ICES WKARBLUE REPORT 2013

ICES ADVISORY COMMITTEE

ICES CM 2013/ACOM:53

Report of the Workshop on the Age Reading of Blue Whiting

10-14 June 2013

Bergen, Norway

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

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Contents

Executive summary

The workshop on age reading of blue whiting (WKARBLUE) was held in Bergen, Norway, from the 10th to the 14th of June 2013. The meeting was co-chaired by Jane A. Godiksen (Norway) and Manolo Meixide (Spain), and included 19 age readers from 11 countries, where one country participated by web-camera.

The objectives of this workshop were to review, document and make recommendations on current methods of aging blue whiting (*Micromesistius poutassou*).

This workshop was preceded by an otolith exchange, which was undertaken using WebGR in the months prior to the workshop. The exchanged otolith collection included 158 images from the previous exchange, 50 of these, along with 100 new otoliths, were also read during the workshop after establishing guidelines for reading. The overall agreement with modal age of the pre-workshop exercise was 56.6%, with a precision of 13.2% CV. The three sets of otoliths read during the workshop had an agreement ranging between 54.5% and 74.1% with a precision ranging from 13.4% to 40.5% CV. The collection with the highest agreement and highest CV was a collection from the Faroe Islands including many young fish, which are easier to read than older specimens.

The main issues during this workshop were identification of the position of the first annual growth ring, false rings and interpretation of the edge. These issues are the same as has been mentioned in previous reports, and thus a reoccurring problem among age readers. A reference collection of images from the workshop will be made and placed in WebGR, this will hopefully be helpful when running into these issues during reading.

Bias in age readings is an issue that would strongly affect the stock assessment. The results of this workshop show that the readers, who submit blue whiting age compositions to the Working Group on Assessment of Widely Distributed Stocks (WGWIDE) presented null or low bias in three of the four samples used. Strong bias was observed in the last sample among both experienced and new readers, and that particular sample was considered by all readers as very difficult to age.

1 Introduction

1.1 Term of reference

WKARBLUE – Workshop on the Age Reading of blue whiting.

The workshop on age reading of blue whiting (*Micromesistius poutassou*), chaired by Jane Amtoft Godiksen (Norway) and Manuel Meixide (Spain), will be established and take place in Bergen, Norway, from 10–14 June 2013, to:

a) Review information on age estimations, otolith exchanges, workshops and validation work done so far.

b) Finalize the report of the otolith exchange carried out in 2010-2011.

c) To make recommendations and produce feedback on the age estimation criteria to increase age estimation precision and accuracy and improve the inter reader agreement.

d) To identify the causes of age determination errors and standardize the age reading between laboratories and to ensure the implementation of the ageing protocol/guidelines.

e) To explore the possibilities to use supplementary information for validating estimated age structures.

f) Address the generic ToR's adopted for workshops on age calibration (see 'PGCCDBS Guidelines for Workshops on Age Calibration').

WKARBLUE will report by September 30, 2013 for attention of ACOM.

1.2 Participants

Participants of the blue whiting workshop in Bergen 2013

Name	Country	Last exchange	Assessment	Expertice
Alexander Pronyuk	Russia		X	Intermediate
Ana Luisa Ferreira	Portugal	X	X	Intermediate
Eugene Mullins	Ireland	X	X	Expert
Friederike Beußel	Germany		X	Trainee
Ines Wilhelms	Germany		X	Trainee
Jaime Alvarez	Norway	X	X	Expert
Jan de Lange	Norway	X	X	Expert
Jane Mills	Scotland		X	Intermediate
Jane Amtoft Godiksen (co-chair)	Norway			
Jean Louis Dufour	France		X	Expert
Jens Arni Thomassen	Faroe Islands			Trainee
Kélig Mahe	France			
Kirsti Børve Eriksen	Norway	X		Trainee
Lis Larsen	Faroe Islands	X	X	Intermediate
Manuel Meixide (co-chair)	Spain			
Poul Vestergaard	Faroe Islands			Intermediate
Rosendo Otero	Spain	X	X	Expert
Sigrun Johannsdottir	Iceland	X	X	Expert
Ståle Kolbeinson	Norway			Trainee
Tatiana Prokhorova	Russia	X		Intermediate
Thomas Pasterkamp	Holland	X	X	Expert
Ørjan Bredal Sørensen	Norway			Trainee

1.3 Acknowledgements

We would like to thank PINRO (Russia) and FAMRI (Faroe Islands) for kindly providing otolith images for the workshop.

Also a big thanks to Kélig Mahe, Tatiana Prokhorova and Eugene Mullins for commenting on the report.

2 Review information on age estimations, otolith exchanges, workshops and validation work done so far (ToR a)

2.1 Otolith exchanges

Several otolith exchanges and workshops were reported in the Report of the Blue whiting Otolith Reading in Tórshaven in 1992 (Anon. 1993), and further exchanges have been done ahead of the workshops in 1992 and 2005. A large exchange was done in 2010/2011 including both images and whole otoliths (Mehl *et al*., 2011).

Year start	Year end	Exchange / workshop	Otolith prep.	Agreement	Issues	Reference
1977	1978	Exchange	Whole / sectioned	Unacceptable variance	First hyaline zone	Anon., 1979
1979	1981	Exchange	Otoliths and images	Mean age varies from 6.3 to 10.6 years	Edge, first zone	Anon., 1981
1981	1983	Workshop	Whole / sectioned	Generally low, but better than previous readings	Otolith treatment before ageing, variation in growth rate, false rings, first ring, edge	Anon., 1983
1984	1986	Exchange		Generally low agreement		Seliverstova et al. 1986 Anon., 1987
1986	1988	Exchange		High (<5 years old) Low (>4 years old)		Monstad and Linkowski 1988 Anon., 1989
1988	1990	Exchange	Whole / sectioned	0-58 % between readers	First zone, edge	Meixide 1990
1990	1992	Exchange followed by workshop	Whole / sectioned	15-94 % between readers	First ring, edge, split rings	Anon., 1993
	2005	Small exchange followed by workshop	Whole (otoliths and images)	> 80 %	First ring, edge, false rings	ICES 2005
2010	2013	Exchange followed by workshop	Whole (otoliths and images)	< 50 %	First ring, edge, split rings	Mehl et al. 2011 This report

2.2 Workshops

Two workshops has been conducted by ICES in 1992 (Anon. 1993) and 2005 (ICES 2005)

2.2.1 Workshop 1992 (Tórshaven, Faroe Islands)

In the 1992 workshop two age reading techniques for blue whiting otoliths were in use; one technique was to analyse them whole, and the other to section the otoliths. By the first method the otoliths are kept in freshwater after sampling and analysed while soaked. They are stored dry in envelopes for later analyses, and upon rereading they are again soaked in freshwater for at least 24 hours. This method is used by Norway and Russia, which together count for more than 80% of the blue whiting landings. Also Spain occasionally uses this method. The other method includes mounting the otoliths in a black polyester resin, whereafter thin slices are cut precisely along the centre of the otoliths. The slices (transverse section of the otoliths) are then mounted and fixed on standard glass microscope slides (Bedford 1983). This method is used by Faroe Islands and Spain. The Spanish method includes keeping the otoliths in seawater until slicing, in order to make the rings more visible.

During the workshop comparisons of the measurements of the observed ring diameters were compared in order to examine the differences between techniques. This made it possible to detect the presence of false rings and to indicate missing rings if the distance between two consecutive rings was too large. The results showed that underestimation of ages mainly were due to missing rings, especially towards the edge or inclusion of false rings.

The conclusions from this exercise were that:

- No clear pattern of the presence of false rings could be seen
- No simple rule exist to decide where a false ring appears
- A possible technique might be to look at the increments from one ring to the next to determine the presence of false rings and to indicate missing rings if the distance between two consecutive rings is too large.

Also, it is necessary to use the same magnification when measuring ring diameter in otoliths. This emerges from the observed systematic difference in mean ring diameter between countries although no difference in mean age could be observed between countries. Correcting for this no differences could be observed in mean annual ring diameter of otoliths from the so-called "northern blue whiting" and the "southern blue whiting" (area VIIIc and IXa).

2.2.2 Workshop 2005 (Hirsthals, Denmark)

During this workshop a set of rules and methods of age estimation of blue whiting was defined. The guidelines for ageing of blue whiting were intended to guide new readers of blue whiting and keep experienced readers on track.

The following guidelines were set for preparation of otoliths used for aging:

- Otoliths should be read whole immersed in water.
- Reading is considered easiest when removed from fish and read immediately.
- If the otolith is stored longer than 7 days in water the shape/composition of the otolith seem to change (due to unstable pH of the water), so the storage is recommended to be done dry. If otoliths are stored dry, soak for 24 hours beforehand. Make sure that the otoliths are proper cleaned before storage. This will enhance the winter rings.
- Use reflected light and magnification X 6/6.4 against a black background where 12 e.p.u (eyepiece units) are equal to 2 mm.

- When ageing an otolith that displays split rings, it may be useful to both 'zoom out' and 'focus out'.
- In older individuals it may be an advantage to grind and polish the otolith in order to see the first annulus.
- The otolith is interpreted by reading up the rostrum area and using the whole otolith pattern as a guide. The advised procedure is to read the otolith sulcus side down.
- Otoliths with translucent edge, sampled from the first half of the year, are aged by counting all translucent annuli, including the edge, if translucent. Fish sampled from the second half of the year, are aged by ignoring a translucent edge if present. This guide is particular useful for fish of ages 1-3.
- When using the measurement scale of the eyepiece unit the following reference guide may be applied as general guidelines:

Age	length (cm)	mean e.p.u
1	18-23	50+
2	23-26	60+
3	25-28	70+
4	27-30	(76)
5	29-33	(79)

- For the older ages (4+) the distances between the rings may vary with sex, and the mean e.p.u for these ages should be regarded as rough guidelines.
- When measuring the distances between rings, point to the outer edge of the translucent zone.
- A 'false' ring known as the 'Baileys zone' (Bailey, 1970) may appear inside the first winter ring, confusion can be eliminated keeping in mind that if a ring is less than 48 e.p.u. it probably is a Bailey's zone.
- The split rings can be differentiated from annual rings as they cannot be followed around the whole otolith.
- Ancillary information such as fish length should not be over relied upon when estimating age. Other information such as, sex of fish and geographic sample location may be considered.
- Due to geographical variation in time of spawning the formation of the first winter ring can occur from October to January.

2.3 Validation

Little has been done to validate age reading of blue whiting. Only one study on southern blue whiting was conducted by Hanchet and Uozumi (1996).

3 Age reading exercise

Before the workshop participants were asked to annotate images of 158 otoliths from the exchange in 2010/2011 using WebGR. After going through these and discussing the guidelines 50 of these otoliths were chosen for re-reading in order to establish if the readers now had a higher agreement. Two new collections consisting of images of 50 from the Faroe Islands and 50 from Russia were also annotated after agreement of the guidelines. A map of collection areas for the different collections is given in Figure 1.

All analyses of the results were performed using the "AGE COMPARATIONS.XLXS" from A.T.G.W. Eltink from RIVO following the recommendation of EFAN (Eltink 2000). The analyses are based on a reference age when there are no validated ages available, which is the case for blue whiting. The readers are arranged according to experience, but are numbered according to their WebGR reader number. Numbers will therefore not show chronological. As several readers were new to reading blue whiting, the modal age was chosen to be all expert readers and intermediate readers who read to assessment. All trainees were excluded from the modal age.

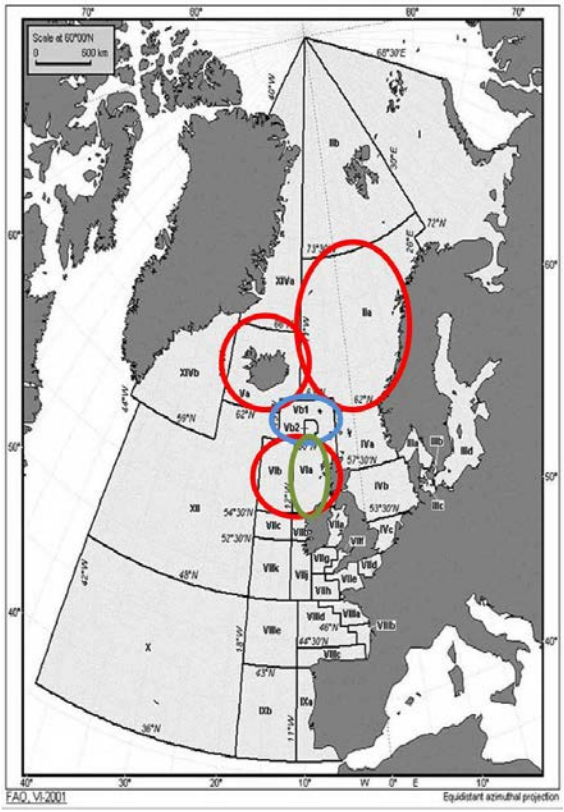

Figure 1. Map of sampling areas of otoliths used in the workshop exercises. Red circles represent the area for the pre-workshop exercise, while the blue circle represents the area of the Faroese collection area. The green circle gives the area of the Russian collection.

3.1 Results

3.1.1 Pre-workshop exercise

The results from the pre-workshop age calibration exercise displayed clear issues in perception of otolith structure. The overall agreement was only 56.6% (ranging between 28.7 and 75.9%) with a precision of 13.2% CV (ranging from 7.7 to 19.5%). Of the 158 otoliths 17 (10.8%) were read with at least 80% agreement (See Annex 5 for figures).

For age readers combined, the relative bias was found to be minimal (-0.07), but for individual age-readers the relative bias varied from -0.84 to +0.67. This shows a significant over- and under-ageing of otoliths by age readers, and high bias was found both among experienced readers and trainees. For fish older than five there is a tendency of underestimating the ages, while overestimation seems to be the main problem among younger individuals. This is also evident on an individual basis where older fish were generally under-aged compared to modal age, while there was variation in whether a reader under- or overestimated the ages of younger fish. The under/over-ageing signifies systematic miss-interpretation of growth structures within the otolith. Wilcoxon inter-reader bias test is presented in Figure 2, and shows the individual observed bias giving a large degree of significant relative bias among age-readers. There is also clear bias among half the readers compared to the modal age.

Only three readers had a percentage agreement higher than 70% and these were the ones who had a coefficient of variation below 10%, five readers had CV above 15% and their percentage agreement lied below 52.6%. The agreement to be aimed for is above 80% and none of the readers managed this during this exercise. The CV was observed to be highest for two years old fish (modal age), but this was subsequently found to be a factor of a small number of observations of this age group combined with high variation within observations. CV for three and four year old fish was a little higher than for older age groups, which were observed to have rather similar CV.

Data on fish length and sex were available to the readers during the reading. It is worth noting that lengths at modal age three is lower than the length at modal age two. Further, from age four there is generally a widespread perception of age for each individual and the lengths are contained within the range of the older ages (Figure 3).

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	*																		
Reader 16	**	**																	
Reader 7	-	-	**																
Reader 17	*	-	**	-															
Reader 19	**	**	**	**	**														
Reader 14	**	-	*	*	-	**													
Reader 5	-	**	**	*	**	**	**												
Reader 20	**	-	**	-	-	**	-	**											
Reader 21	*	-	**	-	-	**	-	**	-										
Reader 10	**	**	-	**	**	**	**	**	**	**									
Reader 12	-	-	**	-	-	**	*	-	-	-	**								
Reader 8	**	**	**	**	**	**	**	**	**	**	*	**							
Reader 4	**	**	**	**	**	**	**	**	**	**	**	**	*						
Reader 2	**	-	**	-	-	**	-	**	-	-	**	*	**	**					
Reader 3	**	**	**	**	**	**	**	*	**	**	**	**	**	**	**				
Reader 11	**	**	-	**	**	**	**	**	**	**	-	**	-	**	**	**			
Reader 6	**	-	**	-	-	**	-	**	-	-	**	-	**	**	-	**	**		
Reader 18	-	-	**	-	-	**	**	-	*	-	**	-	**	**	*	**	**	*	
MODAL	**	-	**	-	-	**	-	**	-	-	**	-	**	**	-	**	**	-	-

Figure 2. Wilcoxon inter reader bias test

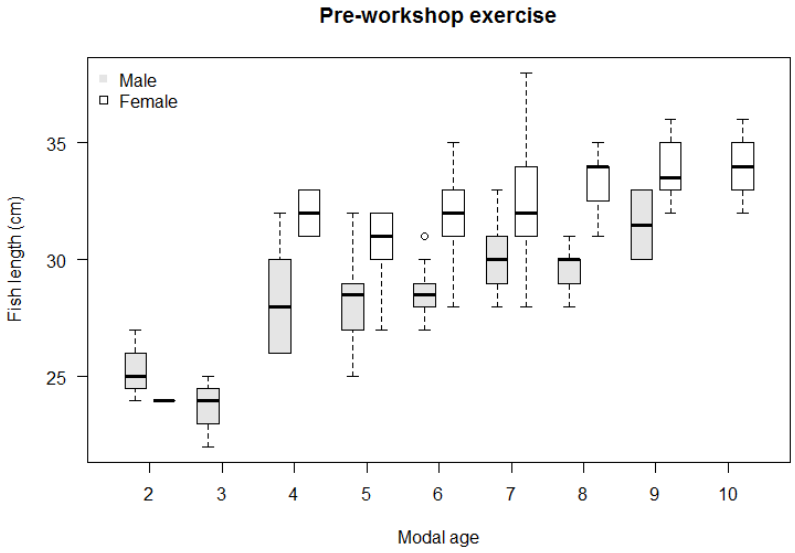

Figure 3. Modal age at length divided in sexes.

3.1.2 Re-reading of subsample

The 50 otoliths chosen from the original dataset had an overall agreement of 54.3% (ranging between 34.0 and 78.0%) with a precision of 14.5% CV (ranging from 6.1 to 19.3%). When these were reread after the agreement of guidelines concerning the determination of the innermost zone, false zones, and interpretation of the edge the overall agreement had increased slightly to 57.0% (ranging between 40.0 and 76.0%) with a precision of 13.4% CV (ranging from 9.1 to 17.6%) (See Annex 5 for figures). 14% of the otoliths had an agreement over 80%, which is a slight increase from the pre-workshop 50 otoliths of 10%.

For all readers combined, the relative bias was at -0.09, but for individual age-readers the relative bias ranged between -0.80 and +0.66. Some readers have changed their age-readings after discussion of the pre-workshop readings and went from under-ageing to over-ageing or vice versa. It was independent of experience whether a reader changed the interpretation of otolith growth zones or stayed with the pre-workshop interpretation.

Over all the ageing has not improved from the pre-workshop reading to the re-reading. Also the inter-reader bias test shows that there is still a rather low agreement between readers (Figure 4). The agreement with modal age has changed for some readers but the general agreement with modal age has not increased much from the pre-workshop exercise. There are the same tendencies of over- and under-ageing compared to modal age as seen in the pre-workshop exercise with rather high deviations from the mean modal age from age 5 and up.

Figure 5 gives an idea of the fish lengths-at-ages from the 50 pre-workshop readings and the re-reading. The aging of the youngest individuals didn't change in the re-reading, but several changes occurred among the older individuals.

a)

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Modal age	**	-	*	-	-	**	-	*	-	-	*	-	**	**	*	*	-	-	-

b)

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	*																		
Reader 16	-	**																	
Reader 7	-	-	-																
Reader 17	**	-	-	-															
Reader 19	-	-	**	-	**														
Reader 14	**	**	**	**	-	**													
Reader 5	-	-	-	-	-	-	**												
Reader 20	-	**	-	**	**	*	**	**											
Reader 21	*	**	*	**	**	**	**	**	-										
Reader 10	**	*	**	*	-	**	-	*	**	**									
Reader 12	-	*	-	-	**	-	**	-	**	**	**								
Reader 8	-	-	-	-	-	-	**	-	**	**	**	-							
Reader 4	**	*	**	**	-	**	-	*	**	**	-	**	*						
Reader 2	-	*	-	-	**	-	**	-	*	**	**	-	-	**					
Reader 3	-	**	-	*	**	-	**	-	*	**	**	-	-	**	-				
Reader 11	**	-	**	-	-	**	-	*	**	**	-	**	-	-	**	**			
Reader 6	**	-	*	-	-	*	**	-	**	**	-	**	-	-	*	**	-		
Reader 18	**	**	**	**	**	**	-	**	**	**	*	**	**	-	**	**	**	**	
MODAL	-	-	-	-	*	-	**	-	**	**	**	-	-	**	-	-	*	-	**

Figure 4. Inter-reader bias of the re-reading. The top part a) gives the bias against modal age of the 50 otoliths from the pre-workshop exercise, and the lower part b) shows the inter-reader bias of the re-reading as well as the agreement with modal age.

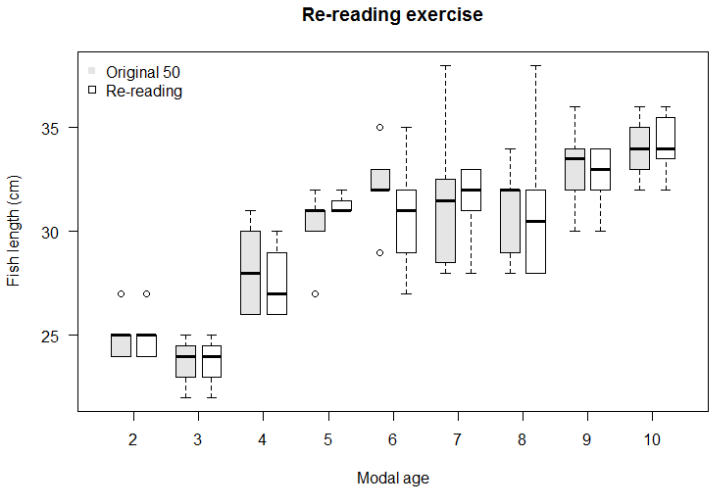

Figure 5. Modal age at length of the 50 otoliths used in the re-reading.

3.1.3 Faroese collection

A collection of 50 otoliths from area Vb captured between April 2012 and May 2013 covering all quarters of the year was annotated during the workshop. Images were prepared by FAMRI ahead of the workshop and contained modal ages between 0 and 10 year old fish, with the majority ranging below 5 years old. The results showed a higher % agreement than seen in the original dataset, and 44% of the otolith readings reached the 80% agreement criterion (See Annex 5 for figures). The overall agreement was 74.1% (ranging 40.8-90.0%) with a precision of 40.5% CV (ranging 6.3-32.1%). For age-readers combined, the relative bias was found to be minimal (-0.01), and for most individual age-readers the relative bias was quite low, however the total range of relative bias was between -0.66 and +0.65. There were tendencies of over-ageing the younger fish while under-ageing the older fish compared to modal age, which was also the case in the pre-workshop exercise, indicating that alterations on the basis of the discussions of the guidelines were only limited taken into account. Only three

age-readers were found to be significantly biased to the modal age (Figure 6), where two were systematically over-ageing and one was under-ageing. Two of these readers are new in blue whiting otolith readings.

Mean length increased with modal age, however, the range of sizes within an age-group varied (Figure 7). Size at modal age 1 ranged over a size also including modal age 0 and 2. Information about sex was missing for many of the fish, and fish size range at age 3 and up may be affected by that.

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	**																		
Reader 16	-	**																	
Reader 7	-	**	-																
Reader 17	-	**	-	-															
Reader 19	-	**	-	-	-														
Reader 14	-	**	-	-	-	-													
Reader 5	-	**	*	-	-	-	-												
Reader 20	-	**	**	-	-	-	-	-											
Reader 21	-	**	-	-	-	*	-	*	**										
Reader 10	-	**	-	-	-	-	-	-	-	-									
Reader 12	-	**	-	-	-	-	-	-	*	-	-								
Reader 8	-	**	*	-	-	-	-	-	-	*	-	*							
Reader 4	-	**	*	-	-	-	-	-	-	*	-	-	-						
Reader 2	-	**	*	-	-	-	-	-	-	*	-	-	-	-					
Reader 3	**	**	**	**	**	*	**	**	**	**	**	**	**	**	*				
Reader 11	-	**	-	-	*	-	-	-	*	-	-	-	-	*	-	**			
Reader 6	*	**	-	-	*	**	-	*	**	-	*	-	*	**	*	**	-		
Reader 18	**	*	-	*	**	**	*	**	**	-	**	-	*	**	**	**	-	-	
MODAL	-	**	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	*	**

Figure 6. Wilcoxon inter-reader bias test.

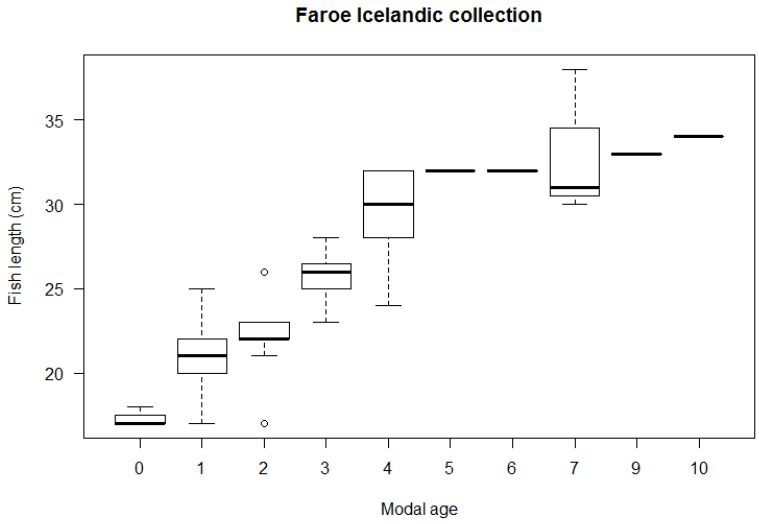

Figure 7. Modal age at length.

3.1.4 Russian collection

A collection of 50 otoliths from area VIa captured in April 2013 was annotated during the workshop. Images were prepared by PINRO ahead of the workshop and contained modal ages between 2 and 9 years, with 60% ranging below 5 years old. There were little agreement among readers and only 6% of the otolith readings reached the 80% agreement criterion (See Annex 5 for figures).

The results showed a % agreement similar to the pre-workshop exercise. The overall agreement was 54.5% (ranging 40.0-76.0%) with a precision of 17.4% CV (ranging 10.7-21.5%).

For age-readers combined, the relative bias was found to be higher than any of the other exercises during this workshop (0.13) and the only that overestimated compared to modal age. The total range of relative bias was between -0.68 and +0.64, and the individual age-readers relative bias was spread out in this range. Except for a few readers, most under-aged older specimens, while over-ageing the younger fish compared to modal age. Again this indicates that alterations on the basis of the discussions of the guidelines were only limited taken into account. Half of the age-readers were found to be significantly biased to the modal age (Figure 8).

Fish length at modal age showed a widepread perception of age for each individual. The length of four year olds were within the range for modal age three (t-test males: p = 0.511, t-test females: p = 0.074, Figure 9).

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	-																		
Reader 16	**	*																	
Reader 7	**	-	-																
Reader 17	**	**	-	*															
Reader 19	**	-	-	-	**														
Reader 14	-	*	**	**	**	**													
Reader 5	**	**	-	*	-	**	**												
Reader 20	**	-	-	-	*	-	**	*											
Reader 21	**	-	-	-	-	-	**	-	-										
Reader 10	**	**	-	-	-	-	**	-	-	-									
Reader 12	*	-	*	-	**	-	-	**	-	-	**								
Reader 8	**	-	-	-	*	-	**	*	-	-	-	-							
Reader 4	**	**	-	*	-	**	**	-	*	-	-	**	*						
Reader 2	*	-	*	-	**	-	-	**	-	*	*	-	-	**					
Reader 3	**	**	**	**	*	**	**	*	**	**	**	**	**	*	**				
Reader 11	-	-	**	*	**	**	-	**	*	**	**	-	*	**	-	**			
Reader 6	-	*	**	**	**	**	-	**	**	**	**	*	**	**	*	**	-		
Reader 18	-	-	**	**	**	**	-	**	*	**	**	-	*	**	-	**	-	-	
MODAL	**	*	-	-	**	-	**	**	-	-	-	*	-	**	*	**	**	**	**

Figure 8. Wilcoxon inter-reader bias test.

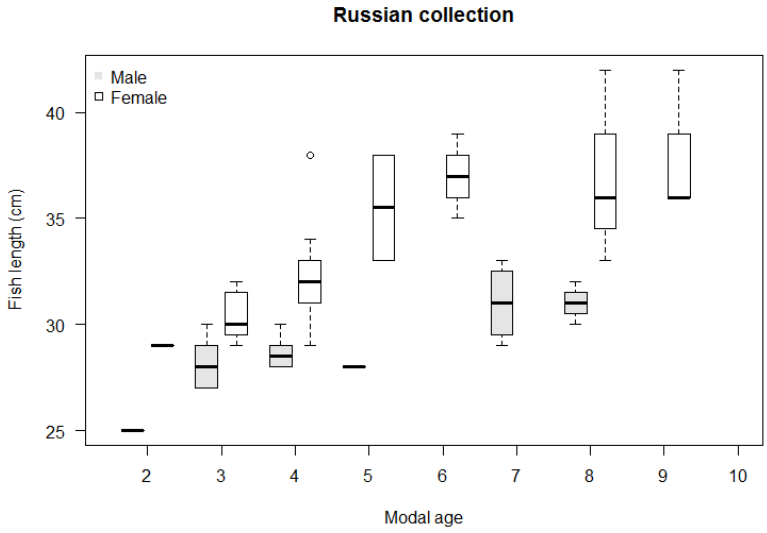

Figure 9. Modal age at length divided in sexes.

3.2 Effects in the assessment of the observed bias

Disagreement in otolith readings is generally a minor problem for assessment purposes if compared with bias. If disagreements were produced by errors randomly distributed, the age readings should not be biased.

Using the Catch-at-age submitted to the WG by the different countries and the corresponding readers bias (or not bias) with the modal age, from the four samples, the results show that:

When using the "old" 50 otoliths, 9.5% of the International Catch-at-age would be biased.

When using the "new" 50 otoliths, 15.4% of the International Catch-at-age would be biased.

When using the "Faroese" 50 otoliths, 0.0% of the International Catch-at-age would be biased.

When using the "Russian" 50 otoliths, 67.8% of the International Catch-at-age would be biased.

There is a clear issue with the Russian sample, which make it difficult to use in assessment. Note that several of the most experienced readers were biased against the modal age in that case. The otoliths were, for unknown reasons, too calcified - being too opaque for clear readings. If the otoliths are just as difficult to read right after capture of the fish, that kind of otolith should be excluded from the Catch-at-age calculations. Nevertheless, the "normal" readings present in the other three samples would not cause too much bias in the total international catch-at-age, and that is very important for assessment.

3.3 Discussion and conclusions

The results of the re-reading indicate that alteration of ageing procedures was difficult both to trainees and experienced readers. Though some changed their age-reading from overestimation to underestimation and vice versa, most continued reading as usual. The use of two new sets of otoliths attempted to look at the more specific problems of blue whiting otolith readings; the first zone, split rings and the edge. The collection from the Faroe Islands included mainly younger fish captured throughout the year, which would give a view of the interpretation of the edge, which turned out to be of some disagreement, especially if an opaque zone had started to form early in the year. Furthermore, there was no measurement bar on the images, which made determination of the inner zone difficult, but when discussing the annotations in plenum the real otoliths were available and used to determine the age. The agreement of this collection was higher than seen for the other collections, which probably was due to the low ages.

The collection from Russia included a large age-span but all fish were captured on the same day during the International blue whiting spawning stock survey (IBWSS) 2013. Yet, due to the narrow zones the edge was difficult to determine in older individuals. These otolith images were very difficult and although the real otoliths were available during the workshop, it was still difficult to age them under a stereomicroscope. There were also many split zones, which it was very difficult to come to an agreement about.

During the discussion of interpretation of the otoliths structures during the workshop it was clear that the guidelines are not enough. Size of the first zone is a good hint of whether it is an annual zone or a Bailey's ring (Bailey, 1970), and a validation study of the first ring should be performed. When going through the images during the workshop, the first zone was usually agreed on. Split rings were the most difficult to agree on, and despite the guidelines being rather specific, they were difficult to interpret and, thus, agreement during discussions at the workshop was rarely achieved.

In order to determine the edge, the main rules are to take into account the birthday January 1st and to divide the year into two half. Otoliths with translucent edge, sampled from the first half of the year, are aged by counting all translucent annuli, including the edge, if translucent. Fish sampled from the second half of the year, are aged by ignoring a translucent edge if present. The problem may occur if translucent edge is present in the 3rd quarter in mature fish. There are no special investigations of this subject for blue whiting but there are different approaches to the decision of this problem for different species. For example there is a scheme for *Mullus* sp. age, according to which tranclucent otoliths edge is ignored in samples from the second half of the year (ICES 2012 – Figure 15). This approach can't be "blindly" applied to the blue whiting due to the higher blue whiting age and different area and migrations. For otoliths of Norwegian spring-spawning herring (*Clupea harengus harengus* L.) timing of the beginning of feeding is a factor which determines initiation of increment precipitation (Prokhorova, 2010). Thus, an opaque zone can occur only in the second half of the year. It is therefore also necessary to consider the features of the formation of the opaque and translucent rings on the blue whiting otoliths to resolve issues. Other main problems appear when the edge is opaque. Young fish (up to three years old) may feed during winter, and a formation of the opaque zone may occur already in March. For example, during the international blue whiting spawning stock survey (IBWSS) it was found that feeding occurred exclusively among immature specimens (Rybakov et al., 2012). Therefore, the discussion of whether to count an opaque edge or not, depends on age of the fish and also area of capture. The division of the year into two half does not necessarily work in all cases for blue whiting.

10 of 19 readers had taken part in the 2010/2011 exchange with the same otoliths. The agreement is slightly higher than during the exchange, but it is still much lower than the results of the 2005 workshop. Many intermediate and trainees were included in the workshop, which may have reduced the agreement. However, there were still large disagreements among the expert readers, indicating that inexperience is not the only reason for the low agreement seen in the last exchange/workshop.

All along the samples used in the workshop, bias was observed in several cases. Bias is a big problem for assessment when some of the main countries do read systematically one year more than the others (or than the modal age). This will result in a misinterpretation of cohorts, which makes it impossible to follow the cohorts through the time-series. That was the case years ago due to the Bailey's zone interpretation, and though the interpretation of the zone is better, it is still an issue. Bias can also be caused by differences in the interpretation of the edge and the false rings. Bias still exists, both between the readers and between readers and the Modal Age, considered as a proxy of True Age. Nevertheless, among the readers that regularly submit age readings to the assessment working group, bias against the Modal Age was only found in one of the four samples, which by the readers was considered to be a very difficult sample to read.

4 Criteria for age determination and validation (ToR c)

4.1 Review of previous work on age determination

The interpretation of blue whiting otoliths is generally difficult. Even in well-marked otolith rings, there are subjective decisions to be made, which are highly dependent on each reader's experience.

This can be observed in the series of exchanges and workshops. During a workshop the agreement between readers increases, but this is not maintained over time. When an exchange is carried on later, the results are again poor. This is because the subjective decisions of every reader eventually return to its own tendency, and also to the incorporation of new readers. It is therefore important to conduct exchanges and workshops regularly. The establishment of a "Reference Collection" is equally important for that.

Few studies have been investigating the determination of the inner zone as an annual ring or as a Bailey's ring (Bailey, 1970) in blue whiting. Gjøsæter *et al*. (1979) counted and measured daily rings in order to establish a connection between otolith growth and fish growth. Based on studies on other temperate fish species they assumed that primary growth zones in otoliths are formed daily, and came to the conclusion that blue whiting may reach a size of 20-25 cm within the first year of life. By counting the daily rings they found that otoliths with one hyaline zone had an average of 227 growth rings (ranged between 120 and 357). They did however not describe the otolith size at these sizes. They concluded, however, that time of hatching stretched over large part of the year.

4.2 General guidelines for age determination. Ageing manual

- Blue whiting **whole otoliths** must be soaked in water 24 hours before reading. No other manipulation is needed. It is, however, important to age the fish shortly after sampling, as the otoliths are clearest then. France uses **sliced otoliths** (after testing against whole otoliths from the Celtic sea and Bay of Biscay). France is not taking part in the International blue whiting spawning stock survey (IBWSS), where age reading of whole otoliths is one of the routine survey procedures.
- Whole otoliths must be **read in water** over a black surface, using **reflected light**. The otolith should not be soaked in water for more than 48 hours each time, as it possibly could affect the ring structure due to the composition of freshwater (Anon.1992).
- Correct **identification of annulus** can be induced by measuring the size of the inner ring. It will thereby be possible to avoid including the Bailey's zone (Bailey, 1970) as the first annual ring. Usually a ring in the size range of 50 to 56 e.p.u (corresponding to 8.33 to 9.33 mm.) can be considered the first annual ring (ICES 2005). The ring called Bailey's zone was first identified by Roger Bailey (Bailey, R.S. 1970); In samples of small blue whiting taken by small-meshed trawl in June 1967, Bailey found two distinct modal size groups, one of them around 8-9 cm, the other 13-15 cm. with no clearly defined winter growth rings in the otoliths. However, he considered that to attain a length of 13-15 cm by late June in these areas was unlikely and therefore proposed that, whereas the smaller size group may have been

spawned that year, the larger ones were more likely to be 1 year old. He also found that most of the otoliths of the second modal group (13-15 cm) showed a very indistinct ring when viewed in transverse section and this, he thought, may have been a weakly developed first winter growth check. That zone was called thereafter Bailey's Zone. Jakupsstovu (1979) suggested that this zone may be associated with a change of habit or depth; in this case it would be equivalent to the "Bowers Zone" found in whiting otoliths (Gambell and Messtorff, 1964). This first zone is formed when the fish are 4-10 cm in length. Bailey (1982) concludes that it is difficult to explain how the youngest age group of blue whiting could have remained totally unobserved throughout their first winter and spring, especially if one considers their undoubted abundance. On the face of it, therefore, Jakupsstovu's interpretation seems more credible, and for the sake of consistency it is probably wisest at present to follow Jakupsstovu's (1979) interpretation in which the age is given by the number of winter rings on the otolith.

- **False rings** are a common issue in blue whiting otoliths. When counting the true annual rings to age the fish, it is important to look at the entire structure of the otolith and follow the sequence of yearly growth. The yearly growth zone increments will most often decrease as the fish get older. When small growth zones are followed by bigger ones, these should be considered as false rings. However, sometimes ring thickness varies within the otolith, and a winter ring may appear very thin, but is in good sequence, which could be a short winter period and not a false ring (Annex 4, Image 1).
- A particular case of false rings are the **split rings** (double rings). In many cases they can be easily identified because they merge when you try to follow them around the otolith. It is important to follow the rings as far as possible to the side of the otolith (Annex 4, Image 2). Zooming out will reduce the possibility of counting split rings.
- **Interpretation of the edge** is determined by the time of capture of the fish**.** The criterion of birthday on January 1st must be used to determine when a hyaline ring in the edge must be counted. Growth of immature fish vary from that of adults, as they may feed for a much longer period, and the opaque zone may therefore start forming much earlier (Annex 4, Image 4). Aging of a fish with an opaque edge present will therefore depend on maturity. Otoliths with translucent edge, sampled from the first half of the year, are aged by counting all translucent annuli, including the edge. Second half of the year, are aged by ignoring a translucent edge if present. This 'translucent edge' is the onset of the winter ring. This onset will also vary with time and by geographic location. This scheme (Annex 4, Image 4) must be clarified and validated in the future. Be aware of which **side of the otolith** is read from. Read from centre to pointy edge, and read on the dorsal side (upside when placed in the inner ear of the fish) (Härkönen, 1986). Often the rings can only be followed from the centre towards one side of the otolith, while they will merge very close to the pointy edge at the other side (Annex 4, Image 3).
- Blue whiting age readings **should avoid otoliths classified as unreadable** or very difficult to interpret (0-25% reliability) according to the following 3-point scale of age reading quality that WKNARC (ICES 2011) recom-

mends to be used by all age readers who provide age data for stock assessments:

AQ1: Easy to age with high precision:

If a scale of 1-100 is applied, where 100 is when the reader has the highest possible confidence in the age reading and 1 is when the reader has no confidence in the age reading, age quality 1 (AQ1), will apply to approximately the top 25% of the possible quality ratings. AQ1 is an indication that the age data are considered reliable for stock assessment.

AQ2: Difficult to age with age with acceptable precision:

Age quality 2 (AQ2), will apply approximately to age readings within 25 and 75 percentiles of the possible quality ratings. AQ2 is an indication that the age data are sufficiently reliable to be used for stock assessment purposes but improvement is required.

AQ3: Unreadable or very difficult to age with acceptable precision:

Age quality 3 (AQ3), will apply to approximately the lowest 25% of the possible quality ratings. 3 AQ3 is an indication that there are serious concerns about the reliability of the age data and/or its value to stock assessment WGs.

- **Reference Collections** should be used as a valuable tool to maintain the accuracy of readers over time.
- **Sexual dimorphism** is present in blue whiting, females grow faster than males, thus are younger in general at similar length to male fish (ICES 2005). Therefore knowledge of the sex of the fish may be used as additional factor when ageing. This can be observed in the ring patterns in the otoliths with male fish tending to have smaller increments due to slower growth, and is especially seen in fish older than 3 years old.
- **Magnification** of images should always be the same (x 0.64), and a measurement bar needs to be included in all images of blue whiting. This is very important in order to correctly determine the inner zonevs.Bailey's zone.

4.2.1 Additional supporting information on age reading

- Mature fish begin to grow later in the year than immature by reason of using the energy resource for gonad maturation cycle vs. using it to the somatic growth only by young fish. New research has shown that blue whiting may mature already around age 1 (ICES 2013a). Thus, when possible, **maturity stage** should be used as an additional indicator for aging of fish caught during the spawning season.
- **Growth** begins when fish start feeding after the winter period/spawning and finish feeding after the accumulation of enough food reserves. In the last quarter, growth is finished due to enough energy resource for next spawning period, and the next winter ring has started to form. Therefore stomach fullness can be used as additional indicator for reading.
- Blue whiting has a wide distribution and a **complicated life cycle** in Atlantic waters. It can be reflected in all phases of the fish growth, and consequently in the otolith. The distribution is reflected in the landings, as shown in the map that the WGWIDE includes each year (Figure 10). The map also shows spawning concentrations west of the British Isles (Porcu-

pine and Rockall Bank). That is during winter, where they don't feed and instead spend energy on spawning, and in the prespawning and post-spawning migrations. There is almost no otolith calcification so it is marking a translucent ring. After that, eggs and larvae drift mainly northward but also partly southward, recruiting to the nursery areas of the north (mainly Norwegian Sea) and the south (mainly Biscay Bay). At the same time, adult blue whiting migrates to the feeding grounds (in the same areas as the nurseries). They spread all around the Norwegian Sea, and part of the stock distribution is so scattered that it can't be detected by the fisher or the surveys. That is shown in the 3rd and 4th maps. In the feeding area the fish grow and the otolith is marking a wide opaque ring.

- Another factor that affects the otolith growth is the **strength of recruitment**. Blue whiting stock alternates from periods of high recruitment regime to others of low recruitment. That affects the otolith growth and any other denso-dependent characteristic.

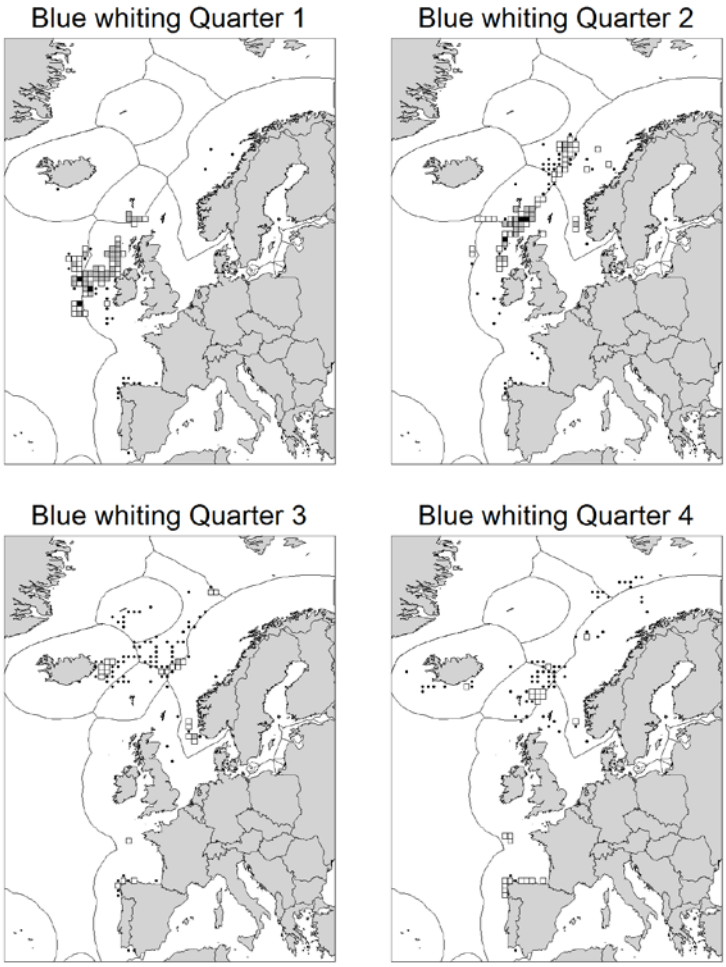

Figure 10. Blue whiting total catches (t) in 2012 by quarter and ICES rectangle. Grading of the symbols: small dots 10–100 t, white squares 100–1000 t, grey squares 1000–10 000 t, and black squares >10 000 t. Catches below 10 t are not shown on the map. The catches on the map constitute 98% of the total catches (ICES 2013b)

5 Assessment of the sources of age determination error (ToR d)

There are several sources of disagreement in age determination, and these issues are the same as has been mentioned in previous reports:

- The identification of the first annual ring. Wrong interpretations can lead to readings of one or two years more than correct. This can be improved by using a size rule for the first annual ring.
- False rings (including split rings). The presence of false and split rings is a severe problem that causes large differences in age. This can be improved using appropriate criteria (sequence, possibility to follow the ring around the otolith). However, these are somehow subjective decisions that rely heavily on the reader's experience.
- The interpretation of the edge. The disagreement in the interpretation of the edge is another source of error that produces a difference of one year in age assigned. This can improve adequately using the criterion of birthday on January 1st. With the current knowledge and tools some subjective decisions still will rely on the reader's experience.

6 Explore the possibilities to use supplementary information for validating estimated age structures (ToR a and ToR e)

(WKAVSG Workshop 2013 – comparison of techniques) (ICES 2013c)

During the WKAVSG workshop the existing methods of validation or/and corroboration/verification were identified:

- Length based methods: Analyses of length compositions to identify present age groups. The modal lengths can then be compared with other independent methods of age estimation. This method does not allow the validation of the periodicity in the deposition of growth zones. This method is inexpensive.
- Marginal Increment Analysis: A successful method to corroborate annual increment formation across large age ranges. This method is, however, hampered by the difficulty in measuring small increments accurately and the need for high contrast between growth zones. An alternative would be to use edge zone analysis. This method is inexpensive.
- Daily increments: A useful tool to 1) identify the first winter ring and 2) to help understand the mechanizms behind observed otolith macrostructure and to corroborate that an annual growth structure is present. This method is moderately expensive.
- Microchemistry: A tool to link otolith macrostructure features (though not necessarily seasonal structures) with environmental conditions through physiological processes affecting otolith accretion. As such not useful for age validation, but rather the understanding of otolith features. This method is expensive.
- Tag-recapture: This is the only direct validation method in use. It is a highly successful method that validates age directly and should be used if common agreement on age interpretation is not achieved. This method is very expensive.

Blue whiting:

i) Length based methods have been used in the past to analyse blue whiting growth, and could be used again, following strong year classes during low recruitment periods.

ii) Marginal Increment Analysis can be also a useful tool and are expected to give good results for this species.

iii) Daily increments analysis could be useful to identify the first winter ring so it is strongly recommended for this species.

iv) Microchemistry and Tag-recapture don't seem to be suitable by now to solve the blue whiting growth uncertainties.

7 Reference collection and otolith image database at WebGR

7.1 Reference collection

A selection of 50 blue whiting otoliths from this workshop will be selected for the reference collection. All otoliths for the reference collection will be chosen in collaboration with the most experienced readers from the workshop and covered an age span from 0 to 10 years old otoliths.

The otoliths and fish information will be uploaded to WebGR through a server at Azti (http://webgr.azti.es/) and at the European Age Readers Forum (EARF).

In some images at EARF there will be an annotation of another colour than the rest, this is because the experienced readers were unsure if those zones were to be counted a year or not. This is not shown in WebGR, where all annotations have the same colour. Instead a comment will be included, so please pay careful attention to the "IMAGE_COMMENT" to the left of the annotation page in WebGR.

7.2 WebGR

It was decided to use WebGR for age reading and annotate the pictures and also to keep the agreed reference collection of blue whiting, because of the easy access for everyone and gives the possibility for every reader to annotate the pictures before seeing the agreed annotations.

WebGR is installed on a server within Azti (Marine and Food Technological Centre) and previously to the meeting a collection of blue whiting otoliths are uploaded to the programme for all readers to use. In addition, two new collections and a subset of the original collection were uploaded. All readers at the workshop have annotated the pictures.

WebGR is Open Source software developed by a consortium of research institutes and software developers from Federal Agency for Agriculture and Food (Germany), which allows everyone to sign up for reading otoliths. The use of WebGR provides the possibility for inexperienced readers to train by accessing images and compare their annotations with the annotations of experienced readers. A reader can easily register at the WebGR website and can enter exercises and pictures to see annotations from other readers.

WebGR has the advantage that it can be used similar to Paint Shop Pro and GIMP, but instead of creating a layer for each reader in a specified file format, WebGR saves each reader's annotation of each image as a set of xy-coordinates that can be mapped on to that image, but the original image and the associated metadata remain unaltered. Each reader is assigned a colour for their annotations.

The experience of using WebGR was generally good among the participants of this workshop. However, server issues at the Azti institute closed WebGR down for several hours and the programme was working slowly during the main part of the workshop, which slowed down the exercises.

Below is a short guideline to WebGR and the use of the reference collection:

First time

- Open the website (http://webgr.azti.es) using Firefox (Internet Explorer and WebGR does not work together. You can download Firefox at www.mozilla.org)

- Register new user (in the menu to the left), and activate the account following the link sent to your e-mail
- In the menu to the left, chose "Search" and click on "List all workshops"
- Send an e-mail to the manager of the workshop of interest for access
- The manager will then include the age reader as a participant for the workshop/reading exercise

From second time and onwards

- Open the website (http://webgr.azti.es)
- Log in
- Chose "My calibration exercises" in the menu to the left
- Chose "annotate" in the left column of the "Calibration exercise list" under the workshop of interest
- Start annotating. Remember to write in the age, this is not done automatically by the programme. Each annotation is ended by clicking "Finalize". This will register the age in the programme. If you press "Save" the annotation will only be available to yourself, and it will be possible to change the annotation later before finalizing.
- Some of the pictures may be small and very dark. It is possible to change the brightness and contrast in WebGR to improve the picture. In the upper right corner is a zoon function.
- A single wrong placed annotation can be removed by "re-annotating" it. Place the curser over the annotation to be deleted and when the cross becomes "bold" click on it, and it will disappear. If the annotations have been saved, just remove the annotation and click "Update", and new age will be recorded (see next page for visualization).
- In the menu "Help" within WebGR (not at the annotation pages) it is possible to download a user manual for WebGR. Page 10 and forwards contain a description of how to annotate.

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Annex 2: WKARBLUE2 terms of reference for the next meeting

The **Workshop on Age reading of blue whiting** (WKARBLUE2), co-chaired by Jane A. Godiksen, Norway and Manolo Meixide, Spain will meet in Vigo, Spain, June 5th – 9th 2017 to:

a) Review new information from validation study on first annual ring identification from daily increments.

b) Review slices and whole otolith analysis from the exchange

c) Clarify the interpretation of annual growth rings (1-3) by sex, maturity and age through image analysis (measurements of ring distances and back calculation).

d) Update on guidelines and common ageing criteria.

e) Increase existing reference collections of otoliths and improve the existing database of otolith images.

f) Analyse the age reading quality from the exchange using the 3-point scale of the image (mentioned in WKNARC)

g) Address the generic ToR's adopted for workshops on age calibration (see 'PGCCDBS Guidelines for Workshops on Age Calibration').

WKARBLUE2 will report by XX.XX.2017 to the attention of the ACOM Committee.

Supporting Information

Annex 3: Recommendations

Blue whiting otoliths has proven to be quite difficult to age, and though guidelines has been constructed, the experience of the reader determines the interpretation of the otolith structure. It is therefore recommended to have regular exchanges and workshops in order to improve the agreement between readers.

Recommandation	Adressed to
1.WKARBLUE2 Workshop in 2017	PGCCDBS, ACOM
2. Age validation study on daily growth rings to solve the growth rings interpretation	PGCCDBS, ACOM, WGWIDE
3.Image Otoliths Exchange of M. poutassou in 2016 Covering northern and southern subpopulations	PGCCDBS, ACOM, WGWIDE
4.Update guideline of ageing criteria	PGCCDBS, ACOM, WGWIDE

Annex 4: Guidelines for age determination

Image 1: Progression in growth structure.

The width of the zones should be expected to become smaller with distance from the nucleus. Variation can be expected due to variation in feeding, spawning etc.

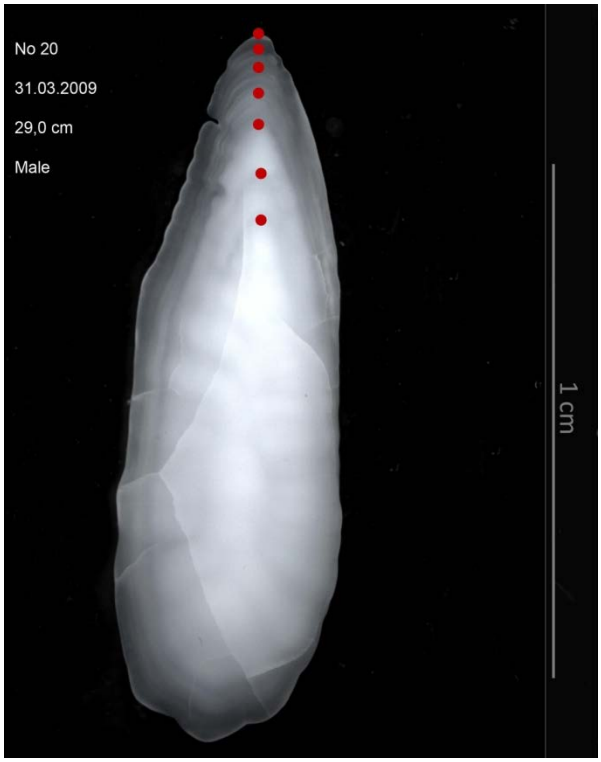


Image 2: Split rings

The empty circles show that where there are split rings. Each empty circle should be counted only as one year.

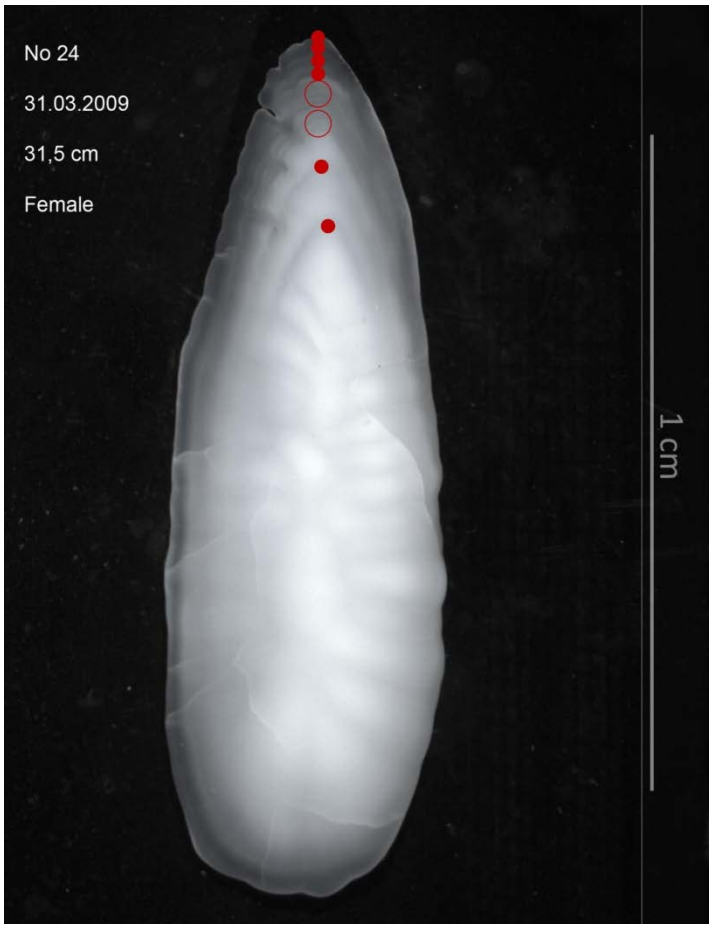


Image 3: Which part of the otolith to read

It is important to be aware of the area to read. The red dots indicate the correct direction to read. However, it is important to keep in mind that it should be possible to follow the rings along the side as well. The lines can clearly be followed on the side with the orange transect, but when reading along the blue transect the age goes from 9 to 7 years old.

We regard the red circle to be within the area it should be possible to follow the zones in order to call them annual zones.

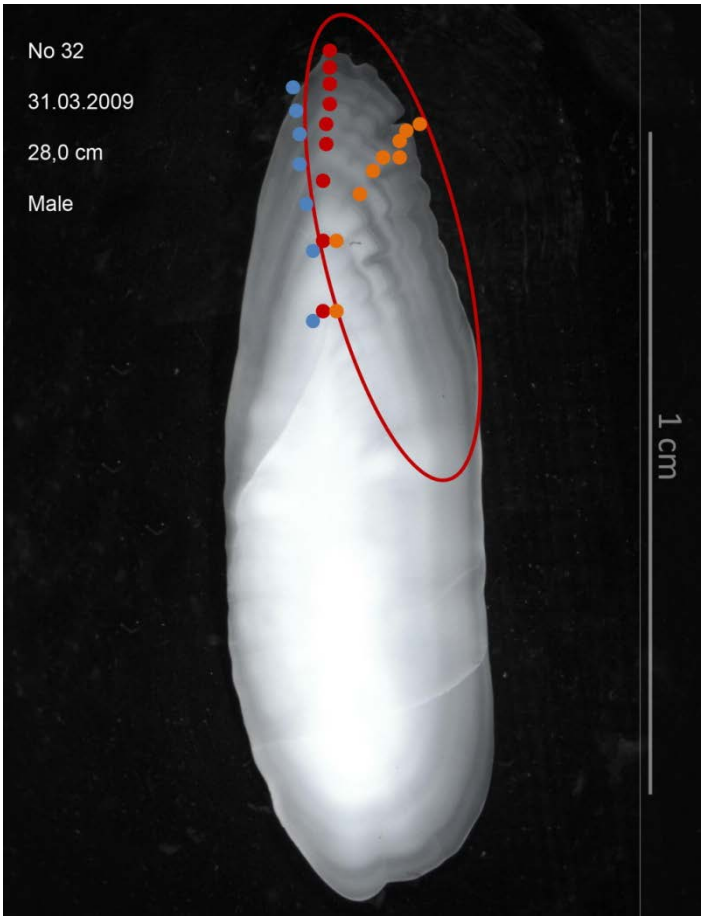
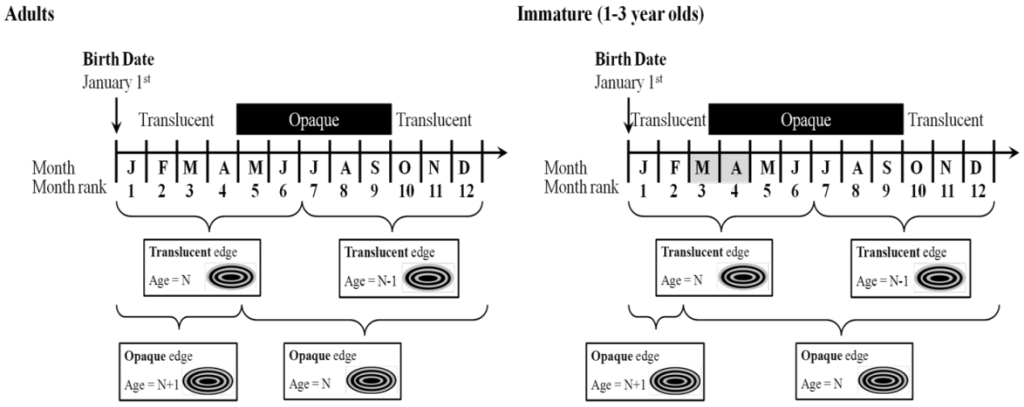


Image 4: Interpretation of the edge

Feeding starts at different times dependent on age and maturity among blue whiting. Adults usually start feeding in May, while immature specimens may start to eat much earlier, and the formation of an opaque ring may start already in March (WD WGWIDE2013). This modified scheme is made for blue whiting using the figure from WKACM2.



Annex 5: Results of exercises

Pre-workshop exercise:

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	21 %	25 %	25 %	0 %	0 %	30 %	23 %	25 %	35 %	49 %	21 %	16 %	23 %	21 %	20 %	25 %	46 %	25 %	38 %	30.4%
3	0 %	22 %	22 %	17 %	0 %	22 %	25 %	0 %	33 %	20 %	17 %	0 %	22 %	22 %	0 %	33 %	25 %	22 %	0 %	16.9%
4	12 %	10 %	10 %	28 %	29 %	32 %	23 %	10 %	18 %	19 %	16 %	21 %	17 %	18 %	9 %	21 %	22 %	31 %	17 %	18.4%
5	6 %	13 %	12 %	13 %	5 %	17 %	11 %	9 %	10 %	12 %	8 %	12 %	25 %	16 %	11 %	14 %	23 %	9 %	15 %	12.2%
6	8 %	10 %	13 %	11 %	15 %	16 %	14 %	9 %	10 %	20 %	14 %	13 %	18 %	20 %	12 %	12 %	17 %	10 %	21 %	13.8%
7	8 %	7 %	12 %	10 %	12 %	14 %	10 %	9 %	9 %	13 %	15 %	10 %	14 %	22 %	11 %	10 %	20 %	10 %	11 %	11.7%
8	6 %	7 %	8 %	12 %	14 %	15 %	15 %	9 %	7 %	12 %	14 %	14 %	15 %	23 %	13 %	11 %	16 %	12 %	9 %	12.0%
9	10 %	7 %	10 %	10 %	9 %	19 %	16 %	13 %	8 %	12 %	16 %	10 %	14 %	12 %	9 %	11 %	11 %	12 %	12 %	11.0%
10	0 %	8 %	8 %	10 %	12 %	11 %	9 %	4 %	10 %	18 %	15 %	11 %	16 %	18 %	13 %	18 %	18 %	9 %	12 %	10.9%
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	7.7%	9.7%	11.9%	11.4%	11.7%	17.1%	13.6%	9.6%	11.0%	15.8%	13.7%	12.2%	17.6%	19.5%	11.4%	13.3%	19.4%	12.0%	14.7%	13.2%
RANKING	1	3	8	6	7	16	12	2	4	15	13	10	17	19	5	11	18	9	14	

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	40 %	80 %	80 %	100 %	100 %	40 %	50 %	80 %	60 %	40 %	40 %	20 %	60 %	40 %	80 %	80 %	40 %	80 %	40 %	61 %
3	100 %	67 %	67 %	67 %	100 %	67 %	33 %	100 %	33 %	50 %	67 %	100 %	67 %	67 %	100 %	33 %	33 %	67 %	100 %	70 %
4	43 %	86 %	86 %	43 %	43 %	57 %	71 %	86 %	71 %	33 %	67 %	29 %	57 %	57 %	86 %	71 %	29 %	57 %	57 %	60 %
5	88 %	85 %	85 %	59 %	93 %	56 %	67 %	85 %	70 %	74 %	81 %	52 %	67 %	52 %	78 %	37 %	26 %	85 %	59 %	68 %
6	77 %	77 %	57 %	69 %	57 %	51 %	54 %	66 %	71 %	69 %	40 %	54 %	34 %	29 %	51 %	57 %	26 %	71 %	54 %	56 %
7	71 %	74 %	57 %	71 %	69 %	54 %	66 %	69 %	57 %	42 %	43 %	60 %	24 %	12 %	57 %	57 %	35 %	71 %	69 %	56 %
8	67 %	67 %	67 %	54 %	46 %	38 %	58 %	58 %	67 %	50 %	46 %	38 %	21 %	25 %	63 %	58 %	25 %	54 %	54 %	50 %
9	75 %	81 %	63 %	63 %	63 %	31 %	38 %	56 %	56 %	31 %	44 %	50 %	50 %	25 %	50 %	38 %	25 %	56 %	56 %	50 %
10	100 %	50 %	83 %	33 %	33 %	67 %	50 %	83 %	33 %	17 %	17 %	50 %	17 %	17 %	17 %	33 %	33 %	50 %	0 %	41 %
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	74.5%	75.9%	67.1%	63.3%	65.2%	49.4%	58.0%	70.3%	63.3%	52.6%	49.7%	50.6%	38.9%	30.1%	60.8%	51.9%	28.7%	68.2%	57.0%	56.6%
RANKING	2	1	5	7	6	16	10	3	7	12	15	14	17	18	9	13	19	4	11	

Figure 5.1. Pre-workshop CV and percentage agreement against modal age for age-readers.

Pre-workshop agreed collection Criterion 80% agreement	
MODAL AGE	n
0	0
1	0
2	1
3	1
4	1
5	8
6	3
7	1
8	1
9	1
10	0
	17

Figure 5.2. Number of otoliths by modal age that achieved over 80% agreement between age readers during the pre-workshop exercise.

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.60	-0.20	-0.20	0.00	0.00	0.80	0.50	-0.20	0.00	1.40	0.60	0.80	0.40	0.60	0.20	-0.20	-0.20	-0.20	0.20	**0.26**
3	0.00	-0.33	-0.33	0.33	0.00	-0.33	-0.67	0.00	0.00	0.50	0.33	0.00	-0.33	-0.33	0.00	0.00	-0.67	-0.33	0.00	**-0.13**
4	0.57	-0.14	-0.14	1.14	0.71	1.29	-0.14	-0.14	0.43	0.33	0.00	1.14	0.14	-0.14	0.14	0.57	-0.43	0.57	0.57	**0.34**
5	0.12	0.15	0.00	0.30	0.07	0.74	0.19	0.19	0.15	0.15	0.11	0.44	-0.41	-0.41	0.19	0.70	-0.07	0.19	0.48	**0.17**
6	0.11	-0.09	-0.54	0.26	-0.26	0.66	0.03	0.31	-0.09	-0.03	-0.43	0.11	-0.63	-0.94	-0.20	0.34	-0.77	0.09	0.17	**-0.10**
7	0.06	0.03	-0.51	0.00	0.17	0.49	-0.17	0.26	-0.14	-0.21	-0.54	-0.09	-0.68	-1.03	-0.14	0.43	-0.32	-0.06	0.06	**-0.12**
8	0.25	0.08	-0.21	-0.33	-0.17	0.92	-0.25	0.42	0.00	0.04	-0.75	-0.13	-0.92	-0.96	-0.08	0.42	-0.79	-0.25	0.04	**-0.14**
9	0.19	0.00	-0.13	-0.13	-0.19	0.50	-0.56	0.19	-0.06	-0.63	-1.00	-0.38	-0.63	-1.25	-0.19	0.44	-0.63	-0.13	-0.13	**-0.25**
10	0.00	-0.17	-0.33	-1.00	-0.17	0.67	-0.67	0.17	-1.00	-0.33	-0.50	-0.33	-1.83	-1.83	-0.83	-0.17	-0.17	-0.67	-1.00	**-0.54**
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	**0.16**	**0.00**	**-0.31**	**0.06**	**-0.03**	**0.67**	**-0.13**	**0.23**	**-0.05**	**-0.03**	**-0.41**	**0.09**	**-0.62**	**-0.84**	**-0.09**	**0.41**	**-0.48**	**-0.03**	**0.12**	**-0.07**
RANKING	**11**	**1**	**13**	**6**	**2**	**18**	**10**	**12**	**5**	**4**	**14**	**7**	**17**	**19**	**8**	**15**	**16**	**3**	**9**	

Figure 4.3. Pre-workshop exercise relative bias at modal age.

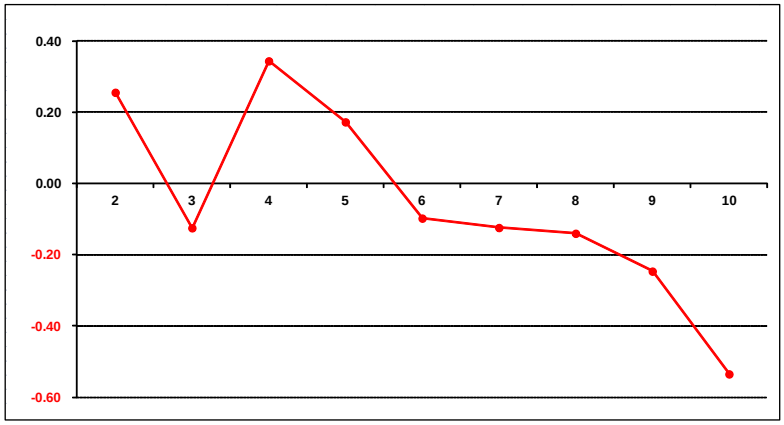


Figure 5.4. The relative bias by modal age.

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	*																		
Reader 16	**	**																	
Reader 7	-	-	**																
Reader 17	*	-	**	-															
Reader 19	**	**	**	**	**														
Reader 14	**	-	*	*	-	**													
Reader 5	-	**	**	*	**	**	**												
Reader 20	**	-	**	-	-	**	-	**											
Reader 21	*	-	**	-	-	**	-	**	-										
Reader 10	**	**	-	**	**	**	**	**	**	**									
Reader 12	-	-	**	-	-	**	*	-	-	-	**								
Reader 8	**	**	**	**	**	**	**	**	**	**	*	**							
Reader 4	**	**	**	**	**	**	**	**	**	**	**	**	*						
Reader 2	**	-	**	-	-	**	-	**	-	-	**	*	**	**					
Reader 3	**	**	**	**	**	**	**	*	**	**	**	**	**	**	**				
Reader 11	**	**	-	**	**	**	**	**	**	**	-	**	-	**	**	**			
Reader 6	**	-	**	-	-	**	-	**	-	-	**	-	**	**	-	**	**		
Reader 18	-	-	**	-	-	**	**	-	*	-	**	-	**	**	*	**	**	*	
MODAL	**	-	**	-	-	**	-	**	-	-	**	-	**	**	-	**	**	-	-

Figure 5.5. Wilcoxon inter reader bias test

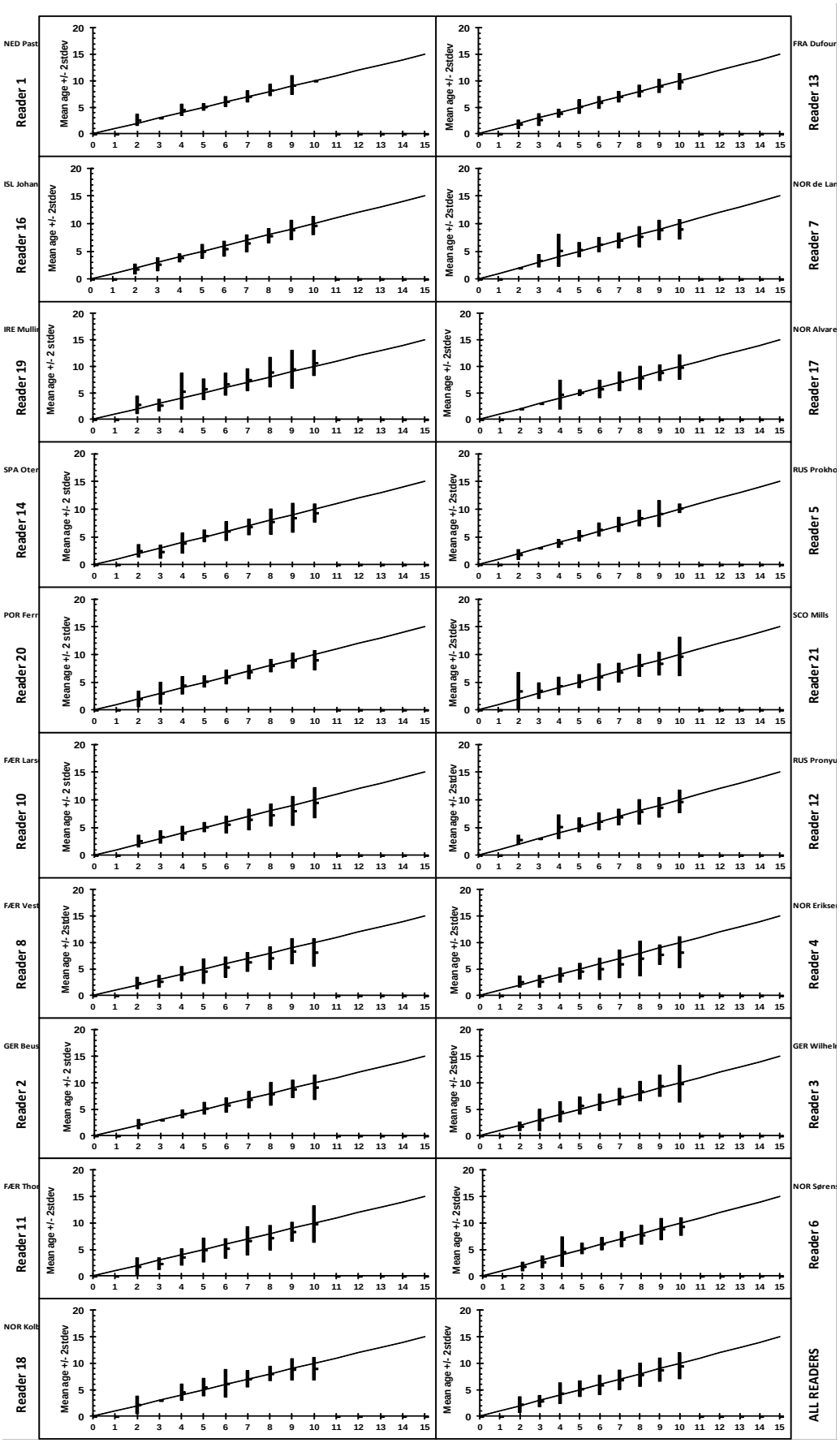


Figure 5.6. Age bias plot for individual age-readers and all age-readers combined pre-workshop calibration

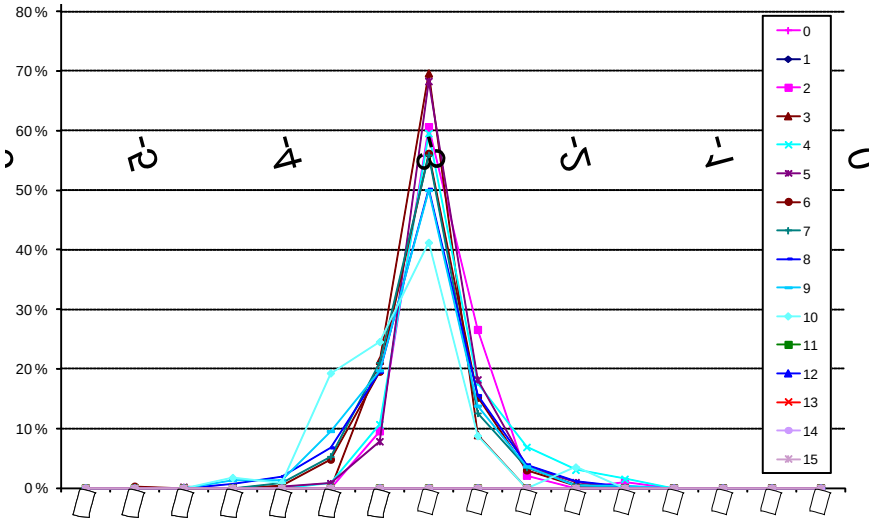


Figure 5.7. The pre-workshop distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age-readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of age reading errors. There appears to be little RELATIVE bias, as the age reading errors are normally distributed.

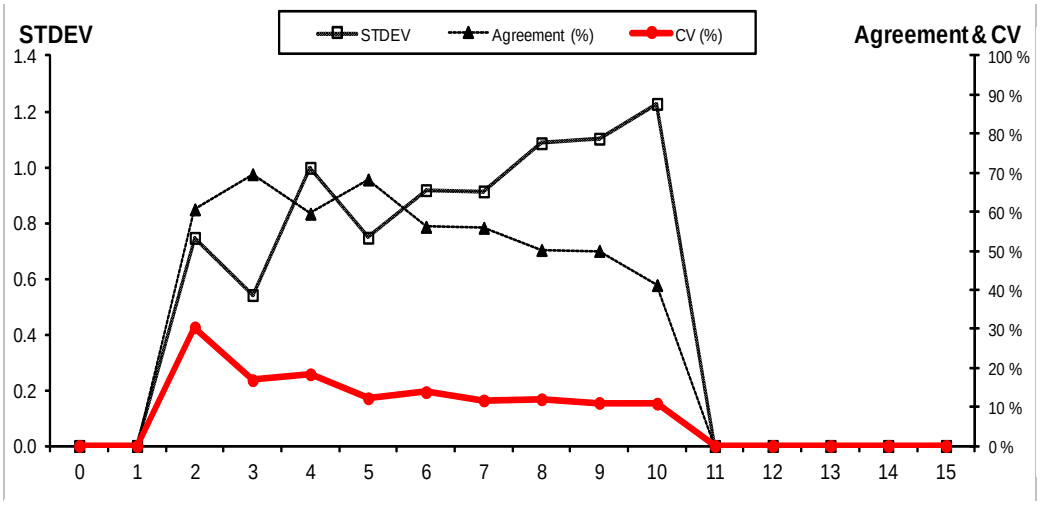


Figure 5.8. The coefficient of variation (CV %), percent agreement and the standard deviation (STDEV) are plotted against MODAL age. CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.

Re-reading exercise:

MODAL age	CV	% agreement
0	-	-
1	-	-
2	30.4%	61 %
3	16.9%	70 %
4	15.4%	64 %
5	12.0%	62 %
6	13.0%	49 %
7	12.0%	56 %
8	13.3%	42 %
9	10.8%	50 %
10	10.9%	41 %
	14.5%	53.7%

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	23 %	25 %	0 %	35 %	20 %	20 %	20 %	25 %	23 %	23 %	21 %	20 %	16 %	23 %	25 %	25 %	0 %	25 %	25 %	22.5%
3	0 %	22 %	33 %	0 %	0 %	22 %	25 %	33 %	33 %	17 %	22 %	17 %	20 %	0 %	22 %	22 %	25 %	22 %	25 %	19.6%
4	20 %	0 %	12 %	0 %	13 %	13 %	29 %	16 %	12 %	0 %	12 %	13 %	0 %	16 %	12 %	12 %	29 %	13 %	27 %	14.4%
5	0 %	16 %	0 %	9 %	33 %	17 %	26 %	11 %	15 %	19 %	11 %	10 %	0 %	11 %	10 %	10 %	18 %	10 %	11 %	14.3%
6	11 %	23 %	25 %	16 %	32 %	28 %	13 %	6 %	21 %	19 %	9 %	12 %	13 %	25 %	12 %	12 %	9 %	12 %	17 %	15.5%
7	7 %	6 %	16 %	0 %	13 %	6 %	9 %	6 %	13 %	10 %	9 %	6 %	11 %	12 %	7 %	7 %	50 %	0 %	13 %	10.9%
8	5 %	5 %	14 %	16 %	15 %	9 %	11 %	6 %	6 %	6 %	16 %	6 %	11 %	24 %	15 %	16 %	16 %	11 %	11 %	12.9%
9	6 %	6 %	6 %	6 %	11 %	4 %	8 %	6 %	6 %	8 %	9 %	0 %	6 %	14 %	6 %	5 %	11 %	6 %	10 %	8.2%
10	4 %	8 %	9 %	10 %	5 %	7 %	18 %	6 %	6 %	10 %	17 %	0 %	14 %	10 %	8 %	10 %	14 %	6 %	8 %	8.8%
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	8.5%	12.0%	12.8%	10.9%	16.4%	13.6%	16.1%	10.7%	13.8%	12.3%	13.3%	8.2%	10.1%	16.1%	12.0%	12.3%	18.2%	10.6%	15.0%	13.4%
RANKING	2	7	11	6	18	13	17	5	14	9	12	1	3	16	8	10	19	4	15	

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	60 %	80 %	100 %	60 %	80 %	80 %	80 %	80 %	60 %	60 %	40 %	80 %	20 %	60 %	80 %	80 %	100 %	80 %	80 %	72 %
3	100 %	67 %	33 %	100 %	0 %	67 %	33 %	33 %	33 %	67 %	67 %	67 %	50 %	100 %	67 %	67 %	33 %	67 %	33 %	57 %
4	50 %	100 %	75 %	100 %	75 %	50 %	75 %	50 %	75 %	100 %	75 %	75 %	100 %	50 %	75 %	75 %	50 %	75 %	25 %	71 %
5	100 %	50 %	100 %	25 %	50 %	50 %	50 %	75 %	0 %	25 %	75 %	75 %	100 %	75 %	50 %	50 %	25 %	50 %	75 %	58 %
6	63 %	38 %	63 %	50 %	25 %	63 %	13 %	88 %	38 %	38 %	25 %	75 %	50 %	13 %	63 %	63 %	63 %	50 %	25 %	47 %
7	67 %	83 %	33 %	100 %	67 %	83 %	67 %	83 %	17 %	33 %	67 %	83 %	50 %	83 %	67 %	67 %	50 %	100 %	50 %	66 %
8	83 %	83 %	67 %	20 %	0 %	50 %	50 %	67 %	50 %	50 %	17 %	67 %	50 %	33 %	17 %	17 %	17 %	50 %	33 %	44 %
9	71 %	71 %	71 %	57 %	57 %	86 %	29 %	71 %	71 %	57 %	14 %	100 %	71 %	29 %	57 %	71 %	14 %	71 %	14 %	57 %
10	86 %	43 %	43 %	57 %	71 %	57 %	29 %	71 %	71 %	29 %	43 %	100 %	57 %	29 %	57 %	57 %	29 %	71 %	14 %	53 %
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	74.0%	66.0%	64.0%	61.2%	49.0%	66.0%	44.0%	72.0%	48.0%	48.0%	42.0%	82.0%	59.2%	46.0%	58.0%	60.0%	42.0%	68.0%	36.0%	57.1%
RANKING	2	5	7	8	12	5	16	3	13	13	17	1	10	15	11	9	17	4	19	

Figure 5.9. The upper table gives CV and % agreement of the 50 otoliths from the pre-workshop exercise. The lower two shows CV and percentage agreement against modal age for age-readers for the re-reading exercise.

50 of original agreed collection Criterion 80% agreement	
MODAL AGE	n
0	0
1	0
2	1
3	1
4	1
5	1
6	0
7	1
8	0
9	0
10	0
	5

Rereading - agreed collection Criterion 80% agreement	
MODAL AGE	n
0	0
1	0
2	2
3	0
4	2
5	1
6	0
7	1
8	0
9	0
10	1
	7

Figure 5.10. Number of otoliths by modal age that achieved over 80% agreement between age readers. The left table gives the agreement of the 50 otoliths of the pre-workshop exercise, while the right table give the agreement after the re-reading.

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.60	-0.20	-0.20	0.00	0.00	0.80	0.50	-0.20	0.00	1.40	0.60	0.80	0.40	0.60	0.20	-0.20	-0.20	-0.20	0.20	**0.26**
3	0.00	-0.33	-0.33	0.33	0.00	-0.33	-0.67	0.00	0.00	0.50	0.33	0.00	-0.33	-0.33	0.00	0.00	-0.67	-0.33	0.00	**-0.13**
4	0.60	-0.20	-0.20	0.60	0.00	1.20	-0.40	-0.20	0.00	0.20	0.00	0.80	0.00	-0.20	0.20	0.40	-0.20	0.20	0.20	**0.16**
5	0.20	0.20	0.20	0.60	0.00	1.20	0.40	0.00	0.40	0.60	0.20	0.80	-0.40	0.00	0.00	1.00	0.80	0.40	0.20	**0.36**
6	0.00	-0.33	-0.83	0.67	0.50	1.00	-0.50	0.00	-0.33	0.50	-0.33	0.50	-0.50	-0.50	-0.67	0.67	-0.33	0.33	0.33	**0.01**
7	0.38	0.25	-0.75	0.25	0.13	1.13	0.13	0.50	-0.13	0.00	-0.50	0.25	-0.57	-1.13	-0.13	0.63	0.38	0.25	0.63	**0.09**
8	0.33	-0.17	-0.50	-0.33	-0.33	0.67	-0.17	0.50	0.33	0.50	-1.17	0.00	-0.67	-1.50	0.00	0.17	-1.17	-0.83	0.00	**-0.23**
9	0.67	-0.17	0.17	-0.33	-0.50	1.33	-0.17	0.67	-0.33	-0.50	-0.67	-0.50	-0.83	-0.50	-0.83	0.50	-0.33	-0.33	0.33	**-0.12**
10	0.00	-0.17	-0.33	-1.00	-0.17	0.67	-0.67	0.17	-1.00	-0.33	-0.50	-0.33	-1.83	-1.83	-0.83	-0.17	-0.17	-0.67	-1.00	**-0.54**
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	**0.32**	**-0.10**	**-0.34**	**0.06**	**-0.04**	**0.92**	**-0.16**	**0.20**	**-0.14**	**0.27**	**-0.30**	**0.24**	**-0.57**	**-0.68**	**-0.26**	**0.36**	**-0.18**	**-0.12**	**0.12**	**-0.02**
RANKING	**14**	**3**	**15**	**2**	**1**	**19**	**7**	**9**	**6**	**12**	**13**	**10**	**17**	**18**	**11**	**16**	**8**	**4**	**5**	

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.40	-0.20	0.00	0.00	0.20	0.20	0.20	-0.20	0.40	0.40	0.60	0.20	0.80	0.40	-0.20	-0.20	0.00	-0.20	-0.20	**0.14**
3	0.00	-0.33	0.00	0.00	-1.00	-0.33	-0.67	0.00	0.00	0.33	-0.33	0.33	0.50	0.00	-0.33	-0.33	-0.67	-0.33	-0.67	**-0.21**
4	0.75	0.00	0.25	0.00	-0.25	0.50	-0.50	-0.50	0.25	0.00	0.25	-0.25	0.00	-0.50	0.25	0.25	-0.75	-0.25	-1.00	**-0.08**
5	0.00	0.00	0.00	0.75	0.00	0.75	-0.25	-0.25	1.50	1.75	-0.25	0.25	0.00	-0.25	0.50	0.50	0.25	0.50	-0.25	**0.29**
6	-0.13	-0.13	0.25	0.13	-0.25	0.13	-1.13	-0.13	1.25	1.00	-0.75	0.38	0.00	-0.13	0.50	0.50	-0.38	-0.25	-1.13	**-0.01**
7	0.33	0.17	0.17	0.00	-0.50	-0.17	0.00	0.17	0.67	0.83	0.00	-0.17	-0.17	-0.33	0.33	0.33	-1.17	0.00	-0.67	**-0.01**
8	0.17	-0.17	0.67	0.20	-0.80	0.17	-0.67	0.33	0.50	0.50	-1.50	0.33	-0.67	-0.67	0.33	0.00	-0.33	-0.67	-0.83	**-0.16**
9	0.00	-0.29	0.00	-0.43	-0.29	0.14	-0.86	0.00	0.00	-0.14	-1.14	0.00	-0.29	-1.14	0.43	0.29	-0.71	-0.29	-1.29	**-0.32**
10	0.14	-0.29	0.43	-0.71	-0.29	-0.14	-1.14	0.00	0.00	0.71	-0.57	0.00	-0.29	-1.14	-0.57	0.00	-0.14	0.00	-1.14	**-0.27**
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	**0.16**	**-0.14**	**0.22**	**-0.06**	**-0.33**	**0.12**	**-0.62**	**-0.04**	**0.52**	**0.60**	**-0.50**	**0.12**	**-0.08**	**-0.48**	**0.16**	**0.18**	**-0.44**	**-0.18**	**-0.86**	**-0.09**
RANKING	**7**	**6**	**11**	**2**	**12**	**4**	**18**	**1**	**16**	**17**	**15**	**5**	**3**	**14**	**8**	**9**	**13**	**10**	**19**	

Figure 5.11. Re-reading exercise relative bias at modal age. The upper table shows the pre-workshop results of the 50 otoliths, while the lower table shows the relative bias of the re-reading exercise.

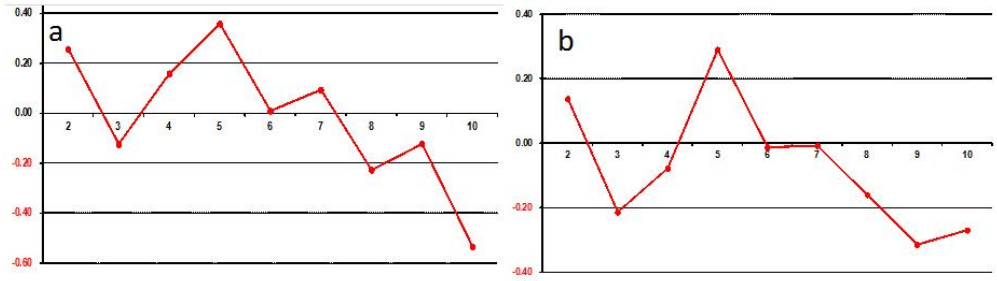


Figure 5.12. Relative bias by modal age of the 50 otoliths re-readings. The left graph (a) shows the readings done before the workshop, while the right graph (b) shows the results of the rereading.

a)	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Modal age	**	-	*	-	-	**	-	*	-	-	*	-	**	**	*	*	-	-	-

b)	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	*																		
Reader 16	-	**																	
Reader 7	-	-	-																
Reader 17	**	-	-	-															
Reader 19	-	-	**	-	**														
Reader 14	**	**	**	**	-	**													
Reader 5	-	-	-	-	-	-	**												
Reader 20	-	**	-	**	**	*	**	**											
Reader 21	*	**	*	**	**	**	**	**	-										
Reader 10	**	*	**	*	-	**	-	*	**	**									
Reader 12	-	*	-	-	**	-	**	-	**	**	**								
Reader 8	-	-	-	-	-	-	**	-	**	**	**	-							
Reader 4	**	*	**	**	-	**	-	*	**	**	-	**	*						
Reader 2	-	*	-	-	**	-	**	-	*	**	**	-	-	**					
Reader 3	-	**	-	*	**	-	**	-	*	**	**	-	-	**	-				
Reader 11	**	-	**	-	-	**	-	*	**	**	-	**	-	-	**	**			
Reader 6	**	-	*	-	-	*	**	-	**	**	-	**	-	-	*	**	-		
Reader 18	**	**	**	**	**	**	-	**	**	**	*	**	**	-	**	**	**	**	
MODAL	-	-	-	-	*	-	**	-	**	**	**	-	-	**	-	-	*	-	**

Figure 5.13. Inter-reader bias of the re-reading. The top part a) gives the bias against modal age of the 50 otoliths from the pre-workshop exercise, and the lower part b) shows the inter-reader bias of the re-reading as well as the agreement with modal age.

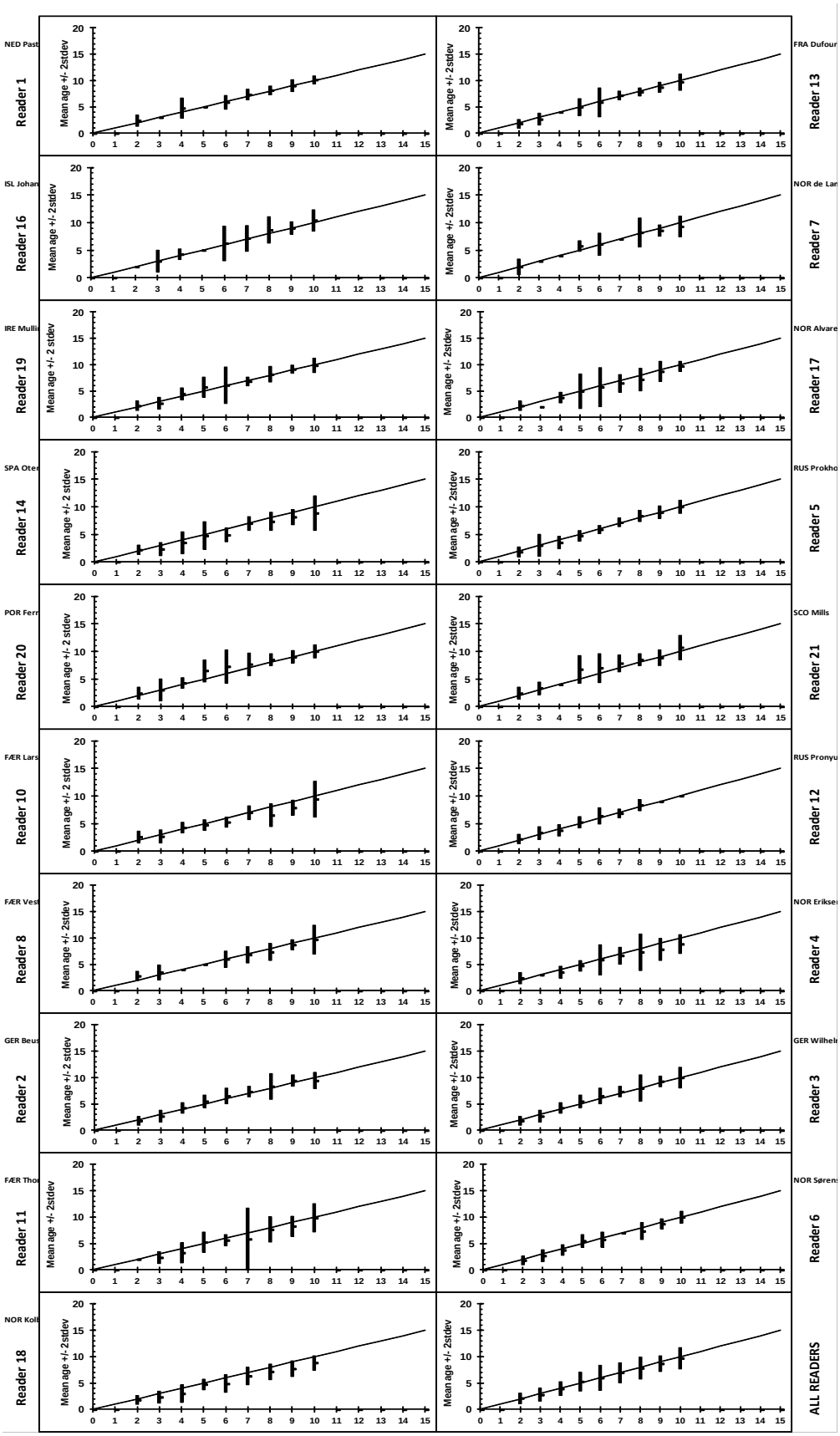


Figure 5.14. Age bias plot for individual age-readers and all age-readers combined.

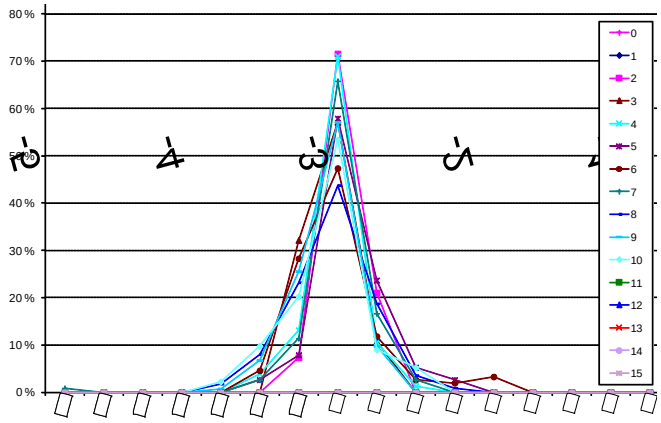


Figure 5.15. The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age-readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of age reading errors. There appears to be no RELATIVE bias, if the age reading errors are normally distributed.

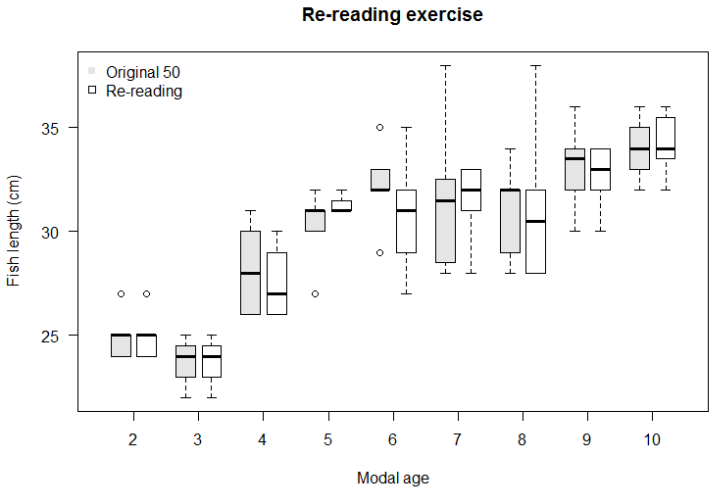


Figure 5.16. Modal age at length of the 50 otoliths used in the re-reading.

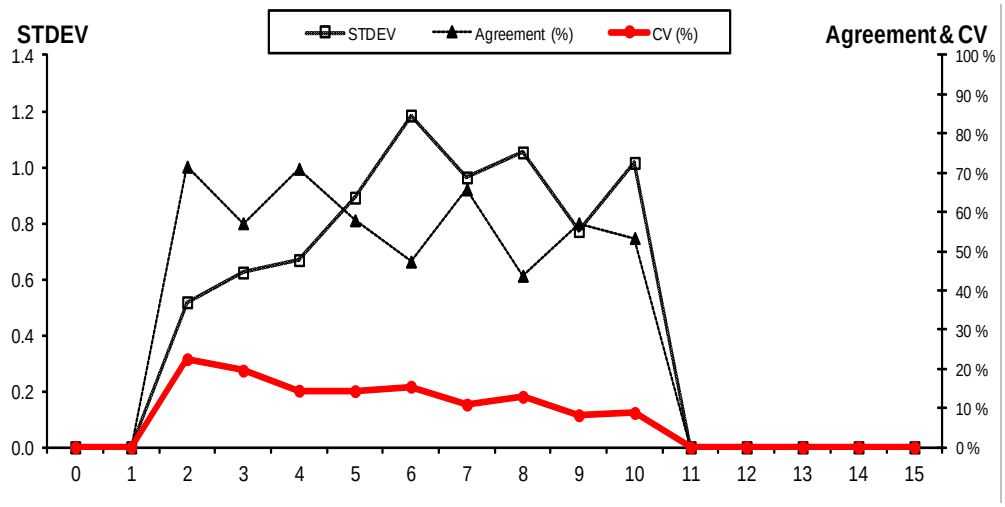


Figure 5.17. The coefficient of variation (CV %), percent agreement and the standard deviation (STDEV) are plotted against MODAL age. CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.

Faroese collection:

Faroe Islandic agreed collection Criterion 80% agreement	
MODAL AGE	n
0	3
1	7
2	5
3	5
4	1
5	0
6	0
7	1
8	0
9	0
10	0
	22

Figure 5.18. Number of otoliths by modal age that achieved over 80% agreement between age readers.

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	Readers
0	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	299.5%
1	23 %	36 %	34 %	0 %	23 %	23 %	0 %	23 %	36 %	42 %	30 %	45 %	53 %	0 %	0 %	0 %	23 %	41 %	42 %	36.9%
2	0 %	30 %	20 %	32 %	0 %	18 %	32 %	18 %	28 %	20 %	0 %	20 %	32 %	18 %	38 %	36 %	25 %	16 %	20 %	20.2%
3	15 %	12 %	19 %	12 %	13 %	12 %	12 %	0 %	13 %	0 %	0 %	23 %	0 %	0 %	13 %	21 %	0 %	12 %	12 %	8.7%
4	0 %	12 %	16 %	16 %	14 %	16 %	16 %	15 %	14 %	0 %	11 %	12 %	22 %	16 %	15 %	24 %	19 %	0 %	0 %	14.9%
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	0 %	8 %	9 %	15 %	0 %	0 %	15 %	0 %	10 %	14 %	0 %	0 %	87 %	14 %	15 %	22 %	0 %	9 %	8 %	16.4%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	18 %	16 %	9 %	0 %	8 %	8 %	0 %	7 %	11 %	0 %	0 %	11 %	11 %	9 %	141 %	11 %	0 %	16 %	0 %	21.8%
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	10.6%	22.4%	20.8%	10.2%	11.7%	14.9%	10.2%	13.1%	22.1%	19.2%	11.4%	24.1%	32.1%	6.3%	16.7%	14.1%	14.5%	19.6%	20.1%	40.2%
RANKING	4	17	15	2	6	10	2	7	16	12	5	18	19	1	11	8	9	13	14	

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL
0	100 %	0 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	0 %	100 %	100 %	100 %	100 %	100 %	100 %	89 %
1	94 %	18 %	35 %	100 %	94 %	94 %	100 %	94 %	65 %	59 %	88 %	76 %	65 %	100 %	100 %	100 %	94 %	53 %	59 %	78 %
2	100 %	67 %	78 %	67 %	100 %	89 %	67 %	89 %	67 %	78 %	100 %	78 %	67 %	89 %	50 %	44 %	78 %	89 %	78 %	78 %
3	71 %	86 %	71 %	86 %	86 %	86 %	86 %	100 %	86 %	100 %	100 %	71 %	100 %	100 %	86 %	57 %	100 %	86 %	86 %	86 %
4	100 %	50 %	67 %	67 %	67 %	50 %	67 %	33 %	67 %	100 %	83 %	67 %	33 %	50 %	33 %	33 %	33 %	100 %	100 %	63 %
5	100 %	0 %	100 %	100 %	100 %	100 %	100 %	100 %	0 %	0 %	100 %	100 %	100 %	0 %	100 %	0 %	100 %	100 %	0 %	68 %
6	0 %	-	0 %	100 %	100 %	100 %	100 %	0 %	0 %	0 %	100 %	100 %	0 %	100 %	0 %	0 %	0 %	0 %	0 %	39 %
7	100 %	33 %	67 %	67 %	100 %	100 %	67 %	100 %	0 %	33 %	100 %	100 %	33 %	33 %	67 %	0 %	100 %	67 %	33 %	63 %
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	50 %	0 %	0 %	100 %	50 %	50 %	100 %	50 %	0 %	100 %	0 %	0 %	0 %	0 %	0 %	0 %	100 %	0 %	100 %	37 %
10	0 %	100 %	0 %	100 %	100 %	100 %	100 %	0 %	0 %	0 %	100 %	0 %	0 %	100 %	100 %	0 %	100 %	0 %	100 %	53 %
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	88.0%	40.8%	56.0%	86.0%	90.0%	86.0%	86.0%	82.0%	60.0%	71.4%	90.0%	74.0%	56.0%	82.0%	73.5%	60.0%	84.0%	70.0%	72.0%	74.1%
RANKING	3	19	17	4	1	4	4	8	15	13	1	10	17	8	11	15	7	14	12	

Figure 5.19. CV and percentage agreement against modal age for age-readers.

MODAL	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18	ALL
0	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
1	0.06	1.06	0.71	0.00	0.06	0.06	0.00	0.06	0.35	0.47	0.12	0.29	0.29	0.00	0.00	0.00	0.06	0.53	0.47	0.24
2	0.00	0.44	0.22	-0.11	0.00	-0.11	-0.11	-0.11	0.11	0.22	0.00	0.22	-0.11	-0.11	0.00	-0.56	0.00	0.11	0.22	0.02
3	0.29	0.14	0.00	0.14	-0.14	0.14	0.14	0.00	-0.14	0.00	0.00	0.43	0.00	0.00	-0.14	-0.43	0.00	0.14	0.14	0.04
4	0.00	0.50	0.00	0.00	-0.33	-0.50	0.00	-0.67	-0.33	0.00	-0.17	0.33	-0.33	-0.50	-0.67	-0.83	0.33	0.00	0.00	-0.17
5	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	1.00	0.00	0.00	0.00	1.00	0.00	-2.00	0.00	0.00	1.00	0.05
6	-1.00	-	-1.00	0.00	0.00	0.00	0.00	-2.00	-2.00	-1.00	0.00	0.00	-2.00	0.00	-1.00	-4.00	2.00	1.00	-1.00	-0.67
7	0.00	0.67	-0.33	0.67	0.00	0.00	0.67	0.00	-1.33	0.00	0.00	0.00	-2.67	0.00	0.67	-1.67	0.00	-0.33	0.67	-0.16
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-1.00	0.00	-1.50	0.00	-0.50	-0.50	0.00	0.50	-2.50	0.00	-1.00	-2.50	-2.50	-1.50	-4.00	-2.50	0.00	0.00	0.00	-1.03
10	-1.00	0.00	-1.00	0.00	0.00	0.00	0.00	1.00	-3.00	-3.00	0.00	-3.00	-4.00	0.00	0.00	-4.00	0.00	-1.00	0.00	-1.00
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	-0.02	0.65	0.16	0.04	-0.06	-0.06	0.04	-0.08	-0.22	0.14	-0.02	0.08	-0.28	-0.12	-0.24	-0.66	0.10	0.20	0.26	-0.01
RANKING	2	18	12	3	5	6	3	8	14	11	1	7	17	10	15	19	9	13	16	

Figure 5.20. Relative bias at modal age.

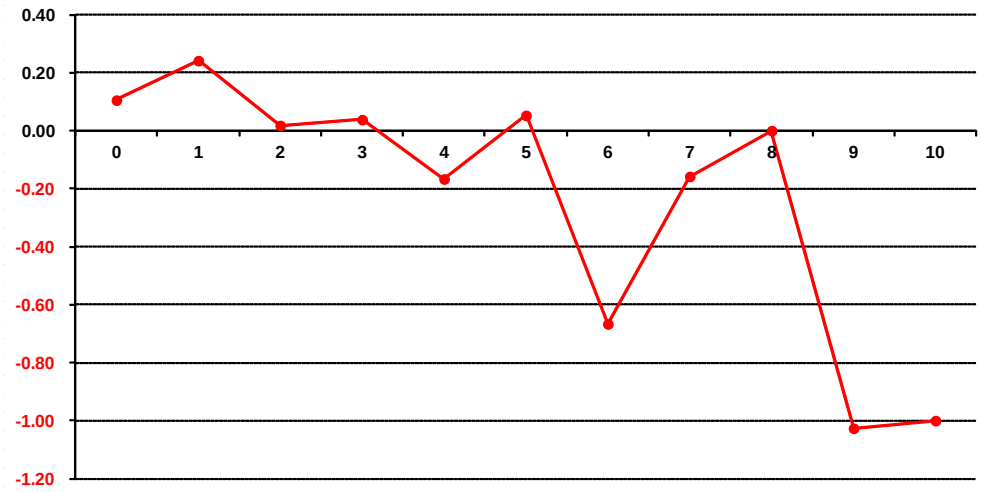


Figure 5.21. The relative bias by modal age.

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	**																		
Reader 16	-	**																	
Reader 7	-	**	-																
Reader 17	-	**	-	-															
Reader 19	-	**	-	-	-														
Reader 14	-	**	-	-	-	-													
Reader 5	-	**	*	-	-	-	-												
Reader 20	-	**	**	-	-	-	-	-											
Reader 21	-	**	-	-	-	*	-	*	**										
Reader 10	-	**	-	-	-	-	-	-	-	-									
Reader 12	-	**	-	-	-	-	-	-	*	-	-								
Reader 8	-	**	*	-	-	-	-	-	-	*	-	*							
Reader 4	-	**	*	-	-	-	-	-	-	*	-	-	-						
Reader 2	-	**	*	-	-	-	-	-	-	*	-	-	-	-					
Reader 3	**	**	**	**	**	*	**	**	**	**	**	**	**	**	*				
Reader 11	-	**	-	-	*	-	-	-	*	-	-	-	-	*	-	**			
Reader 6	*	**	-	-	*	**	-	*	**	-	*	-	*	**	*	**	-		
Reader 18	**	*	-	*	**	**	*	**	**	-	**	-	*	**	**	**	-	-	
MODAL	-	**	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	*	**

Figure 5.22. Wilcoxon inter-reader bias test.

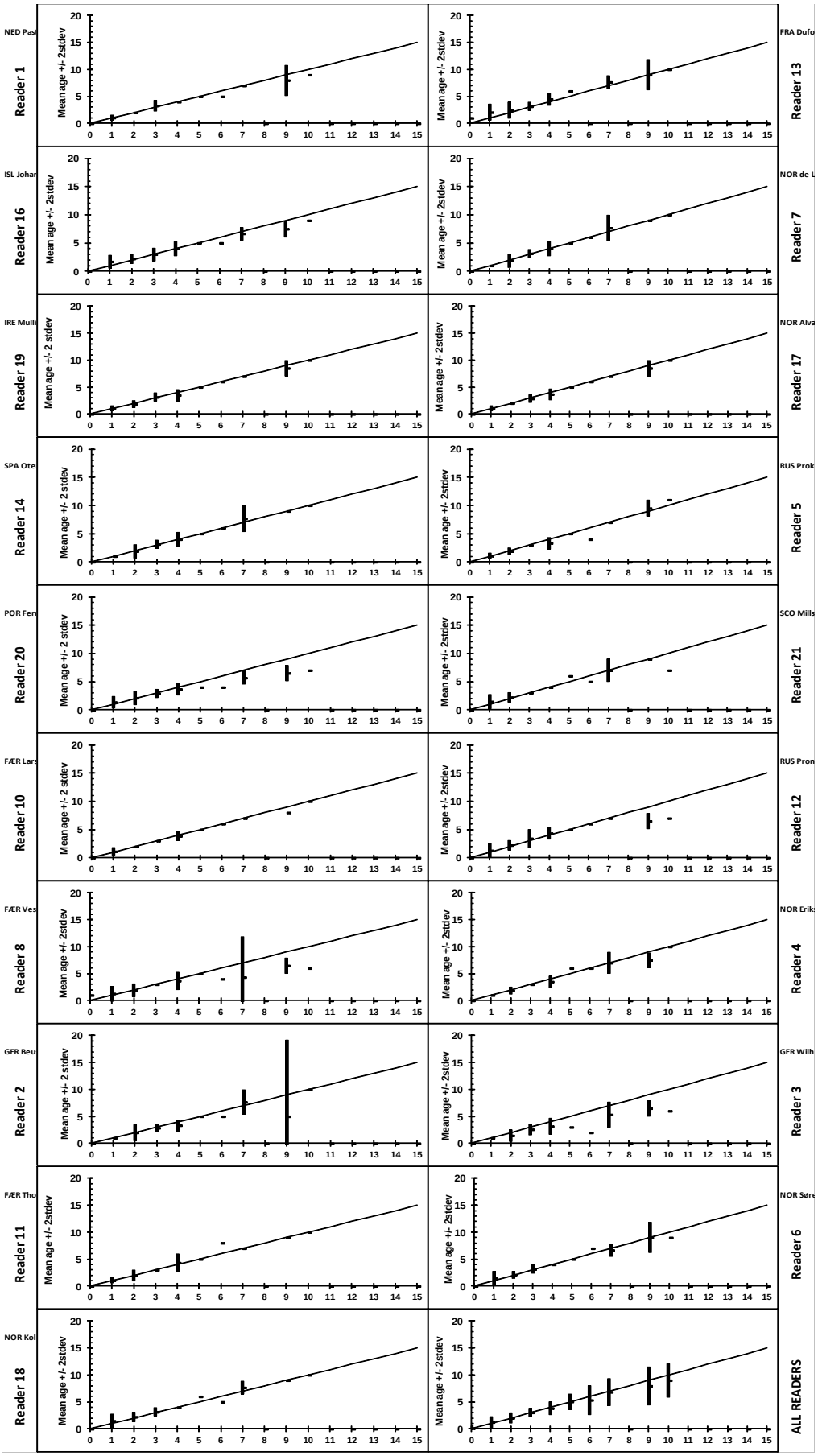


Figure 5.23. Age bias plot for individual age-readers and all age-readers combined.

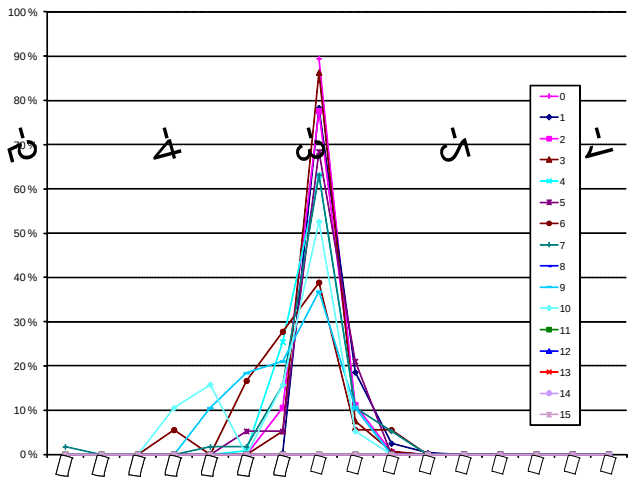


Figure 5.24. The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age-readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of age reading errors. For older ages the distribution is skewed towards underestimation of ages indicating that there appears to be some RELATIVE bias.

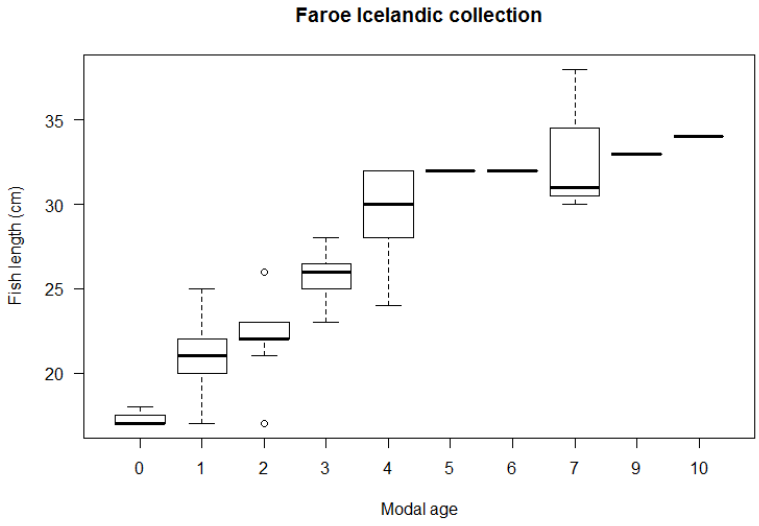


Figure 5.25. Modal age at length.

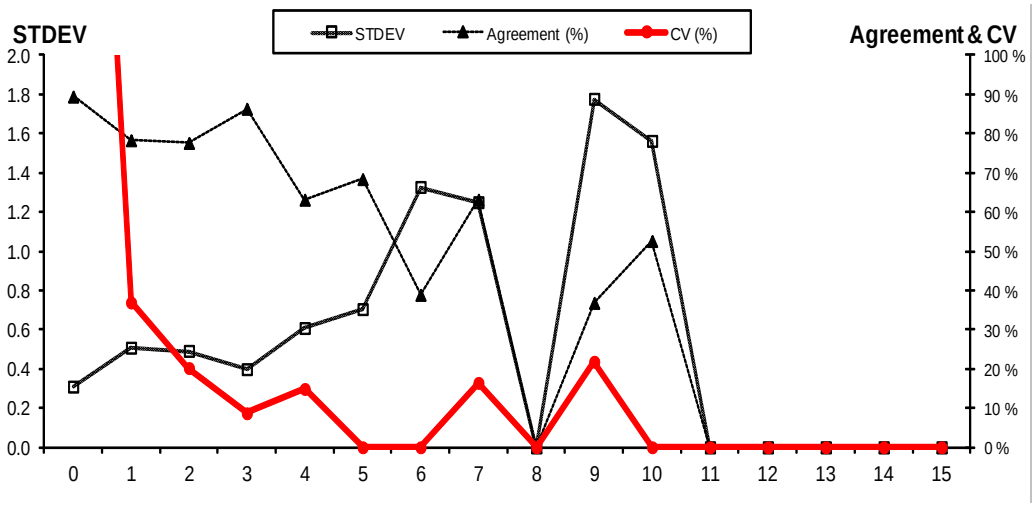


Figure 5.26. The coefficient of variation (CV %), percent agreement and the standard deviation (STDEV) are plotted against MODAL age. CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.

Russian collection:

Russia agreed collection Criterion 80% agreement	
MODAL AGE	n
0	0
1	0
2	0
3	1
4	1
5	0
6	0
7	0
8	0
9	1
10	0
	3

Figure 5.27. Number of otoliths by modal age that achieved over 80% agreement between age readers.

MODAL	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Readers
		13	16	7	17	19	14	5	20	21	10	12	8	4	2	3	11	6	18	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0 %	0 %	0 %	28 %	0 %	0 %	28 %	0 %	0 %	28 %	0 %	20 %	0 %	0 %	47 %	0 %	0 %	47 %		24.5%
3	22 %	24 %	20 %	15 %	0 %	12 %	19 %	0 %	23 %	37 %	23 %	39 %	23 %	14 %	21 %	14 %	30 %	20 %		22.2%
4	14 %	20 %	23 %	18 %	20 %	18 %	22 %	20 %	34 %	24 %	9 %	17 %	34 %	20 %	23 %	23 %	16 %	14 %	19 %	19.5%
5	0 %	11 %	25 %	39 %	16 %	12 %	29 %	16 %	27 %	20 %	12 %	11 %	27 %	0 %	0 %	12 %	27 %	20 %	11 %	18.2%
6	17 %	7 %	8 %	8 %	0 %	9 %	12 %	0 %	17 %	9 %	9 %	9 %	17 %	9 %	9 %	18 %	12 %	8 %	9 %	11.8%
7	0 %	17 %	14 %	0 %	7 %	17 %	8 %	7 %	13 %	9 %	14 %	12 %	13 %	7 %	9 %	17 %	17 %	12 %	17 %	9.9%
8	9 %	9 %	6 %	10 %	10 %	5 %	11 %	10 %	9 %	6 %	7 %	7 %	9 %	13 %	7 %	10 %	6 %	9 %	14 %	10.8%
9	0 %	12 %	6 %	16 %	7 %	6 %	6 %	7 %	0 %	11 %	7 %	6 %	0 %	0 %	0 %	7 %	12 %	10 %	5 %	7.8%
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	12.3%	16.3%	16.2%	14.9%	9.4%	12.1%	17.5%	9.4%	21.0%	21.6%	12.2%	18.9%	21.0%	12.4%	16.4%	15.5%	17.6%	15.8%	10.7%	17.0%
RANKING	6	12	11	8	1	4	14	1	17	19	5	16	17	7	13	9	15	10	3	

MODAL	Reader	Reader	Reader	Reader	Reader	Reader	Reader		Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	ALL
	1	13	16	7	17	19	14	Reader 5	20	21	10	12	8	4	2	3	11	6	18	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0 %	100 %	100 %	50 %	100 %	100 %	50 %	100 %	0 %	50 %	100 %	0 %	0 %	100 %	50 %	100 %	100 %	50 %	50 %	63 %
3	33 %	45 %	67 %	50 %	100 %	83 %	33 %	100 %	50 %	58 %	75 %	42 %	50 %	83 %	50 %	83 %	50 %	17 %	42 %	59 %
4	60 %	40 %	40 %	43 %	73 %	73 %	47 %	73 %	60 %	33 %	87 %	40 %	60 %	40 %	40 %	60 %	47 %	40 %	47 %	53 %
5	100 %	67 %	0 %	0 %	0 %	67 %	67 %	0 %	67 %	33 %	67 %	67 %	67 %	0 %	100 %	67 %	67 %	67 %	67 %	52 %
6	25 %	25 %	75 %	75 %	100 %	50 %	25 %	100 %	25 %	50 %	75 %	50 %	25 %	75 %	50 %	50 %	25 %	75 %	50 %	54 %
7	100 %	50 %	25 %	100 %	75 %	50 %	50 %	75 %	25 %	50 %	25 %	50 %	25 %	75 %	50 %	25 %	25 %	50 %	50 %	51 %
8	57 %	57 %	71 %	43 %	43 %	86 %	29 %	43 %	57 %	71 %	71 %	57 %	57 %	57 %	57 %	0 %	29 %	29 %	29 %	50 %
9	100 %	67 %	33 %	33 %	67 %	33 %	67 %	67 %	100 %	33 %	67 %	67 %	100 %	100 %	100 %	33 %	67 %	33 %	0 %	61 %
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	56.0%	49.0%	52.0%	50.0%	74.0%	72.0%	42.0%	74.0%	52.0%	48.0%	74.0%	46.0%	52.0%	62.0%	54.0%	54.0%	46.0%	38.0%	42.0%	54.6%
RANKING	6	13	9	12	1	4	17	1	9	14	1	15	9	5	7	7	15	19	17	

Figure 5.28. CV and percentage agreement against modal age for age-readers.

MODAL	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	Reader	ALL
	1	13	16	7	17	19	14	5	20	21	10	12	8	4	2	3	11	6	18	
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	1.00	0.50	0.00	1.50	1.00	0.00	1.00	0.00	0.00	1.00	0.50	0.45
3	1.08	0.45	0.00	0.50	0.00	0.17	0.83	0.00	0.42	-0.08	0.17	0.50	0.42	0.00	0.67	-0.17	0.75	1.25	0.75	0.41
4	0.47	-0.07	-0.40	-0.43	-0.40	-0.20	0.47	-0.40	0.07	-0.07	-0.13	0.33	0.07	-0.33	0.53	-0.40	0.27	0.47	0.33	0.01
5	0.00	0.33	-0.33	0.50	-1.33	-0.33	1.00	-1.33	-0.67	0.00	-0.33	0.33	-0.67	-1.00	0.00	-0.33	-0.67	0.67	0.33	-0.21
6	1.25	0.75	0.25	0.25	0.00	0.50	1.00	0.00	-0.25	0.50	-0.25	0.50	-0.25	-0.25	0.50	-0.75	1.00	0.25	0.50	0.29
7	0.00	0.25	-0.25	0.00	-0.25	0.25	0.50	-0.25	0.25	-0.50	-0.25	0.00	0.25	-0.25	-0.50	-1.25	0.50	0.00	0.25	-0.07
8	0.57	0.57	0.29	-0.29	-0.29	0.14	0.57	-0.29	-0.14	-0.29	0.00	-0.43	-0.14	-0.71	-0.43	-2.00	0.71	0.43	0.00	-0.09
9	0.00	0.67	0.67	0.33	-0.33	0.67	0.33	-0.33	0.00	0.00	-0.33	0.33	0.00	0.00	0.00	-0.67	0.67	1.00	1.67	0.25
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	0.62	0.31	-0.06	0.04	-0.28	0.08	0.64	-0.28	0.10	-0.06	-0.08	0.30	0.10	-0.30	0.30	-0.66	0.48	0.66	0.48	0.13
RANKING	16	13	2	1	8	4	17	8	6	3	5	11	6	12	10	18	14	19	14	

Figure 5.29. Relative bias at modal age.

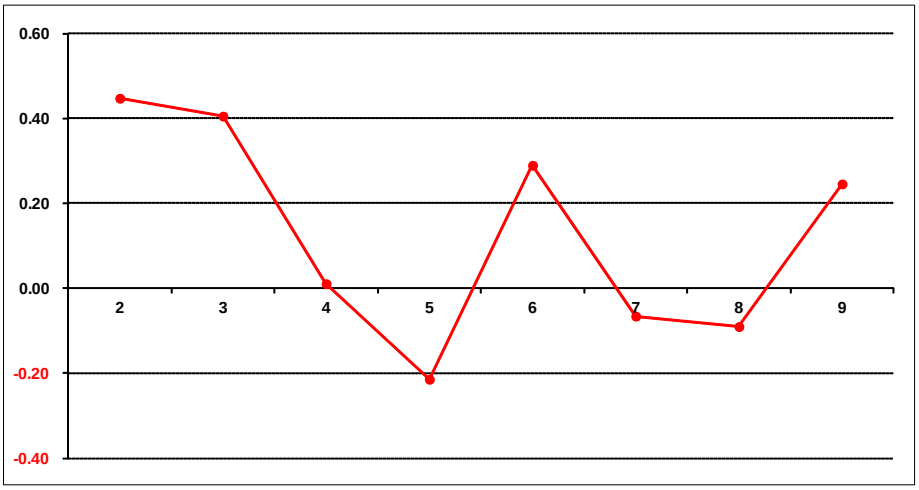


Figure 5.30. The relative bias by modal age.

	Reader 1	Reader 13	Reader 16	Reader 7	Reader 17	Reader 19	Reader 14	Reader 5	Reader 20	Reader 21	Reader 10	Reader 12	Reader 8	Reader 4	Reader 2	Reader 3	Reader 11	Reader 6	Reader 18
Reader 1																			
Reader 13	-																		
Reader 16	**	*																	
Reader 7	**	-	-																
Reader 17	**	**	-	*															
Reader 19	**	-	-	-	**														
Reader 14	-	*	**	**	**	**													
Reader 5	**	**	-	*	-	**	**												
Reader 20	**	-	-	-	*	-	**	*											
Reader 21	**	-	-	-	-	-	**	-	-										
Reader 10	**	**	-	-	-	-	**	-	-	-									
Reader 12	*	-	*	-	**	-	-	**	-	-	**								
Reader 8	**	-	-	-	*	-	**	*	-	-	-	-							
Reader 4	**	**	-	*	-	**	**	-	*	-	-	**	*						
Reader 2	*	-	*	-	**	-	-	**	-	*	*	-	-	**					
Reader 3	**	**	**	**	*	**	**	*	**	**	**	**	**	*	**				
Reader 11	-	-	**	*	**	**	-	**	*	**	**	-	*	**	-	**			
Reader 6	-	*	**	**	**	**	-	**	**	**	**	*	**	**	*	**	-		
Reader 18	-	-	**	**	**	**	-	**	*	**	**	-	*	**	-	**	-	-	
MODAL	**	*	-	-	**	-	**	**	-	-	-	*	-	**	*	**	**	**	**

Figure 5.31. Wilcoxon inter-reader bias test.

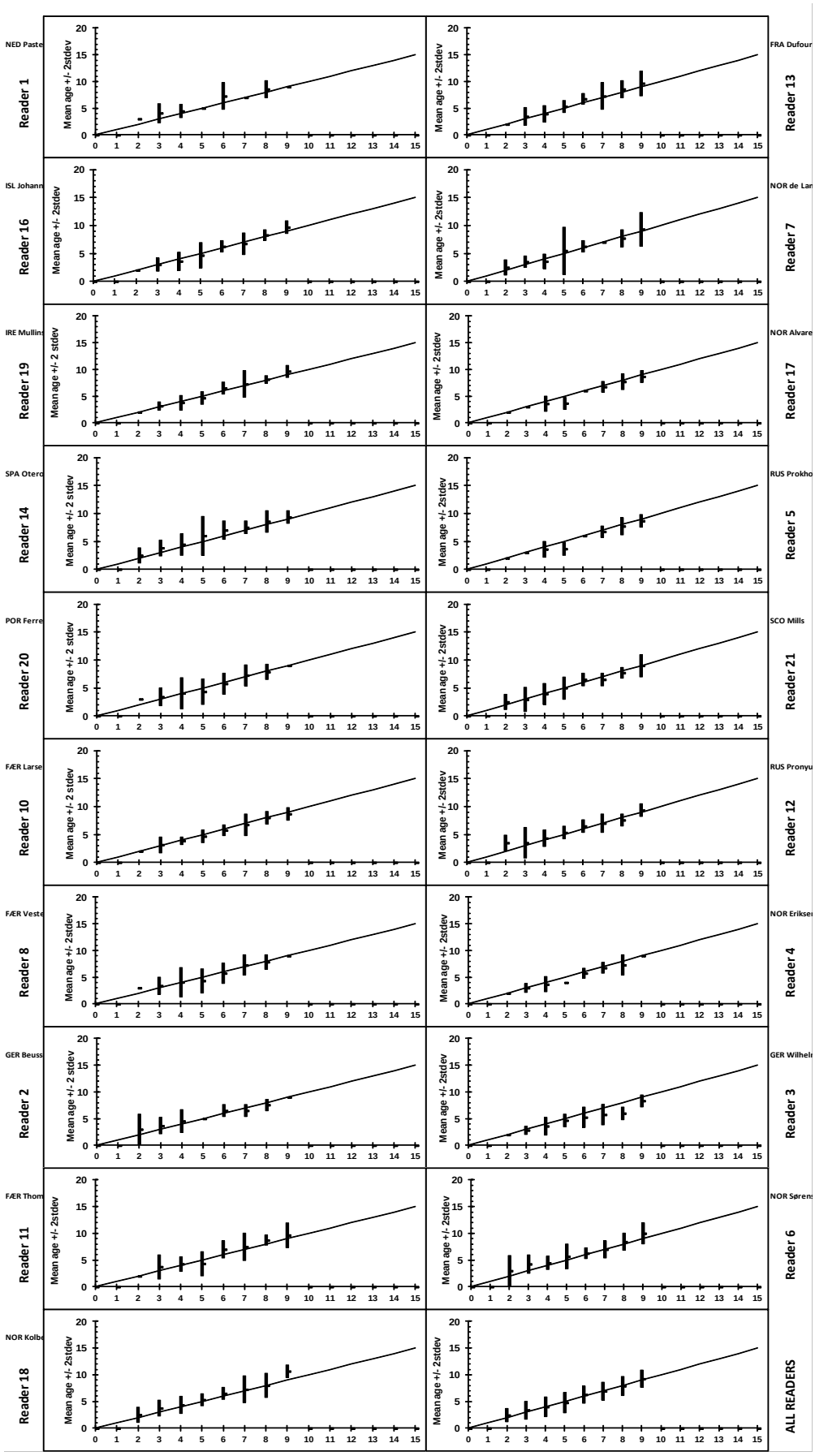


Figure 5.32. Age bias plot for individual age-readers and all age-readers combined.

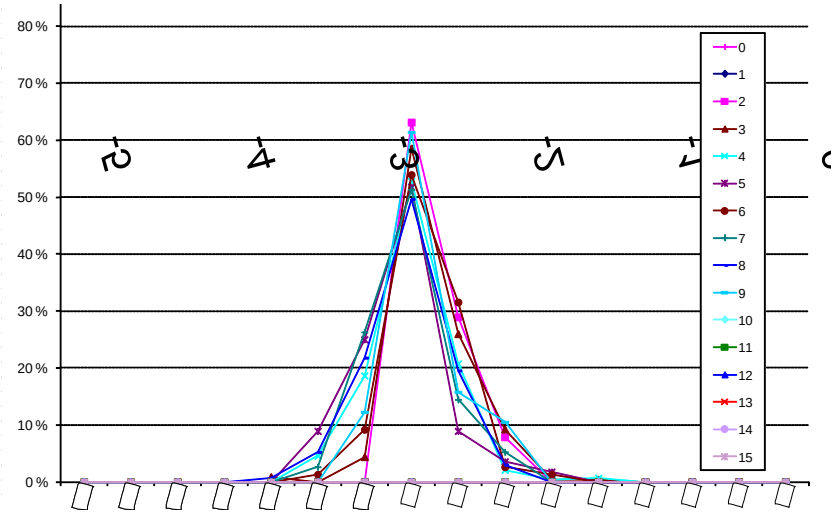


Figure 5.33. The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age-readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of age reading errors. There appears to be no RELATIVE bias, if the age reading errors are normally distributed.

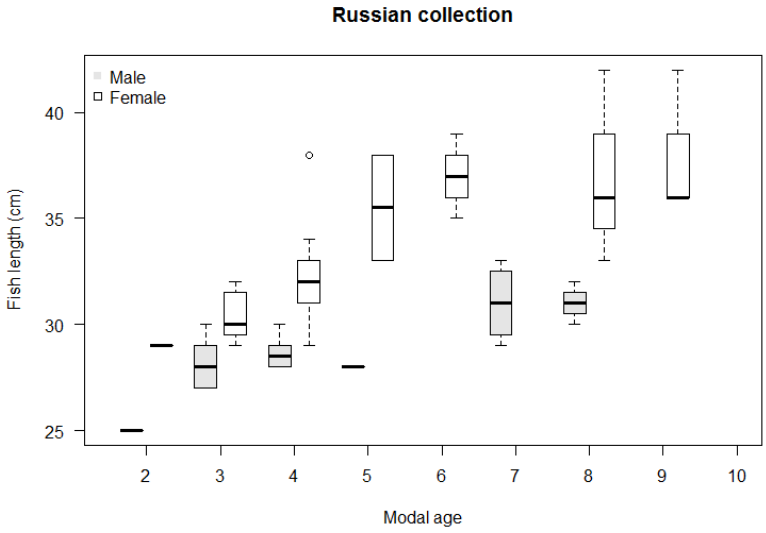


Figure 5.34. Modal age at length divided in sexes.

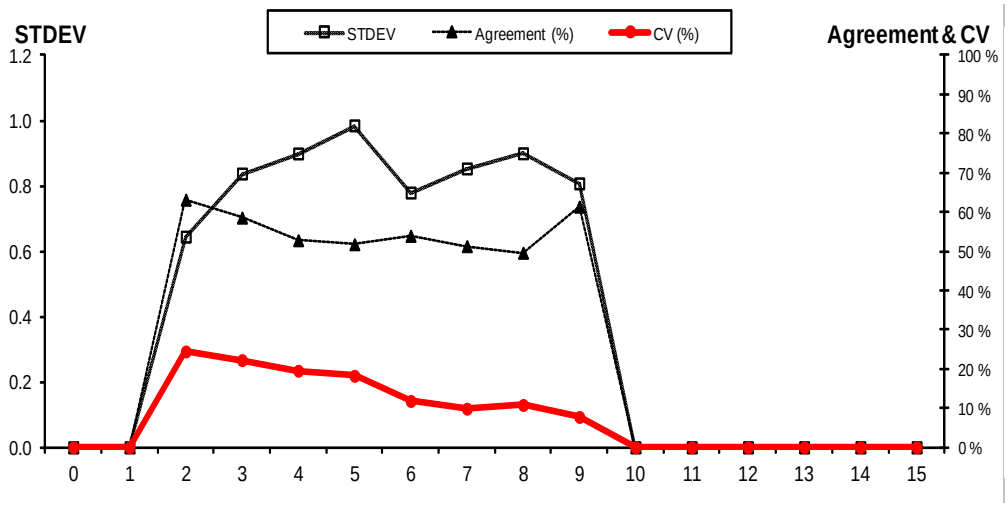


Figure 5.35. The coefficient of variation (CV %), percent agreement and the standard deviation (STDEV) are plotted against MODAL age. CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.