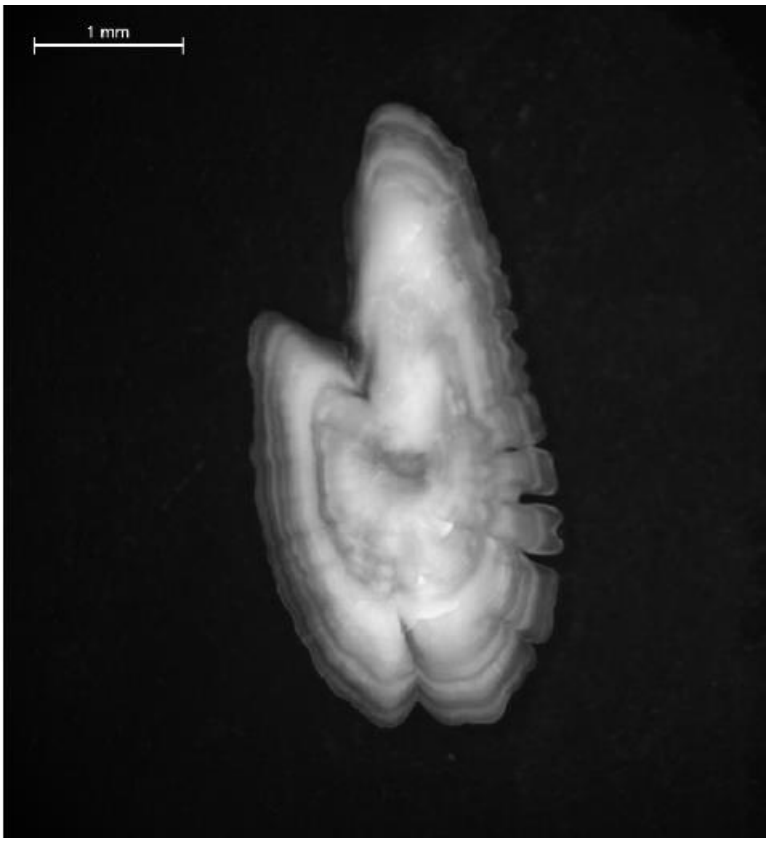
DTU Aqua
National Institute of Aquatic Resources

Report of the 2015

Herring Age Reading Exchange



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Executive Summary

The PGCCDBS (2014) proposed a full scale herring otolith exchange for the Atlantic and Baltic Seas to take place in 2015. The current exchange was initiated in 2015 and followed a small calibration exercise where only 3 institutes participated in reading otoliths from the North Sea and Irish Sea areas. It includes samples from the North Sea, Celtic Sea, Irish Sea and VIa (North and South) areas and was completed by 13 readers from 9 institutes. The aim of this combined exchange was to assess the accuracy of the age readings i.e. the proximity of the estimated ages to the modal age which is determined by an index of average percentage error (APE), percentage agreement and relative bias values, and to assess the precision i.e. the reproducibility of age estimates between readers which is determined using the coefficients of variation (CV). In addition, growth curves were compiled based on the distance data between annotations made on the otolith images hosted on the online annotation tool, WebGR. The growth curves allow for detailed examination of where the main problems with age interpretation are. Finally, Age Error Matrices were compiled for each area; these provide a measure of accuracy of the age readings and will be provided to HAWG 2016.

For the North Sea area (based on expert readers only) the overall APE is 14.8%. Bias in age estimates were found between the German and Dutch readers who are overestimating the ages in comparison to the modal age. Overall CV was 21.1 % and overall percentage agreement 73.6%.

For the Celtic Sea area (based on expert readers only) the overall APE is 14.2%. Bias in age estimates were found between the German and Dutch readers who are overestimating the ages in comparison to the modal age and to a lesser extent the Northern Ireland reader who is underestimating the ages in comparison to the modal age. Overall CV was 19.6 % and overall percentage agreement 75.2%.

For the Irish Sea area (based on expert readers only) the overall APE is 11.6%. Bias in age estimates were found between the German and Dutch readers who are overestimating the ages in comparison to the modal age and to a lesser extent the Northern Ireland reader and one reader from Norway who are underestimating the ages in comparison to the modal age. Overall CV was 16 % and overall percentage agreement 77.7%.

For the West of Scotland Sea area (based on expert readers only) the overall APE is 13.6%. Bias in age estimates were found between the German and Dutch readers and to a lesser extent two readers from Norway who are overestimating the ages in comparison to the modal age. Overall CV was 18.8 % and overall percentage agreement 69.1%.

The combined results show that 3 of the readers (2 of which are experts) are showing significant bias in their age readings. This maybe partly due to the differences which arise in age estimates when fish are aged in terms of “rings” versus “years”. The third reader is repeatedly omitting the first winter ring in the count of age. The age error matrices show that, in most cases, ages are overestimated my more than one year and this indicates that there is more than one ageing problem. The results of the growth curve analyses confirm this but annotation standardisation problems are apparent which can confound the results. Bias tests and plots give a more detailed description of reader performance.

Introduction

The PGCCDBS (2014) proposed a full scale herring otolith exchange for the Atlantic and Baltic Seas to take place in 2015. Prior to the full scale exchange taking place a small calibration exercise was initiated by Denmark's National Institute of Aquatic Resources and AFBI Northern Ireland in 2014 to test for age reading problems, this was done in preparation for HAWG 2015 and included otolith samples from areas IVa, IVb, IVc and VIIa. The level of accuracy of the participants' age readings compared to modal age is indicated by percentage agreement (%agreement), (a high value suggests good agreement). The level of precision i.e. the reproducibility of age estimates is indicated the coefficient of variation (CV), (a low value indicates a high level of reproducibility). The primary age readers from Denmark, Northern Ireland and Scotland participated. For both areas the %agreement was low and the CV high: North Sea - 78.8% agreement and CV of 15.5% and Irish Sea - 86.7% agreement and CV of 7.4%. In both cases the 2 experienced readers (Denmark and Scotland) had a high level of agreement but the inexperienced reader (Northern Ireland) was not in agreement. It was not possible to complete the growth curve analysis as not all readers annotated the images correctly. The aim of the current exercises is to expand on the 2014 exercise, both in terms of number of participants and areas covered (North Sea, Irish Sea, Celtic Sea and VIa West of Scotland) and to provide a more thorough analysis, including growth zone analysis and compilation of age error matrices for HAWG 2016. Preparations are underway for the Baltic Sea exchange.

Participants

Table 1. List of participants

Reader	Name	Country	Institute and address	e-mail	Experience
1 DNK1	Stina Bilstrup Stenersen Hansen	Denmark	DTU Aqua National Institute of Aquatic Resources, Jægersborg Alle 1, 2920 Denmark.	sb@aqua.dtu.dk	Expert
3 NOR2	Anne Liv Johnsen	Norway	Institute of Marine Research, Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	anne.liv.johnsen@imr.no	Expert
4 NOR3	Eilert Hermansen	Norway	Institute of Marine Research, Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	eilert.hermansen@imr.no	Expert
5 NOR4	Jan de Lange	Norway	Institute of Marine Research, Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	jan.de.lange@imr.no	Expert

6 NOR5	Bjãrn vidar Svendsen	Norway	Institute of Marine Research, Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	bjoern.vidar.svendsen@imr.no	Expert
8 GBR2	Louise Straker Cox	United Kingdom	CEFAS, Pakefield Road, Lowestoft, Suffolk, NR33 7QZ, UK	louise.cox@cefas.co.uk	Intermediate: 4 yrs
9 GBR3	Jane Mills	United Kingdom	Marine Scotland Science 375 Victoria Road, Aberdeen, AB11 9DB, Scotland	Jane.Mills@scotland.gsi.gov.uk	Expert
10 GBR1	Ian McCausland	United Kingdom	The Agri-Food & Biosciences Institute, AFBI 18a Newforge Lane BT9 5PX Belfast, Northern Ireland	Ian.McCausland@afbini.gov.uk	Intermediate
11 IRL1	Deirdre Lynch	Ireland	Marine Institute, Rinville, Oranmore, Co. Galway, Ireland	deirdre.lynch@marine.ie	Expert
13 NLD1	Jan Beintema	Netherlands	IMARES, PO Box 68, 1970 AB Ijmuiden, The Netherlands	jan.beintema@wur.nl	Expert
14 DEU1	Gertrud Delfs	Germany	Thünen-Institute of Sea Fisheries Palmaille 9, D- 22767 Hamburg, Germany	gertrud.delfs@ti.bund.de	Expert
15 FRA1	Jean Louis Dufour	France	IFREMER, Centre Manche-mer du Nord, Laboratoire Ressources Halieutiques 150, quai Gambetta, BP 699 62 321 Boulogne sur mer, France	Jean.Louis.Dufour@ifremer.fr	Expert
16 NOR1	Merete Kvalsund	Norway	Institute of Marine Research, Institute of Marine Research, PO Box 1870, N-5817 Bergen, Norway	merete.kvalsund@imr.no	Trainee

Samples

In the early planning phase of the exchange a discussion between the stock co-ordinators lead to the decision that the exchange sets should include only autumn and winter spawning stocks to avoid confusion with stocks which have a different birth date. It was anticipated that the exchange sets would comprise of pairs of unmounted otoliths. Many of the participating institutes mount their otoliths in histokitt or resin which can cause problems when the otoliths are being digitised. Also, in many cases only single otoliths are available. Every effort was used to include pairs of unmounted otoliths in order to optimise the quality of the exchange sets made available to the readers. The exchange consisted of 4 sets of otoliths, one for each of the following areas: North Sea, Irish Sea, Celtic Sea and VIa (N and S), with 50 images per area.

Otoliths from the North Sea (IVa and IVb) were provided by DTU Aqua (Table 2). These had not been mounted in resin or histokitt.

Table 2. Sample overview for the North Sea

North Sea	Jan '13 Q.1	Feb '13 Q.1	Jun '14 Q.2	Jul'13 Q.3	Aug '13 Q.3	Aug '14 Q.3	Sep '13 Q.3	Oct '13 Q.4	Nov '13 Q.4	Dec '13 Q.4	**Total**
IVa	3		7			4		7	2	4	**27**
IVb	4	3		2	11		1			2	**23**
Total	**7**	**3**	**7**	**2**	**11**	**4**	**1**	**7**	**2**	**6**	**50**

Otoliths from the Celtic Sea (VIIg, VIIj and VIIaS) were provided by the Marine Institute Ireland (Table 3). A large number of samples were originally chosen for the exchange. As many of these were mounted in resin on black slides they were not suitable for digitisation. All of the samples were visually inspected and the best quality otoliths were used for the exchange.

Table 3. Sample overview for the Celtic Sea

Celtic Sea	Sep '11 Q.3	Oct '11 Q.4	Oct '13 Q.4	Nov '11 Q.4	Nov '14 Q.4	Dec '11 Q.4	Dec '13 Q.4	**Total**
VIIaS				1		5	8	**14**
VIIg	10	5	2		10			**27**
VIIj		9						**9**
Total	**10**	**14**	**2**	**1**	**10**	**5**	**8**	**50**

Otoliths from the Irish Sea (VIIa) were provided by AFBI Northern Ireland (Table 4). All of the otoliths had been mounted in resin on black slides. All of the samples were visually inspected and the best quality otoliths were used for the exchange.

Table 4. Sample overview for the Irish Sea

Irish Sea	Mar '11 Q.1	Sep '06 Q.3	Sep '11 Q.3	Oct '10 Q.4	**Total**
VIIa	12	9	11	18	**50**
Total	**12**	**9**	**11**	**18**	**50**

Otoliths from the West of Scotland (VIaN and VIaS) were provided by MARLAB Scotland (Table 5). These had not been mounted in resin or histokitt.

Table 5. Sample overview for VIa (N and S)

VIa (N and S)	Feb '15 Q.1	Mar '15 Q.1	Aug '14 Q.3	Sep '14 Q.3	Nov '14 Q.4	**Total**
VIaN	6	1	6	5	7	**25**
VIaS	16				9	**25**
Total	**22**	**1**	**6**	**5**	**16**	**50**

Methods

All otolith were sent to DTU Aqua to ensure that a standard set up and magnification was used for all images. Images of whole otoliths immersed in alcohol were taken on a black background under reflected light using a Leica MZ6 stereo microscope (magnification x2), Leica DFC320 camera and the corresponding Leica Application Software V.4.5. A total of 200 otoliths (50 per area) were digitised and made available on WebGR for annotation.

Prior to the exercise a Skype meeting was held where all readers and national age reader co-ordinators were invited to attend. A demonstration of WebGR plus a demonstration of how the readers were required to annotate the images was given. Readers were also provided with written instructions and an image example of which axis to annotate. They were asked to annotate the nucleus and the start of each translucent zone and give a final estimation of age. The exercises were run as blind tests where the readers could not see the annotations of the other readers.

Four separate calibration exercises were made available on WebGR: North Sea Herring, Irish Sea Herring, Celtic Sea Herring and VIa Herring. All readers will be required to read the otoliths from all areas. Readers were provided with information on the capture date, area and total length (TL).

Analysis

Each of the 4 calibration exercises were analysed separately.

Age data:

An R script was developed which follows the traditional analyses of agreement between readers as used in the Guus Eltink spreadsheet (Eltink, A.T.G.W. 2000):

- average % Agreement (nmodal age/ntotal*100)
- coefficient of variation (CV) (Standard deviation/average*100)
- bias tests and plots

In addition an index of average percentage error (APE) was calculated based on the method outlined by Beamish & Fournier (1981). This method is not independent of fish age and thus provides a better estimate of precision. As the calculations of both CV and APE poses problems if the mean age is close to 0, all observations for which modal age was 0 were omitted from the CV and APE calculations. Inter-reader bias was tested using the Friedman rank sum test followed by a post-hoc pairwise Wilcoxon test for multiple comparisons.
Age error matrices were produced following procedures outlined by WKSABCAL (2014) where the matrix shows the proportion of each modal age mis-aged as other ages. The sum of each row is 1, equal to 100%. For each area all readers were included.

Growth data:

WebGR provides a measure of distance between the annotations made by the readers and thus provides a measure of growth increment width. The "alldistances" dataset from WebGR was used to establish growth curves for each fish and for each reader. For each set of annotations belonging to a single fish and reader, the distance between two consecutive annotations was added to the sum of the previous distances and the distances were cumulated from centre point to the outermost annotated winter ring. These growth curves were analysed using Linear Mixed Effects Models (LMEM).

For all 4 exchanges the model that best fits the data is a model with log (winter ring) and reader as fixed effects and individual images as random effects. The results show significant differences ($p < 0.05$) in the intercept of the LMEM indicating there are differences in the interpretation of the first winter ring and significant differences ($p < 0.05$) in the slope of the LMEM indicating there are differences in the interpretation of the following winter rings. A post-hoc Tukey Contrasts test for multiple pairwise comparisons followed to identify inter reader differences.

While the age data provides information on whether the age readers agree in age estimates, the growth data can identify specifically where the problems are, i.e. differences in intercept only are attributable to problems with the first winter ring, while differences in slope indicate a general inconsistency in structures used for age estimation.

Results

North Sea Exchange

Age data:

When all of the age readers are included the overall percentage agreement is 70.3% with a CV of 24.2%. Problems are already apparent at fish age 0 where the % agreement is only 77% due to three of the readers (NOR1, NLD1 and DEU1) assigning an age of 1 to these fish. NLD1 and DEU1 appear to add an extra age without making an annotation whereas NOR1 marks an extra ring at the edge. In general, the level of agreement decreases as fish age increases (Table 2a). Fish IV_35 (Fig 1a) has the highest level of agreement

at 92% with only DEU1 reading age 5 when the modal age is age 4. The lowest level of agreement is 38% where ages ranging from 8 to 13 are assigned to a fish with modal age 9. The overall CV for modal age 1 is very high at 45%, as only 6 of the 13 readers have a CV of 0. CV decreases to the lowest level of 9.3 % for modal age 5 before increasing again. When only the “expert” readers are included in these calculations the overall % agreement increases slightly to 73.6% and the CV decreases to 21.1%. The overall index of average percentage error (APE) is 17.2% and when calculated based on only the “expert” readers this improves to 14.8%.

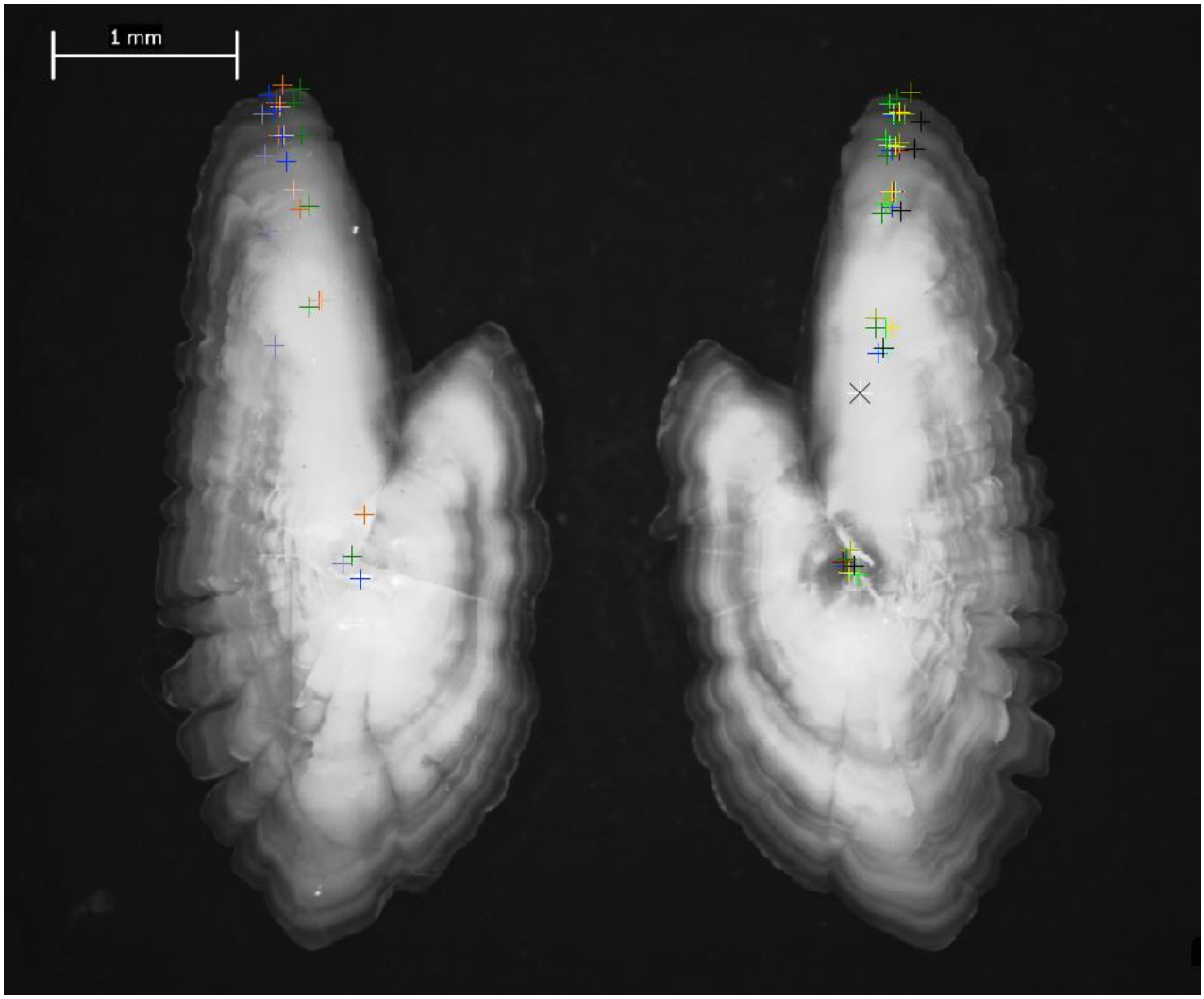

Figure 1a. Herr_IV_35. Modal age 4, capture date 04/09/2013, % agreement 92% and CV 7%

Table 1a shows the age composition based on the estimated ages for all readers. Tables 2a, 3a and 4a show the % Agreement, CV and relative bias based on modal age for all readers.

Table 1a. Age composition based on all readers in the North Sea exchange

Age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Total
0	3	3	3	3	3	3	3	3	4	2	0	3	0	**33**
1	11	8	11	11	11	9	11	11	9	4	3	9	9	**117**
2	10	10	9	8	9	11	9	7	8	6	13	11	10	**121**
3	8	10	9	7	8	10	9	3	10	17	7	9	7	**114**
4	5	4	4	7	4	5	5	12	7	3	9	5	4	**74**
5	3	5	3	4	3	4	3	7	2	5	5	2	8	**54**
6	4	3	5	4	5	2	4	2	4	6	3	5	2	**49**
7	3	4	2	2	3	2	3	2	2	4	4	3	4	**38**
8	1	1	1	3	0	0	1	1	4	1	3	0	3	**19**
9	2	1	2	1	2	3	1	0	0	1	1	3	3	**20**
10	0	0	1	0	1	0	1	1	0	0	0	0	0	**4**
11	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
12	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
13	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
All	**50**	**49**	**50**	**50**	**49**	**49**	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**646**

Table 2a. Percentage Agreement based on all readers in the North Sea exchange

Modal Age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	100	100	100	100	100	100	100	100	100	0	0	100	0	**77**
1	100	80	100	100	100	80	100	80	80	11	0	90	60	**76**
2	89	100	89	89	89	89	89	44	78	11	33	100	89	**76**
3	80	100	90	70	80	90	90	10	80	60	10	90	60	**70**
4	100	80	80	80	75	80	100	80	60	20	0	100	40	**69**
5	100	100	100	100	100	50	100	50	0	50	50	100	100	**77**
6	80	60	100	80	100	25	80	0	60	60	20	100	40	**63**
7	67	100	67	67	100	67	100	0	33	33	0	100	67	**62**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
9	67	33	67	33	67	100	33	0	0	33	33	100	67	**49**
Weighted mean	**88.1**	**85.7**	**90.1**	**82**	**89.8**	**79.6**	**90**	**41.9**	**66**	**30.5**	**13.9**	**96**	**60.1**	**70.3**

Table 3a. Coefficient of Variation (CV) for all readers in the North Sea exchange

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_D EU 1	15_ FRA 1	16_ NOR 1	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	0	35	0	0	0	35	0	35	47	49	0	29	73	**45**
2	18	0	18	18	18	18	18	41	25	12	19	0	43	**24.1**
3	15	0	11	15	16	11	11	27	13	42	8	11	23	**20.8**
4	0	11	11	11	12	12	0	37	34	31	9	0	38	**19.1**
5	0	0	0	0	0	16	0	16	0	13	13	0	0	**9.3**
6	8	10	0	8	0	10	8	45	10	9	7	0	12	**14.3**
7	8	0	8	8	0	9	0	11	14	17	0	0	8	**11.3**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
9	14	13	6	7	6	0	11	33	0	20	18	0	7	**13.9**
Weighted Mean	**8.4**	**10.1**	**7.4**	**9**	**7.9**	**15.9**	**6.9**	**31.3**	**21.7**	**26.7**	**8.2**	**8**	**32.8**	**24.2**

Table 4a. Relative Bias values for all readers in the North Sea (red values indicate negative values and black indicated positive values)

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	0	0	0	0	0	0	0	0	0	1	1	0	1	**0.23**
1	0	0.2	0	0	0	0.2	0	0.2	0	0.89	1	0.1	0.8	**0.26**
2	-0.11	0	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	0	0.89	0.67	0	0.33	**0.09**
3	-0.2	0	-0.1	0.3	0	-0.1	-0.1	1.1	0.2	0.1	0.9	-0.1	0.6	**0.2**
4	0	0.2	0.2	0.2	0.25	-0.2	0	0.8	0.4	0.8	1.2	0	1.4	**0.4**
5	0	0	0	0	0	-0.5	0	-0.5	-1	0.5	0.5	0	0	**-0.08**
6	-0.2	-0.4	0	-0.2	0	-0.75	-0.2	-0.4	-0.4	0.4	0.8	0	0.8	**-0.04**
7	0.33	0	0.33	0.33	0	-0.33	0	-1.67	0	-1	1	0	0.33	**-0.05**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
9	-0.67	-1	0.33	-0.67	0.33	0	0	-0.33	-1	-1.33	2	0	-0.33	**-0.21**
Weighted Mean	**-0.1**	**-0.04**	**0.02**	**0.02**	**0.02**	**-0.12**	**-0.06**	**0.14**	**-0.06**	**0.41**	**0.96**	**0**	**0.62**	**0.14**

Significant bias in age estimates was found between readers (Friedman rank sum test, $p < 0.05$ and Wilcoxon paired test, $p < 0.05$). Table 5a shows the results of the Inter reader and reader against modal age bias tests and indicates that there is bias between readers NLD1, DEU1 and NOR1 and all of the other readers and also with modal age. These results are confirmed by the high positive values of relative bias for these readers (Table 4a), indicating that these readers are generally over estimating the ages in comparison

to the modal age. The age bias plots in Annex 1 confirm these results. The general trend seen in the relative bias values (Table 4a) is for the ages to be overestimated as opposed to underestimated in comparison to modal age, which is also apparent in the age error matrix in Table 6a.

Table 5a. Inter reader bias test for all readers in the North Sea exchange. "-" = no sign of bias (p>0.05); "*" = possibility of bias (0.01<p<0.05) and "* *" = certainty of bias (p<0.01).

	1_ DNK1	**3_ NOR2**	**4_ NOR3**	**5_ NOR4**	**6_ NOR5**	**8_ GBR2**	**9_ GBR3**	**10_ GBR1**	**11_ IRL1**	**13_ NLD1**	**14_ DEU1**	**15_ FRA1**	**16_ NOR1**
1_ DNK1	NA	-	*	-	-	-	-	-	-	**	**	-	**
3_ NOR2	-	NA	-	-	-	-	-	-	-	**	**	-	**
4_ NOR3	*	-	NA	-	-	-	-	-	-	*	**	-	**
5_ NOR4	-	-	-	NA	-	-	-	-	-	*	**	-	**
6_ NOR5	-	-	-	-	NA	-	-	-	-	*	**	-	**
8_ GBR2	-	-	-	-	-	NA	-	-	-	**	**	-	**
9_ GBR3	-	-	-	-	-	-	NA	-	-	**	**	-	**
10_ GBR1	-	-	-	-	-	-	-	NA	-	-	**	-	*
11_ IRL1	-	-	-	-	-	-	-	-	NA	*	**	-	**
13_ NLD1	**	**	*	*	*	**	**	-	*	NA	**	*	-
14_ DEU1	**	**	**	**	**	**	**	**	**	**	NA	**	*
15_ FRA1	-	-	-	-	-	-	-	-	-	*	**	NA	**
16_ NOR1	**	**	**	**	**	**	**	*	**	-	*	**	NA
modal Age	-	-	-	-	-	-	-	-	-	*	**	-	**

Table 6a. Age Error matrix based on all "expert" readers in the North Sea exchange shows the proportion of each modal age estimated correctly (in bold) and mis-aged as other ages (underestimated in red and overestimated in blue).

	Modal Age									
Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	**0.8**	0.02	0	0.01	0	0	0	0	0	0
1	0.2	**0.77**	0.07	0	0	0	0	0	0	0
2	0	0.19	**0.76**	0.06	0	0	0	0	0	0
3	0	0.02	0.17	**0.75**	0.04	0	0	0	0	0
4	0	0	0	0.17	**0.69**	0.1	0	0	0	0
5	0	0	0	0.01	0.2	**0.8**	0.14	0.03	0	0
6	0	0	0	0	0.02	0.1	**0.74**	0.07	0	0.03
7	0	0	0	0	0.04	0	0.12	**0.67**	0	0.07
8	0	0	0	0	0	0	0	0.23	**0**	0.27
9	0	0	0	0	0	0	0	0	0	**0.47**
10	0	0	0	0	0	0	0	0	0	0.1
11	0	0	0	0	0	0	0	0	0	0.03
13	0	0	0	0	0	0	0	0	0	0.03

Growth data:

Figure 2a shows the combined growth curves for all fish and all readers in the North Sea exchange. FRA1 omitted to mark the centre point on every image and therefor his average growth curve falls below all of the others. He was omitted from the analysis. The Linear Mixed Effects Model analysis showed a significant reader effect on both the intercept and slope of the LMEM (LMEM, $p < 0.05$) meaning that there are differences between readers. The post-hoc analysis revealed that GBR1, NDL1, NOR1 and NOR4 stand out from the other readers (just significant) and thus what they are interpreting to be the winter rings differ slightly from the rest of the group. The overlap between GBR1 winter ring 1 and winter ring 2 of the other readers indicates that what he interprets as the first winter ring is in fact the second winter ring. Despite this he still attains a higher overall age.

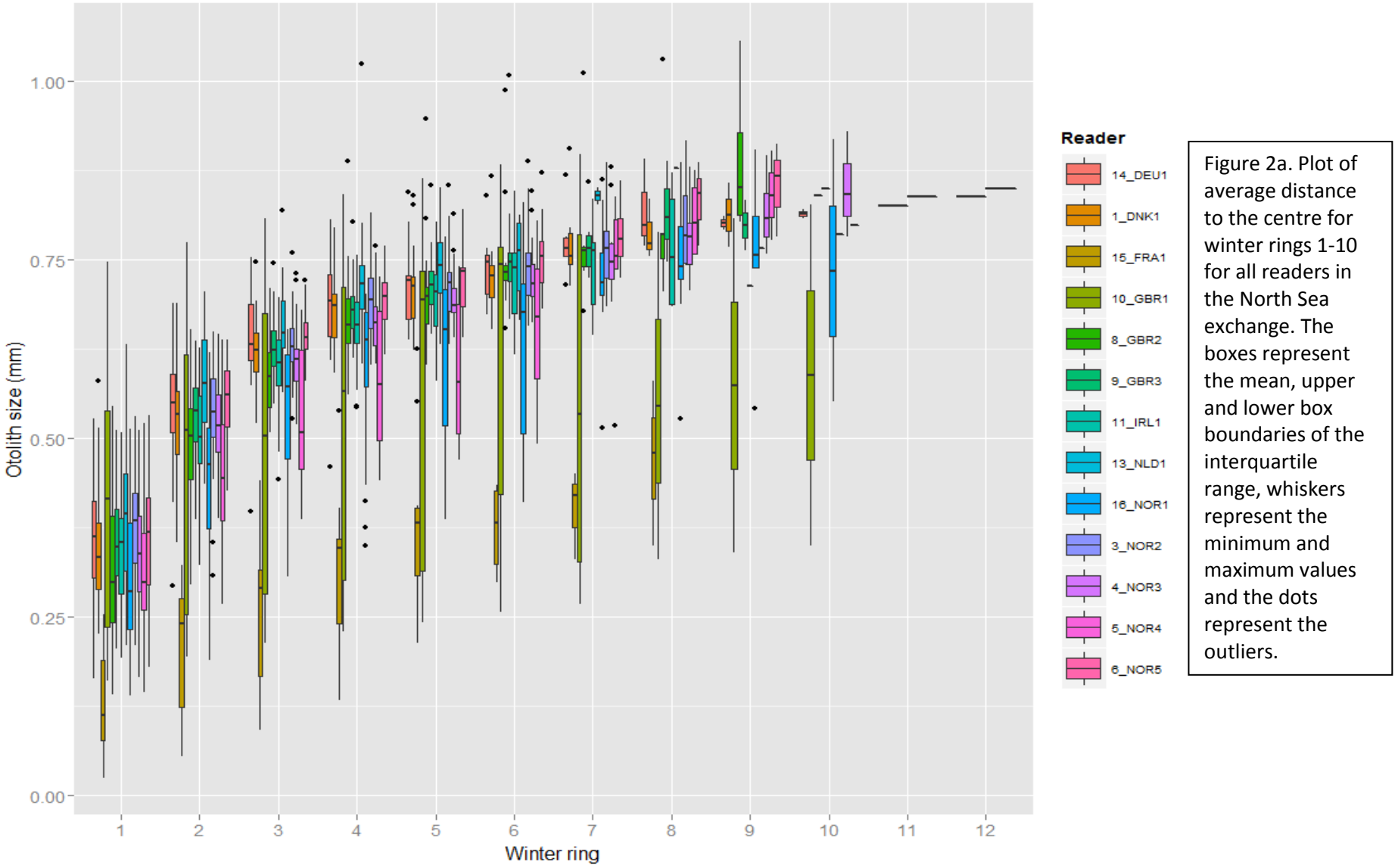

Figure 2a. Plot of average distance to the centre for winter rings 1-10 for all readers in the North Sea exchange. The boxes represent the mean, upper and lower box boundaries of the interquartile range, whiskers represent the minimum and maximum values and the dots represent the outliers.

Celtic Sea Exchange

Age data:

When all of the age readers are included the overall percentage agreement is 73.8% with a CV of 19.8%. For ages 0-4 the average agreement is above 75% with a general decrease in agreement with an increase in age. The CV for modal age 1 is high at 45.4%. NLD1 is overestimating the age by 2 years in most cases and DEU1 overestimating by 1 year in most cases (Figure 1b). This trend continues with the older fish and is confirmed by the relative bias values (Table 4.b) which also shows GBR1 and IRL1 to have a strong negative bias values indicating underestimation of ages in comparison to modal age. CV decreases to a low of 9.1% at modal age 7 but increases slightly again. When only the "expert" readers are included the % agreement increases slightly to 75.2% while the CV improves slightly to 19.6%. The overall index of average percentage error (APE) is 13.5% which when calculated on only the "expert" readers increases to 14.2%.

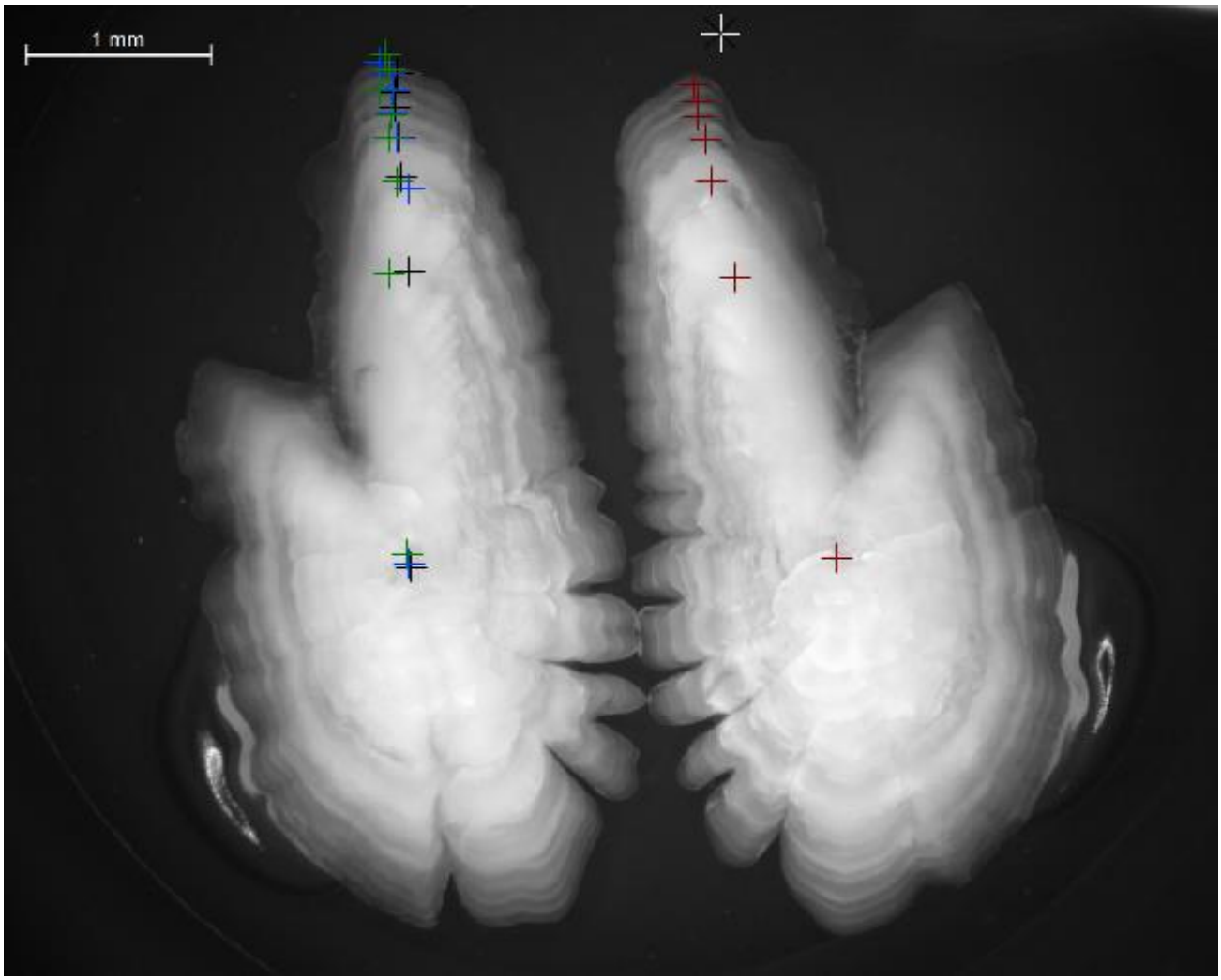

Figure 1b. Herr_VII_39, capture date 02/12/2013, modal age 6, % agreement 77% and CV 11%. Readers GBR1 (blue), NOR5 (black), DEU1 (red) and NLD1 (green) assigning ages 5, 6, 7 and 8 years respectively.

Table 1b shows the age composition based on the estimated ages for all readers. Tables 2b, 3b and 4b show the % Agreement, CV and relative bias based on modal age for all readers.

Table 1b. Age composition based on all readers in the Celtic Sea exchange

Age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Total
1	4	4	4	4	4	4	4	8	4	0	0	4	4	**48**
2	12	10	12	12	12	12	12	8	12	1	4	12	12	**131**
3	12	13	12	12	13	13	12	13	11	6	12	12	7	**148**
4	7	7	7	8	6	6	7	6	9	15	11	7	11	**107**
5	3	6	4	4	4	6	3	10	6	11	8	4	5	**74**
6	6	5	5	6	7	3	8	1	7	10	3	7	7	**75**
7	4	3	4	3	2	4	2	3	0	4	6	2	3	**40**
8	1	0	1	0	1	1	1	1	1	2	3	1	0	**13**
9	1	0	0	0	0	0	0	0	0	1	1	0	0	**3**
10	0	1	1	1	1	1	1	0	0	0	1	1	0	**8**
11	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
12	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
All	**50**	**49**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**649**

Table 2b. Percentage Agreement based on all readers in the Celtic Sea exchange

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	100	100	100	100	100	100	100	100	100	0	0	100	0	**83**
1	100	80	100	100	100	80	100	80	80	11	0	90	60	**79**
2	89	100	89	89	89	89	89	44	78	11	33	100	89	**77**
3	80	100	90	70	80	90	90	10	80	60	10	90	60	**75**
4	100	80	80	80	75	80	100	80	60	20	0	100	40	**75**
5	100	100	100	100	100	50	100	50	0	50	50	100	100	**60**
6	80	60	100	80	100	25	80	0	60	60	20	100	40	**69**
7	67	100	67	67	100	67	100	0	33	33	0	100	67	**54**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
9	67	33	67	33	67	100	33	0	0	33	33	100	67	**54**
10	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Weighted mean	**92.4**	**90.9**	**93**	**88.8**	**91.9**	**78.9**	**93.8**	**52.6**	**65**	**26**	**17.8**	**96.2**	**65.6**	**73.8**

Table 3b. Coefficient of Variation (CV) based on all readers in the Celtic Sea exchange

Modal Age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	0	0	0	0	0	0	0	40	0	18	0	0	0	**45.4**
2	0	14	0	0	0	0	0	46	0	12	0	0	0	**26.9**
3	0	0	0	0	0	0	0	22	9	12	7	0	19	**17.4**
4	0	0	0	0	10	10	0	32	0	10	0	0	10	**14.9**
5	10	0	0	0	0	0	10	11	11	8	8	0	10	**10.6**
6	8	9	8	17	0	14	6	12	10	15	7	0	10	**11.6**
7	0	0	0	11	0	0	11	0	0	11	8	0	11	**9.1**
8	0	0	0	0	0	0	0	0	0	0	0	0	0	**14.1**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
10	0	0	0	0	0	0	0	0	0	0	0	0	0	**13.8**
Weighted Mean	**1.9**	**4.4**	**1.1**	**2.8**	**1.4**	**3.4**	**2.1**	**26.6**	**4.4**	**11.8**	**3.6**	**0**	**8.6**	**19.8**

Table 4b. Relative Bias based on all readers in the Celtic Sea exchange (red values indicate negative values and black indicated positive values)

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	0	0	0	0	0	0	0	0.25	0	1.75	1	0	0	**0.23**
2	0	0.09	0	0	0	0	0	-0.17	0	1.75	1	0	0	**0.21**
3	0	0	0	0	0	0	0	0.08	0.08	1.5	1.08	0	0.58	**0.26**
4	0	0	0	0	-0.14	-0.14	0	-0.43	0	1.43	1	0	-0.14	**0.12**
5	0.25	0	0	0	0	0	0.25	-0.25	-0.25	1.25	1.25	0	0.25	**0.21**
6	0.29	-0.29	0.29	0	0	0	0.14	-1	-0.43	0.43	1.29	0	0	**0.05**
7	0	0	0	-0.5	0	0	-0.5	0	-1	-0.5	1.5	0	-0.5	**-0.12**
8	0	-1	0	-2	0	0	0	0	-2	1	2	0	-1	**-0.23**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
10	-1	0	0	0	0	0	0	-3	-2	-2	2	0	1	**-0.38**
Weighted Mean	**0.04**	**-0.04**	**0.04**	**-0.06**	**-0.02**	**-0.02**	**0.02**	**-0.28**	**-0.18**	**1.24**	**1.14**	**0**	**0.12**	**0.15**

Significant bias in age estimates was found between readers (Friedman rank sum test, $p < 0.05$ and Wilcoxon paired test, $p < 0.05$). Table 5b shows the results of the Inter reader and reader against modal age bias tests and indicates that there is a certainty of bias between NLD1 and DEU1 against the other readers

and modal age. There is also a possibility of bias between GBR1, FRA1 and NOR1 and some of the readers but not against modal age. IRL1 shows some possible bias with some of the readers and with modal age. These results are confirmed by the relative bias values in Table 4.b and the age bias plots in Annex 2. The general trend seen in the relative bias values (Table 4b) is for the ages to be overestimated as opposed to underestimated in comparison to modal age, which is also apparent in the age error matrix in Table 6b.

Table 5b. Inter reader bias test for all readers in the Celtic Sea exchange where "-" = no sign of bias ($p>0.05$); "*" = possibility of bias ($0.01<p<0.05$) and "* *" = certainty of bias ($p<0.01$).

	1_ DNK1	**3_ NOR2**	**4_ NOR3**	**5_ NOR4**	**6_ NOR5**	**8_ GBR2**	**9_ GBR3**	**10_ GBR1**	**11_ IRL1**	**13_ NLD1**	**14_ DEU1**	**15_ FRA1**	**16_ NOR1**
1_ DNK1	NA	-	-	-	-	-	-	*	**	**	**	-	-
3_ NOR2	-	NA	-	-	-	-	-	-	*	**	**	-	-
4_ NOR3	-	-	NA	-	-	-	-	*	*	**	**	-	-
5_ NOR4	-	-	-	NA	-	-	-	-	-	**	**	-	*
6_ NOR5	-	-	-	-	NA	-	-	-	-	**	**	-	-
8_ GBR2	-	-	-	-	-	NA	-	-	-	**	**	-	-
9_ GBR3	-	-	-	-	-	-	NA	*	*	**	**	-	-
10_ GBR1	*	-	*	-	-	-	*	NA	-	**	**	-	*
11_ IRL1	**	*	*	-	-	-	*	-	NA	**	**	*	**
13_ NLD1	**	**	**	**	**	**	**	**	**	NA	-	**	**
14_ DEU1	**	**	**	**	**	**	**	**	**	-	NA	**	**
15_ FRA1	-	-	-	-	-	-	-	-	*	**	**	NA	-
16_ NOR1	-	-	-	*	-	-	-	*	**	**	**	-	NA
Modal Age	-	-	-	-	-	-	-	-	*	**	**	-	-

Table 6b. Age Error matrix based on all "expert" readers in the Celtic Sea exchange shows the proportion of each modal age estimated correctly (in bold) and mis-aged as other ages (underestimated in red and overestimated in blue).

	Modal Age									
Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**0.8**	0	0	0	0	0	0	0	0	0
2	0.12	**0.79**	0	0	0	0	0	0	0	0
3	0.08	0.13	**0.79**	0.01	0	0	0	0	0	0
4	0	0.08	0.15	**0.79**	0.02	0.01	0	0	0	0
5	0	0	0.06	0.16	**0.72**	0.09	0	0	0	0
6	0	0	0	0.04	0.2	**0.66**	0.25	0.2	0	0
7	0	0	0	0	0.05	0.2	**0.65**	0.1	0	0
8	0	0	0	0	0	0.04	0.05	**0.5**	0	0.2
9	0	0	0	0	0	0	0.05	0.1	**0**	0.1
10	0	0	0	0	0	0	0	0.1	0	**0.6**
12	0	0	0	0	0	0	0	0	0	0.1

Growth data:

Figure 2b shows the combined growth curves for all fish and all readers in the Celtic Sea exchange. FRA1 omitted to mark the centre point on every image and therefor his average growth curve falls below all of the others. He was omitted from the analysis. The Linear Mixed Effects Model analysis showed a significant reader effect on both the intercept and slope of the LMEM (LMEM, $p < 0.05$) meaning that there are differences between readers. The same results are seen as with the North Sea exchange where the post-hoc analysis revealed that GBR1, NDL1, NOR1 and NOR4 stand out from the other readers (just significant) and thus what they are interpreting to be the winter rings differ slightly from the rest of the group. This is most obvious for GBR1 as what he interprets to be winter ring 1 is in fact winter ring 2 (Figure 1b).

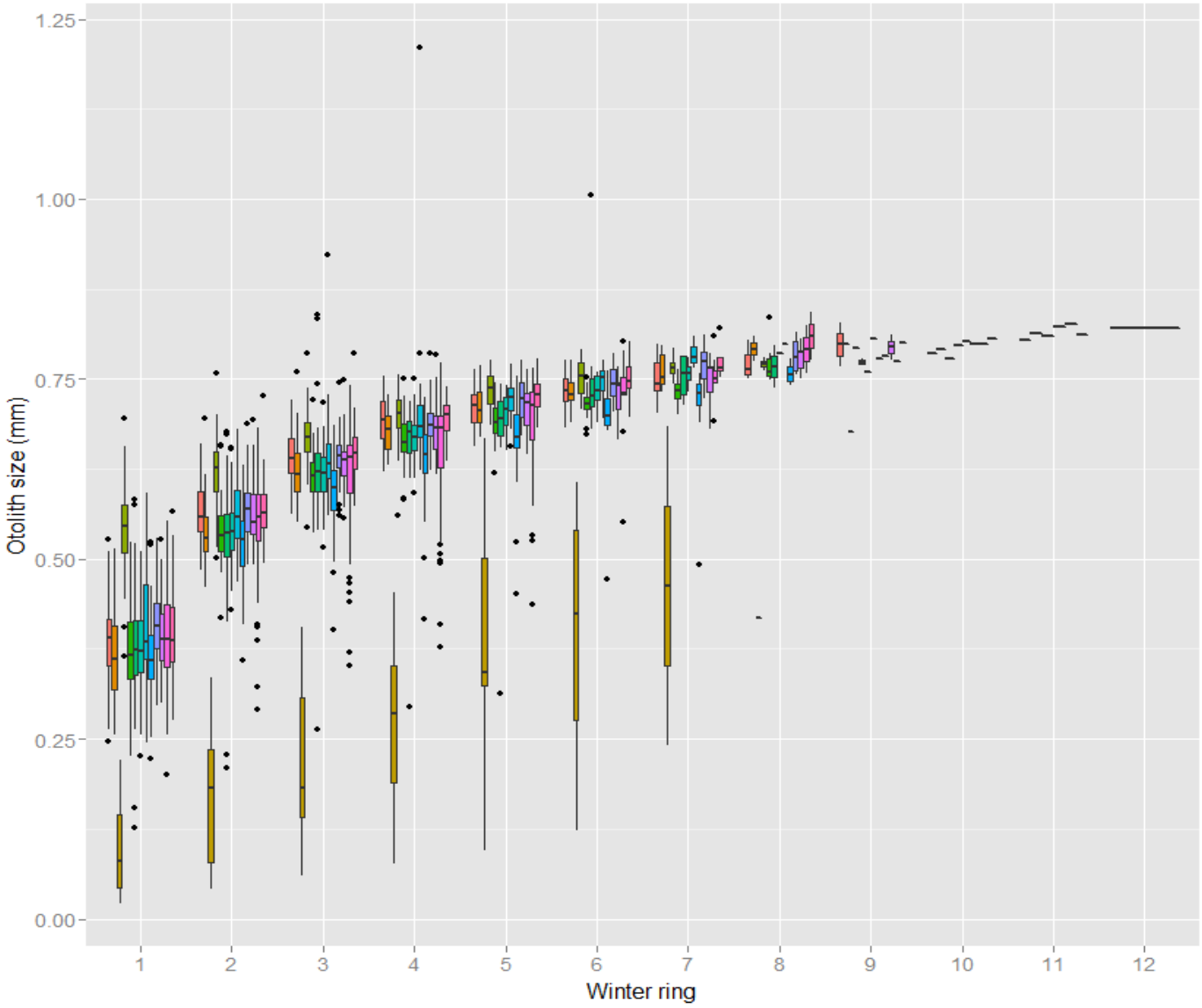

Figure 2b Plot of average distance to the centre for winter rings 1-9 for all readers in the Celtic Sea exchange. The boxes represent the mean, upper and lower box boundaries of the interquartile range, whiskers represent the minimum and maximum values and the dots represent the outliers.

Irish Sea Exchange

Age data:

When all of the age readers are included the overall percentage agreement is 76.9% with a CV of 16.6%. For modal ages 1 and 2 the % agreement is high at 84% and 80% respectively but decreases with an increase in fish age. The % agreement would be higher at these low ages if NLD1 and DEU1 were not overestimating the ages (both have 0% agreement at ages 1, 2 and 3). This trend continues with the older fish and is confirmed by the positive relative bias values in Table 4c which also show GBR1 to have a strong overall negative bias. At modal ages 1 and 2 CV is high at 32.7 and 20% respectively. This gradually decreases to a low of 10.1% at modal age 6 before increasing again. When only the "expert" readers are included the % agreement only improves slightly to 77.7% while the CV decreases to 16%. The overall index of average percentage error (APE) is 11% and when calculated based on only the "expert" readers is 11.6%.

Table 1c shows the age composition based on the estimated ages for all readers. Tables 2c, 3c and 4c show the % Agreement, CV and relative bias based on modal age for all readers.

Table 1c. Age composition for all readers in the Irish Sea exchange

Age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Total
1	6	6	6	6	6	6	6	8	6	0	0	6	7	**69**
2	10	11	11	11	11	10	11	14	11	6	5	11	10	**132**
3	11	11	9	9	9	10	9	7	10	11	11	9	10	**126**
4	13	12	13	13	13	13	13	11	12	10	10	13	13	**159**
5	3	7	4	4	4	4	3	4	7	11	12	4	2	**69**
6	5	2	5	4	5	5	5	3	4	7	5	5	4	**59**
7	0	1	0	1	0	1	0	3	0	4	4	1	2	**17**
8	2	0	2	2	2	1	2	0	0	1	0	1	1	**14**
9	0	0	0	0	0	0	0	0	0	0	2	0	1	**3**
All	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**49**	**50**	**50**	**648**

Table 2c. Percentage agreement based on modal age for all readers in the Irish Sea exchange

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	100	100	100	100	100	100	100	83	100	0	0	100	100	**84**
2	91	100	100	100	100	91	100	73	100	0	0	100	91	**80**
3	100	100	100	100	100	100	100	22	100	0	0	100	100	**79**
4	92	85	100	100	100	92	100	46	92	15	8	100	92	**79**
5	75	75	100	100	100	75	100	25	100	25	0	100	25	**69**
6	100	20	100	80	100	100	100	40	40	40	20	100	60	**69**
7	0	0	0	0	0	100	0	100	0	100	0	100	100	**38**

8	100	0	100	100	100	100	100	0	0	100	0	100	0	**62**
Weighted mean	**91.9**	**82.1**	**98**	**96**	**98**	**93.9**	**98**	**49.9**	**87.9**	**13.9**	**4.2**	**100**	**83.9**	**76.9**

Table 3c. CV based on modal age for all readers in the Irish Sea exchange

Modal age	**1_ DNK 1**	**3_ NOR 2**	**4_ NOR 3**	**5_ NOR 4**	**6_ NOR 5**	**8_ GBR 2**	**9_ GBR 3**	**10_ GBR 1**	**11_ IRL 1**	**13_ NLD 1**	**14_ DEU 1**	**15_ FRA 1**	**16_ NOR 1**	**All**
0	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	0	0	0	0	0	0	0	35	0	0	0	0	0	**32.7**
2	14	0	0	0	0	14	0	27	0	0	0	0	16	**20**
3	0	0	0	0	0	0	0	32	0	8	0	0	0	**15.2**
4	7	10	0	0	0	7	0	23	7	12	6	0	7	**12.1**
5	11	11	0	0	0	11	0	12	0	9	0	0	23	**11.7**
6	0	9	0	7	0	0	0	14	10	8	7	0	18	**10.1**
7	0	0	0	0	0	0	0	0	0	0	0	0	0	**11.8**
8	0	0	0	0	0	0	0	0	0	0	0	0	0	**10.2**
Weighted mean	**5.8**	**4.4**	**0**	**0.7**	**0**	**5.8**	**0**	**24.2**	**2.8**	**6.1**	**2.3**	**0**	**9**	**16.6**

Table 4c. Relative Bias based on modal age for all readers in the Irish Sea exchange (red values indicate negative values and black indicated positive values)

Modal age	**1_ DNK 1**	**3_ NOR 2**	**4_ NOR 3**	**5_ NOR 4**	**6_ NOR 5**	**8_ GBR 2**	**9_ GBR 3**	**10_ GBR 1**	**11_ IRL 1**	**13_ NLD 1**	**14_ DEU 1**	**15_ FRA 1**	**16_ NOR 1**	**All**
0	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
1	0	0	0	0	0	0	0	0.17	0	1	1	0	0	**0.17**
2	0.09	0	0	0	0	0.09	0	-0.27	0	1	1	0	-0.09	**0.14**
3	0	0	0	0	0	0	0	-0.33	0	1.11	1	0	0	**0.14**
4	-0.08	-0.15	0	0	0	0.08	0	-0.15	-0.08	1	0.92	0	-0.08	**0.11**
5	-0.25	-0.25	0	0	0	-0.25	0	-0.75	0	0.75	1	0	0.5	**0.06**
6	0	-0.8	0	0.2	0	0	0	-0.2	-0.6	0.6	0.8	0	0.2	**0.02**
7	1	-1	1	1	1	0	1	0	-1	0	2	0	0	**0.38**
8	0	-1	0	0	0	0	0	-1	-2	0	1	0	1	**-0.15**
Weighted mean	**0**	**-0.18**	**0.02**	**0.04**	**0.02**	**0.02**	**0.02**	**-0.24**	**-0.14**	**0.92**	**0.98**	**0**	**0.04**	**0.12**

Significant bias in age estimates was found between readers (Friedman rank sum test, $p < 0.05$ and Wilcoxon paired test, $p < 0.05$). Table 5c shows the results of the Inter reader and reader against modal age bias tests and indicates that there is a certainty of bias between NLD1 and DEU1 against the other readers and modal age. NOR2 also shows certainty of bias against modal age and a possibility of bias against some

of the other readers. There is a possibility of bias between GBR1 and IRL1 and some of the other readers and also modal age. These results are confirmed by the relative bias values in Table 4c and the age bias plots in Annex 3. The general trend seen in the relative bias values (Table 4c) is for the ages to be overestimated as opposed to underestimated in comparison to modal age, which is also apparent in the age error matrix in Table 6c.

Table 5c. Inter reader bias test for all readers in the Irish Sea exchange. "-" = no sign of bias (p>0.05); "*" = possibility of bias (0.01<p<0.05) and "* *" = certainty of bias (p<0.01).

	1_ DNK1	**3_ NOR2**	**4_ NOR3**	**5_ NOR4**	**6_ NOR5**	**8_ GBR2**	**9_ GBR3**	**10_ GBR1**	**11_ IRL1**	**13_ NLD1**	**14_ DEU1**	**15_ FRA1**	**16_ NOR1**
1_ DNK1	NA	*	-	-	-	-	-	*	-	**	**	-	-
3_ NOR2	*	NA	**	**	**	*	**	-	-	**	**	**	*
4_ NOR3	-	**	NA	-	-	-	-	*	*	**	**	-	-
5_ NOR4	-	**	-	NA	-	-	-	*	*	**	**	-	-
6_ NOR5	-	**	-	-	NA	-	-	*	*	**	**	-	-
8_ GBR2	-	*	-	-	-	NA	-	*	*	**	**	-	-
9_ GBR3	-	**	-	-	-	-	NA	*	*	**	**	-	-
10_ GBR1	*	-	*	*	*	*	*	NA	-	**	**	*	*
11_ IRL1	-	-	*	*	*	*	*	-	NA	**	**	*	-
13_ NLD1	**	**	**	**	**	**	**	**	**	NA	-	**	**
14_ DEU1	**	**	**	**	**	**	**	**	**	-	NA	**	**
15_ FRA1	-	**	-	-	-	-	-	*	*	**	**	NA	-
16_ NOR1	-	*	-	-	-	-	-	*	-	**	**	-	NA
Modal age	-	**	-	-	-	-	-	*	*	**	**	-	-

Table 6c. Age Error matrix based on all "expert" readers in the Irish Sea exchange shows the proportion of each modal age estimated correctly (in bold) and mis-aged as other ages (underestimated in red and overestimated in blue).

	Modal Age							
Age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	**0.81**	0	0	0	0	0	0	0
2	0.19	**0.79**	0	0	0	0	0	0
3	0	0.21	**0.8**	0.03	0	0	0	0
4	0	0	0.19	**0.79**	0.05	0	0	0
5	0	0	0.01	0.16	**0.77**	0.14	0	0
6	0	0	0	0.02	0.18	**0.7**	0.2	0.1
7	0	0	0	0	0	0.16	**0.2**	0.1
8	0	0	0	0	0	0	0.5	**0.7**
9	0	0	0	0	0	0	0.1	0.1

Growth data:

Figure 3a shows the combined growth curves for all fish and all readers in the Irish Sea exchange. FRA1 omitted to mark the centre point on every image and therefor his average growth curve falls below all of the others. He was omitted from the analysis. The Linear Mixed Effects Model analysis showed a significant reader effect on both the intercept and slope of the LMEM (LMEM, $p < 0.05$) meaning that there are differences between readers. The results are more varied this time and the post-hoc analysis revealed more significant differences between the readers. NOR2, NOR3, NOR4 and NOR5 annotations are similar while the rest of the group appear to be annotating the images somewhat differently.

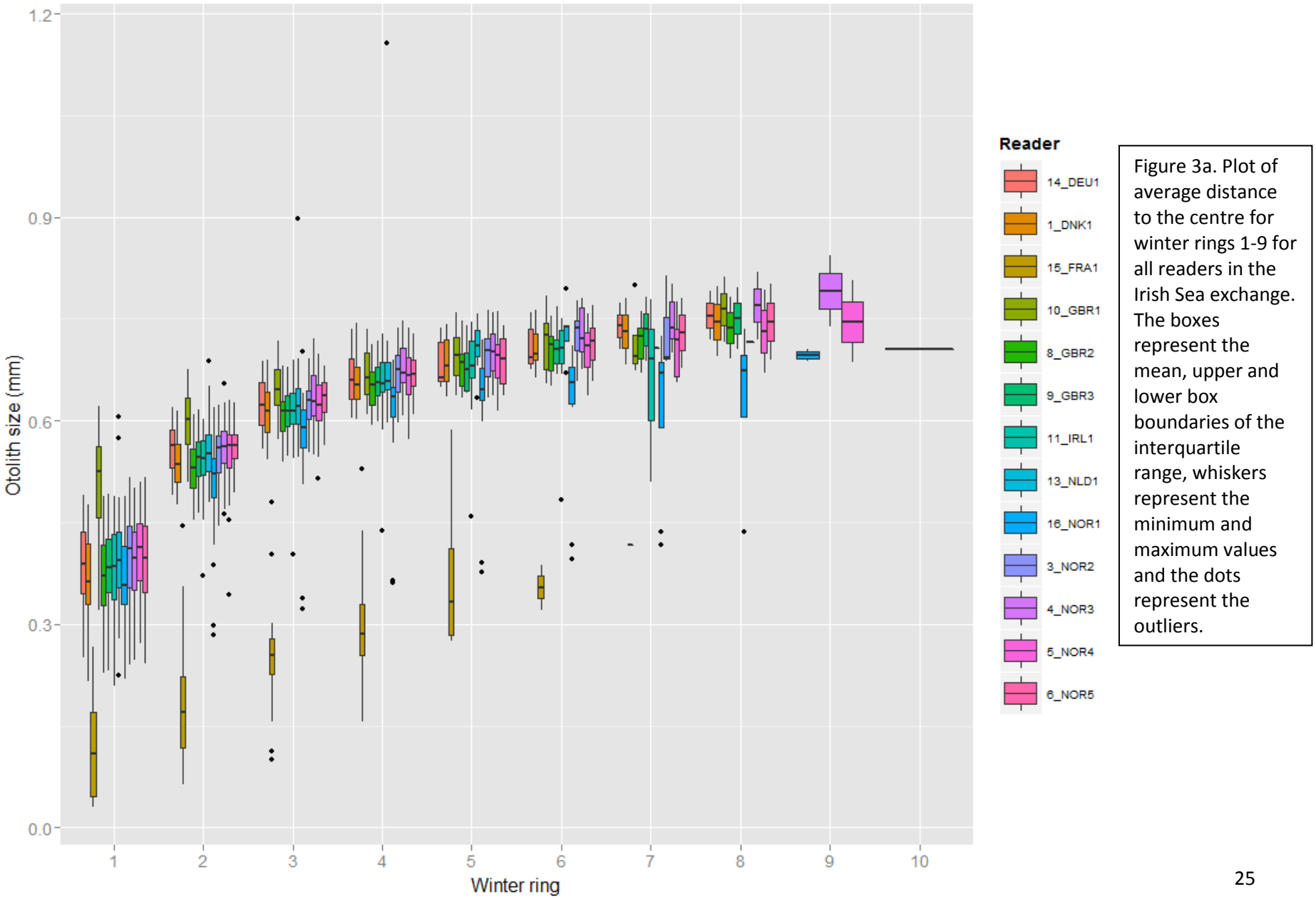

Figure 3a. Plot of average distance to the centre for winter rings 1-9 for all readers in the Irish Sea exchange. The boxes represent the mean, upper and lower box boundaries of the interquartile range, whiskers represent the minimum and maximum values and the dots represent the outliers.

VIa (N and S) Exchange

Age data:

When all of the age readers are included the overall percentage agreement is 66.8% with a CV of 20%. For modal ages 0-3 the % agreement is above 70% with a general decrease seen with an increase in fish age. Figure 4a shows fish VIa_37, modal age 1, % agreement of 69% and CV of 58%. For modal age 1 the average CV is very high at 48.5%, this is partly due to general mis interpretation of the structures combined with a routine overestimation of these young fish by NLD1 and DEU1. This trend continues with the older fish and is shown by the strong positive bias values (Table 4d) for these 2 readers. The CV decreases to a low of 11.4% at age 5 before increasing slightly again. When only the "expert" readers are included the % agreement increases to 69.1% and the CV improves to 18.8%. The overall index of average percentage error (APE) is 13.8% and when calculated based only on the "expert" readers is 13.6%.

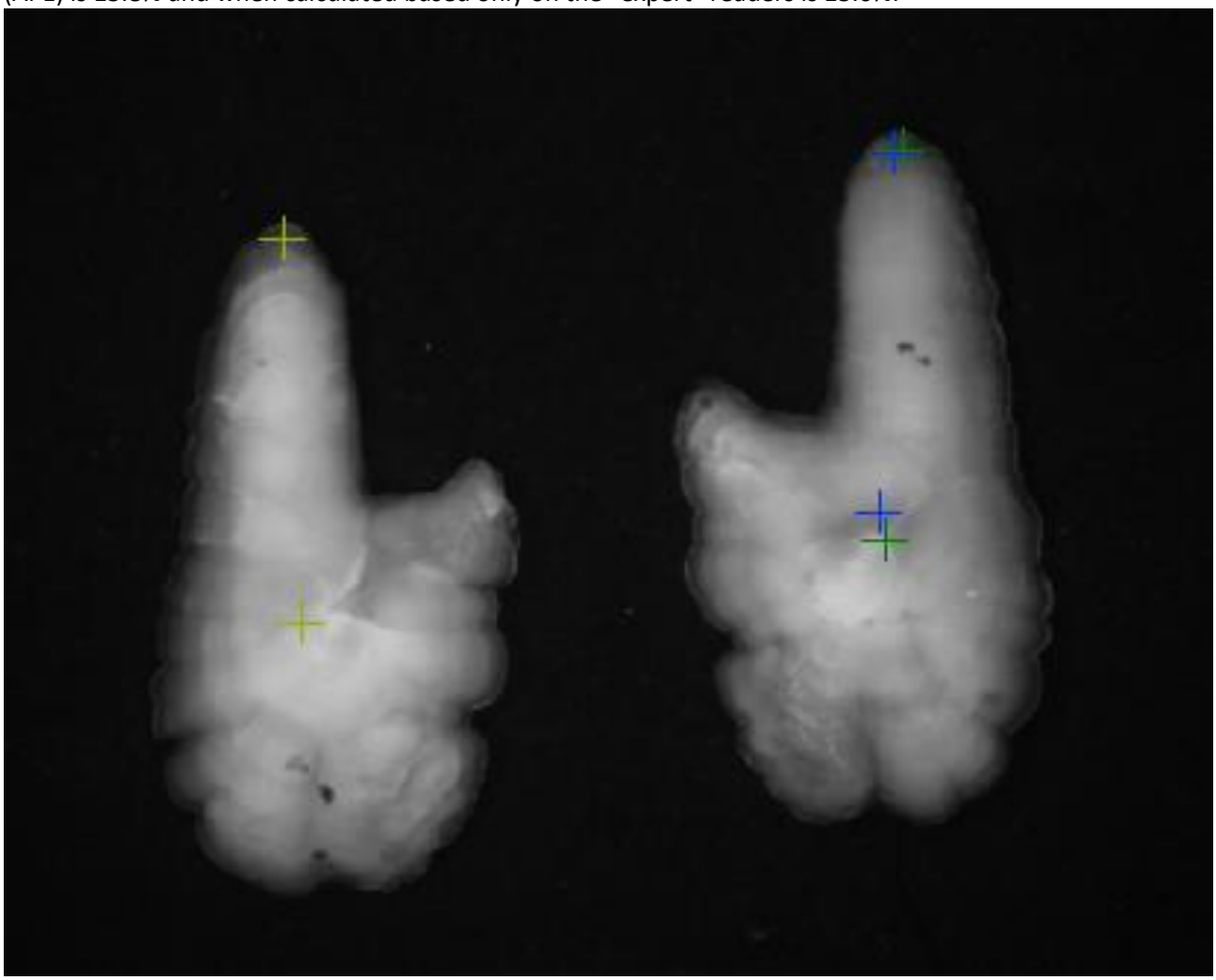

Figure 4a. Herr VIa_37, capture date 25/02/15, 69% agreement, CV 58% and modal age 1. Readers NOR1 (yellow), GBR2 (blue) and NLD1 (green) assigning ages of 0, 1 and 2 respectively.

Table 1d shows the age composition based on the estimated ages for all readers. Tables 2d, 3d and 4d show the % Agreement, CV and relative bias based on modal age for all readers.

Table 1d. Age composition for all readers in the VIa (N and S) exchange

Age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Total
0	1	1	1	3	1	1	1	1	1	1	0	1	2	**15**
1	6	6	6	6	6	6	5	5	5	0	1	6	8	**66**
2	7	7	7	4	7	7	8	8	7	5	6	7	2	**82**
3	7	7	8	10	7	6	7	2	8	9	7	7	12	**97**
4	8	8	7	5	7	14	7	15	8	10	6	8	5	**108**
5	9	8	7	13	11	3	9	11	12	11	6	10	13	**123**
6	7	8	9	3	6	8	9	1	6	5	10	7	4	**83**
7	2	1	1	2	1	2	0	4	0	7	8	1	2	**31**
8	3	2	1	3	1	1	4	3	2	2	2	2	2	**28**
9	0	2	1	0	1	2	0	0	1	0	3	1	0	**11**
10	0	0	2	0	2	0	0	0	0	0	0	0	0	**4**
All	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**50**	**648**

Table 2d. Percentage Agreement based on modal age for all readers in the VIa (N and S) exchange

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	100	100	100	100	100	100	100	100	100	0	0	100	0	**77**
1	100	100	100	33	100	100	83	83	83	0	0	100	50	**72**
2	100	100	100	29	100	100	100	100	86	0	0	100	14	**71**
3	100	100	86	100	100	86	100	29	86	0	0	100	86	**75**
4	100	88	75	38	88	100	88	50	62	25	0	100	38	**65**
5	89	89	67	89	78	22	89	44	89	56	0	100	67	**68**
6	86	100	86	43	57	86	100	14	57	43	14	86	14	**60**
7	100	0	50	50	50	100	0	50	0	0	50	50	100	**46**
8	100	67	33	67	33	33	100	67	67	0	0	67	67	**54**
Weighted mean	**96.1**	**90.1**	**80.1**	**57.3**	**82.1**	**78**	**90.1**	**53.9**	**74**	**20.1**	**4**	**94.1**	**48.1**	**66.8**

Table 3d. CV based on modal age for all readers in the VIa (N and S) exchange

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0	0	0	89	0	0	35	35	35	22	0	0	110	**48.5**
2	0	0	0	50	0	0	0	0	33	0	0	0	55	**26**
3	0	0	12	0	0	12	0	18	12	44	0	0	13	**17.9**
4	0	24	12	22	9	0	9	26	17	10	9	0	22	**16.5**
5	7	7	9	7	8	19	7	12	7	16	7	0	12	**11.4**
6	6	0	6	14	10	6	0	26	10	17	8	6	12	**12.8**
7	0	28	25	9	18	0	20	24	0	0	9	11	0	**13.6**
8	0	7	11	8	12	7	0	8	7	0	0	7	16	**10.6**
Weighted Mean	**2.1**	**6.6**	**7.7**	**25.8**	**5.7**	**6.4**	**7.7**	**18.1**	**16.3**	**15.7**	**4.3**	**1.7**	**31**	**20**

Table 4d. Relative Bias values for all readers in the VIa (N and S) exchange (red values indicate negative values and black indicated positive values)

Modal age	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	All
0	0	0	0	0	0	0	0	0	0	2	1	0	1	**0.31**
1	0	0	0	0	0	0	0.17	0.17	0.17	1.33	1	0	0	**0.22**
2	0	0	0	-0.43	0	0	0	0	0.29	1	1	0	-0.29	**0.12**
3	0	0	0.14	0	0	0.14	0	0.86	0.14	0.43	1	0	-0.14	**0.2**
4	0	0.38	-0.25	-0.12	0.12	0	0.12	1	-0.12	0.75	1.25	0	-0.12	**0.23**
5	0.11	-0.11	0.33	-0.11	0.22	-0.33	0.11	-0.56	-0.11	0.33	1.22	0	0.11	**0.09**
6	-0.14	0	-0.14	-0.71	-0.43	-0.14	0	-0.71	-0.43	0.14	1	-0.14	-1	**-0.21**
7	0	0.5	1.5	0.5	1	0	0	-1	-1	1	0.5	-0.5	0	**0.19**
8	0	0.33	1	-0.33	1.33	0.67	0	-0.33	0.33	-1	1	0.33	-0.67	**0.21**
Weighted Mean	**0**	**0.08**	**0.14**	**-0.2**	**0.12**	**-0.02**	**0.06**	**0.04**	**-0.04**	**0.58**	**1.06**	**-0.02**	**-0.22**	**0.12**

Significant bias in age estimates was found between readers (Friedman rank sum test, $p < 0.05$ and Wilcoxon paired test, $p < 0.05$). Table 5d shows the results of the Inter reader and reader against modal age bias tests and indicates that there is a certainty of bias between NLD1 and DEU1 against the other readers and modal age. NOR1 and NOR4 show a possibility of bias against some of the other readers. These results are confirmed by the relative bias values in Table 4d and the age bias plots in Annex 4. The general trend seen in the relative bias values (Table 4d) is for the ages to be overestimated as opposed to underestimated in comparison to modal age, which is also apparent in the age error matrix in Table 6d.

Table 5d. Inter reader bias test for all readers in the VIa (N and S) exchange. "-" = no sign of bias (p>0.05); "*" = possibility of bias (0.01<p<0.05) and "* *" = certainty of bias (p<0.01).

	1_ DNK1	**3_ NOR2**	**4_ NOR3**	**5_ NOR4**	**6_ NOR5**	**8_ GBR2**	**9_ GBR3**	**10_ GBR1**	**11_ IRL1**	**13_ NLD1**	**14_ DEU1**	**15_ FRA1**	**16_ NOR1**
1_ DNK1	NA	-	-	-	-	-	-	-	-	**	**	-	-
3_ NOR2	-	NA	-	*	-	-	-	-	-	**	**	-	-
4_ NOR3	-	-	NA	*	-	-	-	-	-	*	**	-	*
5_ NOR4	-	*	*	NA	**	-	*	-	-	**	**	-	-
6_ NOR5	-	-	-	**	NA	-	-	-	-	**	**	-	*
8_ GBR2	-	-	-	-	-	NA	-	-	-	**	**	-	-
9_ GBR3	-	-	-	*	-	-	NA	-	-	**	**	-	*
10_ GBR1	-	-	-	-	-	-	-	NA	-	**	**	-	-
11_ IRL1	-	-	-	-	-	-	-	-	NA	**	**	-	-
13_ NLD1	**	**	*	**	**	**	**	**	**	NA	**	**	**
14_ DEU1	**	**	**	**	**	**	**	**	**	**	NA	**	**
15_ FRA1	-	-	-	-	-	-	-	-	-	**	**	NA	-
16_ NOR1	-	-	*	-	*	-	*	-	-	**	**	-	NA
Modal age	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	****	****	**-**	**-**

Table 6d. Age Error matrix based on all "expert" readers in the VIa (N and S) exchange shows the proportion of each modal age estimated correctly (in bold) and mis-aged as other ages (underestimated in red and overestimated in blue).

	Modal Age								
Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	**0.8**	0.03	0	0.01	0	0	0	0	0
1	0.1	**0.7**	0.06	0	0	0	0	0	0
2	0.1	0.23	**0.71**	0	0	0	0	0	0
3	0	0.03	0.21	**0.78**	0.09	0	0	0	0
4	0	0	0.01	0.21	**0.66**	0.04	0.03	0	0
5	0	0	0	0	0.21	**0.74**	0.17	0	0
6	0	0	0	0	0.02	0.18	**0.67**	0.25	0
7	0	0	0	0	0.01	0.03	0.11	**0.35**	0.13
8	0	0	0	0	0	0	0.01	0.25	**0.53**
9	0	0	0	0	0	0	0	0.1	0.23
10	0	0	0	0	0	0	0	0.05	0.1

Growth data:

Figure 4b shows the combined growth curves for all fish and all readers in the VIa (N and S) exchange. FRA1 omitted to mark the centre point on every image and therefor his average growth curve falls below all of the others. He was omitted from the analysis. The Linear Mixed Effects Model analysis showed a significant reader effect on both the intercept and slope of the LMEM (LMEM, $p < 0.05$) meaning that there are differences between readers. GBR1 and GBR2 stand out from the others readers (significant). GBR1 usually omits to mark the first winter ring and on some images is marking along the wrong axis. GBR2 has problems with the older fish. NOR1 also appears to be annotating slightly different in comparison to the other readers.

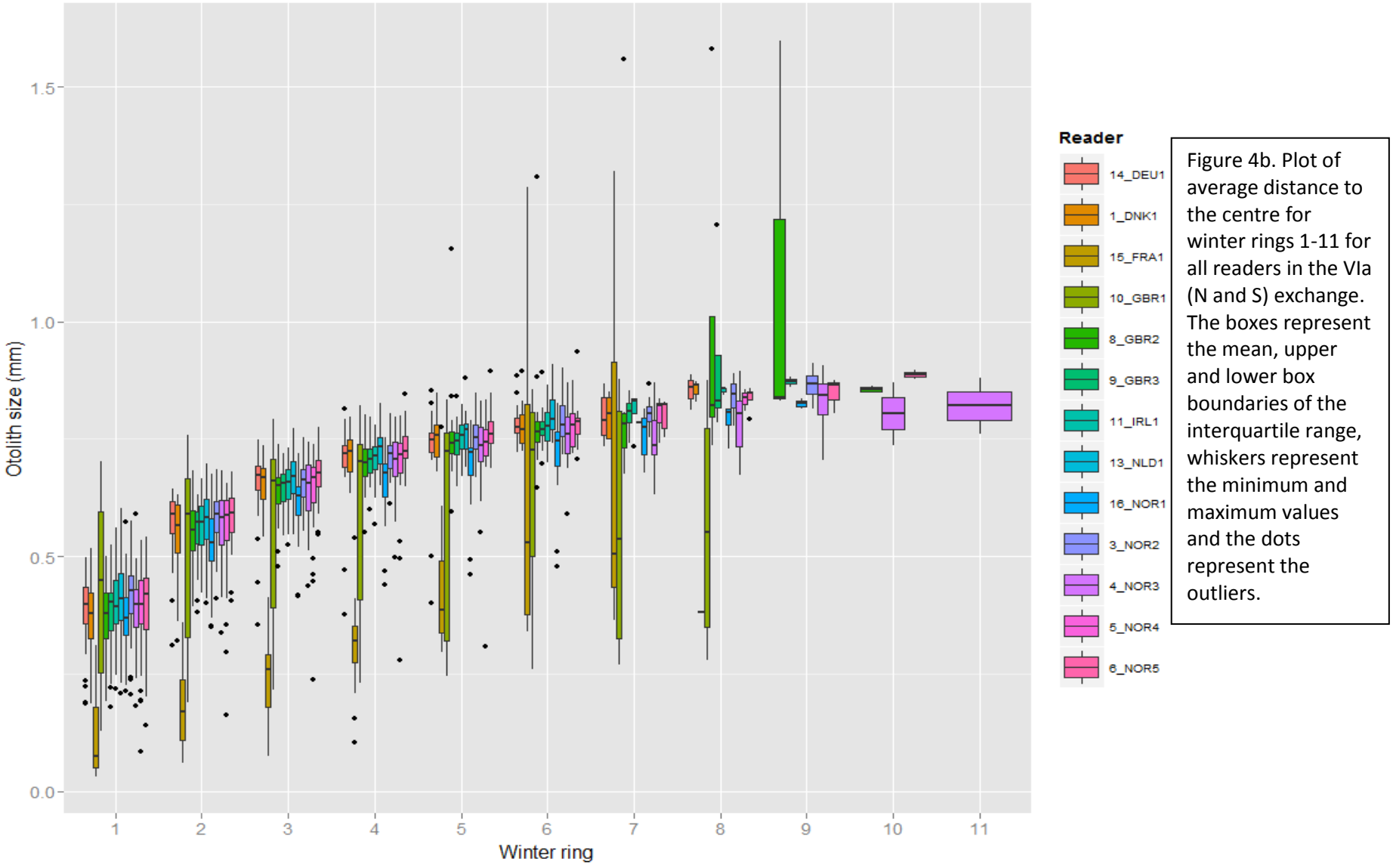

Figure 4b. Plot of average distance to the centre for winter rings 1-11 for all readers in the VIa (N and S) exchange. The boxes represent the mean, upper and lower box boundaries of the interquartile range, whiskers represent the minimum and maximum values and the dots represent the outliers.

Conclusion

This full scale exchange covers 4 separate stocks (North Sea, Celtic Sea, Irish Sea and VIa (North and South) and was completed by 13 readers (10 of which are experts) from 9 institutes. It is not surprising that in comparison to the 2014 calibration exercise the percentage agreement for both the North Sea and Celtic Sea's has decreased given that, firstly, the number of participants has increased from 3 to 10 and secondly, not all readers are experienced in reading otoliths from all areas.

The index of average percentage error (APE) ranges from 11.6% to 14.8% and the coefficient of variation (CV) from 16% to 21.1% and similar problems are apparent for all stocks. For each stock there is a general trend where the overall relative bias values are positive meaning that the readers overestimate the ages in comparison to the modal age. This can also be seen in the age error matrices. This overall positive bias is due mostly to readers NLD1 and DEU1 who are repeatedly estimating 1 and sometimes 2 years over the modal age. For herring stocks, there can be confusion as to whether a fish is aged in terms of "rings" or "years". For autumn spawning herring stocks a difference of one year becomes apparent between the count of "rings" and "years". Readers were asked to provide the age in terms of "years". Providing an age based on a count of "rings" would explain the addition of one extra year to the age, additional years added to the age are then due to misinterpretation of the otoliths structure. The definition of age for these fish should be standardised to avoid further confusion.

In the 2014 calibration exercise the less experienced reader from Northern Ireland (GBR1) had a tendency to underestimate the age as the first winter ring was often not counted. This problem is still apparent and is most obvious by the comparison of the growth curves. The relative bias values confirm this underestimation for both the Celtic Sea and Irish Sea exercises. Interpretation of the subsequent winter rings can also lead to overestimation in some examples, more noticeably the younger fish.

The only other reader who clearly stands out from the group is NOR1, who is a trainee. In general she is overestimating the ages, partly due to misinterpretation of the edge.

For all areas the level of accuracy and precision improves dramatically when the problematic and inexperienced readers are excluded from the calculations. This improvement is slightly less for VIa (N & S). Thus, the compilation of agreed age collections of otoliths should be possible.

The growth curve analyses showed that both the first winter ring and the additional winter rings are interpreted differently by the group and clearly shows the issues associated with the misidentification of the first winter ring for GBR1. The issues associated with incorrectly annotating the images are also apparent as FRA1 omitted to mark the nucleus each time. Some of the other readers did not follow the instructions correctly and different axes were annotated on some occasions. This could lead to a significant difference revealed by the post-hoc analyses. The standardisation of annotation procedures is difficult and it is clear from the images that what the readers interpret to be the nucleus is not exact, nor do all readers interpret the beginning of each winter ring to be in the same place. As the fish age increases the distance between winter rings decreases and annotating the winter rings becomes more difficult, thus the overlap in the distance from centre to winter ring is more apparent for the older fish (from age 6 and over). Written

instructions and a live demonstration using WebGR were provided for the readers but standardisation of annotation procedures is still difficult and may confound the growth analyses results.

Given that for some of the stocks there are just 1 or 2 readers providing age estimates for assessment it did not make sense to compile age error matrices for all stocks. A North Sea matrix will be compiled based only on those readers providing age data for assessment and provided to HAWG 2016.

RECOMMENDATION	ADRESSED TO
1. Compilation of a reference collection of agreed age fish	Age reading labs and WGBIOP
2. Standardisation of whether it is the count of "year" or "rings" which are used to define fish age for age reading exercises.	WGBIOP
3. Standardiation of procedures for annotation of images used in exchanges.	WGBIOP

References

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ICES. 2014b. Report of the Workshop on Statistical Analysis of Biological Calibration Studies (WKSABCAL). ICES CM 2014\ACOM:35.

ICES. 2015. Report of the Herring Assessment Working Group for the Area South of 62°N (HAWG). ICES CM 2015\ACOM:06.

Annex 1 North Sea

Table 1.1. Fish data and all age readings for all fish in the North Sea exchange

Image	Length	Capture date	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Modal Age	% Agreement	CV
Herr_IV_01_.jpg	18.5	29/06/2014	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_IV_02_.jpg	17.5	29/06/2014	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_IV_03_.jpg	16.5	29/06/2014	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_IV_04_.jpg	19.5	29/06/2014	1	1	1	1	1	2	1	1	1	0	2	1	1	**1**	**77**	**46**
Herr_IV_05_.jpg	21.5	29/06/2014	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_IV_06_.jpg	24.5	29/06/2014	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_IV_07_.jpg	23.5	29/06/2014	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_IV_08_.jpg	33.5	05/08/2014	7	7	9	9	9	9	8	7	8	9	9	9	9	**9**	**62**	**10**
Herr_IV_09_.jpg	32.5	05/08/2014	5	5	6	6	6	6	6	10	6	6	6	6	7	**6**	**69**	**20**
Herr_IV_10_.jpg	24	02/08/2014	2	2	2	2	2	2	2	3	3	3	2	2	5	**2**	**69**	**36**
Herr_IV_11_.jpg	22.5	02/08/2014	2	2	2	2	2	2	2	1	2	3	3	2	2	**2**	**77**	**24**
Herr_IV_12_.jpg	14.5	06/02/2013	1	1	1	1	1	1	1	1	0	NA	2	1	5	**1**	**75**	**92**
Herr_IV_13_.jpg	9.5	06/02/2013	1	2	1	1	1	2	1	1	2	1	2	2	2	**1**	**54**	**36**
Herr_IV_14_.jpg	11.5	06/02/2013	1	2	1	1	1	2	1	1	2	2	2	2	2	**2**	**54**	**34**
Herr_IV_15_.jpg	31.2	14/01/2013	9	8	10	8	9	9	10	12	8	8	13	9	9	**9**	**38**	**17**
Herr_IV_16_.jpg	28.5	14/01/2013	4	4	4	4	4	4	4	4	3	3	5	4	4	**4**	**77**	**13**
Herr_IV_17_.jpg	26	03/01/2013	3	3	3	4	3	3	3	4	4	3	4	3	4	**3**	**62**	**15**
Herr_IV_18_.jpg	23.5	03/01/2013	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_IV_19_.jpg	24.5	03/01/2013	3	3	3	3	3	3	3	4	3	4	4	3	3	**3**	**77**	**14**

Herr_IV_20_.jpg	13.5	03/01/2013	1	1	1	1	1	1	1	1	1	2	2	1	2	**1**	**77**	**36**
Herr_IV_21_.jpg	20.5	03/01/2013	2	2	2	2	2	2	2	1	2	3	3	2	2	**2**	**77**	**24**
Herr_IV_22_.jpg	24.5	12/08/2013	2	NA	2	2	2	1	2	3	1	3	2	2	2	**2**	**67**	**30**
Herr_IV_23_.jpg	19.5	12/08/2013	1	1	1	1	1	1	1	2	1	3	2	1	1	**1**	**77**	**48**
Herr_IV_24_.jpg	27.5	12/08/2013	4	4	4	4	4	3	4	8	4	5	5	4	9	**4**	**62**	**36**
Herr_IV_25_.jpg	29.5	12/08/2013	5	5	5	5	5	5	5	5	4	5	5	5	5	**5**	**92**	**6**
Herr_IV_26_.jpg	6.5	08/08/2013	0	0	0	0	0	0	0	0	0	1	1	0	1	**0**	**77**	**-**
Herr_IV_27_.jpg	15.5	08/08/2013	1	2	1	1	1	1	1	1	1	2	2	1	3	**1**	**69**	**47**
Herr_IV_28_.jpg	10.5	31/07/2013	0	0	0	0	0	0	0	0	0	1	1	0	1	**0**	**77**	**-**
Herr_IV_29_.jpg	26	12/08/2013	3	3	3	3	3	3	3	4	3	3	4	3	3	**3**	**85**	**12**
Herr_IV_30_.jpg	12.5	31/07/2013	0	0	0	0	0	0	0	0	0	1	1	0	1	**0**	**77**	**-**
Herr_IV_31_.jpg	25.5	10/08/2013	2	3	2	3	2	3	2	3	4	3	3	2	3	**3**	**54**	**23**
Herr_IV_32_.jpg	28	12/08/2013	2	3	3	3	3	2	3	5	3	3	4	3	5	**3**	**62**	**29**
Herr_IV_33_.jpg	28.5	01/08/2013	3	3	3	3	3	3	3	5	3	3	4	3	3	**3**	**85**	**19**
Herr_IV_34_.jpg	30.5	20/08/2013	9	9	9	8	10	9	9	7	8	6	11	9	8	**9**	**46**	**15**
Herr_IV_35_.jpg	30.6	04/09/2013	4	4	4	4	4	4	4	4	4	4	5	4	4	**4**	**92**	**7**
Herr_IV_36_.jpg	27.9	15/10/2013	6	6	6	5	6	5	6	5	6	7	7	6	8	**6**	**54**	**14**
Herr_IV_37_.jpg	29.4	15/10/2013	6	6	6	6	6	5	6	5	5	6	7	6	6	**6**	**69**	**9**
Herr_IV_38_.jpg	31.2	15/10/2013	8	7	8	8	7	7	7	6	6	7	8	7	8	**7**	**46**	**10**
Herr_IV_39_.jpg	28.5	15/10/2013	6	6	6	6	6	NA	6	4	5	7	7	6	6	**6**	**67**	**13**
Herr_IV_40_.jpg	32.5	14/10/2013	4	4	4	5	NA	4	4	4	7	5	5	4	5	**4**	**58**	**20**
Herr_IV_41_.jpg	26	18/11/2013	3	3	3	3	4	3	3	4	3	5	4	3	4	**3**	**62**	**19**
Herr_IV_42_.jpg	28.8	08/10/2013	6	5	6	6	6	5	5	4	6	6	7	6	7	**6**	**54**	**14**
Herr_IV_43_.jpg	27	08/10/2013	5	5	5	5	5	4	5	4	4	6	6	5	5	**5**	**62**	**13**
Herr_IV_44_.jpg	30.3	26/11/2013	7	7	7	7	7	6	7	5	7	6	8	7	7	**7**	**69**	**11**

Herr_IV_45_.jpg	28.3	09/12/2013	3	3	3	4	3	3	3	6	3	3	4	3	3	**3**	**77**	**26**
Herr_IV_46_.jpg	24.5	09/12/2013	1	1	1	1	1	1	1	2	1	3	2	1	1	**1**	**77**	**48**
Herr_IV_47_.jpg	25.1	09/12/2013	3	3	3	3	3	3	3	2	3	0	4	3	3	**3**	**77**	**33**
Herr_IV_48_.jpg	26.4	09/12/2013	3	3	3	4	3	3	3	4	3	4	4	3	5	**3**	**62**	**19**
Herr_IV_49_.jpg	26.5	23/12/2013	4	5	5	4	5	4	4	4	4	7	6	4	5	**4**	**54**	**20**
Herr_IV_50_.jpg	31.3	24/12/2013	7	7	7	7	7	7	7	5	8	5	8	7	7	**7**	**69**	**13**
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**	**-**	**-**
Means (CV and PA)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**70**	**24**
Total read	**-**	**-**	**50**	**49**	**50**	**50**	**49**	**49**	**50**	**50**	**50**	**49**	**50**	**50**	**50**		**-**	
Total NOT read	**-**	**-**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**		**-**	

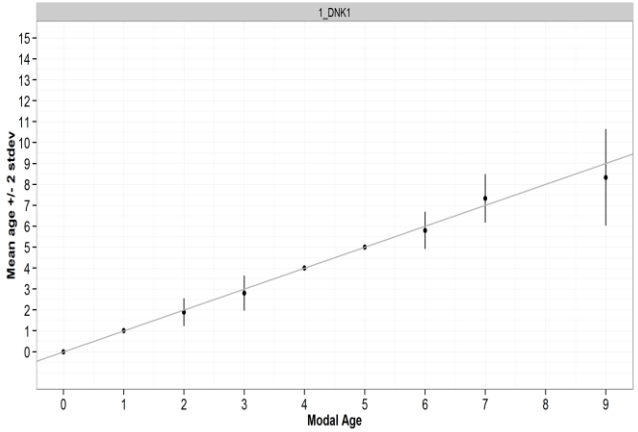
Table 1.2 Age composition for all readers in the North Sea exchange

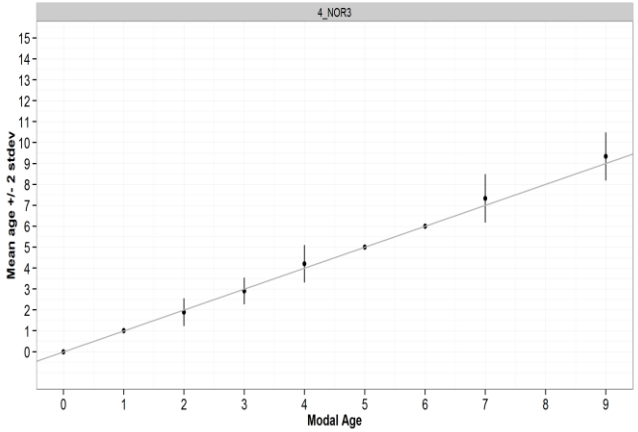
Age	**1_ DNK 1**	**3_ NOR 2**	**4_ NOR 3**	**5_ NOR 4**	**6_ NOR 5**	**8_ GBR 2**	**9_ GBR 3**	**10_ GBR 1**	**11_ IRL 1**	**13_ NLD 1**	**14_ DEU 1**	**15_ FRA 1**	**16_ NOR 1**	**Total**
0	3	3	3	3	3	3	3	3	4	2	0	3	0	**33**
1	11	8	11	11	11	9	11	11	9	4	3	9	9	**117**
2	10	10	9	8	9	11	9	7	8	6	13	11	10	**121**
3	8	10	9	7	8	10	9	3	10	17	7	9	7	**114**
4	5	4	4	7	4	5	5	12	7	3	9	5	4	**74**
5	3	5	3	4	3	4	3	7	2	5	5	2	8	**54**
6	4	3	5	4	5	2	4	2	4	6	3	5	2	**49**
7	3	4	2	2	3	2	3	2	2	4	4	3	4	**38**
8	1	1	1	3	0	0	1	1	4	1	3	0	3	**19**
9	2	1	2	1	2	3	1	0	0	1	1	3	3	**20**

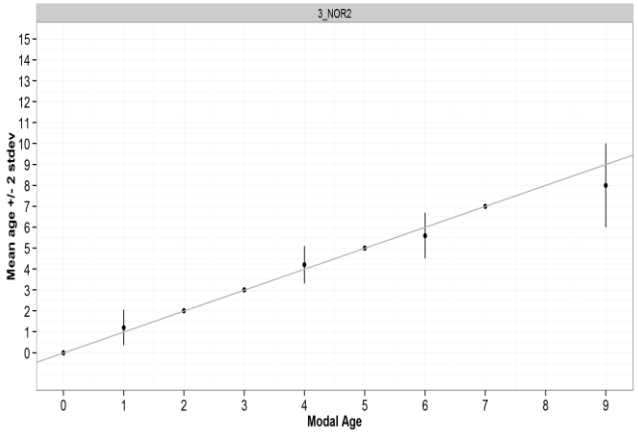
10	0	0	1	0	1	0	1	1	0	0	0	0	0	**4**
11	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
12	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
13	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
All	**50**	**49**	**50**	**50**	**49**	**49**	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**646**

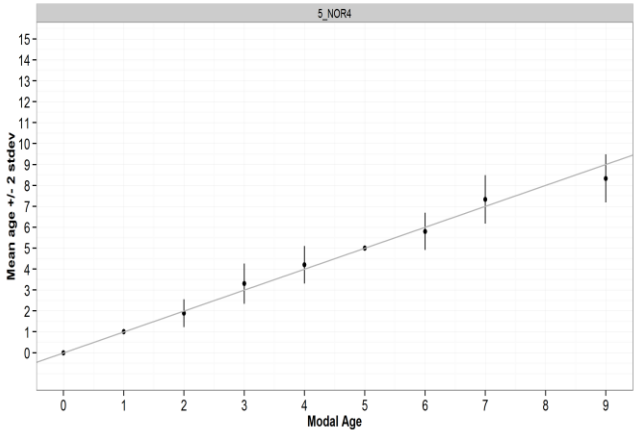
Table 1.3 Mean length at age for all readers in the North Sea exchange

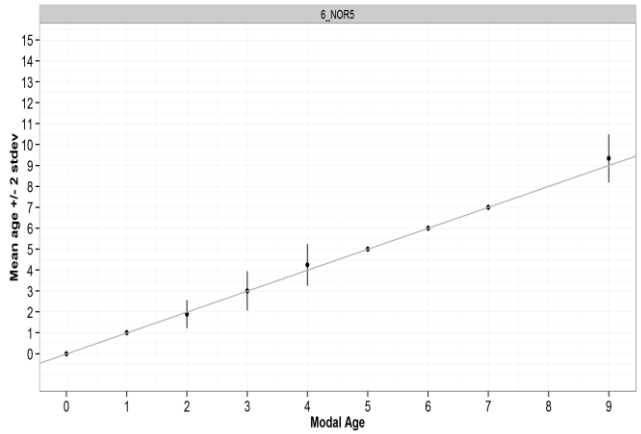
Age	1_ DNK1	3_ NOR2	4_ NOR3	5_ NOR4	6_ NOR5	8_ GBR2	9_ GBR3	10_ GBR1	11_ IRL1	13_ NLD1	14_ DEU1	15_ FRA1	16_ NOR1	Total
0	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	11	22.3	-	9.8	-	**10.7**
1	16.4	18	16.4	16.4	16.4	18.3	16.4	16.3	18.8	9.8	9.8	17.7	16.2	**16.5**
2	23.8	19.6	23.3	23.1	23.3	20.8	23.3	23.2	19.6	15.5	17.6	21	19.5	**21**
3	26.4	26.4	26.5	26.2	26.6	26.4	26.5	24.7	26.5	24.7	23.1	26.5	24.8	**25.8**
4	29.1	29.8	29.8	27.7	28.1	29	29.1	27.6	27.5	27.2	26.5	29.1	27.8	**28.1**
5	29.7	28.9	27.7	29.2	27.7	28.9	28.4	29.3	28.9	29.4	29.7	28.2	26.1	**28.5**
6	28.6	28.6	29.4	29.8	29.4	31.4	29.6	29.8	30.1	29.8	28.7	29.4	28.9	**29.5**
7	31.7	31.6	30.8	30.8	30.9	31.2	30.9	32	31.4	28.5	28.6	30.9	30.7	**30.6**
8	31.2	31.2	31.2	31	-	-	33.5	27.5	31.6	31.2	30.9	-	29.9	**30.9**
9	30.9	30.5	32	33.5	32.4	31.7	30.5	-	-	33.5	33.5	31.7	30.7	**31.7**
10	-	-	31.2	-	30.5	-	31.2	32.5	-	-	-	-	-	**31.4**
11	-	-	-	-	-	-	-	-	-	-	30.5	-	-	**30.5**
12	-	-	-	-	-	-	-	31.2	-	-	-	-	-	**31.2**
13	-	-	-	-	-	-	-	-	-	-	31.2	-	-	**31.2**
Weighted Mean	**23.9**	**23.9**	**23.9**	**23.9**	**23.7**	**23.8**	**23.9**	**23.9**	**23.9**	**24.1**	**23.9**	**23.9**	**23.9**	**23.9**

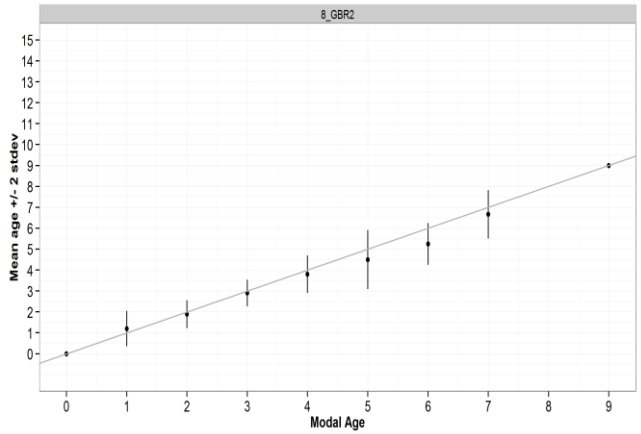

1_DNK1
Mean age +/- 2 stdev
Modal Age

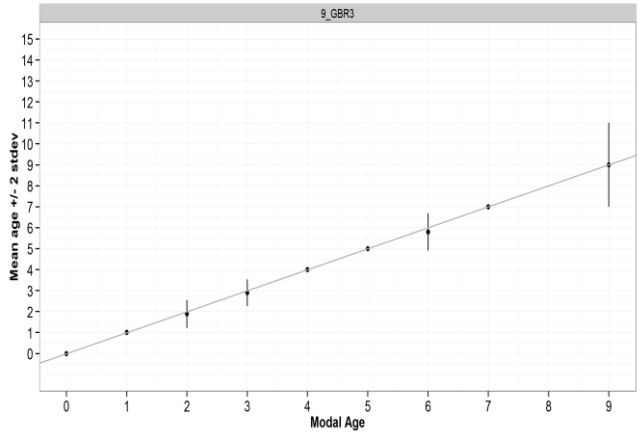

4_NOR3
Mean age +/- 2 stdev
Modal Age

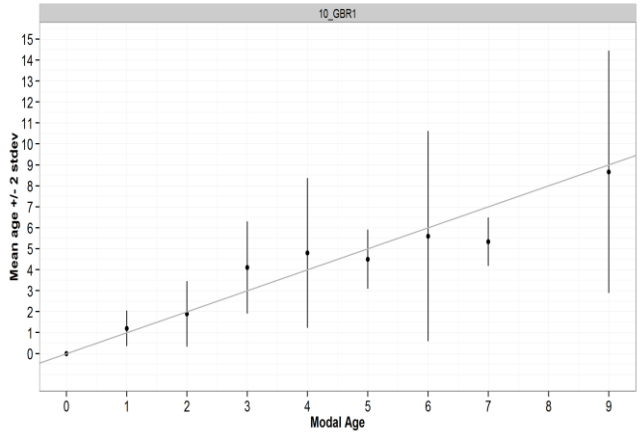

3_NOR2
Mean age +/- 2 stdev
Modal Age

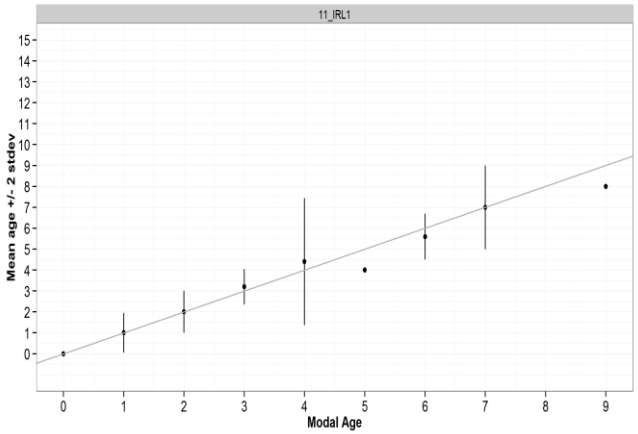

5_NOR4
Mean age +/- 2 stdev
Modal Age

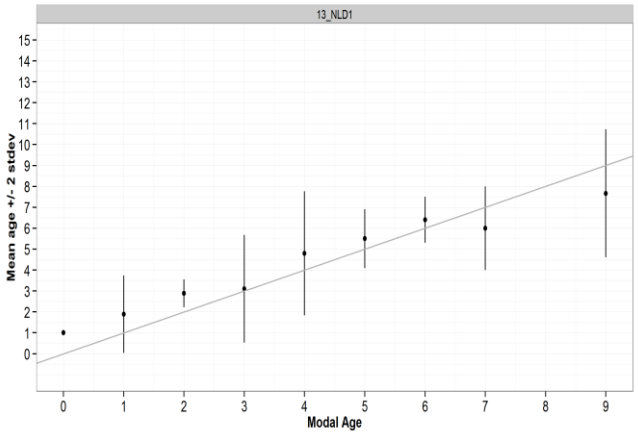

6_NOR5
Mean age +/- 2 stdev
Modal Age

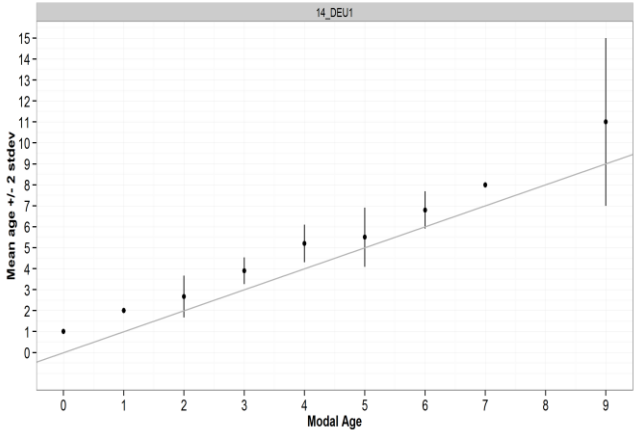

8_GBR2
Mean age +/- 2 stdev
Modal Age

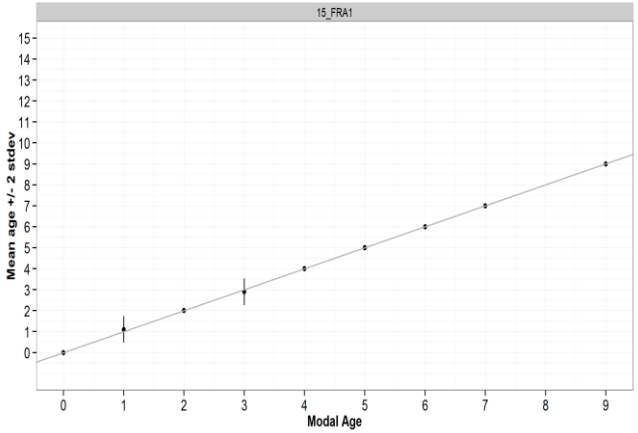

9_GBR3
Mean age +/- 2 stdev
Modal Age


10_GBR1
Mean age +/- 2 stdev
Modal Age


11_IRL1
Mean age +/- 2 stdev
Modal Age


13_NLD1
Mean age +/- 2 stdev
Modal Age


14_DEU1
Mean age +/- 2 stdev
Modal Age


15_FRA1
Mean age +/- 2 stdev
Modal Age

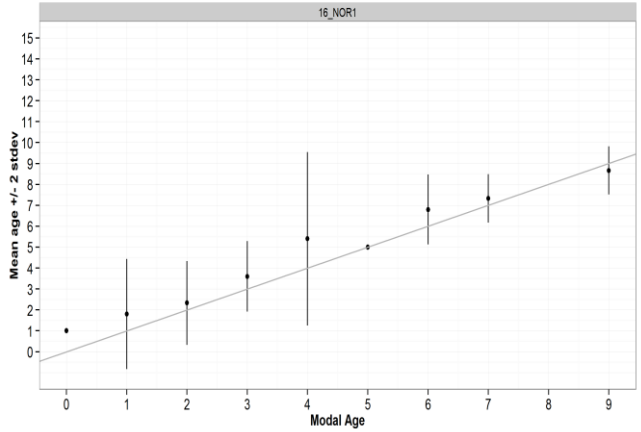


Figure 1.1 Age bias plots for all readers in the North Sea exchange. The diagonal line represents the modal age and the vertical bars are the mean age +/- 2 standard deviations.

Annex 2 Celtic Sea

Table 2.1 Fish data and all age readings for all fish in the Celtic Sea exchange

Image	Length (SC)	Capture date	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Modal Age	& Agree-ment	CV
Herr_VII_01_.jpg	26	28/09/2011	5	5	5	5	5	5	5	5	5	6	6	5	5	**5**	**85**	**7**
Herr_VII_02_.jpg	26.5	28/09/2011	6	5	6	6	6	5	6	5	5	7	7	6	6	**6**	**54**	**12**
Herr_VII_03_.jpg	25	28/09/2011	3	3	3	3	3	3	3	4	3	5	4	3	4	**3**	**69**	**19**
Herr_VII_04_.jpg	27	28/09/2011	5	5	5	5	5	5	5	5	4	6	6	5	5	**5**	**77**	**10**
Herr_VII_05_.jpg	29	28/09/2011	9	10	10	10	10	10	10	7	8	8	12	10	11	**10**	**54**	**14**
Herr_VII_06_.jpg	25.5	28/09/2011	3	3	3	3	3	3	3	4	3	4	4	3	5	**3**	**69**	**19**
Herr_VII_07_.jpg	27.5	28/09/2011	7	7	7	7	7	7	7	7	6	7	8	7	7	**7**	**85**	**6**
Herr_VII_08_.jpg	24	28/09/2011	3	3	3	3	3	3	3	3	3	4	4	3	4	**3**	**77**	**14**
Herr_VII_09_.jpg	25	28/09/2011	3	3	3	3	3	3	3	3	3	4	4	3	4	**3**	**77**	**14**
Herr_VII_10_.jpg	24	28/09/2011	3	3	3	3	3	3	3	3	3	4	4	3	3	**3**	**85**	**12**
Herr_VII_11_.jpg	28	19/10/2011	6	5	5	5	5	5	6	5	5	6	7	5	6	**5**	**62**	**12**
Herr_VII_12_.jpg	23	19/10/2011	1	1	1	1	1	1	1	2	1	2	2	1	1	**1**	**77**	**36**
Herr_VII_13_.jpg	23.5	19/10/2011	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VII_14_.jpg	25	19/10/2011	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VII_15_.jpg	26	19/10/2011	3	3	3	3	3	3	3	3	3	4	5	3	4	**3**	**77**	**19**
Herr_VII_16_.jpg	24	19/10/2011	2	2	2	2	2	2	2	3	2	3	3	2	2	**2**	**77**	**20**
Herr_VII_17_.jpg	29	19/10/2011	7	6	7	7	6	7	7	6	6	6	8	6	7	**6**	**46**	**10**
Herr_VII_18_.jpg	26	19/10/2011	3	3	3	3	3	3	3	4	3	5	4	3	3	**3**	**77**	**19**
Herr_VII_19_.jpg	28	19/10/2011	4	4	4	4	4	4	4	5	4	5	5	4	4	**4**	**77**	**10**

Herr_VII_20_.jpg	22	28/11/2011	2	2	2	2	2	2	2	1	2	4	3	2	2	**2**	**77**	**32**
Herr_VII_21_.jpg	28	02/12/2013	7	6	7	7	6	7	6	5	6	5	7	6	6	**6**	**46**	**12**
Herr_VII_22_.jpg	27.5	10/12/2012	6	6	6	6	6	6	6	5	6	6	7	6	6	**6**	**85**	**7**
Herr_VII_23_.jpg	25.5	10/12/2012	4	4	4	4	4	4	4	3	4	6	5	4	4	**4**	**77**	**17**
Herr_VII_24_.jpg	22	10/12/2012	2	2	2	2	2	2	2	2	2	4	3	2	2	**2**	**85**	**27**
Herr_VII_25_.jpg	25	10/12/2012	2	3	2	2	2	2	2	3	2	4	3	2	2	**2**	**69**	**27**
Herr_VII_26_.jpg	26	10/12/2012	6	5	6	6	6	6	6	4	5	6	7	6	6	**6**	**69**	**13**
Herr_VII_27_.jpg	22	24/10/2012	2	NA	2	2	2	2	2	3	2	4	3	2	2	**2**	**75**	**28**
Herr_VII_28_.jpg	22	24/10/2012	2	2	2	2	2	2	2	1	2	4	3	2	2	**2**	**77**	**32**
Herr_VII_29_.jpg	20.5	24/10/2012	1	1	1	1	1	1	1	1	1	3	2	1	1	**1**	**85**	**49**
Herr_VII_30_.jpg	22.5	24/10/2012	2	2	2	2	2	2	2	1	2	4	3	2	2	**2**	**77**	**32**
Herr_VII_31_.jpg	21	24/10/2012	1	1	1	1	1	1	1	1	1	3	2	1	1	**1**	**85**	**49**
Herr_VII_32_.jpg	19	02/10/2013	1	1	1	1	1	1	1	1	1	3	2	1	1	**1**	**85**	**49**
Herr_VII_33_.jpg	28	23/10/2013	5	5	5	5	5	5	5	4	5	7	6	5	5	**5**	**77**	**13**
Herr_VII_34_.jpg	23.5	02/12/2013	3	3	3	3	3	3	3	2	3	5	4	3	3	**3**	**77**	**22**
Herr_VII_35_.jpg	24	02/12/2013	2	2	2	2	2	2	2	2	2	4	3	2	2	**2**	**85**	**27**
Herr_VII_36_.jpg	24.5	02/12/2013	3	3	3	3	3	3	3	3	4	5	4	3	4	**3**	**69**	**19**
Herr_VII_37_.jpg	21.5	02/12/2013	2	2	2	2	2	2	2	1	2	4	3	2	2	**2**	**77**	**32**
Herr_VII_38_.jpg	25	02/12/2013	4	4	4	4	4	4	4	3	4	6	5	4	4	**4**	**77**	**17**
Herr_VII_39_.jpg	27.5	02/12/2013	6	6	6	6	6	6	6	5	6	8	7	6	6	**6**	**77**	**11**
Herr_VII_40_.jpg	26	02/12/2013	4	4	4	4	3	4	4	5	4	5	5	4	4	**4**	**69**	**13**
Herr_VII_41_.jpg	24.5	10/11/2014	3	3	3	3	3	3	3	3	3	5	4	3	3	**3**	**85**	**19**
Herr_VII_42_.jpg	27	10/11/2014	8	7	8	6	8	8	8	8	6	9	10	8	7	**8**	**54**	**14**
Herr_VII_43_.jpg	25.5	10/11/2014	6	6	6	4	6	5	6	5	5	7	8	6	5	**6**	**46**	**18**
Herr_VII_44_.jpg	27.5	10/11/2014	4	4	4	4	4	4	4	3	4	5	5	4	4	**4**	**77**	**12**

Herr_VII_45_.jpg	23	10/11/2014	2	2	2	2	2	2	2	1	2	4	3	2	2	**2**	**77**	**32**
Herr_VII_46_.jpg	25	10/11/2014	4	4	4	4	4	4	4	2	4	6	5	4	4	**4**	**77**	**21**
Herr_VII_47_.jpg	26.5	10/11/2014	4	4	4	4	4	3	4	4	4	5	5	4	3	**4**	**69**	**14**
Herr_VII_48_.jpg	27.5	10/11/2014	7	7	7	6	7	7	6	7	6	6	9	7	6	**7**	**54**	**12**
Herr_VII_49_.jpg	26	10/11/2014	3	3	3	3	3	3	3	3	3	4	4	3	3	**3**	**85**	**12**
Herr_VII_50_.jpg	24	10/11/2014	3	3	3	3	3	3	3	2	3	5	4	3	3	**3**	**77**	**22**
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**	**-**	**-**
Means (CV and PA)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**74**	**20**
Total read	**-**	**-**	**50**	**49**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**		**-**	
Total NOT read	**-**	**-**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		**-**	

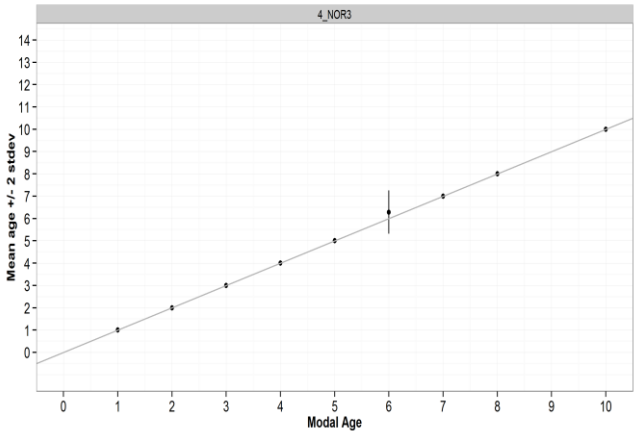
Table 2.2 Age composition for all readers in the Celtic Sea exchange

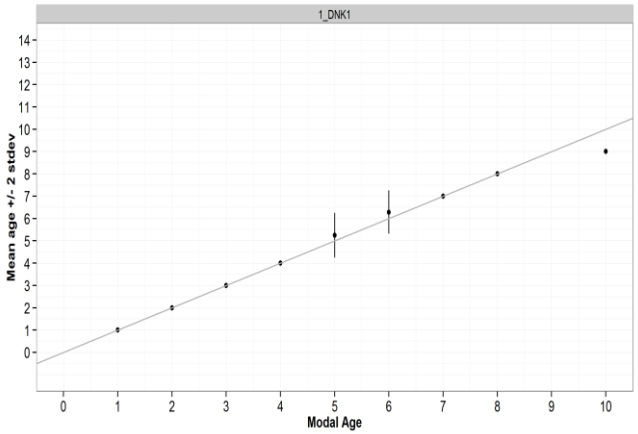
Age	**1_ DNK 1**	**3_ NOR 2**	**4_ NOR 3**	**5_ NOR 4**	**6_ NOR 5**	**8_ GBR 2**	**9_ GBR 3**	**10_ GBR 1**	**11_ IRL 1**	**13_ NLD 1**	**14_ DEU 1**	**15_ FRA 1**	**16_ NOR 1**	**Total**
1	4	4	4	4	4	4	4	8	4	0	0	4	4	**48**
2	12	10	12	12	12	12	12	8	12	1	4	12	12	**131**
3	12	13	12	12	13	13	12	13	11	6	12	12	7	**148**
4	7	7	7	8	6	6	7	6	9	15	11	7	11	**107**
5	3	6	4	4	4	6	3	10	6	11	8	4	5	**74**
6	6	5	5	6	7	3	8	1	7	10	3	7	7	**75**
7	4	3	4	3	2	4	2	3	0	4	6	2	3	**40**
8	1	0	1	0	1	1	1	1	1	2	3	1	0	**13**
9	1	0	0	0	0	0	0	0	0	1	1	0	0	**3**

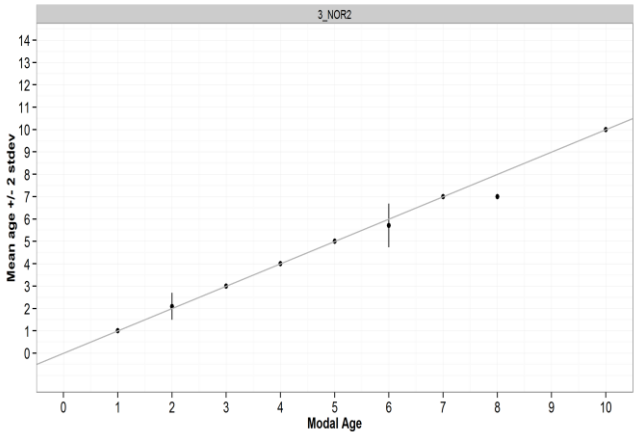
10	0	1	1	1	1	1	1	0	0	0	1	1	0	**8**
11	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
12	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
All	**50**	**49**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**649**

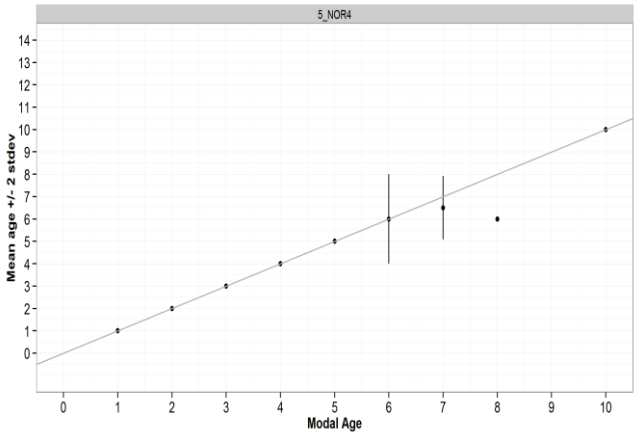
Table 2.3 Mean length at age for all readers in the Celtic Sea exchange

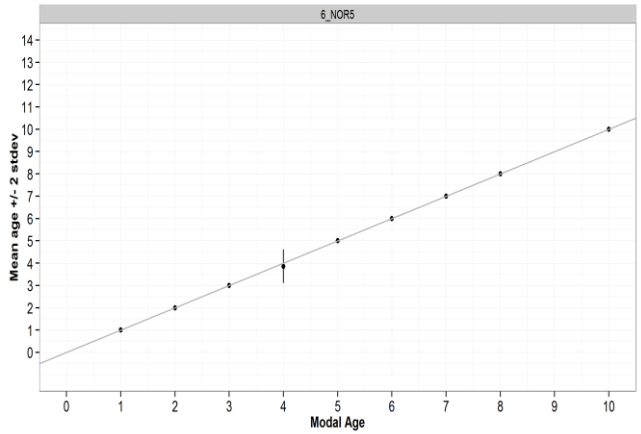
Age	1_ DNK1	3_ NOR2	4_ NOR3	5_ NOR4	6_ NOR5	8_ GBR2	9_ GBR3	10_ GBR1	11_ IRL1	13_ NLD1	14_ DEU1	15_ FRA1	16_ NOR1	Total
1	20.9	20.9	20.9	20.9	20.9	20.9	20.9	21.4	20.9	-	-	20.9	20.9	**21**
2	23	22.9	23	23	23	23	23	23.8	23	23	20.9	23	23	**23**
3	24.8	24.8	24.8	24.8	24.9	25	24.8	24.8	24.9	22.2	23	24.8	24.9	**24.6**
4	26.2	26.2	26.2	26.1	26.2	26.2	26.2	26.2	26.1	23.6	24.7	26.2	25.6	**25.6**
5	27	26.9	27.2	27.2	27.2	26.8	27	27	26.7	25.8	26.2	27.2	26.4	**26.7**
6	26.8	27.5	26.6	27	27.1	27	27.1	29	27.7	26.6	27	27.1	27.3	**27.1**
7	28	27.3	28	28.2	27.5	28	28.2	28	-	26.9	27.2	27.5	27.8	**27.7**
8	27	-	27	-	27	27	27	27	29	28.2	27.3	27	-	**27.4**
9	29	-	-	-	-	-	-	-	-	27	27.5	-	-	**27.8**
10	-	29	29	29	29	29	29	-	-	-	27	29	-	**28.8**
11	-	-	-	-	-	-	-	-	-	-	-	-	29	**29**
12	-	-	-	-	-	-	-	-	-	-	29	-	-	**29**
Weighted Mean	**25**	**25.1**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**

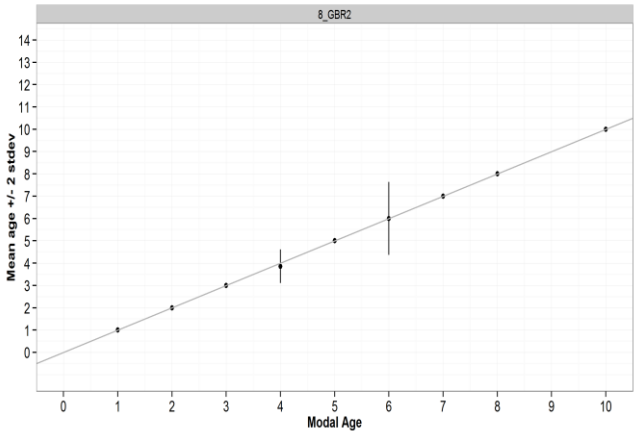

4_NOR3
Mean age +/- 2 stdev
Modal Age

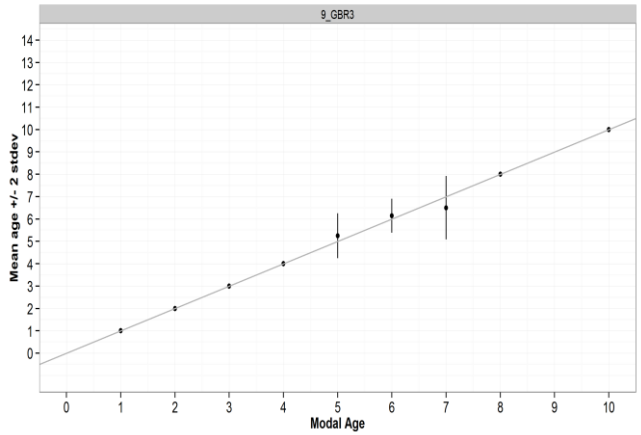

1_DNK1
Mean age +/- 2 stdev
Modal Age

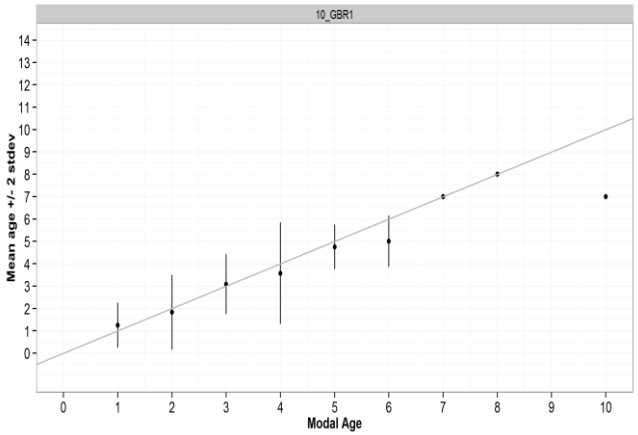

3_NOR2
Mean age +/- 2 stdev
Modal Age

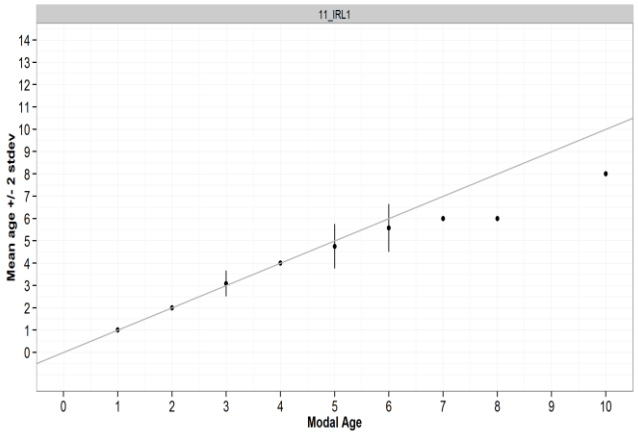

5_NOR4
Mean age +/- 2 stdev
Modal Age

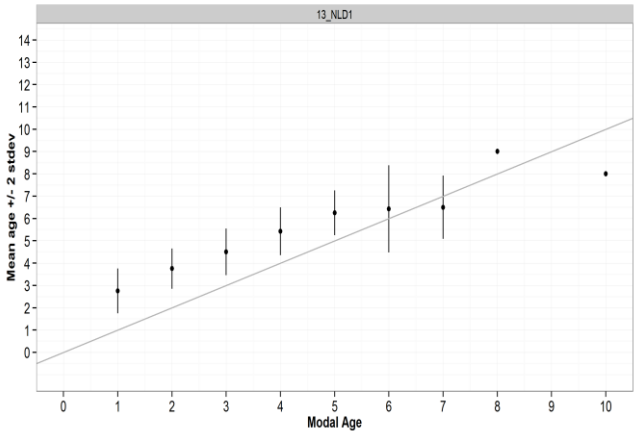

6_NOR5
Mean age +/- 2 stdev
Modal Age

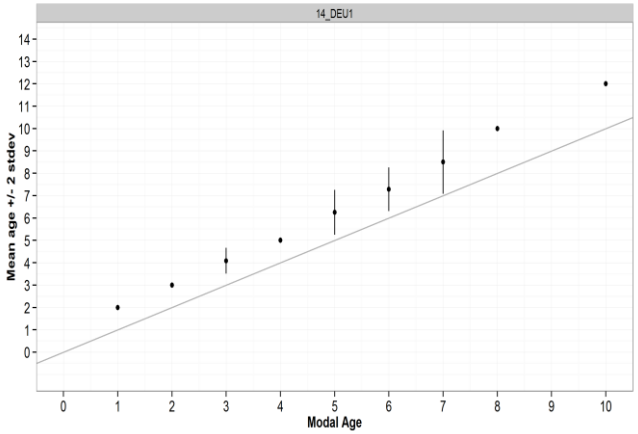

8_GBR2
Mean age +/- 2 stdev
Modal Age

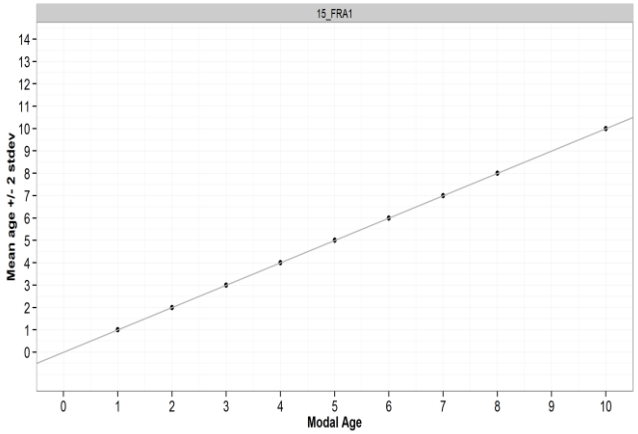

9_GBR3
Mean age +/- 2 stdev
Modal Age


10_GBR1
Mean age +/- 2 stdev
Modal Age


11_IRL1
Mean age +/- 2 stdev
Modal Age


13_NLD1
Mean age +/- 2 stdev
Modal Age


14_DEU1
Mean age +/- 2 stdev
Modal Age


15_FRA1
Mean age +/- 2 stdev
Modal Age

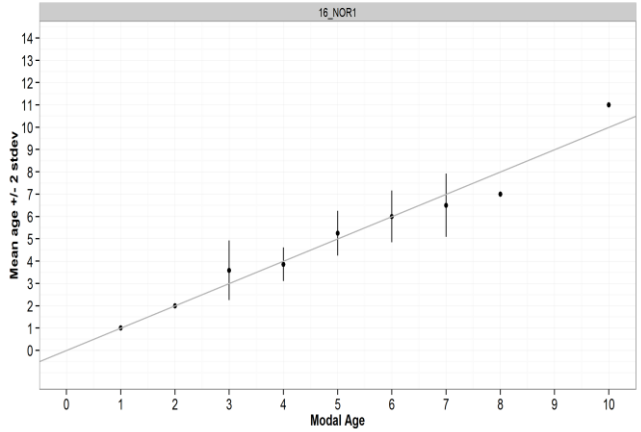


Figure 2.1 Age bias plots for all readers in the Celtic Sea exchange. The diagonal line represents the modal age and the vertical bars are the mean age +/- 2 standard deviations.

Annex 3 Irish Sea

Table 3.1 Fish data and all age readings for all fish in the Irish Sea exchange

Image	Length (SC)	Capture date	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Modal Age	% Agreement	CV
Herr_VIIa_01_.jpg	26.7	01/10/2010	4	4	4	4	4	4	4	4	4	6	5	4	4	**4**	**85**	**14**
Herr_VIIa_02_.jpg	28.1	01/10/2010	8	6	8	8	8	7	8	7	6	7	9	7	7	**7**	**38**	**12**
Herr_VIIa_03_.jpg	27.1	01/10/2010	6	5	6	6	6	6	6	7	6	6	7	6	6	**6**	**77**	**8**
Herr_VIIa_04_.jpg	26.9	01/10/2010	3	3	3	3	3	3	3	4	3	5	4	3	3	**3**	**77**	**19**
Herr_VIIa_05_.jpg	25.4	01/10/2010	4	4	4	4	4	4	4	4	4	6	5	4	4	**4**	**85**	**14**
Herr_VIIa_06_.jpg	27.4	01/10/2010	5	5	5	5	5	5	NA	4	5	6	6	5	7	**5**	**67**	**14**
Herr_VIIa_07_.jpg	16.7	01/09/2011	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_VIIa_08_.jpg	24	01/10/2010	2	2	2	2	2	2	2	1	2	3	3	2	2	**2**	**77**	**24**
Herr_VIIa_09_.jpg	15.5	01/09/2011	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_VIIa_10_.jpg	25.3	01/09/2011	4	4	4	4	4	4	4	4	3	4	5	4	4	**4**	**85**	**10**
Herr_VIIa_11_.jpg	29.2	01/10/2010	6	5	6	7	6	6	6	6	5	6	6	6	8	**6**	**69**	**12**
Herr_VIIa_12_.jpg	24.5	01/10/2010	4	3	4	4	4	4	4	3	4	5	5	4	4	**4**	**69**	**14**
Herr_VIIa_13_.jpg	26.6	01/10/2010	4	4	4	4	4	4	4	4	4	5	5	4	4	**4**	**85**	**9**
Herr_VIIa_14_.jpg	25.5	01/10/2010	4	4	4	4	4	4	4	4	4	5	5	4	4	**4**	**85**	**9**
Herr_VIIa_15_.jpg	21.8	01/10/2010	2	2	2	2	2	2	2	1	2	3	3	2	2	**2**	**77**	**24**
Herr_VIIa_16_.jpg	23.3	01/10/2010	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIIa_17_.jpg	20.5	01/10/2010	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_VIIa_18_.jpg	28.5	01/10/2010	5	5	5	5	5	5	5	5	5	6	6	5	6	**5**	**77**	**8**
Herr_VIIa_19_.jpg	22.6	01/10/2010	2	2	2	2	2	2	2	1	2	3	3	2	1	**2**	**69**	**29**

Herr_VIIa_20_.jpg	23.8	01/03/2011	3	4	4	4	4	4	4	3	4	5	4	4	3	**4**	**69**	**14**
Herr_VIIa_21_.jpg	22	01/10/2010	2	2	2	2	2	3	2	2	2	3	3	2	2	**2**	**77**	**20**
Herr_VIIa_22_.jpg	24.4	01/03/2011	3	3	3	3	3	3	3	4	3	4	4	3	3	**3**	**77**	**14**
Herr_VIIa_23_.jpg	23.4	01/10/2010	3	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**77**	**20**
Herr_VIIa_24_.jpg	24.6	01/03/2011	4	5	5	5	5	4	5	4	5	5	6	5	4	**5**	**62**	**13**
Herr_VIIa_25_.jpg	23.6	01/03/2011	4	4	4	4	4	4	4	3	4	4	5	4	4	**4**	**85**	**10**
Herr_VIIa_26_.jpg	22.8	01/03/2011	3	3	3	3	3	3	3	2	3	4	4	3	3	**3**	**77**	**16**
Herr_VIIa_27_.jpg	22.3	01/03/2011	3	3	3	3	3	3	3	2	3	4	4	3	3	**3**	**77**	**16**
Herr_VIIa_28_.jpg	23.7	01/03/2011	4	4	4	4	4	4	4	3	4	5	5	4	4	**4**	**77**	**12**
Herr_VIIa_29_.jpg	19.5	01/03/2011	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIIa_30_.jpg	20.9	01/03/2011	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIIa_31_.jpg	21.1	01/03/2011	3	3	3	3	3	3	3	2	3	4	4	3	3	**3**	**77**	**16**
Herr_VIIa_32_.jpg	22	01/03/2011	3	3	3	3	3	3	3	2	3	4	4	3	3	**3**	**77**	**16**
Herr_VIIa_33_.jpg	22.2	01/03/2011	3	3	3	3	3	3	3	2	3	4	4	3	3	**3**	**77**	**16**
Herr_VIIa_34_.jpg	27.3	01/09/2011	4	3	4	4	4	5	4	6	4	5	5	4	4	**4**	**62**	**17**
Herr_VIIa_35_.jpg	26.9	01/09/2011	8	7	8	8	8	8	8	7	6	8	9	8	9	**8**	**62**	**10**
Herr_VIIa_36_.jpg	25.6	01/09/2006	4	4	4	4	4	4	4	5	4	5	5	4	4	**4**	**77**	**10**
Herr_VIIa_37_.jpg	25.8	01/09/2006	4	4	4	4	4	4	4	4	4	5	5	4	4	**4**	**85**	**9**
Herr_VIIa_38_.jpg	23.7	01/09/2011	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIIa_39_.jpg	27.6	01/09/2011	6	6	6	6	6	6	6	5	5	7	7	6	6	**6**	**69**	**10**
Herr_VIIa_40_.jpg	26.2	01/09/2011	6	5	6	6	6	6	6	5	6	7	7	6	6	**6**	**69**	**10**
Herr_VIIa_41_.jpg	28	01/09/2011	6	5	6	6	6	6	6	6	5	7	7	6	5	**6**	**62**	**11**
Herr_VIIa_42_.jpg	25.1	01/09/2006	5	4	5	5	5	5	5	4	5	6	6	5	5	**5**	**69**	**12**
Herr_VIIa_43_.jpg	24.8	01/09/2006	3	3	3	3	3	3	3	3	3	4	4	3	3	**3**	**85**	**12**
Herr_VIIa_44_.jpg	24.1	01/09/2006	4	4	4	4	4	4	4	3	4	5	5	4	4	**4**	**77**	**12**

Herr_VIIa_45_.jpg	22.9	01/09/2006	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIIa_46_.jpg	23.7	01/09/2006	3	3	3	3	3	3	3	3	3	4	4	3	3	**3**	**85**	**12**
Herr_VIIa_47_.jpg	21	01/09/2006	1	1	1	1	1	1	1	2	1	2	NA	1	1	**1**	**83**	**33**
Herr_VIIa_48_.jpg	22	01/09/2006	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIIa_49_.jpg	17.1	01/09/2011	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
Herr_VIIa_50_.jpg	18.6	01/09/2011	1	1	1	1	1	1	1	1	1	2	2	1	1	**1**	**85**	**33**
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**	**-**	**-**
Means (CV and PA)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**77.02**	**17**
Total read	**-**	**-**	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**49**	**50**	**50**		**-**	
Total NOT read	**-**	**-**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**		**-**	

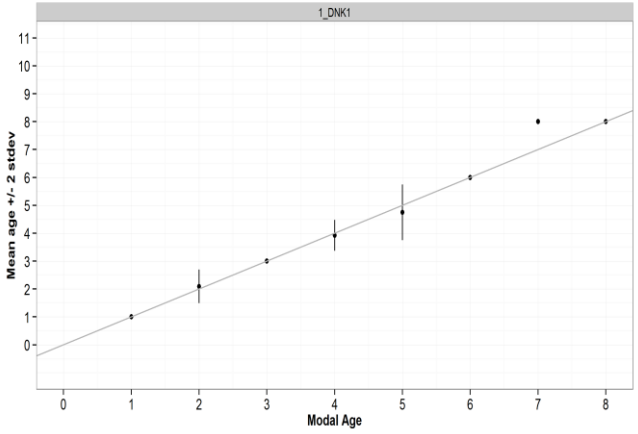
Table 3.2 Age composition for all readers in the Irish Sea exchange

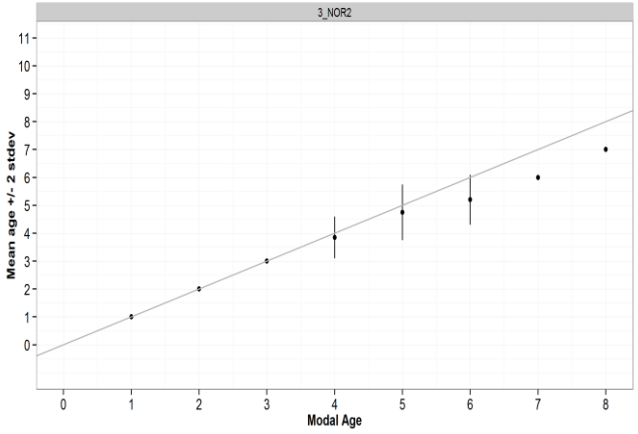
Age	**1_ DNK 1**	**3_ NOR 2**	**4_ NOR 3**	**5_ NOR 4**	**6_ NOR 5**	**8_ GBR 2**	**9_ GBR 3**	**10_ GBR 1**	**11_ IRL 1**	**13_ NLD 1**	**14_ DEU 1**	**15_ FRA 1**	**16_ NOR 1**	**Total**
1	6	6	6	6	6	6	6	8	6	0	0	6	7	**69**
2	10	11	11	11	11	10	11	14	11	6	5	11	10	**132**
3	11	11	9	9	9	10	9	7	10	11	11	9	10	**126**
4	13	12	13	13	13	13	13	11	12	10	10	13	13	**159**
5	3	7	4	4	4	4	3	4	7	11	12	4	2	**69**
6	5	2	5	4	5	5	5	3	4	7	5	5	4	**59**
7	0	1	0	1	0	1	0	3	0	4	4	1	2	**17**
8	2	0	2	2	2	1	2	0	0	1	0	1	1	**14**

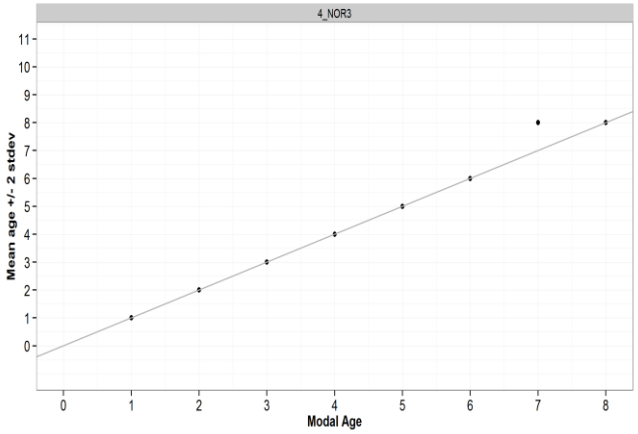
9	0	0	0	0	0	0	0	0	0	0	2	0	1	**3**
All	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**49**	**50**	**50**	**648**

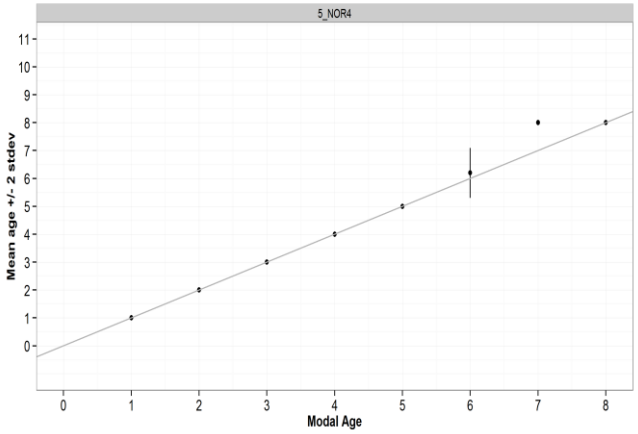
Table 3.3 Mean length at age for all readers in the Irish Sea exchange

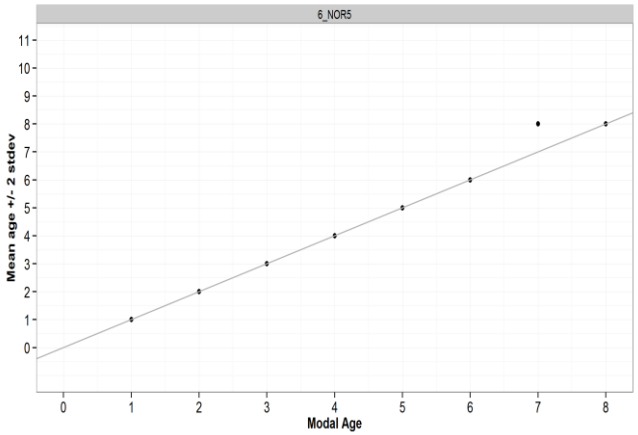
Age	1_ DNK1	3_ NOR2	4_ NOR3	5_ NOR4	6_ NOR5	8_ GBR2	9_ GBR3	10_ GBR1	11_ IRL1	13_ NLD1	14_ DEU1	15_ FRA1	16_ NOR1	Total
1	18.2	18.2	18.2	18.2	18.2	18.2	18.2	19.6	18.2	-	-	18.2	18.9	**18.5**
2	22.3	22.4	22.4	22.4	22.4	22.4	22.4	22.1	22.4	18.2	17.7	22.4	22.4	**22**
3	23.4	23.8	23.4	23.4	23.4	23.2	23.4	24	23.6	22.4	22.4	23.4	23.4	**23.3**
4	25.3	25.1	25.2	25.2	25.2	25	25.2	25.8	25.2	23.2	23.4	25.2	25.3	**25**
5	27	27.3	26.4	26.4	26.4	27.1	26.1	27	27.2	25.3	25.3	26.4	26.6	**26.3**
6	27.6	27.9	27.6	27.2	27.6	27.6	27.6	28.2	27.1	27.1	27	27.6	27.4	**27.5**
7	-	26.9	-	29.2	-	28.1	-	27.4	-	27.5	27.2	28.1	27.8	**27.6**
8	27.5	-	27.5	27.5	27.5	26.9	27.5	-	-	26.9	-	26.9	29.2	**27.5**
9	-	-	-	-	-	-	-	-	-	-	27.5	-	26.9	**27.3**
Weighted Mean	**23.9**	**23.8**	**23.8**	**23.8**	**23.8**	**23.8**	**23.8**	**23.9**	**23.9**	**23.9**	**23.9**	**23.8**	**23.9**	**23.9**

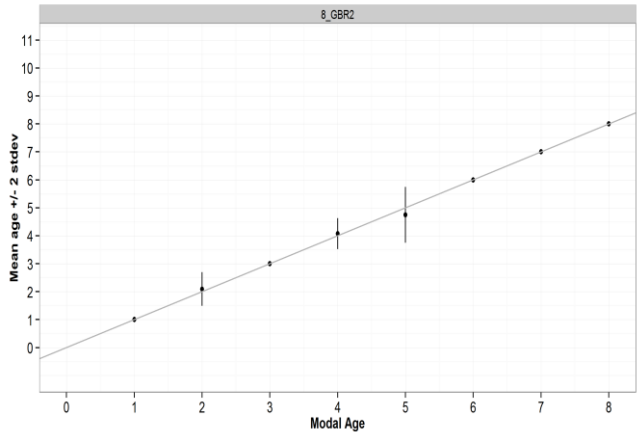

1_DNK1
Mean age +/- 2 stdev
Modal Age

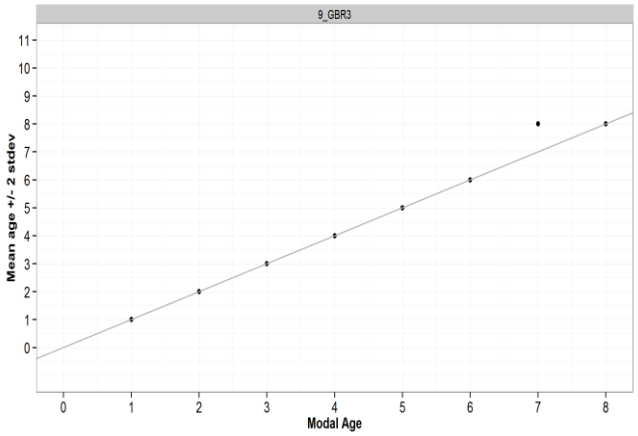

3_NOR2
Mean age +/- 2 stdev
Modal Age

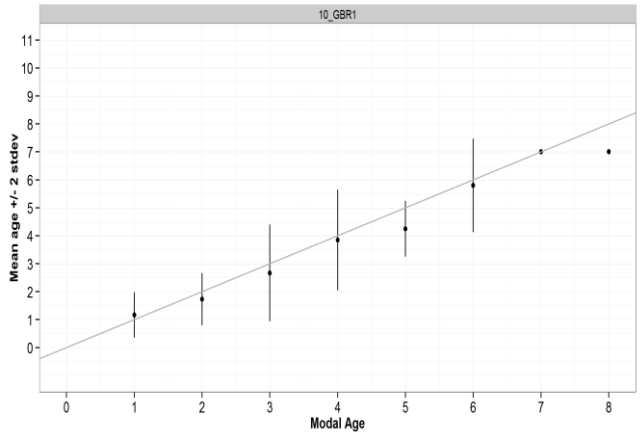

4_NOR3
Mean age +/- 2 stdev
Modal Age

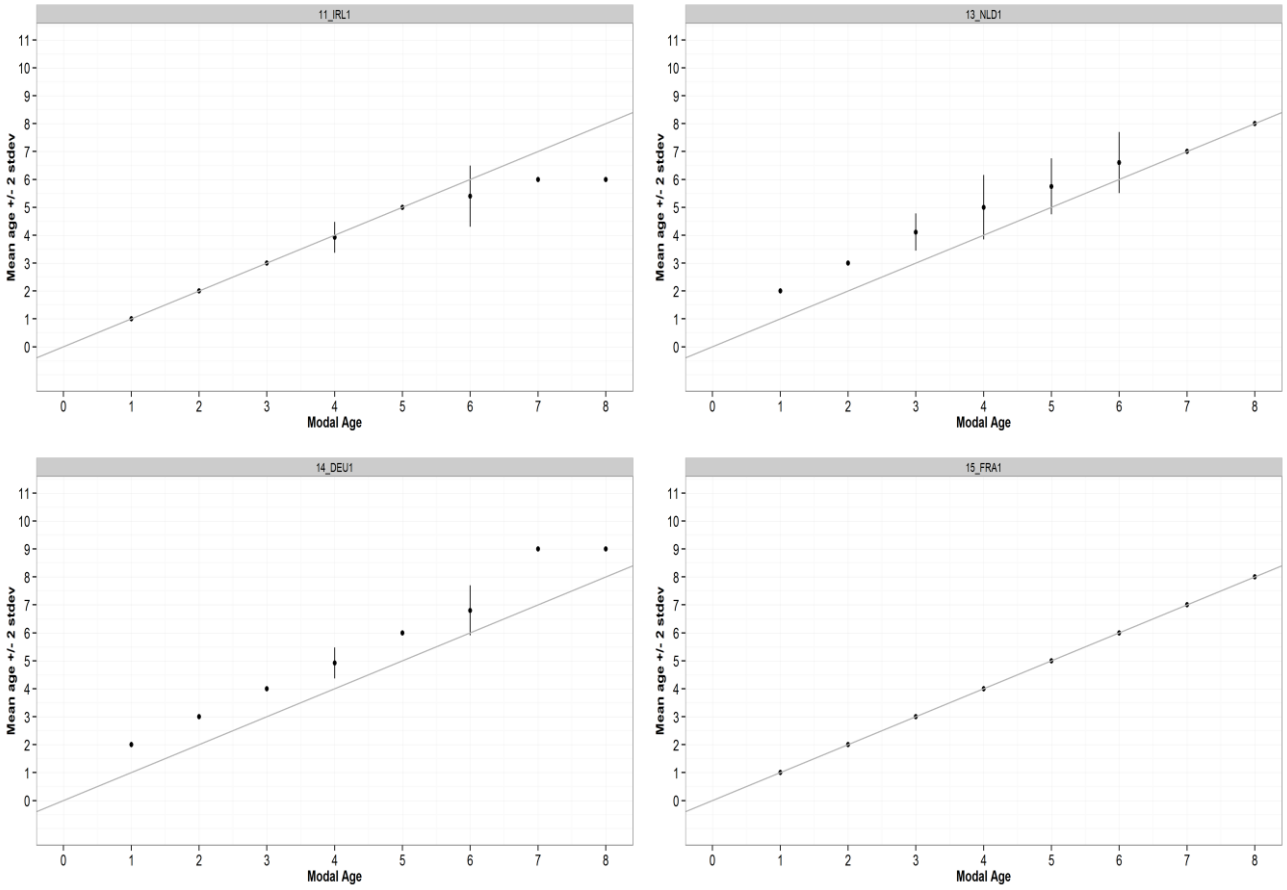

5_NOR4
Mean age +/- 2 stdev
Modal Age


6_NOR5
Mean age +/- 2 stdev
Modal Age


8_GBR2
Mean age +/- 2 stdev
Modal Age


9_GBR3
Mean age +/- 2 stdev
Modal Age


10_GBR1
Mean age +/- 2 stdev
Modal Age


11_IRL1
13_NLD1
14_DEU1
15_FRA1
Mean age +/- 2 stdev
Modal Age

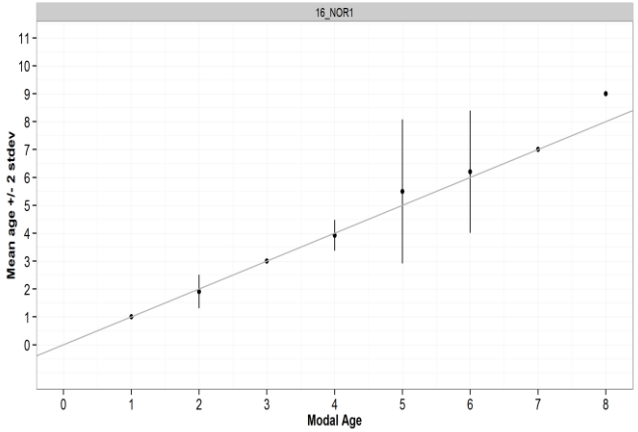


Figure 3.1 Age bias plots for all readers in the Irish Sea exchange. The diagonal line represents the modal age and the vertical bars are the mean age +/- 2 standard deviations.

Annex 4 VIa (N and S)

Table 4.1 Fish data and all age readings for all fish in the VIa (N and S) exchange

Image	Length (SC)	Capture date	1_ DNK 1	3_ NOR 2	4_ NOR 3	5_ NOR 4	6_ NOR 5	8_ GBR 2	9_ GBR 3	10_ GBR 1	11_ IRL 1	13_ NLD 1	14_ DEU 1	15_ FRA 1	16_ NOR 1	Modal Age	% Agreement	CV
Herr_VIa_01_.jpg	30	27/08/2014	6	6	6	6	6	6	6	5	5	7	7	6	6	**6**	**69**	**10**
Herr_VIa_02_.jpg	26.5	27/08/2014	3	3	3	3	3	3	3	4	3	4	4	3	3	**3**	**77**	**14**
Herr_VIa_03_.jpg	30.5	27/08/2014	8	8	10	8	10	9	8	7	8	7	9	9	8	**8**	**46**	**11**
Herr_VIa_04_.jpg	32	27/08/2014	6	6	5	6	6	6	6	6	5	6	7	6	5	**6**	**69**	**9**
Herr_VIa_05_.jpg	32.5	27/08/2014	8	8	8	8	10	9	8	8	8	7	9	8	8	**8**	**69**	**9**
Herr_VIa_06_.jpg	28.5	27/08/2014	5	5	5	5	5	6	5	5	5	5	6	5	6	**5**	**77**	**8**
Herr_VIa_07_.jpg	27.5	01/09/2014	3	3	3	3	3	3	3	4	3	4	4	3	3	**3**	**77**	**14**
Herr_VIa_08_.jpg	26	01/09/2014	4	4	3	4	4	4	4	4	4	5	5	4	4	**4**	**77**	**12**
Herr_VIa_09_.jpg	31.5	01/09/2014	7	6	7	7	7	7	6	5	6	8	8	6	7	**7**	**46**	**13**
Herr_VIa_10_.jpg	29.5	01/09/2014	4	4	4	5	4	4	4	5	5	5	5	4	5	**4**	**54**	**12**
Herr_VIa_11_.jpg	31	01/09/2014	5	5	5	5	5	5	5	5	5	5	6	5	5	**5**	**92**	**5**
Herr_VIa_12_.jpg	24	19/11/2014	2	2	2	2	2	2	2	2	2	3	3	2	2	**2**	**85**	**17**
Herr_VIa_13_.jpg	13.5	19/11/2014	0	0	0	0	0	0	0	0	0	2	1	0	1	**0**	**77**	**-**
Herr_VIa_14_.jpg	29.5	19/11/2014	5	4	5	5	5	4	5	4	5	7	6	5	5	**5**	**62**	**16**
Herr_VIa_15_.jpg	30	19/11/2014	4	4	4	4	4	4	4	7	4	5	5	4	5	**4**	**69**	**20**
Herr_VIa_16_.jpg	21	29/11/2014	1	1	1	1	1	1	1	1	2	3	2	1	1	**1**	**77**	**48**
Herr_VIa_17_.jpg	27	29/11/2014	3	3	4	3	3	3	3	5	3	4	NA	3	3	**3**	**75**	**20**
Herr_VIa_18_.jpg	29	19/11/2014	5	5	5	5	5	4	5	4	5	5	6	5	5	**5**	**77**	**10**
Herr_VIa_19_.jpg	34.5	22/02/2015	7	9	10	8	9	7	8	7	6	8	7	7	7	**7**	**46**	**14**

Herr_Vla_20_.jpg	28	22/02/2015	6	6	6	6	5	6	6	5	6	4	8	6	5	**6**	**62**	**16**
Herr_Vla_21_.jpg	30.5	25/02/2015	4	7	4	4	4	4	4	7	4	5	6	4	4	**4**	**69**	**25**
Herr_Vla_22_.jpg	19.5	25/02/2015	2	2	2	1	2	2	2	2	2	3	3	2	1	**2**	**69**	**29**
Herr_Vla_23_.jpg	13	25/02/2015	1	1	1	2	1	1	1	1	1	2	2	1	1	**1**	**77**	**36**
Herr_Vla_24_.jpg	17	25/02/2015	1	1	1	2	1	1	2	2	1	2	2	1	3	**1**	**54**	**43**
Herr_Vla_25_.jpg	23	07/03/2015	3	3	3	3	3	3	3	3	3	4	4	3	2	**3**	**77**	**16**
Herr_Vla_26_.jpg	27.5	24/11/2014	3	3	3	3	3	3	3	4	4	4	4	3	3	**3**	**69**	**15**
Herr_Vla_27_.jpg	22.5	24/11/2014	2	2	2	3	2	2	2	2	2	3	3	2	3	**2**	**69**	**21**
Herr_Vla_28_.jpg	29.5	24/11/2014	5	5	5	5	5	4	5	4	5	5	6	5	5	**5**	**77**	**10**
Herr_Vla_29_.jpg	28.5	24/11/2014	5	5	6	5	5	4	5	4	4	5	6	5	6	**5**	**54**	**14**
Herr_Vla_30_.jpg	24.5	24/11/2014	2	2	2	2	2	2	2	2	2	3	3	2	3	**2**	**77**	**20**
Herr_Vla_31_.jpg	28	24/11/2014	4	4	4	5	5	4	5	4	4	4	6	4	4	**4**	**69**	**15**
Herr_Vla_32_.jpg	26	28/02/2015	4	4	4	3	4	4	4	4	3	4	5	4	3	**4**	**69**	**14**
Herr_Vla_33_.jpg	25	24/11/2014	3	3	3	3	3	4	3	3	3	4	4	3	3	**3**	**77**	**14**
Herr_Vla_34_.jpg	20.5	27/11/2014	1	1	1	1	1	1	1	1	1	3	2	1	1	**1**	**85**	**49**
Herr_Vla_35_.jpg	29	27/11/2014	5	5	6	5	6	4	5	5	5	6	7	5	5	**5**	**62**	**14**
Herr_Vla_36_.jpg	19.5	25/02/2015	2	2	2	1	2	2	2	2	2	3	3	2	1	**2**	**69**	**29**
Herr_Vla_37_.jpg	14.5	25/02/2015	1	1	1	0	1	1	1	1	1	2	2	1	0	**1**	**69**	**58**
Herr_Vla_38_.jpg	18	28/02/2015	1	1	1	0	1	1	1	1	1	2	2	1	0	**1**	**69**	**58**
Herr_Vla_39_.jpg	28	28/02/2015	5	5	5	4	5	5	5	4	5	4	6	5	4	**5**	**62**	**13**
Herr_Vla_40_.jpg	27	28/02/2015	4	4	4	3	4	4	4	4	4	5	5	4	3	**4**	**69**	**14**
Herr_Vla_41_.jpg	21.5	28/02/2015	2	2	2	1	2	2	2	2	4	3	3	2	1	**2**	**62**	**37**
Herr_Vla_42_.jpg	30.5	28/02/2015	6	5	6	5	6	6	6	5	5	6	7	5	5	**5**	**46**	**12**
Herr_Vla_43_.jpg	23.5	28/02/2015	2	2	2	1	2	2	2	2	2	3	3	2	1	**2**	**69**	**29**
Herr_Vla_44_.jpg	31	28/02/2015	6	6	6	5	6	6	6	5	6	7	7	6	5	**6**	**62**	**11**

Herr_VIa_45_.jpg	32	28/02/2015	6	6	6	5	6	5	6	8	6	7	7	6	5	**6**	**54**	**14**
Herr_VIa_46_.jpg	33.5	28/02/2015	8	9	9	7	8	8	8	8	9	7	9	8	6	**8**	**46**	**11**
Herr_VIa_47_.jpg	28.5	28/02/2015	4	4	3	3	4	4	4	5	3	5	5	4	3	**4**	**46**	**19**
Herr_VIa_48_.jpg	33	28/02/2015	5	6	6	4	5	6	6	4	5	6	6	5	4	**6**	**46**	**16**
Herr_VIa_49_.jpg	22	28/02/2015	6	6	6	5	5	6	6	4	6	6	7	6	5	**6**	**62**	**13**
Herr_VIa_50_.jpg	26	28/02/2015	3	3	3	NA	3	3	3	4	3	0	4	3	3	**3**	**75**	**34**
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**	**-**	**-**
Means (CV and PA)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**67**	**20**
Total read	**-**	**-**	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**50**		**-**	
Total NOT read	**-**	**-**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**		**-**	

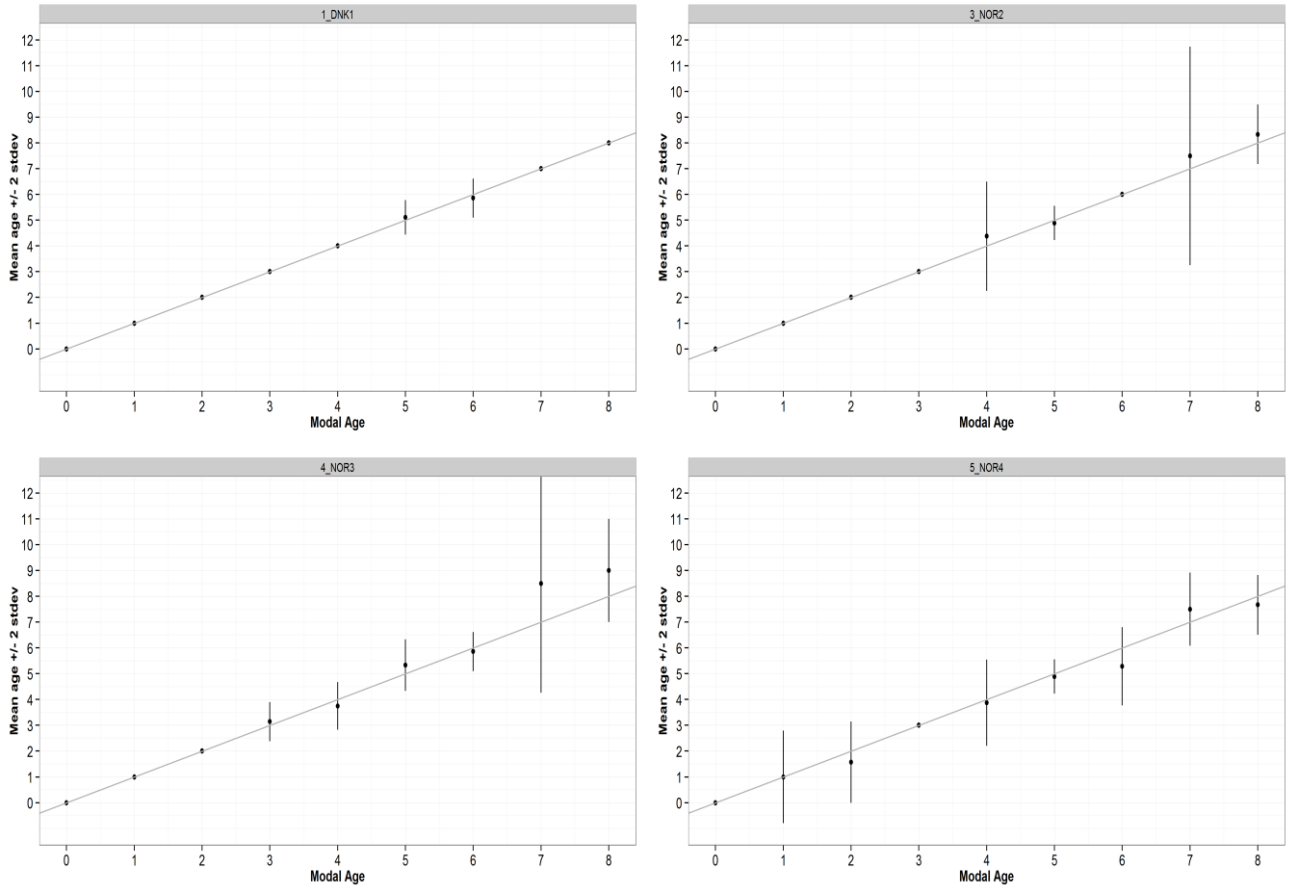
Table 4.2 Age composition for all readers in the VIa (N and S) exchange

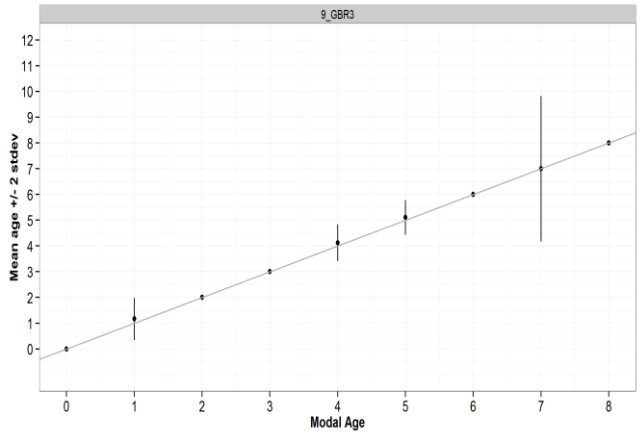
Age	**1_ DNK 1**	**3_ NOR 2**	**4_ NOR 3**	**5_ NOR 4**	**6_ NOR 5**	**8_ GBR 2**	**9_ GBR 3**	**10_ GBR 1**	**11_ IRL 1**	**13_ NLD 1**	**14_ DEU 1**	**15_ FRA 1**	**16_ NOR 1**	**Total**
0	1	1	1	3	1	1	1	1	1	1	0	1	2	**15**
1	6	6	6	6	6	6	5	5	5	0	1	6	8	**66**
2	7	7	7	4	7	7	8	8	7	5	6	7	2	**82**
3	7	7	8	10	7	6	7	2	8	9	7	7	12	**97**
4	8	8	7	5	7	14	7	15	8	10	6	8	5	**108**
5	9	8	7	13	11	3	9	11	12	11	6	10	13	**123**
6	7	8	9	3	6	8	9	1	6	5	10	7	4	**83**
7	2	1	1	2	1	2	0	4	0	7	8	1	2	**31**
8	3	2	1	3	1	1	4	3	2	2	2	2	2	**28**

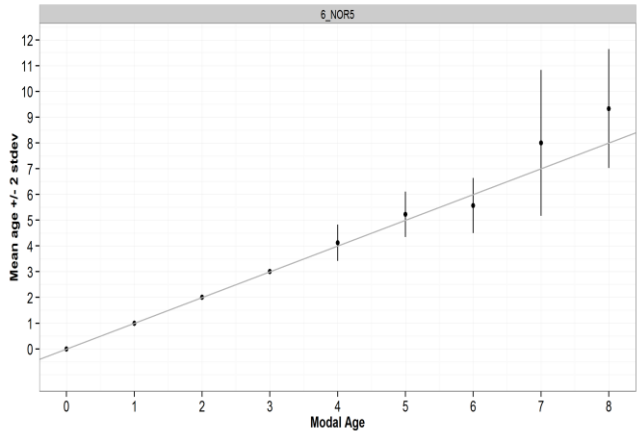
9	0	2	1	0	1	2	0	0	1	0	3	1	0	**11**
10	0	0	2	0	2	0	0	0	0	0	0	0	0	**4**
All	**50**	**50**	**50**	**49**	**50**	**50**	**50**	**50**	**50**	**50**	**49**	**50**	**50**	**648**

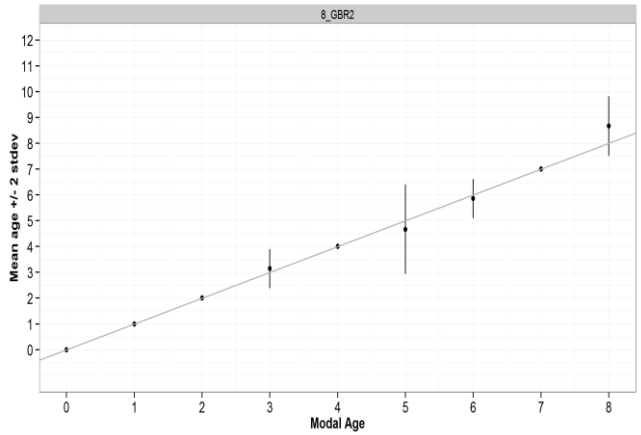
Table 4.3 Mean length at age for all readers in the VIa (N and S) exchange

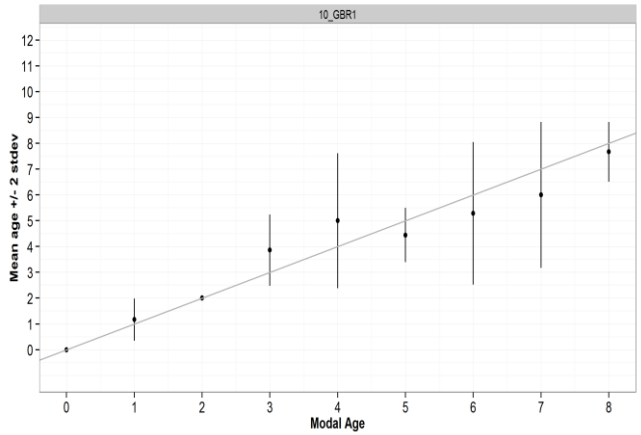
Age	1_ DNK1	3_ NOR2	4_ NOR3	5_ NOR4	6_ NOR5	8_ GBR2	9_ GBR3	10_ GBR1	11_ IRL1	13_ NLD1	14_ DEU1	15_ FRA1	16_ NOR1	Total
0	13.5	13.5	13.5	15.3	13.5	13.5	13.5	13.5	13.5	26	-	13.5	16.2	**15.1**
1	17.3	17.3	17.3	20.9	17.3	17.3	17.4	17.4	16.6	-	13.5	17.3	19	**17.8**
2	22.1	22.1	22.1	19.6	22.1	22.1	21.5	21.5	22.1	15.2	17.3	22.1	23.5	**21.1**
3	26.1	26.1	26.2	26.1	26.1	26.2	26.1	24	26.2	21.8	22.1	26.1	25.4	**25.3**
4	28.2	28.1	28.3	29.5	28.2	28.3	28.2	27.6	27.4	26.6	25.9	28.2	29.1	**27.9**
5	29.6	29.2	29.6	29.1	28.6	30.3	29	29.5	30	28.9	27.8	29.6	29.5	**29.3**
6	29.4	29.9	29.3	30	30.8	29.4	30	32	29.8	29.3	29.6	29.5	30.1	**29.7**
7	33	30.5	31.5	32.5	31.5	33	-	31.4	-	31.3	30.1	34.5	33	**31.5**
8	32.2	31.5	32.5	32.5	33.5	33.5	32.8	32.7	31.5	33	29.8	33	31.5	**32.2**
9	-	34	33.5	-	34.5	31.5	-	-	33.5	-	32.2	30.5	-	**32.7**
10	-	-	32.5	-	31.5	-	-	-	-	-	-	-	-	**32**
Weighted Mean	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**	**26.3**

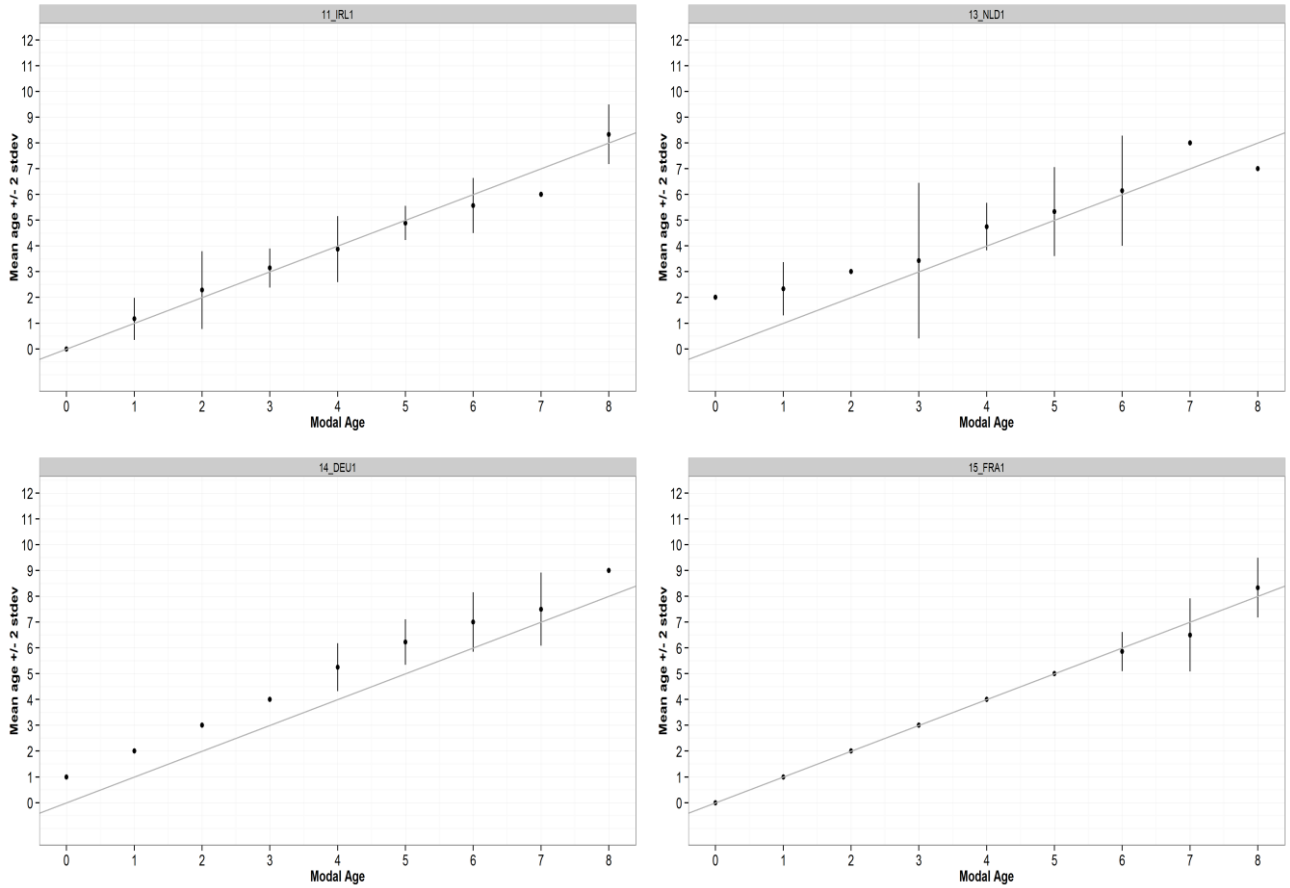

1_DNK1
3_NOR2
4_NOR3
5_NOR4
Mean age +/- 2 stdev
Modal Age


9_GBR3
Mean age +/- 2 stdev
Modal Age


6_NOR5
Mean age +/- 2 stdev
Modal Age


8_GBR2
Mean age +/- 2 stdev
Modal Age


10_GBR1
Mean age +/- 2 stdev
Modal Age


11_IRL1
13_NLD1
14_DEU1
15_FRA1
Mean age +/- 2 stdev
Modal Age

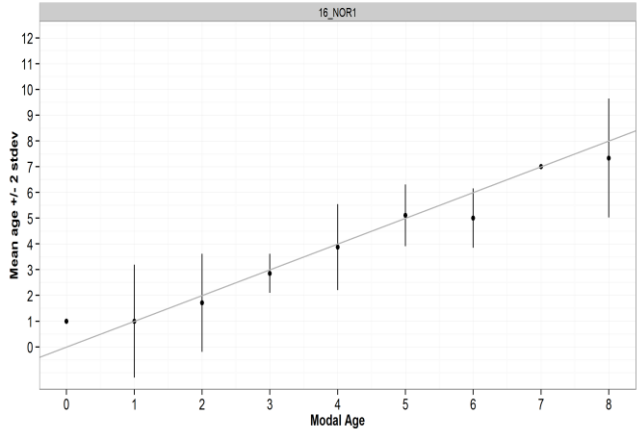


Figure 4.1 Age bias plots for all readers in the VIa (N and S) exchange. The diagonal line represents the modal age and the vertical bars are the mean age +/- 2 standard deviations.