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Report of the Workshop on Age estimation of Whiting (*Merlangius merlangus*) (WKARWHG2)

22-25 November 2016

Lowestoft, UK

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

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Executive summary

Based on the results of a full-scale otolith exchange held in 2015 (Smith, 2015) The Working Group on Biological Parameters (WGBIOP) identified the need for an age reading workshop on whiting otoliths (WKARWHG2). This workshop was hosted by Centre for Environment Fisheries and Aquaculture Science (Lowestoft, UK 22–25 November 2016. Seventeen age readers from nine countries (Belgium, France, Denmark, Norway, Germany, UK, Northern Ireland, Southern Ireland, and Scotland) participated in the workshop. The workshop was chaired by Joanne Smith (UK) and Suzy End (UK) acted as a Workshop supporting expert.

Two otoliths sets, an exercise set of 105 otoliths and a subsample set of 50 otoliths from the original exchange otolith set were aged during the workshop. The exercise set were read first, to highlight any issues/disagreements between age readers and the possible reasons for these. Following recommendations from WGBIOP otoliths from area ICES Division 4b were included in this exercise as this area was not covered in the original exchange set. Readers had the option of ageing the otolith using both an image and the actual otolith under a stereomicroscope. Only a small number of readers chose to use both methods, most choosing to age using images only. After the exercise set was read, the results were presented and differences between interpretations were discussed.

In addition, a small group of experienced section and whole otolith readers carried out a reading exercise (20 otoliths) to compare the percentage agreement obtained by readers using different otolith preparation methods. Since the results from this small exercise were not encouraging, the conclusion from this exercise was that action needed to be taken to ensure that agreements remain high regardless of preparation method used. Also, there were few examples from 4a in the original exchange, which is an area used by Norway, Denmark, and Scotland The additional mini exchange will provide them with a more complete dataset to work with which should help with future exchanges. Post workshop, readers who routinely read whiting otoliths, whole or broken, agreed to conduct an otolith exchange in an attempt to clarify, the level of agreement between these readers and where disagreements occur, the possible reasons for these.

The group also carried out discussions on sectioned vs. whole otoliths as reading methods for whiting. The main conclusions from the exercise and the discussion on whole vs. sectioned otoliths were (Appendix VIII):

- There can be difficulties interpreting the first annual ring due to splits and the wide range of growth that can occur;
- The edge can often be misread causing under/over age estimations;
- Misinterpretation of split rings and Humphries shadow can lead to over ageing of the otolith;
- If the otolith is not cut correctly it can often cause readers problems interpreting true rings.

Subsequently, the subsample of exchange otoliths was re-read to examine if the discussions throughout the week had led to improvement in the consistency of age reading. For this exercise it was agreed that only a subsample of the exchange otoliths (50 otoliths) would be read, to allow more time during the week to be spent on discussions. The subsample set was selected using the following criteria:

- The age range which occurred in the exchange was between 1 and 8 years, but since only one otolith was at age 1 and two otoliths were at age 8, all three of so these were included;
- The remaining otoliths were selected across the age range 2–7 years;
- Two otoliths from each quarter were selected, one with high percentage agreement and one with low;
- After this selection, nine otoliths were required to complete the set so these were selected from ages 2–3 and 6–7, selected as above, representing problematic ages.

The results of this exercise did show an improvement in age reading compared to the same 50 read in the 2015 exchange.

No validation studies have been carried out for whiting age reading as of yet. We propose an otolith chemistry study to validate the true deposition of opaque and translucent material throughout the otolith. WKARWHG2 strongly recommends such a study, as the results will facilitate resolving the most frequent problem encountered when ageing whiting, namely the split rings/Humphry shadow'.

1 Introduction

1.1 Background

Whiting is distributed in the Northeast Atlantic and caught in large numbers in the North Sea, Skagerrak, and Kattegat. Large numbers of both small and large whiting can be found everywhere, with the exception of the Dogger Bank. Large quantities of juvenile can be found during summer in the German Bight and off the Dutch coast, with larger whiting occurring in high densities in south of Shetland during winter. During summer, there is a very high population of adults in the southern half of the North Sea and off the Scottish coast. Western approach whiting spawn mainly off Start Point, off Trevose Head and southeast of Ireland. Spawning takes place from January in the southern North Sea to July in the northern part and between February to May in western channel and the Celtic Sea. Most are mature when they are two years old and some spawn in the second year of life.

Whiting tend to stay close to the bottom of the seabed from 10 to 200 m but will move into midwater in the pursuit of prey. Larger whiting feed mainly on small fish such as herring, cod, haddock, and even their own offspring. Whiting growth is fairly slow in their first year of life and this can vary greatly between individuals.

Whiting is a commercially important species that is caught in a mixed fishery, with large numbers caught throughout the North Sea. Commercial landings have gradually declined since the late 1970s to a historic minimum. Catch rates during the IBTS Q1 survey in the North Sea has fluctuated greatly throughout 1975–2005 and no consistent trend is apparent (ICES, 2004). Whiting has been assessed since the early 1980s using age-aggregated data, which implies a need for routinely quality check of the interpretation of age of whiting by laboratories supplying age-based data to the stock assessment of the whiting stocks.

1.2 Terms of Reference

a) Review information on age estimations and validation work done so far;
b) Analyse the results of exchange programme between ageing labs, using a set of otoliths (images) collection;
c) Clarify the interpretation of annual rings;
d) Improve the current age reading protocol;
e) Create a reference collection of agreed age otoliths;
f) Address the generic ToRs adopted for workshops on age calibration (see 'WGBIOP Guidelines for Workshops on Age Calibration').

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

Otolith exchanges and workshops

Several exchanges and workshops have been executed to date (Table 1.3.1) but the last workshop was in 2005.

Year start	Year end	Exchange / workshop	Readers	Sampled	Otolith prep.	Agreement	Reference
2014	2015	Exchange	16	135	Sectioned	Agreement = 85.9% CV= 13.1% Relative bias = 0.0%	Report of Whiting (*Merlangius merelangius*) Otolith Exchange 2014-2015 Smith, 2014
2005	2005	Workshop	17	120	Sectioned /Broken	Agreement = 80.7% CV= 10.3% Relative bias = 0.0%	Report of the Whiting (*Merlangius merlangus*, L) Otolith Exchange Scheme 2004 and Workshop 2005 Easey *et al.*, 2005
2004	2004	Exchange	11	200	Broken	Agreement = 72.6% CV= 16.3%	Report of the Whiting (*Merlangius merlangus*, L) Otolith Exchange Scheme 2004 and Workshop 2005 Easey *et al.*, 2005
2004	2004	Exchange	18	120	Slides	Agreement = 80.9% CV= 13.7%	Report of the Whiting (*Merlangius merlangus*, L) Otolith Exchange Scheme 2004 and Workshop 2005 Easey *et al.*, 2005
1998	1998	Exchange/Workshop	12	120	Broken	Agreement = 58%	Report of the workshop on otolith ageing of North Sea whiting 1998 ICES CM 1999/G:14
1998	1998	Exchange/Workshop	10	62	Slides	Agreement = 67%	Report of the workshop on otolith ageing of North Sea whiting 1998 ICES CM 1999/G:14
1985	1985	Workshop		673 (Irish sea) 173 (Celtic sea)		Agreement = 80% (Irish sea) 75% (Celtic sea)	
1960	1960	Workshop		244		Agreement = from 38% to 71%	
1959	1959	Exchange				Agreement = from 54% to 94%	

Table 1.3.1. Past whiting otolith exchanges and workshops.

1.4 Validation

In 2013, the Workshop on Age Validation Studies of Gadoids (WKAVSG; ICES, 2013) assembled and compared the results of different validation methods for gadoids species especially the whiting. Only two studies (Ross and Hüssy, 2012; Mahé *et al.*, 2013) presented in this chapter came from to this workshop. There are several different methods (direct and indirect) to validate fish age.

The marginal increment analysis (Figure 1.4.1) is an indirect method used to validate the periodicity of growth rings. For this species, a French study (Mahé *et al.*, 2013) was carried out from 2011 and 2012 on the south of the North Sea-Eastern English Channel (4-7d) and on the Celtic Sea (7f–h). All otoliths were analysed by the TNPC software (www.tnpc.fr; Mahé *et al.*, 2011). The marginal increment (MI) is calculated using the formula:

MI = (Ro-rn)/(rn-rn-1))

where Ro = otolith radius, r = distance from centre to the middle of increment n.

From the otolith section, alternating translucent and opaque bands were visible. The distance between growth rings decreased from the otolith core towards the outer margin. One growth increment consisted of one opaque and one translucent band, from which the opaque area was considered to have been deposited between June and November (Figure 1). The validity of the age determination based on counting opaque bands on otoliths section of whiting was confirmed by the age estimation method analysing marginal increment formation. These results were corroborated by the length-based methods (LFA) applied on the Baltic Sea whiting (Ross and Hüssy, 2012).

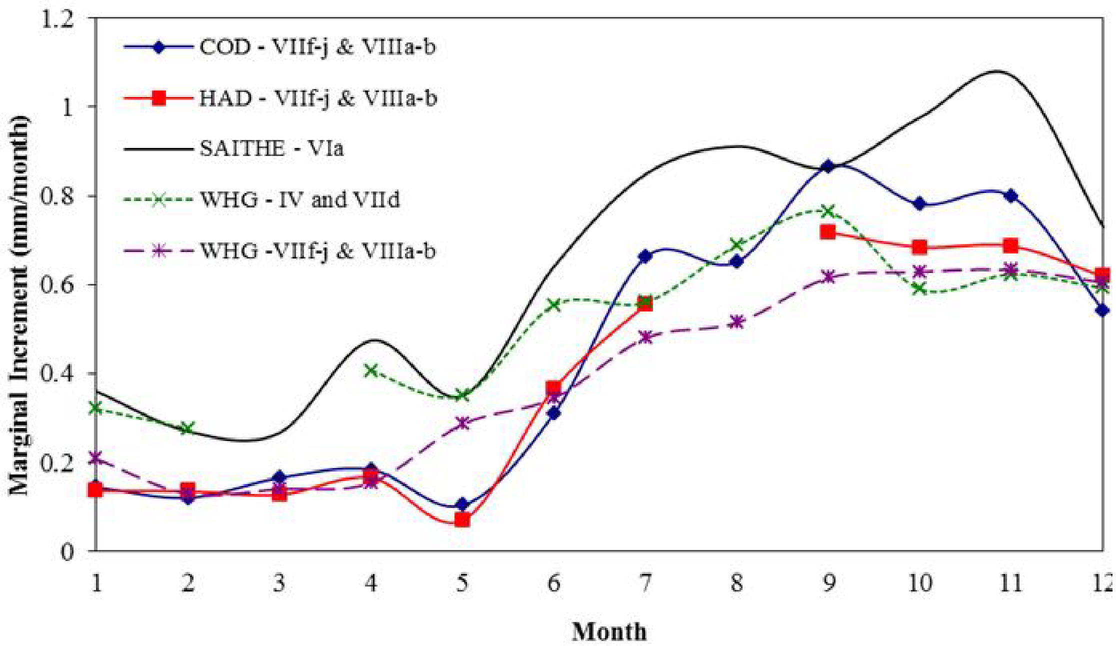

Figure 1.4.1 Marginal increment of Cod, Haddock, Saithe and Whiting in the North Sea (source: French data from 2010 and 2011).

This second study was to identify and validate the first winter ring using the microstructure analysis on the whole otolith (Ross and Hüssy, 2012). The distance from the *nucleus* to the first winter ring showed large variation and there is overlap between the ranges of distances from the *nucleus* to the winter rings i.e. the upper limit for the first annulus was ~3600 μm and the lower limit for the second annulus was ~2900 μm.

Since 2013, no updates of validation studies of whiting ageing appear in the literature.

1.5 Workshops and Exchanges

There have been two previous age reading workshops, the first held in Hirtshals, Denmark (1998) and the second was in Lowestoft, UK (2005). Based on the results of a full-scale otoliths exchange held in 2015 (Smith, 2015), the Working Group on Biological Parameters (WGBIOP) identified the need for another age reading workshop on whiting otoliths (WKARWHG2). This workshop was hosted by Centre for Environment Fisheries and Aquaculture Science (Lowestoft, UK) on 22–25 November 2016.

The exchange set contained sectioned otoliths from 134 fish from 4b, 7e and 7g covering all seasons. During the workshop an exercise set of 108 otoliths, including whole otoliths from ICES Division 4a were read as well as a sub sample set of fifty otoliths from the original exchange set.

The main issues identified during the 2005 and 2016 workshop were:

- The interpretation of the first annual ring due to splits and the wide range of growth that can occur;
- Difficulties in interpreting the edge of some otoliths;
- Misinterpretation of split rings and Humphries shadow;
- Problems in reading when the otolith is not cut correctly.

A guideline for the reading of whiting otoliths was prepared (Appendix VII) and a reference collection of otoliths was presented in the report of this workshop (Appendix V).

1.6 Participants

The Workshop on Age reading of Whiting (WKARWHG2) was held in Lowestoft on 22–25 November 2016. Seventeen age readers from nine countries (Belgium, France, Denmark, Norway, Germany, UK, Northern Ireland, Ireland, and Scotland) participated in this workshop (Appendix I). The workshop was chaired by Joanne Smith (UK) and Suzy End (UK) acted as a Workshop supporting expert.

1.7 Agenda

The meeting was opened at 13:00 pm on Tuesday 22 November and closed at 12:00 pm on Friday 25 November. A detailed agenda was updated each day; the overall agenda is presented in Appendix II.

2 Age reading calibration (ToR b)

2.1 Introduction

Whiting is generally considered to be a difficult species to age, as reflected by the results of the previous workshops and the last exchange (Smith, 2015). The primary goal of this workshop and the pre-workshop exchange was to resolve interpretation differences between readers and laboratories. When the exchange was created, the WKARWHG2 chair was only aware of one country that used a different reading method (whole otoliths) to other institutes so the decision was made to just use slides and images in the exchange. However, to ensure their area was included it was a recommendation from WGBIOP that a selection of 4a whole otoliths should be included in the exercise set read during the workshop. It also became apparent at the workshop that two other institutes do not read otoliths sectioned and use the method of breaking to estimate the age.

2.2 Methods

The exchange set (2015) consisted only of sectioned otoliths and were read by 16 participants from 10 institutes, using sectioned otoliths and WEBGR tool. There were 134 otoliths in total, selected across quarters and from areas 4b, 7e and 7g. Two otoliths sets (exercise set and sub-sample set of original exchange otoliths), were aged during workshop.

Exercise set

The exercise set were read first and consisted of 108 otoliths from areas 4a, 4b, 7e, including both sectioned and whole otoliths Following recommendations from WGBIOP otoliths from area 4b were included in this exercise as this area was not covered in the original exchange set. The otoliths were aged using images in Photoshop and a stereomicroscope. During the exercise it became apparent that not all readers could age the whole otoliths so the ages from these were removed from the final results. After the first exercise was completed, results and otolith interpretations were discussed by projecting otoliths onto a large screen.

Sectionedvs.Whole

A small-scale calibration exercise was also carried out to understand how the two reading technique of sectioned vs. whole compared. Pairs of otoliths from each of twenty fish were set aside for a particular exercise to compare the ages derived using different preparation methods.

One otolith from each pair was left whole and an image was captured of each of these.

Helle Rasmussen (Denmark) and Maria Jarnum (Denmark), experienced in reading whole otoliths, were requested to read the whole otoliths.

The technique employed for ageing whole otoliths is to place the otolith in a black receptacle containing sufficient water to cover the otolith. The otolith is viewed under the microscope using reflected (top) light trained on the wider surface of the otolith. The otolith may be turned over to confirm an age using both surfaces of the otolith. They also had the option of looking at the images of same otolith if they so wished.

The right otolith from each pair (excluding two) was sectioned. Tom Woods (UK) and Fiona Woods (Ireland), experienced in reading sectioned otoliths, were requested to read the sectioned otoliths.

Sectioned otoliths are mounted in a clear resin slide and viewed under microscope using reflected and transmitted lights. The slide may be turned over, reading the section from behind as it were, to confirm an age.

As can be seen in Appendix VIII, Helle and Maria had a 90% agreement rate between them when reading whole otoliths, agreeing on 18 out of the 20 otoliths read. Fiona and Tom had a 100% agreement rate between them when reading sectioned otoliths of the same fish, agreeing on 18 out of the 18 otoliths that had been sectioned. However, when the ages were compared between all readers, there was only complete agreement between both 'whole' readers and both 'sectioned' readers on one sample, sample 504.

In 16 out of the 18 samples read by both 'whole' readers and 'sectioned' readers, reading whole otoliths resulted in a higher age being given than that assigned by readers reading the same otoliths sectioned.

Because of the extremely low agreement between the different reading techniques it was decided to hold a short discussion among the four readers with a view to identifying possible reasons for differences in age determination and make recommendations to improve agreement going forward.

Otoliths and corresponding slides were viewed and respective ages and techniques discussed. The Danish readers demonstrated the whole otolith reading technique and explained how they interpreted the otoliths in order to assign the ages they did. The 'sectioned' readers did not have any confidence in ageing the whole otoliths given their inexperience in ageing fish using this technique. Sectioned otoliths of the same fish were then viewed alternating between transmitted and reflected light and it was apparent that it was easier, using this technique, to differentiate between different growth rings.

The Danish readers break otoliths when they are having difficulty in reading an otolith whole and trainee readers break the vast majority of otoliths to aid in their interpretation of otoliths. Peter Clark (Scotland) believes sectioning is the optimum preparation method but due to budget constraints is unable to get their otoliths processed as such.

Instead the Scottish readers break their otoliths. Peter's high agreement with the 'sectioned' readers would lead us to believe that reading broken otoliths, when sectioning is not an option, gives us the best opportunity to have high agreement between whiting age readers, using different preparation methods.

Peter is in the process of running exchanges with the Norwegians as a training exercise whereby he sends them monthly otoliths. It was suggested that he include the Danes in this so that they too could be trained in interpreting broken otoliths as he does. Currently they read broken otoliths with transmitted light shining directly on top of the broken surface, whereas Scotland reads broken otoliths with transmitted light shining in from the side toward the top of the broken surface.

The overall consensus of the group was that reading whole otoliths produces inaccurate results and is a practice that should not be continued as it is not an accurate method to determine whiting ages.

Following the workshop it has become apparent that a small otolith exchange between Denmark, Norway and Scotland is needed to understand how accurate reading whole whiting otoliths are for age estimation. This will be added to the recommendations.

Re-read of 50 otoliths from original exchange

Following discussions and training a sample of 50 otoliths was selected from the original exchange otoliths to be reread. Readers were asked to annotate the ages in WEBGR using both images and slides.

Twelve age readers participated in both the workshop and the pre-workshop exchange. Ten of these are considered to be experienced to highly experienced readers and two are trainees. In addition, 3 more whiting readers (2 trainees and 1 expert) read just the exchange set during the week of the workshop. Therefore, all calculations were done using the age readings of the 10 expert readers that read both sets to determine modal age.

2.3 Results and discussion

Otolith Exercise

A small-scale exercise was first carried out to gain an understanding of any problem areas that needed to be addressed during the week of the workshop. Sixteen age readers participated in the exercise, eleven of these are considered to be experienced readers and five are trainees. The percentage agreement was good (69%) and increase further (72%) when the trainee readers were removed (Appendix III). Table AIII.1 shows the details, modal age, percentage agreement, CV of each otolith and the age estimation by each participant.

In Table AIII.1 modal ages were calculated for each otolith read, along with percentage agreement, mean age and precision CV, where percentage agreement = 100 x (no. of readers agreeing with modal age/total no. of readers) for each otolith and precision CV = 100 x (standard deviation of age readings/ mean of age readings) for each otolith. Overall percentage agreement ranged from 39 to 88%, with an average of 72%. Out of the 85 otoliths 24 were read with at least 80% agreement and 3 at 100% agreement. The overall precision CV ranged from 0% (corresponding to 100% agreement in readings) to 39%, with an average of 15%. Thirteen participants read all of the 135 otoliths in the exchange, with the other three readings from 79 to 84. Fish number 400 and 483 seemed to cause a problem for readers with ages estimated between 4 and 6 (modal age 4), and 3 and 7 (modal age 3) respectively. Both the images of these otoliths seemed to be of a good quality so it is likely to be the otolith features that are causing variation in the age estimates.

Table AIII.2 examines the readings of individuals at each modal age and summarizes the number of otoliths read, the precision CV, percentage agreement and relative bias of each reader. Percentage agreement showed four readers reached at least 80% agreement, a further two exceeded 75%, whilst remaining ten ranged between 39 and 72%. The lowest agreement came from reader 7 (39%), this seemed to be due to overestimation of ages (see relative bias table AIII.2), this may be due to the reading technique not being familiar to the reader. The highest agreement came from Cefas (Reader 1, 88%).

Figure AIII.1 is a graphical representation of the relative bias table in Table AIII.2. The relative bias tables demonstrate the difference between the mean age for each age group and the modal age for each age group. In these age bias plots any deviation of the points from the solid line indicates a bias when the reader's age estimates are compared with the modal age. Points above and below the line indicate a positive and negative bias, respectively. The vertical bars are drawn plus and minus two standard deviations from the mean age. Short bars indicate consistency of reading at a given modal age. Readers 16, 8, 6, 14, 18, 9, 7, 19 10, 20 show positive relative bias by overestimating the age relative to modal age, while the other six readers underestimated ages.

Individually the relative bias varied between +0.76 to -0.41. Figure AIII.2 is a graphical representation of the coefficient of variation and percentage agreement tables in Tables AIII.2. Overall ranking showed readers 1 and 6 in the top two positions for CV, percentage agreement and relative bias. Readers 5 and 7 were the lowest ranking individuals taking part in the exchange.

Figure AIII.3 shows 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.

Table AIII.3 shows the age compositions and the mean length-at-age obtained by each reader and all readers combined and also the "inter-reader bias test" and the "reader against modal age bias test". There were no clear trends where length classes were over/underestimated.

The "inter-reader bias test" is presented in the bottom panel of Table AI11.3. When comparing each reader to modal age, the percent showing certainty of bias, possible bias and no bias were 50, 0 and 50 percent respectively. Most institutes did not show bias between their own readers, however there was bias seen between two readers at Cefas, this may be because one reader is a trainee.

Re-read subsample of original exchange otoliths

Following discussions and training a sample of 50 otoliths was selected from the original exchange otoliths to be reread. Twelve age readers participated in both the workshop and the pre-workshop exchange. Ten of these are considered to be experienced to highly experienced readers and two are trainees. In addition, 3 more whiting readers (2 trainees and 1 expert) read just the exchange set during the week of the workshop.

Following discussions from the exercise set the percentage agreement on the exchange set was slightly higher (70%) and increase further (74%) when the trainee readers were removed and further again when two readers with very low percentage agreement (readers 5 and 7) were also removed (80%). There also seemed to be an improvement in percentage agreement (experts) between the 2015 (69%) to 2016 (74%) exchange (same set of 50 otoliths). Table AIV.1 shows the details, modal age, percentage agreement, CV of each otolith and the age estimation by each participant.

In Table AIV.1 modal ages were calculated for each otolith read, along with percentage agreement, mean age and precision CV. Overall percentage agreement ranged from 38 to 88 %, with an average of 70 %. Out of the 50 otoliths 19 were read with at least 80 % agreement and 3 at 100% agreement. The overall precision CV ranged from 0% (corresponding to 100% agreement in readings) to 24%, with an average of 15%. Thirteen participants read all of the 50 otoliths in the exchange, with the other two reading 46.

Table AIV.2 examines the readings of individuals at each modal age and summarizes the number of otoliths read, the precision CV, percentage agreement and relative bias of each reader. Percentage agreement showed four readers reached at least 80% agreement, a further two exceeded 75%, while remaining nine ranged between 38 and 74%. The lowest agreement came from reader 5 (38%), there was no clear pattern of over/underestimation of ages (see relative bias table AIV.2), in the original exchange this reader tended to underestimate by a year but this was not apparent in this exchange. The highest agreement came from Marine Institute, Thünen Institute and ILVO (Reader 4, 6 and 9 88%).

Figure AIV.1 is a graphical representation of the relative bias table in Table AIV.2. Readers 4,8,14,16,17,10, and 21 show positive relative bias by overestimating the age relative to modal age, while the other seven readers underestimated ages. Individually the relative bias varied between +0.30 to -0.54.

Figure AIV.2 is a graphical representation of the coefficient of variation and percentage agreement tables in Tables AIV.2. Overall ranking showed readers 9 and 4 in the top two positions for CV, percentage agreement and relative bias. Readers 12 and 5 were the lowest ranking individuals taking part in the exchange.

Figure AIV.3 shows 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.

Table AIV.3 shows the age compositions and the mean length-at-age obtained by each reader and all readers combined and also the "inter-reader bias test" and the "reader against modal age bias test". There were no clear trends where length classes were over/underestimated.

The "inter-reader bias test" is presented in the bottom panel of Table AIV.3. When comparing each reader to modal age, the percent showing certainty of bias, possible bias and no bias were 33.7 and 60% respectively. There was no clear bias seen between readers, however reader 5 was bias to reader 1 and 4. These readers all input ages to the westerly stock assessment. The only bias seen within institutes was at the Marine Institute between readers 4, 19, and 10, this may have been because readers 19 and 10 are still in training

2.4 Main conclusions

Both sets of otloliths were read with an overall percentage agreement (experts) greater than 70%. The percentage agreement was 72% (exercise set) but following discussion and training this did increase to 74% (exchange set) (experts). However, this underestimates the agreement obtained by the experience reader as two experienced readers (readers 5 and 7) often achieved different age estimations from the others. If these readers are excluded, the percentage agreement among experienced readers who contribute age compositions to ICES Assessment Working Group is increased to 80%. The ages of reader 7 may have been different because they use a different preparation technique (whole), it has been recommended that a small-scale exchange take place to determine the accuracy of reading whiting otoliths, whole otoliths vs. sectioned. Reader 5 is familiar with reading otoliths sectioned and may need some additional training to increase the rate of agreement. Younger fish were aged with greatest agreement and smallest variation, as expected.

Looking at the percentage agreement, by grouping the readers by stock, there seems to be good agreement from those readers that contribute age data to the North Sea stock assessment (80%) and a fairly good agreement for those readers collecting age data for Celtic Sea and West of Scotland assessment (74%), however this increases greatly if reader 5 is removed (90%).

The initial exchange and subsequent workshop show that the overall agreement between countries for ageing whiting (sectioned) is encouraging. The discussions showed that most readers agree on the way the annual zones are interpreted but there are still features that cause confusion to some readers, in particularly those with less experience. The first years growth can at time be difficult to distinguish due to splits and the wide range of growth. The wide range of growth rates between fish caught in the same area also adds to problems interpreting true rings as does the occurrence the 'humphries shadow'. We have recommended that an otolith chemistry study should be carried out to gain a better understanding of these features and to validate true annuli.

3 Guidelines (ToR c)

International guidelines were compiled for the interpretation of whiting otoliths (Appendix VII). These guidelines were based on the expertise of the age readers and the discussions held during the workshop.

4 Reference collection (ToR d)

Two reference collections (images) were collated:

1) Agreed age for sectioned otoliths (Appendix V)

2) Age reading problems, including splits and Humphries shadow (Appendix VI)

5 References

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Appendix I: List of Participants

Chair: Joanne Smith, UK

Assisting expert: Suzy End, UK

Reader	Name	Country	Institute	Expert/Trainee	Assessment
1	Tom Woods	England	Cefas	Expert	Yes
4	Fiona Woods	Rep.Ireland	Marine Institute	Expert	Yes
5	Ian Mccausland	N.Ireland	AFBINI	Expert	Yes
6	Ines Wilhelms	Germany	Thünen Institute	Expert	Yes
7	Helle Rasmussen	Denmark	DTU Aqua	Expert	Yes
8	Hildegurn Mjanger	Norway	Institute of Marine Research	Expert	Yes
9	Ilse Maertens	Belgium	ILVO	Expert	Yes
10	Selene Hoey	Rep.Ireland	Marine Institute	Expert	Yes
12	Gary Burt	England	Cefas	Trainee	No
14	Lisbet Solbakken	Norway	Institute of Marine Research	Expert	Yes
16	Friederike Beussel	Germany	Thünen Institute	Expert	Yes
17	Peter Clark	Scotland	Marine Scotland Science	Expert	Yes
18	Martine Moerman	Belgium	ILVO	Expert	Yes
19	Sean o Connor	Rep.Ireland	Marine Institute	Trainee	No
20	Maria Jarnum	Denmark	DTU Aqua	Trainee	No
21	Celina Chantre	France	IFREMER	Trainee	No

Appendix II: Agenda

WKARWHG– Workshop on Age reading of Whiting (*Merlangius merlangus*) (WKARWHG 2016)

Tuesday 22 November

12.15 Arrive to lab

13:00 Fire safety/security introduction

13:30 Introductions: participant backgrounds, organizations

13:45 Explanation of Cefas laboratory and surrounding area, choose lunch menu

14:00 Purpose of the meeting and objectives (TORs)

Skype chat with WHG stock assessor (time to be confirmed)

14:15 Assignment of tasks for the week

14:30 Break

15:00 Discussion of exchange otoliths and begin calibration exercise

17:00 Adjourn

Wednesday 23 November

8:30 Summary of points from the exchange otoliths

9:00 Calibration exercise, including otoliths from 3a, 4b, 7e and 7g (approximately 100 otoliths)

10:30 Break

10:45 Calibration exercise continued

12:30 Group lunch at local pub

14:30 Discussion in training room led by Tom Woods and Fiona Woods

16:00 Break

16:20 Review/discussion of results from calibration exercise

17:30 Adjourn

Thursday 24 November

9:00 Discussion continue

10:45 Break

11.00 Re-read otoliths from exchange

12:30 Lunch

13:30 Continue with exchange otoliths

14:30 Group split to work on reference collection and guideline

15:30 Break

15:45 Recommendations/ moving forward

17:00 Adjourn

Friday 25 November

9:00 Discuss outcomes of the week and future recommendations

09:30 Finalize draft report

12:30 Adjourn WK

Appendix III: Data analyses for all readers – exercise set (from G. Eltink spreadsheet)

Table AIII.1

Reader Ageing Results

Modal Age	Agreement %	Precision CV	Fish length	Reader 16 Ger R1	Reader 8 Nor R2	Reader 5 N.Ir R3	Reader 6 Ger R4	Reader 14 Nor R5	Reader 1 Eng R6	Reader 4 R.Ir R7	Reader 17 Sco R8	Reader 18 Bel R9	Reader 9 Bel R10	Reader 7 Den R11	Reader 21 Fra R12	Reader 19 R.Ir R13	Reader 10 R.Ir R14	Reader 12 Eng R15	Reader 20 Den R16
5	50%	16%	33	4	4	4	4	4	5	5	4	6	5	5	3	5	5	5	5
6	47%	27%	35	6	-	3	6	5	6	5	4	6	6	6	2	5	3	5	6
4	81%	18%	30	4	4	4	4	4	4	4	4	4	4	6	3	4	4	4	6
5	69%	11%	28	5	5	4	5	5	5	5	4	5	5	6	4	4	5	5	5
6	50%	13%	39	5	5	5	6	5	6	6	6	4	6	7	5	6	6	5	6
8	63%	6%	36	9	9	9	8	8	8	8	9	9	8	8	8	9	8	8	8
6	81%	11%	35	6	6	5	6	6	6	6	6	6	6	8	6	5	6	6	6
4	94%	6%	29	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4
5	69%	12%	32	6	5	5	5	5	5	5	6	5	6	7	5	5	5	5	6
7	75%	7%	39	7	6	7	7	7	7	7	7	6	7	7	7	8	7	6	7
5	44%	17%	33	5	5	5	5	6	6	6	5	8	6	8	6	6	5	5	6
8	73%	10%	38	8	8	8	8	8	8	8	8	10	8	10	7	9	-	8	8
5	63%	22%	30	6	4	5	5	5	5	5	5	5	5	5	2	5	4	3	6
7	50%	11%	37	8	7	6	7	7	7	7	7	8	7	9	6	8	8	8	7
2	81%	18%	26	2	2	2	2	2	2	3	2	2	2	2	2	2	3	2	3
6	75%	8%	38	6	6	5	6	7	6	6	6	7	6	6	6	7	6	6	6
3	75%	17%	32	3	3	2	3	3	3	3	2	3	3	4	2	3	3	3	3
5	69%	10%	35	6	5	4	6	5	5	5	6	5	5	6	5	5	5	5	5
4	69%	16%	35	5	4	4	4	5	4	4	4	5	4	6	6	4	4	4	4
5	69%	11%	37	5	5	4	5	5	5	5	5	5	5	6	4	5	6	5	6
2	63%	33%	28	2	2	3	2	2	1	1	2	2	1	2	1	2	2	1	2
2	56%	26%	31	3	2	3	3	2	1	2	3	2	2	3	2	2	3	2	2
2	81%	18%	28	2	2	3	2	2	2	2	2	3	2	3	2	2	2	2	2
3	69%	18%	31	3	2	2	3	2	3	3	3	3	3	3	3	3	3	2	2
3	56%	23%	39	3	2	4	3	3	3	3	2	3	2	4	3	3	4	2	3
2	56%	35%	29	2	2	3	2	2	1	1	2	3	2	2	1	2	3	1	2
3	50%	18%	30	4	3	3	4	4	3	3	3	5	3	4	4	4	4	3	3
4	50%	22%	34	4	-	3	5	-	3	4	4	4	4	5	3	3	4	2	4
3	94%	8%	35	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3
3	81%	21%	32	3	3	3	3	3	3	3	2	3	3	5	3	3	3	2	3
2	88%	16%	31	2	2	2	2	2	2	2	2	3	2	2	2	3	2	2	2
3	88%	11%	38	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	4
3	50%	15%	36	3	3	3	3	4	4	4	3	3	4	4	3	4	4	3	4
2	75%	26%	33	2	2	2	2	3	2	2	2	4	2	2	2	3	2	2	3
3	63%	18%	37	3	4	3	4	4	3	3	3	4	3	3	3	3	4	3	5
4	94%	6%	41	4	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
3	71%	14%	34	3	-	3	3	-	3	3	3	4	3	4	3	3	4	3	4
4	73%	13%	35	4	4	3	4	-	4	4	4	3	4	4	4	5	4	3	4
3	88%	11%	36	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	4
3	69%	18%	39	3	4	3	3	5	3	3	3	3	3	4	3	4	3	3	4
3	63%	18%	39	3	4	3	3	4	3	3	3	3	3	4	3	4	3	2	4
4	69%	17%	42	5	4	4	4	5	4	4	4	3	4	4	4	4	4	3	6
5	50%	14%	46	4	5	4	4	5	5	5	4	4	4	5	4	5	5	3	5
4	69%	11%	40	4	5	4	4	5	4	4	4	4	4	5	4	5	4	4	5
4	50%	22%	37	5	5	3	4	6	4	4	6	4	4	5	3	4	4	3	4
4	94%	6%	48	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4
3	57%	21%	33	4	-	3	3	-	3	3	3	4	3	4	3	4	3	2	2
4	88%	14%	41	4	4	4	3	4	4	4	4	4	4	4	4	4	4	2	4
5	69%	13%	43	5	5	5	5	5	5	5	4	4	5	4	5	5	5	3	4
3	64%	20%	40	3	-	3	3	-	3	3	3	3	2	4	3	4	3	2	4
3	56%	24%	32	3	5	3	3	5	3	3	4	3	3	4	3	4	4	2	3
3	67%	19%	42	3	4	4	3	-	3	3	3	4	3	5	3	3	3	3	4
5	81%	12%	53	5	5	5	5	5	5	5	5	5	5	6	4	7	5	5	5
5	63%	12%	41	4	5	5	4	5	5	5	5	5	5	6	4	4	5	4	5
5	50%	16%	41	5	6	7	5	5	5	5	6	6	6	7	4	5	5	4	5
6	44%	16%	47	6	8	7	6	6	6	7	7	6	8	8	5	8	6	6	5
4	94%	6%	42	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4
3	88%	11%	49	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
6	63%	13%	46	5	6	6	5	6	6	6	6	7	7	7	4	6	6	6	6
5	100%	0%	56	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3	100%	0%	47	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
5	88%	7%	55	5	5	5	5	5	5	5	5	5	5	5	5	6	5	4	5
4	88%	8%	42	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4
3	88%	11%	47	3	3	3	3	3	3	3	3	3	3	4	3	4	3	3	3
4	81%	10%	47	4	4	4	4	4	4	4	4	4	5	5	4	4	4	4	5
6	75%	9%	50	6	6	6	6	6	6	6	6	7	7	6	5	5	6	6	6
6	81%	7%	55	6	6	6	6	6	6	6	6	6	7	7	6	6	6	6	7
5	94%	5%	49	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5
5	75%	10%	47	5	5	4	5	5	5	5	5	5	5	5	4	5	5	4	6
5	73%	11%	47	5	4	5	5	5	5	4	5	5	5	6	4	5	5	5	-
4	100%	0%	47	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
6	63%	10%	54	6	5	6	5	6	6	6	6	6	7	6	5	5	6	5	6
4	63%	14%	43	4	4	3	4	4	3	3	4	4	4	4	3	3	3	4	4
5	69%	13%	45	5	5	6	5	5	5	5	5	6	5	6	5	5	5	4	7
5	75%	10%	52	5	5	5	5	5	5	5	5	6	6	6	5	5	5	4	5
4	63%	15%	44	5	4	4	5	4	4	4	4	5	5	4	3	3	4	4	4
4	69%	16%	52	5	4	4	5	4	4	4	4	5	6	4	4	4	4	3	4
4	88%	9%	42	4	4	4	4	4	4	4	4	4	4	5	4	4	4	3	4
3	40%	26%	36	3	-	4	3	3	4	3	4	4	6	6	4	4	5	3	3
4	56%	24%	36	4	4	4	4	4	5	2	4	3	4	6	4	3	3	3	4
3	69%	40%	36	3	3	5	3	3	3	2	3	3	8	5	3	4	3	3	3
3	44%	29%	39	5	5	4	5	3	3	3	3	4	7	4	4	3	4	3	3
3	56%	21%	38	3	3	4	3	4	3	2	2	3	3	4	3	3	4	3	4
3	63%	15%	39	3	3	4	3	4	3	3	3	3	3	4	4	3	4	3	4
4	50%	22%	37	4	4	4	4	4	3	2	4	3	3	5	4	4	3	3	5
	69.9%	14.9%		85	79	85	85	79	85	85	85	85	85	85	85	85	84	85	84
				0	6	0	0	6	0	0	0	0	0	0	0	0	1	0	1

Table AIII.2

The number of age readings, the coefficient of variation (CV), the percent agreement and the RELATIVE bias are presented by MODAL age for each age reader and for all readers combined. A weighted mean CV and a weighted mean percent agreement are given by reader and all readers combined. The CV's by MODAL age for each individual age reader and all readers combined indicate the precision in age reading by MODAL age. The weighted mean CV's over all MODAL age groups combined indicate the precision in age reading by reader and for all age readers combined.

Whiting Exercise set (Lowestoft, 22-25 November 2016)

NUMBER OF AGE READINGS

	MODAL age	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	112
	3	25	21	25	25	21	25	25	25	25	25	25	25	25	25	25	25	392
	4	21	20	21	21	19	21	21	21	21	21	21	21	21	21	21	21	333
	5	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	18	303
	6	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	143
	7	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	32
	8	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	31
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0-15	85	79	85	85	79	85	85	85	85	85	85	85	85	84	85	84	1346

COEFFICIENT OF VARIATION (CV)

	MODAL age	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20	ALL Readers
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	18%	0%	21%	18%	18%	34%	37%	18%	28%	20%	21%	28%	21%	22%	28%	21%	24.7%
	3	16%	24%	20%	15%	22%	9%	12%	17%	17%	41%	19%	14%	15%	17%	17%	21%	17.8%
	4	10%	8%	11%	11%	13%	11%	17%	11%	16%	14%	15%	17%	15%	9%	20%	15%	13.2%
	5	12%	9%	16%	9%	7%	5%	7%	13%	17%	10%	16%	20%	13%	7%	17%	13%	11.7%
	6	8%	15%	21%	8%	10%	0%	8%	13%	15%	11%	12%	26%	18%	18%	9%	8%	12.5%
	7	9%	11%	11%	0%	0%	0%	0%	0%	20%	0%	18%	11%	0%	9%	20%	0%	9.1%
	8	8%	8%	8%	0%	0%	0%	0%	8%	7%	0%	16%	9%	0%	-	0%	0%	7.8%
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	12.4%	12.5%	16.5%	11.4%	13.4%	9.2%	13.0%	13.5%	17.2%	20.5%	16.9%	18.5%	14.6%	12.8%	17.4%	15.4%	14.9%
	RANKING	3	4	11	2	7	1	6	8	13	16	12	15	9	5	14	10	

PERCENTAGE AGREEMENT

	MODAL age	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	86%	100%	43%	86%	86%	57%	57%	86%	43%	86%	71%	71%	71%	57%	71%	71%	71%
	3	84%	62%	64%	88%	57%	92%	88%	76%	64%	76%	28%	80%	52%	60%	72%	48%	68%
	4	76%	90%	81%	81%	74%	81%	86%	95%	62%	81%	43%	71%	67%	86%	57%	76%	75%
	5	68%	79%	58%	79%	89%	95%	89%	63%	63%	74%	37%	42%	68%	89%	53%	61%	69%
	6	78%	63%	44%	78%	67%	100%	78%	78%	56%	44%	44%	33%	33%	89%	67%	78%	64%
	7	50%	50%	50%	100%	100%	100%	100%	100%	0%	100%	50%	50%	0%	50%	0%	100%	63%
	8	50%	50%	50%	100%	100%	100%	100%	50%	0%	100%	50%	50%	0%	100%	100%	100%	68%
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	76.5%	75.9%	62.4%	83.5%	74.7%	88.2%	84.7%	78.8%	57.6%	75.3%	40.0%	62.4%	56.5%	76.2%	62.4%	65.5%	70.0%
	RANKING	5	7	11	3	9	1	2	4	14	8	16	11	15	6	11	10	

RELATIVE BIAS

	MODAL age	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	0.14	0.00	0.57	0.14	0.14	-0.43	-0.14	0.14	0.71	-0.14	0.29	-0.29	0.29	0.43	-0.29	0.29	0.12
	3	0.20	0.29	0.24	0.16	0.43	0.08	-0.04	-0.08	0.40	0.44	0.92	0.12	0.48	0.44	-0.28	0.40	0.26
	4	0.24	0.10	-0.19	0.10	0.32	-0.10	-0.24	0.10	0.00	0.14	0.71	-0.14	-0.05	-0.14	-0.52	0.33	0.04
	5	0.00	-0.11	-0.16	-0.11	0.00	0.05	0.00	-0.05	0.26	0.16	0.74	-0.63	0.16	0.00	-0.63	0.33	0.00
	6	-0.22	0.00	-0.56	-0.22	-0.11	0.00	0.00	-0.11	0.11	0.67	0.78	-1.11	-0.11	-0.33	-0.33	0.00	-0.10
	7	0.50	-0.50	-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	-0.50	1.00	0.50	0.00	0.00	0.09
	8	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.50	1.50	0.00	1.00	-0.50	1.00	0.00	0.00	0.00	0.32
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	0.13	0.08	-0.02	0.04	0.19	-0.02	-0.08	-0.00	0.28	0.26	0.76	-0.31	0.22	0.11	-0.41	0.30	0.09
	RANKING	8	5	2	4	9	3	6	1	12	11	16	14	10	7	15	13	

Overall ranking

	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20
Ranking Coefficient of Variation	3	4	11	2	7	1	6	8	13	16	12	15	9	5	14	10
Ranking Percentage Agreement	5	7	11	3	9	1	2	4	14	8	16	11	15	6	11	10
Ranking Relative bias	8	5	2	4	9	3	6	1	12	11	16	14	10	7	15	13
OVERALL RANKING	**5**	**5**	**8**	**2**	**9**	**1**	**4**	**3**	**13**	**12**	**16**	**14**	**11**	**7**	**14**	**10**

Table AIII.3

Upper table: The age compositions estimated by each age reader and all age readers combined.

Midle table: The estimated mean length-at-age by age reader and by all age readers combined.

Lower table: Bias tests: non-parametrically with a one-sample Wilcoxon rank sum test. The inter-reader bias test and the reader against MODAL age bias test.

AGE COMPOSITION

	Age	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	3	2	-	-	1	-	2	-	-	2	-	10
	2	6	9	5	6	7	4	8	10	3	8	5	8	5	4	14	7	109
	3	22	13	25	24	13	26	24	20	23	20	9	26	19	22	28	14	328
	4	22	25	29	22	21	19	20	27	25	19	24	28	28	28	18	27	382
	5	21	21	15	21	25	19	18	12	17	16	19	12	20	18	13	16	283
	6	10	7	6	8	8	10	8	11	10	10	16	6	6	9	7	14	146
	7	1	1	3	2	3	2	3	3	3	7	6	2	2	1	-	4	43
	8	2	2	1	2	2	2	2	1	2	4	4	1	3	2	3	2	35
	9	1	1	1	-	-	-	-	1	1	-	1	-	2	-	-	-	8
	10	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	2
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0-15	85	79	85	85	79	85	85	85	85	85	85	85	85	84	85	84	1346

MEAN LENGTH AT AGE

	Age	Germany Reader 16	Norway Reader 8	N Ireland Reader 5	Germany Reader 6	Norway Reader 14	England Reader 1	Rep. Ireland Reader 4	Scotland Reader 17	Belgium Reader 18	Belgium Reader 9	Denmark Reader 7	France Reader 21	Rep. Ireland Reader 19	Rep. Ireland Reader 10	England Reader 12	Denmark Reader 20	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	29.3	28.5	-	-	28.0	-	28.5	-	-	28.5	-	28.7
	2	29.2	30.7	30.6	29.2	29.1	29.5	33.8	31.6	28.3	32.1	29.4	30.8	28.4	30.0	33.6	30.1	30.9
	3	37.1	38.1	36.2	37.6	38.4	37.6	37.3	37.9	36.4	37.4	36.9	37.7	37.7	37.0	38.9	36.6	37.4
	4	39.4	40.0	39.8	39.1	39.6	40.3	40.6	39.3	39.6	39.3	39.5	41.1	38.6	38.6	42.7	39.7	39.7
	5	43.8	42.5	42.6	43.7	41.6	42.4	42.1	45.4	41.9	43.1	41.2	46.4	41.8	42.9	40.8	43.6	42.7
	6	41.1	43.4	47.8	41.8	44.6	43.2	43.8	42.0	43.6	39.3	40.8	38.8	46.2	44.6	44.3	39.1	42.4
	7	39.0	37.0	42.3	38.0	38.0	38.0	41.0	41.0	44.7	45.7	42.0	38.5	45.5	39.0	-	44.0	42.0
	8	37.5	42.5	38.0	37.0	37.0	37.0	37.0	38.0	35.0	39.3	37.8	36.0	41.0	36.5	37.0	37.0	37.9
	9	36.0	36.0	36.0	-	-	-	-	36.0	36.0	-	37.0	-	37.0	-	-	-	36.4
	10	-	-	-	-	-	-	-	-	38.0	-	38.0	-	-	-	-	-	38.0
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d mean	0-15	39.3	39.6	39.3	39.3	39.5	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.2	39.3

Inter-reader bias test and reader against MODAL age bias test

Bias tests: non-parametrically with a one-sample Wilcoxon rank sum test. The inter-reader bias test and the reader against the Modal age bias test

		Reader 16 Ger R1	Reader 8 Nor R2	Reader 5 N.Ir R3	Reader 6 Ger R4	Reader 14 Nor R5	Reader 1 Eng R6	Reader 4 R.Ir R7	Reader 17 Sco R8	Reader 18 Bel R9	Reader 9 Bel R10	Reader 7 Den R11	Reader 21 Fra R12	Reader 19 R.Ir R13	Reader 10 R.Ir R14	Reader 12 Eng R15	Reader 20 Den R16
Reader 16 Ger	R1		* *	* *	-	* *	* *	*	* *	* *	* *	*	*	* *	* *	* *	* *
Reader 8 Nor	R2	* *		* *	* *	-	* *	* *	* *	* *	* *	* *	-	* *	* *	* *	-
Reader 5 N.Ir	R3	* *	* *		* *	* *	* *	* *	* *	* *	*	* *	-	* *	* *	-	-
Reader 6 Ger	R4	-	* *	* *		*	* *	* *	* *	*	*	* *	-	* *	* *	* *	*
Reader 14 Nor	R5	* *	-	* *	*		-	-	* *	* *	* *	-	* *	* *	* *	* *	* *
Reader 1 Eng	R6	* *	* *	* *	* *	-		*	* *	-	-	* *	-	-	-	* *	-
Reader 4 R.Ir	R7	*	* *	* *	* *	-	*		* *	-	-	* *	-	-	-	-	*
Reader 17 Sco	R8	* *	* *	* *	* *	* *	* *	* *		-	-	* *	-	* *	* *	-	-
Reader 18 Bel	R9	* *	* *	* *	*	* *	-	-	-		* *	-	-	* *	* *	* *	* *
Reader 9 Bel	R10	* *	* *	*	*	* *	-	-	-	* *		* *	*	* *	* *	* *	* *
Reader 7 Den	R11	*	* *	* *	* *	-	* *	* *	* *	-	* *		* *	-	* *	* *	-
Reader 21 Fra	R12	*	-	-	-	* *	-	-	-	-	*	* *		-	-	* *	-
Reader 19 R.Ir	R13	* *	* *	* *	* *	* *	-	-	* *	* *	* *	-	-		* *	-	* *
Reader 10 R.Ir	R14	* *	* *	* *	* *	* *	-	-	* *	* *	* *	* *	-	* *		* *	* *
Reader 12 Eng	R15	* *	* *	-	* *	* *	* *	-	-	* *	* *	* *	* *	-	* *		* *
Reader 20 Den	R16	* *	-	-	*	* *	-	*	-	* *	* *	-	-	* *	* *	* *	
Modal		-	* *	* *	* *	-	* *	-	* *	-	-	* *	-	* *	-	* *	-

-	= no sign of bias (p>0.05)
*	= possibility of bias (0.01<p<0.05)
* *	= certainty of bias (p<0.01)

Table AIII.4

2STDEV

MODAL	Germany	Norway	N Ireland	Germany	Norway	England	Rep. Ireland	Scotland	Belgium	Belgium	Denmark	France	Rep. Ireland	Rep. Ireland	England	Denmark	2STDEV
age	Reader 16	Reader 8	Reader 5	Reader 6	Reader 14	Reader 1	Reader 4	Reader 17	Reader 18	Reader 9	Reader 7	Reader 21	Reader 19	Reader 10	Reader 12	Reader 20	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.756	0.000	1.069	0.756	0.756	1.069	1.380	0.756	1.512	0.756	0.976	0.976	0.976	1.069	0.976	0.976	**1.099**
3	1.000	1.568	1.327	0.945	1.493	0.554	0.702	0.987	1.155	2.833	1.519	0.879	1.020	1.166	0.917	1.414	**1.400**
4	0.873	0.616	0.805	0.873	1.165	0.873	1.250	0.873	1.265	1.146	1.434	1.309	1.179	0.717	1.359	1.317	**1.205**
5	1.155	0.918	1.529	0.918	0.667	0.459	0.667	1.243	1.744	1.003	1.867	1.790	1.376	0.667	1.522	1.372	**1.381**
6	0.882	1.852	2.261	0.882	1.202	0.000	1.000	1.563	1.856	1.414	1.667	2.539	2.108	2.000	1.000	1.000	**1.717**
7	1.414	1.414	1.414	0.000	0.000	0.000	0.000	0.000	2.828	0.000	2.828	1.414	0.000	1.414	2.828	0.000	**1.378**
8	1.414	1.414	1.414	0.000	0.000	0.000	0.000	1.414	1.414	0.000	2.828	1.414	0.000	-	0.000	0.000	**1.305**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MEAN AGE

MODAL	Germany	Norway	N Ireland	Germany	Norway	England	Rep. Ireland	Scotland	Belgium	Belgium	Denmark	France	Rep. Ireland	Rep. Ireland	England	Denmark	
age	Reader 16	Reader 8	Reader 5	Reader 6	Reader 14	Reader 1	Reader 4	Reader 17	Reader 18	Reader 9	Reader 7	Reader 21	Reader 19	Reader 10	Reader 12	Reader 20	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2.14	2.00	2.57	2.14	2.14	1.57	1.86	2.14	2.71	1.86	2.29	1.71	2.29	2.43	1.71	2.29	**2.12**
3	3.20	3.29	3.24	3.16	3.43	3.08	2.96	2.92	3.40	3.44	3.92	3.12	3.48	3.44	2.72	3.40	**3.26**
4	4.24	4.10	3.81	4.10	4.32	3.90	3.76	4.10	4.00	4.14	4.71	3.86	3.95	3.86	3.48	4.33	**4.04**
5	5.00	4.89	4.84	4.89	5.00	5.05	5.00	4.95	5.26	5.16	5.74	4.37	5.16	5.00	4.37	5.33	**5.00**
6	5.78	6.00	5.44	5.78	5.89	6.00	6.00	5.89	6.11	6.67	6.78	4.89	5.89	5.67	5.67	6.00	**5.90**
7	7.50	6.50	6.50	7.00	7.00	7.00	7.00	7.00	7.00	7.00	8.00	6.50	8.00	7.50	7.00	7.00	**7.09**
8	8.50	8.50	8.50	8.00	8.00	8.00	8.00	8.50	9.50	8.00	9.00	7.50	9.00	8.00	8.00	8.00	**8.32**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0-15	**4.27**	**4.25**	**4.12**	**4.18**	**4.39**	**4.12**	**4.06**	**4.14**	**4.42**	**4.40**	**4.91**	**3.84**	**4.36**	**4.20**	**3.73**	**4.43**	**4.24**

MEAN AGE +2STDEV

MODAL	Germany	Norway	N Ireland	Germany	Norway	England	Rep. Ireland	Scotland	Belgium	Belgium	Denmark	France	Rep. Ireland	Rep. Ireland	England	Denmark	
age	Reader 16	Reader 8	Reader 5	Reader 6	Reader 14	Reader 1	Reader 4	Reader 17	Reader 18	Reader 9	Reader 7	Reader 21	Reader 19	Reader 10	Reader 12	Reader 20	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	2.899	2.000	3.640	2.899	2.899	2.640	3.237	2.899	4.226	2.613	3.262	2.690	3.262	3.498	2.690	3.262	**3.21**
3	4.200	4.853	4.567	4.105	4.921	3.634	3.662	3.907	4.555	6.273	5.439	3.999	4.500	4.606	3.637	4.814	**4.66**
4	5.111	4.716	4.614	4.968	5.481	4.778	5.012	4.968	5.265	5.289	6.149	5.166	5.132	4.574	4.835	5.650	**5.24**
5	6.155	5.812	6.372	5.812	5.667	5.511	5.667	6.190	7.007	6.161	7.604	6.159	6.534	5.667	5.890	6.705	**6.38**
6	6.660	7.852	7.705	6.660	7.091	6.000	7.000	7.452	7.967	8.081	8.444	7.427	7.997	7.667	6.667	7.000	**7.62**
7	8.914	7.914	7.914	7.000	7.000	7.000	7.000	7.000	9.828	7.000	10.828	7.914	8.000	8.914	9.828	7.000	**8.47**
8	9.914	9.914	9.914	8.000	8.000	8.000	8.000	9.914	10.914	8.000	11.828	8.914	9.000	-	8.000	8.000	**9.63**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MEAN AGE -2STDEV

MODAL	Germany	Norway	N Ireland	Germany	Norway	England	Rep. Ireland	Scotland	Belgium	Belgium	Denmark	France	Rep. Ireland	Rep. Ireland	England	Denmark	
age	Reader 16	Reader 8	Reader 5	Reader 6	Reader 14	Reader 1	Reader 4	Reader 17	Reader 18	Reader 9	Reader 7	Reader 21	Reader 19	Reader 10	Reader 12	Reader 20	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1.387	2.000	1.502	1.387	1.387	0.502	0.477	1.387	1.202	1.101	1.310	0.738	1.310	1.360	0.738	1.310	**1.017**
3	2.200	1.718	1.913	2.215	1.936	2.526	2.258	1.933	2.245	0.607	2.401	2.241	2.460	2.274	1.803	1.986	**1.861**
4	3.365	3.484	3.005	3.222	3.151	3.032	2.512	3.222	2.735	2.996	3.280	2.548	2.773	3.140	2.117	3.017	**2.834**
5	3.845	3.977	3.313	3.977	4.333	4.594	4.333	3.705	3.519	4.155	3.870	2.578	3.781	4.333	2.847	3.961	**3.619**
6	4.896	4.148	3.184	4.896	4.687	6.000	5.000	4.325	4.255	5.252	5.111	2.350	3.781	3.667	4.667	5.000	**4.185**
7	6.086	5.086	5.086	7.000	7.000	7.000	7.000	7.000	4.172	7.000	5.172	5.086	8.000	6.086	4.172	7.000	**5.716**
8	7.086	7.086	7.086	8.000	8.000	8.000	8.000	7.086	8.086	8.000	6.172	6.086	9.000	-	8.000	8.000	**7.018**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

In the age bias plots below the mean age recorded +/- 2stdev of each age reader and all readers combined are plotted against the MODAL age. The estimated mean age corresponds to MODAL age, if the estimated mean age is on the 1:1 equilibrium line (solid line). RELATIVE bias is the age difference between estimated mean age and MODAL age.

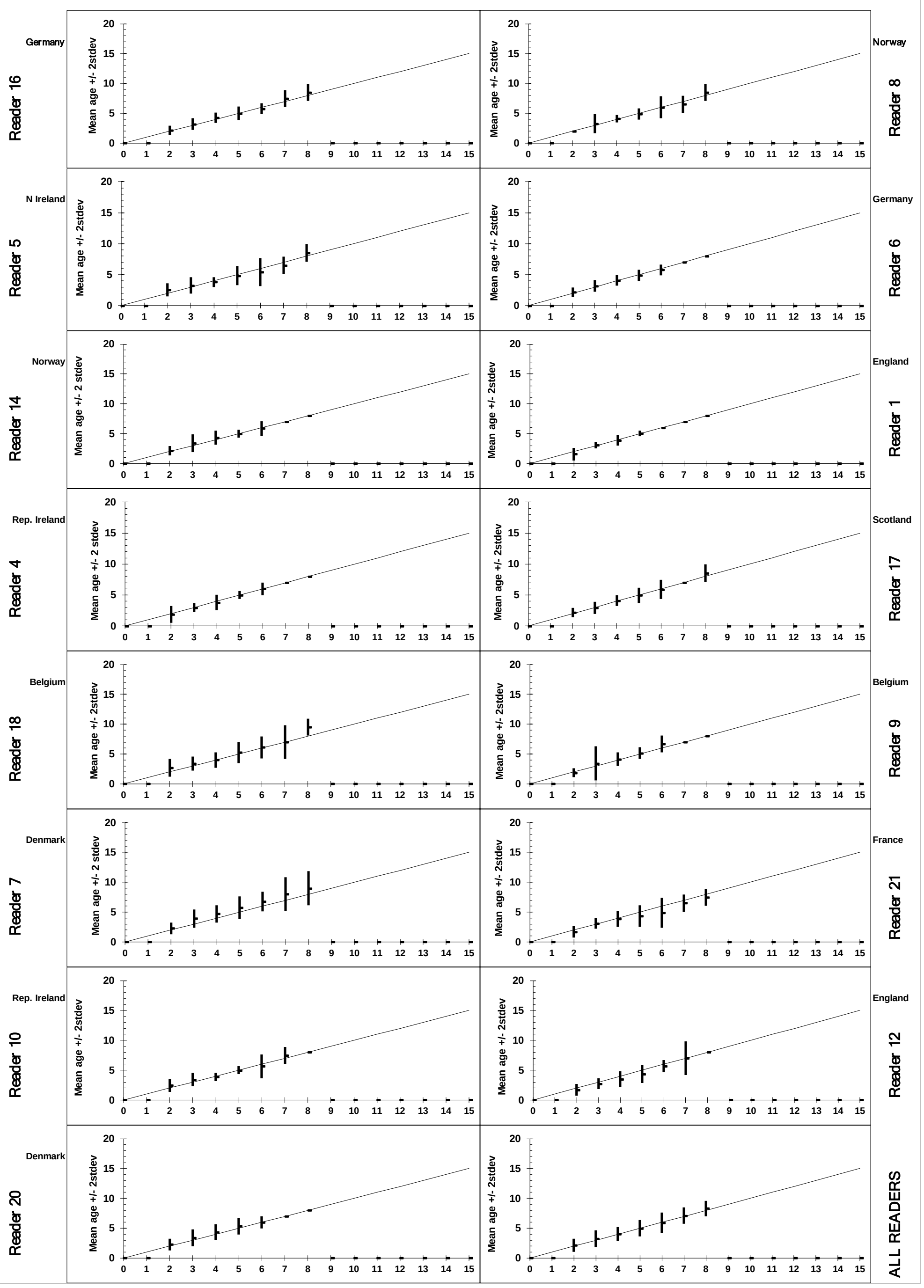
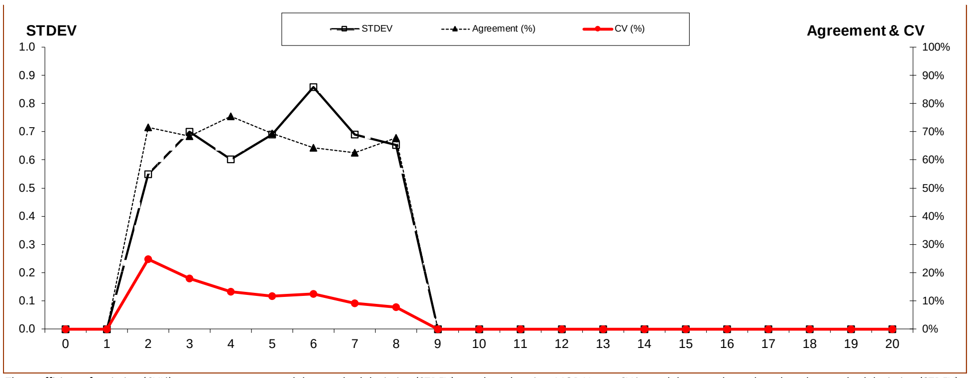
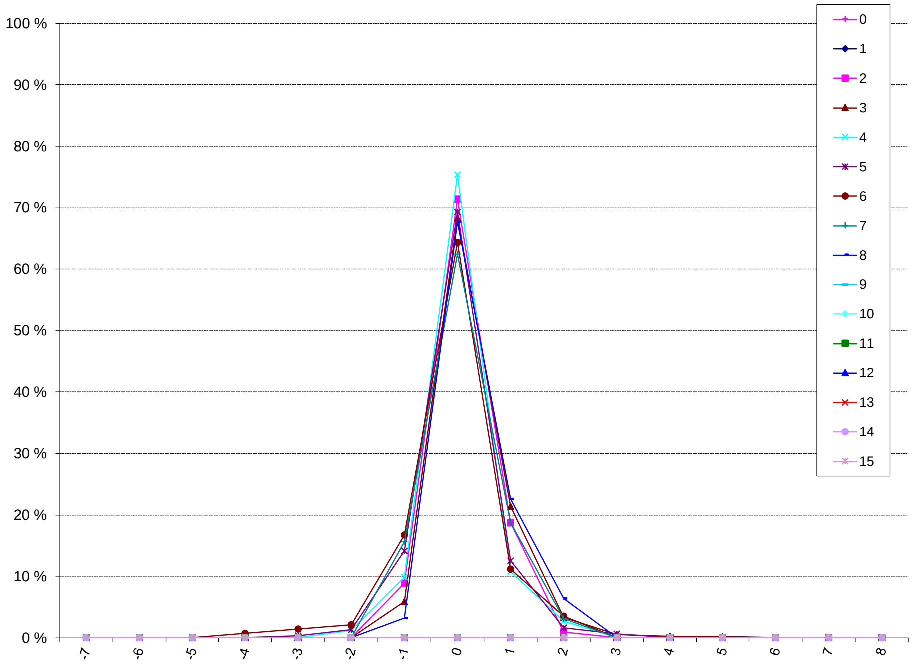


Figure AIII.1



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.

Figure AIII.2



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 the age readings errors. There appears to be no RELATIVE bias, if the age reading errors are normally distributed. The distributions are skewed, if RELATIVE bias occurs.

Figure AIII.3

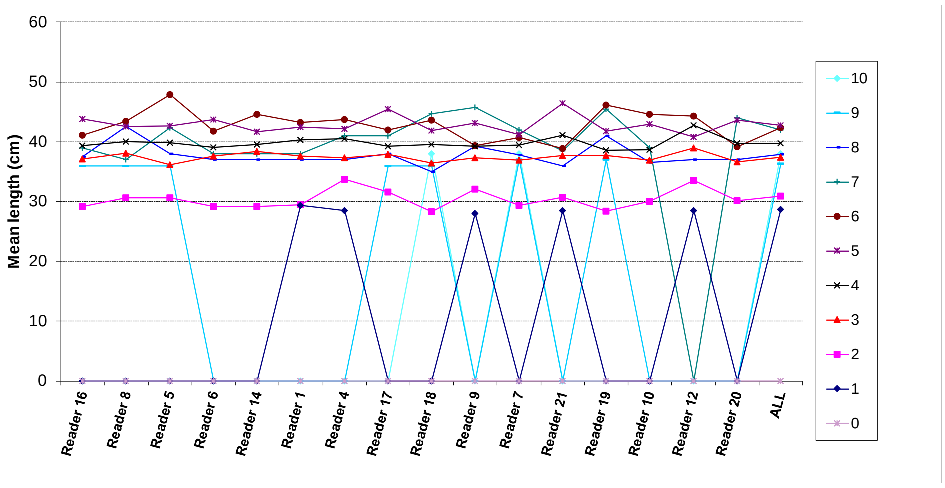


Figure AIII.4

Appendix IV: Data analyses for all readers – exchange re-read set (from G. Eltink spreadsheet)

Table AIV.1

			Reader Ageing Results														
Modal			Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21
Age	Agreement %	Precision CV	Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra
			R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
4	100%	0%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
7	93%	4%	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7
4	40%	22%	4	4	7	7	6	4	5	4	5	6	5	4	4	6	5
5	100%	0%	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3	93%	16%	3	3	5	3	3	3	3	3	3	3	3	3	3	3	3
2	60%	21%	2	2	3	2	2	2	2	2	3	3	3	2	2	3	3
2	100%	0%	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	93%	7%	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4
5	73%	11%	5	5	6	5	5	4	5	5	5	5	5	4	5	5	6
6	60%	11%	6	6	7	6	6	6	6	6	7	6	7	6	8	5	7
4	93%	6%	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4
6	54%	14%	5	7	6	6	6	5	6	5	6	7	6	6	6	4	6
6	67%	9%	5	6	6	6	5	5	5	6	6	6	6	6	6	5	6
3	53%	24%	3	3	4	4	3	3	3	4	5	3	5	2	3	3	4
3	53%	19%	3	4	4	3	3	3	3	2	4	3	4	4	4	3	3
3	87%	11%	3	3	4	3	3	3	3	3	3	3	3	3	4	3	3
2	73%	20%	2	2	2	2	2	2	2	2	2	3	2	3	3	2	3
3	60%	18%	3	4	3	3	4	3	4	3	3	4	3	3	4	5	3
2	93%	12%	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2
7	60%	9%	7	7	7	7	7	6	8	7	8	7	7	6	7	6	8
6	53%	12%	7	6	6	6	6	5	6	7	6	6	5	5	7	6	7
3	47%	22%	3	3	4	3	4	4	4	3	4	4	4	3	6	3	3
3	80%	22%	3	3	5	3	3	3	3	3	3	3	3	2	3	2	3
5	67%	12%	5	5	6	5	5	4	5	5	6	5	5	5	4	4	5
6	87%	6%	6	6	5	6	6	6	6	6	6	6	6	6	6	5	6
4	54%	22%	4	4	3	4	4	3	4	4	5	4	3	3	3	2	3
6	87%	6%	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5
5	47%	21%	4	5	5	5	5	4	4	4	4	5	5	2	4	3	5
6	80%	8%	6	6	5	6	6	6	6	6	6	6	6	6	6	5	7
7	53%	13%	5	7	5	6	7	6	7	7	6	7	7	5	7	6	7
7	47%	24%	6	7	5	7	7	4	6	7	7	7	7	2	6	5	6
7	53%	10%	7	7	6	7	8	6	8	7	7	8	8	7	7	6	7
7	67%	7%	7	7	6	7	7	6	7	7	7	7	7	6	6	6	7
8	53%	10%	8	8	6	7	9	7	8	8	8	8	7	7	8	7	8
5	46%	18%	4	5	5	5	6	6	6	5	6	5	4	2	5	3	6
2	80%	53%	2	2	1	2	2	2	2	2	6	2	1	2	2	2	2
6	40%	24%	5	5	4	6	5	5	6	6	6	6	3	4	3	3	6
4	60%	12%	5	5	5	4	4	4	5	4	5	5	4	4	4	4	4
3	53%	19%	4	4	2	3	3	4	3	3	4	3	3	3	4	3	4
8	53%	13%	7	8	6	6	8	6	9	8	8	8	8	6	8	7	8
3	73%	18%	3	3	2	3	3	3	3	3	3	3	3	2	3	2	4
3	85%	14%	3	3	2	3	3	3	3	3	4	3	3	3	3	3	3
3	87%	12%	3	3	3	3	3	3	3	3	3	3	2	3	3	2	3
2	53%	21%	2	2	2	2	3	3	3	3	2	3	2	2	3	2	3
1	93%	24%	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1
2	93%	13%	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
3	73%	17%	3	3	3	2	3	2	3	3	3	3	2	3	3	2	3
4	53%	18%	4	4	3	4	5	3	5	4	4	4	3	4	3	3	4
6	67%	22%	6	6	3	6	6	4	6	6	5	6	6	6	4	3	6
3	87%	13%	3	3	2	3	3	3	3	3	3	4	3	3	3	3	3
	70%	**14.8%**	50	50	50	50	50	50	50	50	50	50	46	46	50	50	50
			0	0	0	0	0	0	0	0	0	0	4	4	0	0	0

Table AIV.2

The number of age readings, the coefficient of variation (CV), the percent agreement and the RELATIVE bias are presented by MODAL age for each age reader and for all readers combined. A weighted mean CV and a weighted mean percent agreement are given by reader and all readers combined. The CV's by MODAL age for each individual age reader and all readers combined indicate the precision in age reading by MODAL age. The weighted mean CV's over all MODAL age groups combined indicate the precision in age reading by reader and for all age readers combined.

Whiting Exchange set

NUMBER OF AGE READINGS

MODAL age	Eng Reader 1	R.Ir Reader 4	N.Ir Reader 5	Ger Reader 6	Nor Reader 14	Den Reader 7	Nor Reader 8	Bel Reader 9	Ger Reader 16	Sco Reader 17	Bel Reader 18	R.Ir Reader 19	R.Ir Reader 10	Eng Reader 12	Fra Reader 21	TOTAL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
2	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	105
3	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	195
4	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	105
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	75
6	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	135
7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	90
8	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	30
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total 0-15	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	750

COEFFICIENT OF VARIATION (CV)

MODAL age	Eng Reader 1	R.Ir Reader 4	N.Ir Reader 5	Ger Reader 6	Nor Reader 14	Den Reader 7	Nor Reader 8	Bel Reader 9	Ger Reader 16	Sco Reader 17	Bel Reader 18	R.Ir Reader 19	R.Ir Reader 10	Eng Reader 12	Fra Reader 21	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0%	0%	29%	0%	18%	18%	18%	18%	55%	22%	37%	18%	21%	21%	22%	20.1%
3	9%	14%	34%	14%	12%	16%	12%	14%	19%	14%	25%	19%	25%	28%	14%	17.2%
4	9%	9%	32%	26%	18%	13%	12%	0%	12%	18%	18%	13%	13%	31%	14%	12.1%
5	12%	0%	10%	0%	9%	19%	14%	9%	16%	0%	9%	42%	12%	25%	10%	13.6%
6	12%	8%	23%	0%	8%	13%	6%	8%	8%	5%	20%	12%	26%	22%	11%	12.4%
7	13%	0%	13%	6%	6%	17%	11%	0%	9%	6%	6%	34%	8%	11%	9%	11.2%
8	9%	0%	0%	11%	8%	11%	8%	0%	0%	0%	9%	11%	0%	0%	0%	11.5%
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	8.8%	6.3%	23.9%	8.3%	11.3%	15.3%	11.3%	8.4%	18.6%	10.8%	19.9%	20.4%	18.0%	22.5%	12.7%	14.9%
RANKING	4	1	15	2	7	9	6	3	11	5	12	13	10	14	8	

PERCENTAGE AGREEMENT

MODAL age	Eng Reader 1	R.Ir Reader 4	N.Ir Reader 5	Ger Reader 6	Nor Reader 14	Den Reader 7	Nor Reader 8	Bel Reader 9	Ger Reader 16	Sco Reader 17	Bel Reader 18	R.Ir Reader 19	R.Ir Reader 10	Eng Reader 12	Fra Reader 21	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%	100%	100%	100%	93%
2	100%	100%	71%	100%	86%	86%	86%	86%	71%	57%	57%	86%	71%	71%	57%	79%
3	92%	77%	23%	85%	85%	77%	85%	85%	62%	77%	62%	69%	62%	62%	77%	72%
4	86%	86%	29%	86%	71%	71%	57%	100%	57%	71%	57%	71%	71%	57%	71%	70%
5	60%	100%	60%	100%	80%	20%	60%	80%	40%	100%	80%	40%	60%	40%	60%	65%
6	56%	78%	44%	100%	78%	44%	89%	78%	78%	89%	67%	78%	56%	11%	56%	67%
7	67%	100%	17%	83%	83%	17%	50%	100%	67%	83%	83%	33%	67%	17%	67%	62%
8	50%	100%	0%	0%	50%	0%	50%	100%	100%	100%	50%	0%	100%	0%	100%	53%
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	78.0%	88.0%	38.0%	88.0%	80.0%	56.0%	74.0%	88.0%	66.0%	78.0%	66.0%	64.0%	66.0%	44.0%	68.0%	69.5%
RANKING	5	1	15	1	4	13	7	1	9	5	9	12	9	14	8	

RELATIVE BIAS

MODAL age	Eng Reader 1	R.Ir Reader 4	N.Ir Reader 5	Ger Reader 6	Nor Reader 14	Den Reader 7	Nor Reader 8	Bel Reader 9	Ger Reader 16	Sco Reader 17	Bel Reader 18	R.Ir Reader 19	R.Ir Reader 10	Eng Reader 12	Fra Reader 21	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	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	0.07
2	0.00	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.71	0.43	-0.14	0.14	0.29	0.29	0.43	0.18
3	0.08	0.23	0.31	0.00	0.15	0.08	0.15	0.00	0.46	0.23	0.15	-0.15	0.54	-0.15	0.23	0.15
4	0.14	0.14	0.43	0.43	0.43	-0.29	0.43	0.00	0.43	0.43	-0.14	-0.29	-0.29	-0.14	0.00	0.11
5	-0.40	0.00	0.40	0.00	0.20	-0.40	0.00	-0.20	0.20	0.00	-0.20	-1.40	-0.40	-1.00	0.40	-0.19
6	-0.22	0.00	-0.67	0.00	-0.22	-0.67	-0.11	0.00	0.00	0.11	-0.33	-0.33	-0.22	-1.44	0.22	-0.26
7	-0.50	0.00	-1.17	-0.17	0.17	-1.17	0.17	0.00	0.00	0.17	0.17	-1.50	-0.33	-1.00	0.00	-0.34
8	-0.50	0.00	-2.00	-1.50	0.50	-1.50	0.50	0.00	0.00	0.00	-0.50	-1.50	0.00	-1.00	0.00	-0.50
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	-0.12	0.08	-0.16	-0.02	0.14	-0.36	0.14	-0.00	0.30	0.24	-0.08	-0.50	0.02	-0.54	0.20	-0.04
RANKING	6	5	9	3	7	13	8	1	12	11	4	14	2	15	10	

Overall ranking

	Eng Reader 1	R.Ir Reader 4	N.Ir Reader 5	Ger Reader 6	Nor Reader 14	Den Reader 7	Nor Reader 8	Bel Reader 9	Ger Reader 16	Sco Reader 17	Bel Reader 18	R.Ir Reader 19	R.Ir Reader 10	Eng Reader 12	Fra Reader 21
Ranking Coefficient of Variation	4	1	15	2	7	9	6	3	11	5	12	13	10	14	8
Ranking Percentage Agreement	5	1	15	1	4	13	7	1	9	5	9	12	9	14	8
Ranking Relative bias	6	5	9	3	7	13	8	1	12	11	4	14	2	15	10
OVERALL RANKING	**4**	**3**	**13**	**2**	**5**	**12**	**6**	**1**	**11**	**6**	**9**	**13**	**6**	**15**	**10**

Table AIV.3

Upper table: The age compositions estimated by each age reader and all age readers combined.

Midle table: The estimated mean length-at-age by age reader and by all age readers combined.

Lower table: Bias tests: non-parametrically with a one-sample Wilcoxon rank sum test. The inter-reader bias test and the reader against MODAL age bias test.

AGE COMPOSITION

		Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra	
	Age	Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21	**TOTAL**
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	1	1	1	2	1	1	1	1	1	1	-	3	1	1	1	1	**17**
	2	7	7	9	8	6	7	6	7	5	5	6	12	5	10	4	**104**
	3	12	10	7	11	12	13	12	12	9	13	12	12	13	15	14	**177**
	4	9	9	7	7	7	12	7	9	9	8	7	8	12	6	8	**125**
	5	8	7	11	5	7	5	7	5	7	6	7	4	3	9	5	**96**
	6	6	7	11	11	9	10	10	7	11	9	6	10	8	6	8	**129**
	7	6	7	3	7	5	2	3	7	5	6	7	3	5	3	7	**76**
	8	1	2	-	-	2	-	3	2	3	3	2	-	3	-	3	**24**
	9	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	**2**
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Total	**0-15**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**750**

MEAN LENGTH AT AGE

		Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra	
	Age	Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21	**ALL**
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	1	28.0	28.0	27.5	28.0	28.0	28.0	28.0	28.0	28.0	-	27.7	28.0	28.0	28.0	28.0	**27.9**
	2	31.3	31.3	36.2	31.0	30.2	30.0	30.2	30.9	32.2	29.4	33.5	33.1	30.0	31.8	29.8	**31.7**
	3	36.4	36.7	35.6	38.8	37.1	35.5	37.1	38.3	35.0	36.3	35.9	37.4	33.8	38.5	35.6	**36.6**
	4	39.4	38.7	38.7	38.6	41.3	42.5	38.7	38.3	40.3	37.8	43.1	40.1	42.2	41.8	41.0	**40.3**
	5	39.4	39.7	38.5	38.8	36.4	40.4	40.3	39.6	41.7	41.0	38.3	39.5	42.0	38.4	38.4	**39.3**
	6	40.2	42.0	39.5	40.1	41.6	38.2	39.9	40.1	37.0	40.8	41.2	40.2	38.3	38.3	40.0	**39.7**
	7	41.5	38.1	39.3	38.3	38.2	41.5	40.0	39.1	39.6	38.2	37.6	40.3	41.0	42.0	39.9	**39.4**
	8	32.0	37.5	-	-	40.5	-	35.7	37.5	37.3	37.7	40.5	-	38.3	-	37.3	**37.6**
	9	-	-	-	-	32.0	-	43.0	-	-	-	-	-	-	-	-	**37.5**
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
d mean	**0-15**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**	**37.5**

Inter-reader bias test and reader against MODAL age bias test

Bias tests: non-parametrically with a one-sample Wilcoxon rank sum test. The inter-reader bias test and the reader against the Modal age bias test

	Reader 1 Eng R1	Reader 4 R.Ir R2	Reader 5 N.Ir R3	Reader 6 Ger R4	Reader 14 Nor R5	Reader 7 Den R6	Reader 8 Nor R7	Reader 9 Bel R8	Reader 16 Ger R9	Reader 17 Sco R10	Reader 18 Bel R11	Reader 19 R.Ir R12	Reader 10 R.Ir R13	Reader 12 Eng R14	Reader 21 Fra R15
Reader 1 Eng R1		-	* *	* *	-	-	-	-	*	-	* *	-	*	-	-
Reader 4 R.Ir R2	-		*	-	* *	-	* *	*	-	-	*	* *	*	*	* *
Reader 5 N.Ir R3	* *	*		* *	* *	* *	* *	* *	-	-	* *	* *	*	-	-
Reader 6 Ger R4	* *	-	* *		-	-	-	*	-	-	* *	-	* *	-	-
Reader 14 Nor R5	-	* *	* *	-		* *	* *	-	* *	-	-	*	* *	* *	* *
Reader 7 Den R6	-	-	* *	-	* *		* *	-	* *	* *	-	* *	*	*	* *
Reader 8 Nor R7	-	* *	* *	-	* *	* *		-	* *	*	*	*	* *	*	* *
Reader 9 Bel R8	-	*	* *	*	-	-	-		-	-	* *	-	* *	-	-
Reader 16 Ger R9	*	-	-	-	* *	* *	* *	-		* *	-	* *	*	* *	* *
Reader 17 Sco R10	-	-	-	-	-	* *	*	-	* *		-	* *	-	* *	* *
Reader 18 Bel R11	* *	*	* *	* *	-	-	*	* *	-	-		-	* *	-	* *
Reader 19 R.Ir R12	-	* *	* *	-	*	* *	*	-	* *	* *	-		*	* *	-
Reader 10 R.Ir R13	*	*	*	* *	* *	*	* *	* *	*	-	* *	*		*	* *
Reader 12 Eng R14	-	*	-	-	* *	*	*	-	* *	* *	-	* *	*		* *
Reader 21 Fra R15	-	* *	-	-	* *	* *	* *	-	* *	* *	* *	-	* *	* *	
Modal	-	-	* *	-	-	-	-	* *	-	* *	* *	*	* *	-	-

-	= no sign of bias (p>0.05)
*	= possibility of bias (0.01<p<0.05)
* *	= certainty of bias (p<0.01)

Table AIV.4

2STDEV

MODAL	Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra	2STDEV
age	Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21	**ALL**
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.516**
2	0.000	0.000	1.155	0.000	0.756	0.756	0.756	0.756	2.992	1.069	1.380	0.756	0.976	0.976	1.069	**1.136**
3	0.555	0.877	2.219	0.816	0.751	0.987	0.751	0.816	1.320	0.877	1.601	1.109	1.754	1.601	0.877	**1.230**
4	0.756	0.756	2.795	2.268	1.574	0.976	1.069	0.000	1.069	1.574	1.380	0.976	0.976	2.430	1.155	**1.502**
5	1.095	0.000	1.095	0.000	0.894	1.789	1.414	0.894	1.673	0.000	0.894	3.033	1.095	2.000	1.095	**1.566**
6	1.333	1.000	2.449	0.000	0.882	1.414	0.667	1.000	1.000	0.667	2.236	1.414	2.963	2.028	1.333	**1.674**
7	1.673	0.000	1.506	0.816	0.816	1.966	1.506	0.000	1.265	0.816	0.816	3.742	1.033	1.265	1.265	**1.778**
8	1.414	0.000	0.000	1.414	1.414	1.414	1.414	0.000	0.000	0.000	1.414	1.414	0.000	0.000	0.000	**1.722**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MEAN AGE

	MODAL	Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra	
	age	Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21	**ALL**
	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	**1.07**
	2	2.00	2.00	2.00	2.00	2.14	2.14	2.14	2.14	2.71	2.43	1.86	2.14	2.29	2.29	2.43	**2.18**
	3	3.08	3.23	3.31	3.00	3.15	3.08	3.15	3.00	3.46	3.23	3.15	2.85	3.54	2.85	3.23	**3.15**
	4	4.14	4.14	4.43	4.43	4.43	3.71	4.43	4.00	4.43	4.43	3.86	3.71	3.71	3.86	4.00	**4.11**
	5	4.60	5.00	5.40	5.00	5.20	4.60	5.00	4.80	5.20	5.00	4.80	3.60	4.60	4.00	5.40	**4.81**
	6	5.78	6.00	5.33	6.00	5.78	5.33	5.89	6.00	6.00	6.11	5.67	5.67	5.78	4.56	6.22	**5.74**
	7	6.50	7.00	5.83	6.83	7.17	5.83	7.17	7.00	7.00	7.17	7.17	5.50	6.67	6.00	7.00	**6.66**
	8	7.50	8.00	6.00	6.50	8.50	6.50	8.50	8.00	8.00	8.00	7.50	6.50	8.00	7.00	8.00	**7.50**
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d mean	**0-15**	**4.26**	**4.46**	**4.22**	**4.36**	**4.52**	**4.02**	**4.52**	**4.38**	**4.68**	**4.62**	**4.30**	**3.88**	**4.40**	**3.84**	**4.58**	4.34

MEAN AGE +2STDEV

MODAL	Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra	
age	Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21	**ALL**
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1.58**
2	2.000	2.000	3.155	2.000	2.899	2.899	2.899	2.899	5.706	3.498	3.237	2.899	3.262	3.262	3.498	**3.32**
3	3.632	4.108	5.526	3.816	3.905	4.064	3.905	3.816	4.782	4.108	4.755	3.956	5.293	4.447	4.108	**4.38**
4	4.899	4.899	7.223	6.696	6.002	4.690	5.498	4.000	5.498	6.002	5.237	4.690	4.690	6.287	5.155	**5.62**
5	5.695	5.000	6.495	5.000	6.094	6.389	6.414	5.694	6.873	5.000	5.694	6.633	5.695	6.000	6.495	**6.38**
6	7.111	7.000	7.783	6.000	6.660	6.748	6.556	7.000	7.000	6.778	7.903	7.081	8.741	6.583	7.556	**7.42**
7	8.173	7.000	7.339	7.650	7.983	7.800	8.672	7.000	8.265	7.983	7.983	9.242	7.699	7.265	8.265	**8.43**
8	8.914	8.000	6.000	7.914	9.914	7.914	9.914	8.000	8.000	8.000	8.914	7.914	8.000	7.000	8.000	**9.22**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

MEAN AGE -2STDEV

MODAL	Eng	R.Ir	N.Ir	Ger	Nor	Den	Nor	Bel	Ger	Sco	Bel	R.Ir	R.Ir	Eng	Fra	
age	Reader 1	Reader 4	Reader 5	Reader 6	Reader 14	Reader 7	Reader 8	Reader 9	Reader 16	Reader 17	Reader 18	Reader 19	Reader 10	Reader 12	Reader 21	**ALL**
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.550**
2	2.000	2.000	0.845	2.000	1.387	1.387	1.387	1.387	-0.278	1.360	0.477	1.387	1.310	1.310	1.360	**1.045**
3	2.522	2.354	1.089	2.184	2.403	2.090	2.403	2.184	2.141	2.354	1.553	1.737	1.784	1.245	2.354	**1.924**
4	3.387	3.387	1.634	2.161	2.855	2.738	3.360	4.000	3.360	2.855	2.477	2.738	2.738	1.427	2.845	**2.613**
5	3.505	5.000	4.305	5.000	4.306	2.811	3.586	3.906	3.527	5.000	3.906	0.567	3.505	2.000	4.305	**3.247**
6	4.444	5.000	2.884	6.000	4.896	3.919	5.222	5.000	5.000	5.444	3.431	4.252	2.815	2.528	4.889	**4.066**
7	4.827	7.000	4.328	6.017	6.350	3.867	5.661	7.000	5.735	6.350	6.350	1.758	5.634	4.735	5.735	**4.878**
8	6.086	8.000	6.000	5.086	7.086	5.086	7.086	8.000	8.000	8.000	6.086	5.086	8.000	7.000	8.000	**5.778**
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

In the age bias plots below the mean age recorded +/- 2stdev of each age reader and all readers combined are plotted against the MODAL age. The estimated mean age corresponds to MODAL age, if the estimated mean age is on the 1:1 equilibrium line (solid line). RELATIVE bias is the age difference between estimated mean age and MODAL age.

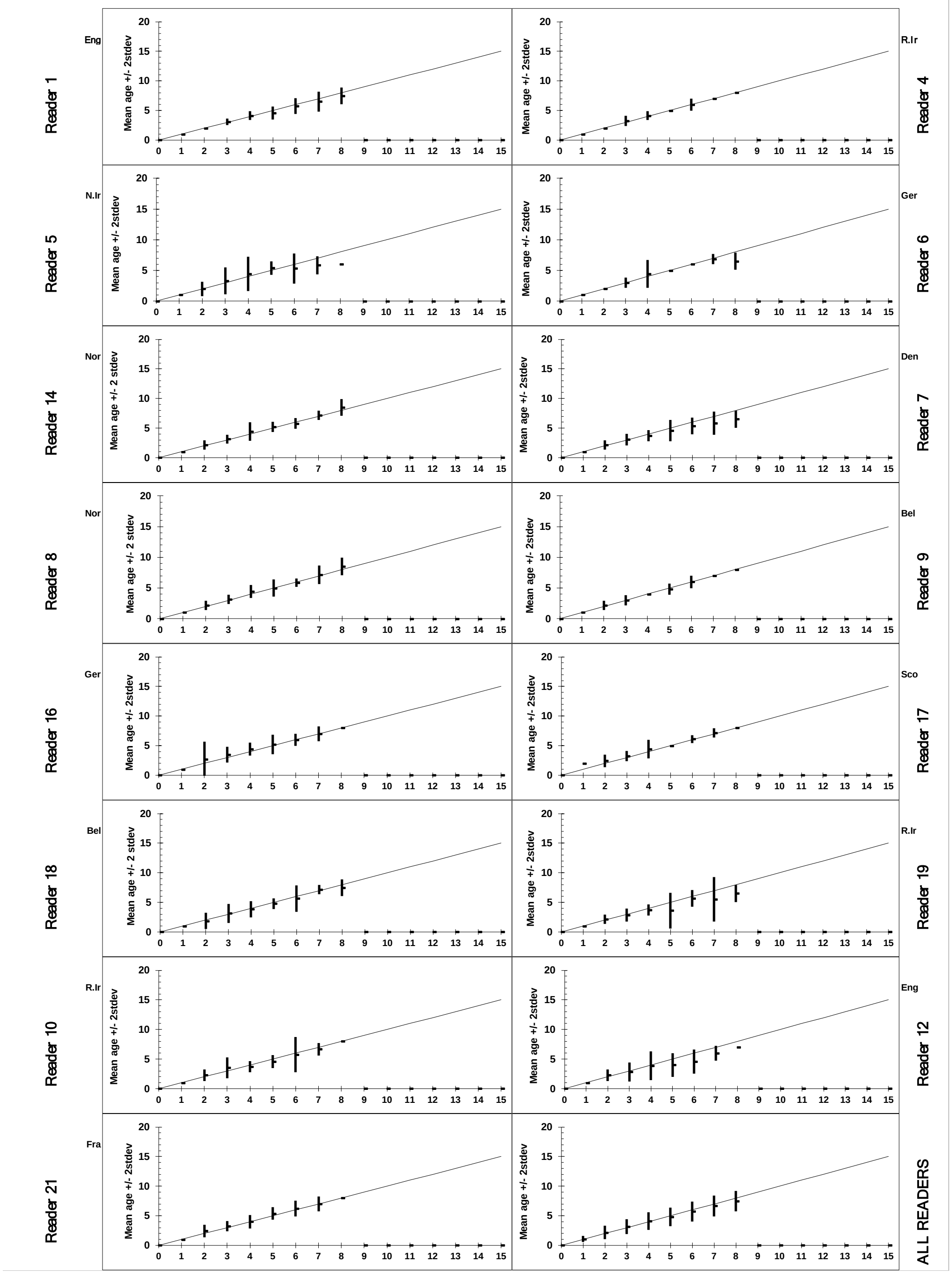


Figure AIV.1

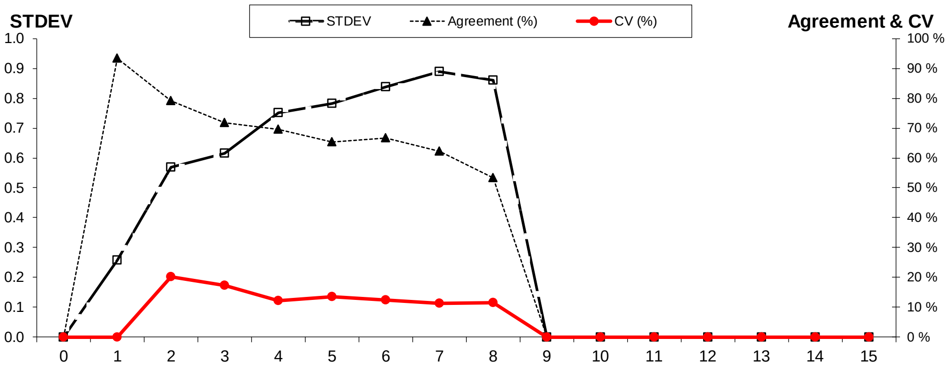


Figure 2 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age.
CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.

Figure AIV.2

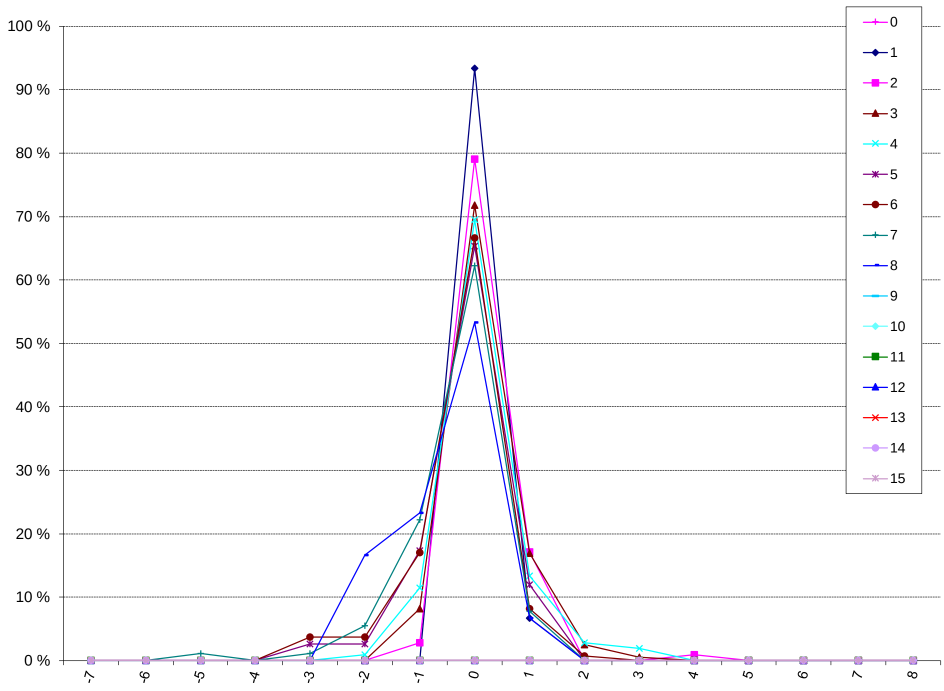
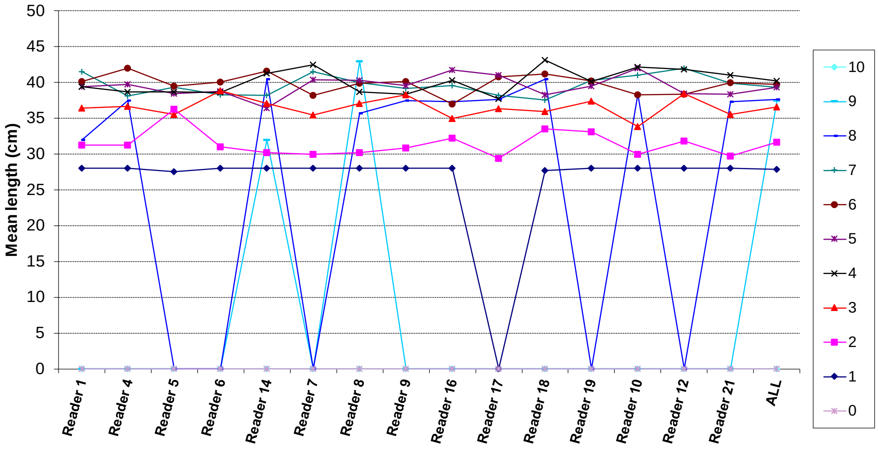


Figure 3 The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no RELATIVE bias, if the age reading errors are normally distributed. The distributions are skewed, if RELATIVE bias occurs.

Figure AIV.3



Mean length (cm)
50
45
40
35
30
25
20
15
10
5
0
Reader 1
Reader 4
Reader 5
Reader 6
Reader 14
Reader 7
Reader 8
Reader 9
Reader 16
Reader 17
Reader 18
Reader 19
Reader 10
Reader 12
Reader 21
ALL
10
9
8
7
6
5
4
3
2
1
0

Figure AIV.4

Appendix V: Reference Collection otoliths with high ages agreed

Fish 1 – area 4bc, May

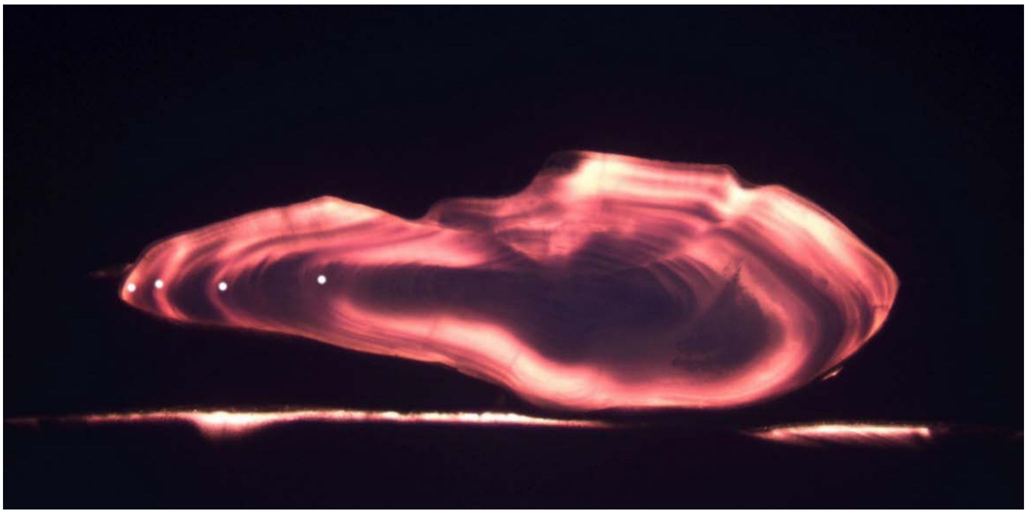


Figure AV_1: Sectioned. Age 4 with 94% agreement, 29 cm, caught in May. Fish no. 407

Fish 2 – area 7g, February

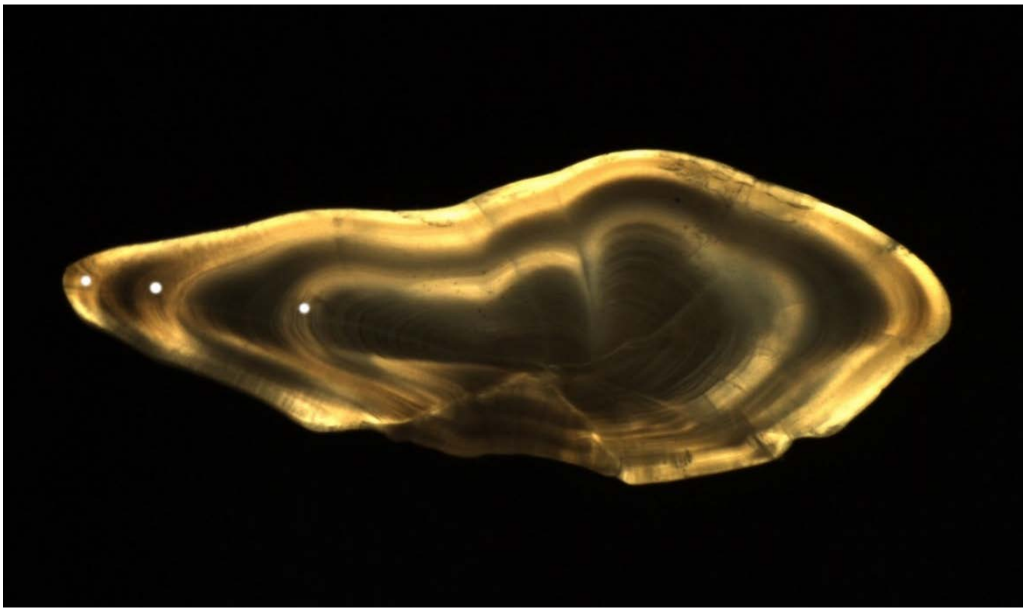


Figure AV_2: Sectioned. Age 3 with 94% agreement, 35 cm, caught in February. Fish no. 428

Fish 3 – area 7g, February

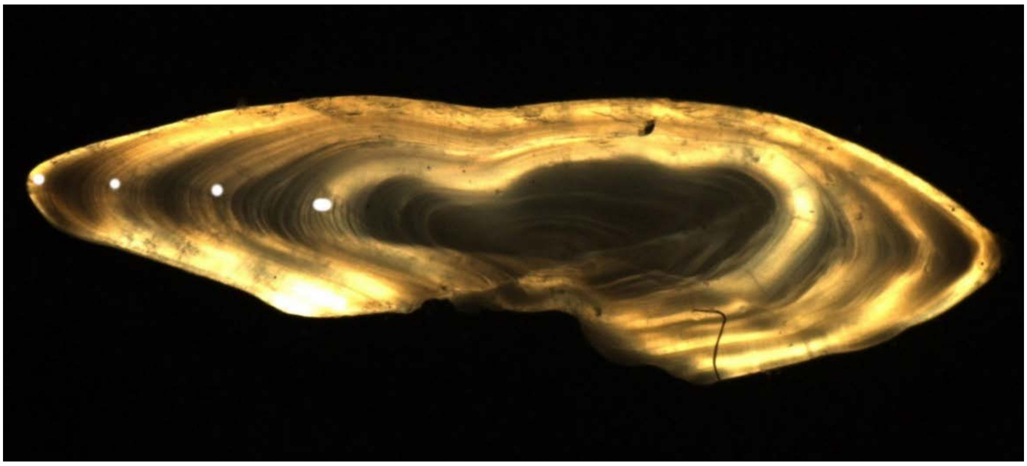


Figure AV_3: Sectioned. Age 4 with 94% agreement, 41 cm, caught in February. Fish no. 435

Fish 4 – area 7g, March

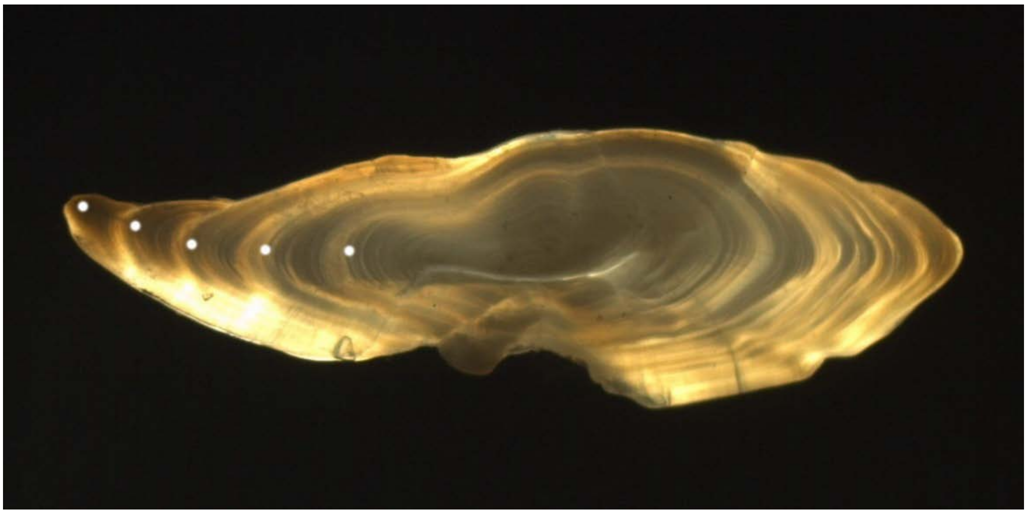


Figure AV_4: Sectioned. Age 5 with 100% agreement, 56 cm, caught in March. Fish no. 459

Fish 5 – area 7g, March

Figure AV_5: Sectioned. Age 5 with 94% agreement, 49 cm, caught in March. Fish no. 467

Fish 6 – area 7g, April

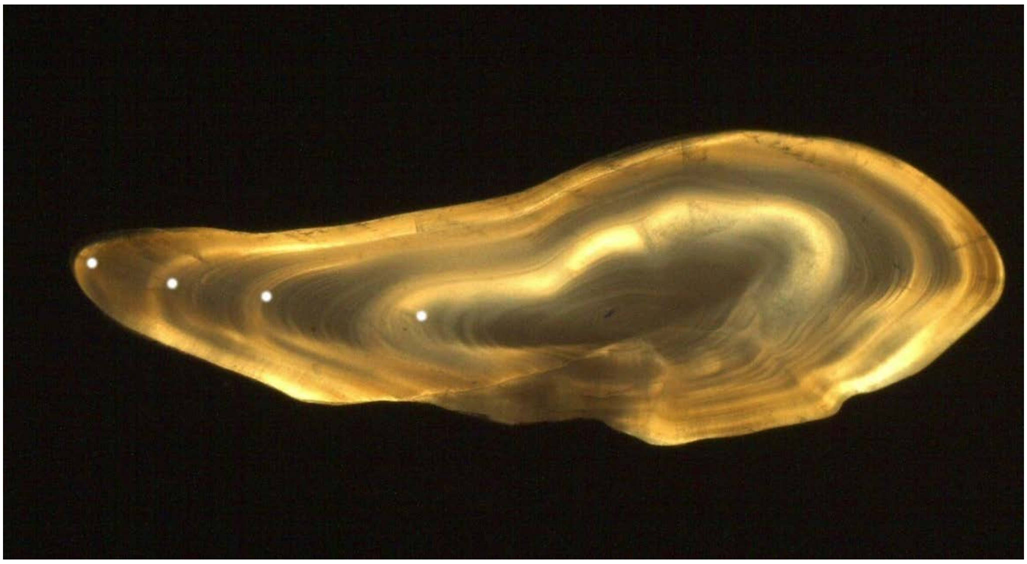


Figure AV_6: Sectioned. Age 4 with 100% agreement, 47 cm, caught in April. Fish no. 470

Fish 7 – area 7g, January

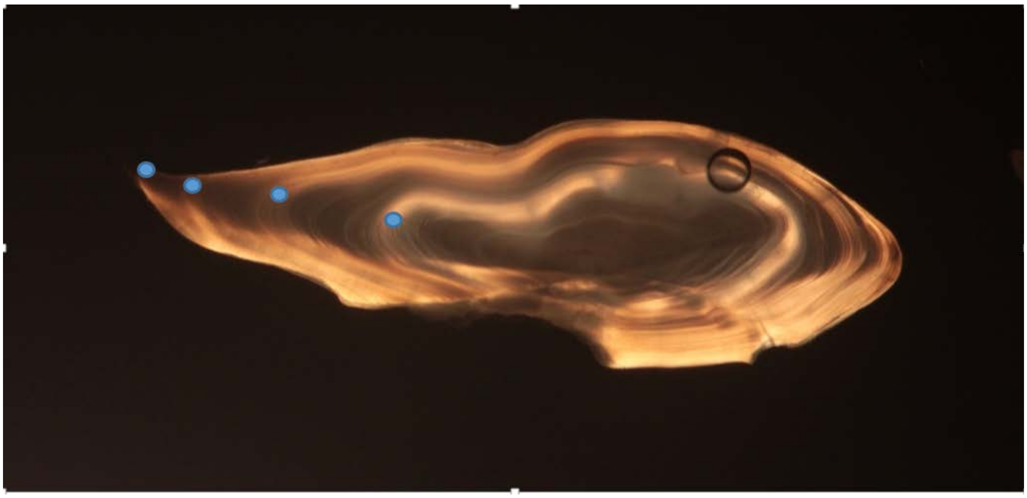


Figure AV_7: Sectioned. Age 4 with 100% agreement, 51 cm, caught in January. Fish no. Wg 1

Fish 8– area 7g, January

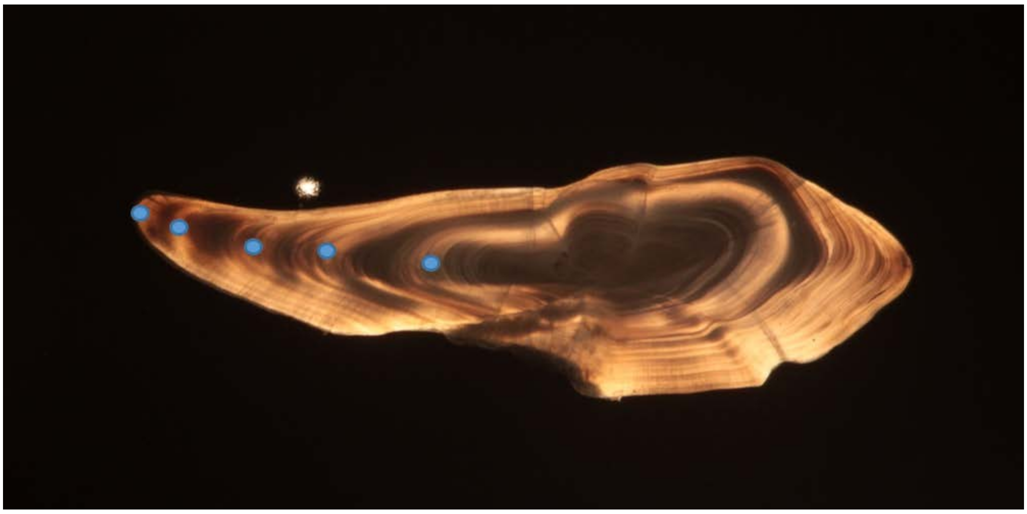


Figure AV_8: Sectioned. Age 5 with 100% agreement, 45 cm, caught in January. Fish no. Wg 10

Fish 9– area 7g, January

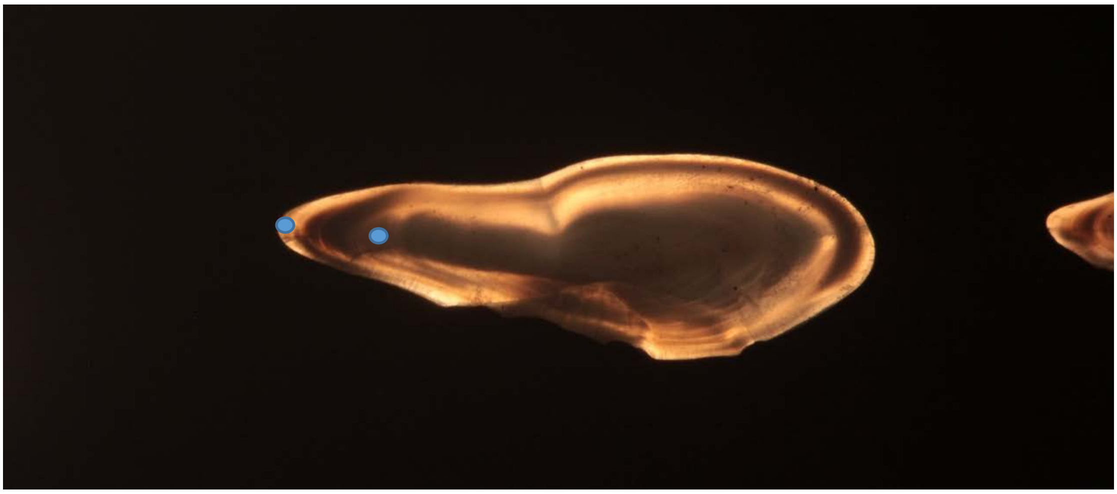


Figure AV_9: Sectioned. Age 2 with 100% agreement, 41 cm, caught in January. Fish no. Wg 20

Appendix VI: Features on whiting otoliths that can cause difficulties for age readers

Fish 1 – Otolith not sectioned correctly

This otolith shows the typical pattern that occurs within the first ring when the section is not quite through the nucleus. This pattern has been described as crenulations by, as the section gets progressively further away from the growth centre the crenulations become bigger to often form a figure of eight pattern while the size of the first ring becomes progressively smaller. Eventually as the section gets further away from the centre of the otolith the figure of eight pattern/crenulations disappear and the first ring will be missed. The crenulations have only just started on this otolith and the first ring is still clear.

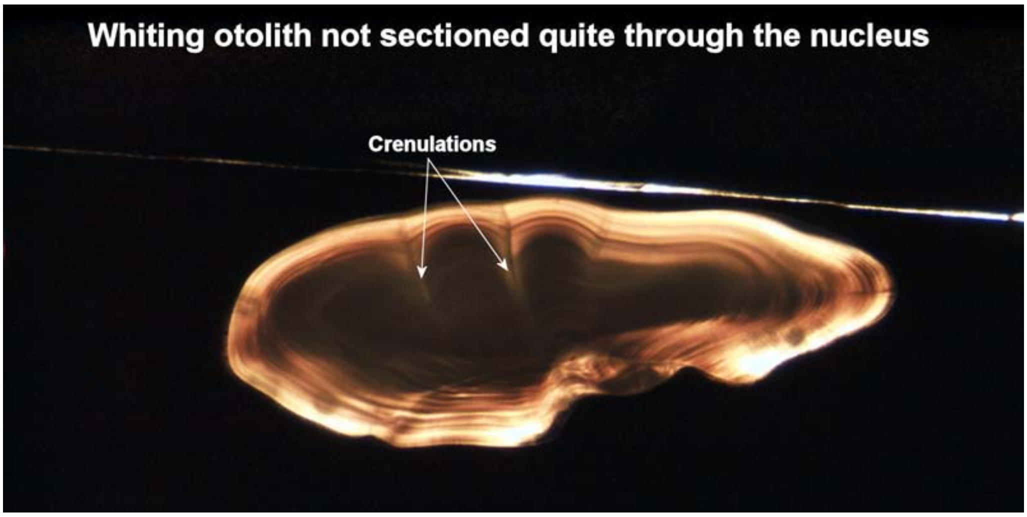


Figure AVI_1: This otolith shows the typical pattern that occurs within the first ring when the section is not quite through the nucleus.

Fish 2 – Otolith resin issue

This section demonstrates how black resin underneath part of an undercut otolith edge can make a translucent edge look opaque when viewed by transmitted light. This effect would be resolved using reflected light.

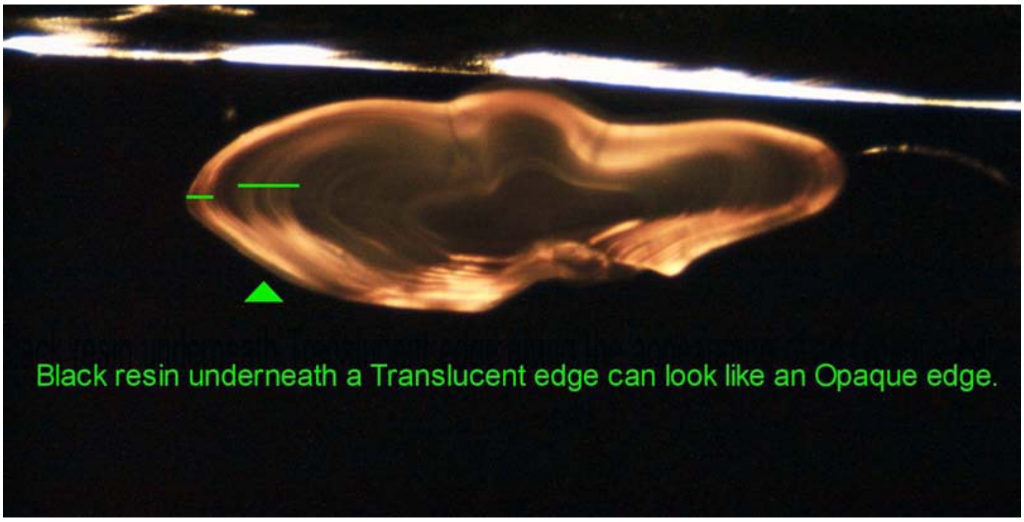


Figure AVI_2: This section demonstrates how black resin underneath part of an undercut otolith edge can make a translucent edge look opaque when viewed by transmitted light

Fish 3 – Humphries Shadow

In whiting otoliths an opaque area lying within the annual translucent increment on the internal face of the rostrum (mainly on dorsal area) has been termed Humphries Shadow (Anon., 1987). It is usually apparent in all translucent increments but sometimes missing in the first one. This can be a useful additional feature to help interpret the increment structure for age estimation, but is not always reliable especially when otoliths do not show this pattern of growth. An annual translucent increment at the edge showing a translucent ring and a Humphries Shadow can be considered a complete year.

Figure AVI_3: Shows a 3-year-old whiting otolith with 3 complete translucent zones and Humphries shadows in each zone.

Appendix VII: Ageing manual

Otolith sampling

This group agreed that it is not important which otolith is used left or right and that for age estimation only one otolith needs to be used.

Diagram of otolith interpretation

The following (Figure VII.1) is a schematic interpretation of the growth development of *Merlangius merlangus* from its birthday on 1 January following it through to age. The translucent zones are used to determine the age, and towards the end of the year the translucent zone is developing, but should not be counted as a fully developed ring until the 1 January.

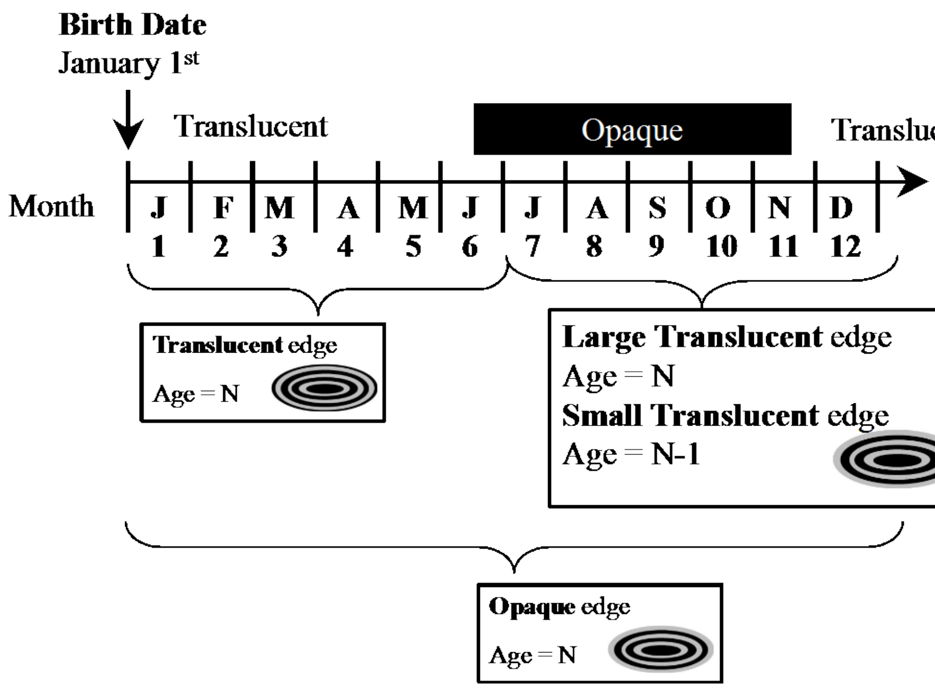


Figure VII.1 : Schematic interpretation of the growth development of the annual zones over the course of a year.

An annulus is characterized by the brightest contrast between the preceding translucent and the subsequent opaque zone deposited in the following year. An annulus should be traceable on the whole otolith or the slice, with the exception of the dorso-medial surface of the rostrum. In a section, problems may arise in the area of the sulcus acusticus and the dorso-medial direction on the medial side.

Preference of source of light

Each reader might use different light sources, reflective or transmitted. It is recommended that if available the otolith should be interrogated by both light methods, as the different light sources can reveal different characteristics of the otolith.

Magnification

The same magnification of between 10x to 20x is recommended to compare the size of growth rings between some otoliths because the widths of consecutive annual growth zones should decrease with increasing age, be careful with the magnification when reading by stereomicroscope, as a high magnification can cause overestimation of the age by mistakenly counting the false rings and annuli. To identify a lot of annuli on the edge for the older fish which are very close together, it is possible to zoom in on the edge area only.

Image characteristics

Different institutes use different methods of otolith preparation for the aging process and the readers recommend when using images to use only calibrated images (with bar of calibration, pretreatments of images could induce bias due to different size of otoliths) and to see the entire slice or the entire whole otolith to follow the annulus around the whole otolith.

When using slides the otolith must be cut through the nucleus as straight as possible to avoid deviation from the horizontal axis and distortion that may cause a 3D effect. Always ensure that the resin fully covers the otolith to make sure there are no gaps which can make the determination of the edge more difficult. When coming across a difficult otolith it may be of benefit to flip over the slide and look at it from the reverse side, this can clarify the structures the reader is viewing.

For broken otoliths it is important to cut the otolith through the nucleus as straight as possible for ease of reading before mounting in plasticine. Coating with water or baby oil and deflecting the light facilitates a clearer reading.

Characteristic of the growth rings

The readers should not interpret the rings of *Merlangius merlangus* as they would other gadoids as *Merlangius merlangus* has very indistinct rings and the shape of the ring around the otolith is not uniform.

For difficult otoliths it may be advisable to refer to adjacent and similar otoliths and compare similar characteristic to reaffirm a decision. Information where available on date of capture, length, area should be used to give the best possible interpretation.

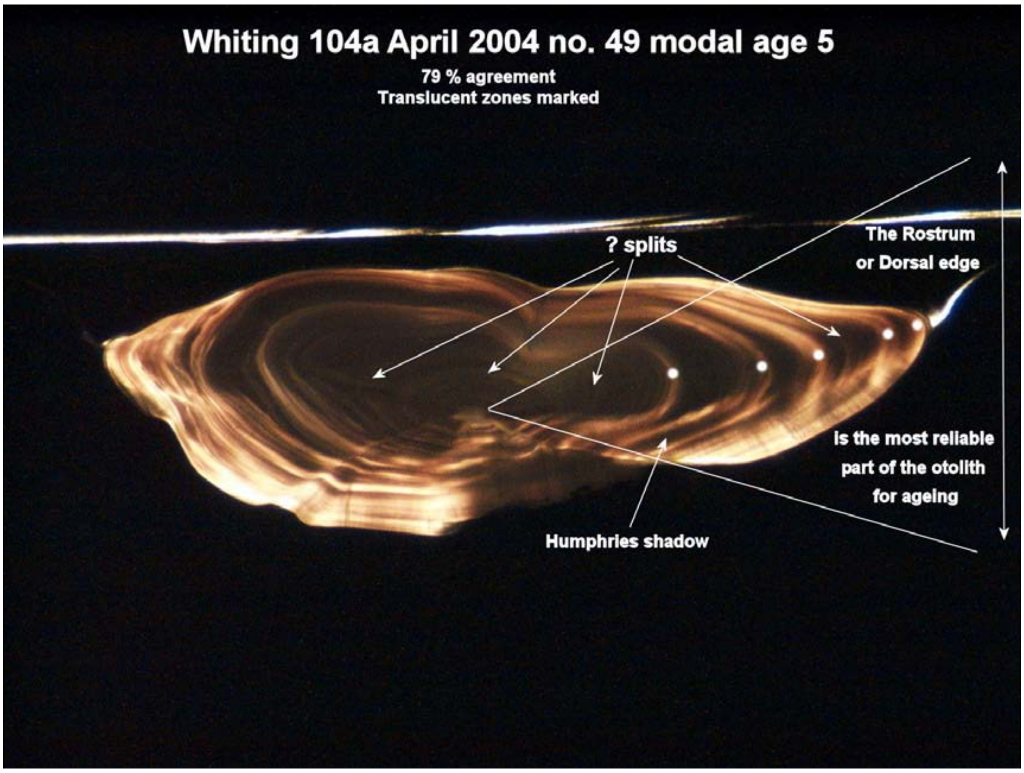


Figure VII.2 diagnostic features for ageing

Appendix VIII: Results sectioned vs. whole otoliths

NUMBER	SAMPLE	FISH	LENGTH	MONTH	AREA	Number	Slide	Age FW	Age TW	Age HR	Age MJ
485	2358	1	19	01/02/2016	4A	29	29	1	1	2	2
486	2358	2	16	01/02/2016	4A	29	29	1	1	2	2
487	2358	3	17	01/02/2016	4A	29	29	1	1	2	2
488	2358	6	16	01/02/2016	4A	29	29	1	1	2	2
489	2358	7	35	01/02/2016	4A	29	29	2	2	3	3
490	2358	9	20	01/02/2016	4A	29	29	-	-	2	2
491	2358	10	27	01/02/2016	4A	29	29	2	2	3	3
492	2358	11	20	01/02/2016	4A	30	30	1	1	2	2
493	2358	16	16	01/02/2016	4A	30	30	1	1	2	2
494	2358	17	30	01/02/2016	4A	30	30	2	2	4	4
495	2358	18	27	01/02/2016	4A	30	30	2	2	3	3
496	2358	19	24	01/02/2016	4A	30	30	2	2	3	3
497	2358	20	28	01/02/2016	4A	30	30	-	-	3	3
498	2358	22	15	01/02/2016	4A	31	31	1	1	2	2
499	2358	23	31	01/02/2016	4A	31	31	2	2	3	3
500	2358	24	33	01/02/2016	4A	31	31	4	4	3	4(3)
501	2358	26	18	01/02/2016	4A	31	31	1	1	2	2
502	2358	27	21	01/02/2016	4A	31	31	1	1	2	2
503	2358	29	29	01/02/2016	4A	31	31	2	2	3	4
504	2358	31	28	01/02/2016	4A	31	31	3	3	3	3

Note: Samples 490 and 497 were not sectioned and thus could not be read by FW and TW.

Appendix IX: Recommendations

Recommendation	Addressed to
WKARWHG2 recommends an age validation study using otolith chemistry to determine the true annuli and to gain a better understanding of 'Humphries shadow' and splits	WGBIOP
WKARWHG2 recommends small-scale otolith exchange between Denmark, Norway and Scotland to determine the accuracy of reading whole otoliths vs. sectioned.	WGBIOP
WKARWHG2 recommends that the guidelines for workshops should be re-written to help chairs understand the stages of organising and running a workshop and to make the workshop more beneficial to age readers that attend.	WGBIOP
WKARWH2 recommends to organize a new ageing exchange and workshop for *merlangus merlangus* to check the use of ageing criteria and the progress in the precision	WGBIOP