DTU Aqua
National Institute of Aquatic Resources

Report of the Sprat Exchange 2014 For the North Sea and Celtic Sea

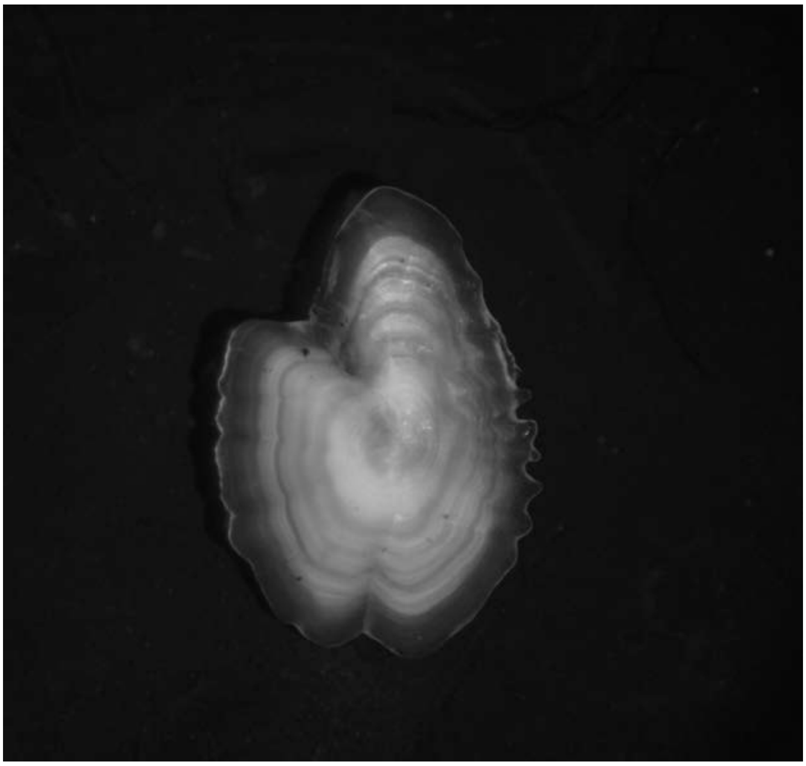

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Table of Contents

Introduction

In 2012 PGCCDBS (Planning Group on Commercial Catch, Discards and Biological Sampling) identified the need for a full scale Sprat exchange to take place for the North Sea area in 2013.

> *" 3.2.3 Proposals for 2013 and beyond (including recommendations for small scale exchanges from long-term planning table) - Sprat: Full scale exchange North Sea only."*

In addition, HAWG (Herring Assessment Working Group) 2012 recommended to the PGCCDBS that Sprat in the Celtic Seas (Subarea VI and VII) be included in this exchange.

> *"Collation of age-length keys of sprat in the Celtic Sea and West of Scotland should be done. A first step should be to validate the ageing of sprat from this area. HAWG recommends including available material on this part of the sprat stock complex in the upcoming large-scale exchange on Sprat in the North Sea. "*

The above-mentioned exchanges were organised and coordinated by DTU AQUA. Due to technical difficulties (see below), only the otoliths from the North Sea area were analysed. This report outlines the results of the North Sea exchange, which was carried out to determine the quality of the age readings.

The objectives of this exchange were to:

a. Examine the level of agreement between the age readings
b. Identify problematic areas in the age determinations

The participating institutes use a variety of preparation and reading methods. For the purpose of this exchange, otoliths were photographed on a black background. The online WebGR tool (available at http://webgr.azti.es/) was used for sharing and annotating the digitised images and partly for the subsequent analysis. The exchange ran from March 2013 to September 2014. Numerous technical problems were encountered during this time including the loss of all data, including readings, from the WebGR server, which resulted in a prolonged running time. Consequently, only those otoliths from North Sea Sprat have been used in the exchange to date with plans to include the Celtic Sea Sprat in a larger scale workshop or exchange at a later date.

Participants

A total of 18 readers with varying levels of expertise from 10 institutes participated in the exchange.

Reader number	Name	Country	Institute	Level of Expertise
1	Jean Louis Dufour	France	IMFREMER	Intermediate
2	Jan Beintema	Netherlands	IMARES	Expert
3	Andre Dijkman	Netherlands	IMARES	Trainee
4	Stina Bilstrup Stenersen Hansen	Denmark	DTU AQUA	Expert
5	Jan de Lange	Norway	IMR	Expert
6	Birgitta Krischansson	Sweden	SLU	Expert
7	Marianne Johansson	Sweden	SLU	Expert
8	Louise Straker Cox	United Kingdom	CEFAS	Trainee
9	Ian McCausland	Northern Ireland	AFBI	Intermediate
11	Gertrud Delfs	Germany	TI BUND	Trainee
12	Maria Jarnum	Denmark	DTU AQUA	Trainee
13	Anne Liv Johnsen	Norway	IMR	Trainee
15	Bjørn Vidar Svendsen	Norway	IMR	Expert
16	Eilert Hermansen	Norway	IMR	Expert
17	Jostein Røttingen	Norway	IMR	Expert
19	Claire Moore	Ireland	GMIT	Trainee
20	Deirdre Lynch	Ireland	MI	Trainee
21	Inger Henriksen	Norway	IMR	Trainee

Materials and Methods

Otolith Collection

For the North Sea exchange the collection of 150 otoliths were provided by DTU AQUA (130) and IMR (20). The length range was from 80-138mm TL, including the months January, February, July, August, September, October, November, December 2010 and ICES Divisions IVb and IVc.

For the Celtic Sea exchange the collection of 100 otoliths were provided by CEFAS. The length range was from 65-145mm TL, including the months October 2011 and November 2012 and ICES Divisions VIIe-k. Ideally the collection should have been comprised of fish of all sizes and times of year but it proved quite difficult to obtain otoliths which had not been mounted in resin or histokitt.

Digitised images were taken of whole otoliths using a standard scale, on a black background under reflected light. All of the images for the North Sea exchange were taken at DTU AQUA. Images for the Celtic Sea exchange were taken at CEFAS. However some of the images were blurry and retaken at AQUA. This resulted in the images from CEFAS being at a slightly larger magnification.

Otolith Exchange

The final exchange consisted of only the otoliths from the North Sea due to the previously described technical difficulties with the WebGR server. Otolith images and the corresponding fish data were uploaded to WebGR. All participants were invited to the exchange, given access to the image set and given instructions on how to complete the exercise.

Reading Procedure

The exchange was run as a blind test meaning that the participants were not allowed to see the annotations made by the other members. The only fish information given to the Readers was the capture date and the date of birth was assumed to be January 1st. Based on recommendations by Torstensen *et al*., (2004) information about the length of the fish was not provided. Readers were instructed to give just one age estimation per fish, provide additional comments in the box allocated for free text and to register a confidence level for their reading based on the 3-point grading system set out in Annex 4.

Statistical Output based on age data

Initially it was anticipated that WebGR would provide the statistical output. However, errors were noted in the APE (Average Percentage Error) and CV (Co-efficient of variation) parameters and no overall mean value of either parameter was given. Thus these outputs were not included in the evaluation of the exchange.

The second approach was to use the Guus Eltink spreadsheet (2000) which is a common tool used in otolith exchanges. This method provides statistics based on the estimated modal age, not verified age, and does not provide any specific information on where the problems exist in regards to the visual identification of the annuli. It does however provide Percent Agreement and Co-efficient of Variation (CV) for each fish and these are useful statistics which give a general overview of the level of agreement and variability between Readers. The Percentage Agreement and Co-efficient of Variation (CV) was calculated for each otolith, firstly based on all Readers and secondly, based on only expert Readers. An overall % Agreement and CV was also calculated for the entire exchange:

% Agreement = 100 x (no. of readers agreeing with modal age / total no. of readers)

CV = 100 x (standard deviation of age readings/ mean of age readings)

A Friedman rank sum test was used to test for differences in age estimates between Readers, followed by a pairwise comparison using Wilcoxon rank test to see which Readers on average read the same.

Measurement data

WebGR provides a measure of distance between the annotations made by the Readers. The “alldistances” dataset is a combination of all Readers measurements of the growth increments. Utilising this data allows for a more descriptive analysis, with the output from WebGR corroborating the visual information obtained from the images.

Measurement of the first annulus

When the exchange was first set up it was not intended that the analyses would utilise growth increment measurement data. As WebGR only provides measurements between two points and the Readers were not instructed to annotate the centre point, the “alldistances” dataset was missing the measurement of the first growth increment i.e from the centre to the first annulus. In order to include this measurement in the analyses, the workshop manager needed to calculate the distance from the centre point to the first annotation made by each Reader. This was done for each image (150) and each Reader (18) once all of the Readers had finalised their readings. Measurements were made using Image J (http://imagej.nih.gov/ij/) software while visually aligning the image from WebGR to the image in Image J. Measurements from Image J were calibrated with the images in WebGR to give an “actual measurement”. The images used for the exchange were of left, right and pairs of otoliths. The Readers had not been given specific guidelines on which otolith and which axis to annotate and thus not one single axis was annotated consistently. Correlations were made between the 5 different axes which the Readers were annotating and conversion factors were calculated. The conversion factors were used to standardise the “actual measurement” to the A1 axis (see Figure 1).

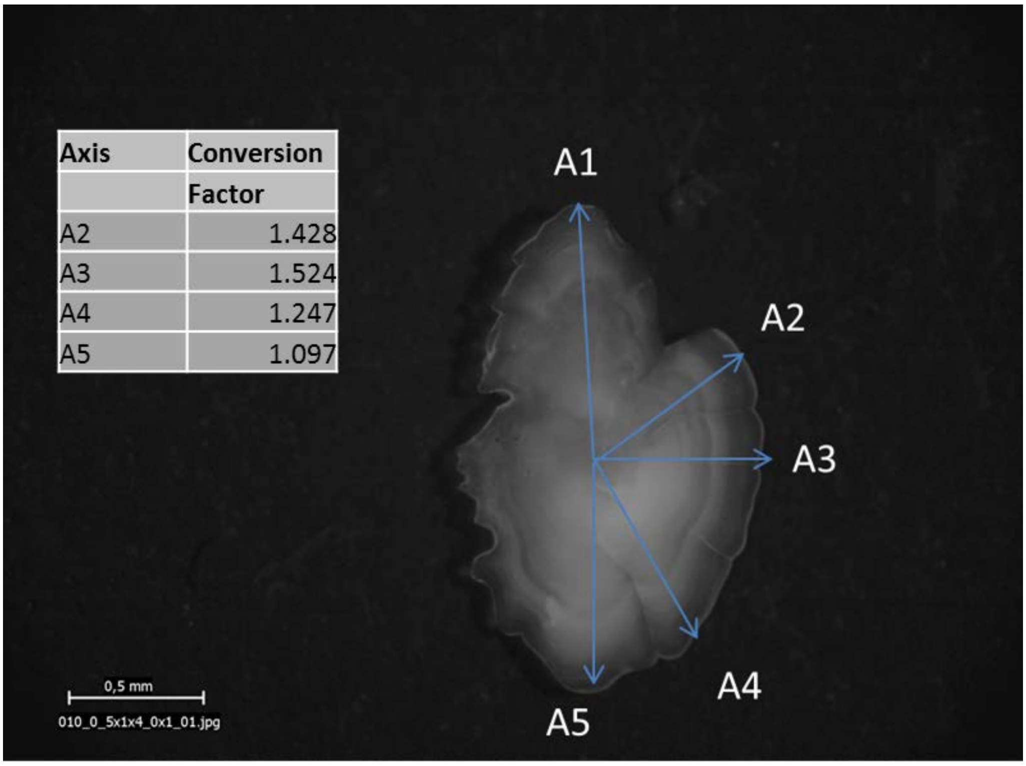

Figure 1. Image of Sprat010 left otolith showing axes 1-5 with inset giving the conversion factors used.

Finally, the WebGR output of “alldistances” was merged with the newly acquired dataset of first annulus measurements so that for each image read by each Reader there was a set of growth increment measurements from the centre point to the first annulus, from first annulus to the second annulus and so on.

Data analysis of measurement data

The combined measurement data was analysed with Linear Mixed Effects Models (LMEM) in R (http://www.r-project.org/). Data for each growth increment was cumulated to give a growth curve for each individual image and Reader. The analysis examines whether there are consistent differences in growth curves estimated by the different Readers.

The model that best fits the data is a model with:

- Fixed effects: Effects on both intercept and slope of the LMEM
- Random effects: Effects of individual images on both intercept and slope

A post-hoc comparison between Readers was carried out using a Tukey Contrasts test which is a multiple comparison test of means where all possible pairs of comparisons were tested.

Results

Age data

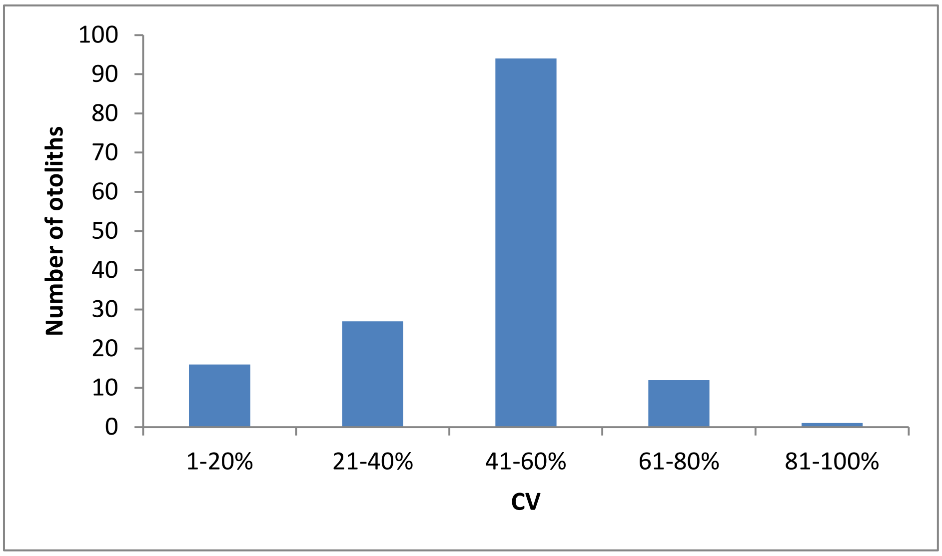

Figure 2. Histogram representing the frequency of CV's for each otolith.

The results based on ages alone are given in Table 1 and Table 2 (Annex 3). They give the estimated ages for each otolith plus a modal age, which is then used to calculate the % agreement and CV for each otolith. Table 1 was calculated using all of the Readers input (zero values were deleted after a visual check of the annotations in WebGR to ensure zero values were due to an omitted age reading rather than an age of 0 years). Table 2 was calculated using only the input of the "expert" Readers.

The overall % Agreement for all Readers was 62% with overall Co-efficient of Variation (CV) of 44%. Based on expert readers alone this improved the % Agreement, up to 78% but with little change in the CV of 45%. A very large proportion of the individual otolith CV falls between 41% and 60% (
Figure 2). Sprat142 had the lowest value % Agreement at 29%.

Figure 3 shows all of the Readers annotations for Sprat142 which had the lowest value % Agreement at 29% and CV of 51% and estimated ages ranging from 1-5. It shows clearly the disagreement between Readers both in regards to the position of the first annulus, the identification of annuli and the overall age.

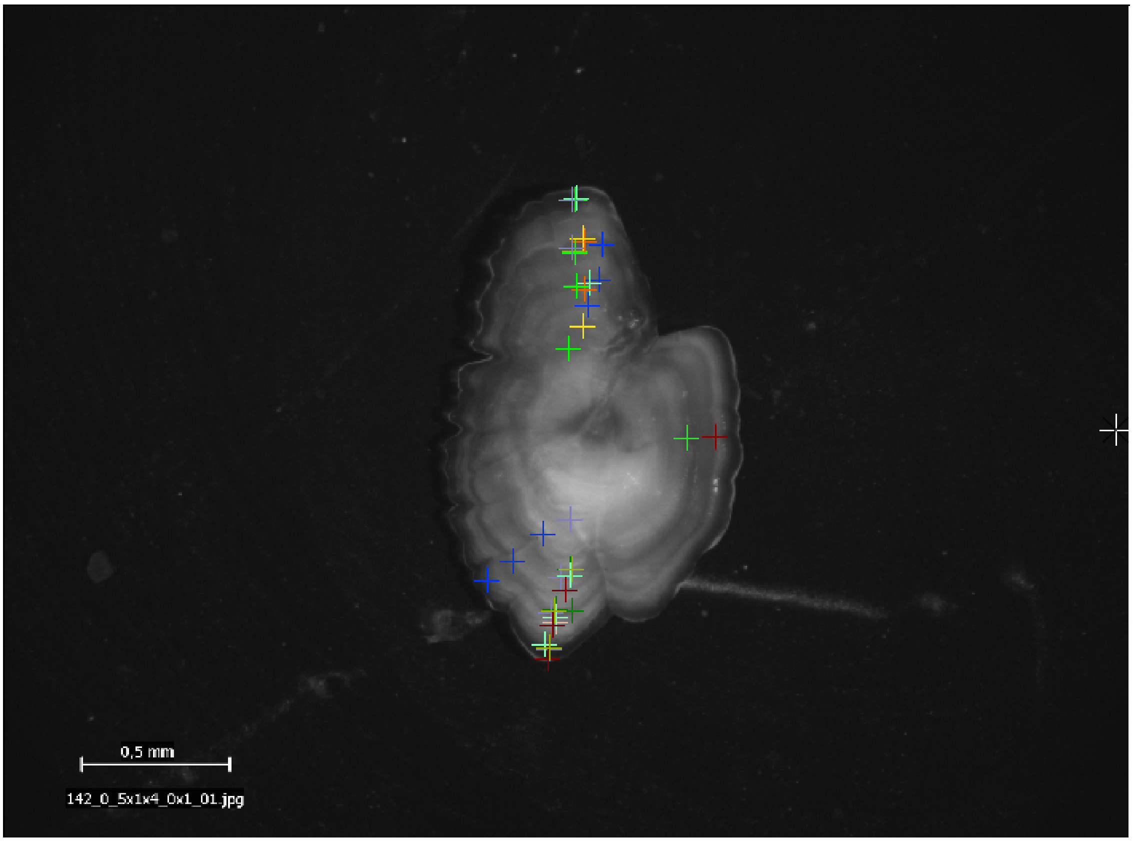

Figure 3. Image of Sprat 142 taken from WebGR shows all readers annotations

The overall highly significant p-value of < 0.0001 from the Friedman rank sum test means that there are significant differences between Readers (in terms of the age estimates). The follow on test to see which Readers on average read the same was not possible as there were too many missing age estimates in the dataset.

The age composition of the sample is shown in Table 3 (Annex 3). Not all readers aged the full set of 150 otoliths. Readers 1, 3,5,7,11,13,15,17,19 and 21 omitted some readings due to a number of reasons: broken, crystalized, difficult otoliths and technical issues with WebGR. A total of 2560 age readings were included in the analyses within an age range of 1-6 years.

Mean length at age for the entire otolith collection is shown in Table 4 and Figure 3.1(see Annex 3).

Measurement data

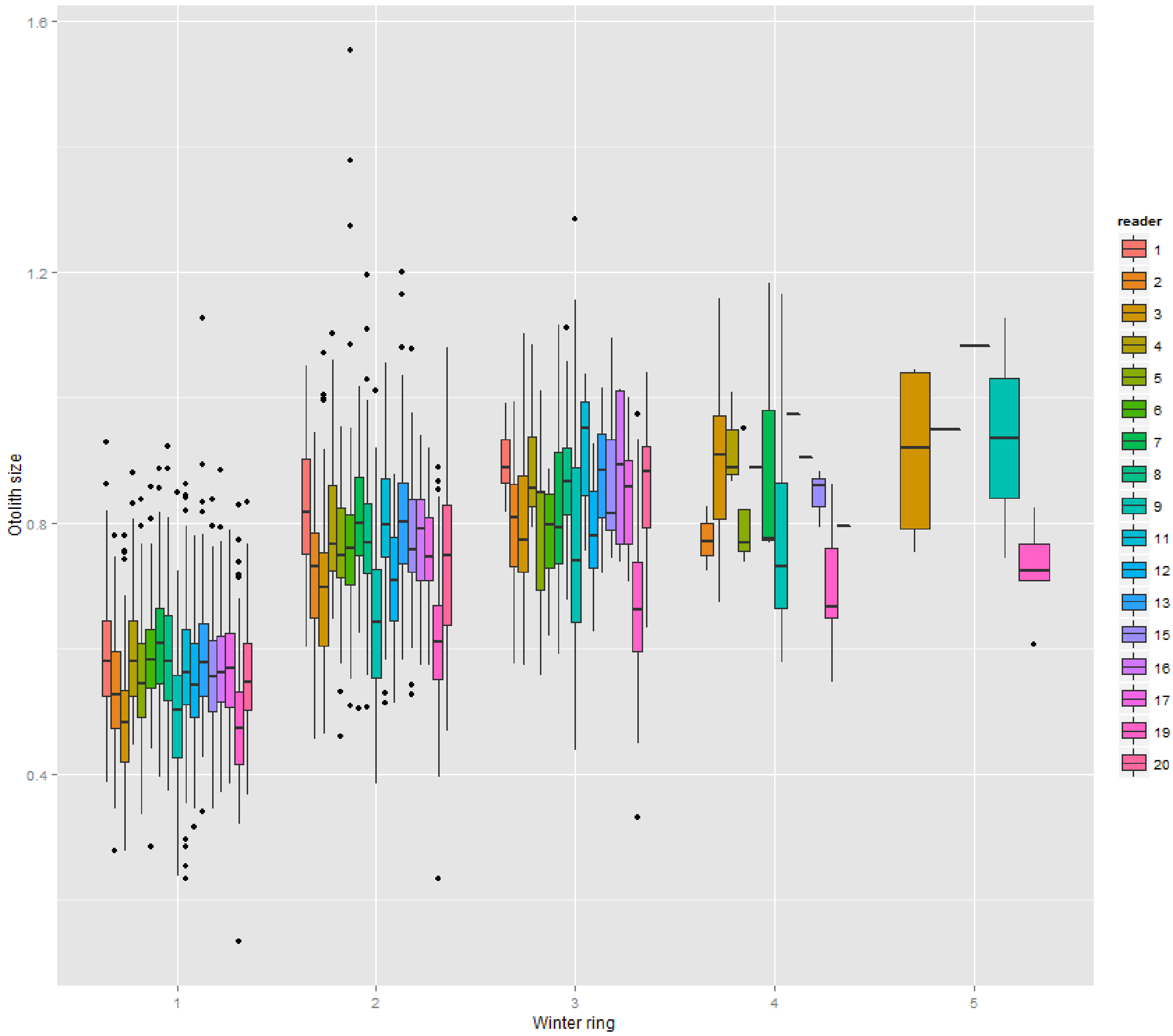

Figure 4 . Plot of average otolith size at annuli 1-5 for all Readers (excluding Reader 21). Boxes represent the mean, upper and lower box boundaries of the interquartile range, whiskers represent the minimum and maximum values and the dots represent the outlier

The results of the best fit model gave highly significant p-values of <0.0001 for Reader effect on both intercept and slope. Thus there are differences between Readers as to what they interpret to be the first annulus but also differences between Readers as to where the additional annuli are. The range of distances from the centre to where the first annulus lies is very large thus the position of the first annulus varies a lot (Figure 4). This is also apparent with the successive annuli. Some Readers (2, 3, 9, 11 and 19) are often annotating an extra annulus close to the centre of the otolith. When looking at the overlap between annulus 1 and 2 it is easy to see that outliers of annulus 1 are in fact within the range of distances of annulus 2 and so the location of the first annulus has clearly not been established.

Given that there is a significant Reader effect a comparison between Readers was conducted using the Tukey Contrasts test to see which Readers are in agreement with each other, see Annex 5 for the full results. In general the Readers can be divided into 3 groups in which the levels of agreement between Readers varies; Readers 1,4,6,7,8,11,13,16,17 in a group which overlaps with Readers 2,5,12,15,20 and a third group which stands more on its own of Readers 3,9,19. Reader 21 needed to be removed from the analyses as the number of omitted age readings was too large.

Figure 5 is of Sprat016 (% agreement of 78%, CV 58%) and shows annotations from Readers 1-21 excluding Readers 2, 3, 9 and 19. It shows clear agreement between readers on the estimated age (all Readers estimating 1 year), however there are some discrepancies as to the actual position of the first annulus. Figure 6 is also of Sprat016 and shows annotations from Readers 2, 3, 9 and 19 where the discrepancies between actual position of the first annulus and the overall age (Readers estimating either 2 or 4 years) are apparent. These two images support the results of the Tukey tests and the general division of subgroups.

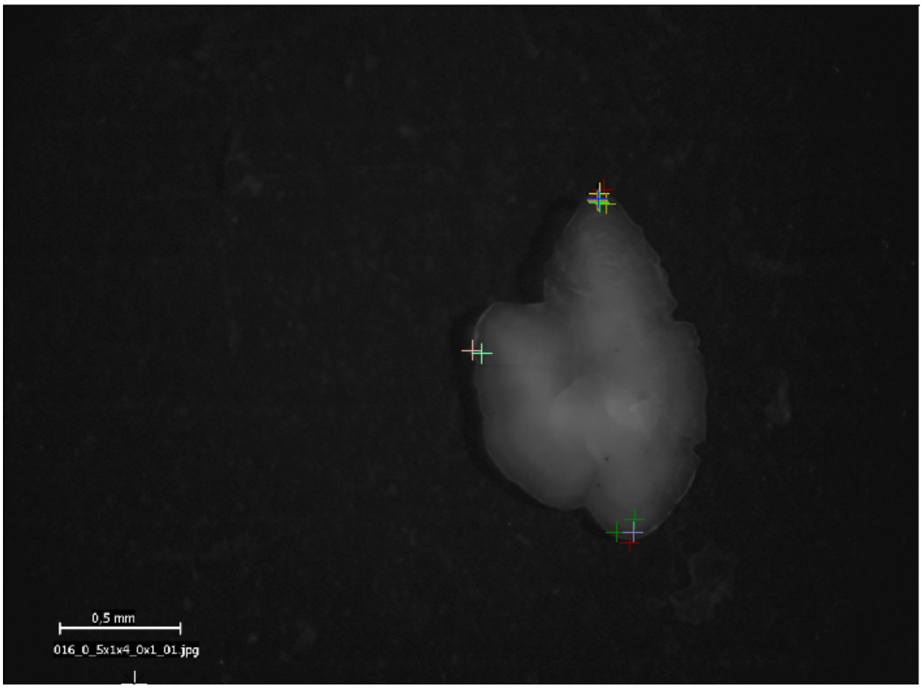

Figure 5. Image of Sprat 016 taken from WebGR shows annotations from Readers 1-21 excluding Readers 2, 3, 9 and 19.

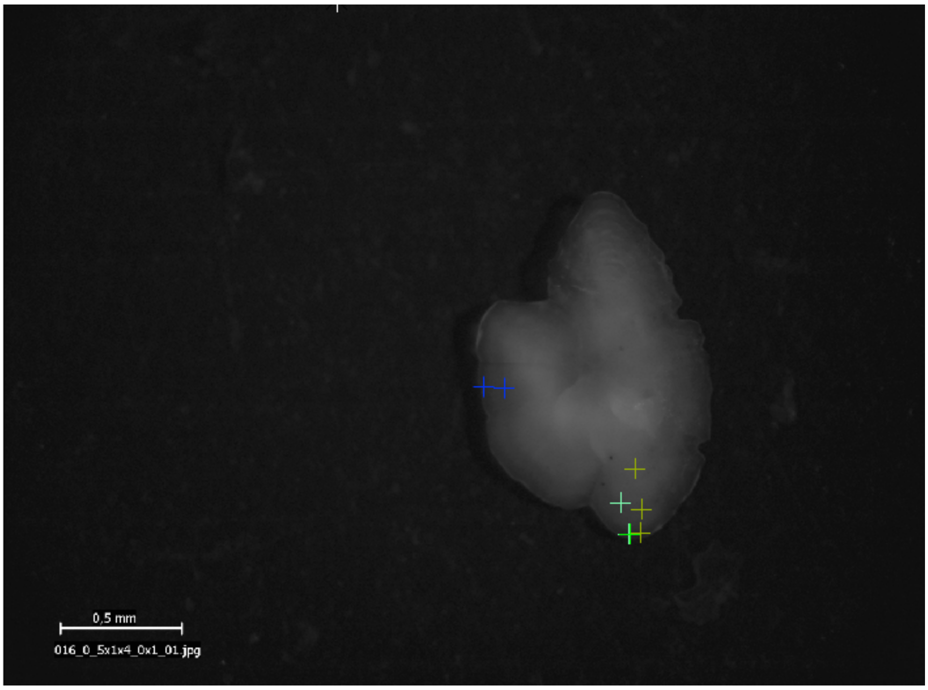

Figure 6. Image of Sprat 016 taken from WebGR shows annotations from Readers 2, 3, 9 and 19.

Discussion and Conclusion

Based on the results from the age data alone it is apparent that the level of disagreement between Readers is very high and that the level of precision is very poor. Based on experts alone the results improved as would be expected, as these are the Readers who have experience in reading Sprat otoliths from the North Sea area. The other Readers are trainees, most of which read Sprat otoliths from other areas.

The calculation of % agreement uses a value of modal age. The modal age is based on the age that is most frequently assigned. It is not however based on a verified age or even on a set of ages from a reference collection. This exchange shows that there is clearly a lack of agreement between Readers in regards to age and therefor the use of modal age could in fact hide discrepancies in age readings which can have serious consequences for age based stock assessments. Using % agreement and CV are useful to give a general overview as to the level of agreement between Readers. Generally speaking an otolith which appears to be difficult to age are indicated with a high CV and a low % agreement.

For this exchange, we decided to move away from the traditional use of the modal age for a large part of the analyses. We tested a method which utilises the measurement data from WebGR and thus allows for a more descriptive analyses of where the problems lie. In this exchange, the problem is 3 fold with disagreement on the overall age, the identification of annuli and the position of the first annulus, as seen in Figure 3. It is a combination of these 3 factors that result in the poor level of agreement and varying precision between readers.

The wide ranges of measurements shown by the box plots and the corresponding outliers give an indication of how the Readers vary when annotating the position of the annuli. Winter ring 1 and 2 have the widest spread of data points and the overlap indicates that the first annulus is not clearly identified by all Readers. WKSPRAT (2013) outlined the problem in regards to identification of the first annulus being probably due to “the prolonged spawning period where a subset of a cohort may over winter as larvae and a winter-ring may not be discernible”. A study based on one reader alone showed that the variation in width of the first winter ring did not differ significantly between otoliths. This study could be expanded to include the samples from this exchange but it would need to be based on precise measurements and thus precise instructions given on how to annotate the images.

It should be noted that the Readers did not always mark the beginning of the annuli and thus the variability in measurements may be interpreted with caution. This point should have been made clear when the instructions for the exchange were given. This is a point to note when conducting this analysis in the future along with instruction for Readers to annotate a single axis.

Microstructure analysis has demonstrated the structural differences between true and false winter rings (Mosegaard and Baron, 1999). This method could be applied in the future to this collection of otoliths in order to clarify the issues with the identification of the subsequent annuli. Information could be compiled on the average distance of these annuli from the centre and thus provide the Readers with measurement guidelines for annuli identification.

It is important to note that the 3 point scale for determining the readability of the otoliths was not applied the second time that the exchange was run and thus this important information is not available. This scale can be useful to provide information to the stock assessors on the reliability of the age readings.

The Celtic Sea image set was not included in the exchange following the crash of WebGR due to technical reasons. The image set was compared visually with the image set from the North Sea to see if any or what differences may exist. The comparison showed the two otolith sets to be both similar in appearance and readability.

The mean length at age for all Readers (Table 4 and Figure 3.1) shows that, for the majority of Readers the increase in age does not always correspond to an increase in mean length. Torstensen *et al*., (2004) recommended not giving fish length data to the age Readers in the first instance. It could be a useful exercise to have the Readers re-read a subset of the images with fish length data provided, to see if there are any apparent differences in the age estimates.

This report cannot give a detailed description of the images and where the annotations differ visually due to the large number of otoliths plus the large number of Readers. The system that WebGR uses to assign colours to the age Readers annotations is not consistent and the symbols assigned to each Reader are all the same. The Readers annotations are now available to all of the participants within the exchange for comparison in WebGR.

A WebGR study proposal has recently been submitted. This proposal includes expansion and changes of the current WebGR, which will improve the usability of this tool for future exchanges, both in terms of ease of use for the Readers but also with an improved statistical output with the inclusion of growth increment measurement data.

Recommendations

The results point to a number of unresolved issues, most importantly, the identification of the first winter ring and the identification of the subsequent annuli. These issues should be addressed collectively as part of a Sprat age reading workshop by; a) expanding the WKSPRAT pilot study on first annulus identification and b) compiling microstructure measurement data for subsequent annuli. By including samples and age Readers from a range of eco-regions a higher level of agreement could be attained across areas.

RECOMMENDATION	ADRESSED TO
1. A calibration workshop to be held on basis of the exchange; first a re-reading of the calibration set using set lines for annotation purposes	WGBIOP
2. Validation of the first annulus	WGBIOP
3. Application of microstructure data to provide guidelines for identification of subsequent annuli	WGBIOP
4. Expansion of the workshop to include samples from other eco-regions	WGBIOP

Problems encountered

Numerous problems were encountered during the exchange, which resulted in a prolonged running time and data issues.

- Difficulties in obtaining otoliths from the Celtic Sea area. Sprat are taken in small numbers on the surveys in this area, the fishery in the area is sporadic and most institutes had their collection mounted in histokitt. The Celtic Sea samples thus only cover Q3 2011 and 2012. Some of the images from 2012 were of poor quality and so all were retaken at DTU AQUA and at the same magnification as the North Sea images. The survey samples collected in 2012 were all below 10cm and so the collection was supplemented with larger samples from the 2011 survey. Only the photographs were available of otoliths mounted in resin with the result being that those from 2011 were at a slightly larger magnification.
- Loss of all data and images from the WebGR server. This occurred after most of the participants had completed the exchange. A lot of time was spent trying to recover the data by AZTI who maintain WebGR voluntarily. Some of the images and data were recovered but unfortunately the exchange itself was lost from the WebGR sever and thus all of the participants were deleted and all of the annotations lost.
- Restoration of the exchange was also problematic as the organiser of the exchange was on maternity leave at the time. Not all of the original participants were included in the new exchange and only the image set for the North Sea was recovered. The exchange had to be extended again to facilitate those participants who were added at a later date. It was decided to run the exchange for the North Sea only and to include the images for the Celtic Sea at a later date.
- Information on the 3 point scale for the confidence that the readers had in their reading was lost when WebGR crashed as the Readers were not asked to provide this reading when making their annotations the second time.
- Incorrect statistical output from WebGR was incorrect. Errors were noted in the APE (Average Percentage Error) and CV (Co-efficient of variation) parameters.
- Addition of measurements of the first annulus. In order to utilise the “alldistances” data from WebGR a measurement from the centre point to the first annulus had to be made. This was done for each Reader for each of the 150 otoliths. As the use of this data was not foreseen instructions had not been given to the participants on which of the pair of otoliths needed to be annotated, along which axis the annotations should be made and also to annotate the centre point. This meant that the Readers had been annotating left and right otoliths (often both) and along different axis (often more than one). Measurements then needed to be standardised based on conversion factors and angle measurements before being merged with the “alldistances” data from WebGR.
- When the Readers do not manually enter the age in the box provided WebGR gives an age estimation of zero. All of the 0 values needed to be manually checked and removed from the dataset
- A full set of age estimates without and 0/missing values is needed for the pairwise comparison tests between Readers.

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Eltink, G.W. (2000) Age reading comparisons. (MS Excel workbook version 1.0 October 2000)

Mosegaard H., Baron P.R. (1999) Validation of annual rings by primary increment characteristics in herring and sprat sagittal otoliths. Lecture at EFAN meeting, notes can be found on the Internet site www.efan.no.

Annex 1. List of participants

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Annex 2. Otolith collection

SAMPLE NAME	LENGTH (mm)	WEIGHT (gr)	SPECIES	CAPTURE DATE	AREA	SAMPLING_INSTITUTE
Sprat003	130	16	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat006	106	8	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat010	107	10	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat011	106	8	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat012	110	8	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat013	111	12	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat018	96	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat016	89	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat022	87	4	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat024	94	4	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat025	95	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat028	115	12	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat029	111	10	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat030	122	14	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat031	108	10	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat032	103	8	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat038	109	8	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat039	103	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat041	99	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat044	94	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat047	93	6	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat049	84	4	Sprattus sprattus	Jan-10	IVb	DTU AQUA
Sprat055	110	11	Sprattus sprattus	Feb-10	IVb	IMR
Sprat057	110	10	Sprattus sprattus	Feb-10	IVb	IMR
Sprat059	80	3	Sprattus sprattus	Feb-10	IVb	IMR
Sprat060	110	9	Sprattus sprattus	Feb-10	IVb	IMR
Sprat061	110	11	Sprattus sprattus	Feb-10	IVb	IMR
Sprat065	115	11	Sprattus sprattus	Feb-10	IVb	IMR
Sprat066	100	6	Sprattus sprattus	Feb-10	IVb	IMR
Sprat068	90	5	Sprattus sprattus	Feb-10	IVb	IMR
Sprat072	120	13	Sprattus sprattus	Feb-10	IVb	IMR
Sprat074	105	7	Sprattus sprattus	Feb-10	IVb	IMR
Sprat079	89	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat096	87	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat097	90	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat099	89	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat102b	96	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat103b	95	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat104b	91	4	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat105b	88	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat108	102	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat109	100	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat111	94	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat112	93	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat113	96	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat114	98	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat115	94	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat087	94	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat117	93	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat118	98	8	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat119	106	10	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat122	89	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat123	90	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat088	91	6	Sprattus sprattus	Jul-10	IVb	DTU AQUA
Sprat140	100	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat142	95	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat143	94	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat144	95	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat147	100	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat151	90	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat152	92	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat155	92	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat157	100	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat160	99	10	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat161	91	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat162	92	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat163	89	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat164	90	6	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat165	94	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat159	100	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat167	105	10	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat168	104	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA

Sprat169	93	8	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat170	89	9	Sprattus sprattus	Aug-10	IVc	DTU AQUA
Sprat172	109	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat173	104	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat174	109	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat175	117	12	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat176	120	12	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat177	109	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat178	108	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat182	105	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat190	115	12	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat194	110	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat198	102	10	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat199	103	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat200	103	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat201	97	6	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat202	95	6	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat203	98	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat204	98	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat206	98	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat216	99	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat217	96	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat218	104	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat219	100	8	Sprattus sprattus	Sep-10	IVb	DTU AQUA
Sprat221	108	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat222	113	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat226	122	20	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat228	106	8	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat235	105	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat236	107	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat238	120	16	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat240	104	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat241	105	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat242	106	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat243	105	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat247	112	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat248	111	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat249	110	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat250	112	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat253	120	18	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat260	112	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat263	110	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat265	105	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat266	112	10	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat267	111	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat268	112	12	Sprattus sprattus	Oct-10	IVb	DTU AQUA
Sprat272	139	20	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat273	133	20	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat274	133	22	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat275	138	24	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat276	121	16	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat277	128	16	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat278	122	16	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat279	128	20	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat281	135	22	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat285	130	22	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat286	127	20	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat291	104	10	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat292	104	8	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat293	91	6	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat296	116	14	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat299	117	14	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat300	126	18	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat301	120	14	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat302	116	14	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat303	115	12	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat304	111	12	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat305	112	10	Sprattus sprattus	Nov-10	IVb	DTU AQUA
Sprat322	120	13	Sprattus sprattus	Dec-10	IVb	IMR
Sprat323	105	8	Sprattus sprattus	Dec-10	IVb	IMR
Sprat324	100	8	Sprattus sprattus	Dec-10	IVb	IMR
Sprat328	90	6	Sprattus sprattus	Dec-10	IVb	IMR
Sprat331	110	9	Sprattus sprattus	Dec-10	IVb	IMR
Sprat332	115	12	Sprattus sprattus	Dec-10	IVb	IMR
Sprat338	100	8	Sprattus sprattus	Dec-10	IVb	IMR
Sprat341	85	5	Sprattus sprattus	Dec-10	IVb	IMR
Sprat343	95	7	Sprattus sprattus	Dec-10	IVb	IMR
Sprat344	90	5	Sprattus sprattus	Dec-10	IVb	IMR

Annex 3. Estimated ages, % agreement and CV's

Table 1. Estimated ages from all readers for all otoliths. Modal age, % agreement and CV given for each otolith plus an overall % agreement and CV.

	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	**Modal**	**Percent**	Precision
	1	2	3	4	5	6	7	8	9	11	12	13	15	16	17	19	20	21	age	agreement	CV
	Dufour	Beintema	Dijkman	Hansen	Lange	Krischansson	Johansson	Straker Cox	McCausland	Delfs	Jarnum	Johnsen	Svendsen	Hermansen	Røttingen	Moore	Lynch	Henriksen			
Sample	France	Netherlands	Netherlands	Denmark	Norway	Sweden	Sweden	U.Kingdom	U.Kingdom	Germany	Denmark	Norway	Norway	Norway	Norway	Ireland	Ireland	Norway			
Sprat003.jpg	3	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	89%	10%
Sprat006.jpg	2	3	3	2	2	2	2	2	5	2	3	2	2	2	2	1	2	3	2	67%	36%
Sprat010.jpg	2	3	3	2	2	2	2	2	3	2	3	2	2	2	2	2	3	2	2	72%	20%
Sprat011.jpg	2	3	3	2	2	2	2	2	3	2	3	2	2	2	2	2	3	2	2	72%	20%
Sprat012.jpg	2	3	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	83%	18%
Sprat013.jpg	3	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	89%	10%
Sprat018.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	89%	15%
Sprat016.jpg	1	4	2	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	78%	58%
Sprat022.jpg	1	3	2	1	1	1	1	1	1	1	1	1	4	1	1	1	1	2	1	78%	61%
Sprat024.jpg	3	3	3	2	3	3	3	2	2	2	2	3	2	2	2	2	2	2	2	61%	21%
Sprat025.jpg	3	3	3	3	3	3	3	2	3	2	2	3	4	2	2	2	3	2	3	56%	22%
Sprat028.jpg	2	3	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	83%	18%
Sprat029.jpg	3	4	4	5	4	4	4	2	4	2	3	4	4	2	3	5	3	-	4	47%	37%
Sprat030.jpg	2	3	-	2	2	2	2	2	3	2	3	2	2	2	2	2	2	2	2	82%	31%
Sprat031.jpg	2	3	-	2	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	82%	31%
Sprat032.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	83%	18%
Sprat038.jpg	2	3	3	2	2	2	2	2	3	2	2	2	3	2	2	5	3	2	2	67%	32%
Sprat039.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	89%	15%
Sprat041.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	89%	15%
Sprat044.jpg	2	3	3	2	2	2	2	2	3	2	2	2	2	2	2	3	2	-	2	76%	32%
Sprat047.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	89%	15%
Sprat049.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	89%	15%
Sprat055.jpg	2	3	3	2	2	2	2	2	3	2	2	3	2	2	2	2	3	2	2	72%	20%
Sprat057.jpg	3	4	4	3	2	2	2	2	5	2	2	2	2	2	2	4	3	3	2	56%	35%
Sprat059.jpg	1	4	5	1	1	1	1	1	4	1	1	1	1	1	1	5	1	3	1	72%	81%
Sprat060.jpg	3	4	4	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	83%	12%
Sprat061.jpg	2	5	6	2	2	2	-	2	4	2	2	2	2	2	2	3	2	-	2	75%	48%
Sprat065.jpg	2	3	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	-	2	82%	18%
Sprat066.jpg	2	4	4	2	2	2	2	2	3	2	2	2	2	2	2	3	3	-	2	71%	30%
Sprat068.jpg	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-	2	88%	16%
Sprat072.jpg	2	3	6	2	2	2	2	2	4	3	3	2	2	2	3	3	2	-	2	59%	40%

Sprat074.jpg	2	3	5	2	2	2	2	2	4	2	2	2	2	2	2	5	2	-	2	76%	42%
Sprat079.jpg	1	3	3	2	1	1	1	2	3	1	1	2	1	1	1	3	1	-	1	59%	52%
Sprat096.jpg	1	3	3	2	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	59%	47%
Sprat097.jpg	1	3	3	2	1	1	1	2	3	1	1	2	1	1	1	2	1	-	1	59%	50%
Sprat099.jpg	1	3	3	2	1	1	1	2	3	1	1	2	1	1	1	3	1	-	1	59%	52%
Sprat102b.jpg	1	3	3	2	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	59%	47%
Sprat103b.jpg	1	3	3	2	1	1	1	2	2	1	1	2	1	1	1	3	1	-	1	59%	50%
Sprat104b.jpg	1	4	4	2	1	1	1	2	3	1	1	-	1	1	1	3	2	-	1	56%	61%
Sprat105b.jpg	2	4	4	2	1	1	1	3	4	2	1	-	2	1	1	3	2	-	1	38%	54%
Sprat108.jpg	1	3	3	2	1	1	1	2	3	2	1	2	1	1	1	2	2	-	1	47%	45%
Sprat109.jpg	2	4	4	2	1	1	1	2	4	1	1	3	1	2	2	4	2	-	2	35%	54%
Sprat111.jpg	1	3	3	2	1	1	1	2	3	1	1	2	1	1	1	2	1	-	1	59%	50%
Sprat112.jpg	1	4	4	2	1	1	1	3	4	-	1	2	1	1	1	4	2	-	1	50%	63%
Sprat113.jpg	1	4	4	2	1	1	1	2	3	1	1	2	1	1	1	3	2	-	1	53%	59%
Sprat114.jpg	1	4	4	1	1	1	1	3	3	1	1	2	1	1	1	3	3	-	1	59%	62%
Sprat115.jpg	1	4	4	2	1	1	1	2	4	1	1	2	1	1	1	2	2	-	1	53%	62%
Sprat087.jpg	1	3	3	2	1	1	1	2	2	1	1	2	1	1	1	3	1	-	1	59%	50%
Sprat117.jpg	2	3	3	2	1	1	1	2	2	2	1	2	1	1	1	2	1	-	1	47%	43%
Sprat118.jpg	1	3	3	2	1	1	1	2	3	1	1	2	1	1	1	3	2	-	1	53%	50%
Sprat119.jpg	1	4	4	2	1	1	1	2	3	2	1	2	1	1	1	2	2	-	1	47%	56%
Sprat122.jpg	1	3	4	2	1	1	1	2	3	1	1	2	1	1	1	5	3	-	1	53%	64%
Sprat123.jpg	1	3	4	2	1	1	1	2	3	1	1	2	1	1	1	2	2	-	1	53%	54%
Sprat088.jpg	1	3	3	2	1	1	1	2	4	1	1	2	1	1	1	3	2	-	1	53%	55%
Sprat140.jpg	1	3	4	2	1	1	1	2	3	2	1	2	1	1	1	2	2	-	1	47%	51%
Sprat142.jpg	2	4	5	2	4	1	1	3	3	2	1	3	2	1	1	3	3	-	1	29%	51%
Sprat143.jpg	1	4	4	2	4	1	1	2	3	1	1	2	1	1	1	3	2	-	1	47%	59%
Sprat144.jpg	1	3	3	1	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	59%	47%
Sprat147.jpg	1	3	4	2	2	1	1	2	2	1	1	2	1	1	1	2	2	-	1	47%	50%
Sprat151.jpg	1	3	3	2	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	53%	45%
Sprat152.jpg	1	3	4	2	2	1	1	2	2	2	1	2	1	1	1	3	2	-	1	41%	48%
Sprat155.jpg	1	3	4	2	2	1	1	2	2	1	1	2	1	1	1	2	2	-	1	47%	50%
Sprat157.jpg	1	3	4	2	2	1	1	2	2	1	1	2	1	1	1	2	2	-	1	47%	50%
Sprat160.jpg	1	3	3	2	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	53%	45%
Sprat161.jpg	1	3	4	2	2	1	1	2	3	1	1	2	1	1	1	2	1	-	1	53%	54%
Sprat162.jpg	1	3	3	2	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	53%	45%
Sprat163.jpg	1	3	4	2	2	1	1	2	3	2	1	2	1	1	1	2	2	-	1	41%	48%
Sprat164.jpg	1	3	3	1	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	59%	47%
Sprat165.jpg	1	3	4	2	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	53%	52%
Sprat159.jpg	1	3	4	2	2	1	1	2	3	1	1	2	1	1	1	3	1	-	1	53%	55%
Sprat167.jpg	1	3	3	2	2	1	2	2	2	1	1	2	1	1	1	2	1	-	1	47%	43%

Sprat168.jpg	1	3	3	2	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	53%	45%
Sprat169.jpg	1	3	3	1	2	1	2	2	2	1	1	2	1	1	1	2	1	-	1	53%	45%
Sprat170.jpg	1	3	3	2	2	1	1	2	2	1	1	2	1	1	1	2	2	-	1	47%	43%
Sprat172.jpg	-	5	4	2	4	2	-	3	3	2	2	3	2	2	2	3	2	-	2	53%	35%
Sprat173.jpg	1	3	3	1	2	1	1	2	2	1	1	2	1	1	1	2	1	-	1	59%	47%
Sprat174.jpg	2	3	3	2	2	2	2	3	3	2	2	2	-	2	2	3	2	-	2	69%	21%
Sprat175.jpg	1	3	5	2	1	1	1	2	3	1	2	2	1	1	1	2	2	-	1	47%	59%
Sprat176.jpg	2	4	4	2	2	2	2	3	2	2	2	3	2	2	2	3	2	-	2	71%	30%
Sprat177.jpg	1	3	3	1	1	1	1	2	2	3	1	2	1	1	1	4	2	-	1	53%	55%
Sprat178.jpg	2	4	4	1	1	1	1	2	3	2	1	2	2	1	1	2	2	-	2	41%	53%
Sprat182.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat190.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat194.jpg	1	3	4	2	2	2	2	3	2	2	2	3	2	2	2	3	2	-	2	65%	30%
Sprat198.jpg	1	3	3	1	1	1	1	2	2	2	1	2	1	1	1	2	2	-	1	53%	45%
Sprat199.jpg	2	4	4	1	1	1	1	3	3	2	1	3	2	1	1	3	2	-	1	41%	53%
Sprat200.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat201.jpg	1	4	4	1	1	1	1	3	3	2	1		1	1	1	3	2	-	1	56%	68%
Sprat202.jpg	1	4	3	1	1	1	1	2	2	1	1	2	1	1	1	3	1	-	1	65%	59%
Sprat203.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat204.jpg	1	3	4	1	1	1	1	2	2	1	1	2	1	1	1	3	2	-	1	59%	57%
Sprat206.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat216.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat217.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	2	-	1	59%	47%
Sprat218.jpg	1	3	3	1	1	1	1	2	3	1	1	2	1	1	1	3	1	-	1	65%	55%
Sprat219.jpg	1	3	3	1	1	1	1	2	3	1	1	2	1	1	1	3	1	-	1	65%	55%
Sprat221.jpg	1	3	3	1	1	1	1	2	1	1	1	2	1	1	1	2	1	-	1	71%	50%
Sprat222.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat226.jpg	2	4	4	2	1	1	1	2	2	1	2	2	2	2	2	3	2	-	2	59%	44%
Sprat228.jpg	1	3	3	2	1	1	1	2	1	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat235.jpg	1	3	4	1	1	1	1	2	2	2	1	2	1	2	1	3	1	-	1	53%	54%
Sprat236.jpg	1	3	3	2	2	1	2	2	3	1	1	2	1	1	1	2	1	-	1	47%	45%
Sprat238.jpg	1	3	3	1	1	1	1	2	3	1	1	2	1	1	1	2	1	-	1	65%	52%
Sprat240.jpg	1	3	3	2	1	1	1	2	3	1	1	2	1	1	1	2	1	-	1	59%	50%
Sprat241.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat242.jpg	1	4	4	1	1	1	1	3	3	1	1	2	1	1	1	3	1	-	1	65%	65%
Sprat243.jpg	1	3	3	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	49%
Sprat247.jpg	1	4	4	2	1	1	1	2	3	1	1	2	1	1	1	2	2	-	1	53%	59%
Sprat248.jpg	1	3	3	1	1	1	1	2	3	1	1	2	1	1	1	2	2	-	1	59%	50%
Sprat249.jpg	1	3	3	1	1	1	1	2	1	1	1	2	1	1	1	2	1	-	1	71%	50%
Sprat250.jpg	1	4	4	2	1	1	2	2	2	1	1	-	1	1	1	2	1	-	1	56%	60%

Sprat253.jpg	3	5	6	4	-	3	5	2	4	3	3	3	1	3	3	4	4	-	3	44%	35%
Sprat260.jpg	2	4	5	2	2	2	2	2	4	2	2	2	1	2	1	2	3	-	2	65%	45%
Sprat263.jpg	1	4	4	2	1	1	1	2	2	2	1	2	1	1	1	2	2	-	1	47%	55%
Sprat265.jpg	1	3	4	1	1	1	1	2	1	1	1	2	1	1	1	2	2	-	1	65%	57%
Sprat266.jpg	2	4	5	2	2	1	2	2	2	2	2	2	1	1	1	2	1	-	2	59%	53%
Sprat267.jpg	1	4	5	2	1	1	2	2	2	2	1	2	1	1	1	2	1	-	1	47%	62%
Sprat268.jpg	1	4	5	1	1	1	1	2	3	1	1	2	1	1	1	3	2	-	1	59%	68%
Sprat272.jpg	2	3	6	2	2	1	2	2	4	1	3	2	1	1	1	2	3	-	2	41%	58%
Sprat273.jpg	2	4	4	2	2	2	2	2	2	2	3	3	2	2	2	3	2	-	2	71%	30%
Sprat274.jpg	2	4	4	2	2	2	3	3	2	2	3	3	2	2	2	3	2	-	2	59%	28%
Sprat275.jpg	2	4	5	4	2	2	2	2	3	2	4	2	2	1	2	2	3	-	2	59%	41%
Sprat276.jpg	2	4	5	2	2	2	2	3	3	2	2	2	2	1	2	3	2	-	2	65%	39%
Sprat277.jpg	2	4	6	2	2	2	2	2	3	3	2	2	1	1	1	2	3	-	2	53%	52%
Sprat278.jpg	2	3	5	2	1	1	1	3	3	2	2	2	1	1	1	2	2	-	2	41%	53%
Sprat279.jpg	2	3	5	2	2	1	2	2	2	1	2	2	1	1	1	2	2	-	2	59%	50%
Sprat281.jpg	2	4	4	2	2	2	2	3	2	2	3	3	2	2	2	3	2	-	2	65%	29%
Sprat285.jpg	2	3	5	2	2	2	2	3	2	2	2	3	2	2	2	3	2	-	2	71%	33%
Sprat286.jpg	2	3	5	2	2	2	2	3	2	2	2	3	2	2	2	3	2	-	2	71%	33%
Sprat291.jpg	1	3	4	1	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	65%	57%
Sprat292.jpg	1	3	3	2	1	1	2	2	1	1	1	2	1	1	1	2	1	-	1	59%	47%
Sprat293.jpg	1	2	3	2	1	1	1	2	1	1	1	2	1	1	1	2	1	-	1	65%	44%
Sprat296.jpg	2	3	4	2	2	2	2	3	2	2	2	2	2	2	1	3	2	-	2	71%	30%
Sprat299.jpg	2	3	4	2	2	2	2	3	2	2	2	2	2	2	2	3	2	-	2	76%	26%
Sprat300.jpg	2	3	5	2	2	2	2	2	3	3	2	2	2	2	2	5	2	-	2	71%	40%
Sprat301.jpg	1	2	4	2	1	1	1	2	2	1	1	2	1	1	1	2	1	-	1	59%	52%
Sprat302.jpg	2	3	4	2	2	2	2	3	2	2	2	2	2	2	2	3	2	-	2	76%	26%
Sprat303.jpg	2	3	4	2	1	1	1	2	2	2	1	2	1	1	1	2	2	-	2	47%	47%
Sprat304.jpg	2	3	5	3	2	2	3	2	2	2	2	2	2	2	1	2	2	-	2	71%	37%
Sprat305.jpg	1	2	4	1	1	1	1	2	2	1	1	2	1	1	1	3	2	-	1	59%	55%
Sprat322.jpg	1	2	5	3	1	1	1	2	1	1	1	2	1	1	1	2	1	-	1	65%	67%
Sprat323.jpg	1	2	3	1	1	1	1	2	1	1	1	1	1	1	1	2	1	-	1	76%	45%
Sprat324.jpg	1	2	3	1	1	1	1	2	1	1	1	1	1	1	1	2	1	-	1	76%	45%
Sprat328.jpg	1	3	4	2	1	1	1	2	1	1	1	1	1	1	-	2	1	-	1	69%	67%
Sprat331.jpg	1	2	4	1	1	1	1	2	1	1	1	1	1	1	1	2	1	-	1	76%	58%
Sprat332.jpg	1	2	4	2	2	1	1	2	1	1	1	2	1	1	1	2	1	-	1	59%	52%
Sprat338.jpg	1	2	3	2	1	1	1	2	1	1	1	1	1	1	1	2	1	-	1	71%	45%
Sprat341.jpg	1	3	3	2	1	1	1	2	1	1	1	1	1	1	1	-	2	-	1	69%	51%
Sprat343.jpg	1	3	3	2	1	1	2	2	1	1	1	1	1	1	1	2	1	-	1	65%	49%
Sprat344.jpg	1	2	3	1	1	1	1	2	1	1	1	1	1	1	1	2	1	-	1	76%	45%
Overall																				**62%**	**44%**

Table 2. Estimated ages from only expert readers for all otoliths. Modal age, % agreement and CV given for each otolith plus an overall % agreement and CV.

Reader	**4**	**5**	**6**	**7**	**15**	**16**	**17**	**2**	**Modal**	**%**	**CV**
	Hansen	Lange	Krischansson	Johansson	Svendsen	Hermansen	Røttingen	Beintema	**age**	**agree**	
	Denmark	Norway	Sweden	Sweden	Norway	Norway	Norway	Netherlands			
Sample											
Sprat003	3	3	3	3	3	3	3	4	3	89%	11%
Sprat006	2	2	2	2	2	2	2	3	2	89%	16%
Sprat010	2	2	2	2	2	2	2	3	2	89%	16%
Sprat011	2	2	2	2	2	2	2	3	2	89%	16%
Sprat012	2	2	2	2	2	2	2	3	2	89%	16%
Sprat013	3	3	3	3	3	3	3	4	3	89%	11%
Sprat018	2	2	2	2	2	2	2	3	2	89%	16%
Sprat016	1	1	1	1	1	1	1	4	1	89%	75%
Sprat022	1	1	1	1	1	4	1	3	1	78%	73%
Sprat024	2	2	3	3	3	2	2	3	3	56%	21%
Sprat025	2	3	3	3	3	4	2	3	3	67%	21%
Sprat028	2	2	2	2	2	2	2	3	2	89%	16%
Sprat029	3	5	4	4	4	4	2	4	4	56%	24%
Sprat030	2	2	2	2	2	2	2	3	2	89%	16%
Sprat031	2	2	2	2	2	2	2	3	2	89%	16%
Sprat032	2	2	2	2	2	2	2	3	2	89%	16%
Sprat038	2	2	2	2	2	3	2	3	2	78%	20%
Sprat039	2	2	2	2	2	2	2	3	2	89%	16%
Sprat041	2	2	2	2	2	2	2	3	2	89%	16%
Sprat044	2	2	2	2	2	2	2	3	2	89%	16%
Sprat047	2	2	2	2	2	2	2	3	2	89%	16%
Sprat049	2	2	2	2	2	2	2	3	2	89%	16%
Sprat055	2	2	2	2	2	2	2	3	2	89%	16%
Sprat057	2	3	2	2	2	2	2	4	2	67%	30%
Sprat059	1	1	1	1	1	1	1	4	1	89%	75%
Sprat060	3	3	3	3	4	3	3	4	3	78%	14%
Sprat061	2	2	2	2	-	2	2	5	2	88%	45%
Sprat065	2	2	2	2	2	2	2	3	2	89%	16%
Sprat066	2	2	2	2	2	2	2	4	2	89%	30%
Sprat068	2	2	2	2	2	2	2	3	2	89%	16%
Sprat072	3	2	2	2	2	2	2	3	2	78%	20%
Sprat074	2	2	2	2	2	2	2	3	2	89%	16%
Sprat079	1	2	1	1	1	1	1	3	1	78%	53%
Sprat096	1	2	1	1	1	1	1	3	1	78%	53%
Sprat097	1	2	1	1	1	1	1	3	1	78%	53%
Sprat099	1	2	1	1	1	1	1	3	1	78%	53%
Sprat102b	1	2	1	1	1	1	1	3	1	78%	53%
Sprat103b	1	2	1	1	1	1	1	3	1	78%	53%
Sprat104b	1	2	1	1	1	1	1	4	1	78%	70%
Sprat105b	1	2	1	1	1	2	1	4	1	56%	60%
Sprat108	1	2	1	1	1	1	1	3	1	78%	53%
Sprat109	2	2	1	1	1	1	2	4	1	44%	55%
Sprat111	1	2	1	1	1	1	1	3	1	78%	53%
Sprat112	1	2	1	1	1	1	1	4	1	78%	70%
Sprat113	1	2	1	1	1	1	1	4	1	78%	70%
Sprat114	1	1	1	1	1	1	1	4	1	89%	75%
Sprat115	1	2	1	1	1	1	1	4	1	78%	70%
Sprat087	1	2	1	1	1	1	1	3	1	78%	53%
Sprat117	1	2	1	1	1	1	1	3	1	67%	50%

Sprat118	1	2	1	1	1	1	1	3	1	78%	53%
Sprat119	1	2	1	1	1	1	1	4	1	78%	70%
Sprat122	1	2	1	1	1	1	1	3	1	78%	53%
Sprat123	1	2	1	1	1	1	1	3	1	78%	53%
Sprat088	1	2	1	1	1	1	1	3	1	78%	53%
Sprat140	1	2	1	1	1	1	1	3	1	78%	53%
Sprat142	1	2	4	1	1	2	1	4	1	44%	61%
Sprat143	1	2	4	1	1	1	1	4	1	67%	73%
Sprat144	1	1	2	1	1	1	1	3	1	78%	53%
Sprat147	1	2	2	1	1	1	1	3	1	67%	50%
Sprat151	1	2	2	1	1	1	1	3	1	67%	50%
Sprat152	1	2	2	1	1	1	1	3	1	67%	50%
Sprat155	1	2	2	1	1	1	1	3	1	67%	50%
Sprat157	1	2	2	1	1	1	1	3	1	67%	50%
Sprat160	1	2	2	1	1	1	1	3	1	67%	50%
Sprat161	1	2	2	1	1	1	1	3	1	67%	50%
Sprat162	1	2	2	1	1	1	1	3	1	67%	50%
Sprat163	1	2	2	1	1	1	1	3	1	67%	50%
Sprat164	1	1	2	1	1	1	1	3	1	78%	53%
Sprat165	1	2	2	1	1	1	1	3	1	67%	50%
Sprat159	1	2	2	1	1	1	1	3	1	67%	50%
Sprat167	1	2	2	1	2	1	1	3	1	56%	47%
Sprat168	1	2	2	1	1	1	1	3	1	67%	50%
Sprat169	1	1	2	1	2	1	1	3	1	67%	50%
Sprat170	1	2	2	1	1	1	1	3	1	67%	50%
Sprat172	2	2	4	2	-	2	2	5	2	71%	46%
Sprat173	1	1	2	1	1	1	1	3	1	78%	53%
Sprat174	2	2	2	2	2	-	2	3	2	88%	17%
Sprat175	1	2	1	1	1	1	1	3	1	78%	53%
Sprat176	2	2	2	2	2	2	2	4	2	89%	30%
Sprat177	1	1	1	1	1	1	1	3	1	89%	55%
Sprat178	1	1	1	1	1	2	1	4	1	67%	65%
Sprat182	1	1	1	1	1	1	1	3	1	89%	55%
Sprat190	1	1	1	1	1	1	1	3	1	89%	55%
Sprat194	2	2	2	2	2	2	2	3	2	78%	25%
Sprat198	1	1	1	1	1	1	1	3	1	89%	55%
Sprat199	1	1	1	1	1	2	1	4	1	67%	65%
Sprat200	1	1	1	1	1	1	1	3	1	89%	55%
Sprat201	1	1	1	1	1	1	1	4	1	89%	75%
Sprat202	1	1	1	1	1	1	1	4	1	89%	75%
Sprat203	1	1	1	1	1	1	1	3	1	89%	55%
Sprat204	1	1	1	1	1	1	1	3	1	89%	55%
Sprat206	1	1	1	1	1	1	1	3	1	89%	55%
Sprat216	1	1	1	1	1	1	1	3	1	89%	55%
Sprat217	1	1	1	1	1	1	1	3	1	89%	55%
Sprat218	1	1	1	1	1	1	1	3	1	89%	55%
Sprat219	1	1	1	1	1	1	1	3	1	89%	55%
Sprat221	1	1	1	1	1	1	1	3	1	89%	55%
Sprat222	1	1	1	1	1	1	1	3	1	89%	55%
Sprat226	2	2	1	1	1	2	2	4	2	56%	49%
Sprat228	1	2	1	1	1	1	1	3	1	78%	53%
Sprat235	1	1	1	1	1	1	2	3	1	78%	53%
Sprat236	1	2	2	1	2	1	1	3	1	56%	47%
Sprat238	1	1	1	1	1	1	1	3	1	89%	55%
Sprat240	1	2	1	1	1	1	1	3	1	78%	53%
Sprat241	1	1	1	1	1	1	1	3	1	89%	55%

Sprat242	1	1	1	1	1	1	1	4	1	89%	75%
Sprat243	1	1	1	1	1	1	1	3	1	89%	55%
Sprat247	1	2	1	1	1	1	1	4	1	78%	70%
Sprat248	1	1	1	1	1	1	1	3	1	89%	55%
Sprat249	1	1	1	1	1	1	1	3	1	89%	55%
Sprat250	1	2	1	1	2	1	1	4	1	67%	65%
Sprat253	3	4	-	3	5	1	3	5	3	50%	39%
Sprat260	1	2	2	2	2	1	2	4	2	67%	43%
Sprat263	1	2	1	1	1	1	1	4	1	78%	70%
Sprat265	1	1	1	1	1	1	1	3	1	89%	55%
Sprat266	1	2	2	1	2	1	1	4	1	44%	55%
Sprat267	1	2	1	1	2	1	1	4	1	67%	65%
Sprat268	1	1	1	1	1	1	1	4	1	89%	75%
Sprat272	1	2	2	1	2	1	1	3	1	44%	42%
Sprat273	2	2	2	2	2	2	2	4	2	89%	30%
Sprat274	2	2	2	2	3	2	2	4	2	78%	30%
Sprat275	2	4	2	2	2	2	1	4	2	67%	43%
Sprat276	2	2	2	2	2	2	1	4	2	78%	37%
Sprat277	1	2	2	2	2	1	1	4	2	56%	49%
Sprat278	1	2	1	1	1	1	1	3	1	67%	50%
Sprat279	1	2	2	1	2	1	1	3	1	44%	42%
Sprat281	2	2	2	2	2	2	2	4	2	89%	30%
Sprat285	2	2	2	2	2	2	2	3	2	89%	16%
Sprat286	2	2	2	2	2	2	2	3	2	89%	16%
Sprat291	1	1	1	1	1	1	1	3	1	89%	55%
Sprat292	1	2	1	1	2	1	1	3	1	67%	50%
Sprat293	1	2	1	1	1	1	1	2	1	78%	36%
Sprat296	1	2	2	2	2	2	2	3	2	78%	25%
Sprat299	2	2	2	2	2	2	2	3	2	89%	16%
Sprat300	2	2	2	2	2	2	2	3	2	89%	16%
Sprat301	1	2	1	1	1	1	1	2	1	78%	36%
Sprat302	2	2	2	2	2	2	2	3	2	89%	16%
Sprat303	1	2	1	1	1	1	1	3	1	67%	50%
Sprat304	1	3	2	2	3	2	2	3	2	56%	30%
Sprat305	1	1	1	1	1	1	1	2	1	89%	30%
Sprat322	1	3	1	1	1	1	1	2	1	78%	53%
Sprat323	1	1	1	1	1	1	1	2	1	89%	30%
Sprat324	1	1	1	1	1	1	1	2	1	89%	30%
Sprat328		2	1	1	1	1	1	3	1	67%	68%
Sprat331	1	1	1	1	1	1	1	2	1	89%	30%
Sprat332	1	2	2	1	1	1	1	2	1	67%	38%
Sprat338	1	2	1	1	1	1	1	2	1	78%	36%
Sprat341	1	2	1	1	1	1	1	3	1	78%	53%
Sprat343	1	2	1	1	2	1	1	3	1	67%	50%
Sprat344	1	1	1	1	1	1	1	2	1	89%	30%
Overall										**78%**	**45%**

Table 3. Age composition based on all Readers

Reader	1	2	3	4	5	6	7	8	9	11	12	13	15	16	17	19	20	21	
	Dufour	Beintema	Dijkman	Hansen	Lange	Krischansson	Johansson	Straker Cox	McCausland	Delfs	Jarnum	Johnsen	Svendsen	Hermansen	Røttingen	Moore	Lynch	Henriksen	
	France	Netherlands	Netherlands	Denmark	Norway	Sweden	Sweden	U.Kingdom	U.Kingdom	Germany	Denmark	Norway	Norway	Norway	Norway	Ireland	Ireland	Norway	
Age																			Total
0																			
1	91	-	-	41	77	102	92	3	17	82	96	11	99	102	103	2	60	1	979
2	50	10	2	99	63	41	47	124	65	59	39	116	43	44	40	90	70	17	1019
3	8	99	71	7	5	6	6	23	53	8	14	18	4	4	6	46	19	6	403
4	-	38	53	2	4	1	2	-	13	-	1	1	3	-	-	5	1	-	124
5	-	3	17	1	-	-	1	-	2	-	-	-	-	-	-	6	-	-	30
6	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Total	**149**	**150**	**148**	**150**	**149**	**150**	**148**	**150**	**150**	**149**	**150**	**146**	**149**	**150**	**149**	**149**	**150**	**24**	**2560**

Table 4. Mean length at age for all Readers

Reader	1	2	3	4	5	6	7	8	9	11	12	13	15	16	17	19	20	21	
	Dufour	Beintema	Dijkman	Hansen	Lange	Krischansson	Johansson	Straker Cox	McCausland	Delfs	Jarnum	Johnsen	Svendsen	Hermansen	Røttingen	Moore	Lynch	Henriksen	
	France	Netherlands	Netherlands	Denmark	Norway	Sweden	Sweden	U.Kingdom	U.Kingdom	Germany	Denmark	Norway	Norway	Norway	Norway	Ireland	Ireland	Norway	**All**
Age																			
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	100	-	-	102	101	101	100	85	101	101	100	94	102	102	102	97	100	89	**101**
2	112	106	88	105	108	112	112	104	105	108	110	104	111	110	111	104	106	102	**107**
3	110	103	100	112	108	110	112	113	106	119	120	115	115	118	117	107	111	108	**107**
4	-	108	106	129	102	111	111	-	105	-	138	111	98	-	-	106	120	-	**107**
5	-	113	116	111	-	-	120	-	108	-	-	-	-	-	-	103	-	-	**112**
6	-	-	123	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**123**

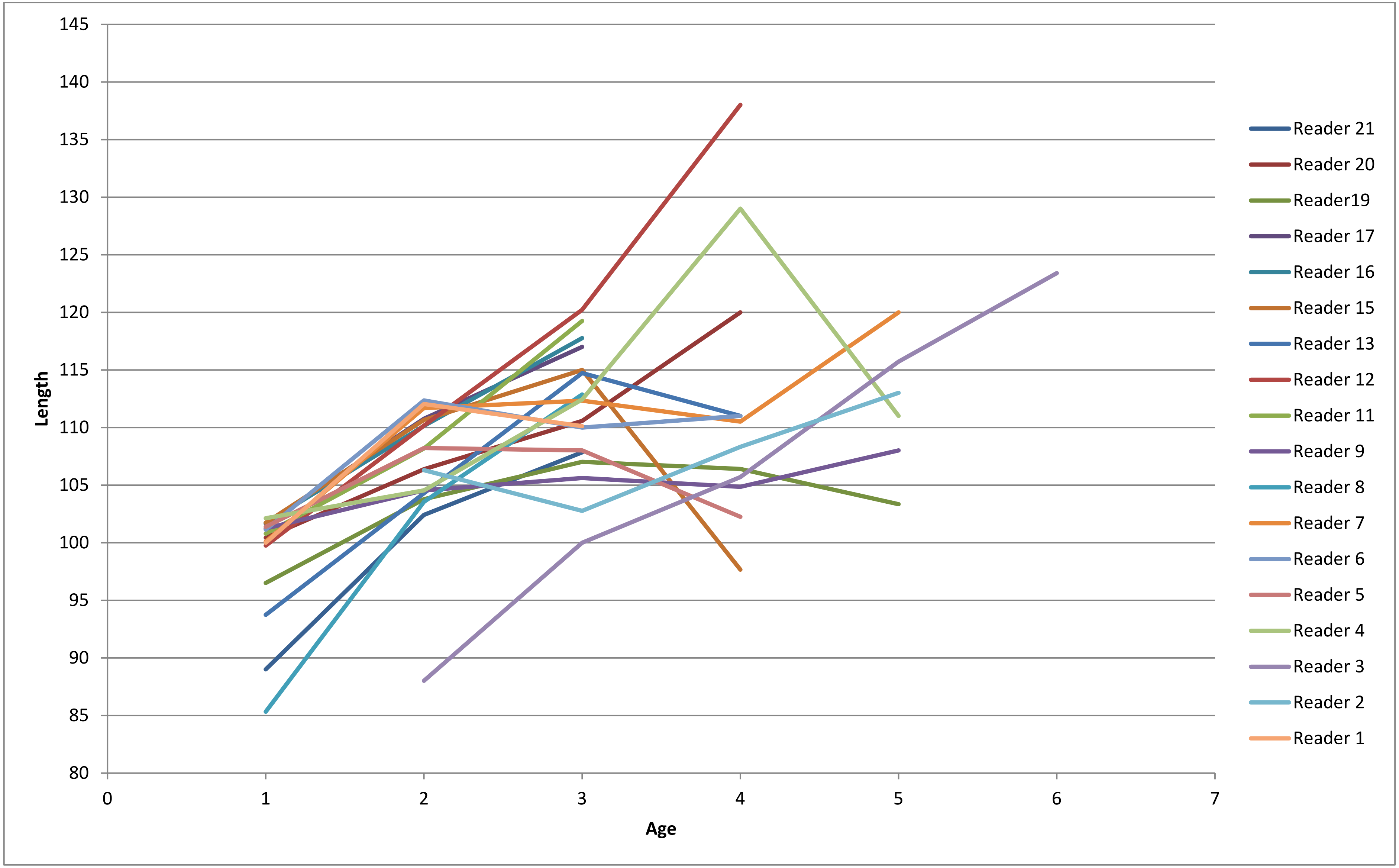

Figure 3.1 Mean length at age

Annex 4. Sprat 3 point grading system

Based on a recommendation from WKNARC (ICES, 2013) all age calibration exchanges and workshops should “register the confidence level the reader has in their otolith reading, reflecting the quality of the data”. These can be directly linked to ageing performance and reliability of age estimates for stock assessment.

Most readers should use a scale of 3 levels of quality:

- Rings can be counted with certainty: 1
- Rings can be counted, but with difficulty and some doubt: 2
- Rings cannot be counted, the otolith is unreadable: 3

Based on the above recommendations the following is the 3point scale to be used for the 2013 Sprat Exchange:

- **AQ1**: Easy to age with high precision.
- **AQ2:** Difficult to age with acceptable precision. Includes uncertainties when identifying the first annulus, the presence of narrow opaque zones and edge interpretation. (If possible, please state in the comments box what the problem is)
- **AQ3:** Unreadable or very difficult to age with acceptable precision.

Annex 5. Results from the Tukey Contrast test

Those marked in red show where the readers read differently (significant codes 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1). Those marked in green show where Readers read the same (ranging from good agreement at 1.0 to poor agreement at 0.1295).

```
Simultaneous Tests for General Linear Hypotheses

Multiple Comparisons of Means: Tukey Contrasts

Fit: lme.formula(fixed=  distance ~ reader + reader : log(winterring),data =
growth.data, random = ~log(winterring) | image, method = "ML")

Linear Hypotheses:

   Reader        Estimate   Std. Error  z value   Pr(>|z|)

   2 - 1 == 0   -5.408e-02  8.757e-03  -6.175    <0.01 ***
   3 - 1 == 0   -1.002e-01  8.672e-03 -11.548    <0.01 ***
   4 - 1 == 0    7.257e-03  8.815e-03   0.823   1.0000
   5 - 1 == 0   -3.491e-02  8.847e-03  -3.946    <0.01 **
   6 - 1 == 0   -2.056e-03  8.860e-03  -0.232   1.0000
7 - 1 == 0    1.860e-02  8.860e-03   2.100   0.7927
   8 - 1 == 0   -2.156e-03  8.817e-03  -0.245   1.0000
   9 - 1 == 0   -9.966e-02  8.712e-03 -11.440    <0.01 ***
   11 - 1 == 0  -2.462e-02  8.880e-03  -2.773   0.3088
   12 - 1 == 0  -3.833e-02  8.847e-03  -4.333    <0.01 **
   13 - 1 == 0   5.771e-03  8.866e-03   0.651   1.0000
   15 - 1 == 0  -3.064e-02  8.881e-03  -3.450   0.0507 .
   16 - 1 == 0  -1.854e-02  8.910e-03  -2.081   0.8034
   17 - 1 == 0  -2.199e-02  8.904e-03  -2.470   0.5237
   19 - 1 == 0  -1.070e-01  8.682e-03 -12.327    <0.01 ***
   20 - 1 == 0  -3.251e-02  8.874e-03  -3.663   0.0250 *
   3 - 2 == 0   -4.608e-02  8.499e-03  -5.422    <0.01 ***
   4 - 2 == 0    6.133e-02  8.655e-03   7.086    <0.01 ***
   5 - 2 == 0    1.917e-02  8.685e-03   2.207   0.7221
   6 - 2 == 0    5.202e-02  8.703e-03   5.977    <0.01 ***
   7 - 2 == 0    7.268e-02  8.704e-03   8.350    <0.01 ***
   8 - 2 == 0    5.192e-02  8.653e-03   6.000    <0.01 ***
   9 - 2 == 0   -4.559e-02  8.545e-03  -5.335    <0.01 ***
   11 - 2 == 0   2.945e-02  8.722e-03   3.377   0.0658 .
   12 - 2 == 0   1.574e-02  8.689e-03   1.812   0.9280
   13 - 2 == 0   5.985e-02  8.705e-03   6.875    <0.01 ***
   15 - 2 == 0   2.343e-02  8.726e-03   2.686   0.3652
   16 - 2 == 0   3.553e-02  8.753e-03   4.059    <0.01 **
   17 - 2 == 0   3.208e-02  8.747e-03   3.668   0.0243 *
   19 - 2 == 0  -5.295e-02  8.514e-03  -6.219    <0.01 ***
   20 - 2 == 0   2.157e-02  8.716e-03   2.475   0.5207
   4 - 3 == 0    1.074e-01  8.569e-03  12.535    <0.01 ***
   5 - 3 == 0    6.525e-02  8.604e-03   7.583    <0.01 ***
   6 - 3 == 0    9.810e-02  8.618e-03  11.382    <0.01 ***
   7 - 3 == 0    1.188e-01  8.619e-03  13.779    <0.01 ***
   8 - 3 == 0    9.800e-02  8.569e-03  11.437    <0.01 ***
   9 - 3 == 0    4.916e-04  8.456e-03   0.058   1.0000
   11 - 3 == 0   7.553e-02  8.635e-03   8.747    <0.01 ***
   12 - 3 == 0   6.182e-02  8.604e-03   7.185    <0.01 ***
   13 - 3 == 0   1.059e-01  8.621e-03  12.287    <0.01 ***
   15 - 3 == 0   6.951e-02  8.640e-03   8.045    <0.01 ***
   16 - 3 == 0   8.161e-02  8.669e-03   9.415    <0.01 ***
   17 - 3 == 0   7.816e-02  8.661e-03   9.024    <0.01 ***
   19 - 3 == 0  -6.872e-03  8.423e-03  -0.816   1.0000
```

```
20 - 3 == 0   6.765e-02  8.630e-03   7.839    <0.01 ***
5 - 4 == 0   -4.216e-02  8.748e-03  -4.820    <0.01 ***
6 - 4 == 0   -9.313e-03  8.760e-03  -1.063   0.9998
7 - 4 == 0    1.135e-02  8.761e-03   1.295   0.9974
8 - 4 == 0   -9.413e-03  8.719e-03  -1.080   0.9997
9 - 4 == 0   -1.069e-01  8.610e-03 -12.418    <0.01 ***
11 - 4 == 0  -3.188e-02  8.783e-03  -3.630   0.0284 *
12 - 4 == 0  -4.559e-02  8.747e-03  -5.212    <0.01 ***
13 - 4 == 0  -1.485e-03  8.766e-03  -0.169   1.0000
15 - 4 == 0  -3.790e-02  8.782e-03  -4.316    <0.01 **
16 - 4 == 0  -2.580e-02  8.813e-03  -2.927   0.2182
17 - 4 == 0  -2.925e-02  8.807e-03  -3.321   0.0773 .
19 - 4 == 0  -1.143e-01  8.577e-03 -13.324    <0.01 ***
20 - 4 == 0  -3.976e-02  8.774e-03  -4.532    <0.01 ***
6 - 5 == 0    3.285e-02  8.793e-03   3.736   0.0190 *
7 - 5 == 0    5.351e-02  8.796e-03   6.083    <0.01 ***
8 - 5 == 0    3.275e-02  8.749e-03   3.743   0.0192 *
9 - 5 == 0   -6.475e-02  8.644e-03  -7.491    <0.01 ***
11 - 5 == 0   1.028e-02  8.814e-03   1.167   0.9993
12 - 5 == 0  -3.426e-03  8.781e-03  -0.390   1.0000
13 - 5 == 0   4.068e-02  8.797e-03   4.624    <0.01 ***
15 - 5 == 0   4.267e-03  8.814e-03   0.484   1.0000
16 - 5 == 0   1.636e-02  8.844e-03   1.850   0.9147
17 - 5 == 0   1.292e-02  8.838e-03   1.461   0.9904
19 - 5 == 0  -7.212e-02  8.612e-03  -8.374    <0.01 ***
20 - 5 == 0   2.402e-03  8.808e-03   0.273   1.0000
7 - 6 == 0    2.066e-02  8.808e-03   2.346   0.6199
8 - 6 == 0   -9.956e-05  8.765e-03  -0.011   1.0000
9 - 6 == 0   -9.761e-02  8.659e-03 -11.273    <0.01 ***
11 - 6 == 0  -2.257e-02  8.827e-03  -2.557   0.4595
12 - 6 == 0  -3.628e-02  8.794e-03  -4.125    <0.01 **
13 - 6 == 0   7.828e-03  8.813e-03   0.888   1.0000
15 - 6 == 0  -2.858e-02  8.827e-03  -3.238   0.0972 .
16 - 6 == 0  -1.649e-02  8.858e-03  -1.861   0.9109
17 - 6 == 0  -1.994e-02  8.851e-03  -2.252   0.6892
19 - 6 == 0  -1.050e-01  8.627e-03 -12.167    <0.01 ***
20 - 6 == 0  -3.045e-02  8.821e-03  -3.452   0.0507 .
8 - 7 == 0   -2.076e-02  8.767e-03  -2.368   0.6021
9 - 7 == 0   -1.183e-01  8.660e-03 -13.657    <0.01 ***
11 - 7 == 0  -4.323e-02  8.829e-03  -4.896    <0.01 ***
12 - 7 == 0  -5.694e-02  8.796e-03  -6.473    <0.01 ***
13 - 7 == 0  -1.283e-02  8.814e-03  -1.456   0.9908
15 - 7 == 0  -4.925e-02  8.830e-03  -5.577    <0.01 ***
16 - 7 == 0  -3.715e-02  8.859e-03  -4.193    <0.01 **
17 - 7 == 0  -4.060e-02  8.853e-03  -4.586    <0.01 ***
19 - 7 == 0  -1.256e-01  8.628e-03 -14.561    <0.01 ***
20 - 7 == 0  -5.111e-02  8.822e-03  -5.794    <0.01 ***
9 - 8 == 0   -9.751e-02  8.611e-03 -11.323    <0.01 ***
11 - 8 == 0  -2.247e-02  8.784e-03  -2.558   0.4582
12 - 8 == 0  -3.618e-02  8.751e-03  -4.134    <0.01 **
13 - 8 == 0   7.927e-03  8.766e-03   0.904   1.0000
15 - 8 == 0  -2.849e-02  8.786e-03  -3.242   0.0958 .
16 - 8 == 0  -1.639e-02  8.814e-03  -1.859   0.9120
17 - 8 == 0  -1.984e-02  8.808e-03  -2.252   0.6900
19 - 8 == 0  -1.049e-01  8.579e-03 -12.224    <0.01 ***
20 - 8 == 0  -3.035e-02  8.778e-03  -3.458   0.0503 .
11 - 9 == 0   7.504e-02  8.679e-03   8.646    <0.01 ***
12 - 9 == 0   6.133e-02  8.644e-03   7.095    <0.01 ***
13 - 9 == 0   1.054e-01  8.663e-03  12.170    <0.01 ***
15 - 9 == 0   6.902e-02  8.680e-03   7.952    <0.01 ***
16 - 9 == 0   8.112e-02  8.709e-03   9.314    <0.01 ***
17 - 9 == 0   7.767e-02  8.703e-03   8.925    <0.01 ***
19 - 9 == 0  -7.363e-03  8.462e-03  -0.870   1.0000
20 - 9 == 0   6.716e-02  8.671e-03   7.745    <0.01 ***
12 - 11 == 0 -1.371e-02  8.814e-03  -1.556   0.9818
13 - 11 == 0  3.040e-02  8.834e-03   3.441   0.0526 .
15 - 11 == 0 -6.017e-03  8.849e-03  -0.680   1.0000
```

```
16 - 11 == 0  6.080e-03  8.877e-03   0.685   1.0000
17 - 11 == 0  2.632e-03  8.870e-03   0.297   1.0000
19 - 11 == 0 -8.240e-02  8.646e-03  -9.531    <0.01 ***
20 - 11 == 0 -7.882e-03  8.841e-03  -0.892   1.0000
13 - 12 == 0  4.411e-02  8.800e-03   5.012    <0.01 ***
15 - 12 == 0  7.693e-03  8.816e-03   0.873   1.0000
16 - 12 == 0  1.979e-02  8.844e-03   2.238   0.7004
17 - 12 == 0  1.634e-02  8.838e-03   1.849   0.9162
19 - 12 == 0 -6.869e-02  8.615e-03  -7.973    <0.01 ***
20 - 12 == 0  5.828e-03  8.807e-03   0.662   1.0000
15 - 13 == 0 -3.641e-02  8.834e-03  -4.122    <0.01 **
16 - 13 == 0 -2.432e-02  8.862e-03  -2.744   0.3262
17 - 13 == 0 -2.776e-02  8.854e-03  -3.136   0.1295
19 - 13 == 0 -1.128e-01  8.629e-03 -13.071    <0.01 ***
20 - 13 == 0 -3.828e-02  8.823e-03  -4.338    <0.01 **
16 - 15 == 0  1.210e-02  8.879e-03   1.362   0.9955
17 - 15 == 0  8.649e-03  8.872e-03   0.975   0.9999
19 - 15 == 0 -7.638e-02  8.648e-03  -8.833    <0.01 ***
20 - 15 == 0 -1.865e-03  8.842e-03  -0.211   1.0000
17 - 16 == 0 -3.448e-03  8.899e-03  -0.387   1.0000
19 - 16 == 0 -8.848e-02  8.679e-03 -10.195    <0.01 ***
20 - 16 == 0 -1.396e-02  8.869e-03  -1.574   0.9795
19 - 17 == 0 -8.503e-02  8.673e-03  -9.805    <0.01 ***
20 - 17 == 0 -1.051e-02  8.861e-03  -1.187   0.9991
20 - 19 == 0  7.452e-02  8.639e-03   8.626    <0.01 ***

Simultaneous Tests for General Linear Hypotheses ---

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Adjusted p values reported -- single-step method)
```