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Report of the Whiting (*Merlangius merlangus*, L) Otolith Exchange Scheme 2004 and Workshop 2005

Cefas
Lowestoft, England
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Foras na Mara

Report of the Whiting (*Merlangius merlangus*, L) Otolith Exchange Scheme 2004 and Workshop 2005

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1. Workshop Report: Cefas Fisheries Laboratory, Lowestoft, NR33 0HT
2. Exchange Report: Fisheries Research Services, The Marine Laboratory, Aberdeen AB11 9DB

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1.1 Introduction

The Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) meeting in Rome in March, 2003, identified whiting (Merlangius merlangus, L) as one species requiring confirmation of ages being assigned by Fisheries Institutes. The previous international workshop on whiting otoliths was held in Hirtshals, Denmark in 1998.

The Planning Group indicated that FRS, Marine Laboratory, Aberdeen would be responsible for the organisation and analysis of the exchange (Gordon Henderson and Aileen Shanks) and that CEFAS, Lowestoft (Mick Easey) would be responsible for the workshop to be held in 2005.

Whiting is generally regarded as one of the most difficult gadoid species to age due to problems in distinguishing true annual rings from other rings.

Different methods of sample preparation and reading technique are used by Institutes engaged in ageing whiting. Some Institutes break their otoliths and embed them in a soft medium prior to examining them under transmitted light, while others section their otoliths and embed them in resin before examining them with transmitted light.

The objectives of the exchange were:

to investigate the levels of agreement on age readings;
to analyse the relative differences between reader ages;
to compare readings by otolith processing method.

1.2 Participants

Name	Institute	Country
I.Maertens	CLO-Sea Fisheries	Belgium
B.Maertens	CLO-Sea Fisheries	Belgium
M.Moerman	CLO-Sea Fisheries	Belgium
H.Rasmussen	DIFR	Denmark
M.Easey	CEFAS	England (UK)
T.Boon	CEFAS	England (UK)
M.Boon	CEFAS	England (UK)
T.Woods	CEFAS	England (UK)
J.Keable	CEFAS	England (UK)
R.Bellail	IFREMER	France
J-L. Dufour	IFREMER	France
D.Schroder	BFA fur Fischerei	Germany
F. Beussel	BFA fur Fischerei	Germany
F.Woods	Marine Institute	Ireland
H.McCormack	Marine Institute	Ireland
I.Hehir	Marine Institute	Ireland
G.Rink	RIVO	Netherlands
W. McCurdy	DARDNI	N. Ireland (UK)
H.Larsen	Inst. Of Marine Research	Norway
L.Solbakken	Inst. Of Marine Research	Norway
P.Clark	FRS	Scotland (UK)
M.Mathewson	FRS	Scotland (UK)
G.Henderson	FRS	Scotland (UK)

1.3 Otoliths Used in Exchange

Due to time constraints, it was not possible to form a collection of otoliths from whiting sampled at all times of year and so the samples were obtained in March and April only of 2004 from various areas around the British Isles both by commercial fishing vessels and from research vessel cruises. The length range of the fish sampled was between 16 and 54 centimetres with mean 31.0cm and standard deviation 6.79cm. A total of 200 pairs of otoliths formed the collection with one otolith of each pair being broken and mounted in modelling clay by FRS while the other otolith of each pair was mounted on a slide by CEFAS. In addition, CEFAS digitised all the images and compiled a CD of them. Thus the whole collection can be thought of as three sets:

broken otolith set
sectioned otolith set
digitised image set on CD.

These otolith sets were circulated around ten European Institutes, including FRS and CEFAS, so that age determinations could be made (see Appendix 2). The broken and sectioned sets were circulated separately as not all Institutes made determinations on both sets. Any number of participants could make determinations within these Institutes. Detailed reading procedures were sent to each Institute (see Appendix 1) which included an instruction to record a single estimate of age for each otolith and not to omit otoliths which were difficult to read. The birthday of whiting was taken to be 1st January. It was hoped that all age readings recorded in Excel workbooks in the format provided would be returned, with the otolith sets, to FRS by the end of December, 2004. In fact, the last of the data were submitted to FRS in late July, 2005.

1.4 Data and Results

1.4.1 Broken set

The set of broken otoliths was read by 11 readers from six Institutes. Of the readers 8 were experienced and 3 were classed as intermediate readers. No novices read the broken otoliths. The spreadsheet was completed according to the instructions contained in Guidelines and Tools for Age Reading Comparisons by Eltink *et al* (2000). Modal ages were calculated for each otolith read, along with percentage agreement, mean age and precision coefficient of variation where

percentage agreement = 100x(no. of readers agreeing with modal age / total no. of readers) (for each otolith)
precision c. v. = 100x(standard deviation of age readings/ mean of age readings) (for each otolith).

Percentage agreement ranged from 27% to 100% with an average of 72.6%. Of the 200 otoliths, 92 were read with at least 80% agreement and, indeed, 26 were read with 100% agreement by the 11 readers. The precision coefficient of variation ranged from 0% (corresponding to 100 % agreement in readings) to 49% (no. 175) with an average of 16.3%. The otolith (no. 182, corresponding to a whiting of length 37cm) with the smallest percentage agreement (27%) provided the following estimates of age:

Age	No. of readers
3	2
4	3
5	3
6	3

The modal age was estimated to be 4 while the mean age in this case is 5.

Table (A3.2) examines the readings of individuals at each modal age and summarises the number of otoliths read, the coefficient of variation, percentage agreement and relative bias of each reader. Modal ages 1 and 7 only were read by some participants with 0% coefficient of variation, that is, they read all the otoliths in question as what turned out to be the modal age (100% agreement). The largest coefficient of variation was 46% which

occurred for age 1. The smallest percentage agreement was 0% which indicated that one reader failed to read either of the two otoliths with modal age 7 as 7. The next smallest percentage agreement was 13% which resulted from one reader's ageing of seven modal age 6 otoliths. Figure (A3.2) shows coefficients of variation and percentage agreement calculated over all 11 readers. The overall relative bias of one reader was zero whilst for another it was +0.76; derived from a positive bias at all individual modal ages (see Figure A3.3). Over all 11 readers there was a tendency to overestimate the age of younger fish and underestimate the age of older fish (see Figure A3.4). This has been found in other studies, (Report of the Workshop on otolith ageing of North Sea Whiting, Hirtshals, Denmark, 23-28 October 1998, ICES CM1999/G: 14). In overall ranking, one experienced reader was ranked 10 and one inexperienced reader was ranked 5.

Plots of age bias are shown in Figure Appendix Figure 3.1. 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.

1.4.2 Sectioned set

From sectioned otoliths, the age estimates of 19 non-novice readers were included in the analysis. The readings of 2 novices were excluded from the analysis after scrutiny of their readings.

The overall percentage agreement was 80.9% with values for individual otoliths ranging from 37% to 100%. A total of 120 otoliths were read with at least 80% agreement. The maximum precision coefficient of variation was 51%. However, it should be pointed out that this arose from 18 readers ageing the sectioned otolith from fish no. 176 as 2 and one reader ageing it as 7 years. The average precision coefficient of variation was 13.7%. The otolith (no. 146, corresponding to a whiting of length 30cm) with the smallest percentage agreement (37%) provided the following estimates of age:

Age	No. of readers
2	1
3	7
4	7
5	4

The modal age was estimated to be three while the mean age in this case is 4.

The five readers with the highest overall ranking had consistently high rankings for percentage agreement, precision coefficient of variation and relative bias which in all five cases was positive.

Figure A4.1 illustrate which readers were judged to provide biased readings when compared with the modal age estimated from all readers.

Figure A4.4 shows that all ages, with the exception of age 7, have a relatively small positive bias.

1.4.3 Comparison between broken and sectioned sets

With both sets of otoliths modal ages ranged between 1 and 7 years. The following table summarises the comparison of modal ages by the two methods of preparation and reading.

	No. of otoliths
Same modal age	177
Broken lower than sectioned	10
Broken higher than sectioned	13

In 21 cases the difference between modal ages was one year but in two cases (fish no. 27 and fish no. 181) the difference was two years. The details are given in Table 1.

Table 1 Details of age estimates for two fish which give a difference of two years in modal age.

Age	Fish no. 27		Fish no. 181	
	Frequency of readings		Frequency of readings	
	Broken	Sectioned	Broken	Sectioned
2	3 (27%)	9 (47%)	-	-
3	3 (27%)	9 (47%)	4 (36%)	10 (53%)
4	4 (36%)	1 (5%)	2 (18%)	8 (42%)
5	1 (9%)	-	5 (45%)	-
6	-	-	-	1 (5%)
All ages	11 (100%)	19 (100%)	11 (100%)	19 (100%)
Modal age	4	2	5	3
Mean age	3	3	4	4

N.B. Any failure of the percentages to add to 100% is due to rounding

For fish 27, there was a tie for modal age read from the sectioned otoliths and so the modal age was determined by the estimate of the highest ranked reader who read the age as 2 years. (There is, of course, the option within the spreadsheet of entering the mean age as the modal age in these circumstances.)

Applying the bias test to the overall modal ages determined by the two methods, no bias was detected between the two methods.

Both the broken and sectioned otolith sets were read by ten readers in six Institutes and for six of these readers there was no evidence of bias between their estimates by the two

methods. For two readers there was evidence of bias towards making higher estimates of age from the broken set while the other two readers showed some evidence of determining lower ages from the broken set.

1.5 Discussion and Conclusions

Both sets of otoliths were read with an overall percentage agreement greater than 70%. The precision coefficient of variation was less than 20% by both methods. However, this underestimates the agreement obtained by the experienced readers as one experienced reader achieved quite different readings from all the others. If this reader is excluded, the percentage agreement amongst experienced readers who contribute age compositions to ICES Assessment Working Groups is increased to over 80%. The sectioned otoliths provided a slightly higher percentage agreement and slightly lower precision coefficient of variation. Younger fish were aged with greatest agreement and smallest variation, as would be expected (see Table 2 and Figure 1).

Table 2 Overall percentage agreement and precision coefficient of variation for the two methods (broken and sectioned).

Modal age	Percentage agreement		Precision coefficient of variation (%)	
	Broken	Sectioned	Broken	Sectioned
0	-	-	-	-
1	88	93	25	21
2	80	87	16	15
3	73	79	16	14
4	70	79	15	11
5	59	76	16	11
6	52	61	15	12
7	73	63	7	9
Overall	73	81	16	14

Of the 26 broken otoliths read with 100% agreement, two were aged 4 years and the rest were judged to be younger whiting. A total of 28 sectioned otoliths were read with complete agreement but only 14 were common to the corresponding list for broken otoliths. The fish numbers of these are as follows:-

Summary of fish numbers for which otoliths were read with 100% agreement.

	Fish numbers
Read by both methods	83 106 109 133 150 161 162 163 169 171 172 173 177 178
Read by broken method only	2 24 86 94 104 113 114 120 140 165 174 186
Read by sectioned method only	3 10 23 29 39 100 102 137 147 153 154 158 167 194

When no clear mode is evident, modal age is determined by the age estimate of the highest ranked reader. Different orderings of the readers can affect their rankings by about one or two places. However, a reader will not go from best to worst, or *vice versa*, when a reasonable number of readers have taken part in an exchange. In the case of no clear modal age, the mean age can be substituted but this requires such otoliths to be identified and this is not easily done within the spreadsheet.

Some individuals performed well in reading the otoliths by both methods while others who read only one set also did well. Some individuals experienced difficulty with one or both methods. Most often the problem lay in overestimating the age which was expressed as a positive reading bias which, in turn, led to a lower percentage agreement and a higher precision coefficient of variation. It is hoped that such readers will be assisted during the workshop.

1.6 Recommendations

The set of otoliths from fish caught in VIId proved challenging to some readers and discussion of these (fish no. 181 to 200) should take place at the workshop.

For future otolith exchanges it is recommended that the calcified structure set contains material that is representative of an annual distribution and a broader spread of ages. Full requirements for assembling such a collection can be found under section 3.3, Guidelines and Tools for Age Reading Comparisons, Eltink et al 2000.

1.7 Acknowledgements

This otolith exchange was possible through the cooperation and participation of all readers from the ten institutes involved and the success of the exchange is entirely due to their efforts. Thanks are due especially to Michael Easey for his help in preparing the sectioned otoliths and for producing the CD's of digital images, to Aileen Shanks for her invaluable help with the analysis and to Guus Eltink for permission to use his spreadsheet for the analysis.

1.8 References

Anon, 1999, Report of the Workshop on Otolith Ageing of North Sea Whiting, Hirshals, Denmark, 23-28 October 1998, ICES CM1999/G: 14.

Eltink, A.T.G.W. 2000. Age reading comparisons. (MS Excel workbook version 1.0 October 2000) Internet: http://www.efan.no

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2. Workshop Report

2.1 Introduction

Following the exchange of otoliths during 2004, it was agreed that it would be useful to hold a workshop to discuss the problems and issues raised by the exchange. The workshop was held at Cefas, Lowestoft on October 17-20th , 2005.

2.2 Workshop Participants

Name	Institute	Country
I. Maertens	CLO-Sea Fisheries	Belgium
B. Maertens	CLO-Sea Fisheries	Belgium
H. Rasmussen	DIFR	Denmark
T. Henriksen	DIFR	Denmark
M. Easey (Chair)	CEFAS	England (UK)
T. Woods	CEFAS	England (UK)
J. Keable	CEFAS	England (UK)
R. Bellail	IFREMER	France
J-L. Dufour	IFREMER	France
D. Schroder	BFA fur Fischerei	Germany
F. Beussel	BFA fur Fischerei	Germany
F.Woods	Marine Institute	Ireland
I.Hehir	Marine Institute	Ireland
H.Larsen	Inst. Of Marine Research	Norway
L.Solbakken	Inst. Of Marine Research	Norway
M.Mathewson	FRS	Scotland (UK)
G.Henderson	FRS	Scotland (UK)

2.3 Methods

The results of the otolith exchange were discussed and various images projected of otoliths that caused the most disagreement. The otolith set from VIId featured initially in this discussion but otoliths with low disagreement from all the other areas were also observed and discussed. At first the digitised images were used but subsequently it was decided to use the actual otolith sections projected from a microscope using alternative transmitted and reflected light as this gave the best method for discussion by the group.

2.3.1 Re-read set

A set of 120 otoliths from the original exchange was re-read by all participants at the workshop. These were from the ICES divisions – VIId, IVa, IVc and VI and were considered to be the more difficult of the original exchange sample. The samples from ICES areas VI (BOL) and (SOL) were excluded, as these were mainly young fish that were relatively easy and gave very good agreement in the original exchange analysis.

These samples were all aged using the sections as some of the broken set appeared to be in the wrong order and although some institutes only age broken otoliths the participants agreed that the sections gave a similar view of the otolith to their normal observation method. It was decided to also age a new set of otoliths from ICES sub-area VIIe-k as these often have different characteristics to the other areas. As a result, a second set of 72 otoliths sectioned and mounted on slides from ICES division VIIe-k were also aged by all participants. These were selected from the normal market samples of CEFAS and comprised samples from the following months in 2004: February, June, August, October and November. These otoliths were all projected using alternate transmitted and reflected light for all the participants to age simultaneously. When this was completed some participants also checked any that they were not happy with using a normal microscope set-up. This was not the ideal way of ageing these fish, as the preferred method would have been for each of the participants to read the sample using a microscope set up as they would normally. However there were concerns that there would not be enough time to complete the re-read of the original exchange and the new VIIe-k sample during the workshop if we adopted that method. At the time all the participants agreed to this protocol but in future individual reading using a microscope would be recommended. The results were then entered in the excel spreadsheet " age comparisons.xls" and analysed. Following the analysis otoliths from the VIIe-k samples were viewed and discussed.

2.4 Results and Discussion

2.4.1 Re-reading of part of the original set (120 otoliths)

- The main results for CV, percentage agreement and relative bias are shown in Table 1. This table gives a comparison between the original analysis personnel and the set re-read at the workshop. The full analysis of the re-read set is shown in **Appendix 6**.
- A comparison between the re-read set for the 17 readers at the workshop and the 19 readers from the original exchange show an overall improvement in percentage agreement from 75.8% to 80.7% and also an improvement in the CV and relative bias following the workshop discussions and viewing images on the first day.
- The workshop personnel achieved 66.4-90.0% percentage agreement with the modal age with 12 personnel achieving higher than 80%. The original exchange personnel achieved 39.2 –90.8 percentage agreement with the modal age with only 9 personnel achieving higher than 80%.
- There was a tendency to over-age the 2-year-old fish and under-age the 5-7 age groups on the re-reading whereas the original people tended to over-age the 2-6 age groups and underage the 7's.
- The percentage agreement for the VIa and VIId samples improved from 76.3 to 85.9 and 71.2 to 84.4 respectively.
- A separate analysis comparing the original readings using the preferred individual's method is shown in **Appendix 8** (Scotland, Norway, Denmark – broken otoliths. The other countries – sections). This analysis did not show a significant difference from the other analyses.

2.4.2 Reading of VIIe-k sample

- The main results for CV, percentage agreement and relative bias are shown in table 2. The full analysis is shown in **appendix 7**.
- The percentage agreement varied from 72.2-94.4 with 12 personnel achieving higher than 80%.
- There was a tendency to over-age the 2 & 3 year old fish and under-age the 5-7's.
- The lowest agreements were in the February and August samples.

2.5 Conclusions

The initial exchange and subsequent workshop figures show that the overall agreement between countries for ageing whiting is encouraging and from the discussions at the workshop it was apparent that there is a high degree of agreement in the way the annual zones are being interpreted between countries. **In particular, readers at the workshop who contribute regularly to age compositions at ICES Assessment Working Groups, achieved agreements exceeding 80%.**

There is still confusion in some fish over the first annual zone because of splits and the wide range of growth that can occur during the first year. It is also often very difficult to decide whether or not to count a ring forming on the edge as being late or early in being laid down thus making a year's difference in the age. The wide difference in growth rates between fish caught in the same area also adds to the problem of interpreting the ring structure as does the limited parts of the otolith where the ring structure is suitable for ageing.

Other aspects covered by the Workshop are noted below:

- National otolith processing and age reading methods are shown in **Appendix 9.**
- A set of images from the exchange showing examples of age groups 1 – 7 plus various otoliths that had poor agreement are shown in **Appendix 10.**
- A series of photos, description and incidence of a shadow effect occurring in many whiting otoliths and known as 'Humphries shadow' are shown in **Appendix 11 (**compiled by Robert Bellail).
- Examples of the whole and broken otolith method of age estimation at DIFRES are shown in **Appendix 12**.

2.6 Recommendations

1. The Workshop noted that institutes where readers showed a low agreement with the other participants in the exchange may require further training, particularly if some of these readers contribute age compositions to ICES Assessment WGs.
2. As reported in the initial analysis there was no significant difference in the results between the two ageing methods of broken otoliths or sections. Each

method has it's own advantages and disadvantages. The Workshop therefore concluded that both ageing method were acceptable for whiting.

The Workshop also made a number of general recommendations on methodology for achieving the best results in ageing whiting:

3. Magnification should be limited to x10-20. Too high a magnification will result in splits being counted as rings.
4. When ageing sections both transmitted and reflected light should always be used to look at each otolith. Whiting often show low contrast between the opaque and translucent zones and transmitted light can show the ring structure more clearly. Reflected light, however can be particularly useful in interpreting the edge. At times an apparent translucent edge when read under transmitted light is simply the effect of too much light coming through since the edge of the otolith can be thinner than the rest of the structure, there could be a small gap in the resin or a translucent split could be forming on the edge. Also, the black resin under the slanting edge of an otolith can make a translucent edge appear to be opaque (**Fig 16 in Appendix 10**). Reflected light will always identify the true material.
5. When ageing, the most reliable part of the otolith is the rostrum or dorsal edge **(Fig 8 in Appendix 10)** and this should be given preference although other parts of the otolith can also be useful.
6. 'Humphries shadow' is a feature that is present on most otoliths although not in every year and as such has only limited use in the interpretation of the ring structure.
7. Image analysis packages can be used to measure ring growth and construct an annual growth curve as an aid in verifying the age. This method is utilised by France. Care would have to be taken not to discount rings just because they do not follow a normal growth pattern.
8. Further efforts should be made to obtain otoliths from whiting of validated age although it is accepted that this will be very difficult to achieve.
9. There was considerable discussion after the workshop about the protocols for preparing images for an exchange. Some participants were in favour of marking all otoliths with the position of the annual rings and retaining copies for discussion at the workshop. This can be very useful for identifying problems between Institutes or readers. However, the method is very time consuming and can result in many hundreds of marked images which cannot be discussed in any detail within the limited time available. The Workshop could not resolve this issue and **Recommended that ICES PGCCDBS should consider this and propose a protocol for use in future exchanges.**

TABLE 1

Workshop re-read of 120 otoliths from original set

COEFFICIENT OF VARIATION (CV)

	RB_FR	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HR_DEN	FW_IRL	FB_GER
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9
all ages	**8.9%**	**7.8%**	**7.2%**	**11.1%**	**9.4%**	**12.3%**	**13.6%**	**9.2%**	**14.5%**
	IH_IRL	JK_ENG	HL_NOR	TW_ENG	TH_DEN	BM_BEL	DS_GER	LS_NOR	**ALL**
	Reader 10	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	**Readers**
all ages	**8.7%**	**8.9%**	**19.4%**	**11.2%**	**13.7%**	**10.9%**	**11.2%**	**19.4%**	**10.3%**

PERCENTAGE AGREEMENT

	RB_FR	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HR_DEN	FW_IRL	FB_GER
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9
all ages	**90.0%**	**87.5%**	**88.3%**	**83.3%**	**85.8%**	**81.7%**	**75.0%**	**80.0%**	**80.0%**
	IH_IRL	JK_ENG	HL_NOR	TW_ENG	TH_DEN	BM_BEL	DS_GER	LS_NOR	**ALL**
	Reader 10	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	**Readers**
all ages	**85.8%**	**85.0%**	**66.4%**	**73.3%**	**73.1%**	**85.8%**	**80.8%**	**68.9%**	**80.7%**

RELATIVE BIAS

	RB_FR	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HR_DEN	FW_IRL	FB_GER
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9
all ages	**-0.00**	**-0.07**	**0.05**	**0.07**	**-0.06**	**0.01**	**0.08**	**-0.21**	**0.08**
	IH_IRL	JK_ENG	HL_NOR	TW_ENG	TH_DEN	BM_BEL	DS_GER	LS_NOR	**ALL**
	Reader 10	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	**Readers**
all ages	**-0.13**	**-0.10**	**-0.05**	**0.25**	**0.07**	**0.02**	**0.06**	**-0.04**	**0.00**

Analysis of the 120 otoliths for the original exchange people

COEFFICIENT OF VARIATION (CV)

	RB_FR	TB_ENG	MB_ENG	PC_SCO	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HM_IRL
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10
all ages	**9.0%**	**11.4%**	**16.4%**	**13.4%**	**12.1%**	**9.8%**	**11.0%**	**16.5%**	**12.5%**	**12.4%**
	WM_NIrl	HR_DEN	GR_NL	FW_IRL	FB_GER	IH_IRL	JK_ENG	HL_NOR	TW_ENG	**ALL**
	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	Reader 18	Reader 19	**Readers**
all ages	**13.0%**	**13.8%**	**26.8%**	**7.0%**	**16.5%**	**8.1%**	**8.1%**	**16.9%**	**10.7%**	**13.0%**

PERCENTAGE AGREEMENT

	RB_FR	TB_ENG	MB_ENG	PC_SCO	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HM_IRL
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10
all ages	**90.0%**	**76.7%**	**63.3%**	**78.3%**	**84.0%**	**83.2%**	**85.8%**	**69.2%**	**77.5%**	**78.3%**
	WM_NIrl	HR_DEN	GR_NL	FW_IRL	FB_GER	IH_IRL	JK_ENG	HL_NOR	TW_ENG	**ALL**
	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	Reader 18	Reader 19	**Readers**
all ages	**81.7%**	**68.3%**	**39.2%**	**90.8%**	**60.8%**	**88.3%**	**86.7%**	**62.5%**	**75.8%**	**75.8%**

RELATIVE BIAS

	RB_FR	TB_ENG	MB_ENG	PC_SCO	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HM_IRL
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10
all ages	**0.00**	**-0.17**	**0.22**	**0.16**	**0.05**	**-0.13**	**0.09**	**0.25**	**0.10**	**0.04**
	WM_NIrl	HR_DEN	GR_NL	FW_IRL	FB_GER	IH_IRL	JK_ENG	HL_NOR	TW_ENG	**ALL**
	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	Reader 18	Reader 19	**Readers**
all ages	**0.18**	**0.28**	**1.07**	**-0.04**	**0.47**	**0.02**	**-0.05**	**0.03**	**-0.11**	**0.13**

TABLE 2 **107e-k**

COEFFICIENT OF VARIATION (CV)

	RB_FR	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HR_DEN	FW_IRL	FB_GER
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9
all ages	**9.9%**	**10.5%**	**10.3%**	**11.8%**	**3.7%**	**12.6%**	**12.2%**	**9.4%**	**13.0%**
	IH_IRL	JK_ENG	HL_NOR	TW_ENG	TH_DEN	BM_BEL	DS_GER	LS_NOR	**ALL**
	Reader 10	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	**Readers**
all ages	**3.6%**	**3.9%**	**14.5%**	**12.1%**	**15.0%**	**5.6%**	**24.3%**	**18.7%**	**10.1%**

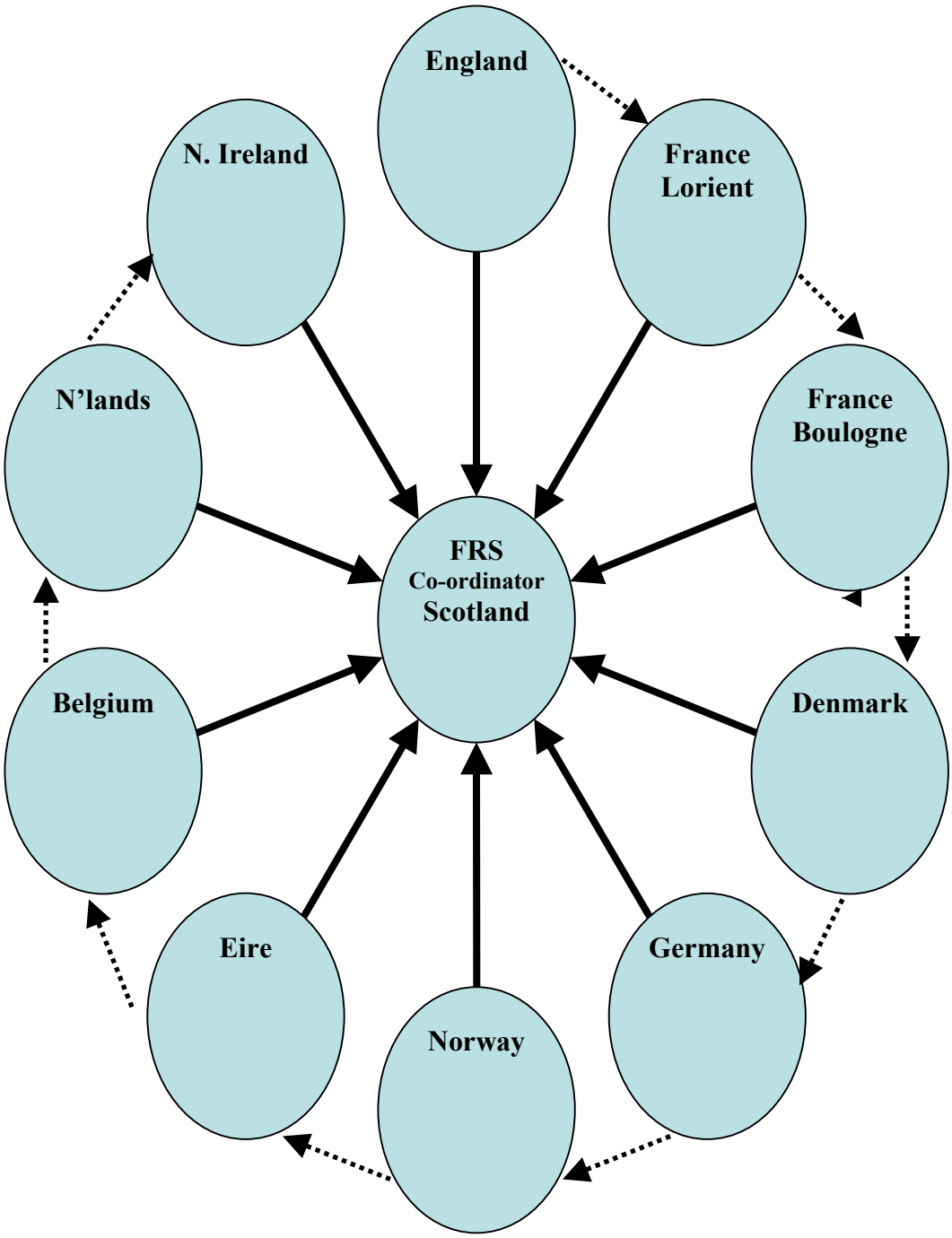
PERCENTAGE AGREEMENT

	RB_FR	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HR_DEN	FW_IRL	FB_GER
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9
all ages	**86.1%**	**83.3%**	**88.9%**	**80.6%**	**93.1%**	**79.2%**	**81.9%**	**84.7%**	**80.6%**
	IH_IRL	JK_ENG	HL_NOR	TW_ENG	TH_DEN	BM_BEL	DS_GER	LS_NOR	**ALL**
	Reader 10	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	**Readers**
	88.9%	**87.5%**	**72.2%**	**80.6%**	**68.1%**	**94.4%**	**76.4%**	**69.4%**	**82.1%**

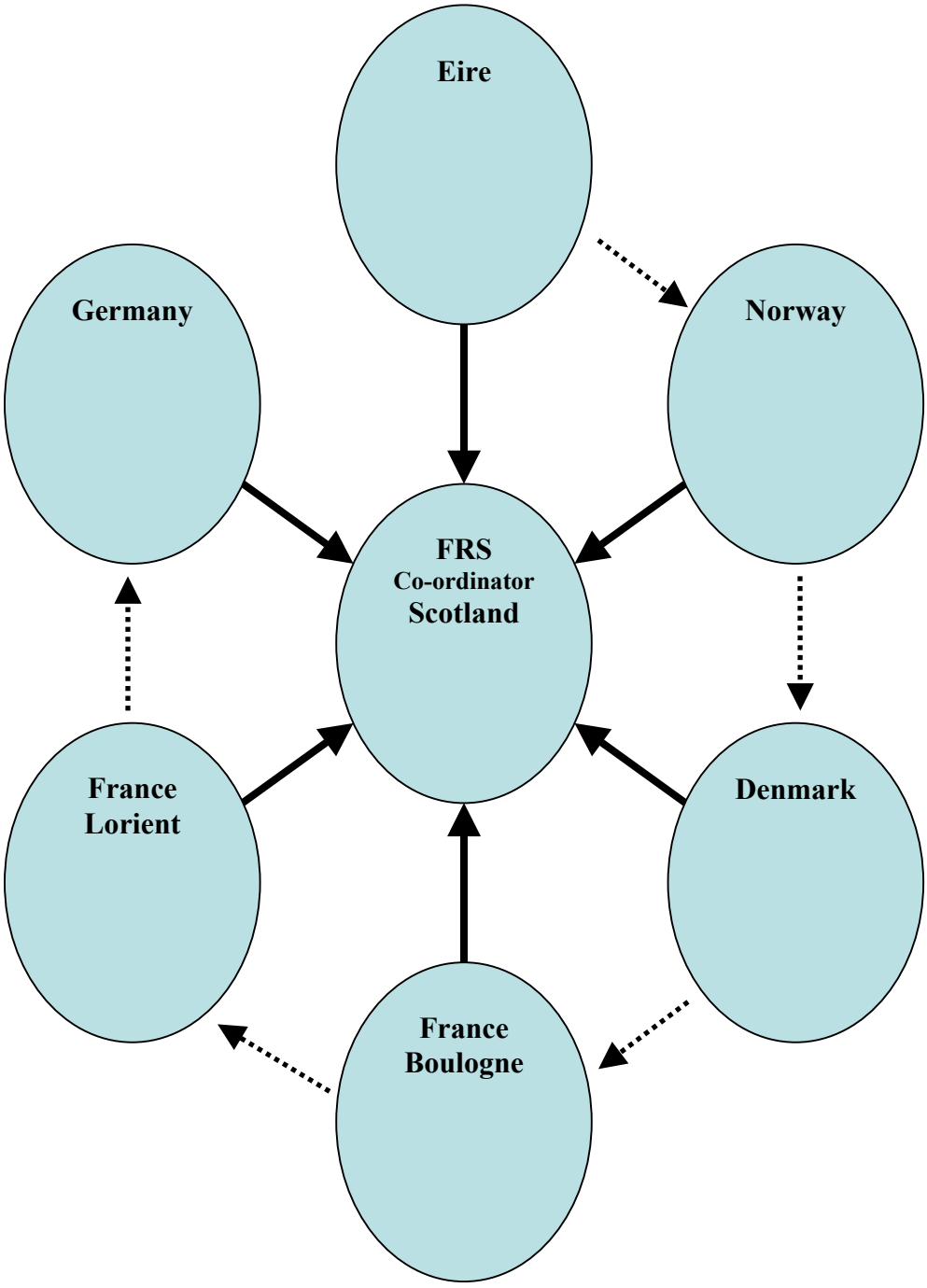
RELATIVE BIAS

	RB_FR	JLD_FR	ME_ENG	GH_SCO	IM_BEL	MM_SCO	HR_DEN	FW_IRL	FB_GER
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9
all ages	**0.04**	**-0.03**	**0.03**	**0.08**	**-0.07**	**0.04**	**-0.03**	**-0.07**	**0.07**
	IH_IRL	JK_ENG	HL_NOR	TW_ENG	TH_DEN	BM_BEL	DS_GER	LS_NOR	**ALL**
	Reader 10	Reader 11	Reader 12	Reader 13	Reader 14	Reader 15	Reader 16	Reader 17	**Readers**
	-0.14	**-0.15**	**0.06**	**0.08**	**-0.06**	**0.03**	**0.03**	**0.01**	**-0.00**

Appendix 1



Path of sectioned otolith material.



Path of broken otolith material.

Appendix 2.

WHITING (Merlangius merlangus) OTOLITH EXCHANGE SCHEME 2004

Protocol for the Whiting otolith exchange in 2004

1. Introduction

The Planning Group on Commercial Catch, Discards and Biological Sampling (PGCCDBS) meeting in Rome in March 2003, identified Whiting as one of the species requiring confirmation of the ages being assigned by Fisheries Institutes. The last workshop on whiting otoliths was held in 1998 in Hirtshals, Denmark.

The planning group indicated that FRS (Aberdeen, Scotland) should be responsible for organising an otolith exchange in 2003/2004, and that CEFAS (Lowestoft, England) would be responsible for organising the workshop to be held in 2005.

Whiting is generally regarded as one of the most difficult gadoid species to age due to the problems in distinguishing true annual rings from other rings, and the differences in repeatability of ages between Institutes.

These basic problems are compounded by the differing methods of sample preparation and reading techniques used by Institutes engaged in ageing of Whiting. Some Institutes break their otoliths and embed them in a soft medium prior to examining them under transmitted light, while others routinely section their otoliths and embed them in resin before examining them with transmitted light.

The objectives of the exchange are:

- To investigate the levels of agreement on age readings.
- To analyse the relative differences between reader ages
- To compare readings by otolith processing method

2. Participants: For the sake of brevity only the co-ordinators or principal contacts have been listed here, full addresses are listed later in this document.

Belgium, CLO – Sea Fisheries Dept. Bart Maertens.

Denmark, Danish Institute for Fisheries Research.
Lotte A. Worsoe Clausen

England (UK), CEFAS Lowestoft Laboratory. Michael Easey

France, IFREMER. Jean-Louis Dufour and Robert Bellail

Germany, BFA fur Fischerei. Dr. Christoph Stransky

Ireland, Marine Institute. Gráinne Ní Chonchúir.

Netherlands, RIVO. Loes Boelle.

Norway, Institute of Marine Research. Harald Larsen.

Scotland (UK), FRS Marine Laboratory. Gordon Henderson

3. Otolith Collection:

Although the exchange scheme was proposed in March 2003, a co-ordinator was not chosen until April 2004. This has caused some problems. Due to the time constraints, it has not been possible to collect samples from the whole of the year, and all samples used in the exchange were collected in March and April 2004. 200 pairs of otoliths were collected from various areas around the coast of the British Isles, some from commercial samples and some collected on a research vessel cruise. One otolith from each pair was broken and mounted in modelling clay by FRS, and the corresponding otolith was sectioned and mounted on slides by CEFAS. In addition, CEFAS digitised all the images and compiled them on a CD.

There are thus three collections:

1) The “broken” otolith set
2) The sectioned otolith set

3) The digitised image set on CD

4. Reading procedure:

Included with this document are the otoliths for the exchange programme. Please read them in accordance with convention. Birthday is assumed to be 1st January. Provide one age estimate only per otolith and do not omit any, as this will influence the results on precision and accuracy.

Broken otolith set:

Each set of otoliths should be clearly marked on the top surface and an additional sticky label will be found on the undersurface to prevent confusion. The otoliths should be read clockwise, with the arrow shaped start point in the twelve o'clock position. They should be examined under transmitted light, using a total magnification of approximately 15 times.

Every care should be taken to prevent damage to the set, as this will reduce precision in age reading for subsequent readers.

Sectioned otolith set:

Slides should be positioned for reading, with the label at the top. The otoliths should be read from left to right, working down towards the bottom.

Included on the CD of the otolith images are the relevant data sheets in Excel format. Please complete these with your ages and a clear indication of the reader and corresponding Institute, and whether the ages refer to sectioned or broken otoliths. When ageing is complete return age data sheets to Aberdeen, via email.

I would encourage you to mark the first ring on any troublesome otoliths on the accompanying CD of otolith images, or any that are otherwise difficult to read, using any painting tool. These can then be discussed at the workshop to find out where differences in age interpretation are originating.

Timetable:

The sectioned and broken otolith sets will be in circulation simultaneously. Should you prefer to read only sectioned otoliths or only broken otoliths, then please pass on the set you do not wish to read to the next person on the list and inform me that you have done so.

Ideally, I would like the sectioned otoliths to travel round the various Institutes, in the following order:

1. Lorient
2. Boulogne
3. Denmark
4. Germany
5. Norway
6. Ireland
7. Scotland

The broken otolith set would take the reverse direction, starting with Norway and returning to Scotland. If all goes well, I would hope to have a copy of all the age readings in Aberdeen by the end of December 2004 for analysis.

Gordon Henderson

10 September 2004

Table 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 comined indicate the precision in age reading by reader and for all age readers combined.

Appendix 3. Whiting Otolith Exchange Scheme 2004 - broken (Lowestoft, October 2005)

NUMBER OF AGE READINGS

	MODAL age	GH_SCO Reader 1	PC_SCO Reader 2	MM_SCO Reader 3	HR_DEN Reader 4	FW_IRL Reader 5	HM_IRL Reader 6	RB_FR Reader 7	JLD_FR Reader 8	IH_IRL Reader 9	DS_GER Reader 10	HL_NOR Reader 11	TOTAL
	0	-	-	-	-	-	-	-	-	-	-	-	-
	1	16	16	16	16	16	16	16	16	16	16	16	**176**
	2	54	54	54	54	54	54	54	54	54	54	54	**594**
	3	45	45	45	45	45	45	45	45	45	45	45	**495**
	4	46	46	46	46	46	46	46	46	46	46	46	**506**
	5	29	29	29	29	29	29	28	29	29	27	29	**316**
	6	8	8	8	8	8	8	7	7	8	8	8	**86**
	7	2	2	2	2	2	2	2	2	2	2	2	**22**
	8	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-
Total	**0-15**	**200**	**200**	**200**	**200**	**200**	**200**	**198**	**199**	**200**	**198**	**200**	**2195**

COEFFICIENT OF VARIATION (CV

	MODAL age	GH_SCO Reader 1	PC_SCO Reader 2	MM_SCO Reader 3	HR_DEN Reader 4	FW_IRL Reader 5	HM_IRL Reader 6	RB_FR Reader 7	JLD_FR Reader 8	IH_IRL Reader 9	DS_GER Reader 10	HL_NOR Reader 11	ALL Readers
	0	-	-	-	-	-	-	-	-	-	-	-	-
	1	0%	0%	0%	33%	46%	0%	0%	0%	36%	24%	36%	**24.9%**
	2	10%	7%	10%	25%	25%	13%	13%	16%	19%	30%	21%	**15.9%**
	3	13%	12%	12%	25%	15%	16%	20%	21%	11%	31%	19%	**16.3%**
	4	12%	14%	13%	15%	11%	17%	17%	12%	12%	22%	18%	**14.8%**
	5	9%	11%	11%	18%	14%	11%	20%	19%	15%	19%	15%	**15.7%**
	6	11%	6%	6%	22%	9%	7%	13%	13%	13%	23%	21%	**14.7%**
	7	0%	0%	0%	11%	0%	11%	11%	11%	0%	0%	20%	**7.4%**
	8	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**10.1%**	**9.8%**	**10.1%**	**22.0%**	**18.6%**	**12.8%**	**15.4%**	**15.4%**	**16.0%**	**25.7%**	**20.1%**	**16.3%**
	RANKING	**3**	**1**	**2**	**10**	**8**	**4**	**6**	**5**	**7**	**11**	**9**	

PERCENTAGE AGREEMENT

	MODAL age	GH_SCO Reader 1	PC_SCO Reader 2	MM_SCO Reader 3	HR_DEN Reader 4	FW_IRL Reader 5	HM_IRL Reader 6	RB_FR Reader 7	JLD_FR Reader 8	IH_IRL Reader 9	DS_GER Reader 10	HL_NOR Reader 11	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-
	1	100%	100%	100%	44%	81%	100%	100%	100%	75%	94%	69%	**88%**
	2	96%	98%	96%	48%	72%	93%	93%	94%	76%	52%	63%	**80%**
	3	84%	91%	87%	58%	76%	76%	69%	71%	89%	33%	71%	**73%**
	4	83%	72%	80%	74%	83%	57%	67%	76%	78%	35%	63%	**70%**
	5	90%	90%	90%	48%	66%	38%	50%	59%	45%	26%	52%	**59%**
	6	63%	88%	88%	75%	25%	13%	29%	86%	38%	38%	38%	**52%**
	7	100%	100%	100%	50%	100%	50%	50%	50%	100%	100%	0%	**73%**
	8	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**88.5%**	**89.0%**	**89.5%**	**57.0%**	**73.5%**	**69.5%**	**73.2%**	**79.4%**	**73.5%**	**43.4%**	**62.0%**	**72.6%**
	RANKING	**3**	**2**	**1**	**10**	**5**	**8**	**7**	**4**	**5**	**11**	**9**	

RELATIVE BIAS

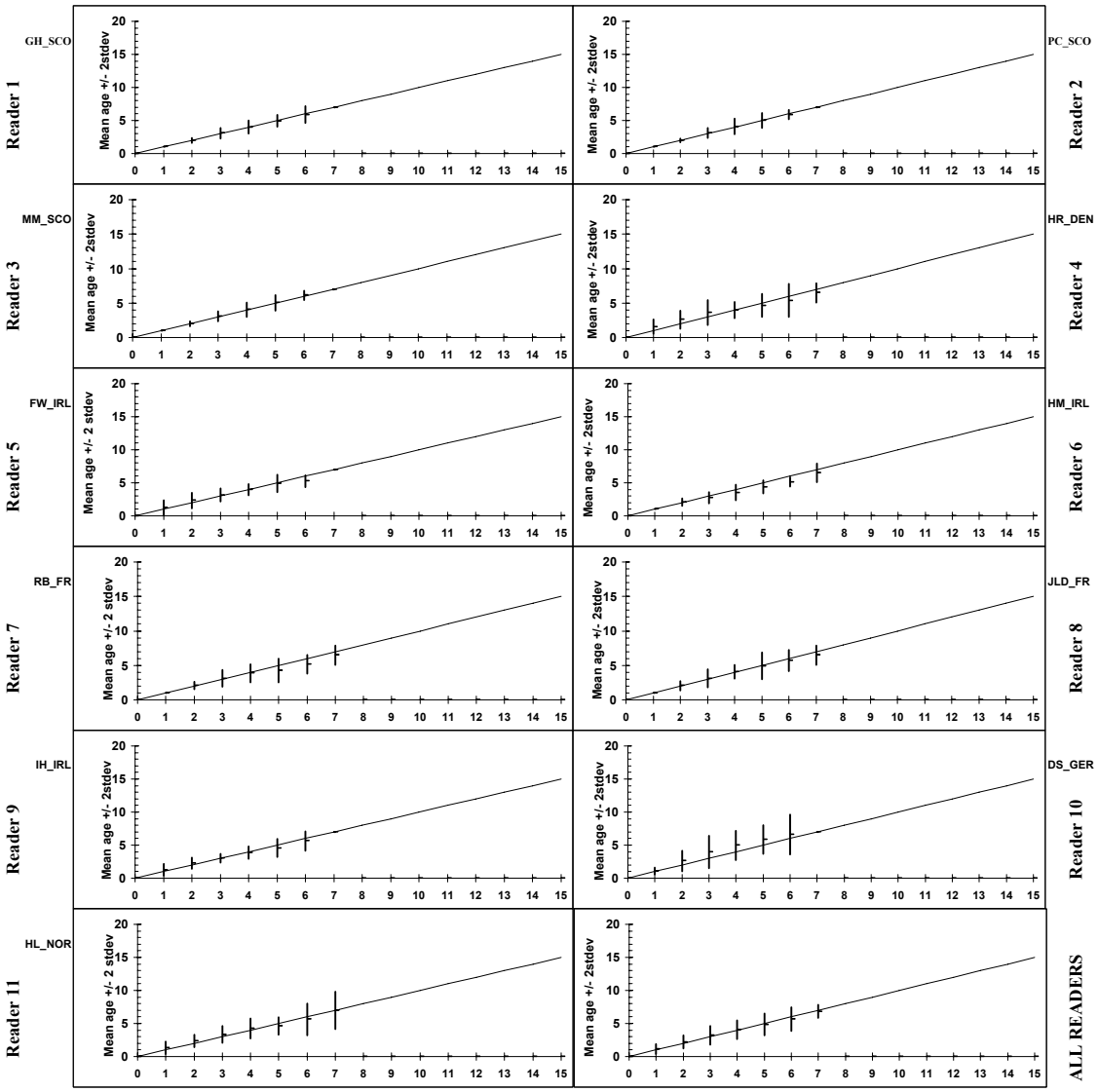
	MODAL age	GH_SCO Reader 1	PC_SCO Reader 2	MM_SCO Reader 3	HR_DEN Reader 4	FW_IRL Reader 5	HM_IRL Reader 6	RB_FR Reader 7	JLD_FR Reader 8	IH_IRL Reader 9	DS_GER Reader 10	HL_NOR Reader 11	ALL
	0	-	-	-	-	-	-	-	-	-	-	-	-
	1	0.00	0.00	0.00	0.56	0.25	0.00	0.00	0.00	0.25	0.06	0.31	**0.13**
	2	0.00	-0.02	0.00	0.61	0.33	0.07	0.07	0.04	0.24	0.63	0.37	**0.21**
	3	0.07	0.11	0.04	0.64	0.16	-0.24	0.11	0.11	0.02	0.98	0.31	**0.21**
	4	-0.02	0.09	0.04	-0.02	0.00	-0.48	-0.15	0.07	-0.13	0.96	0.24	**0.05**
	5	-0.07	-0.03	0.03	-0.34	-0.10	-0.62	-0.71	-0.07	-0.45	0.85	-0.38	**-0.18**
	6	-0.13	-0.13	0.13	-0.63	-0.75	-0.88	-0.86	-0.29	-0.38	0.63	-0.38	**-0.33**
	7	0.00	0.00	0.00	-0.50	0.00	-0.50	-0.50	-0.50	0.00	0.00	0.00	**-0.18**
	8	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean	**0-15**	**-0.00**	**0.03**	**0.03**	**0.27**	**0.10**	**-0.28**	**-0.13**	**0.03**	**-0.02**	**0.76**	**0.18**	**0.09**
	RANKING	**1**	**5**	**4**	**9**	**6**	**10**	**7**	**3**	**2**	**11**	**8**	

Overall ranking

	GH_SCO Reader 1	PC_SCO Reader 2	MM_SCO Reader 3	HR_DEN Reader 4	FW_IRL Reader 5	HM_IRL Reader 6	RB_FR Reader 7	JLD_FR Reader 8	IH_IRL Reader 9	DS_GER Reader 10	HL_NOR Reader 11
Ranking Coefficient of Variation	3	1	2	10	8	4	6	5	7	11	9
Ranking Percentage Agreement	3	2	1	10	5	8	7	4	5	11	9
Ranking Relative bias	1	5	4	9	6	10	7	3	2	11	8
OVERALL RANKING	**1**	**3**	**1**	**10**	**6**	**8**	**7**	**4**	**5**	**11**	**9**

Appendix 3. Whiting Otolith Exchange Scheme 2004 - broken (Lowestoft, October 2005)

Figure 1 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.



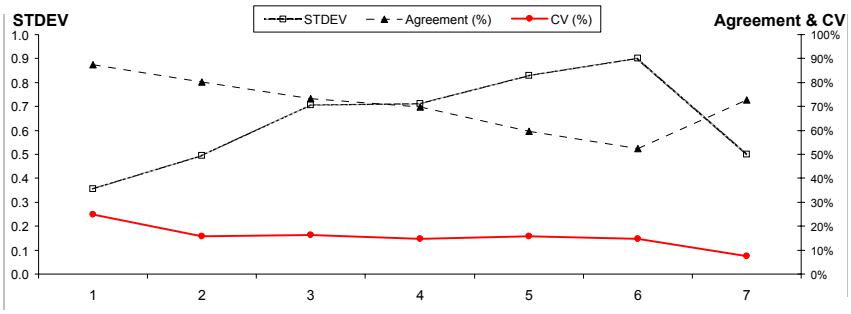


Figure 2 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age.
CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age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

Appendix 3. Whiting Otolith Exchange Scheme 2004 - broken (Lowestoft, October 2005)

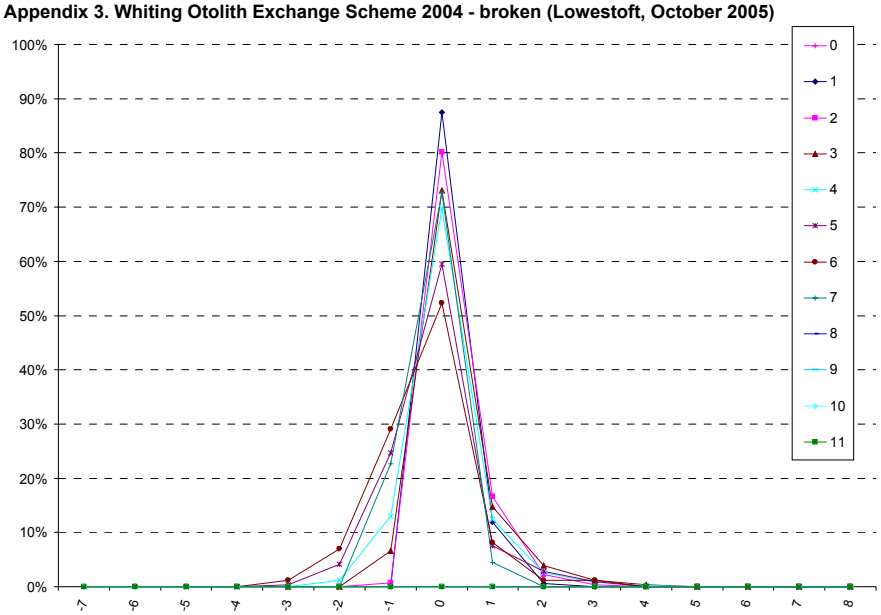


Figure 3 The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no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

Appendix 3. Whiting Otolith Exchange Scheme 2004 - broken (Lowestoft, October 2005)

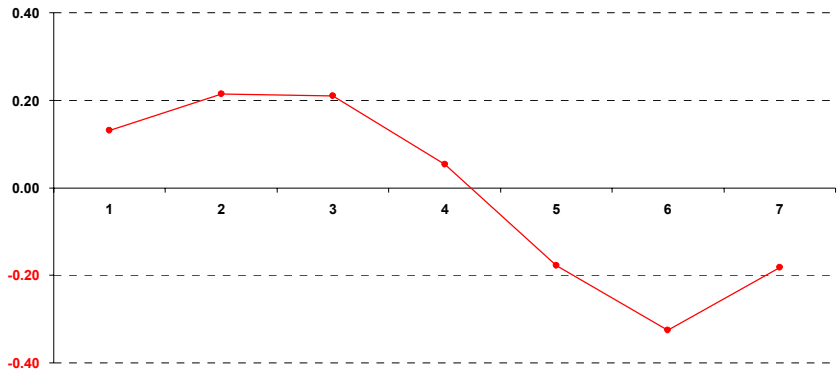


Figure 4 The RELATIVE bias by MODAL age as estimated by all age readers combined.

Table 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 comined indicate the precision in age reading by reader and for all age readers combined.

Appendix 4. Whiting otolith Exchange Scheme 2004 - sectioned (Lowestoft, October 2005)

NUMBER OF AGE READINGS

MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	TOTAL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	323
2	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	1045
3	46	46	46	46	45	45	46	46	46	46	46	46	46	46	46	46	46	46	46	872
4	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	798
5	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	570
6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	152
7	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	38
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total 0-15	200	200	200	200	199	199	200	200	200	200	200	200	200	200	200	200	200	200	200	3798

COEFFICIENT OF VARIATION (CV

MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	23%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	30%	45%	23%	0%	0%	0%	33%	30%	20.6%
2	7%	7%	14%	11%	11%	0%	17%	18%	7%	15%	14%	20%	38%	0%	20%	9%	17%	17%	19%	15.0%
3	11%	16%	20%	14%	17%	15%	12%	18%	18%	12%	19%	14%	34%	10%	18%	14%	10%	16%	7%	14.5%
4	7%	12%	15%	14%	7%	11%	10%	15%	13%	9%	11%	16%	25%	12%	17%	7%	10%	15%	10%	10.7%
5	6%	9%	13%	10%	7%	7%	4%	17%	10%	12%	5%	9%	20%	8%	11%	6%	8%	19%	11%	11.3%
6	6%	9%	14%	9%	16%	8%	11%	12%	8%	13%	11%	17%	25%	9%	9%	9%	9%	11%	10%	12.4%
7	0%	11%	0%	0%	20%	11%	11%	9%	11%	11%	11%	9%	8%	0%	0%	0%	11%	0%	11%	9.1%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	9.0%	9.8%	14.0%	11.1%	10.2%	7.2%	10.5%	15.2%	10.5%	11.1%	11.8%	16.6%	31.4%	8.3%	15.3%	8.4%	10.7%	17.9%	13.6%	13.7%
RANKING	4	5	14	10	6	1	7	15	8	11	12	17	19	2	16	3	9	18	13	

PERCENTAGE AGREEMENT

MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	35%	76%	94%	100%	100%	100%	82%	88%	93%
2	98%	98%	91%	95%	95%	100%	93%	82%	98%	89%	91%	47%	35%	100%	82%	96%	93%	84%	80%	87%
3	89%	76%	72%	83%	82%	80%	87%	76%	72%	85%	78%	70%	46%	91%	65%	83%	91%	74%	96%	79%
4	93%	76%	64%	79%	93%	81%	90%	69%	86%	88%	88%	83%	43%	83%	62%	93%	83%	64%	86%	79%
5	90%	80%	57%	77%	87%	87%	97%	63%	83%	77%	93%	80%	37%	83%	80%	90%	83%	43%	60%	76%
6	88%	75%	38%	75%	75%	75%	50%	75%	63%	50%	50%	38%	38%	75%	25%	75%	75%	63%	50%	61%
7	100%	50%	100%	100%	0%	50%	50%	50%	50%	50%	50%	50%	0%	100%	100%	100%	50%	100%	50%	63%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	93.0%	84.5%	74.5%	85.5%	88.9%	87.9%	90.0%	76.0%	85.5%	85.0%	86.5%	63.5%	42.5%	90.5%	73.0%	91.0%	88.5%	70.5%	81.0%	80.9%
RANKING	1	12	15	9	5	7	4	14	9	11	8	18	19	3	16	2	6	17	13	

RELATIVE BIAS

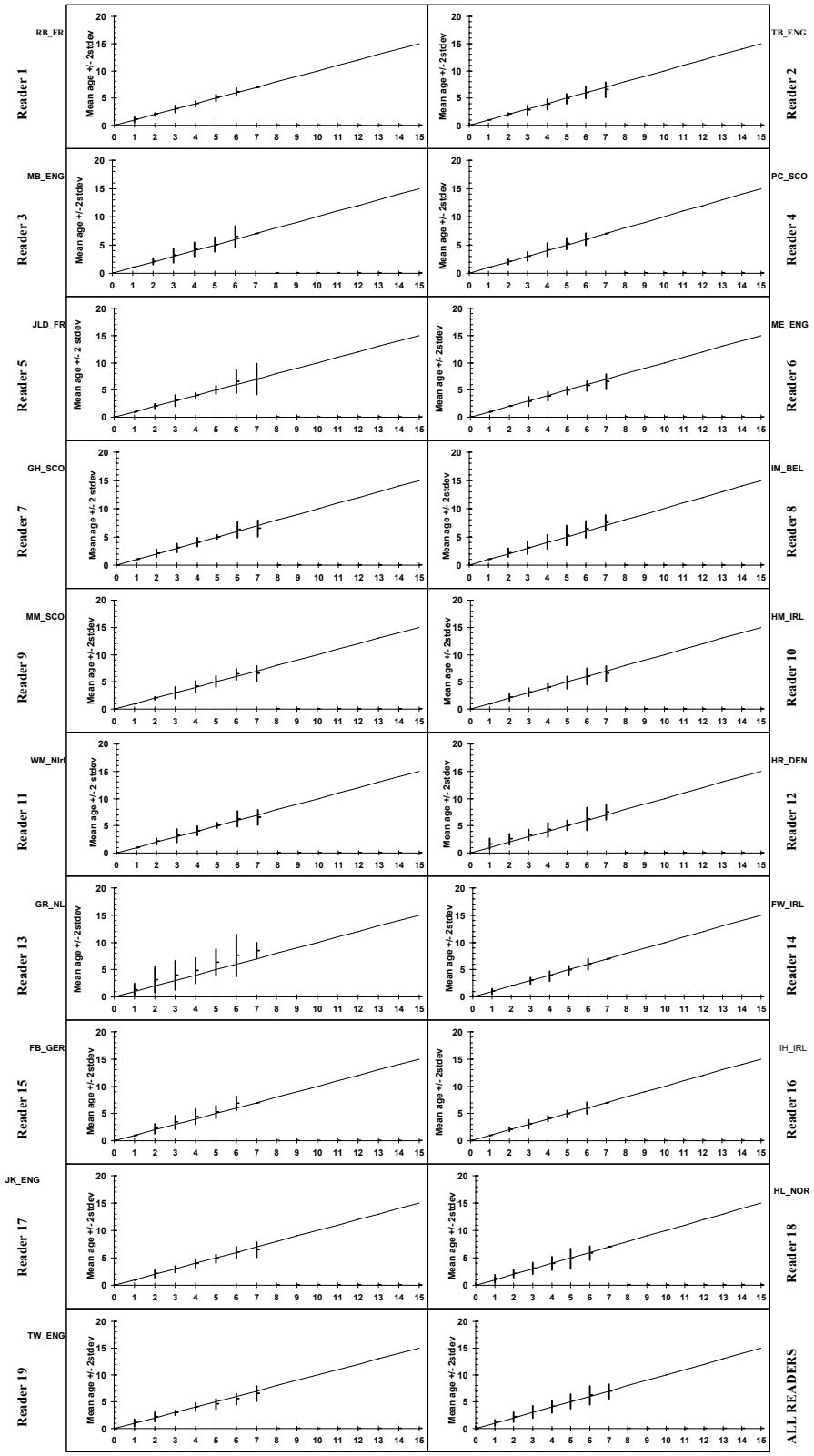
MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.29	0.06	0.00	0.00	0.00	0.18	0.12	0.07
2	0.02	-0.02	0.09	0.05	0.05	0.00	0.09	0.18	0.02	0.11	0.09	0.53	1.09	0.00	0.20	0.04	0.09	0.16	0.16	0.16
3	-0.02	-0.24	0.15	0.00	0.02	-0.16	0.04	0.09	0.02	0.11	0.20	0.30	0.93	-0.04	0.41	0.04	-0.04	0.09	-0.04	0.10
4	-0.02	-0.14	0.24	0.17	-0.02	-0.14	0.07	0.10	0.14	-0.02	0.10	0.26	0.79	-0.19	0.43	0.02	-0.02	-0.02	0.00	0.09
5	0.03	-0.13	0.10	0.27	0.00	-0.13	-0.03	0.30	0.07	-0.13	0.07	0.07	1.30	-0.10	0.27	-0.10	-0.17	-0.20	-0.40	0.06
6	0.13	0.00	0.50	0.00	0.50	-0.25	0.25	0.38	0.38	0.00	0.25	0.25	1.63	0.00	0.88	0.00	0.00	-0.13	-0.50	0.22
7	0.00	-0.50	0.00	0.00	0.00	-0.50	-0.50	0.50	-0.50	-0.50	-0.50	0.50	1.50	0.00	0.00	0.00	-0.50	0.00	-0.50	-0.08
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	0.01	-0.12	0.15	0.09	0.04	-0.10	0.05	0.16	0.06	0.02	0.11	0.35	0.98	-0.06	0.32	0.01	-0.02	0.04	-0.04	0.11
RANKING	1	14	15	11	5	12	8	16	9	4	13	18	19	9	17	2	3	6	7	

Overall ranking

	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19
Ranking Coefficient of Variation	4	5	14	10	6	1	7	15	8	11	12	17	19	2	16	3	9	18	13
Ranking Percentage Agreement	1	12	15	9	5	7	4	14	9	11	8	18	19	3	16	2	6	17	13
Ranking Relative bias	1	14	15	11	5	12	8	16	9	4	13	18	19	9	17	2	3	6	7
OVERALL RANKING	1	11	15	10	4	7	6	16	8	8	12	18	19	3	17	2	5	14	12

Appendix 4. Whiting otolith Exchange Scheme 2004 - sectioned (Lowestoft, October 2005)

Figure 1 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.



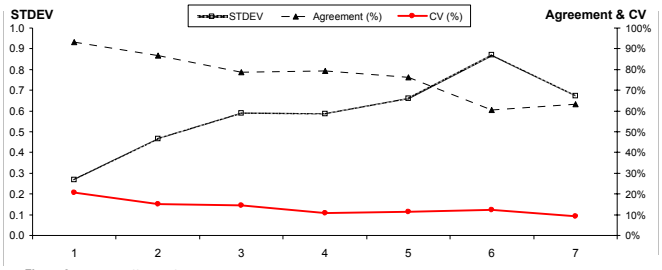


Figure 2 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age.
CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age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

Appendix 4. Whiting otolith Exchange Scheme 2004 - sectioned (Lowestoft, October 2005)

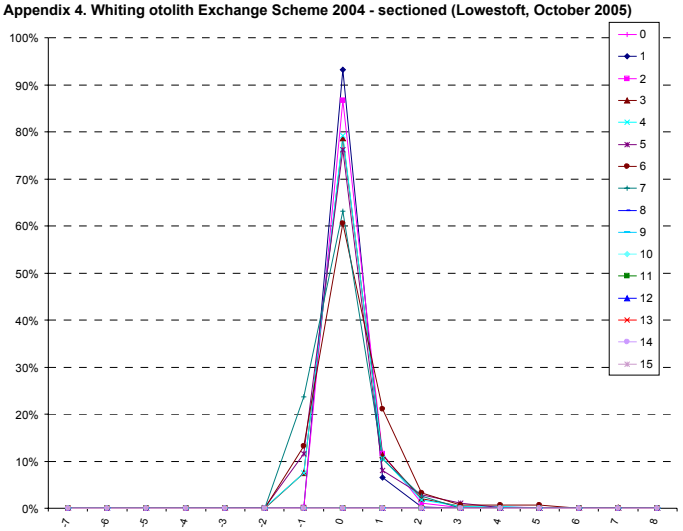


Figure 3 The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no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

Appendix 4. Whiting otolith Exchange Scheme 2004 - sectioned (Lowestoft, October 2005)

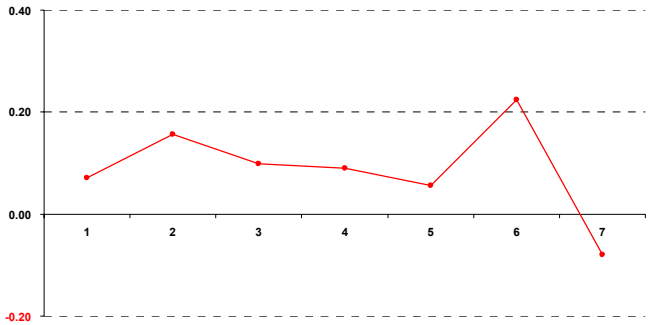


Figure 4 The RELATIVE bias by MODAL age as estimated by all age readers combined.

Appendix 5:

Figure 1 Comparison of distributions of percentage agreement and precision coefficient of variation for broken and sectioned otoliths.

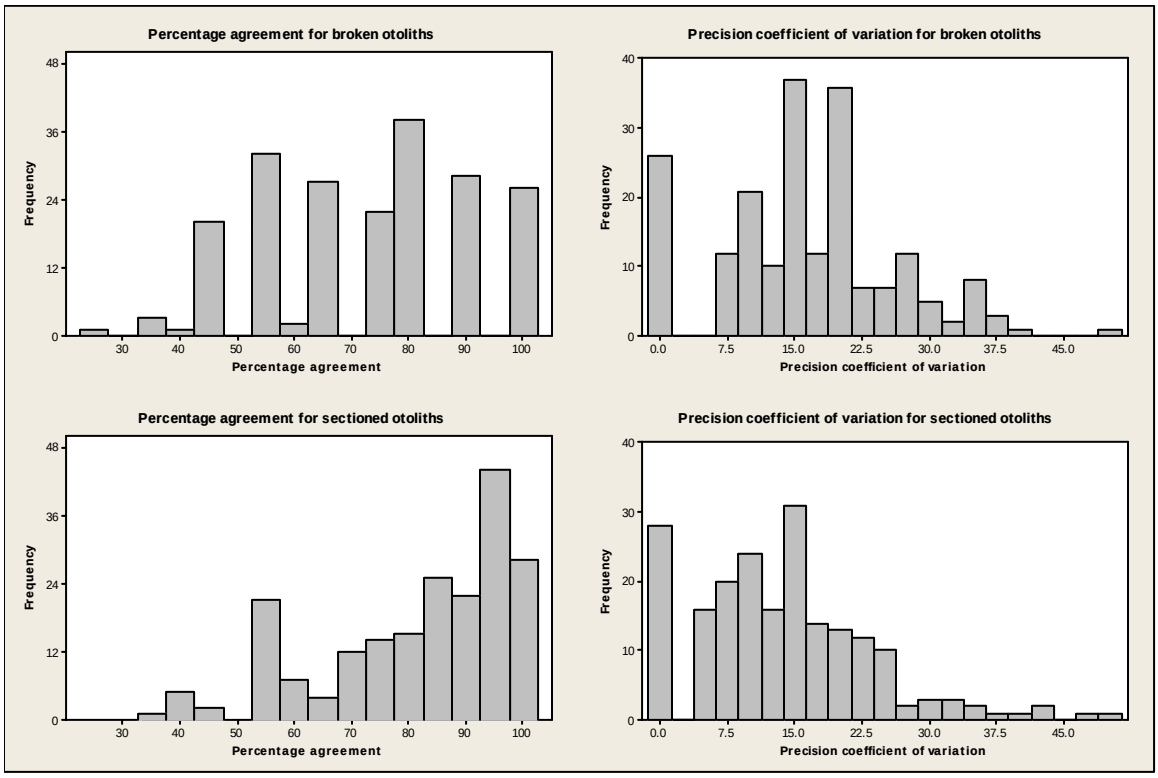


Table 2 The number of age readings, the coefficient of variation (CV), the percent agreement and the RELATIVE bias are presented by MODAL age for each age reader and for all readers combined. A weighted mean CV and a weighted mean percent agreement are given by reader and all readers combined. The CV's 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 comined indicate the precision in age reading by reader and for all age readers combined.

Appendix 6 Whiting otolith Exchange Scheme 2004 - re-read sectioned (Lowestoft, October 2005)

NUMBER OF AGE READINGS

MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	TOTAL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	**51**
2	15	15	15	15	15	15	15	15	15	15	15	15	15	14	15	15	14	**253**
3	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	**663**
4	31	31	31	31	31	31	31	31	31	31	31	30	31	31	31	31	31	**526**
5	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	**408**
6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	**119**
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**17**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total **0-15**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**119**	**120**	**119**	**120**	**120**	**119**	**2037**

COEFFICIENT OF VARIATION (CV

MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0%	0%	0%	0%	0%	0%	0%	0%	87%	0%	0%	0%	0%	0%	0%	0%	0%	**8.6%**
2	12%	0%	0%	19%	12%	16%	26%	0%	25%	12%	0%	31%	20%	21%	0%	19%	17%	**13.3%**
3	11%	9%	9%	12%	8%	13%	10%	13%	12%	9%	12%	21%	14%	12%	15%	10%	26%	**10.8%**
4	9%	9%	10%	13%	11%	12%	15%	9%	13%	5%	10%	21%	11%	13%	17%	13%	23%	**10.7%**
5	7%	9%	6%	6%	10%	11%	13%	11%	8%	10%	10%	13%	7%	16%	7%	9%	12%	**8.3%**
6	0%	9%	6%	10%	9%	9%	12%	10%	8%	14%	6%	12%	0%	12%	0%	6%	9%	**7.2%**
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean **0-15**	**8.9%**	**7.8%**	**7.2%**	**11.1%**	**9.4%**	**12.3%**	**13.6%**	**9.2%**	**14.5%**	**8.7%**	**8.9%**	**19.4%**	**11.2%**	**13.7%**	**10.9%**	**11.2%**	**19.4%**	**10.3%**
RANKING	**4**	**2**	**1**	**9**	**7**	**12**	**13**	**6**	**15**	**3**	**5**	**16**	**10**	**14**	**8**	**11**	**17**	

PERCENTAGE AGREEMENT

MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	100%	100%	100%	100%	100%	100%	100%	100%	67%	100%	100%	100%	100%	100%	100%	100%	100%	**98%**
2	93%	100%	100%	80%	93%	87%	67%	100%	67%	93%	100%	80%	47%	64%	100%	80%	86%	**85%**
3	90%	92%	92%	87%	95%	85%	90%	85%	85%	92%	87%	74%	72%	82%	87%	90%	69%	**86%**
4	87%	87%	77%	74%	81%	77%	61%	87%	84%	97%	84%	47%	71%	74%	71%	71%	52%	**75%**
5	88%	79%	92%	92%	75%	79%	75%	58%	83%	67%	75%	71%	88%	63%	88%	79%	75%	**78%**
6	100%	71%	86%	71%	71%	71%	57%	57%	71%	57%	86%	57%	100%	57%	100%	86%	71%	**75%**
7	100%	0%	0%	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%	100%	100%	0%	100%	**47%**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean **0-15**	**90.0%**	**87.5%**	**88.3%**	**83.3%**	**85.8%**	**81.7%**	**75.0%**	**80.0%**	**80.0%**	**85.8%**	**85.0%**	**66.4%**	**73.3%**	**73.1%**	**85.8%**	**80.8%**	**68.9%**	**80.7%**
RANKING	**1**	**3**	**2**	**8**	**4**	**9**	**13**	**11**	**11**	**4**	**7**	**17**	**14**	**15**	**4**	**10**	**16**	

RELATIVE BIAS

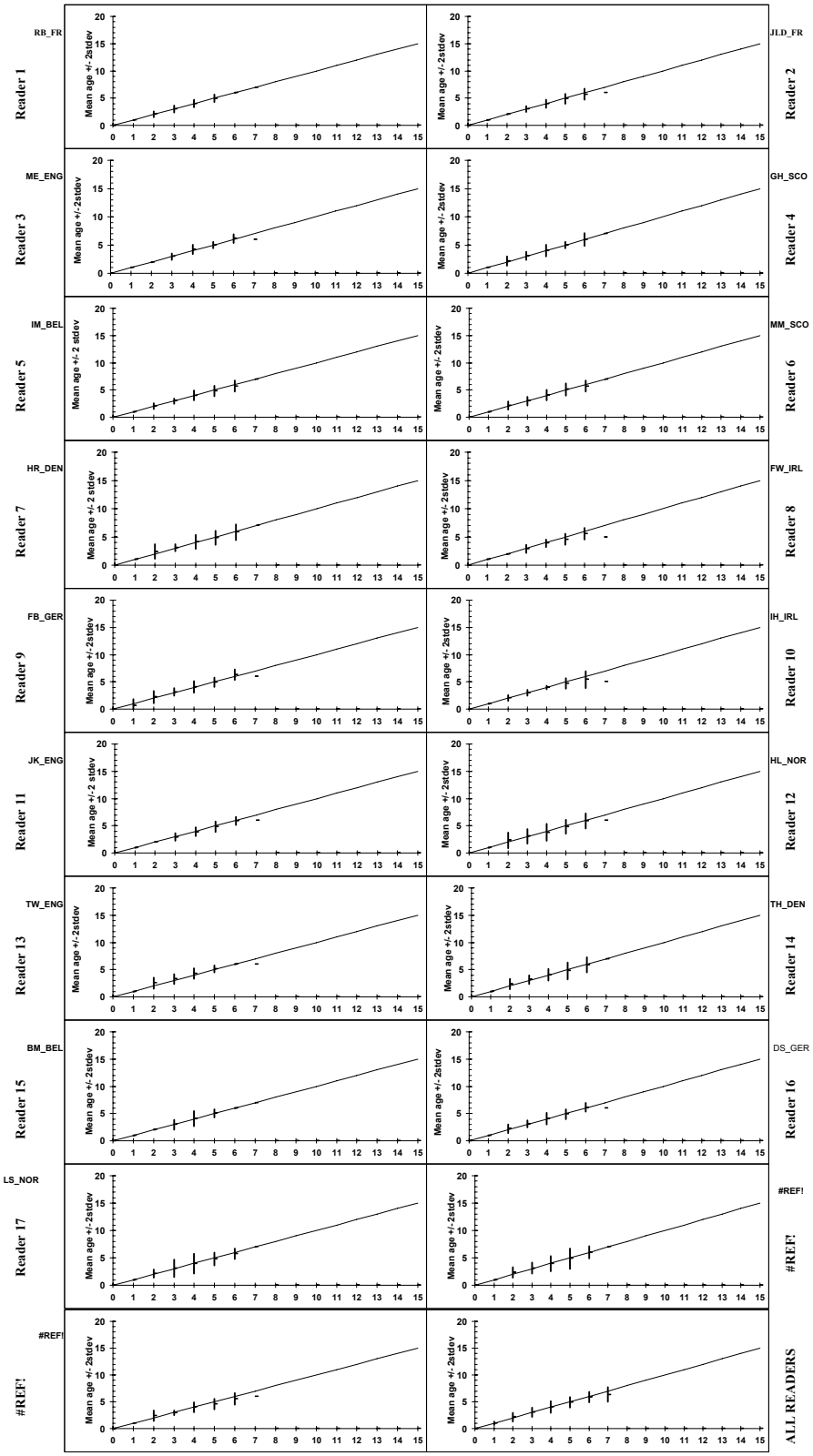
MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.02**
2	0.07	0.00	0.00	0.20	0.07	0.13	0.40	0.00	0.20	0.07	0.00	0.33	0.53	0.36	0.00	0.20	0.14	**0.16**
3	0.00	-0.03	-0.03	0.08	-0.05	-0.05	0.10	-0.15	0.15	-0.03	-0.08	0.05	0.28	0.18	-0.05	0.10	0.05	**0.03**
4	0.00	-0.06	0.23	0.06	0.00	0.03	0.13	-0.13	0.06	-0.03	-0.10	-0.23	0.29	0.06	0.10	0.10	-0.06	**0.03**
5	-0.04	-0.13	0.00	0.00	-0.17	0.08	-0.13	-0.42	-0.08	-0.33	-0.17	-0.17	0.13	-0.21	0.04	-0.13	-0.21	**-0.11**
6	0.00	-0.29	0.14	0.00	-0.29	-0.29	-0.14	-0.43	0.29	-0.57	-0.14	-0.14	0.00	-0.14	0.00	0.14	-0.29	**-0.13**
7	0.00	-1.00	-1.00	0.00	0.00	0.00	0.00	-2.00	-1.00	-2.00	-1.00	-1.00	-1.00	0.00	0.00	-1.00	0.00	**-0.65**
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean **0-15**	**-0.00**	**-0.07**	**0.05**	**0.07**	**-0.06**	**0.01**	**0.08**	**-0.21**	**0.08**	**-0.13**	**-0.10**	**-0.05**	**0.25**	**0.07**	**0.02**	**0.06**	**-0.04**	**0.00**
RANKING	**1**	**11**	**5**	**9**	**7**	**2**	**13**	**16**	**12**	**15**	**14**	**6**	**17**	**10**	**3**	**8**	**4**	

Overall ranking

	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17
Ranking Coefficient of Variation	4	2	1	9	7	12	13	6	15	3	5	16	10	14	8	11	17
Ranking Percentage Agreement	1	3	2	8	4	9	13	11	11	4	7	17	14	15	4	10	16
Ranking Relative bias	1	11	5	9	7	2	13	16	12	15	14	6	17	10	3	8	4
OVERALL RANKING	**1**	**4**	**2**	**8**	**5**	**7**	**14**	**11**	**13**	**6**	**8**	**14**	**17**	**14**	**3**	**10**	**12**

Appendix 6 Whiting otolith Exchange Scheme 2004 - re-read sectioned (Lowestoft, October 2005)

Figure 1 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.



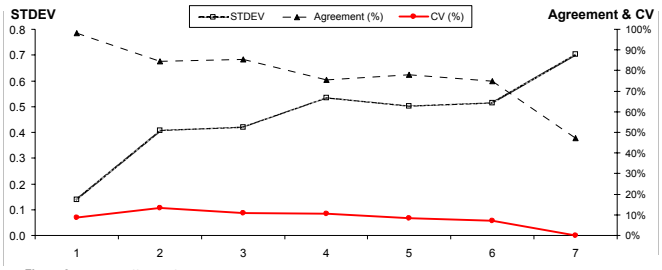


Figure 2 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age.
CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age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

Appendix 6 Whiting otolith Exchange Scheme 2004 - re-read sectioned (Lowestoft, October 2005)

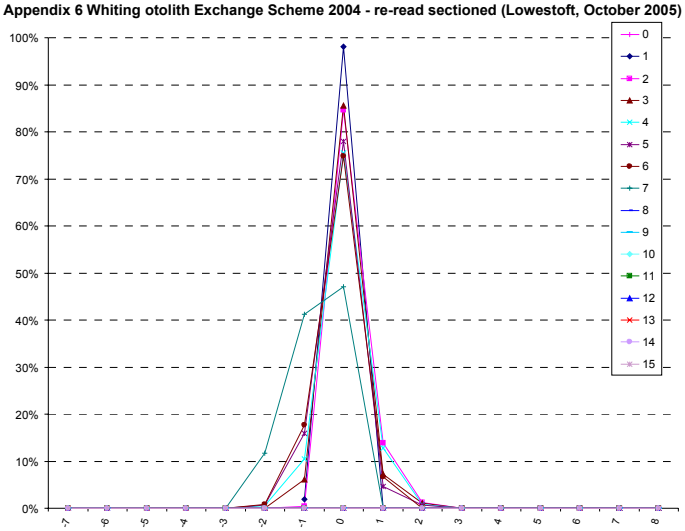


Figure 3 The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no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

Appendix 6 Whiting otolith Exchange Scheme 2004 - re-read sectioned (Lowestoft, October 2005)

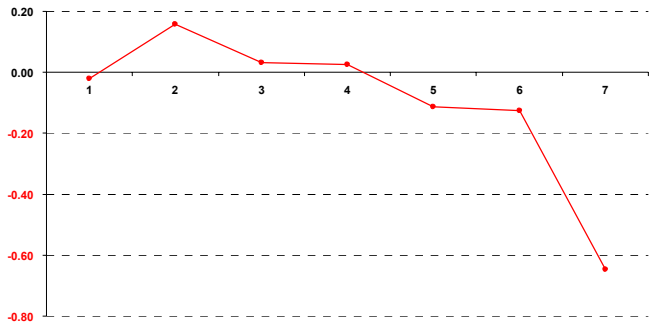


Figure 4 The RELATIVE bias by MODAL age as estimated by all age readers combined.

Table 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 comined indicate the precision in age reading by reader and for all age readers combined.

Appendix 7 Whiting otolith Exchange Scheme 2004 - 107e-k (Lowestoft, October 2005)

NUMBER OF AGE READINGS

MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	TOTAL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	102
2	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	306
3	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	272
4	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	221
5	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	272
6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	34
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total 0-15	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	1224

COEFFICIENT OF VARIATION (CV

MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	35%	35%	5.0%
2	18%	11%	15%	18%	0%	18%	11%	18%	18%	0%	0%	21%	15%	15%	11%	33%	20%	12.8%
3	8%	14%	17%	12%	0%	15%	21%	8%	21%	0%	0%	20%	19%	23%	0%	22%	21%	10.2%
4	9%	16%	7%	18%	12%	16%	12%	7%	13%	10%	10%	13%	12%	14%	9%	14%	17%	10.2%
5	9%	5%	5%	7%	7%	7%	10%	8%	7%	8%	9%	10%	9%	16%	5%	22%	13%	7.7%
6	0%	13%	13%	0%	0%	13%	13%	0%	0%	0%	0%	13%	0%	0%	0%	28%	13%	10.3%
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	9.9%	10.5%	10.3%	11.8%	3.7%	12.6%	12.2%	9.4%	13.0%	3.6%	3.9%	14.5%	12.1%	15.0%	5.6%	24.3%	18.7%	10.1%
RANKING	6	8	7	9	2	12	11	5	13	1	3	14	10	15	4	17	16	

PERCENTAGE AGREEMENT

MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	83%	83%	98%
2	83%	94%	89%	83%	100%	83%	94%	83%	83%	100%	100%	56%	89%	89%	94%	78%	72%	87%
3	94%	81%	88%	88%	100%	81%	75%	94%	69%	100%	100%	81%	69%	69%	100%	75%	75%	85%
4	85%	62%	92%	54%	77%	62%	77%	92%	77%	85%	85%	77%	77%	69%	85%	69%	77%	76%
5	81%	94%	94%	88%	88%	88%	75%	81%	88%	81%	75%	75%	81%	38%	94%	88%	56%	80%
6	100%	50%	50%	100%	100%	50%	50%	0%	100%	0%	0%	50%	100%	0%	100%	50%	50%	56%
7	0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	100%	100%	0%	0%	24%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	86.1%	83.3%	88.9%	80.6%	93.1%	79.2%	81.9%	84.7%	80.6%	88.9%	87.5%	72.2%	80.6%	68.1%	94.4%	76.4%	69.4%	82.1%
RANKING	6	8	3	10	2	13	9	7	10	3	5	15	10	17	1	14	16	

RELATIVE BIAS

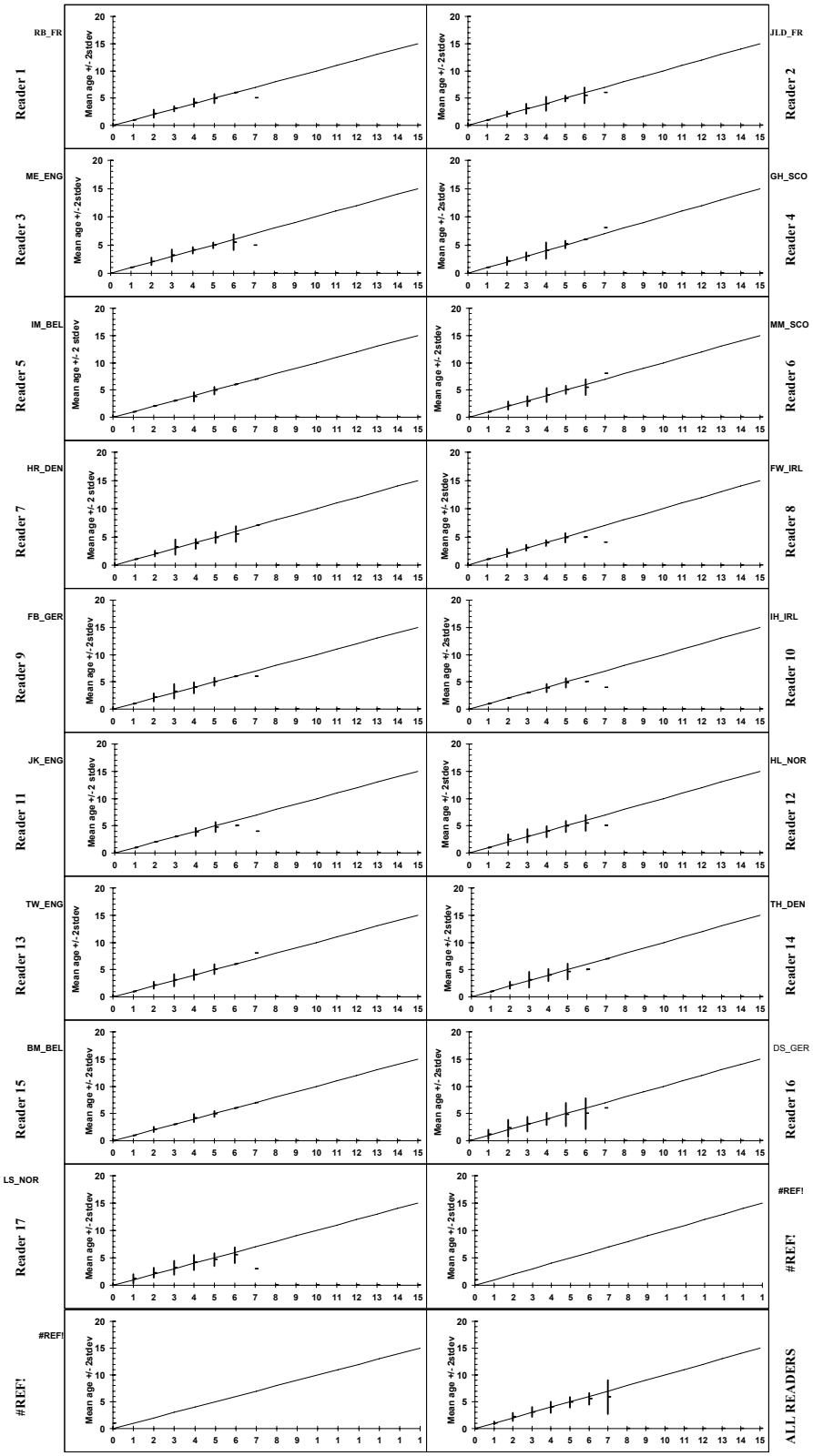
MODAL age	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.02
2	0.17	0.06	0.11	0.17	0.00	0.17	0.06	0.17	0.17	0.00	0.00	0.44	0.11	0.11	0.06	0.33	0.28	0.14
3	0.06	0.06	0.19	0.00	0.00	-0.06	0.19	0.06	0.25	0.00	0.00	0.13	0.06	0.13	0.00	0.06	0.19	0.08
4	0.15	-0.08	0.08	0.00	-0.23	0.08	-0.23	-0.08	-0.08	-0.15	-0.15	-0.08	0.08	0.00	0.15	0.00	0.15	-0.02
5	-0.06	-0.06	-0.06	0.13	-0.13	0.00	-0.13	-0.19	0.00	-0.19	-0.25	-0.13	0.06	-0.38	-0.06	-0.19	-0.31	-0.11
6	0.00	-0.50	-0.50	0.00	0.00	-0.50	-0.50	-1.00	0.00	-1.00	-1.00	-0.50	0.00	-1.00	0.00	-1.00	-0.50	-0.47
7	-2.00	-1.00	-2.00	1.00	0.00	1.00	0.00	-3.00	-1.00	-3.00	-3.00	-2.00	1.00	0.00	0.00	-1.00	-4.00	-1.12
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	0.04	-0.03	0.03	0.08	-0.07	0.04	-0.03	-0.07	0.07	-0.14	-0.15	0.06	0.08	-0.06	0.03	0.03	0.01	-0.00
RANKING	8	6	2	14	12	7	5	13	11	16	17	10	14	9	3	4	1	

Overall ranking

	RB_FR Reader 1	JLD_FR Reader 2	ME_ENG Reader 3	GH_SCO Reader 4	IM_BEL Reader 5	MM_SCO Reader 6	HR_DEN Reader 7	FW_IRL Reader 8	FB_GER Reader 9	IH_IRL Reader 10	JK_ENG Reader 11	HL_NOR Reader 12	TW_ENG Reader 13	TH_DEN Reader 14	BM_BEL Reader 15	DS_GER Reader 16	LS_NOR Reader 17
Ranking Coefficient of Variation	6	8	7	9	2	12	11	5	13	1	3	14	10	15	4	17	16
Ranking Percentage Agreement	6	8	3	10	2	13	9	7	10	3	5	15	10	17	1	14	16
Ranking Relative bias	8	6	2	14	12	7	5	13	11	16	17	10	14	9	3	4	1
OVERALL RANKING	4	6	2	11	3	10	7	7	13	4	7	16	13	17	1	15	11

Appendix 7 Whiting otolith Exchange Scheme 2004 - 107e-k (Lowestoft, October 2005)

Figure 1 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.



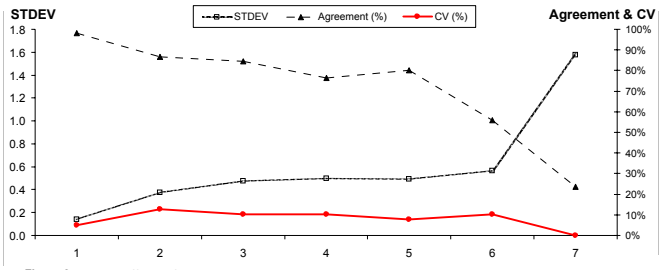


Figure 2 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age.
CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age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

Appendix 7 Whiting otolith Exchange Scheme 2004 - 107e-k (Lowestoft, October 2005)

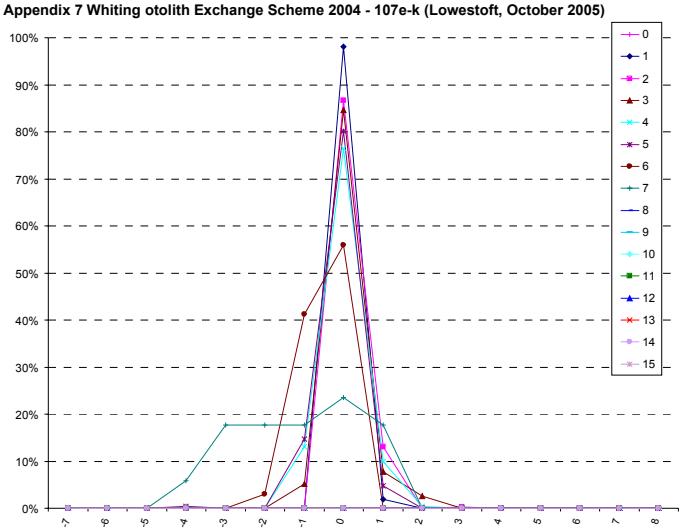


Figure 3 The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no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

Appendix 7 Whiting otolith Exchange Scheme 2004 - 107e-k (Lowestoft, October 2005)

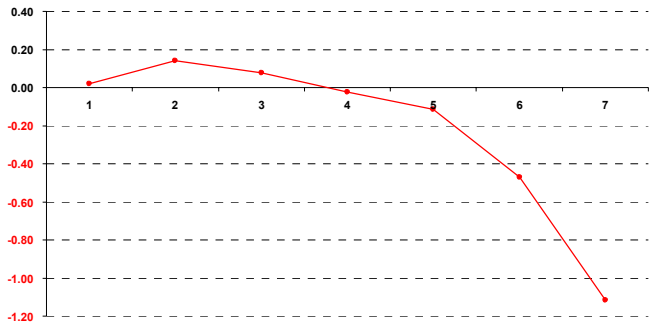


Figure 4 The RELATIVE bias by MODAL age as estimated by all age readers combined.

Table 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 comined indicate the precision in age reading by reader and for all age readers combined.

Appendix 8 Whiting Exchange 2004 -preferred method (Scot, Nor, Den, broken)(rest-sections)

NUMBER OF AGE READINGS

MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	TOTAL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	323
2	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	1026
3	48	48	48	48	47	47	48	48	48	48	48	48	48	48	48	48	48	48	48	910
4	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	760
5	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	589
6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	152
7	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	38
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total 0-15	200	200	200	200	199	199	200	200	200	200	200	200	200	200	200	200	200	200	200	3798

COEFFICIENT OF VARIATION (CV

MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	ALL Readers
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	23%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	32%	45%	23%	0%	0%	0%	36%	30%	22.3%
2	7%	7%	14%	9%	9%	0%	13%	17%	9%	14%	14%	26%	38%	0%	20%	9%	17%	22%	19%	16.1%
3	13%	16%	21%	12%	17%	15%	12%	18%	13%	12%	20%	24%	34%	11%	19%	15%	11%	21%	8%	15.6%
4	7%	12%	13%	12%	7%	10%	7%	15%	9%	8%	8%	15%	23%	12%	13%	7%	9%	19%	9%	10.4%
5	7%	9%	13%	7%	8%	8%	6%	16%	6%	12%	6%	21%	20%	9%	12%	7%	8%	15%	11%	12.7%
6	6%	9%	14%	9%	16%	8%	11%	12%	7%	13%	11%	8%	25%	9%	9%	9%	9%	14%	10%	12.2%
7	0%	11%	0%	0%	20%	11%	0%	9%	0%	11%	11%	11%	8%	0%	0%	0%	11%	20%	11%	9.7%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	9.6%	10.0%	14.0%	9.4%	10.0%	7.4%	9.2%	15.1%	8.7%	10.7%	11.6%	22.2%	31.1%	8.6%	15.0%	9.0%	10.6%	20.9%	13.6%	14.6%
RANKING	7	8	14	6	9	1	5	16	3	11	12	18	19	2	15	4	10	17	13	

PERCENTAGE AGREEMENT

MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	41%	76%	94%	100%	100%	100%	65%	88%	93%
2	98%	98%	91%	96%	96%	100%	98%	83%	96%	91%	91%	46%	35%	100%	81%	96%	93%	59%	81%	86%
3	85%	75%	69%	92%	81%	79%	88%	75%	83%	85%	75%	54%	46%	90%	65%	79%	90%	65%	94%	77%
4	93%	78%	65%	80%	93%	83%	93%	70%	88%	90%	90%	70%	45%	85%	65%	93%	88%	63%	88%	80%
5	87%	77%	55%	87%	84%	84%	90%	65%	90%	74%	90%	32%	35%	81%	77%	87%	84%	45%	61%	73%
6	88%	75%	38%	75%	75%	75%	63%	75%	75%	50%	50%	75%	38%	75%	25%	75%	75%	38%	50%	63%
7	100%	50%	100%	100%	0%	50%	100%	50%	100%	50%	50%	50%	0%	100%	100%	100%	50%	0%	50%	63%
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	91.5%	84.0%	73.5%	90.0%	88.4%	87.4%	92.0%	76.5%	90.0%	85.5%	85.5%	51.5%	43.0%	90.0%	73.0%	89.5%	89.0%	58.0%	81.5%	80.0%
RANKING	2	12	15	3	8	9	1	14	3	10	10	18	19	3	16	6	7	17	13	

RELATIVE BIAS

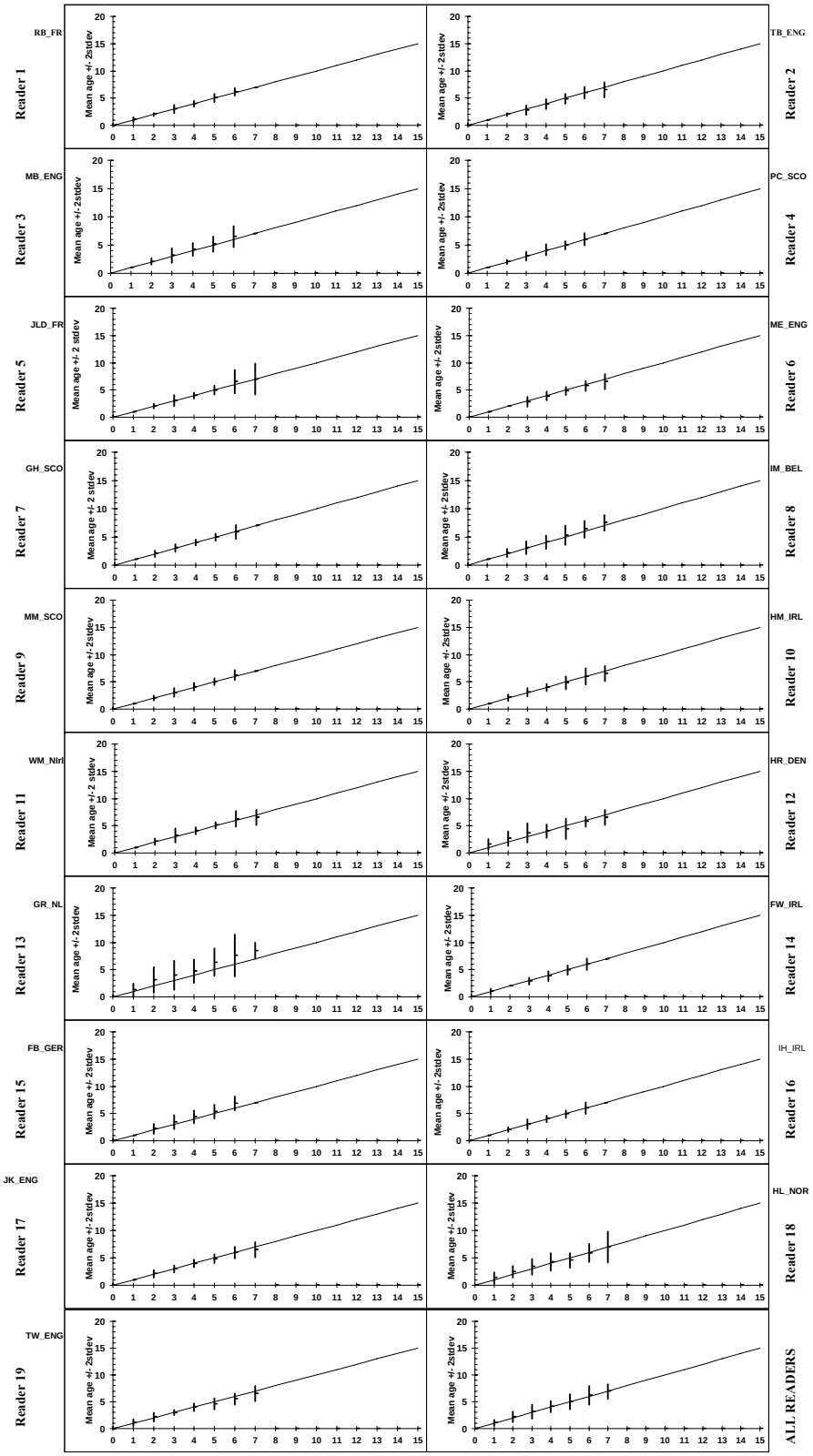
MODAL age	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19	ALL
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.29	0.06	0.00	0.00	0.00	0.35	0.12	0.08
2	0.02	-0.02	0.09	0.04	0.04	0.00	0.04	0.17	0.04	0.09	0.09	0.65	1.09	0.00	0.20	0.04	0.09	0.43	0.15	0.17
3	-0.02	-0.25	0.15	0.06	0.04	-0.17	0.04	0.10	0.04	0.10	0.19	0.69	0.94	-0.06	0.38	0.04	-0.06	0.35	-0.02	0.13
4	-0.02	-0.13	0.20	0.18	-0.02	-0.13	0.03	0.08	0.08	0.00	0.05	0.03	0.70	-0.18	0.40	0.03	-0.02	0.23	-0.02	0.08
5	0.00	-0.16	0.13	-0.06	-0.03	-0.16	-0.03	0.29	0.03	-0.16	0.10	-0.58	1.35	-0.13	0.32	-0.13	-0.16	-0.45	-0.39	-0.01
6	0.13	0.00	0.50	0.00	0.50	-0.25	-0.13	0.38	0.25	0.00	0.25	-0.25	1.63	0.00	0.88	0.00	0.00	-0.13	-0.50	0.17
7	0.00	-0.50	0.00	0.00	0.00	-0.50	0.00	0.50	0.00	-0.50	-0.50	-0.50	1.50	0.00	0.00	0.00	-0.50	0.00	-0.50	-0.08
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weighted mean 0-15	0.01	-0.12	0.14	0.05	0.03	-0.11	0.02	0.15	0.05	0.02	0.10	0.29	0.98	-0.06	0.31	0.01	-0.03	0.20	-0.04	0.10
RANKING	1	13	14	8	6	12	3	15	9	4	11	17	19	10	18	2	5	16	7	

Overall ranking

	RB_FR Reader 1	TB_ENG Reader 2	MB_ENG Reader 3	PC_SCO Reader 4	JLD_FR Reader 5	ME_ENG Reader 6	GH_SCO Reader 7	IM_BEL Reader 8	MM_SCO Reader 9	HM_IRL Reader 10	WM_NIrl Reader 11	HR_DEN Reader 12	GR_NL Reader 13	FW_IRL Reader 14	FB_GER Reader 15	IH_IRL Reader 16	JK_ENG Reader 17	HL_NOR Reader 18	TW_ENG Reader 19
Ranking Coefficient of Variation	7	8	14	6	9	1	5	16	3	11	12	18	19	2	15	4	10	17	13
Ranking Percentage Agreement	2	12	15	3	8	9	1	14	3	10	10	18	19	3	16	6	7	17	13
Ranking Relative bias	1	13	14	8	6	12	3	15	9	4	11	17	19	10	18	2	5	16	7
OVERALL RANKING	2	11	14	6	9	7	1	15	4	10	11	18	19	4	16	3	7	17	11

Appendix 8 Whiting Exchange 2004 -preferred method (Scot, Nor, Den, broken)(rest-sections)

Figure 1 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.



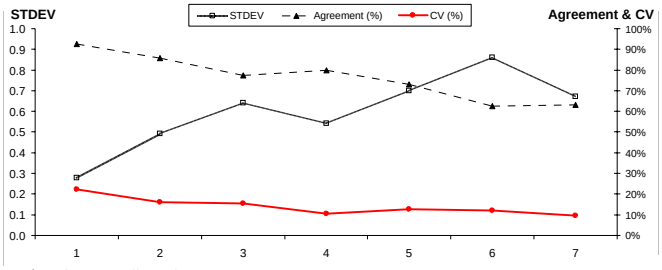


Figure 2 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age.
CV is much less age dependent than the standard deviation (STDEV) and the percent agreement. CV is therefore a better index for the precision in age reading. Problems in age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

Appendix 8 Whiting Exchange 2004 -preferred method (Scot, Nor, Den, broken)(rest-sections)

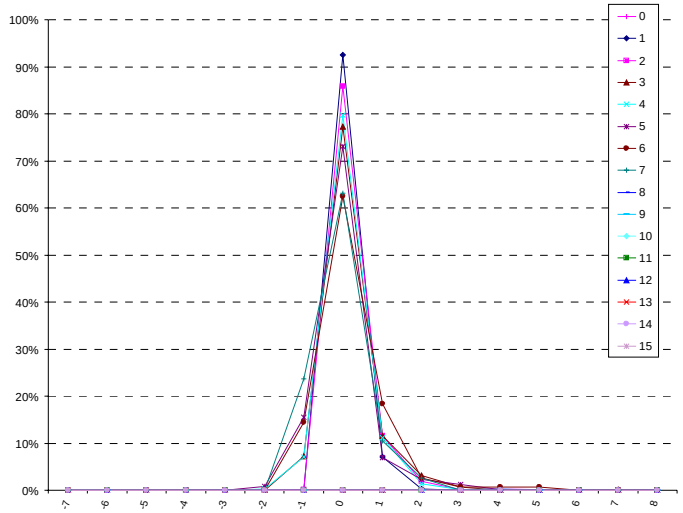


Figure 3 The distribution of the age reading errors in percentage by MODAL age as observed from the whole group of age readers in an age reading comparison to MODAL age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no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

Appendix 8 Whiting Exchange 2004 -preferred method (Scot, Nor, Den, broken)(rest-sections)

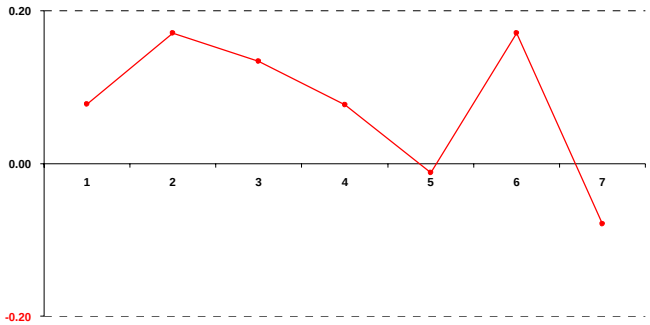


Figure 4 The RELATIVE bias by MODAL age as estimated by all age readers combined.

Appendix 9

National procedures 2005

Belgium

After extraction from the fish, the otoliths are stored in paper envelopes. At first (this approach is adopted at the 2005 whiting ageing workshop in Lowestoft), the otoliths are read as a whole. Prior to the reading, the otoliths are put into distilled water for at least 24 hours. Then they are put into a black recipient filled with water for ageing using reflected light. A photograph is taken for archiving and easy re-evaluation.
The otoliths are embedded in a black epoxy resin and sectioned for a second reading using transmitted and reflected light. A xyz-table together with a camera and monitor are used to position the otoliths so that the sections are through the nucleus. Slides of 0.45-0.50 mm are made by a high speed sectioning machine equipped with a diamond blade (Bennetts' sectioning machine). The slides are rinsed with tab water and left to dry for app. two or three hours. After mounting of the slides onto a glass using superglue, a binocular microscope combined with a digital camera is used for ageing on screen. A thin layer of oil is used as a "clearing" agent. The system allows on screen ageing using transmitted, reflected (bench light) and ring-reflected light. The readers can look down the binocular microscope when desired. Magnification can vary from 6.5 to 45. A photograph is taken again for archiving and easy re-evaluation.
The otoliths are aged using predominantly the dorsal edge. Transmitted light at low magnification is used at first. We then switch to reflected light to evaluate the edge and confirm the pattern seen with transmitted light. Higher magnification can be used for more detail switching between transmitted and reflected light at any time.

Denmark

After removal from the fish, the otoliths are cleaned, dried, stored in small paper envelopes or in ice cube trays If possible, we take two otoliths. Before reading, the otolith is kept in water for at least 24 hours. We read the otolith whole if possible, otherwise we break one of them, and compare the whole and the broken. To look at the otoliths we use a binocular microscope with a magnification from x 6.3-16. We use reflected light. To break the otoliths we use our fingernails or a small wire cutter. The otolith is held by a pair of tweezers and dipped into water, alcohol, or a mixture of both.

Whiting otoliths are not sampled from the commercial fishery in the North Sea on a regular basis due to the fact that there are very small landings of this species for human consumption. Whiting more or less only occur in the small-mesh fishery for industrial purposes. From this fishery the institute gets around 500 samples spread over the year and since whiting are not present in them all we do not get a large amount of whiting otoliths from the commercial fishery; we obtain the bulk of our whiting otoliths from Danish research vessel surveys. From the

surveys we get some otoliths depending on the area RV DANA has to cover on the 2 yearly trips to the North Sea. The number of otoliths taken varies between 500 – 700 per survey (1500 – 2000 otoliths per year).
The experience of reading whiting otoliths is connected to 2 different people in Hirtshals. One person has 7 years of experience and one is a novice.

England
Otoliths are embedded in black polyester resin blocks. Thin sections (0.5-0.6mm) are cut through the nucleus from the blocks using an adapted engineering surface grinding machine fitted with an electroplated diamond grit blade running at high speed (3,000rpm). The sections are mounted on glass microscope slides using clear resin and the top surface is protected with a glass cover slip.

Three people age all the whiting. One is very experienced and the other two have just become fully trained. The experienced person has trained and checks the other two and has 40 years experience of otolith reading of various roundfish including whiting. The other two have been ageing whiting for approximately 4 years each.

Leica binocular microscopes are used at x10 - 20 magnification. Transmitted light is the main lighting method but reflected light is also used especially to identify the edge. All combinations of lighting and otolith orientation may be used with difficult otoliths.
Approximately 1800 per year are aged from the commercial fisheries plus a further 3000 are aged from various research vessel surveys.

France
Otoliths are encapsulated in polyester resin blocks with one or two layers of otoliths. Both translucent or black coloured resin was used. Two or three thin transversal sections are produced. For one layer of otoliths, sections are around 0.2-0.3 mm thick and for two layers of otoliths the thickness of a section is around 0.5 mm. At least one section is passing through the nucleus and all sections are passing through the opaque zone of the birth year. The cutting is done with a high-speed industrial and a diamond grid saw blade. The sections are not mounted so before reading both surfaces are cleared with oil. The equipment used for reading is a binocular microscope with x6-x15 magnification, fitted with a numerical camera plug to a PC or a monitor. Transmitted and reflected lights are used alternately from a source adjustable for brightness. Reading is mainly done from the screen. Pictures and their interpretation can be stored with T.N.P.C in a database.

North Sea (IVb-c), Eastern English Channel (VIId) and Celtic Sea whiting otoliths are sampled from surveys (IBTS, CGFS and EVHOE) and landings at fish

markets under the Data Collection Regulation. JL Dufour and R Bellail , the two French readers of whiting otoliths have around 20 years experience on gadoid species (cod, saithe, haddock, ling) reading yearly 8 000 and 4 500 otolihs respectively.

Germany

Otoliths are embedded in transparent resin and 0.5mm sections sawed through the centre. The sections are mainly aged using transmitted light but reflected light is also used
under a binocular microscope at x10 - 15 magnification.

There are two whiting readers. The main reader has 20 years of otolith reading experience on different gadoid species, including whiting (ca.3000/year) and the other one has 4 years experience.

Ireland

Otoliths are embedded in blocks of black polyester resin. Using a single blade high speed sectioning saw manufactured by pilses, a transverse section (0.6mm thick) is cut through the nucleus. The sections are mounted onto glass microscope slides using Histokitt resin ® as a mounting medium. A thin layer of Histokitt is painted over the section to protect the surface.

A camera is attached to the microscope and images of the sectioned otoliths are projected onto a monitor for age estimation. Sections are read using transmitted light, however, reflected light is occasionally used to aid interpretation. In some cases it may be necessary to read down the eyepieces.

There are three whiting otolith readers in the Marine Institute. Reader one has three years experience and is responsible for reading commercial and discard otoliths. Reader two has reads survey otoliths. Reader three performs quality control checks on readers one and two. Inter-calibration checks are also carried out between readers one and two.

Readers one and two age whiting from ICES Divisions VIa, VIIa, VIIg, VIIj and VIIb. Approximately 8,000 sectioned otoliths are read annually.

Netherlands

Until 1996 otoliths were prepared for reading by breaking. After this the sectioning method was adopted. From 1997 the otoliths from cod and whiting were put into small blocks and sectioned. The sections are mounted on glass and are not protected; the reason being that in future years people may wish to do some more research with them. During reading oil is used as a ‘clearing’

agent. The equipment used is a binocular microscope with x12 magnification and transmitted light is preferred.

There is one reader who has 10 years experience and one reader in training. North Sea whiting otoliths are derived from both survey and market sources and number between 2,000 and 2,500 annually.

Northern Ireland

Whiting otoliths (sagittae) are embedded in black resin blocks from which thin sagittal sections, (0.4mm) are cut through the nucleus using an OTOLIN high speed (3,600 rpm) otolith cutting saw. Both sagittae are collected but only one is selected at random for age estimation. The thin sections are mounted on double-sized glass microscope slides using high quality clear styrene resin (casting resin) and the top surface is protected with a glass cover slip.

A Wild M7 zoom binocular microscope (magnification range 12-62X) is used for most of the otolith age estimation work, but Wild M5 binocular microscopes are also used occasionally. Typically 16X is the preferred magnification for age estimation of whiting otoliths, with 12X used to gain perspective and up to 20X used to resolve closely packed hyaline zones in older whiting. Typically, transmitted light is used most often, with reflected light mainly used to identify annual Hyaline growth zones near the otolith edge, but all combinations of magnification, lighting level and otolith orientation are used with difficult otoliths. Illumination levels are maintained at the lowest possible levels for accurate age estimation.

A video camera and monitor are used to discuss some difficult otoliths with other readers and (if requested) to demonstrate annual growth patterns in unusually fast or slow growing fish to scientists presenting data at ICES working groups.

Currently one very experienced person ages all the whiting otoliths. Two other persons are occasional readers and two additional readers will be trained during the next 12 months. The experienced person has trained and checks the other readers and has over 25 years experience of otolith reading of various species including whiting, cod, haddock, herring and more recently hake and sprat, in addition to reading scallop *P. maximus* shell hinge plates for over 30 years.

For most of the last 25 years, the age estimations have been entered directly into a computer database by the reader, at the time of the initial age estimation. When making the initial reading, the reader only has access to the sample details and the fish number for each otolith. The ages are estimated ‘blind’ and then entered into the database. When the initial reading of the sample is complete, the next block key reveals the biological details (including length and weight) for each fish, giving the reader an opportunity to re-read any difficult / suspect otoliths and correct any keyboard errors. Typically the experienced reader would change less

that 0-3% of the initial readings, with more revision being required when reading otoliths from unfamiliar stocks e.g. otolith workshop exchanges. Approximately 3,500 whiting otoliths are read each year. Some samples are collected from market sampling and discard surveys at sea, but the majority of the whiting otoliths (circa 2400) are collected during VIIa research vessel cruises.

Norway

The whiting otoliths are stored in small paper envelopes recorded with information on length and weight. Both otoliths are taken. The otoliths are broken across the nucleus and mounted in plasticine with the cut surface uppermost. A thin film of water is applied to this surface. The otoliths are examined by using a binocular microscope with a magnification ranging from 6.3 – 16. The otoliths are read using reflected light. By holding a pencil between the lamp and the otolith a shadow is cast over the broken surface, which allows the “side transmitted” light to highlight the opaque and translucent zones. We read about 300 samples a year; all samples are collected from surveys in the North Sea. The experience of reading whiting otoliths is connected to 2 different persons in Bergen. One person has 10 years of experience and one is a novice.

Scotland

Otoliths are cut in half using a scalpel and mounted with the cut surface uppermost and the proximal surface to the outside of a circular container (jar or bottle top) filled with plasticine (modelling clay). A thin film of baby oil is applied to the cut surface and the otolith is examined using a stereo zoom microscope with x10 eyepieces and, generally, a 1.5-2.0 objective. The otolith is then illuminated from the side using a free standing bench lamp, which is adjustable for focus and brightness. By holding a finger between the lamp and otolith a shadow is cast over the broken surface which allows the ‘side transmitted’ light to highlight the opaque and translucent zones.

Whiting otoliths taken from commercial samples are read by one person who has 28 years experience with this species as well as experience with cod, haddock, saithe, anglerfish and megrim. All demersal otoliths collected from the Discard Sampling Project are read by another person who has eighteen years experience. In the case of whiting, this reader regularly refers to more experienced readers and a low level of checking is routinely carried out. Currently between 7,000 and 10,000 whiting otoliths are aged per year from commercial samples and 4,000 – 6,000 from the discard programme. Approximately 5,000 – 6000 whiting collected on research vessel surveys are read by a third person with 10 years experience of this species in addition to experience of cod, haddock, saithe and Norway pout.

Appendix 10

SELECTED IMAGES FROM THE WHITING OTOLITH AGEING EXCHANGE 2004/2005

The following images have been selected from the exchange otoliths to illustrate age groups 1-7 which had a high agreement plus other images of otoliths which had low agreement and also other factors affecting ageing. Modal ages of the sectioned otoliths are given for each otolith along with the spread of ages from the exchange participants.

Figures 1 – 7 Otoliths from age groups 1-7 with high agreement.
Figure 8 Diagnostic features for ageing
Figures 9 – 11 Otoliths with poor agreement. The modal age has been marked on the translucent zones.
Figures 12 – 13 Two otoliths with very poor agreement.
Figure 14 An otolith with a very distinct split inside the first year.
Figure 15 An otolith that has not been sectioned quite through the centre of the nucleus.
Figure 16 Illustrating how black resin underneath part of an undercut otolith edge can make a translucent edge look opaque when viewed by transmitted light.(Supplied by W.McCurdy)

Ages are based on the original analysis. All the images were marked for the modal age on the translucent zones by W.McCurdy (DARDNI) except for figs 4 and 8.

Fig 1

Fish No. 158 March 2004 106a Outer Hebrides - modal age 1
100% agreement

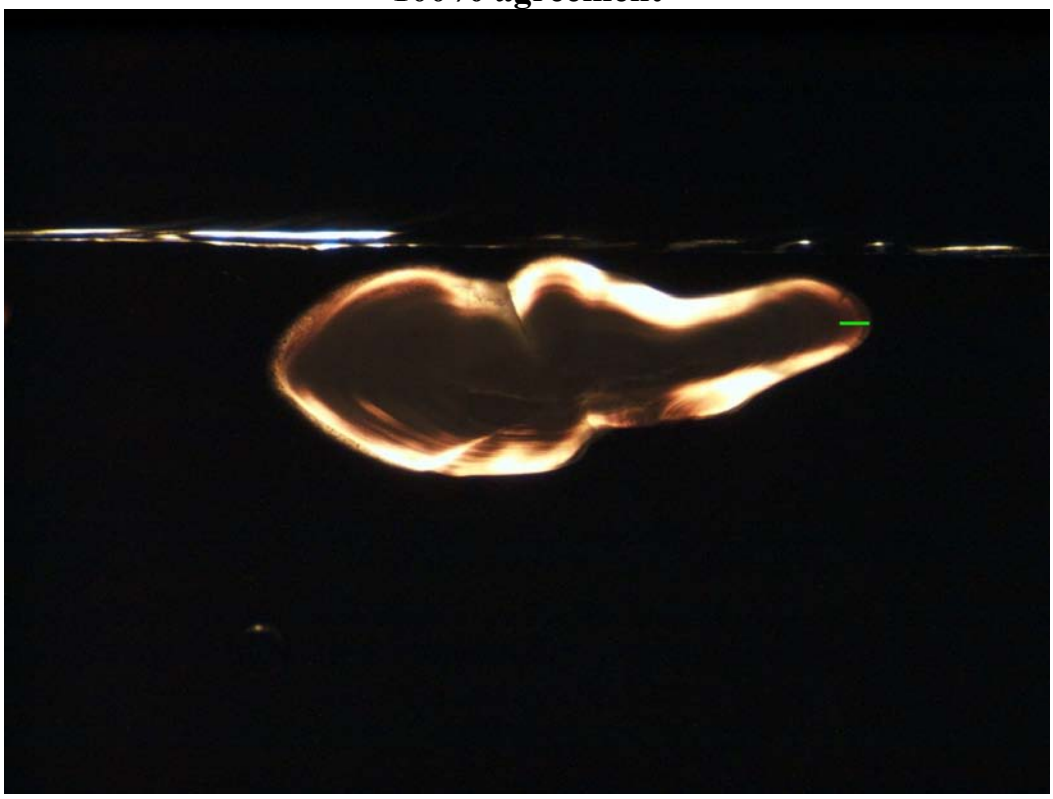


Fig 2

Fish No. 100 March 2004 106a Butt of Lewis - modal age 2
100% agreement

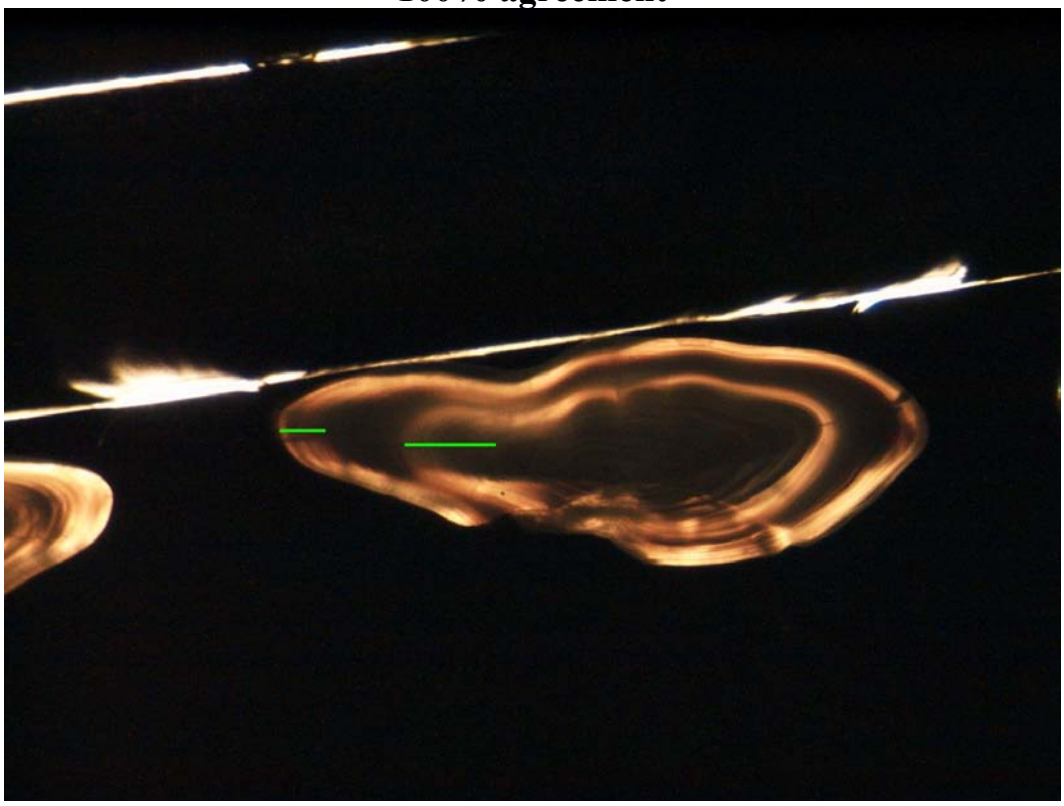


Fig 3

Fish No. 3 April 2004 104a - modal age 3
100% agreement

Fig 4

Fish No. 194 April 2004 107d - modal age 4
100% agreement

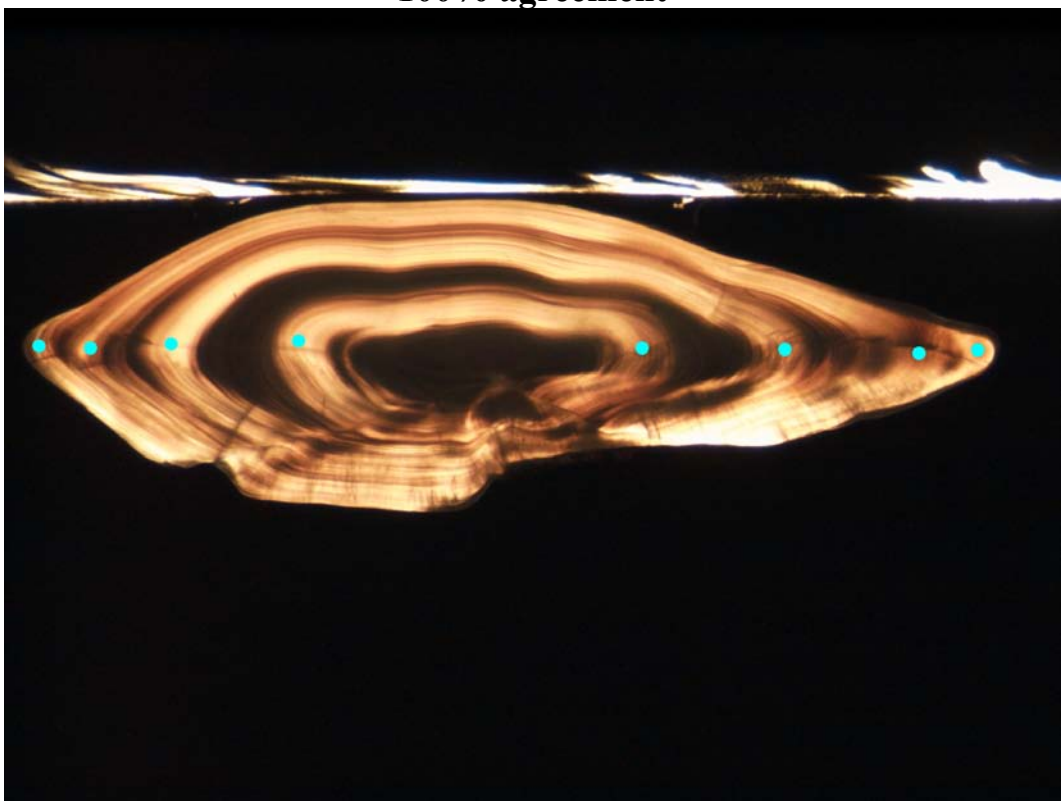


Fig 5

Fish No. 39 April 2004 104a - modal age 5
100% agreement

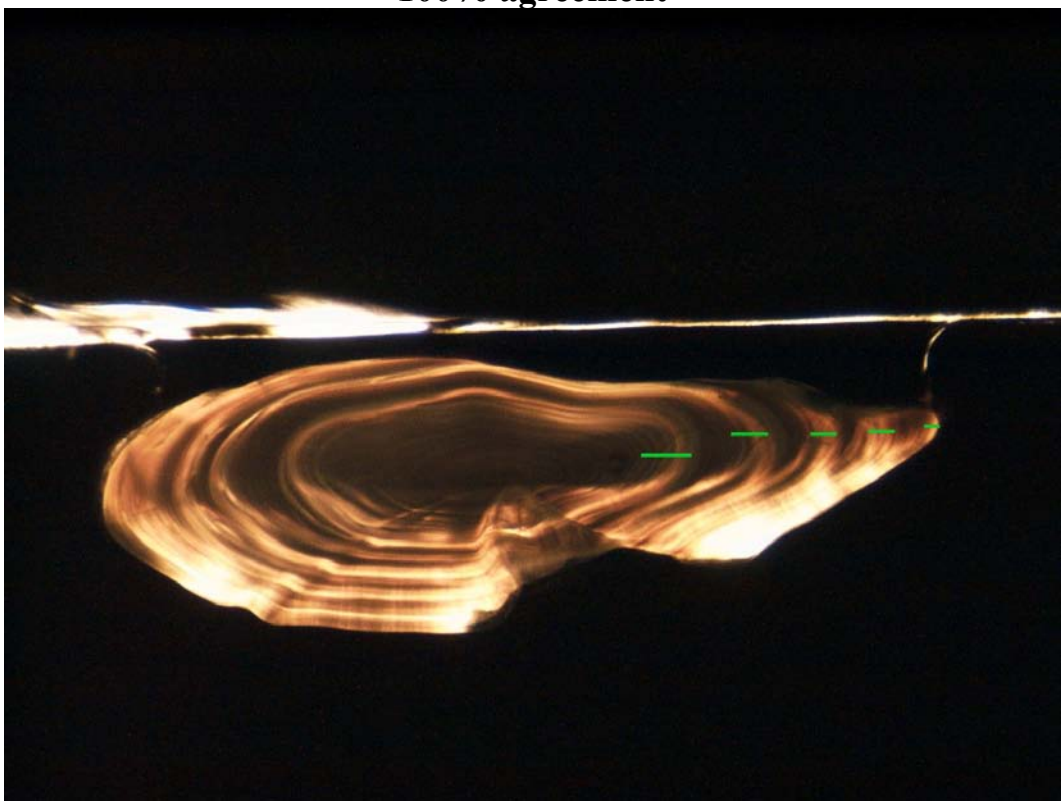


Fig 6

Fish No. 41 April 2004 104a - modal age 6 - 74% agreement
Age range 14 x 6 and 5 x 7 ? split inside first ring

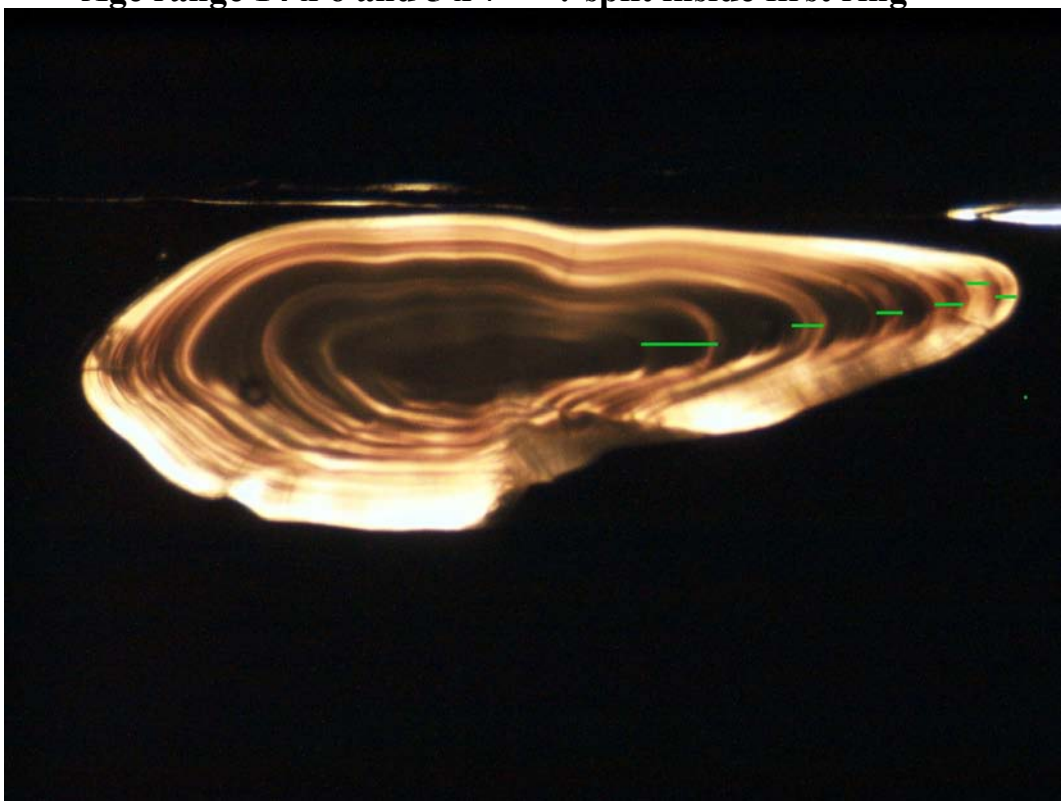


Fig 7

Fish No. 90 March 2004 106a Butt of Lewis - modal age 7 - 74% agreement
Age range 1 x 6, 14 x 7, 4 x 8

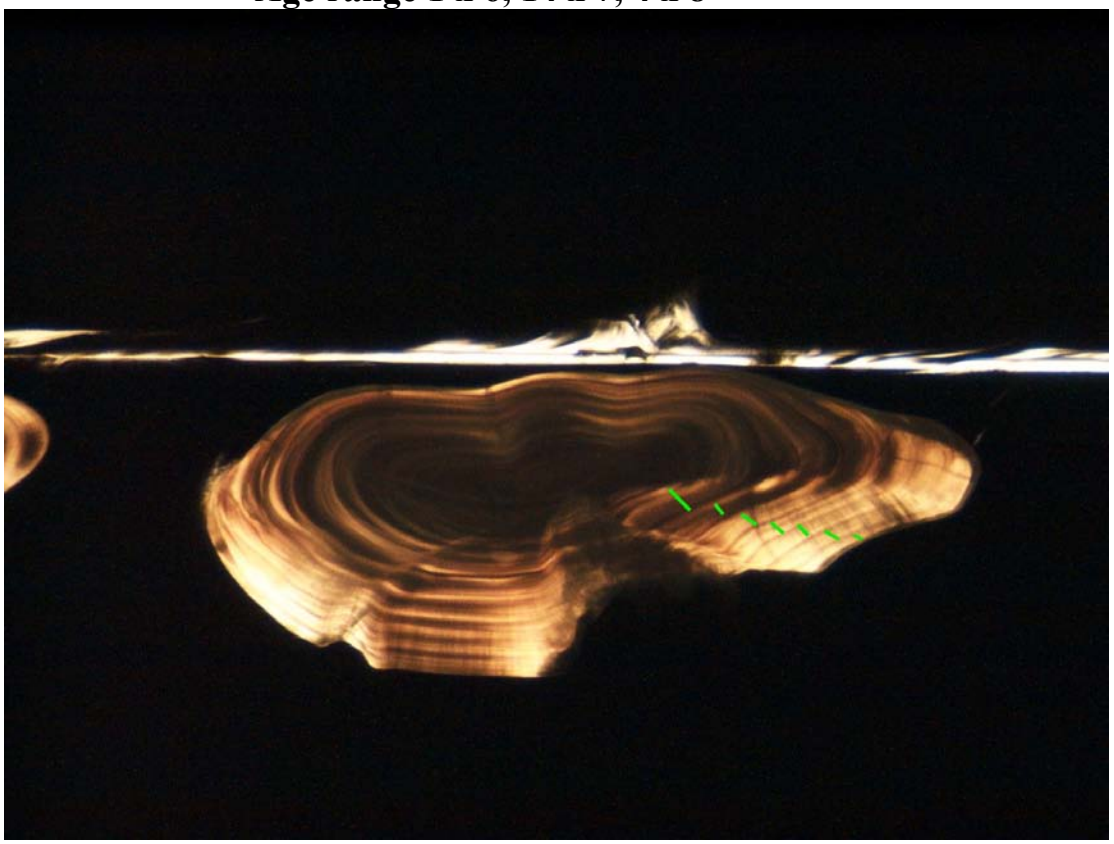


Fig 8

Diagnostic features for ageing

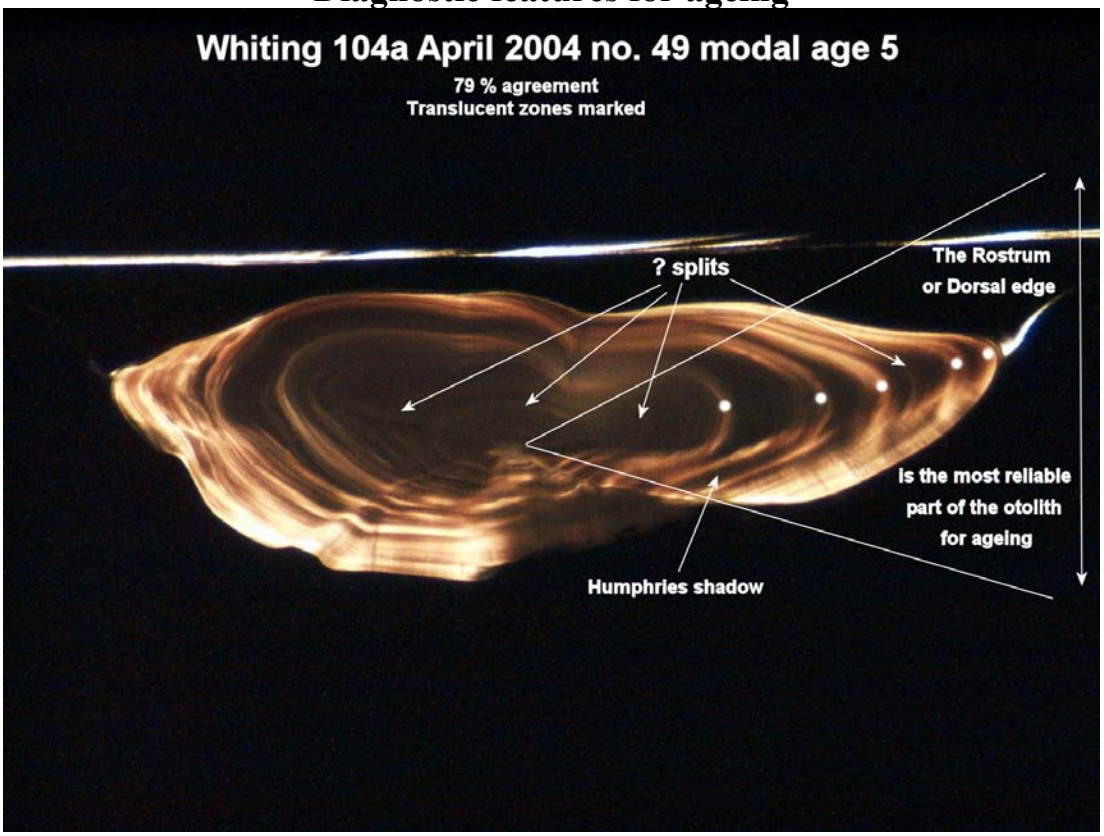


Fig 9

Fish No. 5 April 2004 104a - modal age 2 - 53% agreement

Age range 10 x 2 and 9 x 3

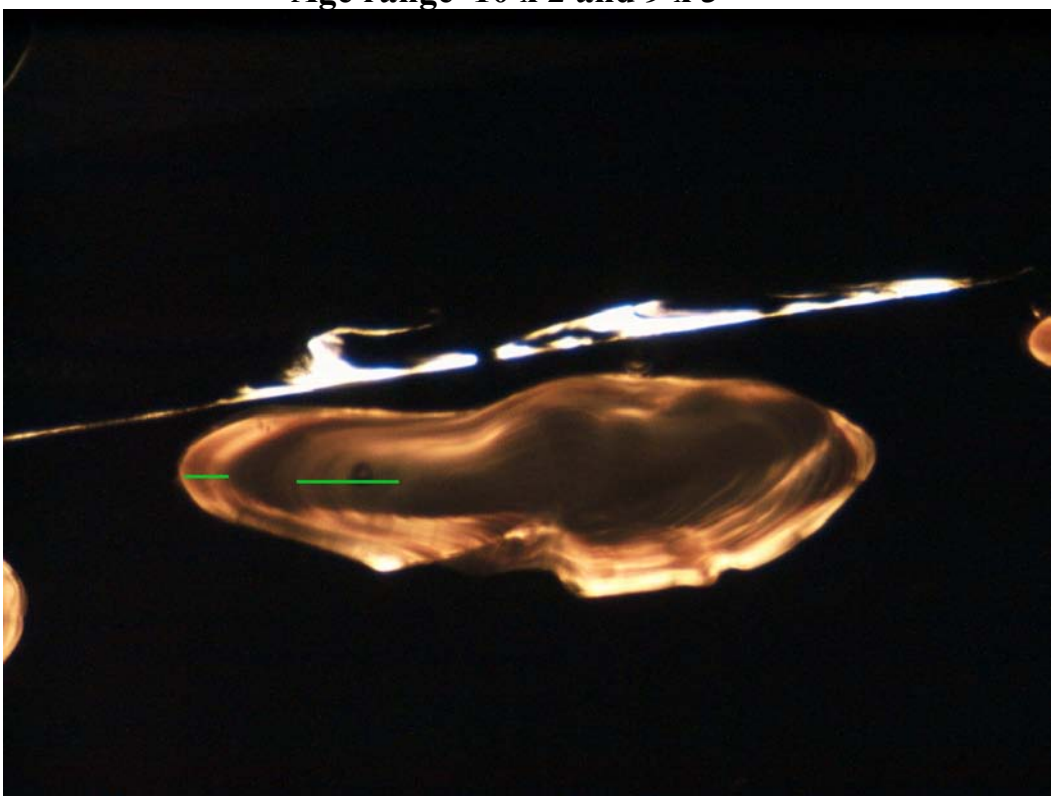


Fig 10

Fish No. 50 April 2004 104a - modal age 4 - 53% agreement
Age range 1 x 3, 10 x 4, 7 x 5, 1 x 6

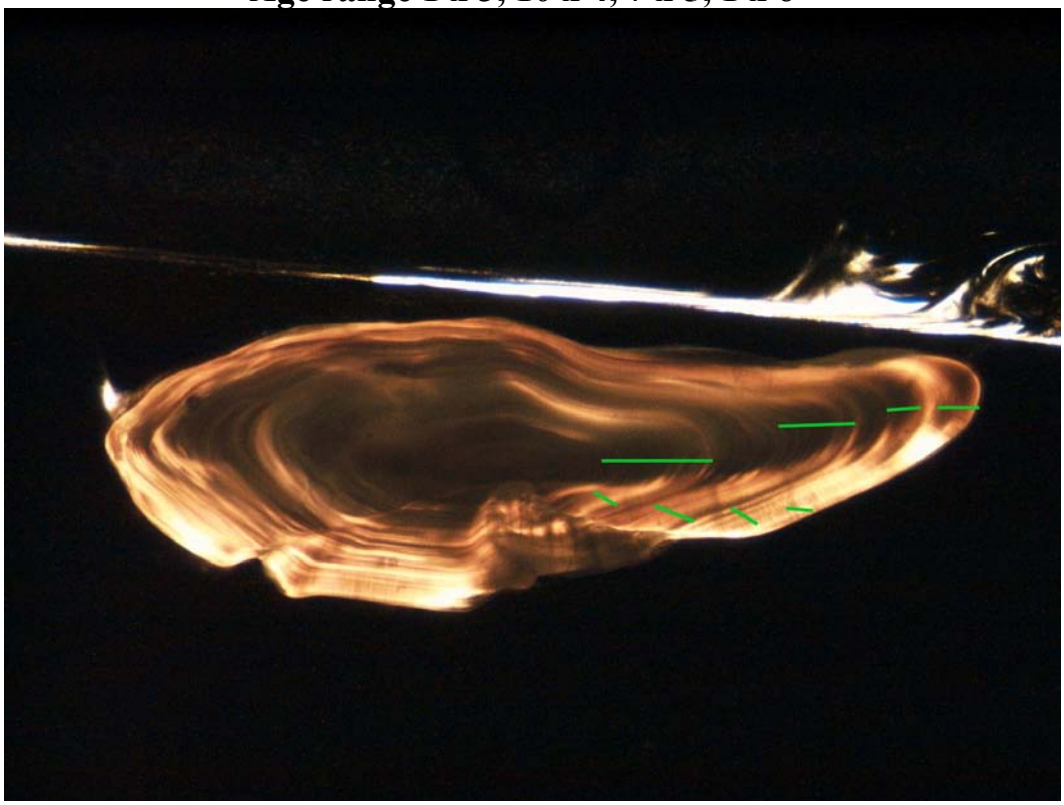


Fig 11

Fish No. 40 April 2004 104a - modal age 6 - 58% agreement
Age range 2 x 5, 11 x 6, 5 x 7, 1 x 8

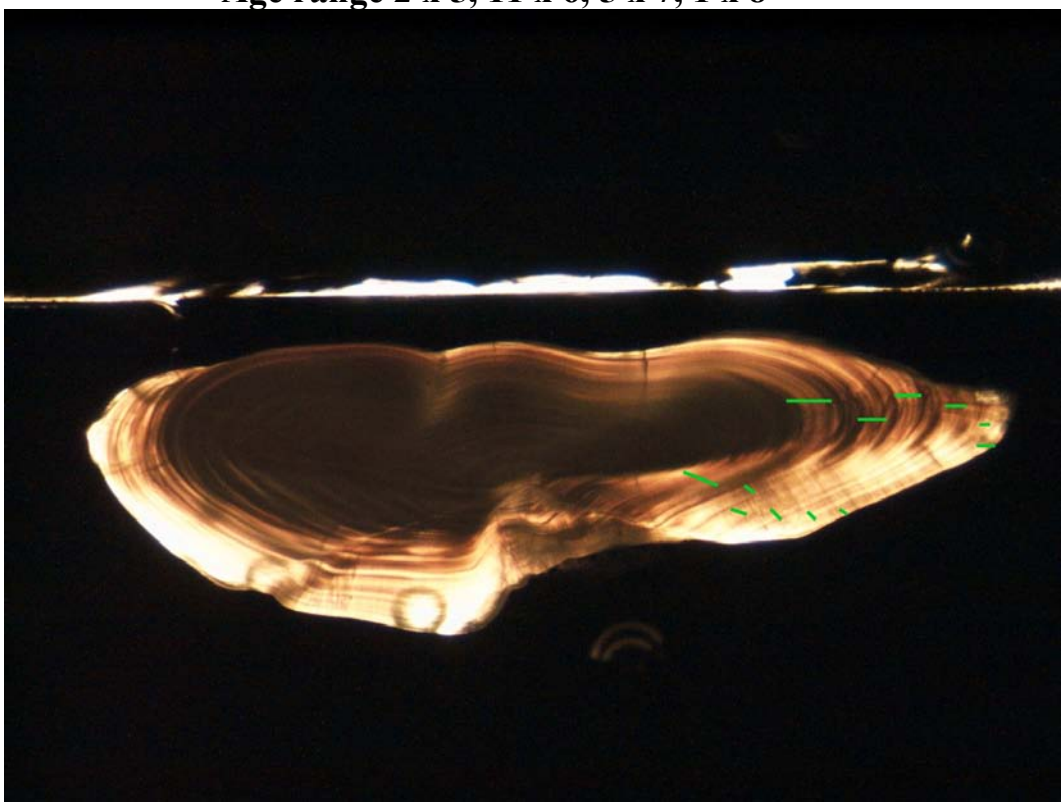


Fig 12

Fish No. 146 March 2004 106a Outer Hebrides - modal age 3
37% agreement - age range 1 x 2, 7 x 3, 7 x 4, 4 x 5
(Note that for this otolith there was a tie for the sectioned modal age)
N.B. The broken modal age was 4

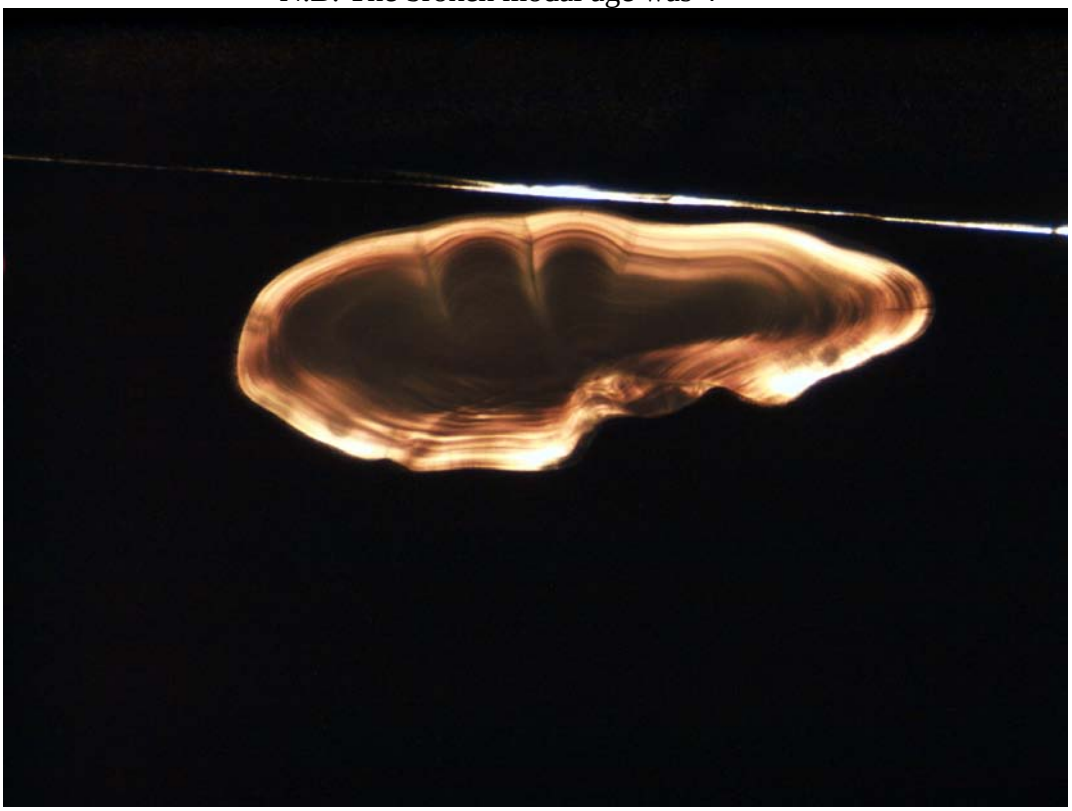


Fig 13

Fish No. 143 March 2004 106a Outer Hebrides - modal age 6
42% agreement - age range 2 x 5, 8 x 6, 6 x 7, 1 x 8, 1 x 9, 1 x 10

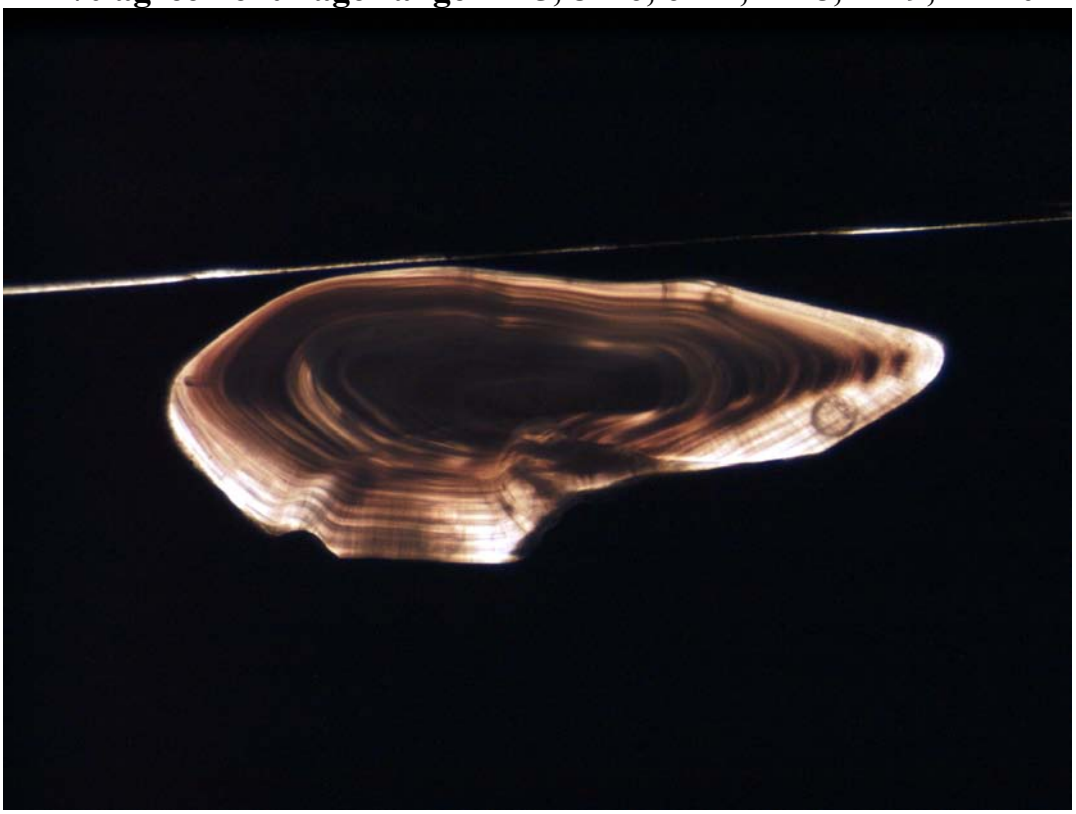


Fig 14

Fish No. 155 March 2004 106a Outer Hebrides - modal age 2
95% agreement - age range 18 x 2, 1 x 3

The translucent zone inside the first ring on this otolith was considered to be a split by most of the participants

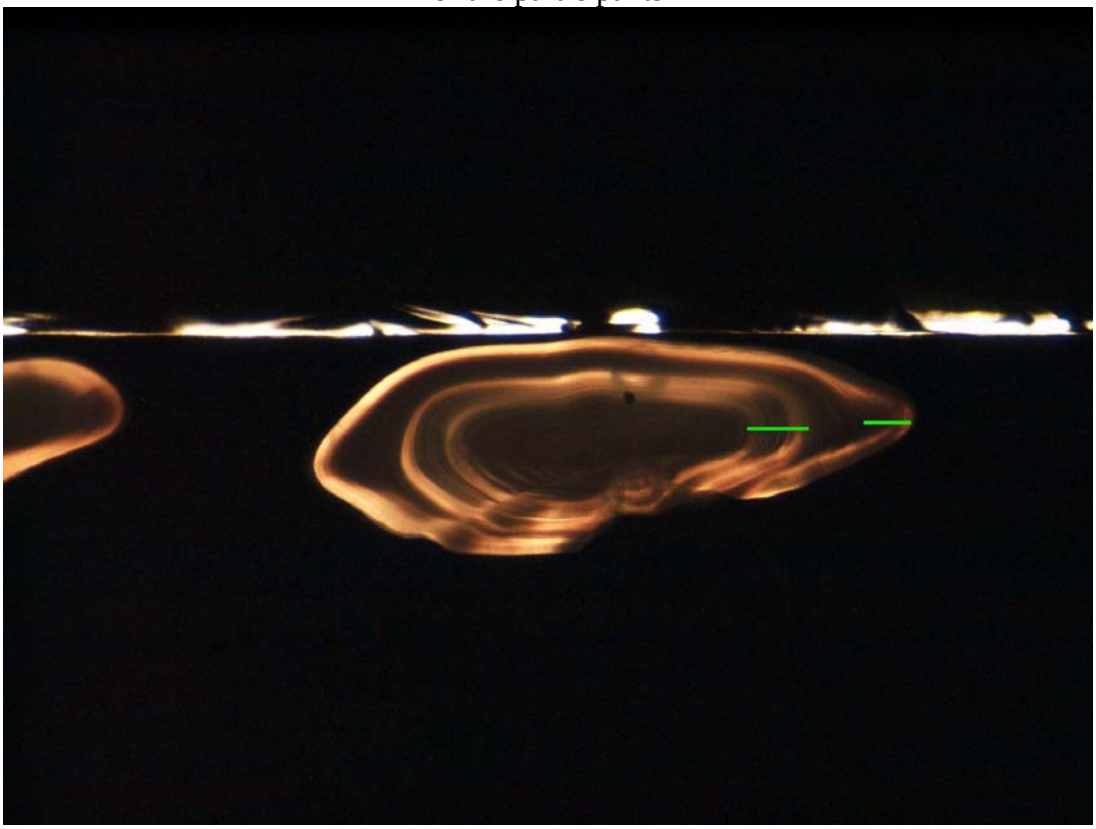


Fig 15

Fish No. 146 March 2004 106a Outer Hebrides

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 Willie McCurdy and, 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.

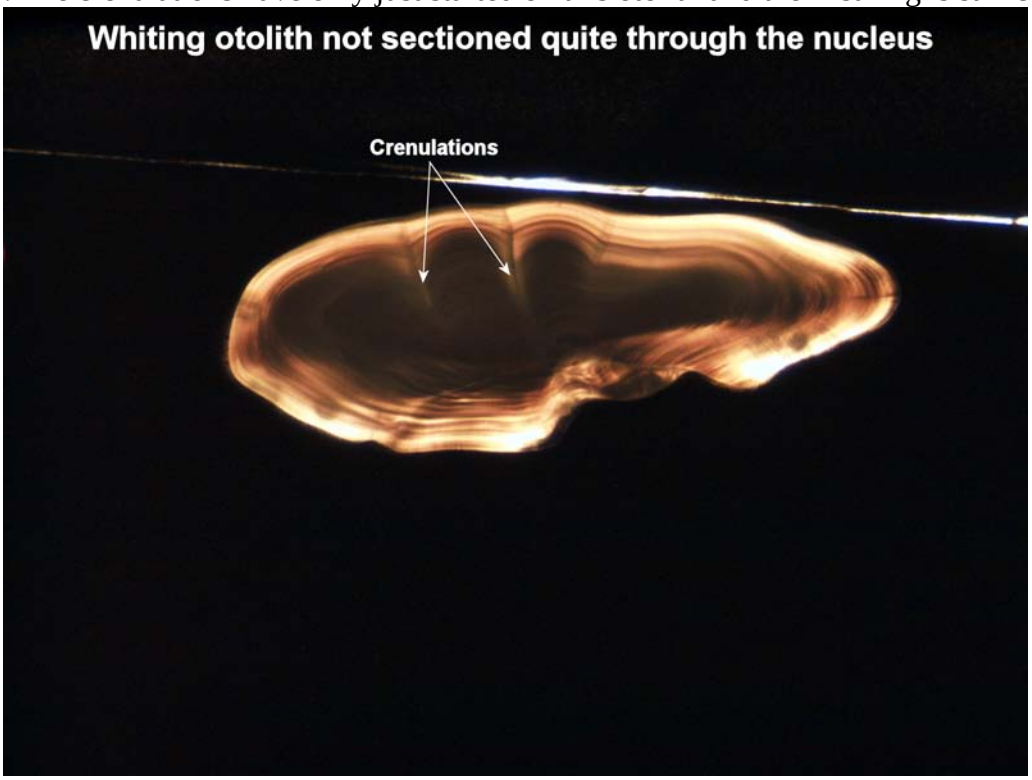
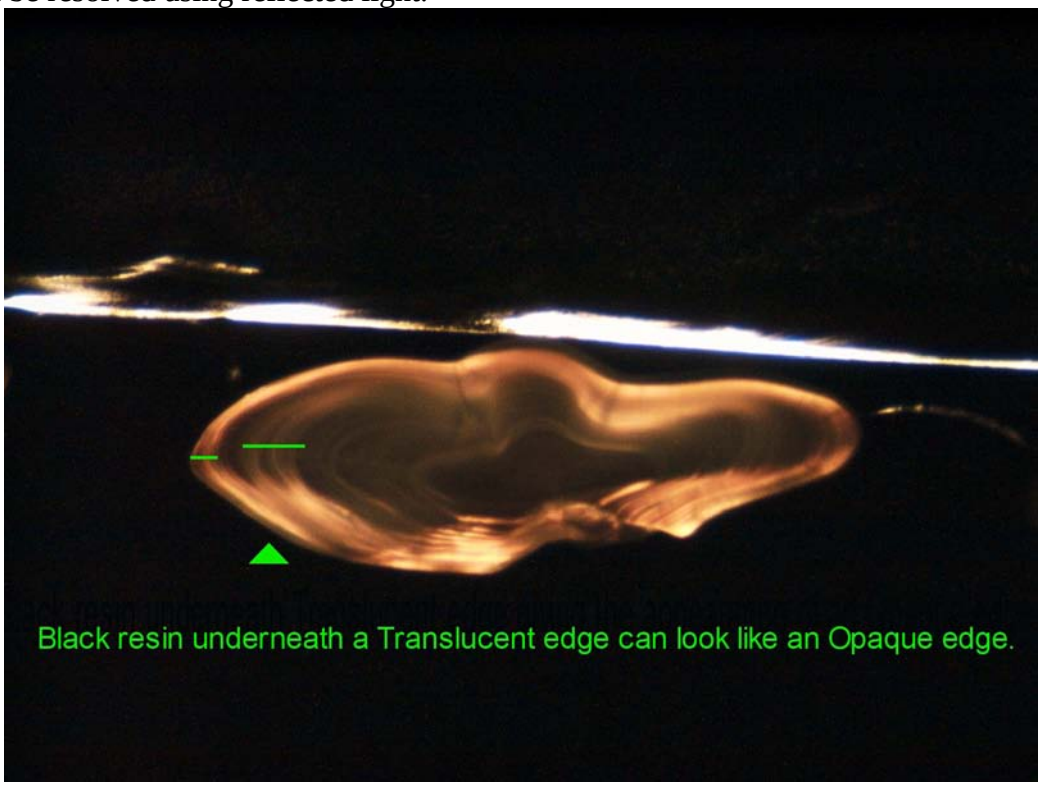


Fig 16

Fish no. 124 March 2004 106a Butt of Lewis

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.



Appendix 11

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 XX shows a 3-year-old whiting otolith with 3 complete translucent zones and Humphries shadows in each zone.

R.Belail
24/01/06

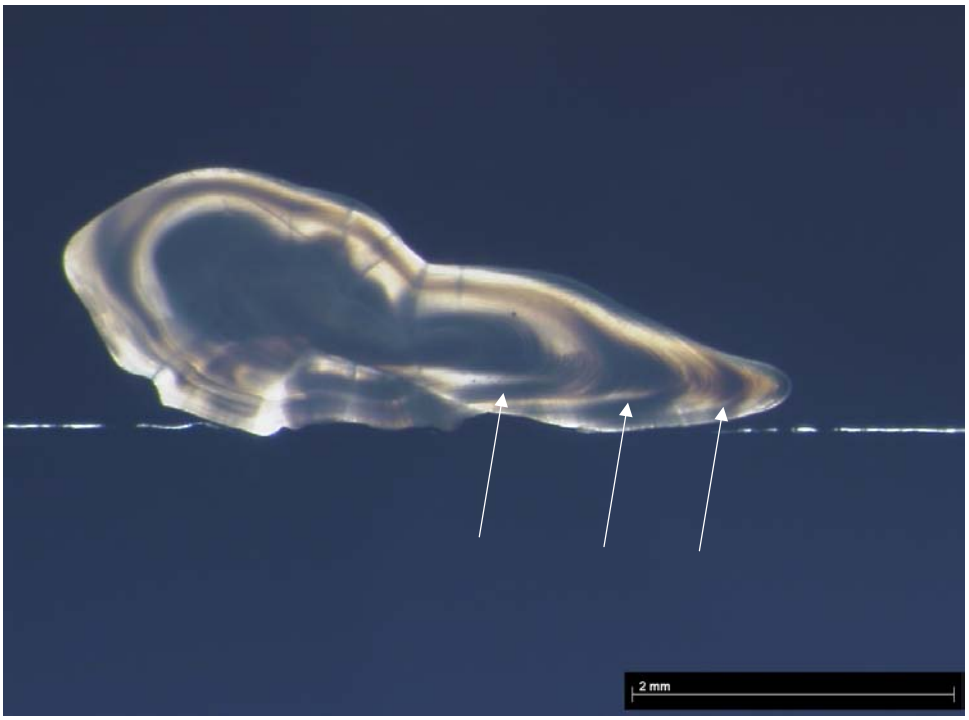


Figure XX. Section of a sagitta otolith from a 3-year-old 31 cm Celtic Sea whiting caught in March 2005 viewed by transmitted light showing the "Humphries Shadows" in the dorsal area (arrowed).
Note that the third translucent zone is not apparent in the ventral area
Image TNPC 4.1 in transmitted light

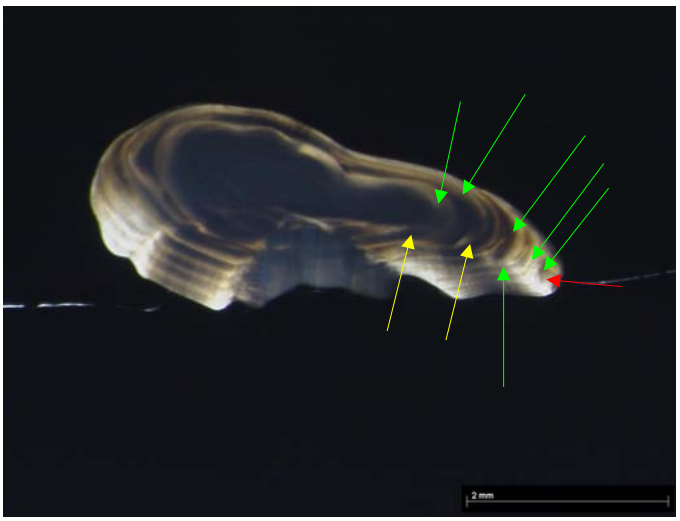


Figure XXX

Celtic sea whiting landed in July 2005
Fish length: 30 cm
6 annual transluscent increments (TI= green arrows)
Age group= 6
Humphries shadow clearly visible in TI 1 and 2 (HS= yellow arrows)
Narrow opaque increment at the dorsal edge (red arrow)

Diagnostic: age 6, edge NO

Figure XXX
Transverse section of left *sagitta* viewed with transmitted light and showing a compact morphology with a small extend of the dorsal area. Growth increments more deposited on the internal area of the otolith.

Otoliths showing this pattern of growth are more difficult to read. A growth model with a pattern of decreasing trend of the thickness of opaque increments from year to year cannot easily be applied. In this case, the increments in dorsal-internal and ventral-internal areas are also used for the diagnostic.
Image R Bellail/Ifremer/TNPC 4.1

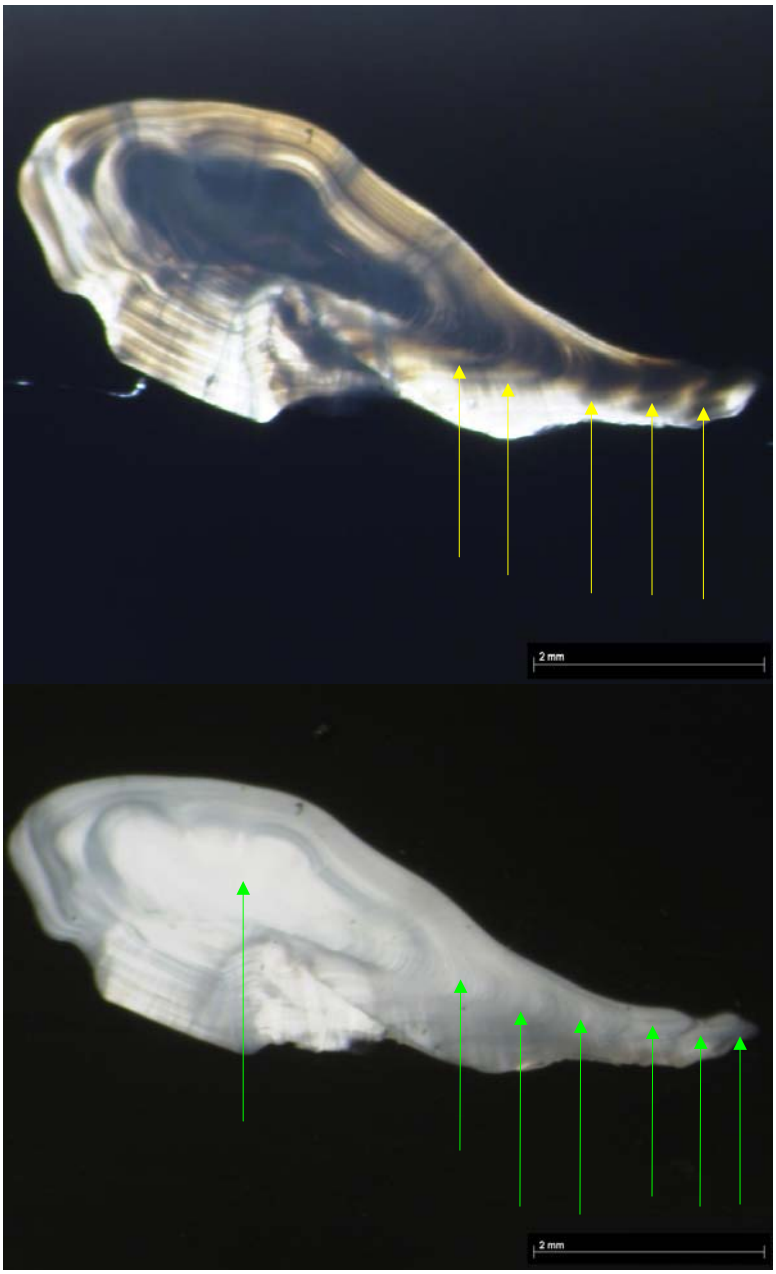


Figure XXXX

Celtic Sea whiting caught in June 2005
Lcm of the fish: 57 cm
Image with transmitted light

6 complete transluscent increments counted 1,2,3,4,5,6 give age group 6

Yellow arrows = Visible Humpries shadows in transluscent zones 2, 3, 4, 5, 6.

Same section viewed in reflected light showing a narrow opaque zone at the edge

Count: opaque zones 0,1,2,3,4,5,6= green arrows

REFERENCES:

ANON., 1987. Study of age determination of whiting from the Irish Sea and Celtic Sea. Report of a workshop at FRC Dublin, 11-14 May 1987. EC Contract XIV.B.1 n° 3858. 14p + Annex

ANON., 1998. Workshop on otoliths reading of North Sea whiting held at Hirtshals, 22-28 October 1998.

Occurrence of Humphries shadows in a sample of Celtic Sea whiting (VIIg) otoliths

landora LO 17/08/05

Lcm	Age group	n° of annual transluscent increment whereHumphries shadow is clearly visible 1	2	3	4	5	6	7
29	2		x					
30	2	x	x					
30	2		x					
32	2	x	x					
32	2	x	x					
32	2	x	x					
32	2		x					
33	2	x	x					
33	2	x	x					
32	2		x					
33	2	x	x					
34	2	x	x					
31	3		x					
32	3	x	x	x				
42	3		x					
32	3	x	x					
34	3		x					
32	3							
33	3	x	x	x				
34	3		x	x				
35	3		x					
35	3	x	x	x				
36	3		x					
39	4	x	x					
40	4	x	x	x	x			
41	4		x	x				
41	4	x	x					
42	4		x	x	x			
44	4		x					
44	4							
46	4		x					
45	4	x	x	x				
45	4	x	x					
46	4	x						
46	4		x	x				
36	4	x	x					
36	4		x	x	x			
38	4		x	x	x			
39	4	x	x	x				
61	4		x	x				

Lcm	Age group	n° of annual transluscent increment whereHumphries shadow is clearly visible 1	2	3	4	5	6	7
31	5	x	x					
39	5	x	x	x	x	x		
32	5	x	x					
41	5	x	x					
42	5	x	x					
42	5	x	x					
43	5		x	x	x	x		
33	5	x	x	x	x			
34	5		x					
43	5	x	x					
45	5	x						
50	5							
34	5	x	x					
43	5	x	x	x	x	x		
44	5	x	x					
46	5	x	x	x	x	x		
47	5	x	x	x				
47	5	x	x	x	x	x		
37	5	x	x	x	x			
48	5	x	x					
49	5	x	x					
40	5	x	x					
31	6	x	x					
40	6	x	x					
31	6	x	x	x				
41	6	x	x					
42	6	x	x					
43	6	x	x	x	x	x	x	
33	6	x	x					
33	6	x	x					
43	6	x	x					
44	6	x						
35	6	x	x					
36	6	x	x					
44	6	x						
45	6	x	x					
33	6	x	x					
42	6	x	x					
34	6		x					
35	6	x	x					
45	6	x	x					
35	6	x						
36	6	x	x	x	x			
46	6	x	x	x	x	x	x	
47	6	x	x					
37	6	x	x	x				
38	6	x	x	x				
49	6	x	x	x	x	x	x	
51	6	x	x					
38	6	x	x	x				
53	6	x	x	x				
55	6	x	x	x	x	x	x	
44	7		x					

Sections of otoliths of Celtic Sea whiting (VIIg) sampled in August 2005.
Occurrence of Humphries shadows in annual transluscent increments in sections. 94 otoliths read on 06/02/06 (R Bellail) and one was unreadable.

- 85 (91%) show a pattern in the 2nd year
- 63 otoliths (67%) show a pattern in the first two years.
- Only 20 otoliths (22%) show a pattern in **all** annual transluscent increments.
- 3 otoliths (3%) have not shown a pattern with Humphries shadows.

N.B. It must be remembered that this sample has been taken from several year classes.

Appendix 12

Whiting age estimation at DIFRES – whole otolith approach

Lotte Worsoe Clausen
Helle Rasmussen

Both sagitta are taken from each individual, and collected otoliths are kept in trays with one otolith pair per hole from a couple of days to several months until the age determination. Prior to the age estimation the otoliths are soaked in Millipore water for at least 24 hours.

The reading is done using a binocular (Leica MZ6) and reflected focused light ('cold light') pointed to the otolith from both the left and the right side in an angle of 45 degrees and with a distance to the glass container of 22 mm (left light source) and 40 mm (right light source). The magnification varies, however the most frequently used is 0.63X. Larger magnification is occasionally used when estimating older individuals to see the edge of the otolith. The reading direction of the translucent age structures varies depending on the age and difficulty of the otolith (figures 1 - 6).
If an otolith proves to be too difficult to read whole it is broken right in the centre and polished shortly to create a smooth surface. It is important to ensure the breakage to be right on the centre to facilitate the age reading. The otolith fixed with forceps and placed in a small glass container (20 mm high with a diameter of 44mm) filled with Millipore water to the point where the surface of the broken otolith is submerged in the water (fig. 2, 4 and 6).
Approximately 10 out of 100 otoliths need to be broken in order to make an accurate age estimation and this number varies with area and age distribution; the higher frequency of younger individuals the higher frequency of breaking and polishing. The placement and appearance of the first wintering is often somewhat diffuse in young individuals and is better displayed in broken otoliths.

Occasionally a dissection microscope with reflected light (Leica MZ12) connected with a camera (Leica DC 300F) to an image analysis system (Leica IM50 ™) is used to facilitate the discussion of individual otoliths on a computer screen and ultimately for measurements of various features, e.g. the distance from the centre to the first winter ring.

Age estimation is done without the knowledge of fish lengths though they are recorded in the database that contains all information on sampled fish. However, when the age-length distribution has been computed prior to the delivery of data to the Assessment Working Group in ICES, the ALK for the different areas and quarters (or months) are examined in order to pick out possible errors in either age estimation or length measurements.

The otolith macrostructure is different between the areas from which samples are obtained and as the accuracy and precision of the age determination relies on both a synchronously formation of one opaque and one translucent zone in all individuals and that this pattern is recognisable for all individuals in the population, the time and location of catch is considered vital information for the age estimation of whiting. This information is always included in the age estimation process.

North sea whiting otoliths caught in February 2006

Broken and whole otoliths from 3 fish viewed by reflected light

Figures 1 and 2
2 years old – ageing similar by either method

Figure 1. Broken otolith

Figure 2. Whole otolith

Figures 3 and 4
3 years old – this otolith is easier to age on the broken section

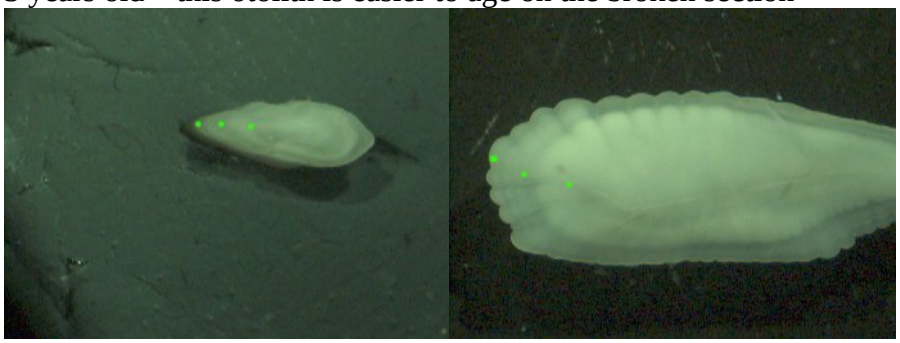


Figure 3. Broken otolith

Figure 4. Whole otolith

Figures 5 and 6
6 years old – this otolith is easier to age on the whole otolith. All 6 rings were visible in the live broken otolith though this is not clear in the captured picture.

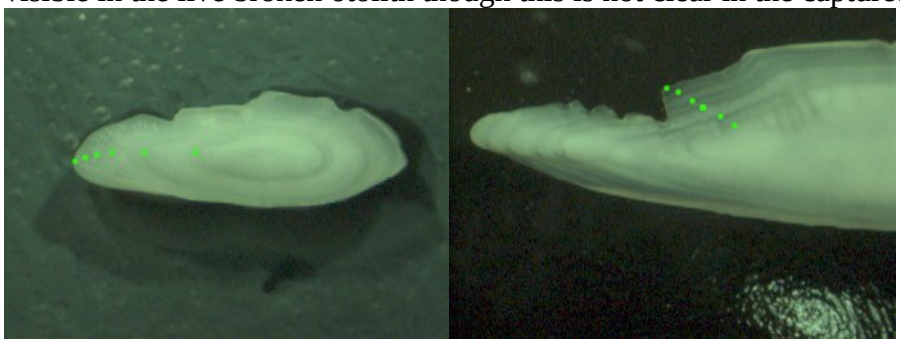


Figure 5. Broken otolith

Figure 6. Whole otolith

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