538	108.669	17.223	5.987	9.603	1.818	1.965	0.866	225.892
2004	NSAS	IIIaS	C	2.101	13.469	56.722	2.841	0.042	0.142	0.012	0.000		75.329
2004	NSAS	IIIaS	D	51.099	12.863	14.546	0.651	0.008	0.004				79.172
2004	NSAS	IIIaS	C, D	53.201	26.332	71.268	3.492	0.050	0.146	0.012	0.000	0.000	154.501
2004	WBSS	IIIaN	C	5.867	10.584	7.222	18.180	5.404	4.336	1.849	0.552	0.197	54.193
2004	WBSS	IIIaN	D	12.524	44.332	15.146	17.487	4.579	4.640	0.910	0.387	0.156	100.162
2004	WBSS	IIIaN	C, D	18.391	54.916	22.368	35.668	9.983	8.976	2.760	0.939	0.353	154.355
2004	WBSS	IIIaS	C	0.691	67.858	49.064	24.465	4.524	3.650	0.737	0.118	0.092	151.200
2004	WBSS	IIIaS	D	6.587	86.568	9.451	5.948	0.215	0.106	0.007			108.883
2004	WBSS	IIIaS	C, D	7.278	154.426	58.515	30.413	4.739	3.757	0.745	0.118	0.092	260.082
2004	WBSS	IIIa	C, D	25.670	209.342	80.883	66.080	14.722	12.733	3.504	1.057	0.446	414.437
2004	WBSS	22	F	207.583	171.265	13.840	1.385	0.503					394.575
2004	WBSS	23	F	0.144	10.005	5.611	2.045	0.570	1.099	0.187	0.074	0.006	19.741
2004	WBSS	24	F	10.158	67.142	82.338	67.359	73.899	73.301	44.264	13.290	10.416	442.166
2004	WBSS	22-24	F	217.885	248.412	101.789	70.788	74.972	74.400	44.450	13.363	10.422	856.482
2004	WBSS	TOTAL	A, C, D, F	243.554	457.754	197.812	164.766	93.214	91.242	48.957	14.876	11.013	1323.190
2005	WBSS	IV	A	0.000	0.000	6.569	17.434	12.680	2.573	3.787	1.084	0.714	44.841
2005	NSAS	IIIaN	C	2.616	132.321	91.881	8.585	4.177	2.038	1.865	0.232	0.147	243.862
2005	NSAS	IIIaN	D	34.402	87.607	40.397	3.606	0.604	0.234	0.327	0.198		167.375
2005	NSAS	IIIaN	C, D	37.017	219.928	132.278	12.190	4.780	2.272	2.192	0.430	0.147	411.237
2005	NSAS	IIIaS	C	8.732	42.243	23.971	3.848	0.558	0.104	0.082	0.045	0.013	79.596
2005	NSAS	IIIaS	D	50.688	45.285	2.924	0.132	0.017					99.047
2005	NSAS	IIIaS	C, D	59.421	87.528	26.895	3.980	0.575	0.104	0.082	0.045	0.013	178.643
2005	WBSS	IIIaN	C	4.744	31.455	82.297	27.059	20.170	3.811	4.631	1.031	0.495	175.694
2005	WBSS	IIIaN	D	86.019	10.636	15.223	3.965	3.613	0.149	0.377	0.238		120.221
2005	WBSS	IIIaN	C, D	90.763	42.092	97.520	31.023	23.783	3.960	5.008	1.270	0.495	295.915
2005	WBSS	IIIaS	C	0.574	30.866	93.219	26.515	10.364	2.802	2.705	1.110	0.197	168.352
2005	WBSS	IIIaS	D	3.983	24.651	6.027	0.379	0.105					35.145
2005	WBSS	IIIaS	C, D	4.557	55.517	99.245	26.894	10.469	2.802	2.705	1.110	0.197	203.497
2005	WBSS	IIIa	C, D	95.320	97.609	196.766	57.917	34.252	6.762	7.713	2.380	0.692	499.412
2005	WBSS	22	F	7.369	175.398	25.746	1.986						210.499
2005	WBSS	23	F	1.007	4.144	22.097	3.583	2.238	1.254	1.071	0.097	0.039	35.530
2005	WBSS	24	F	3.210	28.020	68.048	96.913	81.223	50.050	53.124	27.670	11.175	419.433
2005	WBSS	22-24	F	11.586	207.562	115.890	102.482	83.461	51.304	54.195	27.767	11.214	665.461
2005	WBSS	TOTAL	A, C, D, F	106.906	305.171	319.225	177.833	130.394	60.639	65.695	31.231	12.620	1209.714
2006	WBSS	IV	A	0.000	0.129	3.514	8.783	13.962	22.370	5.102	5.258	3.055	62.173
2006	NSAS	IIIaN	C	4.263	64.487	27.876	6.541	2.172	2.106	0.401	0.277	0.124	108.248
2006	NSAS	IIIaN	D	6.008	16.767	5.866	2.817	0.824	1.235	0.145	0.084	0.049	33.794
2006	NSAS	IIIaN	C, D	10.271	81.254	33.742	9.358	2.995	3.341	0.546	0.362	0.173	142.042
2006	NSAS	IIIaS	C	1.768	28.826	14.176	0.789	0.246	0.003	0.015	0.013	0.006	45.841
2006	NSAS	IIIaS	D	23.049	40.049	2.258	0.052	0.015		0.002	0.003	0.001	65.429
2006	NSAS	IIIaS	C, D	24.817	68.875	16.433	0.841	0.260	0.003	0.018	0.016	0.007	111.270
2006	WBSS	IIIaN	C	0.369	5.687	50.219	40.951	17.331	13.696	3.374	3.335	1.361	136.322
2006	WBSS	IIIaN	D	0.121	7.074	11.503	10.926	3.289	5.010	0.561	0.367	0.201	39.053
2006	WBSS	IIIaN	C, D	0.491	12.760	61.723	51.877	20.620	18.706	3.935	3.703	1.562	175.376
2006	WBSS	IIIaS	C	1.735	36.073	40.789	45.603	12.003	12.611	1.475	1.055	0.473	151.817
2006	WBSS	IIIaS	D	1.430	40.704	6.048	3.226	0.636	0.709	0.090	0.061	0.034	52.937
2006	WBSS	IIIaS	C, D	3.165	76.777	46.836	48.829	12.639	13.320	1.565	1.116	0.506	204.754
2006	WBSS	IIIa	C, D	3.656	89.537	108.559	100.706	33.260	32.026	5.500	4.818	2.068	380.130
2006	WBSS	22	F	0.012	11.074	13.686	13.872	9.073	4.216	2.596	1.628	0.848	57.005
2006	WBSS	23	F	0.172	6.242	7.167	8.006	5.805	1.845	0.828	0.609	0.295	30.969
2006	WBSS	24	F	0.466	27.446	51.217	97.117	86.853	36.944	27.940	19.873	11.014	358.870
2006	WBSS	22-24	F	0.650	44.762	72.070	118.995	101.731	43.005	31.364	22.110	12.157	446.844
2006	WBSS	TOTAL	A, C, D, F	4.305	134.427	184.143	228.485	148.952	97.401	41.966	32.186	17.280	889.147

continued **5/6**

Table 1 Catch in Numbers at age/WR (CANUM, in millions) by stock, area, and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+	TOTAL
2007	WBSS	IV	A	0.000	0.000	0.074	2.627	1.253	0.596	0.806	0.377	0.613	6.345
2007	NSAS	IIIaN	C	0.278	95.889	19.584	1.243	0.049	1.157	0.054	0.585	0.003	118.841
2007	NSAS	IIIaN	D	6.501	10.384	6.528	0.172	0.082	0.070	0.092	0.012	0.003	23.843
2007	NSAS	IIIaN	C, D	6.778	106.273	26.112	1.415	0.132	1.227	0.146	0.597	0.005	142.684
2007	NSAS	IIIaS	C	13.911	54.388	39.940	0.620	0.297	0.205	0.105	0.035	0.013	109.514
2007	NSAS	IIIaS	D	46.963	28.645	10.843	0.037	0.017	0.009	0.010	0.000		86.526
2007	NSAS	IIIaS	C, D	60.874	83.033	50.784	0.657	0.314	0.215	0.115	0.035	0.013	196.040
2007	WBSS	IIIaN	C	0.005	39.842	34.187	17.181	15.261	6.333	2.808	4.664	1.367	121.649
2007	WBSS	IIIaN	D	0.071	2.033	3.204	1.867	2.612	0.849	0.851	0.149	0.133	11.768
2007	WBSS	IIIaN	C, D	0.076	41.875	37.391	19.048	17.873	7.182	3.659	4.814	1.500	133.417
2007	WBSS	IIIaS	C	0.225	50.241	45.340	14.758	11.335	4.855	4.562	1.036	0.564	132.917
2007	WBSS	IIIaS	D	1.325	11.739	8.072	0.478	0.347	0.148	0.420	0.012		22.542
2007	WBSS	IIIaS	C, D	1.550	61.980	53.413	15.236	11.682	5.003	4.982	1.048	0.564	155.458
2007	WBSS	IIIa	C, D	1.626	103.855	90.804	34.284	29.555	12.185	8.641	5.862	2.064	288.875
2007	WBSS	22	F	2.457	22.969	10.724	6.947	3.792	1.351	1.313	0.527	0.385	50.465
2007	WBSS	23	F	6.413	27.490	6.048	3.925	3.086	2.013	0.956	0.772		50.702
2007	WBSS	24	F	0.225	17.730	77.084	96.122	89.175	48.851	18.483	13.719	11.697	373.088
2007	WBSS	22-24	F	9.095	68.189	93.857	106.993	96.054	52.215	20.752	15.017	12.082	474.255
2007	WBSS	TOTAL	A, C, D, F	10.721	172.044	184.735	143.904	126.861	64.996	30.199	21.256	14.759	769.475
2008	WBSS	IV	A	0.000	0.000	0.070	0.087	0.167	0.077	0.081	0.182	0.035	0.700
2008	NSAS	IIIaN	C	3.855	46.916	31.940	0.652	0.086	0.146	0.056	0.072	0.036	83.760
2008	NSAS	IIIaN	D	1.743	8.210	14.973	0.060	0.001	0.001	0.000	0.000	0.000	24.989
2008	NSAS	IIIaN	C, D	5.598	55.126	46.913	0.713	0.087	0.147	0.056	0.073	0.036	108.750
2008	NSAS	IIIaS	C	0.483	12.296	20.636	1.031	0.149					34.595
2008	NSAS	IIIaS	D	79.581	19.173	4.454	0.135	0.015					103.358
2008	NSAS	IIIaS	C, D	80.065	31.469	25.090	1.165	0.163	0.000	0.000	0.000	0.000	137.953
2008	WBSS	IIIaN	C	0.806	65.741	36.391	19.793	8.261	10.852	4.852	1.550	0.774	149.022
2008	WBSS	IIIaN	D	0.327	3.905	6.169	2.800	0.601	0.465	0.320	0.140	0.134	14.862
2008	WBSS	IIIaN	C, D	1.134	69.646	42.561	22.592	8.862	11.318	5.173	1.690	0.908	163.884
2008	WBSS	IIIaS	C	0.018	27.077	24.093	14.462	4.162	3.601	2.428	2.625	0.347	78.814
2008	WBSS	IIIaS	D	3.751	5.041	4.342	1.783	0.287	0.132	0.045	0.001	0.014	15.398
2008	WBSS	IIIaS	C, D	3.769	32.118	28.435	16.245	4.450	3.734	2.474	2.626	0.361	94.212
2008	WBSS	IIIa	C, D	4.903	101.764	70.996	38.837	13.312	15.051	7.647	4.317	1.269	258.096
2008	WBSS	22	F	2.427	29.223	3.274	4.856	1.069	0.679	1.904	1.394	3.553	48.380
2008	WBSS	23	F	0.174	2.068	6.720	10.359	10.383	7.692	3.188	1.197	2.195	43.977
2008	WBSS	24	F	2.105	42.377	58.444	82.916	64.203	62.366	32.479	10.669	12.726	368.286
2008	WBSS	22-24	F	4.707	73.668	68.438	98.131	75.655	70.738	37.572	13.260	18.475	460.643
2008	WBSS	TOTAL	A, C, D, F	9.610	175.432	139.504	137.056	89.134	85.866	45.299	17.758	19.779	719.439
2009	WBSS	IV	A	0.000	0.000	1.017	2.075	3.375	1.423	1.733	4.471	3.144	17.237
2009	NSAS	IIIaN	C	0.362	43.240	4.969	0.047	0.217				0.103	48.939
2009	NSAS	IIIaN	D	30.670	0.415	0.494	0.001	0.004				0.000	31.584
2009	NSAS	IIIaN	C, D	31.033	43.654	5.463	0.049	0.222	0.000	0.000	0.000	0.103	80.523
2009	NSAS	IIIaS	C	0.605	6.371	1.463	0.297						8.736
2009	NSAS	IIIaS	D	85.114	27.495	0.106	0.006						112.721
2009	NSAS	IIIaS	C, D	85.719	33.866	1.569	0.303	0.000	0.000	0.000	0.000	0.000	121.457
2009	WBSS	IIIaN	C	0.376	58.515	74.114	20.541	14.340	7.690	4.989	2.598	1.209	184.372
2009	WBSS	IIIaN	D	8.666	6.642	8.369	1.958	0.841	0.367	0.210	0.156	0.200	27.411
2009	WBSS	IIIaN	C, D	9.042	65.157	82.483	22.500	15.181	8.058	5.199	2.755	1.409	211.782
2009	WBSS	IIIaS	C	0.066	32.795	45.823	20.832	5.813	1.310	0.856	0.444	0.713	108.652
2009	WBSS	IIIaS	D	5.692	51.650	2.969	0.446	0.071	0.089	0.013	0.007	0.019	60.957
2009	WBSS	IIIaS	C, D	5.758	84.445	48.792	21.277	5.885	1.399	0.869	0.451	0.732	169.609
2009	WBSS	IIIa	C, D	14.800	149.602	131.275	43.777	21.066	9.457	6.068	3.206	2.141	381.392
2009	WBSS	22	F	5.311	16.491	21.154	4.764	1.221	0.832	0.281	0.253	0.245	50.551
2009	WBSS	23	F	0.049	1.999	19.896	9.794	3.032	0.734	0.610	0.152	0.157	36.424
2009	WBSS	24	F	0.574	12.991	69.665	40.921	41.242	35.645	31.057	12.825	6.842	251.762
2009	WBSS	22-24	F	5.934	31.481	110.715	55.478	45.495	37.211	31.948	13.230	7.244	338.738
2009	WBSS	TOTAL	A, C, D, F	20.734	181.083	243.007	101.330	69.937	48.091	39.750	20.907	12.529	737.367
2010	WBSS	IV	A	0.000	0.026	0.032	0.518	0.985	0.389	0.518	0.270	1.018	3.756
2010	NSAS	IIIaN	C	0.000	99.440	30.051	0.285	0.145	0.099	0.016	0.059	0.014	130.109
2010	NSAS	IIIaN	D	45.944	22.463	0.045	0.001						68.453
2010	NSAS	IIIaN	C, D	45.944	121.903	30.096	0.285	0.145	0.099	0.016	0.059	0.014	198.561
2010	NSAS	IIIaS	C	0.064	21.025	9.312							30.400
2010	NSAS	IIIaS	D	2.607	54.099	3.905							60.611
2010	NSAS	IIIaS	C, D	2.671	75.124	13.216	0.000	0.000	0.000	0.000	0.000	0.000	91.011
2010	WBSS	IIIaN	C		21.720	71.890	27.935	10.403	5.532	3.019	1.921	2.417	144.836
2010	WBSS	IIIaN	D	5.687	0.216	0.135	0.099						6.136
2010	WBSS	IIIaN	C, D	5.687	21.936	72.025	28.034	10.403	5.532	3.019	1.921	2.417	150.972
2010	WBSS	IIIaS	C	0.230	20.022	24.999	15.008	6.681	1.555	1.158	0.847	0.322	70.822
2010	WBSS	IIIaS	D	3.192	6.610	8.048	0.103	0.310	0.083				18.347
2010	WBSS	IIIaS	C, D	3.422	26.631	33.048	15.112	6.991	1.638	1.158	0.847	0.322	89.169
2010	WBSS	IIIa	C, D	9.109	48.567	105.072	43.145	17.394	7.170	4.177	2.768	2.739	240.141
2010	WBSS	22	F	0.692	11.784	7.033	5.236	2.181	1.399	1.370	0.467	1.112	31.273
2010	WBSS	23	F	0.487	2.323	3.124	3.342	1.887	1.306	0.584	0.235	0.233	13.519
2010	WBSS	24	F	2.107	12.383	21.157	30.728	24.388	19.716	11.941	7.256	6.160	135.836
2010	WBSS	22-24	F	3.285	26.490	31.314	39.307	28.455	22.420	13.894	7.958	7.505	180.628
2010	WBSS	TOTAL	A, C, D, F	12.394	75.083	136.419	82.970	46.833	29.979	18.589	10.996	11.262	424.525

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Table 1 Catch in Numbers at age/WR (CANUM, in millions) by stock, area, and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+	TOTAL
2011	WBSS	IV	A	0.000	0.000	0.063	0.442	0.400	0.235	0.069	0.109	0.298	1.617
2011	NSAS	IIIaN	C	1.687	13.603	55.257	1.148	0.078	0.171	0.117	0.094	0.019	72.175
2011	NSAS	IIIaN	D	167.278	5.037	0.222	0.007						172.544
2011	NSAS	IIIaN	C, D	168.966	18.640	55.480	1.155	0.078	0.171	0.117	0.094	0.019	244.720
2011	NSAS	IIIaS	C	0.575	5.810	4.458	1.910	0.200					12.953
2011	NSAS	IIIaS	D	34.255	10.982	1.525	0.150						46.912
2011	NSAS	IIIaS	C, D	34.829	16.792	5.983	2.060	0.200	0.000	0.000	0.000	0.000	59.865
2011	WBSS	IIIaN	C	0.061	21.891	15.011	11.384	6.279	3.083	1.190	0.734	0.561	60.194
2011	WBSS	IIIaN	D	4.482	0.235	0.030	0.053						4.799
2011	WBSS	IIIaN	C, D	4.543	22.126	15.040	11.437	6.279	3.083	1.190	0.734	0.561	64.994
2011	WBSS	IIIaS	C	0.028	19.967	13.478	8.539	6.711	2.673	1.723	0.180	0.262	53.562
2011	WBSS	IIIaS	D	1.598	40.965	1.287	0.537						44.387
2011	WBSS	IIIaS	C, D	1.626	60.932	14.765	9.076	6.711	2.673	1.723	0.180	0.262	97.949
2011	WBSS	IIIa	C, D	6.169	83.058	29.806	20.513	12.990	5.756	2.913	0.915	0.822	162.943
2011	WBSS	22	F	0.482	3.974	1.360	1.101	2.275	1.435	1.314	0.823	0.556	13.321
2011	WBSS	23	F	1.264	1.077	1.119	1.368	1.342	0.584	0.373	0.122	0.165	7.414
2011	WBSS	24	F	3.897	10.408	13.934	15.363	32.317	19.620	17.962	10.267	7.493	131.260
2011	WBSS	22-24	F	5.643	15.458	16.413	17.831	35.934	21.639	19.649	11.212	8.214	151.995
2011	WBSS	TOTAL	A, C, D, F	11.813	98.516	46.282	38.787	49.324	27.630	22.632	12.236	9.335	316.555

Table 2 Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011.

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Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
1991	WBSS	IV	A	0.0	0.0	119.0	173.0	196.0	220.0	225.0	277.0	260.0
1991	NSAS	IIIaN	C									
1991	NSAS	IIIaN	D									
1991	NSAS	IIIaN	C, D	24.3	42.4	88.8	99.0	140.8	154.2	157.1	160.1	176.9
1991	NSAS	IIIaS	C									
1991	NSAS	IIIaS	D									
1991	NSAS	IIIaS	C, D	27.1	35.8	43.2	71.5	83.8	103.5	123.7	132.3	173.3
1991	WBSS	IIIaN	C									
1991	WBSS	IIIaN	D									
1991	WBSS	IIIaN	C, D	0.0	59.2	108.6	121.2	143.8	160.4	167.1	175.9	201.8
1991	WBSS	IIIaS	C									
1991	WBSS	IIIaS	D									
1991	WBSS	IIIaS	C, D	33.0	47.2	49.7	71.7	85.1	96.7	109.1	122.7	137.9
1991	WBSS	IIIa	C, D	33.0	48.6	68.6	97.0	128.4	139.7	157.3	167.8	186.2
1991	WBSS	22	F									
1991	WBSS	23	F									
1991	WBSS	24	F									
1991	WBSS	22-24	F	11.5	31.5	60.4	83.2	105.2	126.6	145.6	160.0	163.7
1991	WBSS	TOTAL	A, C, D, F	29.6	34.8	66.8	94.9	123.4	139.0	155.6	170.9	182.6
1992	WBSS	IV	A	0.0	0.0	81.0	179.0	198.0	213.0	232.0	255.0	291.0
1992	NSAS	IIIaN	C									
1992	NSAS	IIIaN	D									
1992	NSAS	IIIaN	C, D	12.6	58.2	88.6	133.2	165.9	175.3	186.5	198.8	200.3
1992	NSAS	IIIaS	C									
1992	NSAS	IIIaS	D									
1992	NSAS	IIIaS	C, D	11.2	32.7	68.0	91.0	112.1	140.2	171.6	193.3	211.8
1992	WBSS	IIIaN	C									
1992	WBSS	IIIaN	D									
1992	WBSS	IIIaN	C, D	0.0	62.8	101.3	129.7	146.7	171.8	182.4	188.4	181.9
1992	WBSS	IIIaS	C									
1992	WBSS	IIIaS	D									
1992	WBSS	IIIaS	C, D	13.9	39.2	72.5	83.9	104.1	135.1	152.2	170.0	203.4
1992	WBSS	IIIa	C, D	13.9	44.1	87.0	108.9	131.4	160.7	174.7	184.5	187.9
1992	WBSS	22	F									
1992	WBSS	23	F									
1992	WBSS	24	F									
1992	WBSS	22-24	F	19.1	23.3	44.8	77.4	99.2	123.3	152.9	166.2	184.2
1992	WBSS	TOTAL	A, C, D, F	15.2	34.5	67.3	94.4	116.3	141.7	165.1	175.8	191.5
1993	WBSS	IV	A	0.0	0.0	102.0	146.0	199.0	220.0	236.0	261.0	290.0
1993	NSAS	IIIaN	C									
1993	NSAS	IIIaN	D									
1993	NSAS	IIIaN	C, D	12.7	32.8	88.7	141.4	132.2	235.7	237.8	178.3	199.8
1993	NSAS	IIIaS	C									
1993	NSAS	IIIaS	D									
1993	NSAS	IIIaS	C, D	11.3	18.5	39.6	140.1	135.0	186.3	259.4	302.6	304.2
1993	WBSS	IIIaN	C									
1993	WBSS	IIIaN	D									
1993	WBSS	IIIaN	C, D	0.0	29.6	100.0	131.9	149.9	167.9	190.9	194.3	212.4
1993	WBSS	IIIaS	C									
1993	WBSS	IIIaS	D									
1993	WBSS	IIIaS	C, D	15.1	24.4	52.9	106.0	120.4	147.9	182.2	196.5	220.9
1993	WBSS	IIIa	C, D	15.1	25.9	81.1	126.6	142.7	163.0	189.2	194.8	214.1
1993	WBSS	22	F									
1993	WBSS	23	F									
1993	WBSS	24	F									
1993	WBSS	22-24	F	16.2	24.5	44.5	73.6	94.1	122.4	149.4	168.5	178.7
1993	WBSS	TOTAL	A, C, D, F	15.3	25.5	68.0	102.0	114.3	136.1	168.0	182.3	198.9
1994	WBSS	IV	A	0.0	0.0	122.0	150.0	177.0	205.0	237.0	251.0	250.0
1994	NSAS	IIIaN	C									
1994	NSAS	IIIaN	D									
1994	NSAS	IIIaN	C, D	15.6	48.9	89.7	111.6	140.5	159.0	189.0	200.0	214.3
1994	NSAS	IIIaS	C									
1994	NSAS	IIIaS	D									
1994	NSAS	IIIaS	C, D	18.7	25.8	57.7	94.2	117.4	153.5	152.3	190.2	211.2
1994	WBSS	IIIaN	C									
1994	WBSS	IIIaN	D									
1994	WBSS	IIIaN	C, D	0.0	62.9	110.5	131.6	151.7	164.0	191.9	203.1	217.5
1994	WBSS	IIIaS	C									
1994	WBSS	IIIaS	D									
1994	WBSS	IIIaS	C, D	20.2	38.4	68.6	97.4	128.0	158.1	160.4	185.3	162.2
1994	WBSS	IIIa	C, D	20.2	42.6	93.9	118.8	146.5	162.7	184.5	197.2	195.6
1994	WBSS	22	F									
1994	WBSS	23	F									
1994	WBSS	24	F									
1994	WBSS	22-24	F	12.9	28.2	54.2	76.4	95.0	117.7	133.6	154.3	173.9
1994	WBSS	TOTAL	A, C, D, F	14.6	37.0	83.3	103.2	122.1	141.1	156.5	170.5	186.0

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Table 2 Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
1995	WBSS	IV	A	0.0	0.0	135.0	174.0	197.0	205.0	261.0	266.0	277.0
1995	NSAS	IIIaN	C									
1995	NSAS	IIIaN	D									
1995	NSAS	IIIaN	C, D	10.9	44.3	91.2	147.0	167.2	206.8	216.0	236.0	240.6
1995	NSAS	IIIaS	C									
1995	NSAS	IIIaS	D									
1995	NSAS	IIIaS	C, D	16.6	30.6	71.3	117.7	155.7	194.3	196.7	238.3	260.1
1995	WBSS	IIIaN	C									
1995	WBSS	IIIaN	D									
1995	WBSS	IIIaN	C, D	0.0	45.8	105.5	155.8	168.9	203.1	211.4	228.7	234.4
1995	WBSS	IIIaS	C									
1995	WBSS	IIIaS	D									
1995	WBSS	IIIaS	C, D	17.9	40.5	82.8	120.3	150.4	193.2	194.6	213.1	226.6
1995	WBSS	IIIa	C, D	17.9	41.5	97.1	145.9	162.3	199.3	205.2	224.2	231.0
1995	WBSS	22	F									
1995	WBSS	23	F									
1995	WBSS	24	F									
1995	WBSS	22-24	F	9.3	16.3	42.8	68.3	88.9	125.4	150.4	193.3	207.4
1995	WBSS	TOTAL	A, C, D, F	10.1	20.9	70.9	108.4	128.8	155.0	173.8	208.2	217.7
1996	WBSS	IV	A									
1996	NSAS	IIIaN	C									
1996	NSAS	IIIaN	D									
1996	NSAS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1996	NSAS	IIIaS	C									
1996	NSAS	IIIaS	D									
1996	NSAS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1996	WBSS	IIIaN	C									
1996	WBSS	IIIaN	D									
1996	WBSS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1996	WBSS	IIIaS	C									
1996	WBSS	IIIaS	D									
1996	WBSS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1996	WBSS	IIIa	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1996	WBSS	22	F									
1996	WBSS	23	F									
1996	WBSS	24	F									
1996	WBSS	22-24	F	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1996	WBSS	TOTAL	A, C, D, F	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!
1997	WBSS	IV	A									
1997	NSAS	IIIaN	C									
1997	NSAS	IIIaN	D									
1997	NSAS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1997	NSAS	IIIaS	C									
1997	NSAS	IIIaS	D									
1997	NSAS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1997	WBSS	IIIaN	C									
1997	WBSS	IIIaN	D									
1997	WBSS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1997	WBSS	IIIaS	C									
1997	WBSS	IIIaS	D									
1997	WBSS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1997	WBSS	IIIa	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1997	WBSS	22	F	17.2	20.0	50.5	104.1	142.2	167.2	188.0	202.0	197.0
1997	WBSS	23	F	42.0	72.4	74.9	102.8	125.8	156.2	184.4	193.7	215.0
1997	WBSS	24	F	42.0	62.2	63.9	100.7	119.2	153.3	180.9	197.3	210.4
1997	WBSS	22-24	F	30.4	24.7	58.4	101.0	120.7	155.2	181.6	197.7	209.4
1997	WBSS	TOTAL	A, C, D, F	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!
1998	WBSS	IV	A									
1998	NSAS	IIIaN	C									
1998	NSAS	IIIaN	D									
1998	NSAS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1998	NSAS	IIIaS	C									
1998	NSAS	IIIaS	D									
1998	NSAS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1998	WBSS	IIIaN	C									
1998	WBSS	IIIaN	D									
1998	WBSS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1998	WBSS	IIIaS	C									
1998	WBSS	IIIaS	D									
1998	WBSS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1998	WBSS	IIIa	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1998	WBSS	22	F									
1998	WBSS	23	F									
1998	WBSS	24	F									
1998	WBSS	22-24	F	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

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Table 2 Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
1998	WBSS	TOTAL	A, C, D, F	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!
1999	WBSS	IV	A									
1999	NSAS	IIIaN	C									
1999	NSAS	IIIaN	D									
1999	NSAS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1999	NSAS	IIIaS	C									
1999	NSAS	IIIaS	D									
1999	NSAS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1999	WBSS	IIIaN	C									
1999	WBSS	IIIaN	D									
1999	WBSS	IIIaN	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1999	WBSS	IIIaS	C									
1999	WBSS	IIIaS	D									
1999	WBSS	IIIaS	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1999	WBSS	IIIa	C, D	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1999	WBSS	22	F									
1999	WBSS	23	F									
1999	WBSS	24	F									
1999	WBSS	22-24	F	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1999	WBSS	TOTAL	A, C, D, F	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!	#WERT!
2000	WBSS	IV	A	0.0	0.0	140.8	165.2	183.9	207.0	202.4	217.5	266.3
2000	NSAS	IIIaN	C	21.6	50.1	85.0	115.1	164.0	190.9	183.7	211.9	220.3
2000	NSAS	IIIaN	D	19.7	20.0	55.7	127.8	158.0	168.2	188.5	169.9	
2000	NSAS	IIIaN	C, D	20.4	36.5	81.8	115.5	163.2	190.8	184.2	189.4	220.3
2000	NSAS	IIIaS	C	22.4	25.6	56.3	90.3	154.9	168.8	148.0		132.0
2000	NSAS	IIIaS	D	22.6	13.0	83.2	112.4	172.0		201.0		177.0
2000	NSAS	IIIaS	C, D	22.5	18.3	56.3	90.4	155.2	168.8	149.5		133.9
2000	WBSS	IIIaN	C	21.6	51.3	79.7	114.5	138.9	158.4	154.7	179.8	158.8
2000	WBSS	IIIaN	D	22.5	41.5	65.1	130.7	153.9	168.2	193.3	80.4	
2000	WBSS	IIIaN	C, D	21.9	49.5	78.3	115.6	139.0	158.5	155.2	177.9	158.8
2000	WBSS	IIIaS	C	22.9	38.4	60.7	92.0	139.6	170.5	101.0	94.0	132.0
2000	WBSS	IIIaS	D	24.8	14.4	84.1	112.2	166.4	136.5	201.0		149.9
2000	WBSS	IIIaS	C, D	24.7	29.7	60.8	92.0	139.8	170.4	101.4	94.0	133.7
2000	WBSS	IIIa	C, D	22.6	31.9	68.4	108.3	139.1	160.0	146.8	175.0	155.3
2000	WBSS	22	F	13.5	20.1	33.6	109.1	150.2	161.0	154.7	171.7	172.7
2000	WBSS	23	F	24.1	29.9	68.3	90.8	122.3	124.7	136.6	150.9	117.7
2000	WBSS	24	F	16.9	25.3	51.6	79.1	120.7	130.3	142.3	151.4	130.8
2000	WBSS	22-24	F	16.5	22.2	42.8	80.4	123.5	133.2	143.4	155.4	151.4
2000	WBSS	TOTAL	A, C, D, F	21.14	25.53	59.82	99.02	133.88	145.41	147.70	159.47	159.93
2001	WBSS	IV	A	0.0	79.0	127.5	151.4	178.4	188.4	198.2	220.8	266.5
2001	NSAS	IIIaN	C	30.0	90.7	86.3	115.4	132.0	171.8	225.7	171.6	202.3
2001	NSAS	IIIaN	D	7.6	31.4	69.0	109.6	133.4	148.9	155.0	165.9	184.1
2001	NSAS	IIIaN	C, D	7.8	66.1	85.6	115.1	132.0	171.1	223.7	169.5	191.8
2001	NSAS	IIIaS	C	23.7	44.3	62.0	92.7	113.6	74.8			
2001	NSAS	IIIaS	D	9.3	22.1	53.3	68.5					
2001	NSAS	IIIaS	C, D	9.7	36.0	61.2	92.2	113.6	74.8			
2001	WBSS	IIIaN	C	30.0	74.9	90.1	114.9	149.3	171.8	194.3	171.6	202.3
2001	WBSS	IIIaN	D	7.6	31.4	69.0	109.6	133.4	148.9	155.0	165.9	184.1
2001	WBSS	IIIaN	C, D	7.8	53.4	89.3	114.7	148.7	171.1	187.6	169.5	191.8
2001	WBSS	IIIaS	C	23.7	57.2	67.2	91.8	116.3	97.7	125.0	103.1	147.0
2001	WBSS	IIIaS	D	9.3	23.6	53.5	63.5	101.9	122.8	125.8	108.0	169.0
2001	WBSS	IIIaS	C, D	9.7	48.3	66.3	91.1	116.0	99.0	125.1	103.5	148.4
2001	WBSS	IIIa	C, D	9.0	50.8	73.3	104.6	137.5	161.7	184.5	167.2	190.4
2001	WBSS	22	F	12.8	20.2	44.8	56.4	90.2	120.0			
2001	WBSS	23	F			63.3	108.3	141.9	197.3	197.3		248.0
2001	WBSS	24	F	16.5	26.1	47.6	71.5	93.1	150.4	144.1	145.5	151.5
2001	WBSS	22-24	F	12.9	22.1	46.7	68.9	93.3	150.4	144.5	145.5	152.2
2001	WBSS	TOTAL	A, C, D, F	12.29	24.13	59.23	86.07	108.73	156.48	155.62	155.13	170.91
2002	WBSS	IV	A	0.0	0.0	143.1	154.2	165.2	186.4	197.6	207.5	223.5
2002	NSAS	IIIaN	C	14.5	55.0	101.3	120.7	142.7	160.6	178.7	177.4	221.4
2002	NSAS	IIIaN	D	11.6	14.5	95.9	136.3	142.7	170.0	179.7		179.0
2002	NSAS	IIIaN	C, D	11.7	38.0	100.8	122.3	142.7	160.9	178.7	177.4	218.6
2002	NSAS	IIIaS	C	15.5	47.4	81.8	112.2					
2002	NSAS	IIIaS	D	12.6	33.4	60.8						
2002	NSAS	IIIaS	C, D	12.6	38.6	80.8	112.2					
2002	WBSS	IIIaN	C	9.5	52.8	101.7	126.1	150.1	174.0	187.1	193.0	227.1
2002	WBSS	IIIaN	D	10.2	18.4	92.7	136.3	142.7	170.0	179.7		179.0
2002	WBSS	IIIaN	C, D	10.2	39.9	101.6	126.4	149.6	173.8	186.7	193.0	223.8
2002	WBSS	IIIaS	C		36.6	75.8	100.8	123.3	149.2	193.5	175.0	197.6
2002	WBSS	IIIaS	D		14.4	20.9						
2002	WBSS	IIIaS	C, D		16.7	62.8	100.8	123.3	149.2	193.5	175.0	197.6
2002	WBSS	IIIa	C, D	10.2	20.4	75.2	113.2	138.4	163.4	188.3	192.1	211.9
2002	WBSS	22	F	10.7	22.2	56.4	90.1	127.7	175.3	198.2	199.0	210.2
2002	WBSS	23	F		45.0	71.1	98.0	143.0	189.3	195.1	231.5	189.2
2002	WBSS	24	F	12.5	31.6	57.1	80.7	106.7	126.5	184.0	174.3	152.6
2002	WBSS	22-24	F	10.8	27.3	57.8	81.7	108.8	132.1	186.6	177.8	157.7
2002	WBSS	TOTAL	A, C, D, F	10.53	21.27	69.98	96.78	119.56	140.03	187.63	181.41	171.70

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Table 2 Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
2003	WBSS	IV	A	0.0	0.0	101.4	135.6	141.4	163.2	175.2	184.6	192.3
2003	NSAS	IIIaN	C	28.5	65.1	79.0	131.1	153.1	166.6	192.4	214.7	188.4
2003	NSAS	IIIaN	D	23.6	35.5	49.7	111.0	141.6	176.6	152.2	245.5	194.3
2003	NSAS	IIIaN	C, D	23.7	53.7	72.2	130.4	153.0	166.7	190.0	214.8	188.5
2003	NSAS	IIIaS	C	12.0	38.7	57.0	88.7	121.8	133.3	195.4	126.3	103.2
2003	NSAS	IIIaS	D	12.5	17.4	40.9	81.4	110.2	125.3	123.2	126.3	172.5
2003	NSAS	IIIaS	C, D	12.3	22.7	53.9	87.8	121.0	133.2	195.2	126.3	133.0
2003	WBSS	IIIaN	C	28.5	71.3	86.9	126.7	143.8	146.0	164.0	170.1	165.8
2003	WBSS	IIIaN	D	23.6	60.8	53.4	106.1	127.9	142.0	148.0	151.9	163.8
2003	WBSS	IIIaN	C, D	23.7	68.9	81.9	125.7	143.2	145.7	162.7	168.6	165.6
2003	WBSS	IIIaS	C	12.9	49.9	72.9	97.3	116.3	127.5	139.6	126.3	107.5
2003	WBSS	IIIaS	D	12.5	20.5	49.3	89.1	112.9	82.2	77.8	126.3	133.9
2003	WBSS	IIIaS	C, D	12.6	31.9	69.3	96.4	116.0	120.7	126.7	126.3	113.1
2003	WBSS	IIIa	C, D	13.0	37.4	76.5	112.2	131.8	138.1	148.6	163.6	147.2
2003	WBSS	22	F	23.0	27.9	43.3	85.1	93.0	107.2	119.8	117.7	107.0
2003	WBSS	23	F		13.9	83.7	121.8	169.1	200.4	199.0	126.3	174.5
2003	WBSS	24	F	22.4	25.6	45.5	72.0	92.4	115.5	125.6	160.6	162.6
2003	WBSS	22-24	F	22.4	25.8	46.4	75.3	95.2	117.2	125.9	157.1	162.6
2003	WBSS	TOTAL	A, C, D, F	13.25	31.52	67.11	90.75	107.92	122.34	131.88	160.29	162.52
2004	WBSS	IV	A	0.0	0.0	120.6	132.8	163.9	165.9	174.8	184.3	207.9
2004	NSAS	IIIaN	C	22.2	69.0	74.3	126.3	138.4	149.4	168.6	186.8	177.8
2004	NSAS	IIIaN	D	30.5	63.9	80.7	127.8	147.4	171.3	185.2	182.8	213.0
2004	NSAS	IIIaN	C, D	27.9	64.6	77.3	127.0	140.8	151.8	170.7	186.6	178.5
2004	NSAS	IIIaS	C	34.4	56.1	63.4	99.8	151.6	147.2	157.8	185.8	
2004	NSAS	IIIaS	D	18.4	22.5	44.4	41.4	149.5	157.0			
2004	NSAS	IIIaS	C, D	19.0	39.7	59.5	88.9	151.3	147.5	157.8	185.8	
2004	WBSS	IIIaN	C	22.2	63.4	91.4	128.7	145.7	165.3	169.8	189.8	186.4
2004	WBSS	IIIaN	D	30.6	62.2	93.5	124.9	144.7	155.0	174.6	180.0	185.5
2004	WBSS	IIIaN	C, D	27.9	62.5	92.8	126.8	145.2	159.9	171.4	185.7	186.0
2004	WBSS	IIIaS	C	36.4	55.9	71.0	101.9	131.3	141.9	162.5	174.0	158.2
2004	WBSS	IIIaS	D	23.7	21.1	50.9	47.6	147.4	149.5	182.0		
2004	WBSS	IIIaS	C, D	24.9	36.4	67.8	91.3	132.0	142.1	162.7	174.0	158.2
2004	WBSS	IIIa	C, D	27.1	43.2	74.7	110.5	141.0	154.7	169.5	184.4	180.3
2004	WBSS	22	F	3.4	9.4	32.5	60.3	65.0				
2004	WBSS	23	F	22.3	54.3	80.1	121.4	151.4	154.0	154.2	170.6	173.0
2004	WBSS	24	F	9.4	21.0	47.7	76.7	96.2	125.1	150.4	165.8	151.0
2004	WBSS	22-24	F	3.7	14.3	47.4	77.7	96.4	125.5	150.4	165.8	151.0
2004	WBSS	TOTAL	A, C, D, F	6.18	27.54	64.19	100.17	105.96	131.39	152.28	167.68	152.95
2005	WBSS	IV	A	0.0	0.0	107.1	153.9	167.6	179.3	188.7	186.4	208.4
2005	NSAS	IIIaN	C	30.6	68.7	74.0	111.3	157.6	176.9	190.4	229.2	215.1
2005	NSAS	IIIaN	D	19.3	34.9	68.4	106.2	159.8	156.6	160.4	177.6	
2005	NSAS	IIIaN	C, D	20.1	55.2	72.3	109.8	157.9	174.8	186.0	205.4	215.1
2005	NSAS	IIIaS	C	25.5	53.0	65.4	94.2	128.4	144.7	146.2	150.1	140.4
2005	NSAS	IIIaS	D	12.4	25.1	59.2	84.5	98.0				
2005	NSAS	IIIaS	C, D	14.3	38.6	64.8	93.9	127.5	144.7	146.2	150.1	140.4
2005	WBSS	IIIaN	C	22.8	77.9	100.6	124.9	147.7	162.8	183.7	198.2	210.5
2005	WBSS	IIIaN	D	13.6	52.8	80.1	111.4	141.2	149.0	153.1	172.7	
2005	WBSS	IIIaN	C, D	14.1	71.6	97.4	123.2	146.8	162.3	181.4	193.4	210.5
2005	WBSS	IIIaS	C	24.8	55.2	73.7	99.0	128.8	148.0	149.6	153.2	147.7
2005	WBSS	IIIaS	D	12.2	25.9	57.8	86.7	103.8				
2005	WBSS	IIIaS	C, D	13.8	42.2	72.7	98.8	128.5	148.0	149.6	153.2	147.7
2005	WBSS	IIIa	C, D	14.1	54.9	84.9	111.9	141.2	156.3	170.2	174.6	192.6
2005	WBSS	22	F	11.3	10.8	32.1	65.3					
2005	WBSS	23	F	24.1	42.0	53.7	72.6	119.0	97.4	138.2	147.1	139.6
2005	WBSS	24	F	15.6	31.4	52.6	73.5	88.5	116.0	143.7	159.9	170.3
2005	WBSS	22-24	F	13.6	14.2	48.3	73.3	89.3	115.5	143.6	159.9	170.2
2005	WBSS	TOTAL	A, C, D, F	14.01	27.19	72.08	93.78	110.57	122.80	149.33	161.92	173.55
2006	WBSS	IV	A	0.0	24.7	124.6	148.8	164.1	175.2	214.0	224.3	236.7
2006	NSAS	IIIaN	C	17.1	76.4	86.7	122.1	143.9	184.4	188.4	212.3	206.5
2006	NSAS	IIIaN	D	16.0	51.4	76.2	113.1	136.9	187.6	197.4	224.6	208.4
2006	NSAS	IIIaN	C, D	16.4	71.2	84.9	119.4	142.0	185.5	190.8	215.2	207.0
2006	NSAS	IIIaS	C	28.6	49.1	70.2	97.4	118.4	143.5	177.3	224.8	202.2
2006	NSAS	IIIaS	D	12.3	20.8	51.5	105.0	133.2		189.0	230.8	215.0
2006	NSAS	IIIaS	C, D	13.5	32.7	67.6	97.9	119.2	143.5	178.9	226.0	204.3
2006	WBSS	IIIaN	C	15.0	68.2	93.0	124.1	145.9	176.4	181.7	196.5	203.5
2006	WBSS	IIIaN	D	15.0	22.5	78.6	113.9	138.0	184.2	197.3	222.3	207.8
2006	WBSS	IIIaN	C, D	15.0	42.9	90.3	121.9	144.6	178.5	183.9	199.0	204.0
2006	WBSS	IIIaS	C	28.6	54.1	73.5	98.0	117.5	172.2	181.6	178.9	175.3
2006	WBSS	IIIaS	D	14.2	24.8	59.9	107.0	131.0	169.7	188.5	202.2	185.9
2006	WBSS	IIIaS	C, D	22.1	38.6	71.7	98.6	118.2	172.0	182.0	180.2	176.0
2006	WBSS	IIIa	C, D	21.1	39.2	82.3	110.6	134.6	175.8	183.4	194.7	197.2
2006	WBSS	22	F	22.0	15.1	49.4	87.3	119.6	146.5	161.5	165.7	196.7
2006	WBSS	23	F	21.2	48.0	70.0	86.5	96.2	103.8	112.7	142.5	174.8
2006	WBSS	24	F	21.2	38.4	56.8	83.3	100.7	123.9	143.2	177.7	167.8
2006	WBSS	22-24	F	21.2	34.0	56.7	84.0	102.2	125.3	143.9	175.8	170.0
2006	WBSS	TOTAL	A, C, D, F	21.16	37.44	73.06	98.20	115.21	153.37	157.60	186.58	185.01

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Table 2 Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011.

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
2007	WBSS	IV	A	0.0	0.0	156.6	148.2	156.5	185.0	185.8	199.3	224.9
2007	NSAS	IIIaN	C	34.4	81.9	97.2	120.4	126.5	153.5	181.1	175.3	221.9
2007	NSAS	IIIaN	D	21.9	65.3	61.0	84.4	130.3	142.2	191.0	166.0	215.9
2007	NSAS	IIIaN	C, D	22.4	80.3	88.1	116.0	128.9	152.9	187.4	175.1	219.0
2007	NSAS	IIIaS	C	48.5	51.3	63.6	91.3	122.0	144.3	178.0	166.7	127.9
2007	NSAS	IIIaS	D	20.9	18.7	57.3	90.2	131.0	164.9	190.4	139.0	
2007	NSAS	IIIaS	C, D	27.2	40.1	62.3	91.2	122.5	145.2	179.2	166.5	127.9
2007	WBSS	IIIaN	C	30.0	83.3	108.5	124.8	148.7	168.7	213.4	179.1	230.3
2007	WBSS	IIIaN	D	20.9	71.6	72.9	102.0	136.1	147.7	192.0	170.5	210.7
2007	WBSS	IIIaN	C, D	21.5	82.7	105.5	122.5	146.9	166.2	208.4	178.9	228.5
2007	WBSS	IIIaS	C	47.6	60.9	72.8	101.8	123.4	145.6	177.5	170.0	153.5
2007	WBSS	IIIaS	D	21.6	24.7	58.2	90.6	131.0	164.7	190.4	139.0	
2007	WBSS	IIIaS	C, D	25.4	54.1	70.6	101.5	123.6	146.2	178.6	169.7	153.5
2007	WBSS	IIIa	C, D	25.2	65.6	84.9	113.2	137.7	158.0	191.2	177.2	208.0
2007	WBSS	22	F	12.6	11.2	44.4	68.9	90.1	114.7	128.1	112.6	158.9
2007	WBSS	23	F	11.5	40.2	60.6	86.7	125.9	152.4	168.9	167.1	
2007	WBSS	24	F	16.0	30.0	58.8	74.9	106.3	120.2	140.2	164.4	186.4
2007	WBSS	22-24	F	11.9	27.8	57.3	74.9	106.3	121.3	140.8	162.7	185.5
2007	WBSS	TOTAL	A, C, D, F	13.89	50.62	70.92	85.38	114.09	128.79	156.40	167.35	190.30
2008	WBSS	IV	A	0.0	0.0	141.8	164.7	165.7	168.0	192.2	199.4	215.9
2008	NSAS	IIIaN	C	36.7	75.3	95.7	120.9	156.5	167.6	175.5	187.3	196.7
2008	NSAS	IIIaN	D	26.0	42.2	88.0	110.7	175.6	186.7	161.1	184.0	171.8
2008	NSAS	IIIaN	C, D	33.4	70.3	93.2	120.1	156.7	167.7	175.4	187.3	196.6
2008	NSAS	IIIaS	C	31.0	52.8	73.7	101.5	129.0				
2008	NSAS	IIIaS	D	14.9	24.0	73.5	109.6	130.6				
2008	NSAS	IIIaS	C, D	15.0	35.2	73.7	102.4	129.1				
2008	WBSS	IIIaN	C	36.5	78.5	104.0	124.4	152.5	178.2	180.0	188.0	197.6
2008	WBSS	IIIaN	D	25.9	67.8	88.7	110.3	143.5	181.1	192.1	203.9	192.8
2008	WBSS	IIIaN	C, D	33.4	77.9	101.8	122.6	151.9	178.3	180.8	189.3	196.9
2008	WBSS	IIIaS	C	22.4	62.9	75.1	102.0	121.4	150.2	182.7	207.0	194.9
2008	WBSS	IIIaS	D	14.9	30.0	73.9	109.9	131.3	138.7	162.0	237.7	158.3
2008	WBSS	IIIaS	C, D	14.9	57.7	74.9	102.9	122.1	149.8	182.3	207.0	193.5
2008	WBSS	IIIa	C, D	19.2	71.5	91.0	114.4	141.9	171.3	181.3	200.1	195.9
2008	WBSS	22	F	11.8	13.0	48.3	64.2	66.2	127.1	152.6	195.3	204.6
2008	WBSS	23	F	19.2	55.8	86.4	118.3	142.3	146.7	152.1	182.3	194.5
2008	WBSS	24	F	21.2	52.4	63.4	85.2	105.8	131.6	138.7	150.8	163.0
2008	WBSS	22-24	F	16.3	36.9	64.9	87.7	110.3	133.2	140.6	158.3	174.8
2008	WBSS	TOTAL	A, C, D, F	17.77	56.98	78.22	95.28	115.09	139.90	147.53	168.89	176.18
2009	WBSS	IV	A	0.0	0.0	138.1	170.1	211.1	211.0	248.1	248.4	284.5
2009	NSAS	IIIaN	C	23.0	90.9	123.4	141.2	206.7				268.5
2009	NSAS	IIIaN	D	11.7	64.3	95.7	148.4	186.4				263.0
2009	NSAS	IIIaN	C, D	11.8	90.6	120.9	141.4	206.4				268.5
2009	NSAS	IIIaS	C	14.8	55.3	29.7	71.3					
2009	NSAS	IIIaS	D	8.5	11.9	56.8	89.6					
2009	NSAS	IIIaS	C, D	8.5	20.0	31.6	71.7					
2009	WBSS	IIIaN	C	23.9	82.1	120.2	153.8	178.8	182.0	209.8	204.9	226.6
2009	WBSS	IIIaN	D	15.2	57.9	97.9	139.2	164.3	181.6	210.1	206.5	201.2
2009	WBSS	IIIaN	C, D	15.6	79.6	117.9	152.5	178.0	182.0	209.8	205.0	223.0
2009	WBSS	IIIaS	C	16.0	59.6	41.7	77.4	115.4	149.2	169.5	181.7	221.3
2009	WBSS	IIIaS	D	10.0	12.4	56.6	87.3	118.1	136.8	213.7	212.2	253.4
2009	WBSS	IIIaS	C, D	10.1	30.7	42.6	77.6	115.4	148.4	170.2	182.2	222.1
2009	WBSS	IIIa	C, D	13.4	52.0	89.9	116.1	160.5	177.0	204.1	201.8	222.7
2009	WBSS	22	F	10.1	12.7	41.8	67.4	105.0	112.0	161.5	175.2	214.0
2009	WBSS	23	F	23.5	57.7	79.3	113.6	165.4	178.9	195.6	208.1	216.3
2009	WBSS	24	F	13.2	43.5	41.1	87.6	121.2	145.3	159.7	170.6	179.9
2009	WBSS	22-24	F	10.5	28.3	48.1	90.5	123.7	145.2	160.4	171.2	181.8
2009	WBSS	TOTAL	A, C, D, F	12.61	47.90	71.05	103.19	139.03	153.42	170.88	192.37	214.60
2010	WBSS	IV	A	0.0	67.8	132.3	157.3	200.3	205.6	210.9	219.0	235.2
2010	NSAS	IIIaN	C	0.0	75.5	80.4	122.3	149.3	191.3	221.5	216.3	204.5
2010	NSAS	IIIaN	D	7.4	18.4	37.0	114.0					
2010	NSAS	IIIaN	C, D	7.4	65.0	80.3	122.3	149.3	191.3	221.5	216.3	204.5
2010	NSAS	IIIaS	C	27.9	57.3	80.8						
2010	NSAS	IIIaS	D	8.4	15.6	39.9						
2010	NSAS	IIIaS	C, D	8.9	27.3	68.7						
2010	WBSS	IIIaN	C	0.0	76.5	89.8	131.5	159.7	199.0	220.0	214.5	228.4
2010	WBSS	IIIaN	D	7.6	24.7	37.0	114.0					
2010	WBSS	IIIaN	C, D	7.6	76.0	89.7	131.4	159.7	199.0	220.0	214.5	228.4
2010	WBSS	IIIaS	C	27.9	55.1	82.7	121.7	158.4	177.0	187.2	205.2	205.8
2010	WBSS	IIIaS	D	7.8	16.3	40.0	75.0	41.0	111.0			
2010	WBSS	IIIaS	C, D	9.2	45.5	72.3	121.4	153.2	173.6	187.2	205.2	205.8
2010	WBSS	IIIa	C, D	8.2	59.3	84.2	127.9	157.1	193.2	210.9	211.7	225.7
2010	WBSS	22	F	10.9	14.6	40.1	75.6	115.2	140.4	160.8	188.6	186.6
2010	WBSS	23	F	11.5	41.0	61.5	84.9	100.4	121.5	135.8	178.9	162.7
2010	WBSS	24	F	12.8	25.9	54.8	89.2	121.7	158.0	173.4	192.5	196.6
2010	WBSS	22-24	F	12.2	22.2	52.2	87.1	119.8	154.8	170.6	191.9	194.1
2010	WBSS	TOTAL	A, C, D, F	9.28	46.19	76.88	108.73	135.35	164.64	180.78	197.51	205.51

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Table 2 Mean weight at age/WR in the catch (WECA, in grams) by stock, area and fleet for the years 1991-2011

Year	Stock	Area	Fleet	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
2011	WBSS	IV	A	0.0	0.0	149.7	167.0	182.8	207.8	213.0	210.6	218.8
2011	NSAS	IIIaN	C	22.7	56.0	85.9	125.5	164.6	191.5	193.2	234.3	248.3
2011	NSAS	IIIaN	D	6.2	14.8	45.2	71.1					
2011	NSAS	IIIaN	C, D	6.3	44.9	85.7	125.2	164.6	191.5	193.2	234.3	248.3
2011	NSAS	IIIaS	C	17.6	46.0	69.7	109.5	121.8				
2011	NSAS	IIIaS	D	12.9	12.8	45.0	71.1					
2011	NSAS	IIIaS	C, D	13.0	24.3	63.4						
2011	WBSS	IIIaN	C	22.8	55.0	99.3	130.4	157.1	186.6	196.7	220.8	216.8
2011	WBSS	IIIaN	D	6.2	27.0	45.1	71.1					
2011	WBSS	IIIaN	C, D	6.4	54.7	99.2	130.2	157.1	186.6	196.7	220.8	216.8
2011	WBSS	IIIaS	C	18.8	46.3	81.7	107.9	122.0	148.0	177.4	201.6	193.2
2011	WBSS	IIIaS	D	13.9	16.1	44.8	71.1					
2011	WBSS	IIIaS	C, D	14.0	26.0	78.4	105.8	122.0	148.0	177.4	201.6	193.2
2011	WBSS	IIIa	C, D	8.4	33.7	88.9	119.4	138.9	168.7	185.3	217.0	209.3
2011	WBSS	22	F	12.3	12.8	48.3	84.1	131.8	153.2	168.7	182.4	193.3
2011	WBSS	23	F	14.5	32.4	66.9	82.8	111.4	136.8	149.7	151.9	159.2
2011	WBSS	24	F	11.8	25.8	54.8	77.2	111.9	135.3	146.0	159.7	166.3
2011	WBSS	22-24	F	12.4	23.0	55.1	78.1	113.2	136.6	147.6	161.2	168.0
2011	WBSS	TOTAL	A, C, D, F	10.33	31.99	76.99	100.93	120.51	143.86	152.63	165.85	173.27

Table 3 Mean weight at age/WR in the stock (WEST, in grams) for the years 2001-2011, which equals quarter 1 overall estimates.

Year	Stock	Area	Fleet	Quarter	WR 0	WR 1	WR 2	WR 3	WR 4	WR 5	WR 6	WR 7	WR 8+
1991	WBSS	TOTAL	A, C, D, F	1									
1992	WBSS	TOTAL	A, C, D, F	1									
1993	WBSS	TOTAL	A, C, D, F	1									
1994	WBSS	TOTAL	A, C, D, F	1									
1995	WBSS	TOTAL	A, C, D, F	1									
1996	WBSS	TOTAL	A, C, D, F	1									
1997	WBSS	TOTAL	A, C, D, F	1									
1998	WBSS	TOTAL	A, C, D, F	1									
1999	WBSS	TOTAL	A, C, D, F	1									
2000	WBSS	TOTAL	A, C, D, F	1									
2001	WBSS	TOTAL	A, C, D, F	1		16.78	50.85	78.26	115.83	168.90	176.12	167.73	180.31 revised
2002	WBSS	TOTAL	A, C, D, F	1		16.45	63.68	90.46	123.88	173.65	198.30	198.01	203.63
2003	WBSS	TOTAL	A, C, D, F	1		14.44	44.47	79.26	105.09	126.81	150.61	172.87	184.71
2004	WBSS	TOTAL	A, C, D, F	1		13.06	45.61	81.06	109.25	143.99	162.85	193.21	207.59
2005	WBSS	TOTAL	A, C, D, F	1		12.60	51.36	80.00	106.57	132.21	157.33	167.66	182.05
2006	WBSS	TOTAL	A, C, D, F	1		18.46	62.10	95.27	117.40	165.93	171.02	185.84	187.08
2007	WBSS	TOTAL	A, C, D, F	1		14.97	55.44	79.91	113.88	142.65	170.78	174.94	188.36
2008	WBSS	TOTAL	A, C, D, F	1		28.57	71.36	91.33	112.88	148.05	163.21	185.01	187.73
2009	WBSS	TOTAL	A, C, D, F	1		23.37	51.89	90.10	130.49	156.47	174.08	184.71	199.12 revised?
2010	WBSS	TOTAL	A, C, D, F	1		14.04	62.65	97.35	128.33	161.76	181.31	202.29	204.47
2011	WBSS	TOTAL	A, C, D, F	1		9.46	57.78	95.44	126.08	155.50	173.03	184.56	192.39

Table 4 Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012. 1/7

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
1991	WBSS	IV	A	9,936.7	
1991	NSAS	IIIaN	C	0.0	
1991	NSAS	IIIaN	D	0.0	
1991	NSAS	IIIaN	C, D	55,922.9	
1991	NSAS	IIIaS	C	0.0	
1991	NSAS	IIIaS	D	0.0	
1991	NSAS	IIIaS	C, D	20,652.5	
1991	WBSS	IIIaN	C	0.0	
1991	WBSS	IIIaN	D	0.0	
1991	WBSS	IIIaN	C, D	68,840.3	
1991	WBSS	IIIaS	C	0.0	
1991	WBSS	IIIaS	D	0.0	
1991	WBSS	IIIaS	C, D	42,909.6	
1991	WBSS	IIIa	C, D	111,749.9	
1991	WBSS	22	F	0.0	
1991	WBSS	23	F	0.0	
1991	WBSS	24	F	0.0	
1991	WBSS	22-24	F	69,886.5	
1991	WBSS	TOTAL	A, C, D, F	191,573.1	191,573.0
1991	TOTAL	IIIa&22-24	C, D, F	258,211.7	257,800.0
1992	WBSS	IV	A	8,794.4	
1992	NSAS	IIIaN	C	0.0	
1992	NSAS	IIIaN	D	0.0	
1992	NSAS	IIIaN	C, D	104,641.7	
1992	NSAS	IIIaS	C	0.0	
1992	NSAS	IIIaS	D	0.0	
1992	NSAS	IIIaS	C, D	21,609.5	
1992	WBSS	IIIaN	C	0.0	
1992	WBSS	IIIaN	D	0.0	
1992	WBSS	IIIaN	C, D	62,670.1	
1992	WBSS	IIIaS	C	0.0	
1992	WBSS	IIIaS	D	0.0	
1992	WBSS	IIIaS	C, D	38,058.6	
1992	WBSS	IIIa	C, D	100,728.6	
1992	WBSS	22	F	0.0	
1992	WBSS	23	F	0.0	
1992	WBSS	24	F	0.0	
1992	WBSS	22-24	F	84,888.2	
1992	WBSS	TOTAL	A, C, D, F	194,411.3	194,411.0
1992	TOTAL	IIIa&22-24	C, D, F	311,868.1	311,400.0
1993	WBSS	IV	A	9,703.0	
1993	NSAS	IIIaN	C	0.0	
1993	NSAS	IIIaN	D	0.0	
1993	NSAS	IIIaN	C, D	100,043.3	
1993	NSAS	IIIaS	C	0.0	
1993	NSAS	IIIaS	D	0.0	
1993	NSAS	IIIaS	C, D	18,691.2	
1993	WBSS	IIIaN	C	0.0	
1993	WBSS	IIIaN	D	0.0	
1993	WBSS	IIIaN	C, D	68,134.8	
1993	WBSS	IIIaS	C	0.0	
1993	WBSS	IIIaS	D	0.0	
1993	WBSS	IIIaS	C, D	26,660.2	
1993	WBSS	IIIa	C, D	94,795.0	
1993	WBSS	22	F	0.0	
1993	WBSS	23	F	0.0	
1993	WBSS	24	F	0.0	
1993	WBSS	22-24	F	80,511.9	
1993	WBSS	TOTAL	A, C, D, F	185,009.9	185,010.0
1993	TOTAL	IIIa&22-24	C, D, F	294,041.4	294,900.0

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Table 4 **Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012.**

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
1994	WBSS	IV	A	14,310.3	
1994	NSAS	IIIaN	C	0.0	
1994	NSAS	IIIaN	D	0.0	
1994	NSAS	IIIaN	C, D	64,685.4	
1994	NSAS	IIIaS	C	0.0	
1994	NSAS	IIIaS	D	0.0	
1994	NSAS	IIIaS	C, D	11,126.1	
1994	WBSS	IIIaN	C	0.0	
1994	WBSS	IIIaN	D	0.0	
1994	WBSS	IIIaN	C, D	63,954.3	
1994	WBSS	IIIaS	C	0.0	
1994	WBSS	IIIaS	D	0.0	
1994	WBSS	IIIaS	C, D	27,748.8	
1994	WBSS	IIIa	C, D	91,703.1	
1994	WBSS	22	F	0.0	
1994	WBSS	23	F	0.0	
1994	WBSS	24	F	0.0	
1994	WBSS	22-24	F	66,424.8	
1994	WBSS	TOTAL	A, C, D, F	172,438.2	172,438.0
1994	TOTAL	IIIa&22-24	C, D, F	233,939.3	234,400.0
1995	WBSS	IV	A	10,149.5	
1995	NSAS	IIIaN	C	0.0	
1995	NSAS	IIIaN	D	0.0	
1995	NSAS	IIIaN	C, D	60,077.5	
1995	NSAS	IIIaS	C	0.0	
1995	NSAS	IIIaS	D	0.0	
1995	NSAS	IIIaS	C, D	16,602.7	
1995	WBSS	IIIaN	C	0.0	
1995	WBSS	IIIaN	D	0.0	IIIaN:
1995	WBSS	IIIaN	C, D	48,850.8	108,900.0
1995	WBSS	IIIaS	C	0.0	
1995	WBSS	IIIaS	D	0.0	IIIaS:
1995	WBSS	IIIaS	C, D	31,126.9	47,700.0
1995	WBSS	IIIa	C, D	79,977.7	
1995	WBSS	22	F	0.0	
1995	WBSS	23	F	0.0	
1995	WBSS	24	F	0.0	
1995	WBSS	22-24	F	74,156.8	74,400.0
1995	WBSS	TOTAL	A, C, D, F	164,284.0	150,831.0
1995	TOTAL	IIIa&22-24	C, D, F	230,814.7	231,000.0
1996	WBSS	IV	A	0.000	
1996	NSAS	IIIaN	C	0.000	
1996	NSAS	IIIaN	D	0.000	
1996	NSAS	IIIaN	C, D	0.000	
1996	NSAS	IIIaS	C	0.000	
1996	NSAS	IIIaS	D	0.000	
1996	NSAS	IIIaS	C, D	0.000	
1996	WBSS	IIIaN	C	0.000	
1996	WBSS	IIIaN	D	0.000	
1996	WBSS	IIIaN	C, D	0.000	
1996	WBSS	IIIaS	C	0.000	
1996	WBSS	IIIaS	D	0.000	
1996	WBSS	IIIaS	C, D	0.000	
1996	WBSS	IIIa	C, D	0.000	
1996	WBSS	22	F	0.000	
1996	WBSS	23	F	0.000	
1996	WBSS	24	F	0.000	
1996	WBSS	22-24	F	0.000	
1996	WBSS	TOTAL	A, C, D, F	0.000	121,266.0
1996	TOTAL	IIIa&22-24	C, D, F	0.000	172,700.0

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Table 4 Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012.

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
1997	WBSS	IV	A	0.0	
1997	NSAS	IIIaN	C	0.0	
1997	NSAS	IIIaN	D	0.0	
1997	NSAS	IIIaN	C, D	0.0	
1997	NSAS	IIIaS	C	0.0	
1997	NSAS	IIIaS	D	0.0	
1997	NSAS	IIIaS	C, D	0.0	
1997	WBSS	IIIaN	C	0.0	
1997	WBSS	IIIaN	D	0.0	
1997	WBSS	IIIaN	C, D	0.0	
1997	WBSS	IIIaS	C	0.0	
1997	WBSS	IIIaS	D	0.0	
1997	WBSS	IIIaS	C, D	0.0	
1997	WBSS	IIIa	C, D	0.0	
1997	WBSS	22	F	19,308.9	
1997	WBSS	23	F	2,330.6	
1997	WBSS	24	F	45,530.8	
1997	WBSS	22-24	F	67,170.3	67,000.0
1997	WBSS	TOTAL	A, C, D, F	67,170.3	115,588.0
1997	TOTAL	IIIa&22-24	C, D, F	67,170.3	149,800.0
1998	WBSS	IV	A	0.000	
1998	NSAS	IIIaN	C	0.000	
1998	NSAS	IIIaN	D	0.000	
1998	NSAS	IIIaN	C, D	0.000	
1998	NSAS	IIIaS	C	0.000	
1998	NSAS	IIIaS	D	0.000	
1998	NSAS	IIIaS	C, D	0.000	
1998	WBSS	IIIaN	C	0.000	
1998	WBSS	IIIaN	D	0.000	
1998	WBSS	IIIaN	C, D	0.000	
1998	WBSS	IIIaS	C	0.000	
1998	WBSS	IIIaS	D	0.000	
1998	WBSS	IIIaS	C, D	0.000	
1998	WBSS	IIIa	C, D	0.000	
1998	WBSS	22	F	0.000	
1998	WBSS	23	F	0.000	
1998	WBSS	24	F	0.000	
1998	WBSS	22-24	F	0.000	
1998	WBSS	TOTAL	A, C, D, F	0.000	107,032.0
1998	TOTAL	IIIa&22-24	C, D, F	0.000	169,400.0
1999	WBSS	IV	A	0.0	
1999	NSAS	IIIaN	C	0.0	
1999	NSAS	IIIaN	D	0.0	
1999	NSAS	IIIaN	C, D	0.0	
1999	NSAS	IIIaS	C	0.0	
1999	NSAS	IIIaS	D	0.0	
1999	NSAS	IIIaS	C, D	0.0	
1999	WBSS	IIIaN	C	0.0	
1999	WBSS	IIIaN	D	0.0	
1999	WBSS	IIIaN	C, D	0.0	
1999	WBSS	IIIaS	C	0.0	
1999	WBSS	IIIaS	D	0.0	
1999	WBSS	IIIaS	C, D	0.0	
1999	WBSS	IIIa	C, D	0.0	
1999	WBSS	22	F	0.0	
1999	WBSS	23	F	0.0	
1999	WBSS	24	F	0.0	
1999	WBSS	22-24	F	0.0	
1999	WBSS	TOTAL	A, C, D, F	0.0	97,240.0
1999	TOTAL	IIIa&22-24	C, D, F	0.0	137,200.0

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Table 4 Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012.

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
2000	WBSS	IV	A	6,649.3	
2000	NSAS	IIIaN	C	30,042.0	
2000	NSAS	IIIaN	D	7,874.1	
2000	NSAS	IIIaN	C, D	37,916.1	
2000	NSAS	IIIaS	C	6,956.0	
2000	NSAS	IIIaS	D	5,216.9	
2000	NSAS	IIIaS	C, D	12,172.9	
2000	WBSS	IIIaN	C	31,109.4	
2000	WBSS	IIIaN	D	2,589.8	
2000	WBSS	IIIaN	C, D	33,699.2	
2000	WBSS	IIIaS	C	21,774.0	
2000	WBSS	IIIaS	D	2,251.4	
2000	WBSS	IIIaS	C, D	24,025.4	
2000	WBSS	IIIa	C, D	57,724.6	71,633.4
2000	WBSS	22	F	14,755.8	12.5%
2000	WBSS	23	F	1,023.0	
2000	WBSS	24	F	38,124.9	
2000	WBSS	22-24	F	53,903.7	
2000	WBSS	TOTAL	A, C, D, F	118,277.7	142,270.0
2000	TOTAL	IIIa&22-24	C, D, F	161,717.3	162,000.0
2001	WBSS	IV	A	6,449.6	
2001	NSAS	IIIaN	C	21,201.0	
2001	NSAS	IIIaN	D	6,953.2	
2001	NSAS	IIIaN	C, D	28,154.1	
2001	NSAS	IIIaS	C	12,940.5	
2001	NSAS	IIIaS	D	6,159.1	
2001	NSAS	IIIaS	C, D	19,099.6	
2001	WBSS	IIIaN	C	18,037.2	
2001	WBSS	IIIaN	D	1,684.6	
2001	WBSS	IIIaN	C, D	19,721.8	
2001	WBSS	IIIaS	C	14,492.4	
2001	WBSS	IIIaS	D	1,415.6	
2001	WBSS	IIIaS	C, D	15,908.0	
2001	WBSS	IIIa	C, D	35,629.7	
2001	WBSS	22	F	22,079.0	20.9%
2001	WBSS	23	F	838.9	
2001	WBSS	24	F	40,808.2	
2001	WBSS	22-24	F	63,726.1	revis. in 2011
2001	WBSS	TOTAL	A, C, D, F	105,805.4	105,803.0
2001	TOTAL	IIIa&22-24	C, D, F	146,609.6	145,600.0
2002	WBSS	IV	A	6,651.6	
2002	NSAS	IIIaN	C	16,121.6	
2002	NSAS	IIIaN	D	4,650.9	
2002	NSAS	IIIaN	C, D	20,772.6	
2002	NSAS	IIIaS	C	937.7	
2002	NSAS	IIIaS	D	4,494.8	
2002	NSAS	IIIaS	C, D	5,432.5	
2002	WBSS	IIIaN	C	20,649.1	
2002	WBSS	IIIaN	D	1,963.0	
2002	WBSS	IIIaN	C, D	22,612.0	
2002	WBSS	IIIaS	C	17,512.1	
2002	WBSS	IIIaS	D	6,768.2	
2002	WBSS	IIIaS	C, D	24,280.3	
2002	WBSS	IIIa	C, D	46,892.3	
2002	WBSS	22	F	6,547.6	6.2%
2002	WBSS	23	F	1,396.8	
2002	WBSS	24	F	44,702.3	
2002	WBSS	22-24	F	52,646.7	
2002	WBSS	TOTAL	A, C, D, F	106,190.6	106,191.0
2002	TOTAL	IIIa&22-24	C, D, F	125,744.1	125,600.0

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Table 4 Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012.

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
2003	WBSS	IV	A	2,407.9	
2003	NSAS	IIIaN	C	18,622.0	
2003	NSAS	IIIaN	D	4,117.0	
2003	NSAS	IIIaN	C, D	22,739.0	
2003	NSAS	IIIaS	C	5,494.5	
2003	NSAS	IIIaS	D	4,264.4	
2003	NSAS	IIIaS	C, D	9,758.9	
2003	WBSS	IIIaN	C	19,620.3	
2003	WBSS	IIIaN	D	1,525.9	
2003	WBSS	IIIaN	C, D	21,146.2	
2003	WBSS	IIIaS	C	11,936.2	
2003	WBSS	IIIaS	D	2,504.3	
2003	WBSS	IIIaS	C, D	14,440.5	
2003	WBSS	IIIa	C, D	35,586.7	
2003	WBSS	22	F	4,757.3	6.1%
2003	WBSS	23	F	1,734.4	
2003	WBSS	24	F	33,823.2	
2003	WBSS	22-24	F	40,315.0	
2003	WBSS	TOTAL	A, C, D, F	78,309.6	78,309.0
2003	TOTAL	IIIa&22-24	C, D, F	108,399.6	108,500.0
2004	WBSS	IV	A	7,078.9	
2004	NSAS	IIIaN	C	8,702.2	
2004	NSAS	IIIaN	D	8,873.6	
2004	NSAS	IIIaN	C, D	17,575.7	
2004	NSAS	IIIaS	C	4,735.7	
2004	NSAS	IIIaS	D	1,902.1	
2004	NSAS	IIIaS	C, D	6,637.8	
2004	WBSS	IIIaN	C	5,760.6	
2004	WBSS	IIIaN	D	8,381.4	
2004	WBSS	IIIaN	C, D	14,142.0	
2004	WBSS	IIIaS	C	11,064.2	
2004	WBSS	IIIaS	D	2,793.2	
2004	WBSS	IIIaS	C, D	13,857.4	
2004	WBSS	IIIa	C, D	27,999.3	
2004	WBSS	22	F	2,881.4	3.8%
2004	WBSS	23	F	1,542.7	
2004	WBSS	24	F	37,312.4	
2004	WBSS	22-24	F	41,736.5	
2004	WBSS	TOTAL	A, C, D, F	76,814.7	76,815.0
2004	TOTAL	IIIa&22-24	C, D, F	93,949.4	93,900.0
2005	WBSS	IV	A	7,038.3	
2005	NSAS	IIIaN	C	18,383.0	
2005	NSAS	IIIaN	D	7,089.6	
2005	NSAS	IIIaN	C, D	25,472.6	
2005	NSAS	IIIaS	C	4,501.4	
2005	NSAS	IIIaS	D	1,952.5	
2005	NSAS	IIIaS	C, D	6,453.9	
2005	WBSS	IIIaN	C	18,977.1	
2005	WBSS	IIIaN	D	4,023.4	
2005	WBSS	IIIaN	C, D	23,000.6	
2005	WBSS	IIIaS	C	13,562.3	
2005	WBSS	IIIaS	D	1,079.7	
2005	WBSS	IIIaS	C, D	14,642.0	
2005	WBSS	IIIa	C, D	37,642.6	
2005	WBSS	22	F	2,929.7	3.3%
2005	WBSS	23	F	2,202.2	
2005	WBSS	24	F	38,592.9	
2005	WBSS	22-24	F	43,724.8	
2005	WBSS	TOTAL	A, C, D, F	88,405.6	88,406.0
2005	TOTAL	IIIa&22-24	C, D, F	113,293.9	113,300.0

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Table 4 **Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012.**

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
2006	WBSS	IV	A	10,953.3	
2006	NSAS	IIIaN	C	9,073.3	
2006	NSAS	IIIaN	D	2,125.1	
2006	NSAS	IIIaN	C, D	11,198.4	
2006	NSAS	IIIaS	C	2,574.9	
2006	NSAS	IIIaS	D	1,242.0	
2006	NSAS	IIIaS	C, D	3,816.9	
2006	WBSS	IIIaN	C	16,630.9	
2006	WBSS	IIIaN	D	3,919.8	
2006	WBSS	IIIaN	C, D	20,550.7	
2006	WBSS	IIIaS	C	13,588.9	
2006	WBSS	IIIaS	D	1,976.9	
2006	WBSS	IIIaS	C, D	15,565.7	
2006	WBSS	IIIa	C, D	36,116.5	
2006	WBSS	22	F	4,612.2	5.2%
2006	WBSS	23	F	2,479.4	
2006	WBSS	24	F	34,769.5	
2006	WBSS	22-24	F	41,861.2	
2006	WBSS	TOTAL	A, C, D, F	88,930.9	90,549.0
2006	TOTAL	IIIa&22-24	C, D, F	92,992.9	93,000.0
2007	WBSS	IV	A	1,069.8	ok
2007	NSAS	IIIaN	C	10,211.1	
2007	NSAS	IIIaN	D	1,273.5	
2007	NSAS	IIIaN	C, D	11,484.6	
2007	NSAS	IIIaS	C	6,156.9	
2007	NSAS	IIIaS	D	2,146.9	
2007	NSAS	IIIaS	C, D	8,303.8	
2007	WBSS	IIIaN	C	14,258.2	
2007	WBSS	IIIaN	D	1,268.6	IIIaN:
2007	WBSS	IIIaN	C, D	15,526.8	27,011.4
2007	WBSS	IIIaS	C	11,052.3	
2007	WBSS	IIIaS	D	983.5	IIIaS:
2007	WBSS	IIIaS	C, D	12,035.8	20,339.7
2007	WBSS	IIIa	C, D	27,562.6	47,351.0
2007	WBSS	22	F	2,028.0	2.97%
2007	WBSS	23	F	2,870.1	22-24:
2007	WBSS	24	F	34,649.7	36,677.7
2007	WBSS	22-24	F	39,547.8	
2007	WBSS	TOTAL	A, C, D, F	68,180.2	68,997.0
2007	TOTAL	IIIa&22-24	C, D, F	86,898.8	87,700.0
2008	WBSS	IV	A	124.4	
2008	NSAS	IIIaN	C	6,876.5	
2008	NSAS	IIIaN	D	1,715.9	
2008	NSAS	IIIaN	C, D	8,592.4	
2008	NSAS	IIIaS	C	2,309.1	
2008	NSAS	IIIaS	D	1,987.7	
2008	NSAS	IIIaS	C, D	4,296.8	
2008	WBSS	IIIaN	C	15,950.2	
2008	WBSS	IIIaN	D	1,415.7	
2008	WBSS	IIIaN	C, D	17,366.0	
2008	WBSS	IIIaS	C	7,088.0	
2008	WBSS	IIIaS	D	789.5	
2008	WBSS	IIIaS	C, D	7,877.4	
2008	WBSS	IIIa	C, D	25,243.4	
2008	WBSS	22	F	2,326.1	3.3%
2008	WBSS	23	F	5,660.0	
2008	WBSS	24	F	36,222.1	38,548.3
2008	WBSS	22-24	F	44,208.3	
2008	WBSS	TOTAL	A, C, D, F	69,576.1	68,484.0
2008	TOTAL	IIIa&22-24	C, D, F	82,340.9	82,300.0

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Table 4 Total Landings (CATON, 1000 t) calculated as sum of products of CANUM and WECA (SOP) by stock, area and fleet for the years 1991-2011 compared to the final overall values used during HAWG 2012.

Year	Stock	Area	Fleet	SOP (1000 t)	HAWG 2012
2009	WBSS	IV	A	3,940.8	
2009	NSAS	IIIaN	C	4,630.5	
2009	NSAS	IIIaN	D	432.5	
2009	NSAS	IIIaN	C, D	5,063.0	
2009	NSAS	IIIaS	C	426.0	
2009	NSAS	IIIaS	D	1,053.1	
2009	NSAS	IIIaS	C, D	1,479.1	
2009	WBSS	IIIaN	C	22,698.2	
2009	WBSS	IIIaN	D	1,929.9	
2009	WBSS	IIIaN	C, D	24,628.1	
2009	WBSS	IIIaS	C	6,728.2	
2009	WBSS	IIIaS	D	932.7	
2009	WBSS	IIIaS	C, D	7,660.9	
2009	WBSS	IIIa	C, D	32,289.0	
2009	WBSS	22	F	1,832.1	2.7%
2009	WBSS	23	F	3,623.4	
2009	WBSS	24	F	25,576.7	
2009	WBSS	22-24	F	31,032.2	
2009	WBSS	TOTAL	A, C, D, F	67,261.9	67,262.0
2009	TOTAL	IIIa&22-24	C, D, F	69,863.2	69,900.0
2010	WBSS	IV	A	772.5	
2010	NSAS	IIIaN	C	10,018.6	
2010	NSAS	IIIaN	D	756.5	
2010	NSAS	IIIaN	C, D	10,775.1	
2010	NSAS	IIIaS	C	1,959.4	
2010	NSAS	IIIaS	D	1,024.1	
2010	NSAS	IIIaS	C, D	2,983.5	
2010	WBSS	IIIaN	C	16,182.5	
2010	WBSS	IIIaN	D	65.1	
2010	WBSS	IIIaN	C, D	16,247.5	
2010	WBSS	IIIaS	C	6,792.6	
2010	WBSS	IIIaS	D	483.9	
2010	WBSS	IIIaS	C, D	7,276.5	
2010	WBSS	IIIa	C, D	23,524.0	
2010	WBSS	22	F	1,821.0	4.3%
2010	WBSS	23	F	1,083.9	
2010	WBSS	24	F	15,012.2	
2010	WBSS	22-24	F	17,917.1	
2010	WBSS	TOTAL	A, C, D, F	42,213.6	42,214.0
2010	TOTAL	IIIa&22-24	C, D, F	55,199.7	55,200.0
2011	WBSS	IV	A	308.3	
2011	NSAS	IIIaN	C	5,785.8	
2011	NSAS	IIIaN	D	1,119.0	
2011	NSAS	IIIaN	C, D	6,904.8	
2011	NSAS	IIIaS	C	821.9	
2011	NSAS	IIIaS	D	661.5	
2011	NSAS	IIIaS	C, D	1,483.4	
2011	WBSS	IIIaN	C	6,260.8	
2011	WBSS	IIIaN	D	39.1	
2011	WBSS	IIIaN	C, D	6,300.0	
2011	WBSS	IIIaS	C	4,554.7	
2011	WBSS	IIIaS	D	778.5	
2011	WBSS	IIIaS	C, D	5,333.2	
2011	WBSS	IIIa	C, D	11,633.2	
2011	WBSS	22	F	1,214.4	4.4%
2011	WBSS	23	F	571.4	
2011	WBSS	24	F	14,044.6	
2011	WBSS	22-24	F	15,830.3	
2011	WBSS	TOTAL	A, C, D, F	27,771.8	27,771.8
2011	TOTAL	IIIa&22-24	C, D, F	35,851.8	35,851.8

WD 6 Maturity of herring (*Clupea harengus*) sampled during the German Acoustic Survey (GERAS)

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Abstract

Annual acoustic investigations were carried out in SD 21 – 24 during the joint German – Danish acoustic survey (GERAS), which is part of the Baltic International Autumn Acoustic Survey (BIAS) in the whole Baltic Sea. In autumn, older Western Baltic spring spawning herring (WBSSH) of age group 2+ are concentrated in SD 23 and SD 24 with variable spatial distribution. Data of GERAS were used to estimate annual maturity ogives. The acoustic survey is conducted about 4 to 5 months prior to the start of the main spawning season of WBSSH. Any GERAS estimates on maturity ogives could therefore only be taken as an indicator for spawning, since they represent an underestimation of the spawning part of the population. The fraction of spawning herring within age group 2 to 4 has increased since 2004 and reached values close to or above the ones presently used within the WBSSH stock assessment. The proportion of spawners within age group 1 even increased above 10 % after 2006, while in the assessment, 0 % is assumed. The study suggests that the presently used constant maturity ogives within the assessment represent at least an underestimation of the fraction of spawning herring.

Introduction

The size of the spawning stock biomass (SSB) is one of the important tools, which is used to regulate the fishery. SSB is estimated by combining the total stock biomass with the proportion of the spawning individuals. The proportion of spawning individuals at age is described by a logistic function (maturity ogive), which is presently assumed to be constant within the WBSSH assessment since the start of the data series in 1991. These values were further explored by analyses of Gröhsler and Müller (2004) (Tab. 1). New estimates of the proportion of spawners (PS) of WBSSH were produced based on the IBTS surveys in the Kattegat in quarter 1 (Bartolino, 2012 et al., WKPELA, November 2012). The temporal development of the data between 1996 and 2011 indicated two periods with different PS. Low level of ~ 60 % of PS was observed between 1996 and 2001 followed by estimates of PS ~ 90 % between 2003 and 2012 (Bartolino et al., 2012, WKPELA, November 2012). At the time of IBTS Q1 data sampling in the Kattegat most of the WBSSH start to spawn in the more southern areas of ICES SD 22 and SD 24. Therefore, any PS based on IBTS in Q1 in the Kattegat may be regarded as not representative for the main, broader distributed stock of WBSSH at that time.

Annual acoustic investigations were carried out in SD 21 – 24 during the joint German – Danish acoustic survey (GERAS) as part of the Baltic International Autumn Acoustic Survey (BIAS) in the whole Baltic Sea. In autumn, older WBSSH of age group 2+ are concentrated in SD 23 and SD 24 with a variable spatial distribution (Miethe et al. 2012, in prep.). Data of GERAS were used to estimate annual maturity ogives. The acoustic survey is conducted about 4 to 5 months prior to the start of the main spawning season of WBSSH. Therefore, any GERAS estimates on maturity ogives could only be taken as an indicator for spawning since they represent an underestimation of the spawning part of the population.

Material and Methods

Maturity samples taken during GERAS in SD 21 to 24 in October were available for the years 1994 to 2011. Only the data of SD 23 and 24 were used in the study because the density of age group 2+ was too low in the other areas covered by GERAS (SD 21 and SD 22) in most years. The analyses were conducted based on ICES rectangle in order to include any spatial variations. The rectangles 41G2 and 40G2 in SD 23 and 38G2 to 39G4 in SD 24 were used in the present analyses. Other rectangles, which were covered within GERAS, were not included in the analysis because only acoustic data were available (39G2 in SD 23) or they were not regularly covered year by year (Fig. 1). The maturity stage was macroscopically determined with an 8 scale key adapted from Maier, 1908 for WBSSH (Gröhsler and Müller, 2004; ICES 2012/SSGESST:02/BITS manual). Table 2 describes the used definitions of the maturity stages.

The biological data of GERAS are sampled to determine the mean length frequency of WBSSH per rectangle, which is then further distributed by age according to an age - length by SD. This procedure follows the guidelines, which are given in the BIAS manual (ICES 2012/SSGESST:02). All maturity stages 3 (prespawning) to stage 8 (spent) were defined as spawner.

All individuals in the years 2005-2011 were assigned to WBSSH or CBH based on a separation function (SF) (Gröhsler et al. 2012). It was not possible to apply the separation function for the earlier period covering the years 1994 to 2004 due to different growth parameters of WBSSH at that time (WD 02: Oeberst, Gröhsler and Schaber).

The age-length key per SD of spawners and non spawners was combined with the mean length distribution of herring per rectangle to estimate PS. The PS per ICES subdivision was estimated as weighted average of the estimates of all covered rectangles where the number of individuals at age was used as weighing factor.

Within the present assessment of WBSSH, the PS at age 0 and 1 is assumed to be zero, whereas in all ages larger 4 the PS was fixed to 1 (Tab. 1). The numbers of sampled herring with age group 4 and older in the biological samples were low after classification into the groups of WBSSH and CBH as well as spawner and non spawner. This resulted in variable proportions of spawners, which not in all cases reached 100 %. Therefore, the analyses within the present study were only directed to the ages 2 to 4. In addition, the development of PS of age 1 was separately evaluated.

Ranges of maturity stages by year, SD and age group were used to compare the status of maturation. In addition the development of the total stock biomass (TSB) and the spawning stock biomass (SSB) of the WBSSH and the North Sea herring stock were taken into account to explain the observed developments.

Results

In most years, low densities of mostly younger herring, which are characterised to be non spawner (PS of 0 %) were recorded in the northern rectangle of SD 23 (41G2). In years with a higher density of herring in this area, a variable proportion of PS was found (Fig. 2).

This was in contrast to the temporal fluctuations of PS in the southern located rectangle of SD 23 (40G2) (Fig. 2, GERAS was not able to cover SD 23 in 2001). This rectangle was mostly characterised by older herring. The proportion of age groups 2 and 4 showed large variations from year to year with a positive trend of an increased fraction of spawners from 2003/2004 onwards. The largest variations were observed between 1994 and 2002.

The temporal development of PS in SD 23 differed from the one in SD 24 (Fig. 3). SD 24 showed large variations of PS in the western area (rectangles 39G2 and 38G2) with a clear positive trend of increased PS for age group 2 from 2004 onwards. The developments of PS in the other parts of SD 24 showed a similar development of PS compared to the results of the northern rectangle of SD 23 (40G2), which showed a decrease of PS from 1994 to 1998 and increase from 2002 onwards. The PS values of age group 2 and 3 reached a similar level as in age group 4. The overall development of PS per SD (SD 23 and SD 24) was dominated by the contribution of the results of rectangle 40G2 in SD 23 and of rectangles 38G2, 39G2, 38G3 and 39G3 in SD 24. Both areas showed a similar trend of an increasing fraction of spawners between 1994 and 2011 (Fig. 4).

The PS values of age group 1 were below 0.05 in SD 23 during the total period, but have been above 0.10 in SD 24 since 2006 with a maximum of 0.27 in 2009 (not shown in the figures).

Variation of the range of maturity stages from 1994 to 2011

The proportion of maturity stage 2 (MS 2) of age group 2 decreased from 1994 to 2011 in SD 23, whereas at the same time the proportion of MS 4 & 5 (prespawning) showed the opposite trend (Fig. 5). Similar developments were found for age groups 3 to 5. Since 2005, lower proportions of spawning herring (MS 6 & 7) have been observed in age groups 4 and 5. Similar developments of the proportion of maturity stages per year and age group were observed in SD 24 (Fig. 6). Spawning herring (i.e. MS 6 & 7) only occurred in the later years 2005, 2006 and 2009 – 2011, thus reflecting an earlier beginning of spawning as compared to the period 1995 – 2004.

The increasing PS between 2004 and 2011 was correlated with an increasing proportion of maturity stages MS 4 & 5 and MS 6 & 7, indicating an earlier beginning of spawning. The observed increase of the PS values cannot be explained by development of the condition (Fulton factor) of herring during the acoustic surveys because the condition of herring in SD 23 and 24 showed significant variations from year to year, but did not show the same trend as the development of PS (GLM model).

Discussion

The survey time of GERAS is not optimal to estimate any maturity ogive for the total stock and any estimates from this survey most likely give an underestimation of the fraction of spawners. However, the PS values of age group 2 based on GERAS are larger than 0.2, which is presently used within the assessment (Tab. 1). This indicates that the age 2 values would need a revision. The PS values of age group 3 of GERAS were lower than the one used in the assessment. This was also the case for age group 4 until 2007. Thereafter the PS values were partly above the assessment one. Overall the GERAS results indicate that the values of PS of age group 2 and age group 4, which are presently used within the assessment, represent an underestimation of the fraction of spawners at least since 2007.

Asynchronous fluctuations of PS values from year to year were observed in all age groups. Therefore, it can be assumed that the fluctuations are partly determined by small sample sizes and uncertainty of ageing.

The observed increase of the PS values cannot be explained by the development of the condition (Fulton factor) of herring during the acoustic surveys, because herring condition in SD 23 and 24 showed significant variations from year to year, but, not the same trend as the development of PS (based on GLM analyses).

The observed increase of the PS values also cannot be explained by the development of TSB and SSB of WBSSH. The stock size decreased from 1994 onwards with temporary increases in TSB between 1998 and 2002 as well as between 2004 and 2006. The development of SSB was similar, but the estimates between 1996 and 2000 were at nearly the same level as between 2007 and 2011, which is not in accordance with the development of PS.

North Sea autumn herring (NSASH) is partly a prey competitor of the WBSSH during the summer feeding season in the Skagerrak/Kattegat and the North Sea (ICES, 2012, HAWG). The TSB and the SSB values of this stock have been increasing since 2004 with a temporary maximum in 2003 and a temporary minimum in 2007 and are not correlated with the development of the PS values of WBSSH.

Conclusion

The survey time of GERAS is not optimal to estimate any maturity ogive for the total stock, and any estimates from this survey most likely give an underestimation of the fraction of spawners. The GERAS results indicate that the values of PS of age groups 2 and 4, which are presently used within the assessment, represent an underestimation of the fraction of spawners at least since 2007.

The variations of PS from year to year are most likely driven by the variable beginning of maturation of herring in October. The processes triggering maturation are unclear.

An increasing proportion of herring with maturity stage 6 and 7 in October within the last years indicates increasing spawning activities in late autumn and winter. The reasons for the observed shift are still unclear.

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Report of the Baltic Fisheries Assessment Working Group (WGBFAS). ICES CM 2012/ACOM:10, Annex 16: 749-772.

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Heincke, F., 1898. Naturgeschichte des Herings. Abhandl. des Seefischverb. 2:1–223.

Figures

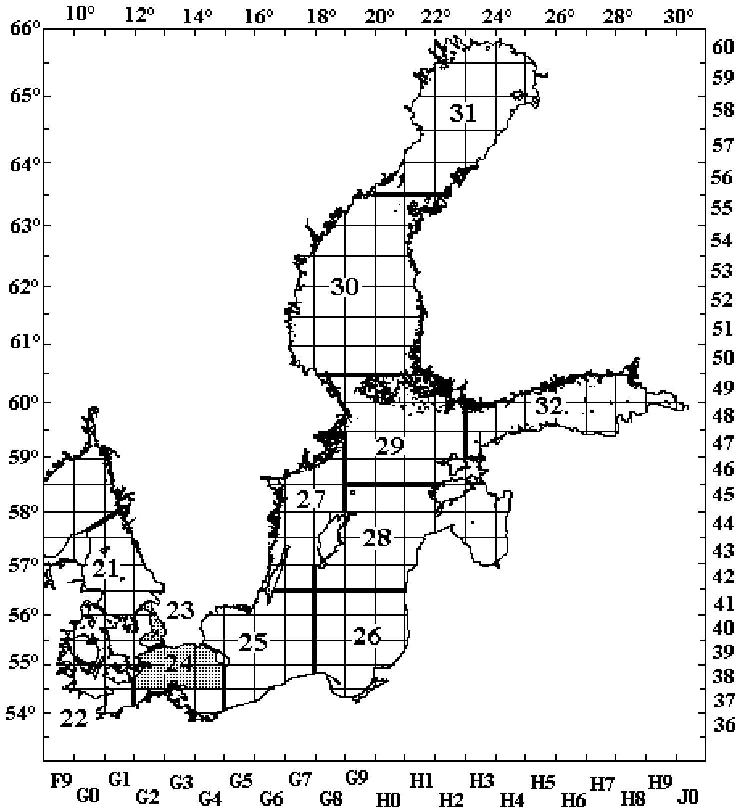

Figure 1: Baltic Sea with the notation of rectangles. The marked rectangles were used in the present analyses.

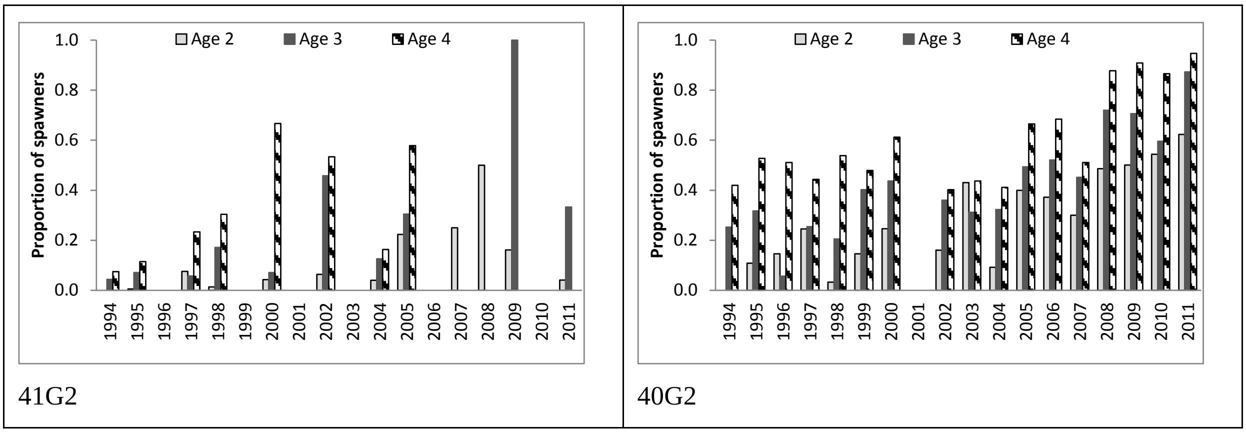

Figure 2: Proportion of spawning herring of age groups 2 to 4 in the northern part of SD 23 (Rectangle 41G2) and in the southern part of SD 23 (Rectangle 40G2) for the years 1994-2011. No data are available in 2001, since GERAS was not able to cover this area at that time.

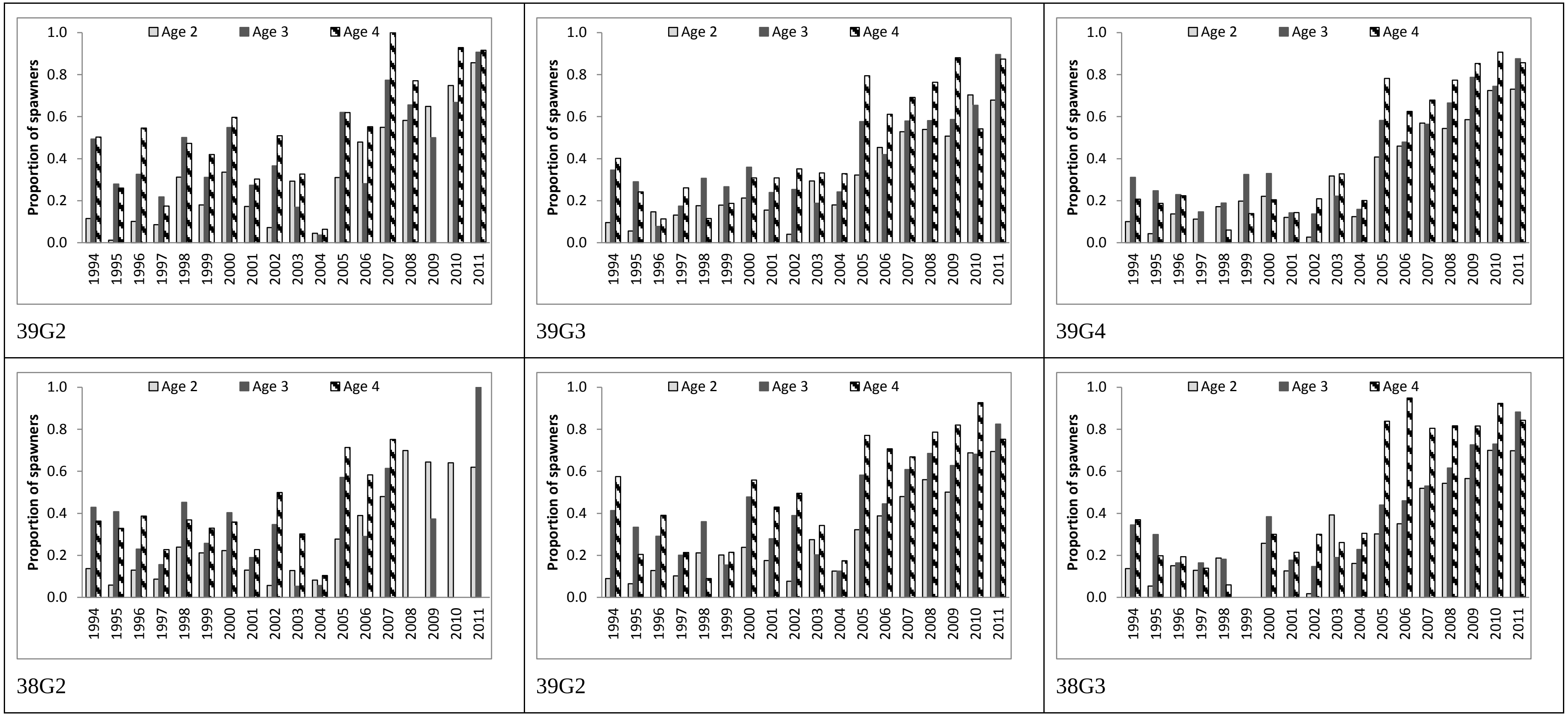

Figure 3: Proportion of spawning herring of age groups 2 to 4 in SD 24 by rectangle for the years 1994-2011.

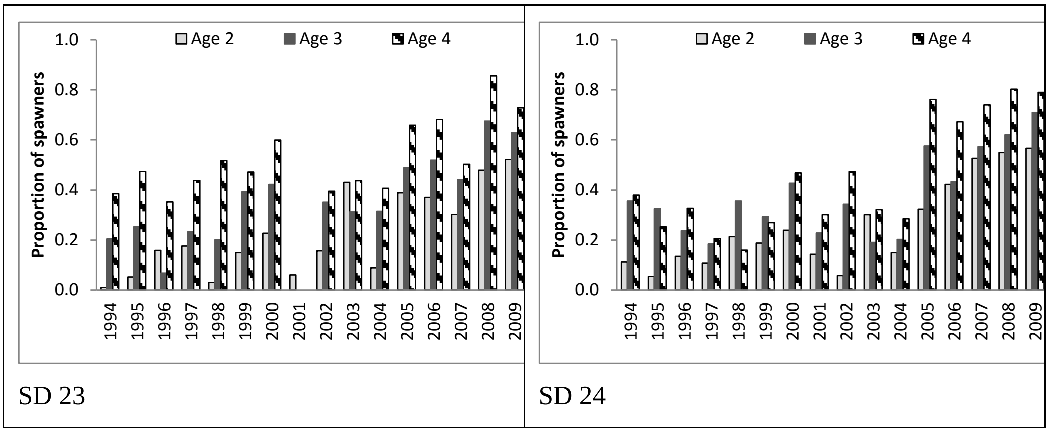

Figure 4: Proportion of spawning herring of age groups 2 to 4 in SD 23 and SD 24.

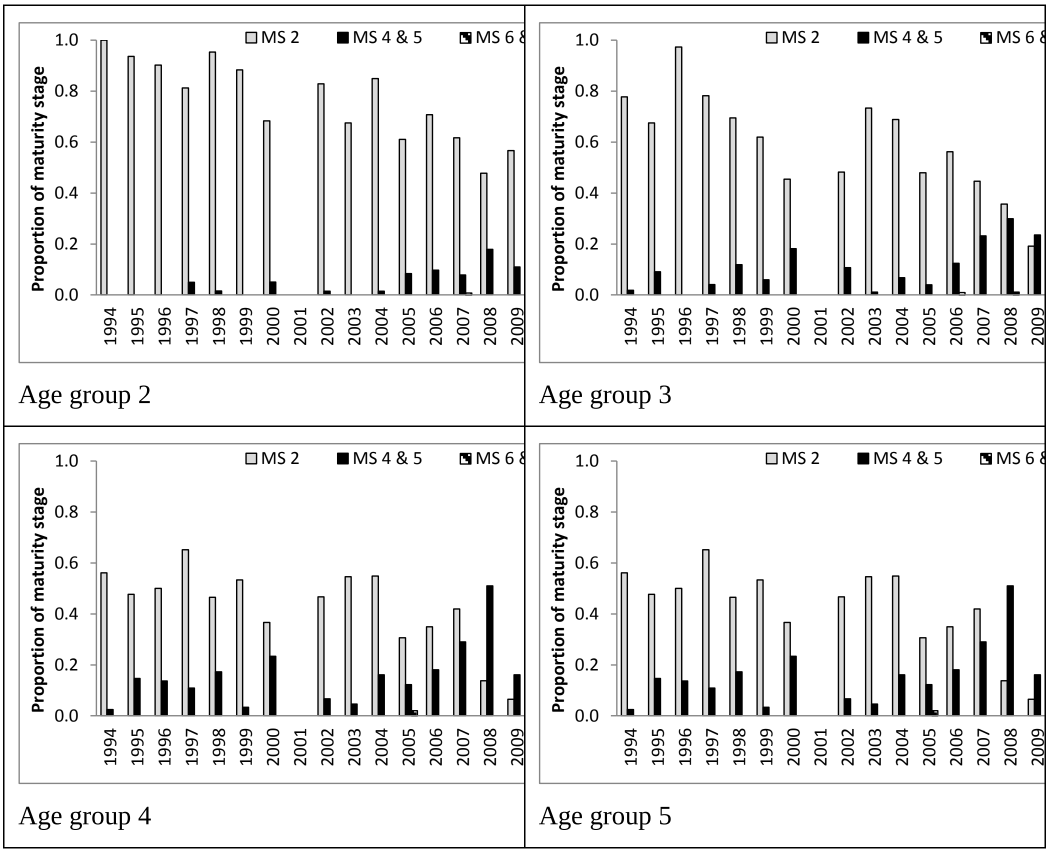

Figure 5: Development of the proportion of maturity stages (MS) 2, 4 & 5 and 6 & 7 in SD 23 by age groups 2 to 5 for the years 1994-2011.

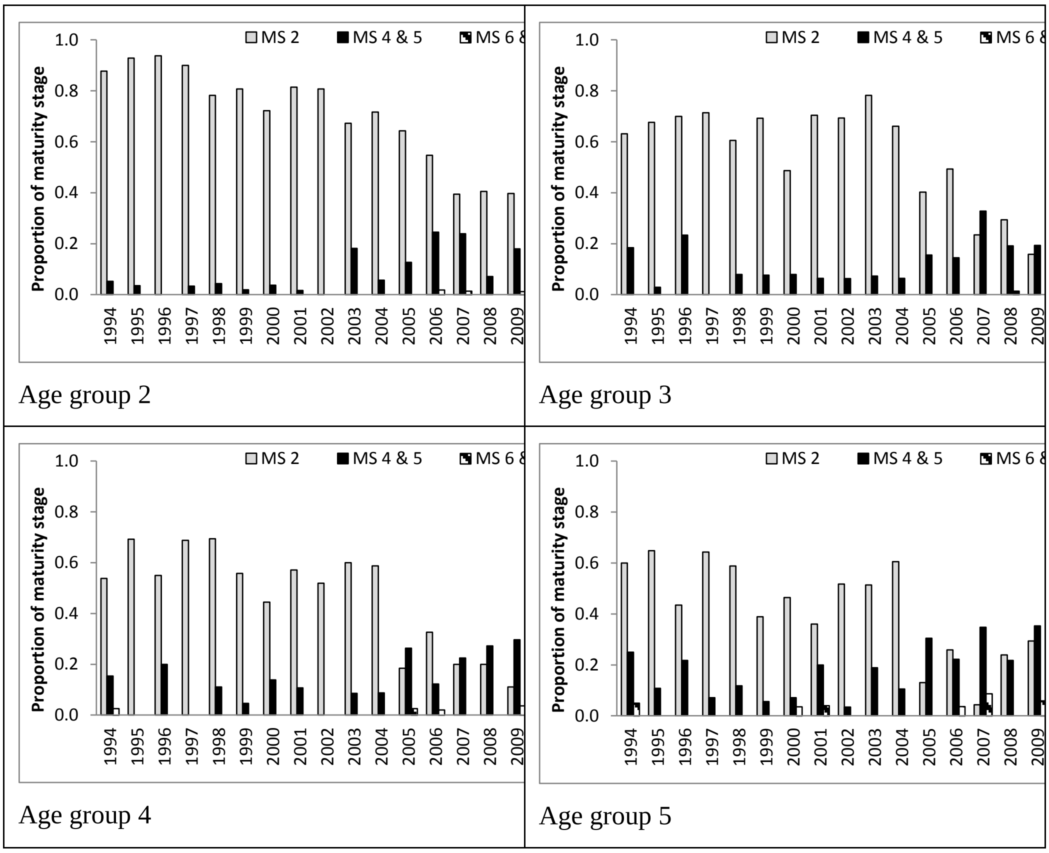

Figure 6: Development of the proportion of maturity stages (MS) 2, 4 & 5 and 6 & 7 in SD 24 by age groups 2 to 5 for the years 1994-2011.

Tables

Table 1: Maturity ogive recently used by HAWG (ICES 2012/ACOM:06) for the Western Baltic Spring Spawning Herring (WBSSH).

Age/W-rings	0	1	2	3	4	5	6	7	8+
Maturity	0.00	0.00	0.20	0.75	0.90	1.00	1.00	1.00	1.00

Table 2: Modified eight degree scale of Heincke (1898) with respect to a five degree scale, which is recommended in the Baltic International Trawl Survey (BITS) Manual (ICES CM 1999/H:1); Notations of the maturity stages (Gröhsler and Müller, 2004).

Maturity stage according to scale of BITS	Maturity scale according to modif. Scale of Heinke	Purpose to estimate SSB	Estimation of sexual maturity
I - virgin	I - juvenile	Non-spawner	immature
II - maturing	III - preparatory IV - maturing V - mature	Spawner	mature
III - spawning	VI - spawning VII - partly spent	Spawner	mature
IV - spent	VIII - spent	Spawner	mature
V - resting	II - resting	Non-spawner	mature

WD 7 Quality of age determination

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Abstract

Earlier age readings from herring captured in 2009 (SD 26) and 2011 (SD 23) were repeated to investigate the quality of age determination. The repeated aging showed an agreement of 84 % (Subdivision/SD 26) and 90 % (SD 23) compared to the initial reading. Differences of ± 1 year were observed in 12 % and 10 % in SD 26 and SD 23, respectively. In both initial years, a higher proportion of differences of 1 year was found. Only in SD 26, reading differences of more than 1 year were observed (3 %). The analyses did not indicate systematic trends in the ageing of herring by the German reader.

Introduction

The age of fish is a basic parameter in most stock assessment models. Errors within the ageing process directly influence the stock assessment results. Inter-calibration experiments are conducted to assess the variability in ageing. In order to compare the ageing of Baltic herring based on otolith reading, ICES conducted Study Groups and workshops in 1997, 1998, 2001, 2005 and 2008 (ICES, 1997, 1998, 2007, 2005, 2008).

The study group on "Baltic Herring Age-Reading" in 2001 discussed the results of two exchange exercises in 1997 and 1998 and further age readings during the meeting. About 60 % of otoliths of the two exchange exercises were aged differently. The ageing exercise, which was conducted during the meeting, found a high agreement for age group 0, but the degree of agreement decreased with increasing age reaching only 47.2 % for age group 8.

Otoliths from Denmark, Germany, Latvia and Sweden were used for the inter calibration of ageing in 2008 (ICES, 2008). The members of the workshop stated that "The average agreement with the modal age reached from 82.4% in the German sample to 91.5% in the Latvian sample. The average agreement was 86.9%. The study group and the workshops showed that the interpretation of age by different readers was relative variable in the past, but that the agreement in age reading increased to more than 80 % in 2008".

All studies compared the ageing of different readers by using the same otoliths. Repeated ageing of the same otolith by the same reader were not conducted. The aim of this study was to assess the quality of one reader by repeated ageing of the same otoliths.

Material and Methods

Otoliths of herring captured in ICES subdivision 26 during the acoustic surveys in March 2009 (BASS) were aged in 2009 and in 2012 by the same age reader at the Institute of Baltic Sea Fisheries (OSF). This age reader is in general responsible for the ageing of all herring otoliths. The same information as in 2009 was available for the repeated ageing (length, date of capture, etc.). In total, 189 otoliths were read twice. The lengths of herring ranged from 9.75 cm to 25.75 cm and the age reading results from 2009 from 1 to 13 years.

The Second exercise of repeated age reading was carried out with otoliths from herring captured in SD 23 during the acoustic survey in October 2011 (BIAS). The otoliths were aged during the routine processing and the repeated age determination was carried out December 2012. The majority of herring aged by German readers was captured in the western Baltic Sea. In total, 551 otoliths from SD 23 were aged twice. The length of herring ranged from 19.25 cm to 30.25 cm and the age reading results from 2009 ranged from 1to 7 years.

In addition, results of inter-calibration experiments of herring age reading in 2005 and 2008 were used for comparison (ICES 2005 and 2008).

Results

The differences between the first reading in 2009 and the second reading in 2011 of SD 26 herring varied between age_{2009} -1 and age_{2009} +3 (Fig. 1). In one case the difference was -1, in 159 cases the cases the difference was 0, in 22 cases the difference was +1, in 6 cases the difference was +2 and in one case the difference was +3. The results illustrate the high level of agreement of the ageing procedure with a tendency to overestimate the age within the repeated readings.

The relation between the first and second ageing was close to the line of x = y (, Fig. 2) indicating that the differences of aging did not significantly increase with increasing age. In addition, the variability of the interpretation of the otolith did not increase with increasing age.

Higher agreement of the repeated ageing was found for SD 23 herring during the second exercise. In 469 of 551 cases the same age was determined (90 %) (Fig. 3). A difference of age -1 was found for 11 otoliths (2 %), and in 44 cases the second reading was age +1 (8 %). As observed in the first exercise, the proportion of age +1 was higher compared to -1. However, differences of more than one year were not observed. The hypothesis that the mean of the differences between the first and repeated reading does not significantly differ from zero was confirmed by a t-test (p= 0.03).

The relation between the first and second ageing was close to the line of x = y (Fig. 4) indicating that the differences of aging did not increase with increasing age. In addition, the variability of the interpretation of the otolith did not increase with increasing age.

The agreement of a repeated ageing of the same herring otoliths was close to the agreement of both readers of the OSF who participated the workshops in 2005 and 2008 (ICES 2005 and 2008). The absolute and relative frequency of the differences in ageing of 238 otoliths is given in Table 1.

The observed higher proportion of otoliths with higher age in the repeated age determination compared to the proportion of otoliths with lower age was partly determined by a slightly different procedure employed by the reader. During the process of repeated ageing, the reader is in general more concentrated than during the routine work where a higher speed of ageing is required. This small change in the routine may explain the small tendency to overestimate the age during the second reading.

Conclusion

There is no indication of a systematic trend in the ageing of herring by the German reader. It is suggested, that the present type of inter-calibration of readers should be regularly repeated by all countries to identify any systematic shift or increase of the random differences.

References

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Figures

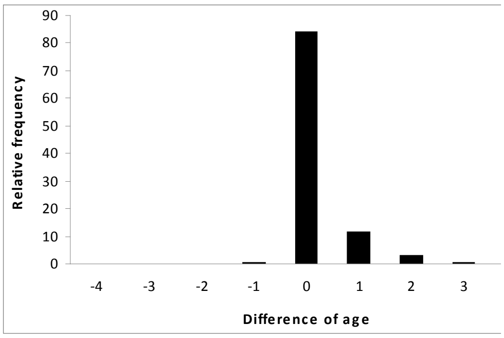

Figure 1: Relative frequency of the difference of the first ageing in 2009 and the repeated second one in 2011 of herring sampled in SD 26 (N = 159).

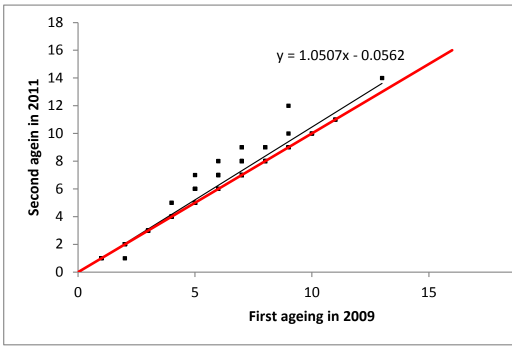

Figure 2: Relation between the first ageing in 2009 and second ageing in 2011 (dots) of herring sampled in SD 26 inclusive the trend (red line) and the values of x = y (black line).

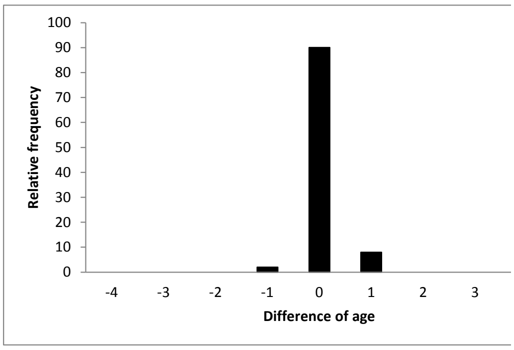

Figure 3: Relative frequency of the difference of the first ageing in 2011 and the repeated second one in 2012 of herring sampled in SD 26 (N = 551).

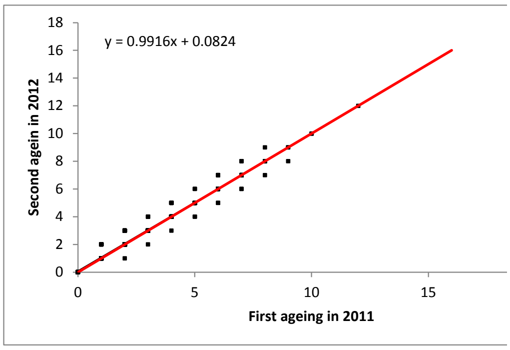

Figure 4: Relation between the first ageing in 2011 and second ageing in 2012 (dots) of herring sampled in SD 26 inclusive the trend (red line) and the values of x = y (black line).

Tables

Table 1: Absolute and relative frequency of the ageing of herring by two German readers at the ICES workshops in 2005 and 2008 (ICES 2005 and 2008)

Difference in age	-4	-3	-2	-1	0	1	2
Absolute frequency	1	0	3	7	207	18	2
Relative frequency	0.4	0.0	1.3	2.9	87.0	7.6	0.8

WD 8 Ruegen Herring Larvae Survey and N20 Larval Index

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Abstract

The inshore waters of Strelasund/Greifswalder Bodden (ICES SD 24) are considered the main spawning area of Ruegen herring which represents a significant component of the Western Baltic spring spawning (WBSS) herring stock. The German Institute of Baltic Sea Fisheries (TI-OF), Rostock, and its predecessor monitors the density of herring larvae as a vector of recruitment success since 1977 within the frame work of the Ruegen Herring Larvae Survey (RHLS). It delivers a unique high-resolution dataset on larval herring growth & survival dynamics in the Western Baltic Sea. A sampling grid including 35 stations is sampled weekly using a Bongo-net during the main reproduction period from March to June. The data collected provide an important baseline for detailed investigation of spawning- and recruitment ecology of Western Baltic spring spawning (WBSS) herring stocks. As a fishery-independent indicator of stock development, the recruitment index is incorporated into the ICES Herring Assessment Working Group (HAWG) advice since 2007 as the only 0-group recruitment index for the assessment of Western Baltic Spring Spawning herring.The entire survey design has been externally reviewed and carefully adjusted in recent years. This Working Document intents to provide an update on the status of survey resulting time series, concluding that regular correlations of consecutive juvenile stages on increasing spatial scales underline the hypotheses that i) the Ruegen herring spawning component contributes significantly to the WBSS herring stock and ii) the majority of natural early life stage mortality occurs before larvae reach a total length of 20 mm supporting the validity of the index.

Introduction

Because of the immense economical and cultural importance of inshore spawning herring for the Baltic Sea region, scientific investigation of spawning ground distribution and larval herring abundance has a quite extensive history in the area. In the German part of the Western Baltic Sea sporadic studies on larval herring abundance in coastal waters and transitional bays, lagoons and estuaries date back as far as the 1920’s. During the 1930’s a significant shift occurred when Western Baltic herring landings previously composed of autumn spawning stocks suddenly became dominated by spring spawning fish (Biester 1989). The first studies on Rügen spring spawning herring are reported from 1937-1939 and in a second campaign 1958-1961 (Biester 1989) (see also below: Discussion & Future prospects). A regular sampling of herring larvae on the major inshore spawning grounds of Greifwald Bay (German: Bodden) was initially established in the late 1970’s. Along the underlying hypothesis that larval numbers in this important retention area might indicate annual production of Western Baltic spring spawning herring (WBSS herring) the Ruegen herring larvae survey (RHLS) was continued with adequate but minor modification until the present day.

In 2006 the rationale and methodology of the survey was reviewed by external scientists (Dickey-Collas & Nash 2006). Major uncertainties were highlighted including catch efficiency of used mesh sizes in respect of lager larvae and potential export of larvae passively transported from the GWB area to open coastal waters. Additionally the rationale of the “survival index” derived by larval numbers reaching a critical total length of 30 mm was re-evaluated. As a result, multiple adjustments in the survey design and laboratory analyses were applied in the following years to increase survey precision. Important changes included e.g. the equipment of Bongo gear with differing mesh sizes including a larger mesh on one Bongo ring to cope for net avoidance of lager larvae (see below Materials & Methods for details), the station grid of the survey was extended to connected coastal waters in the Pommeranian Bay for a pilot study on larval export and the survey duration was expanded starting earlier in the season in mid –March (if ice cover allows) instead of mid-April. Another outcome of the review process was the revision of the former Rügen herring larvae index (N30). Based on the observation that the strength of the surviving year class of recruits is already determined before larvae reach a total length of 20mm (Oeberst et al. 2009), the critical size for larvae to reach to be taken into account as a “survivor” was adjusted from 30 mm to 20 mm TL. These observations are in general consensus with findings on early life stage mortalities of herring (and many other species) throughout global pelagic systems (Hjort 1914, 1925, Cushing 1990). Generating the annual survival index, basically the total amount of larvae in the area is calculated reaching the critical length of 20 mm during the entire spawning period (N20 index, see Oeberst et al. 2009 for details). Besides ichthyoplankton sampling, simultaneous hydrographic measurements provide data on the physico-chemical environment of larval herring on a suitably small scale to characterize habitat conditions for ichthyoplankton in GWB and the adjacent Strelasund area that are also incorporated into index calculations in form of larval growth models. While ichthyoplankton sampling with classical, horizontal plankton nets remained more or less unchanged throughout the decades, hydrographic measuring techniques are subject of a rapidly developing technology that is becoming more and more sophisticated. Compensating for potential artifacts due to gear adjustment over the decades is one of the major challenges of validating the larval time series back in time. Currently the validated time series of the N20 survival index dates back to 1992. To receive an annual recruitment index for WBSS herring, the larval N20 index is correlated with the 1-wr and 2-wr juvenile numbers as derived from the annual hydroacoustic surveys (GERAS). The formerly used 0-wr herring is not used anymore for this purpose because of major technical issues with 0-group herring including weak coverage of shallow coastal habitats with hydroacoustic gear. The N20 time series from 1992 onwards is used by the ICES Herring Assessment Working Group (HAWG) since 2008 as the only 0-group recruitment index for the assessment of WBSS herring.

A second external review of the RHLS program was accomplished in 2011 (Dickey-Collas & Nash 2011). The outcome was basically positive as far as the monitoring is concerned but some “tensions” were criticized between monitoring output and basic research efforts on larval herring ecology. According to the descriptive nature of a monitoring program, the results generally generate more questions than answers on the complex subject of herring early life history ecology. The main question addressed by the immense effort is how larval survival fluctuates over time and how the survival of the current year (or any particular year) is weighed relative to general trends- both key questions to reliable assessment. Related to the subject of bridging monitoring results with ecosystem analysis are changes applied to the current survey protocols. Since 2011 a new protocol incorporates numerical keys for recording and quantifying the “bycatch” organisms found in the Bongo nets. This not only provides data on the ichthyoplankton composition of the estuarine fish community but also a relative metric of inter-annual stickleback (*Gasterosteus aculeatus*) densities that might have a significant top-down effect on early life stage herring (Kotterba unpublished results).

An additional challenge is to gain insight on historical data sets on larval herring survival dynamics and distribution by retrieving data from the initial survey years including the periods 1977-1991 and to incorporate these data into modern data bases. During 2012 an effort was made to collect all former (handwritten) documents, organize their content and transfer information into meta-databases for further processing (Stürmer 2012 unpubl. report). The aim of these efforts is to extend the N20 time series as back in history as possible to visualize important changes in recruitment strength and to more precisely display general trends of Ruegen herring recruitment dynamics.

Material & Methods

Sampling of larval herring

From early March until late June, 35 stations on 5 horizontal strata are sampled weekly throughout Strelasund/Greifswalder Bodden (Fig.1). Herring larvae are assessed quantitatively using a plankton-Bongo net performing stepwise-oblique-tows (surface and each subsequent 1 m depth step 30 sec. tow time) down to 1 m above ground. Consequently the total time for each tow depends on the particular water depth at the station. To assess larvae of multiple size classes, the nets simultaneously used in the RHLS-Bongo have different mesh sizes (335 and 780 µm) to account for size dependent catch efficiency i.e. assuming that larger larvae have higher potential to avoid the 335 µm net, the 780 µm net is used for inter calibration of mesh size effects. Samples are preserved in 4% buffered (Borax) Formalin.

Sample processing

In the lab, all larvae are counted for each sample under the stereomicroscope. Larvae are measured to the nearest millimeter (TL). If the number of larvae/sample exceeds 1000, a random sub-sample of 600 larvae is measured for length distribution.

All developmental stages are quantified and recorded. Only larvae that reach a TL of 20mm are used for the (N20) assessment (see Oeberst et al. 2009 and citations therein)

Quantifying filtered water volume

To measure the filtered water volume, the Bongo-frame is equipped with a total of 3 mechanical flow meters. To evaluate differing clogging effects due to mesh size, each center of both net rings is equipped with a flow meter. An additional flow meter is installed on the outside of the Bongo frame as a control measurement of the “true” water volume passed without any clogging effect. Differences measured by the three flow meters are used to calibrate for the particular water volume/mesh size. Calculation of the filtered volume from flow meter data is performed as follows:

*Filtered volume [m³] = 0.287 [m²] * flow meter difference * 0.3[m]*

Where 0.287 is the radius of the used plankton net (Ø 0.6 m), flow meter difference taken from readings at the beginning and the end of trawl, 0.3 is a constant calibration factor for the flow meter type used.

Since the launch of the new research vessel („FFS CLUPEA“), an electronical flowmeter system (HYDROBIOS) will be used starting in 2013. However, simultaneous measurements with mechanical flowmeter units will be continued for calibration and back-up purposes.

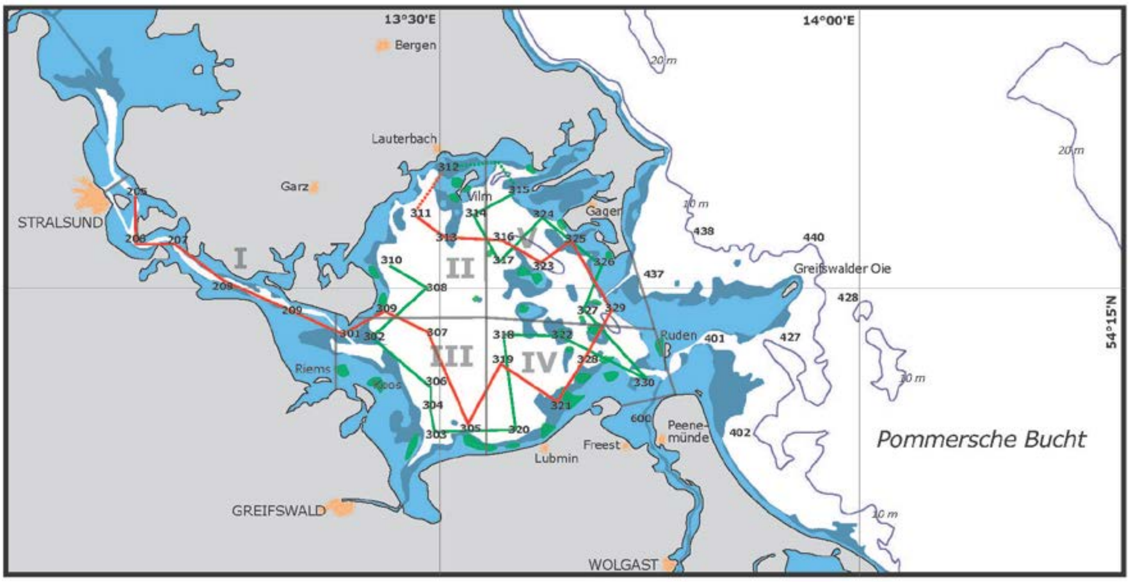

Fig. 1 Sampling grid and definition of strata (I-IV) for the RHLS standard survey. Stations located in Strelasund (#200) are sampled on the first survey day. Stations located in GWB (#300) sampled counter clockwise (red line) on the first day and clockwise on the second day (green). *Graph, C. Zimmermann*

Hydrographic measurements

In addition to the larval assessment, hydrographic variables are measured on each station. This includes data collection on Secchi-depth as well as sea surface and –bottom data on temperatures, salinities, turbidity and dissolved oxygen content (CTD data, Sea-Bird incorp.). Additionally vertical profiles of these variables are taken (CTD) on each station. Since 2012 an additional Fluorescence probe is used on the CTD to measure depth profiles of *in situ* Chlorophyll (CHL) *a* contents. CHL *a* content is a widely used proxy for primary production and thus an important variable that might structure pelagic food webs. Regular measurements of CHL *a* will provide *in situ* data on spatial and temporal pattern of primary production that might help in finding explanatory variables for herring larvae distribution and variability.

Data processing

Data are stored on a centralized database where data access is open, however, changes and data entry is restricted to authorized personnel to allow for controlled data handling. Assessment data are stored in an electronic data base (Software: MySQL) based on an internal server (back up on separate server). All non-current (prior 2010) data sets are protected against changes by a trigger (program script) limited to reading access. Standardized validation procedures are conducted on all assessment relevant data sets to provide continuous, reliable data. Missing data are adequately highlighted and if necessary estimates of missing hydrographic data are conducted by means of linear regression with valid data points and then highlighted as such in separate data base tables (e.g. “Temp. Estimate”).

Index calculation

The annual N20 larval survival index is calculated by correcting weekly growth of larvae for seasonal temperature change and taking the sum of larvae reaching ≥ 20 mm by every week of the survey until the end of the investigation period. On the spatial scale, the 35 sampling stations are assigned to 5 strata and mean larval abundance on stations of each stratum are extrapolated to the entire strata area. The final sum of 20 mm larvae derived from weekly intervals is incorporated into the annual N20 index (Fig.2) (see Oeberst et. al. 2009 for detailed description of the method and rationale).

Sample analysis

Herring larvae were identified, counted, and measured (total length to 1 mm below) in the laboratory. No corrections were made for shrinkage caused by fixation. For large samples (>1000 larvae), three subsamples of ~200 larvae were measured and the remaining larvae were counted. The size distributions of the subsamples were raised to the total number caught.

For each station *i* of week *j* and stratum *h*, the number of larvae by length group *k* per m² ($C_{i,h,j,k}$) was estimated, based on the volume of filtered water (measured by flowmeter) and the maximum sampled water depth of the tow (Müller and Klenz, 1994). The mean daily growth of the larvae (DG, mm d^{-1}) was estimated from a linear regression on surface temperature (T in °C; Oeberst *et al.*, 2009) as follows:

$$\mathrm{DG} = 0.033 + 0.035\,T. \tag{1}$$

The N20 abundance index

The index calculated (N20) represents a summation of all the larvae that reached a length of 20 mm over the entire survey period. The length of 20 mm was chosen to minimize the effects of variable mortality during the transition from the yolk-sac stage to the active-feeding stage, and of gear avoidance by large larvae because of their increased swimming speed. A two-step algorithm was used to account for growth during each sampling cruise and to minimize the possibility of double-counting larvae:

(i) Larvae can grow >1 mm during the 2–5 d of a sampling cruise, depending on water temperature. Therefore, the length distribution of each station was corrected to represent the first day of each sampling week if the mean DG between the first day of the cruise ($D_{1,j}$) and the sampling day of the station ($D_{i,j}$) was ≥1 mm using

$$C'_{i,h,j,k} = C_{i,h,j,k-x}, \tag{2}$$

where x is estimated by

$$x = \mathrm{ROUND}[\mathrm{DG}_{i,j}(D_{i,j} - D_{1,j})]. \tag{3}$$

The arithmetic means by stratum ($C'_{h,j,k}$) were calculated from $C'_{i,h,j,k}$, then the overall stratified mean for the total area by week ($C'_{j,k}$) was calculated using the surface areas of the strata as weighting factors.

(ii) The number of larvae of cruise *j* contributing to the N20 index was defined as the number of larvae ($C'_{j,k}$) that reach a length of >21 mm by the first day of the next survey $j + 1$, using the average T data and the number of days multiplied by the total area of the Strelasund and the Greifswalder Bodden ($A = 514 \times 10^6$ m²). A threshold of 21 mm was used because the length measurements were to the millimetre below. The contribution of the last cruise was estimated differently because information about subsequent development is lacking. In this case, all larvae ≤20 mm contributed to the index. The N20 index was calculated as:

$$\mathrm{N20} = A \sum_{j=1}^{n} \sum_{k=k(j)}^{20} C'_{j,k}, \tag{4}$$

where n denotes the number of cruises of the year, and k_j the minimum length of herring larvae during cruise *j* which was incorporated into the index of cruise *k* dependent on the mean surface temperature. The term k_j was estimated by

$$k_j = 21 - \mathrm{ROUND}[(0.033 + 0.035\,T_j)(D_{j+1} - D_j)]. \tag{5}$$

For the final cruise, k_j was defined as 5 mm. Mortality of larvae between cruise *j* and $j + 1$ was not taken into account.

Figure 2. Original, detailed description of sampling scheme and N20 index calculation by Oeberst et al. 2009.

Inter-calibration of data received by old „FFK CLUPEA" and new „FFS CLUPEA" vessel data

To control for vessel specific bias in ichthyoplankton sampling, an inter-calibration survey was conducted prior to the start of operation of the new vessel „FFS CLUPEA" (Fig.3). For the duration of two weeks in late April 2012 the standard station grid of the RHLS 35 stations were sampled according to the RHLS sampling protocol simultaneously with both vessels. Additionally, single stations were sampled multiple times with both vessels to cope for spatial variability between stations.

Figure. 3 The new vessel "„FFS CLUPEA"" took over the RHLS survey operation in late April 2012. It provides accommodation for 4 scientists, laboratory space and sophisticated means of oceanographic measuring.

Results & Discussion

N20-time series 1992-2012

Throughout the two decades of the RHLS time series the mean annual N20 ranges at about 7300 million herring larvae.

Despite immense inter-annual variability (Fig.4), N20 values in the 1990's were regularly above the 10 000 million mark. Since the year 2000 to the present an index of this magnitude was observed in 2002 only whereas in general index values during the past 12 years range below the time series mean. However, after several consecutive years with low larval numbers from 2005 to 2008 a slightly increasing trend towards the time series mean was recorded until the recent 2012 RHLS resulted in an exceptionally low larval index (1,140 million).

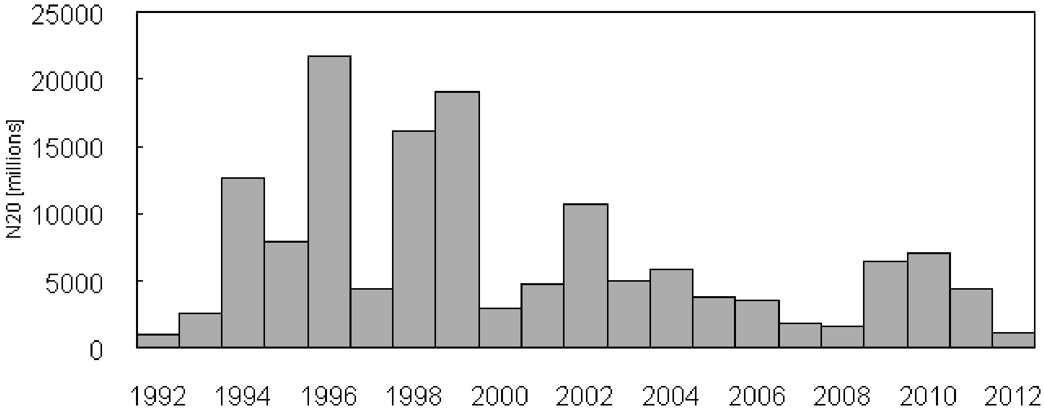

Figure 4. Validated RHLS time series with N20 index data presented as annual sum of 20 mm larvae in millions.

The reasons for the drastic fluctuations of larval numbers along the time series are not yet understood, nor can the general decreasing trend of from the early 1990's to the 2000's be explained satisfyingly. Comparisons of physical and biological environmental variables between particularly strong and weak N20 years respectively, did not yet result in the identification of any single driving factor. While physical variables such as salinity and dissolved oxygen content are rather stable during the herring spawning season, preceding winter conditions and seasonal temperature curves vary significantly between years. Interestingly, temperature differences alone do not explain seasonal variability of the spawning processes nor can they be directly related to the year class strength of surviving larvae expressed as N20 index. Exemplarily the low N20 year of 2008 does not differ from the exceptionally strong year 2009 in respect of seasonal temperature progress. The year class 2010, however, followed a relatively strong winter with prolonged cold weather periods and extensive ice cover on the spawning grounds. Never the less, the 2010 year class resulted in a similarly strong N20 index as the previous 2009 year class that followed a comparably mild winter without ice cover. Further studies that relate to ecosystem functioning and mechanistic research are subject of current investigation and selected case studies are presented in WD 09. However, recent results derived by time series analyses of seasonal patterns of *in situ* larval abundance and survival dynamics point on important survival bottlenecks located in ontogenetic stages as early as egg development and spawning ecology (Polte et al. submitted).

Based on preliminary results from the vessel inter-calibration survey conducted prior to the start of operation of the new vessel "„FFS CLUPEA“" into the RHLS, the exceptionally low 2012 N20 index is not considered a result of sampling bias due to switch of vessels. Although processing of ichthyoplankton sampling has not been concluded and thus data on larval numbers are not yet available, the data on filtered water volumes of both vessels fishing simultaneously, showed no significant difference (ANOVA, df =1, F = 3.03, p = 0.1, n= 36). This already provides a relatively reliable proxy of sampling performance that did not prove to show a higher variability between vessels than it does between stations (spatial variability along the sampling grid is a regular observation). The mean volume of filtered water / m fished water depth in was 12, 4 m³ (SD 1.6 m³) on board the old vessel and 11, 7 m³ (SD 1.7 m³) fishing with the new vessel.

Despite widely unknown drivers of inter-annual index variability, the N20 is considered a reliable tool to predict the year class strength of the recruiting 0-group. This assumption has been based on strong, recurring correlations of the N20 data with the 1-wr juvenile index as derived from the GERAS hydrocaoustic surveys. Since 2007 the described adjustments of the survey design were incorporated following the 2006 review process. These adjustments did not affect the prediction strength of the N20 data from 2007 until 2011 since data still correlate strongly (R= 0.8, r^2 = 0.6, n = 18) with 1-wr juveniles (Fig 5). Recent data from 2007 to 2010 (Fig. 5, red icons) are well in line with results of former years. Therefore careful adjustments as consequence of the review process as described above are not considered to influence the power of the used N20 index. The data point associated with GERAS of the year 2001 is marked in yellow. This data point represents an outlier since ICES SD 23 could not be covered during this survey.

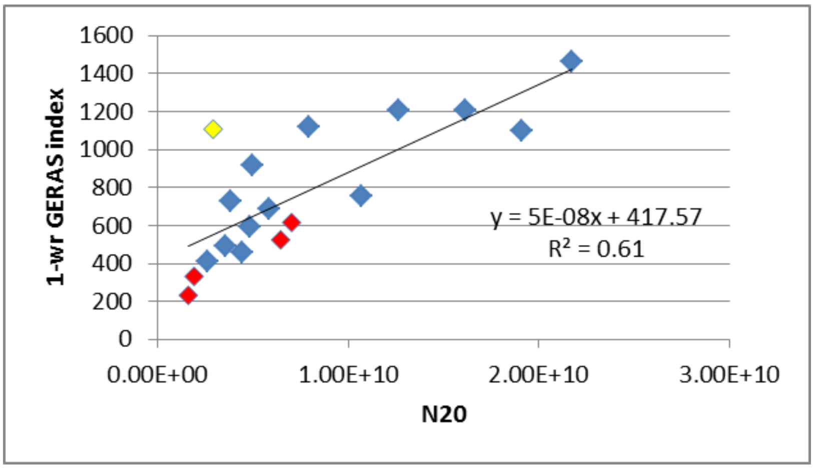

Fig.5 Correlation of N20 and 1wr-GERAS Index (1992-2010). Data points following on survey adjustments (2007-2010) are indicated in red. The yellow data point indicates the 2001 GERAS, which is considered non-representative.

Future perspectives

Retrieving historical data sets and transferring those from handwritten notes etc. into modern data bases is a major challenge for the immediate future of the working group. An estimated workload of about 1000 hrs of data entry is to be accomplished to incorporate all sampling protocols and larvae data into the digital data base. Now that a comprehensive inventory of existing data sets is accomplished, a detailed action plan will be developed immediately to allow for soon access of the data to extend the N20 time series as far back in time as data validity allows. Basically, issues in incorporating historical data can be summarized to i) standardization issues (sampling gear/ mesh sizes, lab analyses / larval length measurements);

ii) hydrography (sporadic, missing, or difficult to reconstruct) and iii) work load necessary to integrate data into current data bases.

Historical data sets include highly informative results; however the potential to incorporate data into the current N20 time series differs according to applied sampling protocols, used gear and restraints of survey duration and completeness of sampling grids. According to Stürmer (2012) systematical data sets on historical dynamic of larval herring in the area can be structured as follows: Suvey data 1926-1937 are not adequate for N20 calculation due to methodological restrains, survey period and –area. Survey data 1951-1959 are generally not adequate for N20 calculation due to similar restraints; however an N20 index might potentially be generated for single years. Survey data 1977-1991 are in general considered adequate for a valid N20 calculation; however there are 5 years identified during the 1970's and-80's that might prove not suitable due to technical issues.

Conclusions

As a result of the external reviews the survey design of the RHLS was greatly improved and efforts were made to test many of the underlying assumptions (also see WD 09). Nowadays the data base includes important base line data of larval dynamics to develop directed hypotheses conduct focused case studies in mechanistic recruitment ecology. A major aim of the survey and the N20 index is of course to provide a regular, reliable metric to apply in WBSS stock assessment. As indicated by continuous correlation of the N20 with the 1-wr juveniles (from SD 22-24) as derived by the GERAS hydroacoustic survey, the recent adjustments of the RHLS survey design are in harmony with the requirements of time series continuity and rather contribute to the strength of survey results. Technical additions to the survey, the new vessel in particular, contribute greatly to the logistically demanding survey program. Future challenges to be immediately addressed include the process of the retrieving historical survey data. The rationale of considering Greifswald Bay the most important spawning ground should be tested in the near future e.g. by a (multi-national) broad scale survey of all known inshore spawning areas. And on the rather long term basis scientifically sound case studies will address an increasing number of potential drivers and stressors of recruitment ecology.

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WD 9 Stock components and early life cycle ecology of Western Baltic spring spawning herring - prospects of recent research results with potential implication for stock assessment strategy

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Abstract

Western Baltic spring spawning herring (WBSSH) are composed of multiple spawning components reproducing in various regions and inshore sub-basins of the coastal Western Baltic Sea. The Ruegen herring component is considered to contribute most to the WBSSH stock providing the rationale in using larval indices derived in the major spawning ground and larval retention area as a valid assessment tool. The Ruegen herring larvae survey (RHLS) and the resulting (N20) larval index provide one metric of annual recruitment success; however those monitoring data can only provide limited information on the driving mechanisms responsible for variability of early life stage mortalities. In the effort to investigate those ecological mechanisms several case studies were conducted along with the annual RHLS focusing on top-down control of herring offspring as well as bottom up effects related to food quality and quantity for rearing herring larvae. Climatic drivers such as effects of local storm events on egg mortality were addressed by student theses as well as the role of wind drift on larval dispersal. Since the understanding of causes and magnitudes of natural mortality might have important implications for assessment work, we compiled recent case studies on herring early life stage ecology within this Working document although most of them presently represent work in progress. Those studies particularly include:

1. Survival bottlenecks in the early ontogenesis of Atlantic herring (*Clupea harengus*, L.) in coastal lagoon spawning areas of the Western Baltic Sea
2. Resident estuarine predator community controls herring recruitment success
3. Distinct spawning waves of Herring are differently affected by spawn predators
4. Temperature dependent digestion of herring (*Clupea harengus*, L.) eggs by the three- spined stickleback (*Gasterosteus aculeatus*, L.)
5. Influence of storm induced turbulence on Ruegen herring egg mortalities
6. Abundance of early herring (*Clupea harengus*, L.) larvae in the littoral zone of inshore lagoons in the Western Baltic Sea
7. Vertical distribution of Herring Larvae in the Greifswalder Bodden
8. Recruitment failure of Western Baltic Spring Spawning Herring – is it caused by food availability for the larvae?
9. Nutritional situation for larval Atlantic herring (*Clupea harengus*, L.) in the western Baltic Sea
10. Essential fatty acid (docosahexaeonic acid, DHA) availability affects growth of larval herring in the field
11. Wind induced variability in coastal larval retention areas: a case study on Western Baltic Spring-Spawning Herring´
12. Identifying Spawning Sites of Western Baltic Herring using a Particle Back-tracking Scheme

Western Baltic Spring Spawners - spawning components in the Western Baltic

Herring spawning components uphold significant levels of reproductive isolation, possibly affected by selective differences among spawning and/or larval habitats (Limborg et al. 2012). Genetic stratification is likely maintained by mechanisms of natal homing, larval retention and natural selection (Gaggiotti et al. 2009). In the Western Baltic tagging and genetic studies suggest that three to four more or less well-described stock components, that either spawn and use the area as nursery or migrate through it: Rügen herring (abbreviated RHS), local (autumn) spawning Fehmarn herring, herring from the Kattegat and Inner Danish waters, and potentially other Western Baltic herring stocks, each of which have different contributions to the fishery and ecosystem. The RHS are assumed to make up the majority of the western Baltic Sea herring in the area (ICES 2010) and the stock spawn around the Geifswalder Bodden, mainly in March-May, but with some autumn spawning also (e.g. Nielsen *et al.* 2001; Bekkevold *et al.,* 2007).The other herring populations occurring in the area are found in many of the bays in the area, where at least Kiel, Møn, Schlei, Flensburg, Fåborg, and Fehmarn have been reported as spawning sites for these apparently less abundant herring stocks.

Herring migratory patterns and habitat use in the Skagerrak have previously been studied based on population differences in morphological traits such as vertebral number, spawning time (spring, autumn or winter; estimated from otolith microstructure) and age distributions (review in ICES 2010). Stock separation by use of otolith microstructure uses visual inspection of season-specific daily increment pattern in the larval otolith (ICES, 2004; Clausen et al., 2007) to separate herring stocks according to their spawning time. The method was validated by Clausen et al. (2007) and the study showed that the method can discriminate herring with different spawning times, even when a sympatric existence of herring with different spawning times is the case (Brophy and Danilowicz 2002, 2003, Bekkevold et al., 2007). However, different populations with similar spawning periods may not be resolved with the present level of analysis (Mosegaard et al., 2001, Clausen et al., 2007). Otolith shape analysis has been used to discriminate between populations for a variety of species and for herring this approach has had increasing success with development of imaging techniques and statistical methods.

Genetically based stock discrimination analyses in herring have demonstrated that spawning stocks (populations) can be separated and their migratory behaviour assessed using genetic markers (Bekkevold *et al.* 2005; Ruzzante *et al.* 2006; Gaggiotti et al. 2009; Limborg et al. 2012). RHS can e.g. be genetically distinguished from other herring in the North Sea-Baltic Sea area, and genetic marker data have consequently been used to determine the temporal and spatial distributions of RHS in the Skagerrak feeding area (Bekkevold et al. 2011). However, such techniques have until now not been applied to directly assess migrations in the western Baltic Sea and the Fehmarn area specifically. Novel high-resolution, genomic markers (Single Nucleotide Polymorphisms, SNPs) provide an improved tool for genetic stock identification of individuals and for determining migration patterns in East Atlantic herring (Helyar et al. 2012; Limborg et al. 2012; Nielsen et al. 2012; Bekkevold et al, in prep).

The ICES Herring assessment Working Group (HAWG) make annually use of biological samples routinely collected to estimate the composition of the catches in terms of stock components. The analysis of stock composition in commercial samples for stock assessment and management purposes of the herring populations in the North Sea and adjacent areas has been routine since the beginning of the 1990's. The herring samples are split into management stocks by their seasonal spawning type (winter, spring and autumn); however each type is composed of several local stock components having the same spawning time but belonging to separate local population (Limborg et al. 2012; ICES 2009). The method for separation of the herring stock components has developed during the past decades. Prior to 1996, the splitting key used by ICES was calculated from a sample-based mean vertebral count. In the period from 1996 to 2001 splitting keys were constructed using information from a combination of vertebral counts and otolith microstructure methods (ICES, 2001). From 2001 and onwards, the splitting keys have been constructed solely using the otolith microstructure method which uses visual inspection of season-specific daily increment pattern in the larval centre of the otolith (ICES, 2004; Clausen *et al.*, 2007). The method was validated by Clausen *et al*. (2007) and the study showed that the method can discriminate herring with different spawning times, even when a sympatric existence of herring with different spawning times is the case (Brophy and Danilowicz 2002, 2003, Bekkevold *et al.*, 2007).

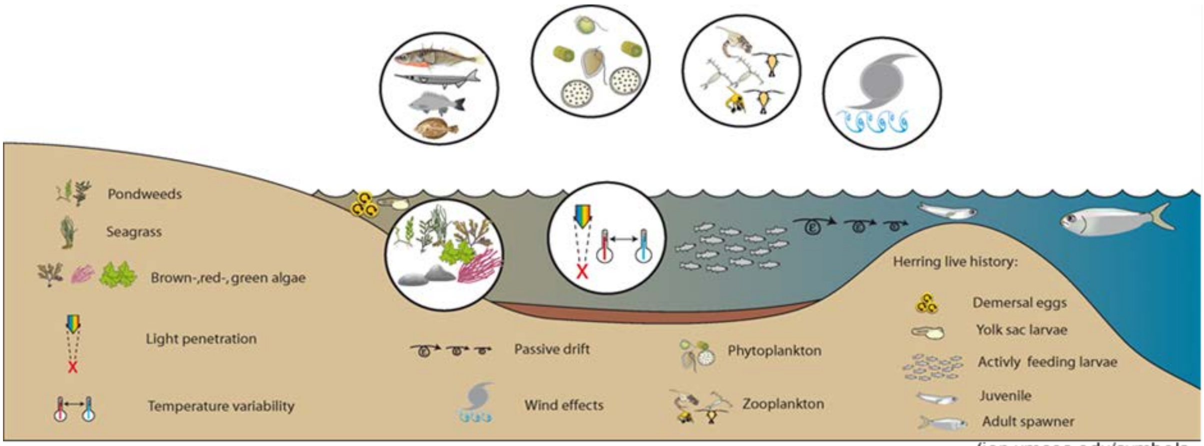
Conclusively; Morphological, genetic and acoustic analyses show that herring in the Western Baltic (here defined by the entire transition zone between the North Sea and the Central Baltic Sea) display stock structure and stock specific migration behaviour. Sub-structure is mainly upheld in connection with spawning, as different sub-stocks mix extensively on feeding and wintering grounds. Neighbouring spawning-stocks are generally genetically more closely related with each other than more distant stocks. However, discontinuities in genetic patterns occur; mainly where environmental conditions change abruptly, suggesting a role for local adaptation in shaping differentiation among sub-stocks. This implies that potential loss of locally adapted populations is expected to affect overall stock recruitment, as immigrants may be less successful at completing life cycles, compared to native stocks.

Early life history ecology of WBSS Herring –case studies 2010 to 2013

The annual Ruegen herring larvae survey and the resulting N20 larval herring index provides a reliable tool for WBSSH stock assessment purpose (see WD 08) and an important baseline for detailed investigation of spawning- and recruitment ecology of Western Baltic spring spawning herring. However the causes for the observed recruitment variability along the N20 time series and the general downward trend of recruitment success from the 1990’s to the early 2000’s remain yet unknown. Since monitoring data bear limited potential to investigate the driving mechanisms that cause major larval mortalities. Identifying those mechanisms must widely remain subject of directed case studies including approaches of adequate hypothesis testing. However, time series analysis can greatly assist with basic mechanistic research by e.g. identifying survival bottlenecks focusing research on significant life stages and environmental conditions and by generating focused hypotheses as a sound basis for experimental and modeling approaches or combinations of both.

To understand the major bottlenecks of early life stage survival, the suite of determining variables driving differing life stages of early ontogenetic development must be investigated (Fig 1.). Since WBSS herring relies on inshore, transitional waters for spawning and larval retention, the suit of environmental drivers of reproduction success potentially differs from other North Atlantic stocks recruiting from coastal shelf spawning areas.

To address various questions on early herring life history ecology, several supplementary samplings were integrated into the Ruegen herring larvae survey (WD 08) during recent years. The scope of this paragraph is to present a compiled overview on the results of case studies recently conducted on Ruegen herring ecology.



(ian.umces.edu/symbols)

Figure 1. Diagram including potential drivers of WBSSH production in transitional waters of the Baltic Sea. A suite of multiple variables might drive reproduction success while composition of major influences might differ between years.

Supplementary samplings and investigations accompanying the RHLS during recent years included systematic data collection and experimentation along the early herring life cycle on spawning substrate composition and distribution (Hammer et al. 2009), herring egg predation, effects of storm events on egg mortality, larval herring nutrition and larval dispersal by prevailing wind drift.

Selected case studies conducted during the period 2010 to 2013 and widely funded by the Femern Bælt A/S Science Provision Project are compiled below:

Survival bottlenecks in the early ontogenesis of Atlantic herring (*Clupea harengus*, L.) in coastal lagoon spawning areas of the Western Baltic Sea

P. Polte, P. Kotterba, C. Hammer and T. Gröhsler (submitted)

Although knowledge on crucial variables affecting larval herring survival increased since the latest stock collapse in the 1970's, the understanding of particular mechanisms of early herring life history mortalities are still a major task of fishery science in the North Atlantic Ocean. Dominant drivers of larval survival and year class strength of recruitment are basically considered to be linked to oceanographic dispersal, sea temperatures and food availability in the critical phase when larvae start feeding actively. However, research progress on larval herring survival dynamics indicates that driving variables might not only vary on population level and region of spawning grounds but also include a suite of multiple factors acting on differing larval developmental stages. Hypothesizing that in inshore systems of the Western Baltic Sea bottlenecks of herring development occur prior to the point of first feeding, we analyzed an extensive time series of weekly ichthyoplankton samples in respect of the abundance of early stage larvae in Greifswald Bay, a major spawning ground of Western Baltic spring spawning herring. Additionally we investigated whether distinct hatching cohorts contribute differently to two established survival indices on the level of i) surviving larvae in Greifswald Bay (*N20 larval index*) and on the level of 1+-group juveniles (*1-wr- index*) in the overall Western Baltic Sea. Results reveal that abundances of the earliest larval stage explain 62 % of the variability of later stage larvae and 61 % of the variability of surviving juveniles indicating pre-hatching survival bottlenecks. Additionally our findings demonstrate that hatching cohorts occurring later during the spawning season contribute most to the surviving year class whereas earlier hatching cohorts not result in significant growth and survival indicating an additional bottleneck at the critical period when larvae start feeding. Locating these survival bottlenecks in shallow inshore spawning areas will provide a sound baseline for explicit analyses investigating survival mechanisms in coastal lagoons of the Baltic Sea.

Resident estuarine predator community controls herring recruitment success

Kotterba, P.; Hammer, C. and Polte, P. (in prep.)

Interactions between oceanic fish species and resident estuarine fish communities are often neglected in research facing the recruitment success of an oceanic species. Nevertheless, many species inhabiting the pelagic oceanic system enter transitional waters periodically for reproductive purposes. In order to quantify the potential effects of local predators on these migrating species, we used the Western Baltic herring as an example of a pelagic species entering the shallow estuary-like lagoons in spring for spawning and the local fish community mainly dominated by the three-spined stickleback. Predator exclosure experiments were performed to quantify direct predation effects on the density of deposited herring spawn. In total, four different experiments were performed in the field during the spring spawning period of herring in 2012. The first three experiments used natural spawning substrate while the fourth experiment was based on a newly developed design using artificially spawned experimental units (ASEU).

For the experiments with the natural spawn substrate, a van-Veen Grabber sampling was used to estimate the spawn density prior and after the experiment. The herring spawn was then either protected against predators with a cage of fine mesh or left unprotected. An experiment artefact control was set up, consisting of a cage without side walls of net. Each treatment was replicated six times, the exposure time varied between the experiments (5 to 10 days). The experiment using ASEUs was set up to reduce the sampling error of natural substrate caused by patchy distribution of macrophytes and herring spawn. Flower pots were used as artificial substrate for herring spawn which was received from ripe and running herring caught with gill nets. The units were transferred to the field, fixed at the sea bottom exposed to the local predator community for three days. As in the exclusion experiments, the units were either protected by fine mesh cages or unprotected or treated with an artefact control. An additional treatment was used consisting of empty plant pots in order to control the effects of possible new spawning events which could otherwise mask predation effects. The density and condition of herring eggs on the experimental units was analysed using predefined subareas and imaging software.

For every experiment, ambient conditions were recorded including hydrographical measurements. The density and the composition of the local predator community were estimated using standardised beach seine catches and time lapse camera records.

We found a significant reduction of herring spawn at the unprotected ASEUs of 75% within a period of only three days. These findings prove that predation on herring spawn can have a crucial effect on the survival of herring eggs. The predator community during the experiments was mainly composed of *Gasterosteus aculeatus* and juvenile *Perca fluviatilis.*

Pairwise analysis of pre-and and post exposure ASEU sub-areas resulted in the relation between initial egg density and the percentage spawn consumed by predators. In conclusion it could be shown that higher spawn densities induce a higher egg mortality caused by predation.

Distinct spawning waves of Herring are differently affected by spawn predators

Kotterba, P.; Hammer, C. and Polte, P. (in prep.)

An overlap between a predator and its prey is the fundamental premise for significant predation effects on the prey population. The overlap can be determined by different spatial and temporal patterns e.g. habitat preferences and seasonality. The latter might be the factor characterising the trophic interaction between the Atlantic Herring entering the estuarine systems of the western Baltic Sea periodically for spawning and the resident fish community feeding on the herring spawn.

In order to analyse the temporal overlap between the three-spined stickleback (*Gasterosteus aculeatus*), which appears to be the dominant species in many Baltic estuarine systems, and herring spawn, we established fixed transects in a major spawning ground of Western Baltic Herring and analysed the weekly herring spawn density and predator abundances between March and June 2012. Prior to the definition of the fixed transects, a video transect campaign was conducted to monitor the macrophyte density and composition in our study area.

Based on these results, at two spawning beds each, three transects were established at different depths and macrophyte assemblages. The flora composition was dominated by pond weeds (*Pomatogeton spp*.) at the shallowest transect while eel grass (*Zostera marina*) was dominated the lower littoral zone. The transects in the intermediate littoral zone were characterised by a mixed macrophyte composition. The stickleback density was estimated using standardised beach seine catches, while a representative subsample of the haul was frozen for later stomach content analyses. The ambient hydrographical parameters were recorded for each transect. Additionally, fixed temperature loggers were established at different depth at the spawning beds in December 2011.

Although sample processing has not been concluded yet, we observed spawning to occur in distinct waves within the period between March and June. Stickleback abundances were relatively low during the early spawning wave in March but increased drastically in mid- April. Preliminary results reveal that later spawning waves are significantly more affected by spawn predators than early ones.

Temperature dependent digestion of herring (*Clupea harengus*, L.) eggs by the three- spined stickleback (*Gasterosteus aculeatus*, L.)

P. Kotterba, C. Hammer, C. Kühn and P. Polte (in prep.)

Trophic interactions between predators and prey are influenced by numerous factors, while the actual predator-prey overlap is generally accepted to be the controlling aspect in most of these relations. On the other hand, in cases where the prey is not limited, the predator's consumption of a prey is controlled by its capability of handling and digesting the prey organisms. An example for the latter situation can be observed during the spring spawning period of Ruegen herring in the shallow lagoons of the Western Baltic Sea. The amount of spawn deposited on the spawning beds leads to an *ad libitum* availability of herring eggs for the resident predator community which is dominated by the three spined stickleback *Gasterosteus aculeatus*.

In order to estimate the amount of herring spawn that can potentially be consumed by sticklebacks, we conducted a standardized laboratory experiment at different ambient temperatures. We collected sticklebacks from the Greifswalder Bodden, a major spawning ground of Western Baltic herring. Fishes were transferred to 300 l tanks and adapted to different temperatures (11 and 15°C) for at least 72 h. During the adaptation time, the fish were not fed to assure empty stomachs at the beginning of the experiment. For each temperature applied, four replicate tanks were used each containing 100 sticklebacks. Prior to the experiment start, five fishes were sampled from each tank to estimate the biomass of mucus in the empty stomachs. The sticklebacks were then fed for one hour with an *ad libitum* amount of herring spawn. Directly after feeding, another five fishes were sampled from each tank and the remaining food was removed from the tanks. Until 12 h post feeding, a sample of five fishes was taken every hour and the remaining fishes were sampled after 24 h.

The preliminary analyses showed a strong temperature dependence of both, initial stomach content directly after feeding and the digestion rate. At both temperatures, after 4 hours 30-40 % of the prey was already digested. After 12 hours, 80% was digested at 15 °C and 50 % at 11°C.

If compared to other prey specific digestion rates (e.g. Rajasilta 1980: consumption of Daphnia and other invertebrates), it appears that herring spawn was digested more slowly (at least at 11 °C) than other food analysed in other studies. That implies that for trophodynamic modelling, not just predator specific digestion must be considered but also prey specific consumption rates.

Influence of storm induced turbulence on Ruegen herring egg mortalities

D. Moll, P. Kotterba and P. Polte (in prep.)

Strong winds can evidently harm shallow water spawning beds (Hourston & Rosenthal 1976). At wind forces of 4 bft eggs in a depth up to 2.5 m can be impacted by turbulences. Wind forces from 8 bft on lead to wave action and hydrodynamic forcing down to a depth of 6 m and induces heavy losses of spawning substrate during storm events. The littoral area of Greifswalder Bodden, includes substantial herring spawning beds located shallower than 2m water depth (Hammer et al. 2009). There, spawning Ruegen herring attach their demersal eggs predominantly to macrophytes such as pond weed (*Pomatogeton spp*.) and eelgrass (*Zostera marina*). Those rooted, flowering plants (as opposed to marine algae) form extensive beds in the littoral zone where they are dominated by pond weed stands in the upper zone down to ca. 1.5m and dominated *by Z. marina* below to approximately 3.5m (Munkes 2005). In this study, particularly the shallow pond weed spawning beds were considered extremely exposed to storm induced turbulence. However, immense egg losses caused by storms are only anecdotally reported in the area. During the 2012 spawning season, two fixed index transects were sampled weekly for egg densities on geographically opposite locations in NW and SW Greifswalder Bodden respectively. Once these data are processed, they will provide a suitable background to quantify egg loss caused by an extensive storm period during the major spawning peak in late April. Preliminary data gathered by systematical sampling of beach litter after the storm revealed a total of 118 million herring eggs attached to a dry weight of 904 kg macrophyte litter on an investigated beach stretch of 570m length. The observed egg mortality is considered to be underrepresented since part of the macrophyte litter was continuously transported by the storm and sampling took place a day after the storm passed. The effect of single storm events on herring reproduction in the spawning areas and on the recruitment of the entire WBSS stock is presently unknown. However, further analyses of data sets received by this case study will provide a first quantitative estimation local storm effects on Ruegen herring reproduction.

Abundance of early herring (*Clupea harengus*, L.) larvae in the littoral zone of inshore lagoons in the Western Baltic Sea

S. Beyer, P. Kotterba and P. Polte (in prep.)

Studies on marine ichthyoplankton dynamics particularly on early life stages of pelagic fish, such as herring are generally focused on outer shelf bank spawning areas where larval dispersal and survival is widely subjected to large scale oceanography. Larval herring of Atlantic sub-populations spawned in shallow inshore lagoons of the Baltic Sea develop in a quite different suite of coastal habitats than their shelf bank spawned counterparts in the neighboring North Sea, known for sensitive responses to climate patterns (e.g. Fässler et al. 2011). Hypothesizing that herring larvae hatched in the littoral zone of shallow brackish lagoons avoid the increased temperatures in the littoral zone during further development, we sampled pelagic and littoral sites in a major spawning ground of Western Baltic spring spawning herring using a combination of benthic sledge and horizontally towed plankton nets. Despite escalating temperature increases in the littoral zone above 4 m depth, the results of this study revealed considerable larval abundance in topographically different shore zone habitats. However, in general larval numbers did not exceed abundances found in the pelagic zone. In the littoral zone, site specific topography however was found to structure larval abundance along the littoral depth gradient from the zone shallower than 1 m to that shallower 3 m. At the site with a steep littoral gradient, more larvae were found occurring in very shallow waters of the upper littoral zone, whereas larvae occurred mainly between 2 and 3 m at a site characterized by an extensive vegetated sand shoal. Among varying size classes of larval pre-flexion stages there was no particular stratification according to littoral depth gradients or pelagic and littoral sites. However, early hatchlings at the yolk-sac stage were predominately found in the deeper zones of the littoral zone below 2 m water depth. This study implicates that ichthyoplankton research in sheltered near-shore ecosystems should take into account potential qualitative ecological functions of littoral habitats for dispersal and survival of larval fish. However, quantitatively, in respect of larval numbers, shallow littoral habitats are not considered as a significant bias in pelagic larvae surveys.

Vertical distribution of Herring Larvae in the Greifswalder Bodden

J. Heiler, C. Hammer, P. Kotterba and P. Polte (Inform. Fish. Res., 59: 25-29, in Germany)

Larvae of the Western Baltic Spring Spawning Herring were sampled in the Greifswalder Bodden in the framework of the Ruegen herring larvae survey to investigate whether they are homogeneously distributed throughout the vertical water body. Previous research assumed homogeneous vertical distribution because of the shallowness of the Greifswalder Bodden and due to evident hydrographical mixing of water in respect of temperatures, salinity and dissolved oxygen contents. Two null hypotheses were tested, one which presumes homogenous vertical distribution of herring larvae and another which presumes even vertical distribution within different larval length classes in the Greifswalder Bodden. Sampling took place at three different stations in the Greifswalder Bodden during April and results showed significant differences of larval abundances between the sampled depths and also significant differences of the length classes between the sampled depths. Therefore both null hypotheses can be rejected and a homogeneous vertical distribution of the herring larvae in the Greifswalder Bodden can be excluded. These findings provide an important base line for future studies and bear implications for future studies on predator-prey overlap and development of hydrodynamic distribution models.

Recruitment failure of Western Baltic Spring Spawning Herring – is it caused by food availability for the larvae?

J. Hesse, C. Hammer, G. Winkler, C. Zimmermann, D. Stepputtis and C. von Dorrien (in prep.)

The recruitment (n20-index, i.e. index of abundance of 20mm larvae) of the spawning stock biomass of the Western Baltic Spring Spawning Herring (WBSS) declined between 2004 and 2008 annually by 15-35% and reached a historical low in 2008. In 2009 however, the recruitment reached again the average of the time series. Approximately 80% of the WBSS migrates into the Greifswalder Bodden (GWB), an estuary at the German coast for spawning in a typical retention area from early March into June. It was hypothesized that the zooplankton density and compositions in the years 2008 and 2009 were different causing different recruitment in both years. The density and composition of the zooplankton and the stomach content of the herring larvae were analyzed and it was found that in 2008 the density of nominal prey items was 70,000-80,000 ind.*m^{-3} and about half of what was available in 2009. An extensive literature comparison shows that there are great differences in the field prey concentrations for herring larvae of different stocks and regions. Apparently herring larvae of different stocks survive at far lower prey densities as found in the GWB in 2008. For the WBSS a density of about 200,000 ind.*m^{-3} seems to be optimal. The nominal zooplankton consisted predominantly of *Acartia* developmental stages and adults, and in addition to a small extent of *Eurytemora* and cyclopoid copepod developmental stages and adults. It was found that Cyclopoid copepods were positively selected. It is concluded that the high Acartia-nauplii density during two weeks in 2009 might have caused the recruitment success in 2009 but that the lower densities in 2008 are not necessarily the cause of the failure in 2008.

Nutritional situation for larval Atlantic herring (*Clupea harengus*, L.) in the western Baltic Sea

M. Paulsen, C. Hammer, A. M. Malzahn, P. Polte, C. von Dorrien and C. Clemmesen (ICES JMR, accepted)

The Greifswalder Bodden (GWB) is known as the most important nursery area for the Western Baltic spring spawning herring. However, reasons for this dominance are missing. Therefore we investigated larval growth conditions in the GWB and Kiel Canal (KC). We investigated prey quantity and quality (copepod abundance and essential fatty acid (EFA) content) as well as biochemically derived growth rates along with fatty acids of larval herring in spring 2011. A significant correlation between larval growth and larval EFA content could be observed in the GWB. The highest growth rates and EFA contents in the larval herring coincided with high food quality. Compensating effects of food quality on food quantity and *vice versa* could be observed in the GWB and the KC alike, leading to constant growth rates of larval herring in both cases. While larval growth rates in the KC were high early in the season, highest growth rates in the GWB were achieved late in the season. In conclusion, none of the areas was superior to the other, indicating similar growth conditions for larval herring within the region.

Essential fatty acid (docosahexaeonic acid, DHA) availability affects growth of larval herring in the field

M. Paulsen, C. Clemmesen and A. M. Malzahn (Marine Biology, accepted)

Larval fish growth and survival depends not only on prey quantity, but also on prey quality. To investigate effects of fatty acids on larval herring growth we collected different prey organisms and larval herring (*Clupea harengus* L.) in the Kiel Canal during the spring season 2009. Along with biotic background data we analysed fatty acids in prey organisms and in the larvae as well as biochemically derived growth rates of the larvae as the response variable. Larval herring reached their highest RNA/DNA derived growth rates only at high DHA contents. When the ratio of copepodids to low quality cirriped nauplii was low, larval growth as well as their DHA content was significantly negatively affected. This was true even when food abundance was increasing. This finding indicates that even in mixed, natural feeding conditions growth variations come along with DHA availability in larval fish.

Wind induced variability in coastal larval retention areas: a case study on Western Baltic Spring-Spawning Herring

R. K. Bauer, D. Stepputtis, U. Gräwe, C. Zimmermann and C. Hammer (*Fisheries & Oceanography, accepted*)

The investigation of larval dispersal and retention, their variability and dependence on wind conditions, has become a major topic in fisheries research owing to potential effects on stock recruitment and stock structuring. The present study quantifies the wind-induced variability of larval retention of herring in a highly productive coastal lagoon of the Western Baltic Sea. This lagoon, the Greifswalder Bodden, represents the main spawning area of Western Baltic Spring-Spawning Herring, a stock that has recently undergone a continuous decline in recruitment. The study tests whether or not this decline was related to changes in larval retention, more precisely to changes in wind conditions, the main forcing of the lagoon's circulation. To answer this, a model approach was applied. Larvae were tracked as Lagrangian drifters under constant and variable wind conditions, ex-amining the main drift patterns and reconstructing the incidents during the period of recruitment decline. For the latter, weekly cohorts of virtual larvae were released in the lagoon over the entire spawning period (April–June; >16 w). The fraction of retained larvae per cohort was related to observed larval abundances. On this basis, a new retention index was defined to evaluate the annual larval retention. The results presented cannot explain the observed recruitment decline but characterize the lagoon as an important larval retention area by virtue of unsteady wind conditions that prevent a steady outflow of larvae.

Identifying Spawning Sites of Western Baltic Herring using a Particle Backtracking Scheme

R. K. Bauer, U. Gräwe, D. Stepputtis, C. Zimmermann and C. Hammer (in prep.)

The recruitment success of diverse herring stocks is subject to strong fluctuations, but appears often to be determined already during the early life stages. In order to investigate the recruitment and its affecting factors, particularly those during the egg stage, it is crucial to examine the processes at the spawning sites which, however, remain often poorly explored. A recent decline in the recruitment of Western Baltic spring-spawning herring (WBSSH) has increased the need to fill this lack of knowledge for this specific stock, especially since one bottle-neck in the recruitment seems to be located before hatching. Within this study, the specific spawning sites of WBSSH during 2003 and 2009 were examined within its main spawning ground, the Greifswalder Bodden lagoon. Instead of using common techniques such as diving operations and underwater-videography which are costly and seldom suitable to map larger areas, a model approach was applied. 6–10 mm herring larvae, recorded by larval surveys during March-June of the respective model years, were tracked back by a Eularian particle tracking model. Identified areas are compared with prior field investigations but also with respect to variations between years, sizes classes and different applied growth models which are needed to define hatching dates. Results indicate that larvae are caught in the vicinity of respective hatching sites, but show also a strong variability of successful spawning sites that may either reflect variations in the spawning site selection or changes in the spawning site quality.

GENERAL CONCLUSIONS & FUTURE PERSPECTIVES

Baltic Sea herring stocks are generally considered to rely on the productivity of particular regional spawning populations. Along the inshore-offshore gradients of Western Baltic watersheds, transitional waters, such as bays, lagoons and estuaries seem to represent significant areas for herring reproduction as i) important spawning grounds and ii) retention of early development stages.

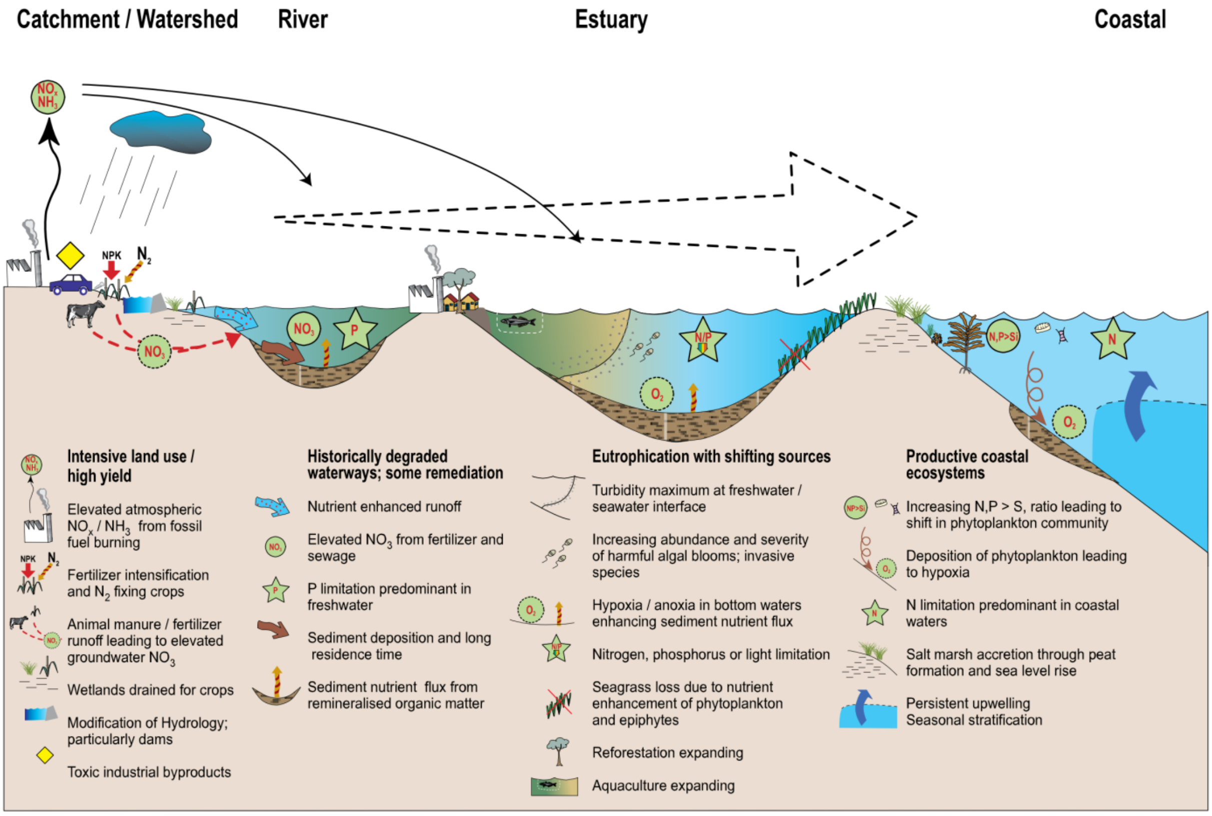


Figure 2. Shifts of environmental variables along a coastal gradient as composed by LOICZ –Land Ocean Interactions in the Coastal Zone, *Source:* IAN Science Communication Forum, *http://ian.umces.edu/loicz.*

To investigate differing scale effects on our perception of fish stock condition, it is essential to understand the contribution of individual habitats or coastal systems to the overall productivity of the Baltic Sea. For inshore spawning herring stocks, early life history bottlenecks might occur on a scale of individual bays and lagoons.

Along the coastal Western Baltic Sea those nursery areas might be of differing quality as juveniles exported might contribute in varying quantities to the adult stocks (definition of "nursery area" in Beck et al. 2001). Hence, it is a major challenge to quantify the role of small- and meso scale drivers and stressors for overall recruitment strength. Ruegen herring is considered a significant component of the spring spawning herring stock in the Western Baltic Sea. A mechanistic understanding of the effects of local events on early stage mortalities on the overall WBSS recruitment, however, is rather limited. Case studies on basic herring early life history ecology as outlined above help identifying the suite of potential causes of egg and larval mortalities on the major spawning grounds. These local stressors include e.g. egg predation by sticklebacks that heavily feed on herring spawn, a highly fluctuating physic-chemical environment in the shallow transitional waters and single storm events causing drastic losses of herring eggs by devastating macrophyte spawning beds.

However, consequences of local mechanisms on larval survival might potentially be compensated by the number and diversity of spawning sites along coastal gradients (Fig.2). The rationale in hypothesizing cascading scale effects is supported by current WBSSH recruitment time series and the relationship of indices derived on differing spatial scales. The larval recruitment index annually derived by the number of herring larvae generated by the particular Ruegen Island inshore system (Greifswald Bay) is considered to reflect recruitment patterns of the Western Baltic spring spawning stock. This implies a relation between larger scale recruitment success and regional survival bottlenecks. On the other hand the N20 time series of herring recruitment strength provides a sound background to test the magnitudes of regional effects on the overall WBSSH stock.

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Maturity at age in the WBSS herring

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Motivation of the study and background

The current assessment of the Western Baltic Spring Spawning (WBSS) herring stock is based on the use of a fixed maturity at age vector applied throughout the whole time period covered by the assessment (i.e., 1991-2011; ICES 2012/ACOM:06). A mean maturity at age was applied since 1991 (ICES CM 1992/Assess:13) based on the following proportion of mature fish at age: age0-1 (0%), age2 (20%), age3 (75%), age4 (90%), age5+ (100%). Some investigations on the maturity ogives were presented in the past during the HAWG meeting in 2002 and 2004 (WD Gröhsler and Müller 2002 and 2004). Those results suggested that the maturity ogives of WBSS may have a significant interannual variability, and there were indications that the age groups 2 to 4 may be generally overestimated. However the lack of conclusive results prevented from modification of the fixed maturity ogive assumption. As observed in a number of other fish species, including gadoids and flatfish, the assumption of fixed maturation time may be violated, with important consequences for the estimation of stock reproductive potential and spawning stock biomass. For this reason, we analysed all the available survey data on WBSS herring maturity, to investigate temporal variations in the maturity schedule of this stock that could be included in future assessment.

During the IBTS Q1 and Q3 a large number of herring have been consistently sampled for age, sex and maturity in the Kattegat and Skagerrak (ICES Subdivision 20-21). This represents an enormous amount of information for the estimation of maturity of herring in the area. We have to recognise that the IBTS data have important limits for the estimation of maturity at age of the WBSS herring because sampling does not cover the whole distribution of the stock, and in particular does not occur in the main spawning areas. Other important limits concern the mixing of the North Sea Autumn Spawning (NSAS)

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and WBSS herring stocks which is known to occur in the Kattegat and Skagerrak, and that may represent a confounding effect and source of uncertainty in our estimations. In favour of the IBTS data we have to consider that samples from Q1 cover the pre-spawning period which is considered ideal for estimation of maturity. Moreover, considering the migration patterns of NSAS and WBSS herring, mixing is expected to occur mostly with juvenile NSAS and not with the adults NSAS.

Here, we specifically investigated the possibility to use IBTS Q1 dataset to estimate maturity at age of WBSS.

Data

The data used in the present investigation have been yearly collected in the 1^{st} quarter of the each year during the International Bottom Trawl Survey (IBTS). Each ICES statistical rectangle (1.0 degree longitude x 0.5 degree latitude) is usually fished by the vessels of two different countries, so that typically, at least two hauls are taken per rectangle. However, the Kattegat and Skagerrak areas represent an exception as only Sweden is sampling in those two subdivisions (SD20 and 21), with an average of about 45 hauls per quarter per year. The gear used is a demersal trawl and haul duration is approximately 30 min. From each haul the catch is sub-sampled for collection of biological parameters, namely length, age, sex and maturity. In agreement with the IBTS manual (available at http://www.ices.dk/products/SurveyProtocols/SISP1-IBTSVIII.pdf) a minimum of 8 specimens are collected per 0.5 cm length class. In total, more than 20,400 fish have been sampled for age, sex and maturity in the IBTS Q1 conducted in the Kattegat and Skagerrak (SD20-21) during the time period 1991-2011. Maturity data are based on macroscopical gonadal inspection and designated with a number in the range 1-4 (immature, maturing, spawning and spent; ICES 1996) or 1-8 (1-2 immature, 3-5 maturing, 6 spawning, 7 spent, 8 recovering). The 1-8 maturity scale has been regularly used except in 1993 and 1994 when the 1-4 maturity scale was adopted. For each individual, maturity was treated as a binomial event, considering mature those individuals ranked as maturing or higher, and immature all the others.

In addition to maturity, two important information were considered in our analysis. They include information on individual vertebral count, and information on stock origin as derived from otolith inspection.

Vertebral number in fish species is generally not fixed. Variability is known to be related to diversity at a stock level, and to environmental conditions (particularly temperature) experienced during the early phases of larval development. Between 1991 and 2002 (1993-1995 excluded) a number of 8,635 fish were randomly selected from the IBTS samples their vertebrae counted.

Since 2002 a number of 50 otolith per age class (ages 1, 2, 3, 4+), ICES subdivision and quarter, were randomly sampled and examined further for stock identification. The analysis separates three groups of herring, i.e. autumn, winters and spring spawners. In order to differentiate the spawning type, the center of the otolith needs to be looked at. To be able to see the increments the otolith is grinded using different polishing papers. The center of the otolith is subsequently observed under a stereomicroscope for assessing the spawning type. Spring spawners are identified by their wide and clear increments, which rapidly increase close to the center. The spring spawning herring is often from Rugen in the northeast Germany. Also the otoliths belonging to the so called local stocks from the fjords show a series of narrow, but high contrast rings close to the centre followed by a sudden increase in rings width. Autumn spawners are identified by their thin, narrow increments. The otoliths display low contrast in opacity between dark and light rings. A barcode-structure is very often discernible. This is a small area where the increments are tight, about 200 micron from the center. Winter spawners show higher contrast between dark and light rings. The otoliths display regular ring pattern with increasing distance between the individual rings. Like in autumn a very even pattern is evident. After about 200 microns wide high-contrast rings are often very evident.

Outcomes

Data from Q1 in the Kattegat-Skagerrak (SD20-21) were used to evaluate the impact of mixing between Autumn, Spring and Winter spawning herring (here referred as NSAS, WBSS and local winter spawners) on the estimation of maturity at age of the only WBSS.

During the year 2002, both vertebral count and stock identification via otolith examination were conducted on herring samples from IBTS. This offered an excellent opportunity to look at the possibilty to calibrate the two techniques and eventually use the number of vertebrae to discriminate different stocks of herring with the purpose of maturity at age estimation, also for the period before 2002. Distribution of vertebral counted in fish identified as WBSS, NSAS and winter spawning herring show extensive overlap (Fig. 1). This suggests poor resolution in the vertebral count as mean to discriminate WBSS from NSAS and local winter spawning populations.

The relevance of the different stocks on the age composition of the catch from the survey was inspected from 2002 onwards, when otolith based stock identification was available (Fig. 2). NSAS herring occur mostly in ages 1-3, with progressive reduction of their relevance from age 1 (dominated by NSAS) to age 3 (dominated by WBSS). As expected most of the NSAS herring examined were immature (result not shown). Variations in

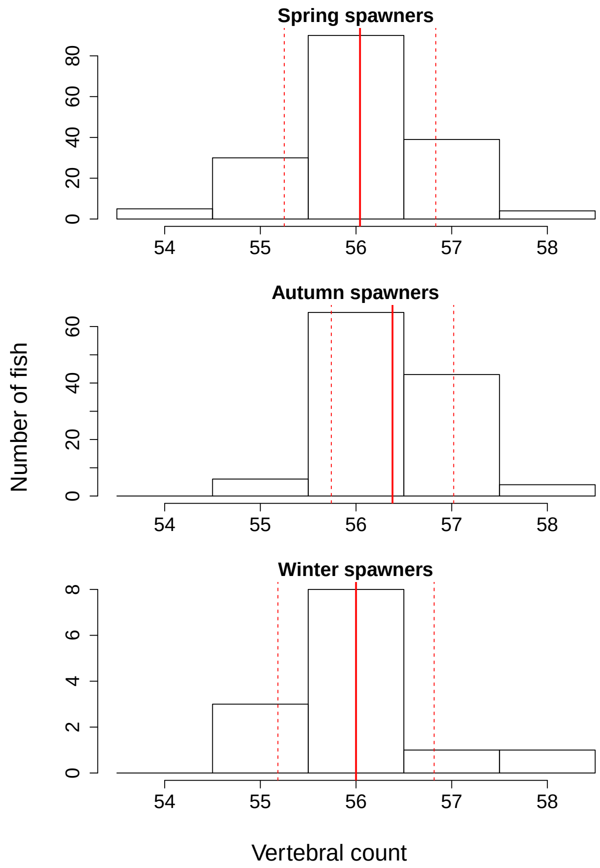

Figure 1: Number of fish by vertebral number and stock (stock discrimination based on otolith) for the year 2002 from IBTS Q1 SD20-21 data. Mean and standard deviation of the distribution are shown as continuous and dotted red line respectively.

the relative importance of NSAS and WBSS were observed mainly for age 1 and age 2. Moreover, it is important to notice that the relative contribution of the winter spawning herring populations to the mixed aged structure was minor for the whole time series of data (Fig. 2), mostly due to the small size of these local stocks compared to the WBSS herring population.

Finally, we investigated the effect of stock mixing on the estimation of maturity at age of WBSS. Fish identified at the stock level, were used to compute the proportion of mature fish at age. Calculation of the proportion of mature fish at age was done for the only WBSS, for the combined WBSS + NSAS, and regardless their stock of origin (i.e., WBSS + NSAS + winter local spawners). Results are shown in Figure 3.

Estimation of proportion of mature at age 2 for the only WBSS herring shows an interesting temporal pattern. In 2002, the proportion of mature age 2 WBSS was estimated to be 0.1. A progressive increase of this proportion was observed from 2002 up to 2008 when it reaches the value of 0.57, then followed by a decrease with a final value of 0.23 in 2011.

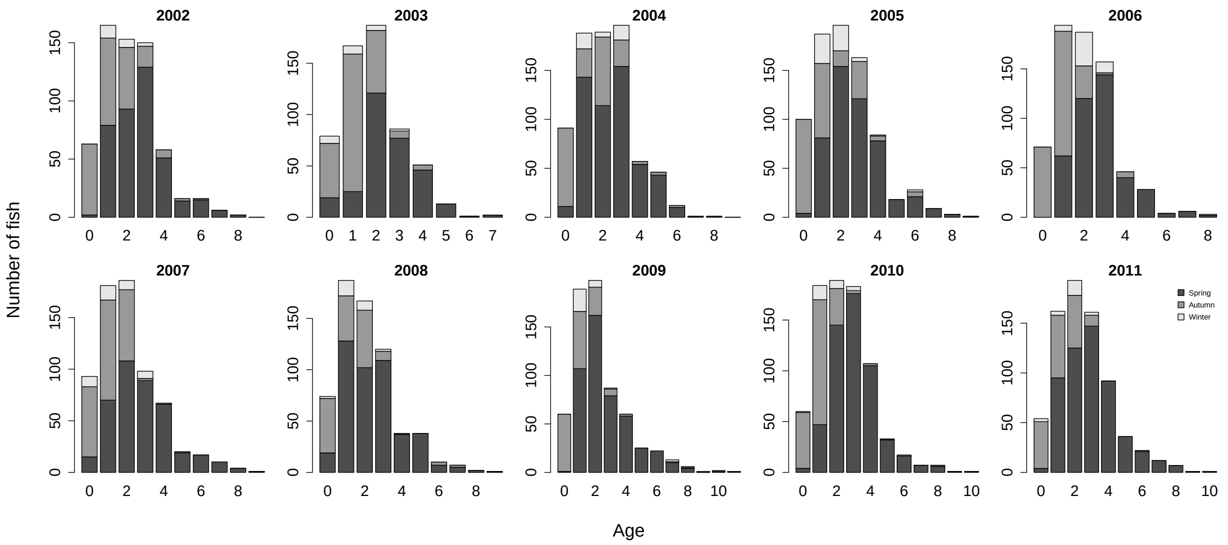

Figure 2: Number of fish by age and stock (stock discrimination based on otolith) for the period 2002-2011 from IBTS Q1 SD20-21 data.

As expected the winter spawning populations have a minor negligible contribution on the estimation of the maturity ogive. On the contrary, mixing with NSAS affects mosly the estimate of the proportion of mature fish at age 2, and in some years also age 3. No relevant differences on the estimation of the maturity at age were observed for age 1 (all immature fish), and age 4 (mostly mature, and in any case characterised by low occurrence of NSAS fish).

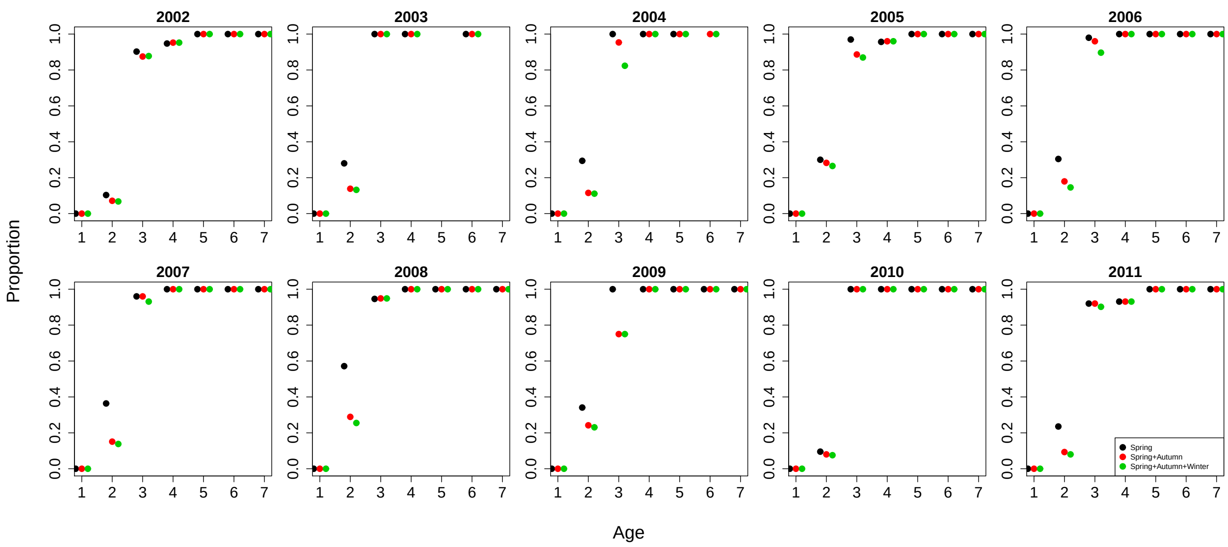

Figure 3: Proportion of mature at age of herring calculated for the only WBSS, and for the mixed stocks (NSAS and winter spawners), for the period 2002-2011 from IBTS Q1 data in SD20-21.

These results suggest that stock-mixing may represent a relevant issue in the estimation of proportion of mature at age WBSS herring due to the confounding effect of immature NSAS in the Kattegat (SD 20) and Skagerrak (SD 21) area. I particular, mixing with NSAS tends to inflate the proportion of immature age 2 fish in the IBTS mixed sample, but in some years also age 3 (i.e., 2004, 2005, 2009), resulting in underestimation of the proportion of mature herring. Before 2002, the lack of information on stock identification and the confounding effect of stock mixing prevent the estimation of the correct proportion of mature at age for the only WBSS herring.

Conclusions

The available survey data on herring maturity are representative of the pre-spawning period for WBSS, but do not sample the whole distribution of the stock during that time of the year. In particular, during the 1^{st} quarter of the year large part of the mature WBSS have left the Kattegat and Skagerrak areas, and can be found in the western Baltic which is not sampled by the IBTS survey. Moreover, we found that mixing between WBSS, NSAS and local winter spawners represents a relevant issue for correct estimation of maturity ogives of WBSS. Before 2002, no information on stock identification is available from the IBTS data, and it is not possible to account for the cofounding effect of stock mixing before this period. We found that information from vertebral count is not of help in this respect. Beside the existence of an interannual variability in the proportion of mature at age from IBTS data, which may be expected to have a high influence on the estimation of the spawning stock biomass of WBSS, it is not possible for the time being to reconstruct a time variable maturity ogive representative of the whole WBSS herring stock and for the whole time period covered by the assessment.

Historical landing data

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Motivation of the study and background

The status of marine fish stocks is generally evaluated against established baselines often referred as biological reference points. The study of historical trends of fish abundance is recognized as crucial elements for the estimation of biological reference points used for the long-term sustainable management of exploited fish populations (Jackson et al., 2001; ICES, 2007). Beside this, the assessment of most of the exploited fish stocks in the North Atlantic is usually based on information covering the last few decades only, and thus including populations already heavily exploited (Pinnegar and Engelhard, 2008).

The assessment of the Western Baltic Spring Spawning (WBSS) herring stock is based on data from 1991, and everything before this year may be considered historical within this context. We investigate the availability of commercial landing data of herring and biological data from commericial sampling in the area covered by the distribution of WBSS herring stock.

Data

Official landing statistics from 1950 have been retrieved from the ICES database $http://www.ices.dk/fish/CATChSTATISTICS.asp$ and scrutinized for their consistency in the temporal and spatial coverage in the area of interest for the WBSS herring, which include the ICES Subdivisions 20-24. Landing data are characterized by two intrinsic levels of quality, as the database was initially constructed for the period 1973-onwards, and then extended back in time to the period 1950-1972. The data represent the nominal commercial catch (live weight equivalent of landings in tonnes, excluded discards). Data are organized in the database according to the following fields: Country, Year, Species, Catch, Division.

We inspected the SLU database for biological samples of commercial catch of herring collected by Sweden in the Kattegat, Skagerrak and western Baltic (SD20-24) since 1980s. Electronic data prior 1990s were only available from 1986, moreover they were too few and sparse, and we decided not proceeding with further inspection for the purpose of evaluating historical information (Fig. 1).

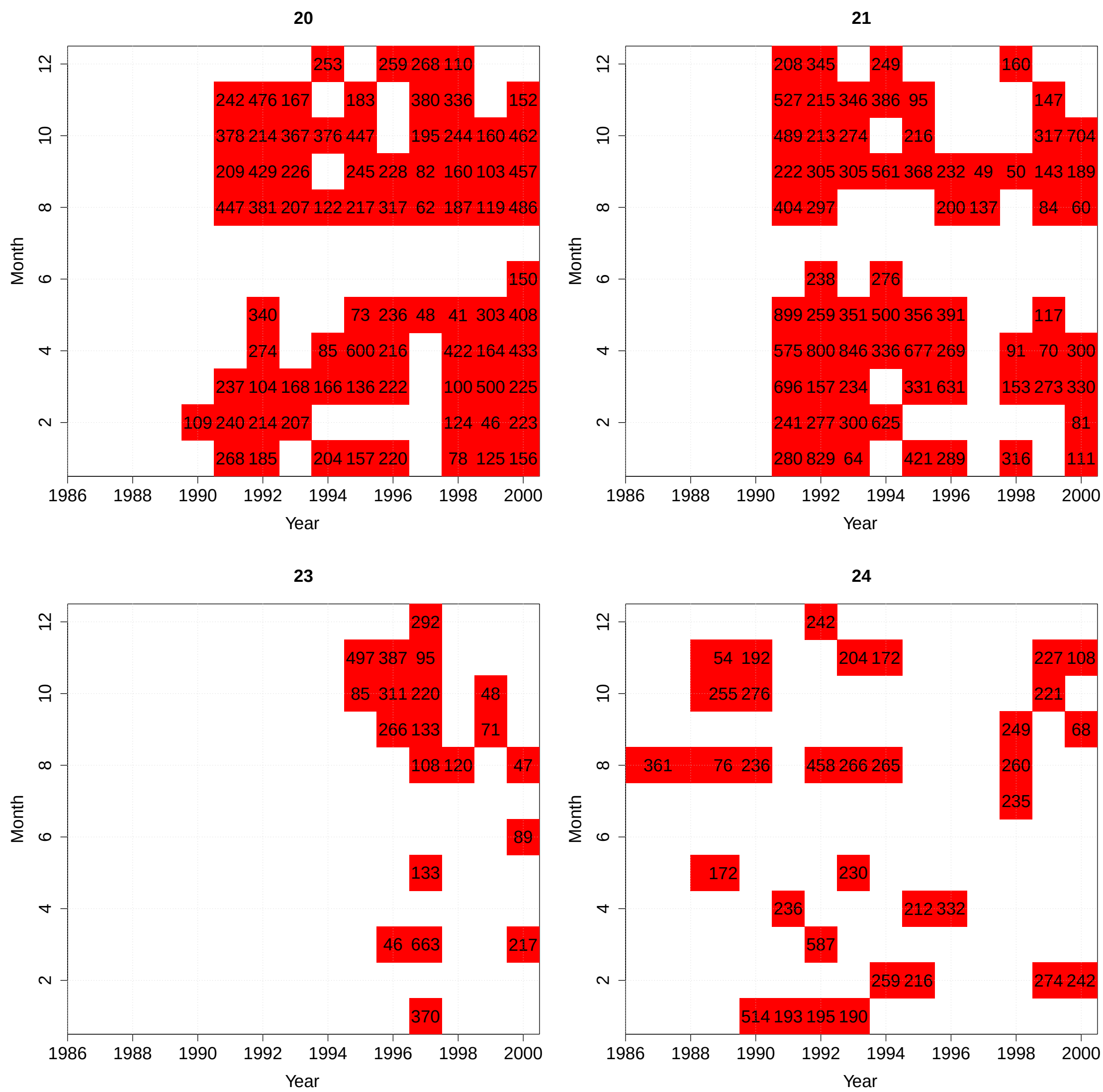

Figure 1: In red is the distribution of the biological commercial samples with the number of fish collected by year, month and ICES subdivision from 1986 to 2000.

Results

The detail of information on the fishing area (IC division) reported in the landing statistics of herring is changed along time. Particularly in the early years, information on the the fishing areas has not be recorded as detailed as in the current ICES system. We found that during the 1960s and 1970s large part of the landings of herring are not disaggregated among the different ICES subdivisions of the Baltic (IIId = SD24-31). Similarly, part of the landings from Kattegat (IIIa 21) and Skagerrak (IIIa 20) are merged with landings from the North Sea (IV) (Fig. 2). Only from the end of the 1970s-early 1980s, landings from the SD24 in the Baltic are separated from the rest of the Baltic herring landings. Approximately from the same period also the landings from the central and western part of the North Sea are separated from those from the eastern North Sea, Skagerrak and Kattegat (Fig. 2 and 3).

The landings of herring in the study area (regardless the stock of origin, hence including North Sea Autumn Spawners (NSAS), WBSS, and local stocks) are dominated by catches from area IIIa (Fig. 3). The time series shows rather different patterns in the landings from different areas. A progressive increase of landings during the 1980s is observed in IIIa, with maximum levels of more than 170,000 tons in 1988 and 1992, followed by a rapid drop in 1996. Landings in IIIb-c have a peak in 1998, but overall a progressive reduction along the whole time series. Landings are reported for the only SD24 from 1983 when the catches were reported to be more than 65,000 tons; this is followed by a drop in 1991 when only 5,500 tons of herring were reported, and then highly variable catches during the following 20 years.

Comparison of landing statistics with catch data from the WBSS herring assessment shows good correlation between these two sources of information (R-sq=0.78, p-value<0.001; Fig. 3). Main differences may be explained by the fact that the landing statistics (1) do not account for mixing of NSAS herring in IIIa, (2) do not include landings of WBSS in the North Sea, (3) do not include discards.

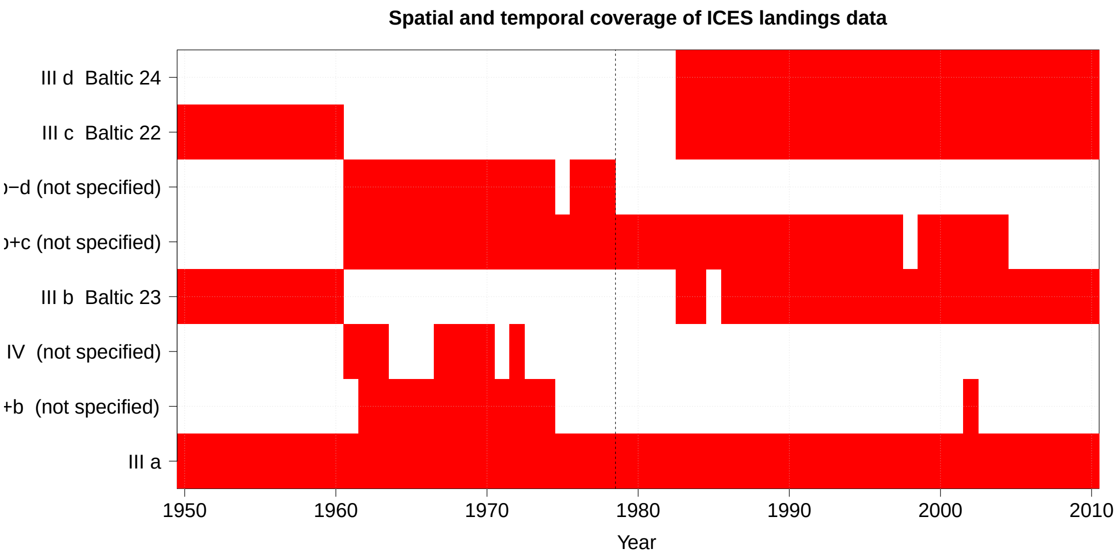

Figure 2: Official landing statistics of herring for the period 1950-2010 from the ICES database. In red the areas and periods as they appear in the database. The level of spatial aggregation is a mixture of the different ICES systems, including Divisions and Subdivisions during different periods of time. IIIa = SD20-21, IIIb = SD23, IIIc = SD22, IIId = SD24-31, IVa = SD..., IVb = ..., IV = ...

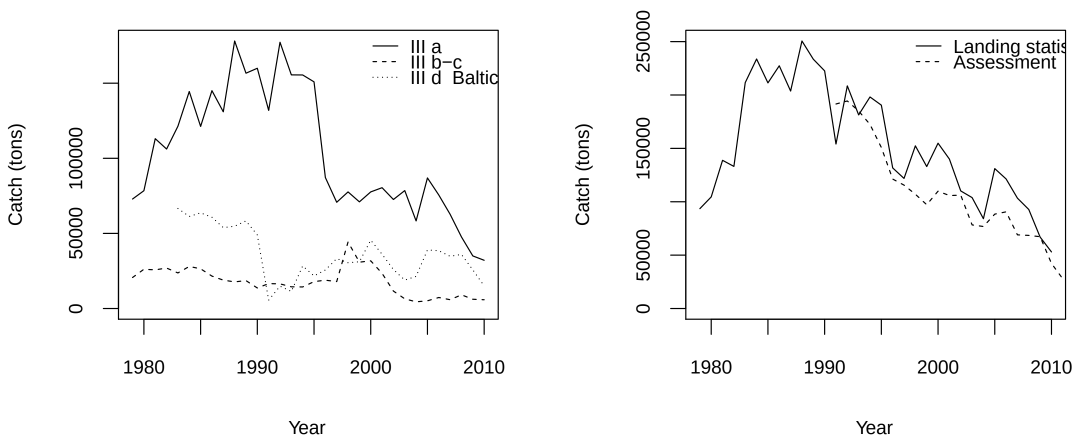

Figure 3: Time series of official landing statistics of herring for the period 1983-2010 separated for different ICES divisions. IIIa = SD20-21, IIIb-c = SD22-23 (left), and overlaid with landing data used in the assessment of WBSS (right).

Conclusions

The official landing statistics available from ICES are consistent with landing data used in the assessment and may be considered a valuable information to describe major patterns in the fishing landings of herring in the area of distribution of WBSS herring. The lack of a consistent definition of the fishing areas along time, limit the use of data for the purpose of this benchmark to the 1980s-onwards. However, there are a number of issues that need to be addressed before it would be feasible and sound to extend the input time series of landings for the assessment. They include: (1) calculate the proportion of NSAS and WBSS herring in the catches from the Kattegat-Skagerrak landings, (2) disaggregate North Sea landings from division (IV) to subdivision level (not shown in the analysis and results) to subset only those areas where WBSS herring occurs (IVa-b), (3) correct for the occurrence of discards, misreporting and transfer. In addition, (4) data from biological samples of commercial catch from 1980s are available but they are not yet in an electronic format.