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Report of the Workshop on Age Reading of Saithe (*Pollachius virens*) (WKARPV)

26–29 May 2015

Boulogne-sur-Mer, France

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CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

The workshop on age reading of Saithe (*Pollachius virens*) (WKARPV) was held in Boulogne-sur-Mer, France, from 26 to 29 May 2015. The meeting was co-chaired by Kélig Mahé (France) and Jane A. Godiksen (Norway), and included eight age readers from four countries.

The objectives of this first workshop were to review, document and make recommendations on current methods of aging saithe (*Pollachius virens*).

This workshop was preceded by an otolith exchange in 2013, which was undertaken using WebGR. Participants who hadn't taken part in the exchange were asked to annotate the images in the months prior to the workshop, however, due to problems with accessing WebGR only a limited amount of the readers managed to do this in time. The otolith collection included 298 images from the North Sea and the Barents Sea. The overall agreement with modal age of the pre-workshop exercise was 85.9%, with a precision of 6.2% CV. The images were analysed and the differences discussed and guidelines were established from this discussion. To test the guidelines a set of 50 otoliths from the Barents Sea was read during the workshop. These were read both with reflected and transmitted light and had an agreement ranging between 79.2% and 82.3% with a precision ranging from 3.7% to 4.6% CV. There was clear bias between the individual readers using the two different light sources. Width measurement analysis of the 50 otoliths was carried out in plenary after agreeing on the ages of 48 of the 50 otoliths to determine the continuity of the position of the growth rings.

In general, the understanding of the annual rings was high between the readers, and there was little disagreement, however, since the otolith preparation is different among institutes, there was discussion especially about the perception of the edge. Readers used to reading broken otoliths found it difficult to read the edges of the image of the slides. Therefore, we recommend that both broken and slides are compared during the next saithe exchange along with images on WebGR.

1 Introduction

1.1 Term of reference

WKARPV – Workshop on the Age Reading of saithe.

The Workshop on Age Reading of Saithe (*Pollachius virens*) (WKARPV), chaired by Kélig Mahé, France, and Jane Godiksen, Norway, will be held in Boulogne-sur-Mer, France, 26–29 May 2015 to:

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

b) Analyse the results of the exchanges 2013 and 2008;

c) Analyse growth increment patterns and compile the guideline for the interpretation of saithe otoliths;

d) Create a reference collection of well-defined otoliths;

e) Address the generic ToRs adopted for workshops on age calibration.

WKARPV will report by 15 of June 2015 for the attention of SSGIEOM, WGBIOP, WGNSSK, NWWG, AFWG, SCICOM and ACOM.

1.2 Participants

Name	Country	Expertise	Assessment	2008 exchange	2013 exchange
Kélig Mahé (chair)	France	Coordinator			
Jane Godiksen (chair)	Norway	Coordinator			
Karine Sevin	France	Expert	X		X
Lisbet Solbakken	Norway	Expert	X		X
Mandy Gault	Scotland	Expert	X	X	
Peter Clark	Scotland	Expert	X		
James Dooley	Scotland	Trainee			
Susanne Hansen	Denmark	Trainee			
Romain Elleboode	France	Expert		X	
Clémence Oudard	France	Trainee			

WKARPV-participants at the entrance of Ifremer in Boulogne-sur-Mer. From left to right: Clémence Oudard, James Dooley, Lisbet Solbakken, Susanne Hansen, Romain Elleboode, Jane Godiksen, Kélig Mahé, Mandy Gault, Karine Sevin, and Peter Clark.

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

2.1 Otolith exchanges

Only two exchanges have been executed to date (Table 2.1.1).

Table 2.1.1. Past saithe otolith exchanges.

Year start	Year end	Exchange / workshop	Otolith prep.	Agreement	Issues	Reference
2013	2013	Exchange	Slides WebGR	85.9%	Closed edge of age >8	Report of the Saithe (*Pollachius virens*, L.) Otolith Exchange 2013 Mahé *et al.*, 2014
2007	2008	Exchange	Slides WebGR	95% IVa 82.8% VIa	Position of ring	Report of the Saithe (*Pollachius virens*, L.) Otolith Exchange Scheme 2007–2008 Mahé, 2009

2.2 Workshops

This is the first workshop arranged on saithe by ICES.

2.3 Validation

Little has been done to validate age reading of *Pollachius virens*. Only two studies have tried to validate the age, and none of these has the true age of the fish as a reference.

2.3.1 Neilson *et al.* (2003)

Neilson *et al.* (2003) studied the age and growth of Canadian east coast saithe. Saithe were marked and released at relatively young ages in Canadian waters during 1979–1984. Some of the recaptured tagged fish were returned with the corresponding otoliths for each individual, and age determinations were completed. Thus, it was possible to make individual comparisons of otolith-derived ages and assumed ages. The comparisons revealed a tendency of otolith readers to overestimate the ages by one year.

Using fish assumed to be age 1 upon release (based on previous studies of growth during the larval and juvenile phases of saithe life history), they compared the increments of growth observed between fish released and recaptured in the eastern and western portions of the management unit.

Comparisons of mean lengths-at-age (age determined from otolith examination) and the lengths at the assumed age (age at release, plus years at liberty) of recaptured fish indicated no significant differences. Though these findings indicate a potential bias in age determination during the 1980s, results from stock assessments indicate that strong and weak cohorts were tracked well during that period.

Validation of the method of age determination by otolith reading is important to make sure we are giving the correct ages to fish to an age based assessment.

2.3.2 Mahé *et al.* (2013)

There are several different methods (direct and indirect) to validate fish age. The marginal increment analysis (Figure 2.3.2.1) is an indirect method used to validate the periodicity of growth rings. For this species, a French study (Mahé *et al.*, 2013) was carried out from 2011 and 2012 on the West of Scotland (ICES area: VIa). 1166 otoliths were analysed by the TNPC software (www.tnpc.fr; Mahé *et al.*, 2011).

The marginal increment (MI) is calculated using the formula:

$$MI = (Ro-r_n)/(r_n-r_{n-1}))$$

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

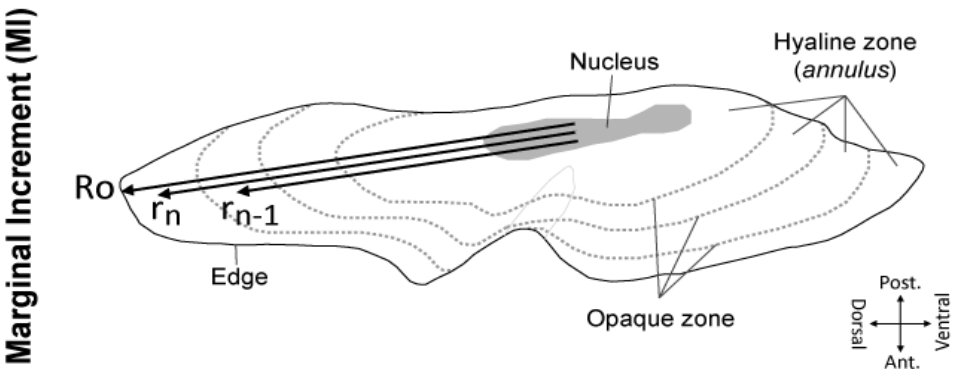

Figure 2.3.2.1. Marginal increment analysis.

From the otolith section, alternating translucent and opaque bands were clearly visible. The distance between growth rings decreased from the otolith core towards the outer margin. One growth increment consisted of one opaque and one translucent band, from which the opaque area was considered to have been deposited between June and November (Figure 2.3.2.2). The validity of the age determination based on counting opaque bands on otoliths section of saithe was confirmed by the age estimation method analysing marginal increment formation.

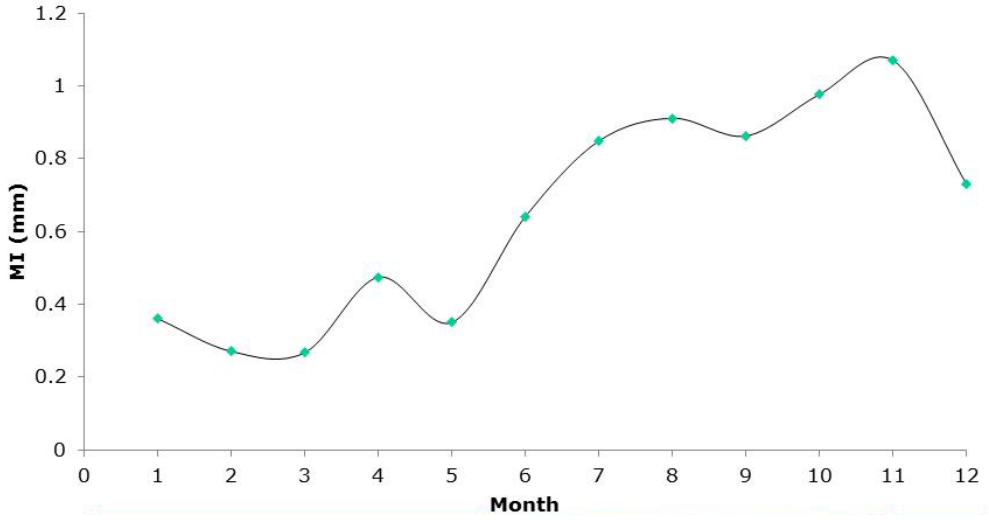

Figure 2.3.2.2. Monthly Marginal Increment Analysis.

3 Review of techniques

During this meeting, the data compiled by the WKNARC 1 meeting (ICES, 2011) were extracted. All institutes used the otolith as calcified piece for ageing the saithe. However, the choice of preparation method differs between sampling areas and laboratories within the same ecoregion (Table 3.1).

Table 3.1. Preparation methods of saithe otolith by Area.

		Preparation method of otolith		
Area	ICES division	break	section	whole or break and polish
Barents Sea	27.2a2	1		
Norwegian Sea	27.2a		1	
Celtic sea	27.6,7	1	1	
	27.7		1	
Greenland and Iceland Seas	27.14b2		1	
	27.5		1	
North Sea	27. 3a,4	1		
	27.3a	1		
	27.3a,4ab			1
	27.4	1	3	
West Greenland	21.1		1	
Total		5	9	1

Nine countries study the age of saithe (Table 3.2) using two different preparation methods. Three countries (Norway, Sweden, and UK-Scotland) read the otolith broken, while five countries (France, Germany, Iceland, Ireland, and UK-England and Wales) section the otoliths before reading. Denmark either breaks and polishes the otolith before reading or read them whole.

Table 3.2. Preparation methods of saithe otolith by country.

	Preparation method of otolith		
Countries	break	section	whole or break and polish
Denmark			X
France		X	
Germany		X	
Iceland		X	
Ireland		X	
Norway	X		
Sweden	X		
UK (England and Wales)		X	
UK (Scotland)	X		

4 Analyse the results of the exchanges 2008 and 2013

To date only two exchanges of saithe otoliths has been accomplished. The first exchange in 2008 consisted of both otolith sections and images, while the exchange in 2013 only consisted of images.

4.1 Exchange 2007/2008

The exchange collection consisted of slides of transverse sections of 291 otoliths (154 from ICES area IVa and 137 from ICES area VIa), and a CD with images of the otoliths for annotation. Images of the otoliths were taken using both transmitted light and reflected light, and all participants could annotate the positions of the growth rings on the images.

Agreements between age-readers were calculated using the Guus Elting spreadsheet (Eltink, 2000).

20 readers participated in reading the otoliths from ICES area IVa. Their percentage agreement ranged from 60% to 100% with an average percentage of 95.9%. 19 of the 20 readers present a percentage of agreement higher than 90%, and 73 otoliths out of 154 were read with 100% agreement (47.4%). It should be noted that all readers read all the otoliths. The precision CV ranged from 0% (corresponding to 100% agreement in readings) to 21% with an average of 3.3%. The otoliths read were never older than 8 years old and the majority of these fish were read as 4 years of age. There were very few differences between the readings. However, those seen were on the position of the first ring.

18 readers participated in reading otoliths from ICES area VIa. The percentage agreement ranged from 28% to 100% with the average agreement of 82.8%. Out of 137 otoliths 29 otoliths were read with 100% agreement (21.2%). The otoliths ranged in age from 3–15. The highest percentage agreement of 95% was with fish aged 3 and 4 years. The precision CV ranged from 0% to 22% with an average of 5.4%.

It was reported that Saithe is a relatively easy species to read and that exchanges must continue to ensure quality of new readers every three years.

It was also mentioned that it would be interesting to compare the two methods of preparation both slide sectioning and breaking.

It was also necessary to present a direct or indirect validation of the formation of first annual growth ring.

4.2 Exchange 2013

13 readers from five countries (France, Germany, Iceland, Sweden, and Norway) participated.

The studied collection consisted of images of 295 otoliths from the Barents Sea (ICES area IIa; n = 24), North Sea (IV, n = 34) and West of Scotland (IVa, n = 237). Fish length ranged between 37 and 96 cm, with mean 60 cm.

Date of birth is set to the 1 January as convention. One annulus consists of one opaque and one translucent zone. For the age estimation, translucent zones were counted. One image of each otolith was uploaded to WebGR (http://webgr.azti.es/ce/search/myce), where the readers were to annotate. The images were taken in either transmitted light or reflected light.

The WebGR tool was used to this exchange. The use of WebGR tool for the exchange has some advantages: (i) it can facilitate and accelerate the whole exchange process, (ii) annotated images are obtained for every otolith which allows to compare age readings directly and to identify possible sources of bias (iii) it is very easy for the chairman to compile the results. However, the use of WebGR tool for the exchange present some limits: (i) the WebGR tool is not very intuitive tool (ii) the WebGR could be jammed (as during the half of the 2013 year) (iii) it is not always possible to upload a large batch of images (problem with the format of the csv file with Windows 7).

Agreements between age-readers were calculated using the Guus Eltink spreadsheet (Eltink, 2000).

Mean precision of age estimation for individual fish were a CV of 6.2% and the percent agreement to modal age of 85.9%. 54 of 298 otoliths were read with 100% agreement (18%). There were variations in precision of the age estimation between individual fish, with CV ranging from 0 to 27% and percent agreement ranging from 40% to 100%.

It was reported that the precision of Age estimation from the North Sea was not as good as than those from the others areas. However, the size and age of fish from the North Sea were bigger than those from the others areas. The differences are primarily explained by the position and the number of rings after the eighth and close the edge.

5 Age reading exercise

Going through the exercise from 2013 it was clear that the main issues in reading saithe were not false zones or determination of the inner zone. The only real problem was the edge of older individuals read in a way the reader was not used to. For readers usually reading broken otoliths, reading images of slides was a bit difficult, while readers used to reading from slides had fewer problems reading the edge of the otoliths from images.

We tried to make a comparison of 50 otoliths photographed with both transmitted and reflected light to see if this would help on the edge perception. The exercise included otoliths from ICES areas I and IIa. Data on fish length and capture date was available to the readers during the reading.

Also, ten otoliths from ICES area VIa were prepared to be read as broken otoliths, and slides with different light sources. However, this was only meant as a small test to see if one reader who normally reads broken otoliths would recognize the same issues when reading both preparations. The purpose was that this would give us an opportunity to consider the need for sending the actual otoliths around to the different reading institutes for next exchange.

5.1 Results

5.1.1 Exercise of reflected vs. transmitted light of 50 new otoliths

50 otoliths from the Barents Sea were photographed with both reflected and transmitted light.

5.1.1.1 Reflected light

The results from the reflected light age calibration exercise had an overall agreement of 79.2% (ranging between 25 and 100%) with a precision of 4.6% CV (ranging from 0 to 17%). Of the 50 otoliths 29 (58%) were read with at least 80% agreement (See Annex 1 for figures), and 22 were read with 100% agreement.

For age readers combined, the relative bias was found to be minimal (-0.04), and for individual age-readers the relative bias varied from -0.2 to +0.12. In general there was a tendency of underestimation of ages, especially for fish older than six years old. The underageing signifies systematic miss-interpretation of growth structures within the otolith, and the discussions during the workshop revealed that the problem was the unclear edge due to the cutting and photographing of the otolith. Wilcoxon inter-reader bias test is presented in Annex 1, and shows the individual observed bias among age-readers.

The inter-reader bias test showed high agreement between readers and also with modal age. The four readers reading for assessment had almost no signs of bias between them (Annex 1).

Percentage of agreement with modal age was highest during winter (82.2–91.3%) and lowest in April (65.3%), however, this was due the fact that the specimens were all ages older than 6 years.

5.1.1.2 Transmitted light

The results from the transmitted light age calibration exercise had an overall agreement of 82.3% (ranging between 25 and 100%) with a precision of 3.7% CV (ranging from 0 to 15%). Of the 50 otoliths 33 (66%) were read with at least 80% agreement (See Annex 2), and 23 were read with 100% agreement.

For age readers combined, the relative bias was found to be minimal (-0.08), and for individual age-readers the relative bias varied from -0.18 to +0.04. In general there was a tendency of underestimation of ages, especially for fish older than six years old. The underageing signifies systematic miss-interpretation of growth structures within the otolith, and as mentioned for the reflected light analysis the problem was due to confusion of the edge due to the cutting and photographing of the otolith. Wilcoxon inter-reader bias test is presented in Annex 2, and shows the individual observed bias among age-readers.

The inter-reader bias test showed relatively high agreement between readers and also with modal age. However, the four readers reading for assessment had possibilities of bias between them (Annex 2). Reader one is the only assessment reader used to reading slides, and the three others mentioned that for them the edges particularly difficult using this method.

Percentage of agreement with modal age was again lowest during April (63.9%), while the other months had an agreement between 80.4 and 93.8%. This was due to the fact that the specimens were all in the ages older than 6 in April, while younger age classes were represented in the other months.

5.1.1.3 Individual results

To compare the two methods for each individual reader, we used the ATAQCS sheet made by Cefas (Mark Etherton).

The results indicate that most of the readers had a rather low agreement between the two methods of interpretation. The average agreement was 78% (range between 66% and 98%).

5.1.2 Agreed age vs. modal age

We went through all 50 images in plenary and came to an agreement on age for 49 of the images. These ages are considered "correct" ages, and were compared to the modal age (which is based on the four assessment readers) for both reflected and transmitted light.

The results of the reflected light showed a percentage agreement of 75.5%. There was no bias towards either over- or underestimation of ages, and no more than one year off the agreed age (Figure 5.1.2.1A).

The results of the transmitted light had a percentage agreement of 79.6%. There was a tendency of bias towards overestimation of the ages compared to the agreed ages. In general overestimation was by one year except in one occasion where it was a two year difference (Figure 5.1.2.1B).

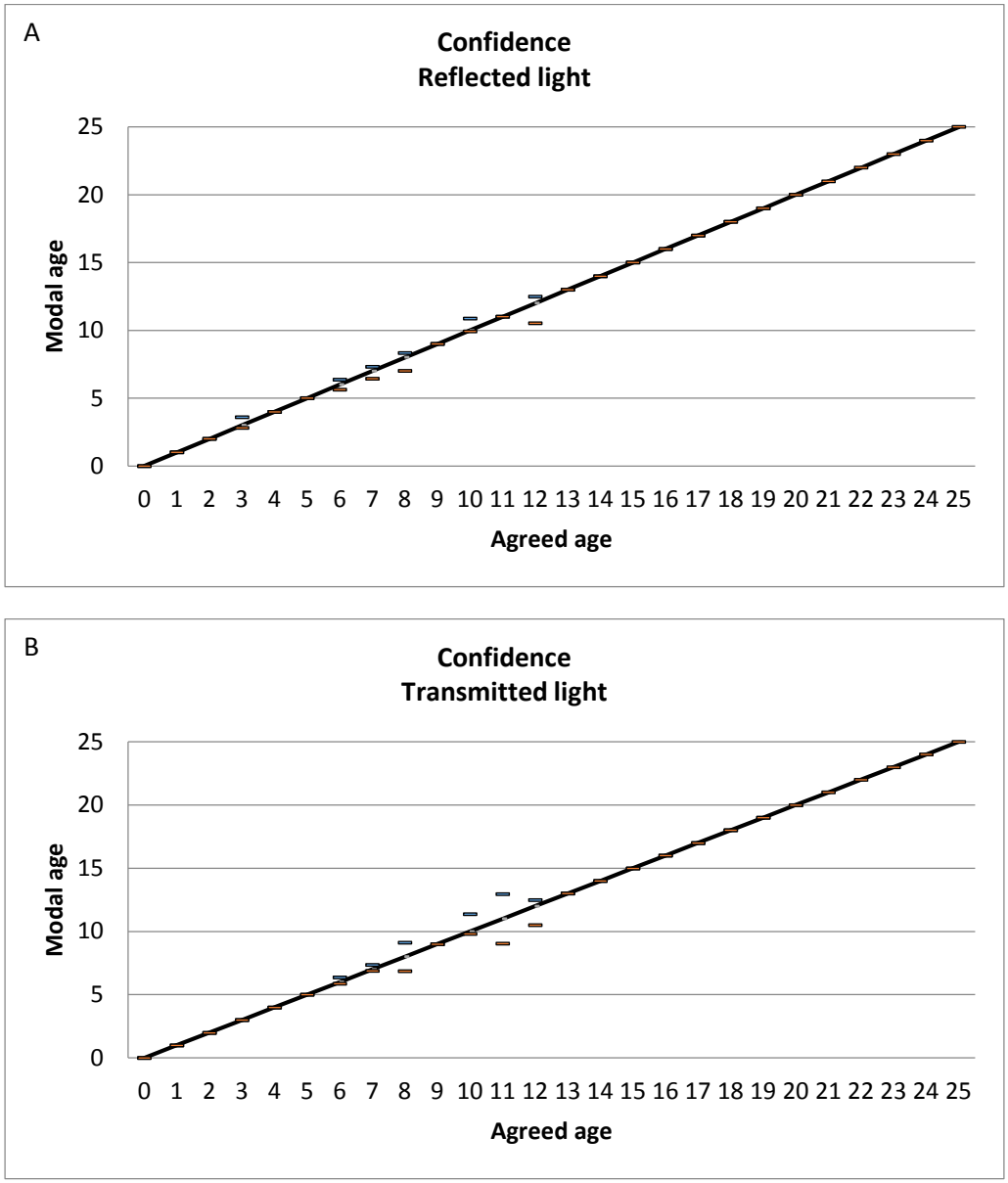

Figure 5.1.2.1. Agreed age vs. modal age of reflected (A) and transmitted (B) light source.

5.1.3 Broken vs. sectioned

Because of the problems with the edge of the images taken from the slides among the readers normally reading broken otoliths, we included a small set of 10 otoliths (age 4 to 6) from West of Scotland (ICES area VIa) of both broken and sectioned otoliths (Figure 4). It was thought that this would give an impression of the difference between the interpretation of broken otoliths and slides.

For each fish, one otolith was broken and the second otolith was sectioned (thickness 0.4 mm) to compare the difference between two different preparation techniques. Only one reader was to observe the three techniques and images were obtained from each technique:

- Broken otolith;
- Section by transmitted light;
- Section by reflected light.

The first results showed no difference in perception, but it will very important to compare the three methods with the large sets covering several sampling areas and older age classes.

Figure 4. The different techniques for age reading of saithe.

The complete set of images can be seen in Annex 3.

5.2 Discussion and conclusions

The two different light sources were tested using 50 otoliths because several participants explained that, during the analysis of the 2013 exchange, it was confusing to read in a light that showed the colours differently from what they usually read. We hoped this exercise would give an indication of this. Because the preparation methods were different from what many readers normally read, there should not be too much emphasis put on to the percentage agreement of this exercise.

The overall percent agreements were quite similar in the two light source tests (reflected light 79.2%; transmitted light 82.3%). People who are used to read broken otoliths usually use a light source from the side and they shade the otolith so the dark and light zones will be similar to what is seen using transmitted light. The slightly higher percent agreement could possibly be explained by this light source being more similar to what the "broken" readers are used to see. The inter-reader bias test showed that the three expert readers, who normally read broken otoliths (Readers 2, 3, and 4), had no signs of bias between them when reading the transmitted light, but they all had possibility of bias with Reader 1, who usually read slides, but normally use reflected light.

All readers were individually compared to themselves (transmitted vs. reflected) using the ATAQCS-sheet. The average personal agreement was 78%, proving a possible intra-reader bias from the source of light for the reader. Several readers mentioned that they could see from the capture date that the fish should have an edge that needed to be counted, but since they couldn't see it on the image they wouldn't do it. Therefore they knew some of the ageings were wrong, but for the test they would only read what they actually saw on the image.

The 50 otoliths were annotated in plenary to have an "agreed age". 49 of the otoliths came out of this with an agreed age, while one had a disagreement between readers. The ages of the 49 was compared to the modal age of the reflected/transmitted test. The percent of agreement depending on the light source was 75.5% and 79.6%. There were little signs of tendencies towards under- or overestimation of ages, and this

might be due to either of the light sources always being the wrong way of reading for some readers.

At the end of this meeting, a last exercise included 10 pairs of otoliths (right and left of the same fish) was carried out to observe if the preparation techniques of otoliths (broken *vs.* slides) could be a source of bias. The first results do not appear to show the difference between readings from the preparation techniques of otoliths. However, it was a single test, using only young individuals, and a larger set of otoliths must be completed in future to conclude on this question.

The results obtained during this workshop showed that light and preparation of the otolith is very important when arranging a calibration exercise. Furthermore, the quality of the images is very important. In this exercise several images had too dark a core and too vague an edge. This indicates that for future exchanges, structures as well as images should be available using the preparation methods used by the participating readers. Readers should be compared using only the method and light that they are used to. This will give a useful comparison of readings done by the different institutes.

Few of the institutes participating in the workshop are collecting more than one otolith from saithe. In order to arrange next exchange with both slides and broken otoliths, it is important to have a collection consisting of both otoliths. Therefore all institutes participating agreed on collecting both otoliths from 50 fish from their areas and sending them, as well as a data sheet with fish data, to Norway for preparation and safekeeping. All age classes should be represented from each area. This will provide an excellent collection for an exchange, where each institute will be able to read the otolith in the way they normally do, and thereby the results would be much more comparable.

6 Analyse growth increment patterns and compile the guideline for the interpretation of saithe otoliths (ToR c)

6.1 Measurements of the 50 Norwegian otoliths

The exercise was done using the TNPC software (www.tnpc.fr) developed by Ifremer institute. Each *annulus* was manually identified and the distance to the *nucleus* was automatically measured on the determined reading axis. It was decided that the analysis would be based on slides provided by IMR, Norway, during this workshop, which the ages were agreed on in plenary by all readers. The set of measurements was, therefore, composed of 48 calibrated images from the Barents Sea (Figure 6.1.1; Table 6.1.1).

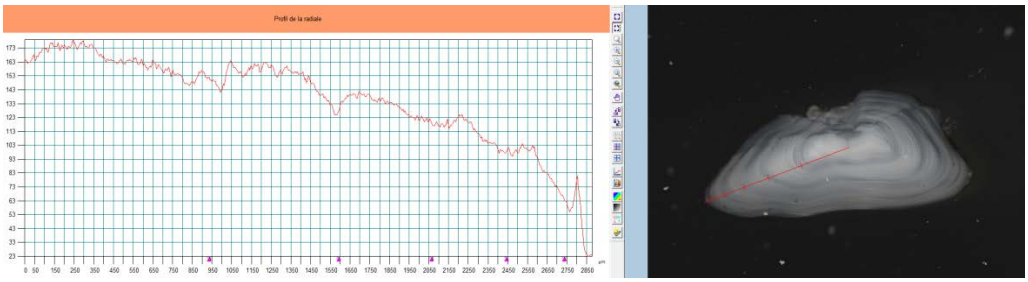

Figure 6.1.1. The measurements realized on the calibrated images of saithe otoliths from TNPC software.

Each zone was measured from the centre to the middle of the translucent zone. The measurements of the otoliths showed how the width of the growth ring decreases with age. The first two growth rings could be clearly identified by the distance from the nucleus (the core). In this exercise the first growth ring in all images was less than 2 mm, and the growth rings 1 and 2 were less than 3 mm combined (Table 6.1.2 and Figure 6.1.2). There was a similar trend found looking at the individual growth curves. The relationship between the age and the otolith *radius* was significant (Figure 6.1.3, $P<0.001$).

This image analysis could be helpful in identifying the growth rings of otoliths, particularly for the earlier ages zones, before the zones become too narrow.

Table 6.1.1. Statistical data of the age and otolith *radius* of saithe in the Barents Sea set (N=48).

	Age (year)	Otolith Radius (mm)
Minimum	2	0.31
Maximum	16	0.618
Mean	6.458	0.461
S.D	3.108	0.071

Table 6.1.2. Measurements (mm) achieved on the saithe otoliths from the Barents Sea (N=48).

Age (year)	Number	Max	Min	Mean	S.D
1	48	0.24	0.08	0.16	0.03
2	48	0.30	0.12	0.24	0.03
3	45	0.37	0.15	0.30	0.04
4	40	0.43	0.18	0.35	0.04
5	35	0.44	0.20	0.39	0.04
6	30	0.49	0.22	0.42	0.05
7	22	0.50	0.23	0.44	0.05
8	14	0.51	0.42	0.47	0.03
9	11	0.54	0.44	0.49	0.03
10	10	0.56	0.46	0.51	0.03
11	5	0.57	0.47	0.53	0.04
12	3	0.58	0.55	0.56	0.02
13	1	0.57	0.57	0.57	
14	1	0.58	0.58	0.58	
15	1	0.59	0.59	0.59	
16	1	0.61	0.61	0.61	

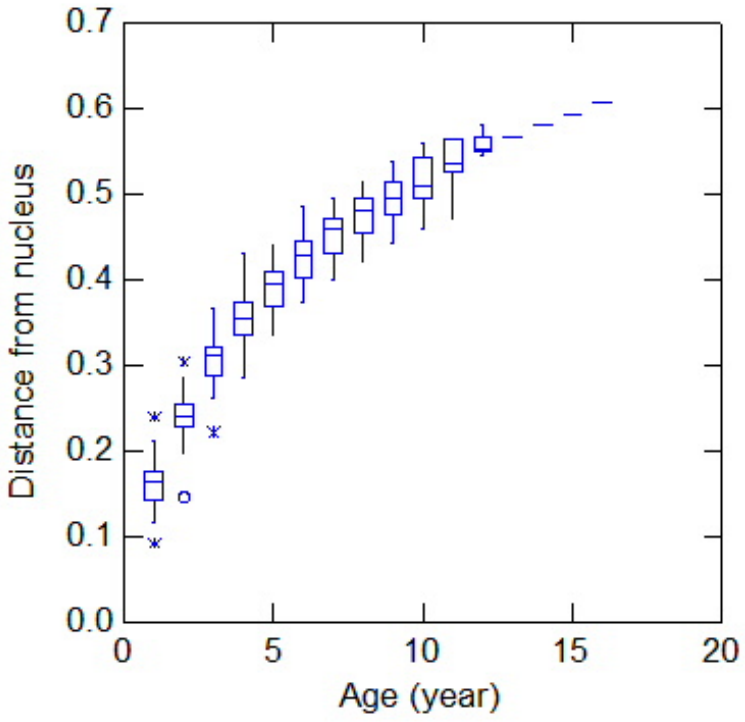

Figure 6.1.2. Box-plot of all rings identified as growth ring on 48 saithe otoliths from the Barents Sea.

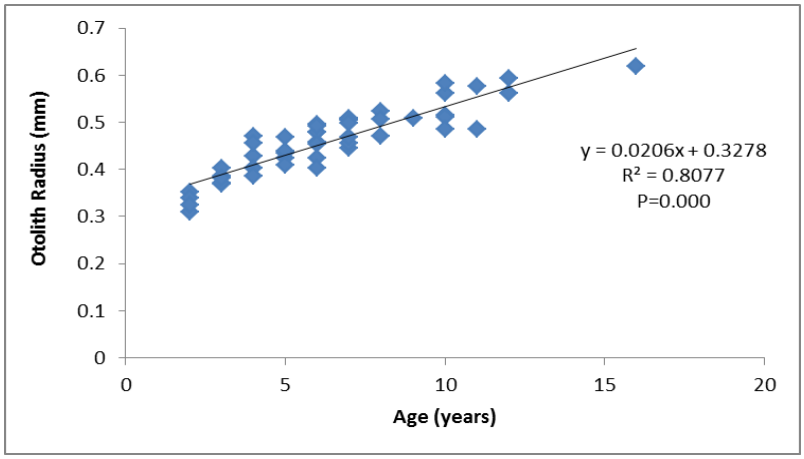

Figure 6.1.3. Relationship between age and the otolith radius on 48 saithe otoliths from the Barents Sea (P<0.001).

6.2 Guidelines for age interpretation

The following (Figure 6.2.1) is a schematic interpretation of the growth development of saithe from its birthday on 1 January following it through to age four on the following 1 January. The translucent zones are used to determine the age, and towards the end of the year the translucent zone is developing, but should not be counted as a fully developed ring until the 1 January.

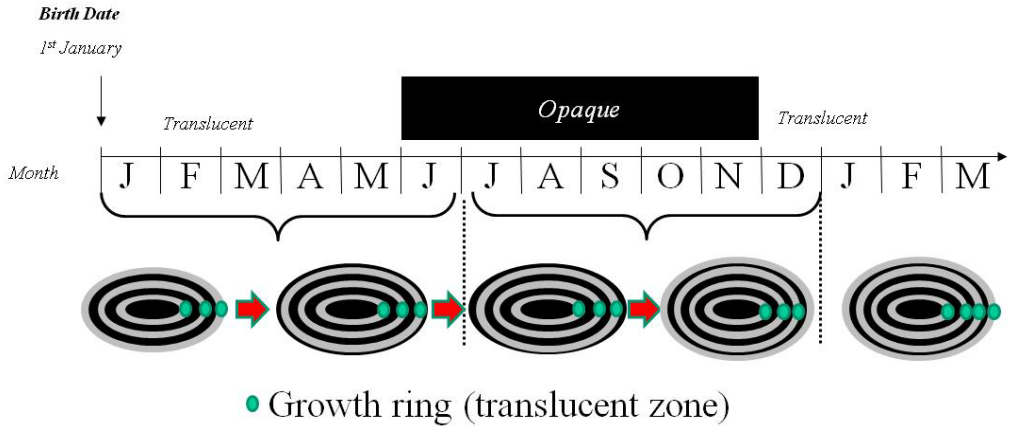

Figure 6.2.1. Schematic interpretation of the growth development of the annual zones over the course of a year. The arrows indicate the development of growth rings (translucent and opaque zones) during the year.

Important Guidelines to follow when interpreting the age:

- Information about area, date of catch, length, is required to allow the reader to make an educated interpretation of the otolith.
- Follow the preferred axis of reading (Figure 6.2.2).
- Be careful with the magnification when reading by stereomicroscope, as a high magnification can cause confusion, especially among older fish (10 years and above).
- June and July are problematic months due to the interpretation of the edge. This can be caused by different growth rates in various areas.

Figure 6.2.2. It is necessary to use the same axis of the saithe image, especially when measuring the width of the zones as well.

7 Create a reference collection of well-defined otoliths (ToR d)

22 sectioned saithe otoliths from the Barents Sea were selected for the reference collection. All otoliths for the reference collection were chosen to include two otoliths per age group and covered an age span from 2 to 12 years old otoliths.

The annotated otoliths and fish information can be found in Annex 4 and is uploaded as a word document to the Age Readers Forum.

8 List of participants

Name	Country	e-mail
Kélig Mahé (chair)	France	Kelig.mahe@ifremer.fr
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Clémence Oudard	France	Clemence.oudard@ifremer.fr

* Reading for assessment

9 References

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Mahe K., Sevin K., Petursdottir G., Finnbogadottir G., Wilhelms I., Beußel F., Bland B., Solbakken L., Seim S.E., Holm E., Mjanger H., Senneset H., Ottesen M.V., Skadal J. 2014. Report of the Saithe (Polliachius virens, L.) Otolith Exchange 2013. http://archimer.ifremer.fr/doc/00185/29595/

Neilson J.D., Stobo W.T., Perley P. 2013. Age and Growth of Canadian East Coast Pollock: Comparison of Results from Otolith Examination and Mark–Recapture Studies

Annex 1: Details results of 50 otoliths under reflected light

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

The modal age was calculated by the four readers (grey columns) who participate to saithe assessment (Table A1.1).

Table A1.1. CV, Percentage agreement and relative bias against modal age for age-readers.

NUMBER OF AGE READINGS

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	TOTAL
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	4	4	4	4	4	4	4	4	32
	3	4	4	4	4	4	4	4	4	32
	4	6	6	6	6	6	6	6	6	48
	5	6	6	6	6	6	6	6	6	48
	6	9	9	9	9	9	9	9	9	72
	7	7	7	7	7	7	7	7	7	56
	8	3	3	3	3	3	3	3	3	24
	9	-	-	-	-	-	-	-	-	-
	10	4	4	4	4	4	4	4	4	32
	11	5	5	5	5	5	5	5	5	40
	12	1	1	1	1	1	1	1	1	8
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-
	15	1	1	1	1	1	1	1	1	8
Total	0-15	50	50	50	50	50	50	50	49	399

COEFFICIENT OF VARIATION (CV)

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	ALL Readers
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	0%	0%	22%	0%	0%	0%	0%	0%	4.2%
	3	0%	0%	0%	0%	0%	0%	0%	0%	0.0%
	4	0%	11%	10%	14%	0%	11%	11%	11%	5.5%
	5	0%	8%	15%	0%	8%	8%	15%	8%	4.1%
	6	6%	7%	5%	5%	0%	7%	6%	38%	7.0%
	7	6%	6%	6%	6%	10%	8%	6%	8%	4.8%
	8	8%	11%	11%	0%	0%	8%	7%	7%	7.1%
	9	-	-	-	-	-	-	-	-	-
	10	5%	5%	8%	10%	5%	6%	0%	5%	6.6%
	11	4%	6%	18%	5%	4%	8%	7%	8%	7.6%
	12	-	-	-	-	-	-	-	-	-
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	6%	-
	15	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	3.1%	6.0%	9.6%	4.8%	3.2%	6.4%	6.0%	12.1%	5.3%
	RANKING	1	4	7	3	2	6	5	8	

PERCENTAGE AGREEMENT

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	ALL
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	100%	100%	75%	100%	100%	100%	100%	100%	97%
	3	100%	100%	100%	100%	100%	100%	100%	100%	100%
	4	100%	83%	83%	67%	100%	83%	83%	83%	85%
	5	100%	83%	67%	100%	83%	83%	83%	83%	85%
	6	89%	78%	89%	89%	100%	78%	89%	78%	86%
	7	86%	86%	86%	86%	57%	71%	86%	71%	79%
	8	67%	33%	33%	100%	100%	67%	33%	67%	63%
	9	-	-	-	-	-	-	-	-	-
	10	75%	75%	50%	50%	75%	50%	0%	75%	56%
	11	80%	60%	80%	60%	80%	40%	20%	20%	55%
	12	0%	100%	100%	100%	0%	100%	0%	100%	63%
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-
	15	100%	100%	100%	100%	100%	0%	0%	0%	63%
Weighted mean	0-15	88.0%	80.0%	78.0%	84.0%	86.0%	74.0%	68.0%	75.5%	79.2%
	RANKING	1	4	5	3	2	7	8	6	

RELATIVE BIAS

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	ALL
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.03
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	-0.17	0.17	-0.33	0.00	-0.17	-0.17	-0.17	-0.10
	5	0.00	0.17	0.50	0.00	0.17	0.17	0.33	0.17	0.19
	6	-0.11	0.22	0.11	0.11	0.00	0.22	-0.11	-0.56	-0.01
	7	-0.14	-0.14	-0.14	-0.14	-0.14	0.00	-0.14	0.00	-0.11
	8	-0.33	1.00	1.00	0.00	0.00	-0.33	0.67	0.33	0.29
	9	-	-	-	-	-	-	-	-	-
	10	-0.25	-0.25	0.00	-0.75	-0.25	-0.50	-1.00	0.25	-0.34
	11	-0.20	0.00	-0.80	-0.40	-0.20	-0.20	-1.00	0.40	-0.30
	12	-1.00	0.00	0.00	0.00	-1.00	0.00	-1.00	0.00	-0.38
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-
	15	0.00	0.00	0.00	0.00	0.00	1.00	-1.00	1.00	0.13
Weighted mean	0-15	-0.12	0.06	0.08	-0.14	-0.06	-0.02	-0.20	0.00	-0.05
	RANKING	6	4	5	7	3	2	8	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 (Figure A1.1). 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.

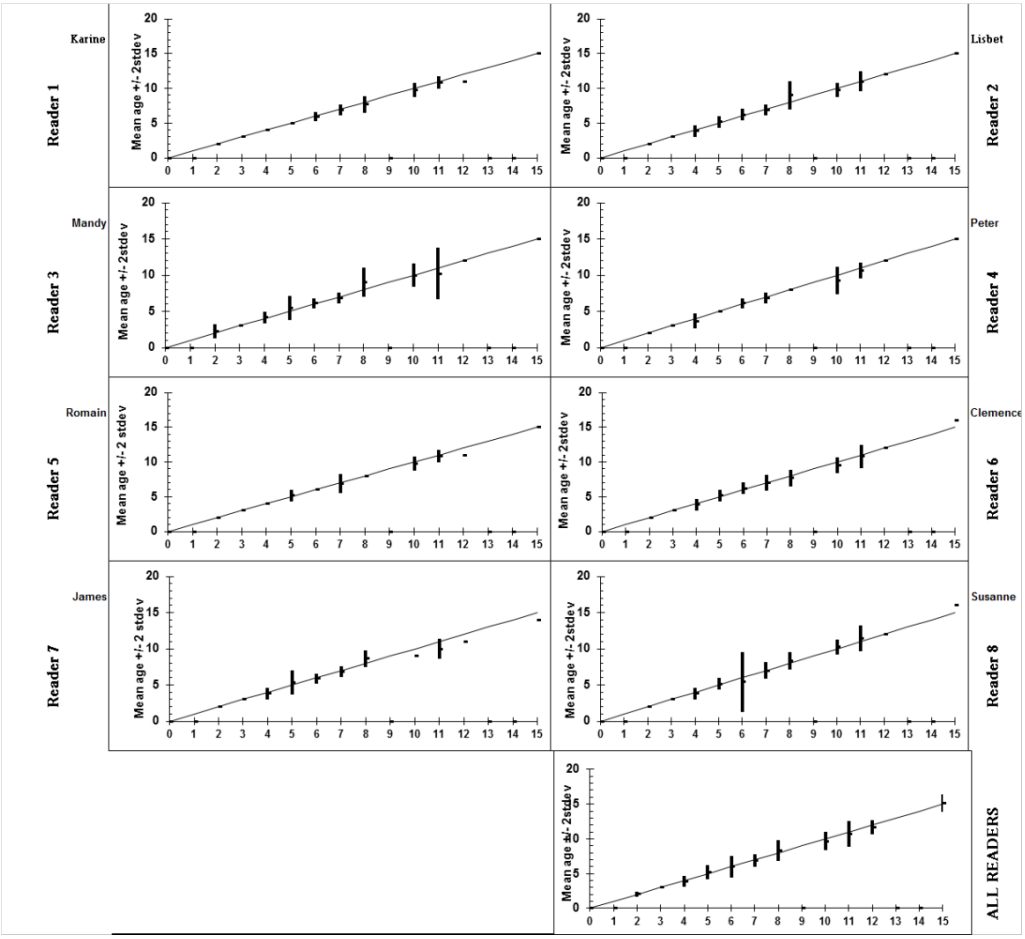


Figure A1.1. Age bias plot for individual age-readers and all age-readers combined

The coefficient of variation (CV%), percentage of agreement and the standard deviation (STDEV) are plotted against MODAL age (Figure A1.2). CV is much less age dependent than the standard deviation (STDEV) and the percentage of agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.

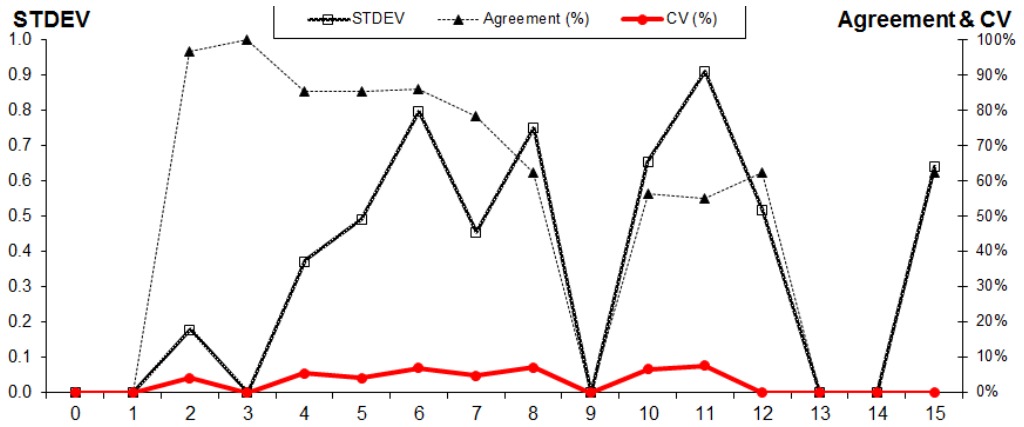


Figure A1.2. Coefficient of variation, percent agreement and the standard deviation against modal age.

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 (Figure A1.3). The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no RELATIVE bias, if the age reading errors are normally distributed. The distributions are skewed, if RELATIVE bias occurs.

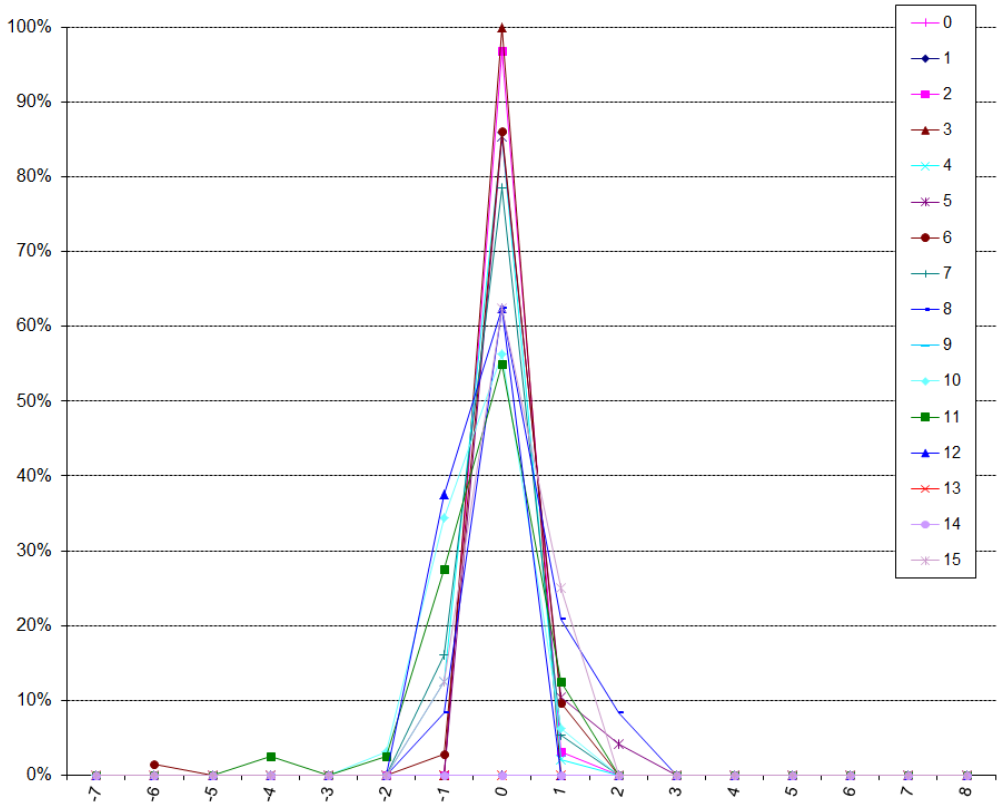


Figure A1.3 Distribution of the age reading errors in percentage by modal age

Annex 2: Details results of 50 otoliths under transmitted light

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

The modal age was calculated by the four readers (grey columns) who contribute to saithe assessment (Table A2.1).

Table A2.1. CV, Percentage agreement and relative bias against modal age for age-readers.

NUMBER OF AGE READINGS

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	TOTAL
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	4	4	4	4	4	4	4	4	32
	3	5	5	5	5	5	5	5	5	40
	4	5	5	5	5	5	5	5	5	40
	5	5	5	5	5	5	5	5	5	40
	6	8	8	8	8	8	8	8	8	64
	7	9	9	9	9	9	9	9	9	72
	8	2	2	2	2	2	2	2	2	16
	9	1	1	1	1	1	1	1	1	8
	10	5	5	5	5	5	5	5	5	40
	11	2	2	2	2	2	2	2	2	16
	12	3	3	3	3	3	3	3	3	24
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-
Total	0-15	50	50	50	50	50	50	50	50	400

COEFFICIENT OF VARIATION (CV)

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	ALL Readers
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	0%	0%	0%	0%	0%	0%	0%	0%	0.0%
	3	0%	0%	0%	14%	14%	0%	14%	0%	3.1%
	4	0%	0%	11%	0%	0%	0%	0%	0%	1.7%
	5	0%	9%	0%	0%	0%	0%	9%	0%	1.8%
	6	0%	7%	6%	0%	0%	0%	6%	0%	2.9%
	7	0%	7%	5%	0%	0%	7%	9%	11%	4.8%
	8	0%	0%	9%	0%	0%	9%	9%	9%	3.6%
	9	-	-	-	-	-	-	-	-	-
	10	10%	9%	5%	7%	14%	9%	7%	5%	6.9%
	11	0%	0%	0%	0%	0%	13%	0%	0%	4.6%
	12	6%	0%	0%	5%	11%	9%	9%	5%	6.4%
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	6%	-
	15	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	1.3%	4.2%	3.7%	2.4%	3.4%	3.7%	6.5%	3.2%	3.7%
RANKING		1	7	6	2	4	5	8	3	

PERCENTAGE AGREEMENT

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	ALL
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	100%	100%	100%	100%	100%	100%	100%	100%	100%
	3	100%	100%	100%	80%	80%	100%	80%	100%	93%
	4	100%	100%	80%	100%	100%	100%	100%	100%	98%
	5	100%	80%	100%	100%	100%	100%	80%	100%	95%
	6	100%	75%	88%	100%	100%	100%	88%	100%	94%
	7	100%	78%	89%	100%	100%	78%	56%	44%	81%
	8	100%	100%	50%	100%	100%	50%	50%	50%	75%
	9	0%	100%	100%	100%	0%	0%	0%	100%	50%
	10	60%	40%	80%	60%	40%	20%	60%	60%	53%
	11	100%	100%	100%	100%	100%	0%	0%	100%	75%
	12	0%	100%	100%	33%	33%	33%	33%	67%	50%
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	86.0%	82.0%	88.0%	88.0%	84.0%	74.0%	68.0%	80.0%	81.3%
RANKING		3	5	1	1	4	7	8	6	

RELATIVE BIAS

	MODAL age	Karine Reader 1	Lisbet Reader 2	Mandy Reader 3	Peter Reader 4	Romain Reader 5	Clemence Reader 6	James Reader 7	Susanne Reader 8	ALL
	0	-	-	-	-	-	-	-	-	-
	1	-	-	-	-	-	-	-	-	-
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.20	0.20	0.00	0.20	0.00	0.08
	4	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.03
	5	0.00	0.20	0.00	0.00	0.00	0.00	0.20	0.00	0.05
	6	0.00	0.25	-0.13	0.00	0.00	0.00	-0.13	0.00	0.00
	7	0.00	0.00	0.11	0.00	0.00	0.00	0.22	-0.11	0.03
	8	0.00	0.00	-0.50	0.00	0.00	-0.50	-0.50	-0.50	-0.25
	9	-1.00	0.00	0.00	0.00	-1.00	-1.00	-1.00	0.00	-0.50
	10	-0.60	-0.20	-0.20	0.00	-1.00	-0.40	0.00	0.40	-0.25
	11	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	-0.13
	12	-1.67	0.00	0.00	-0.67	-1.33	-1.00	-1.00	-0.33	-0.75
	13	-	-	-	-	-	-	-	-	-
	14	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-
Weighted mean	0-15	-0.18	0.04	-0.02	-0.02	-0.18	-0.14	-0.08	-0.02	-0.08
RANKING		7	4	3	2	8	6	5	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 (Figure A2.1). 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.

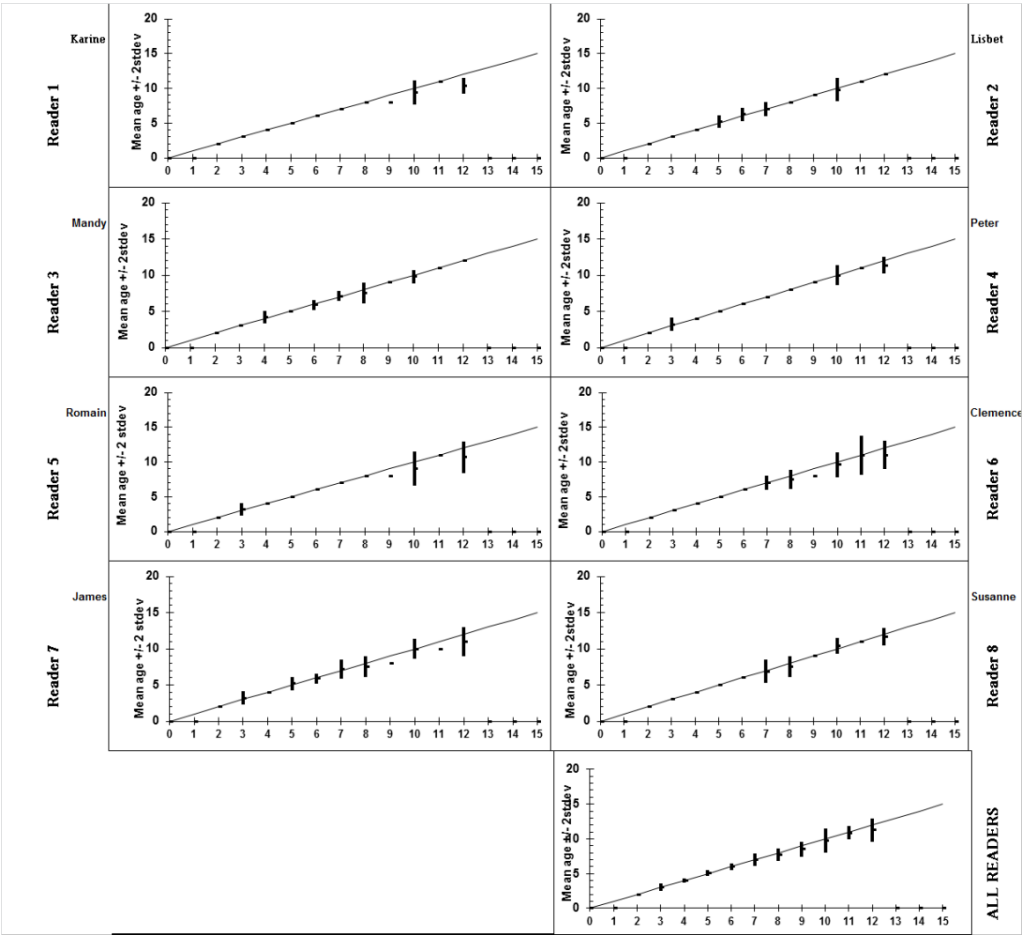


Figure A2.1. Age bias plot for individual age-readers and all age-readers combined

The coefficient of variation (CV%), percentage of agreement and the standard deviation (STDEV) are plotted against MODAL age (Figure A2.2). CV is much less age dependent than the standard deviation (STDEV) and the percentage of agreement. CV is therefore a better index for the precision in age reading. Problems in age reading are indicated by relatively high CV's at age.

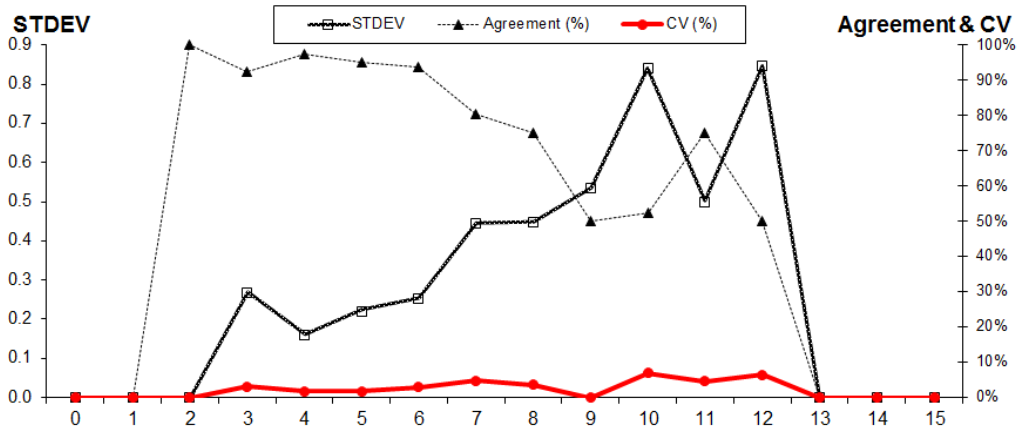


Figure A2.2. Coefficient of variation, percent agreement and the standard deviation against modal age.

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 (Figure A2.3). The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no RELATIVE bias, if the age reading errors are normally distributed. The distributions are skewed, if RELATIVE bias occurs.

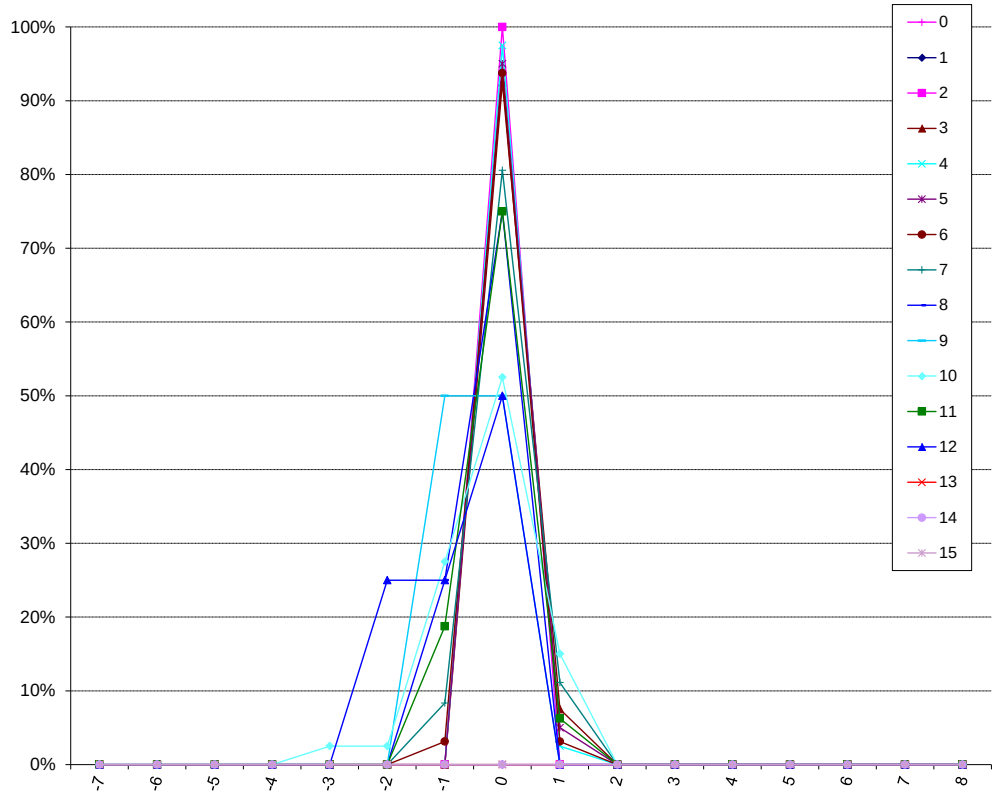
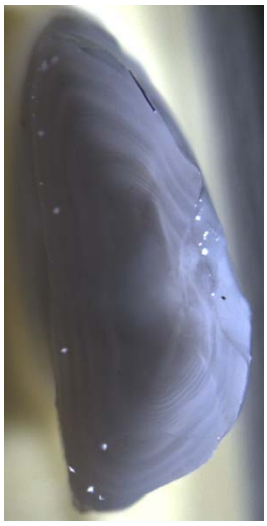


Figure A2.3 Distribution of the age reading errors in percentage by modal age

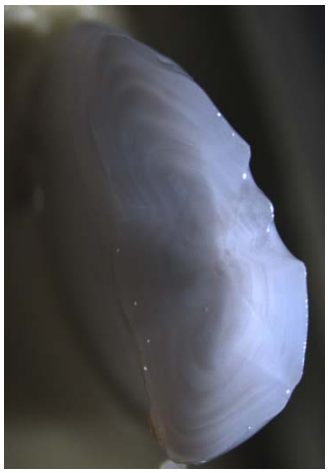
Annex 3: Broken *vs.* Slide transmitted vs. Slide reflected

TL	Broken otolith	Section by transmitted light	Section by reflected light
54 cm			
49 cm			
47 cm			

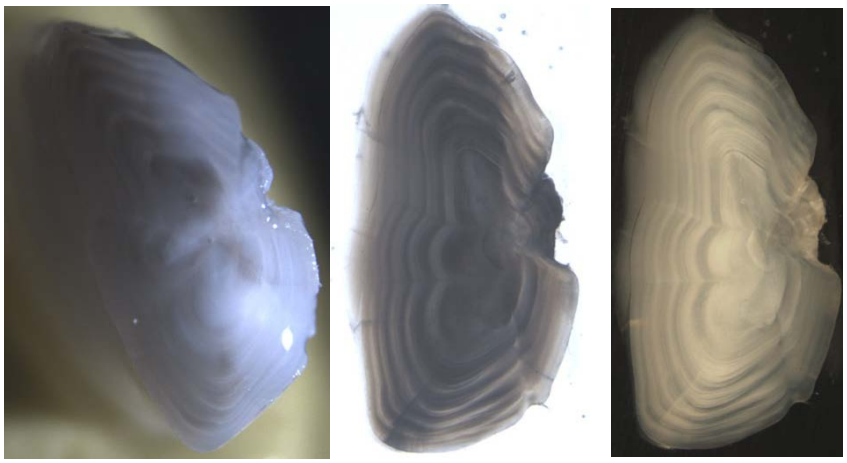
54 cm

60 cm

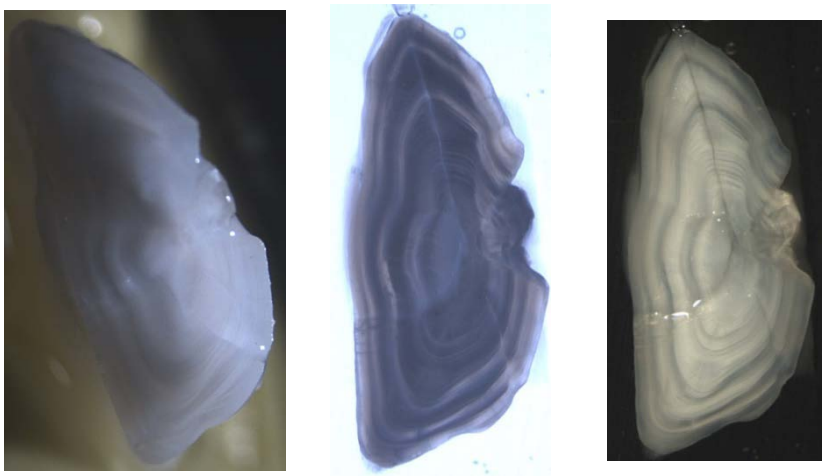
51 cm



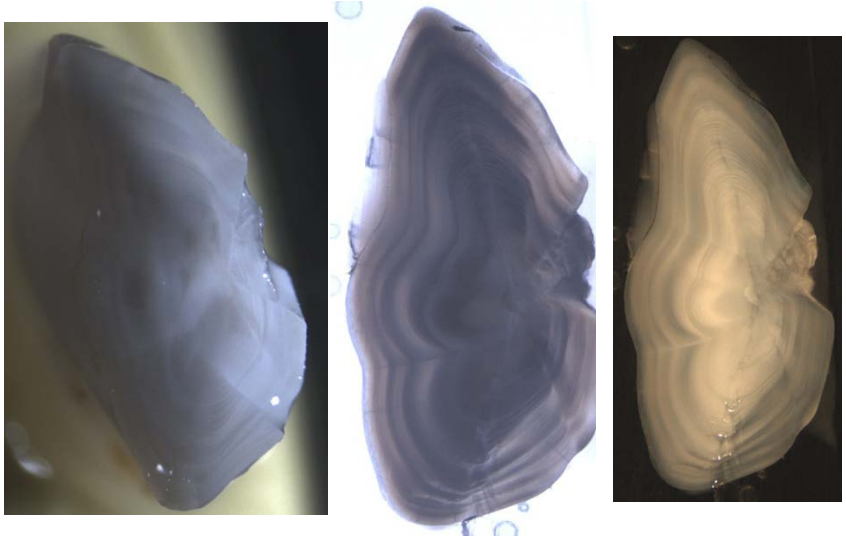
54 cm



56 cm

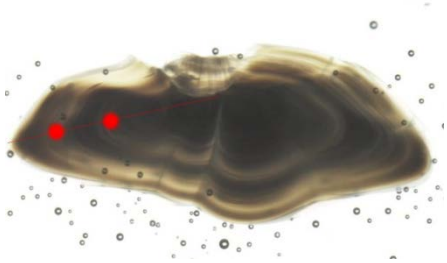


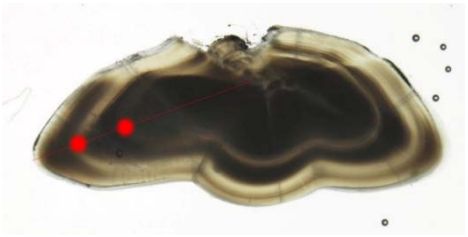
56 cm



57 cm

Annex 4 – Reference collection





FISH SAMPLE CODE	28_WKARPV_NO	36_WKARPV_NO
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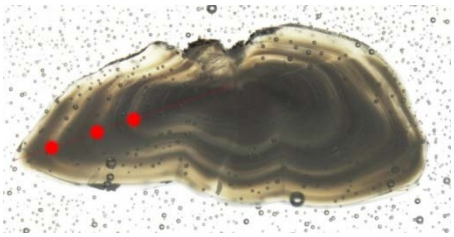
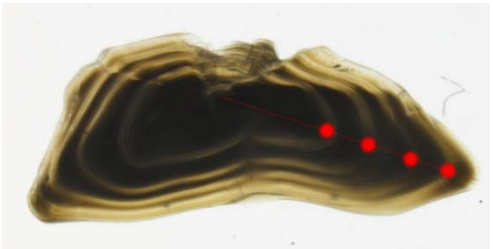
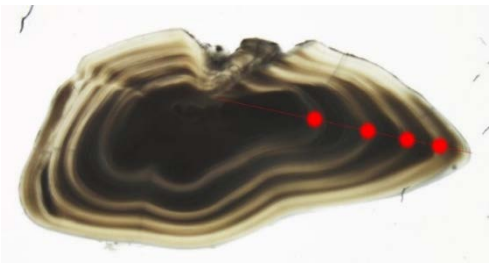
SAMPLING DATE	04.10.2014	10.10.2014
AGE	2	2

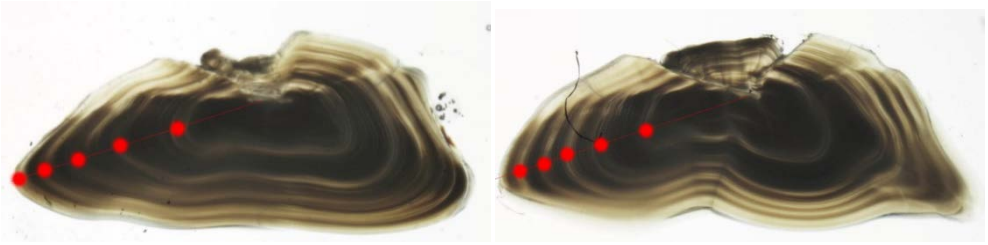


FISH SAMPLE CODE	31_WKARPV_NO	41_WKARPV_NO
LENGTH	430	470
SAMPLING DATE	10.10.2014	14.10.2014
AGE	3	3

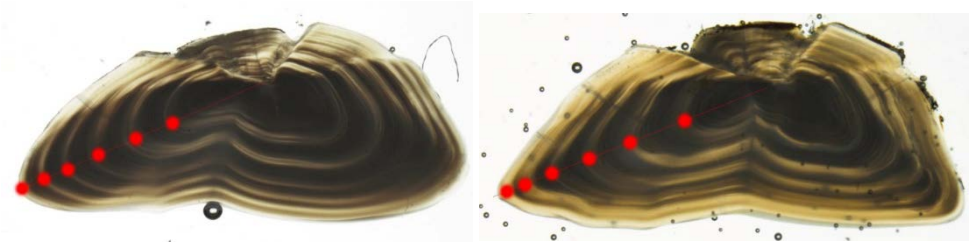




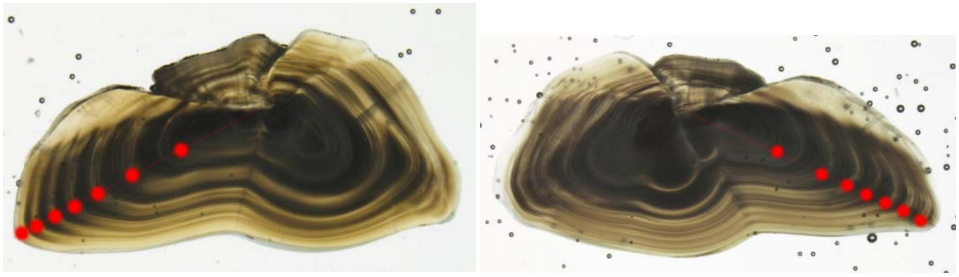
FISH SAMPLE CODE	12_WKARPV_NO	34_WKARPV_NO
LENGTH	490	460
SAMPLING DATE	08.07.2014	10.10.2014
AGE	4	4



FISH SAMPLE CODE	4_WKARPV_NO	33_WKARPV_NO
LENGTH	570	560
SAMPLING DATE	06.01.2014	10.10.2014
AGE	5	5



FISH SAMPLE CODE	1_WKARPV_NO	16_WKARPV_NO
LENGTH	600	610
SAMPLING DATE	06.01.2014	08.08.2014
AGE	6	6



FISH SAMPLE CODE	15_WKARPV_NO	19_WKARPV_NO
LENGTH	560	580
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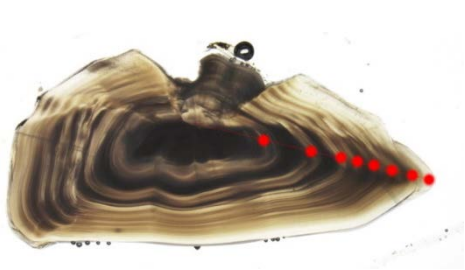
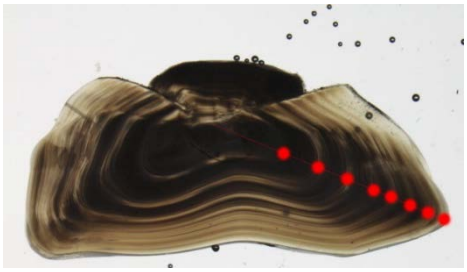
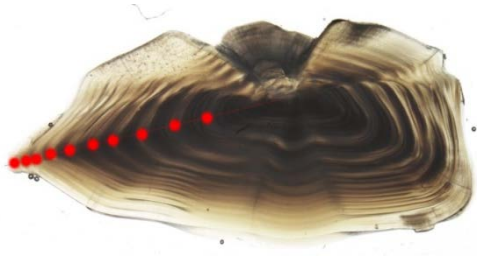
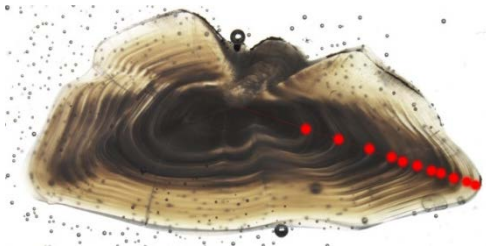
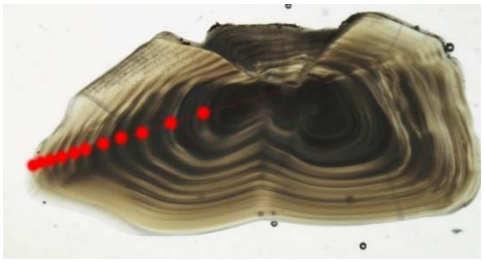
AGE	7	7

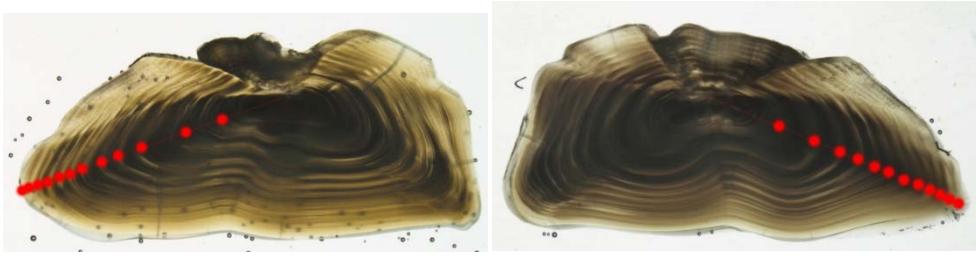
FISH SAMPLE CODE	47_WKARPV_NO	48_WKARPV_NO
LENGTH	840	770
SAMPLING DATE	04.04.2013	04.04.2013
AGE	8	8



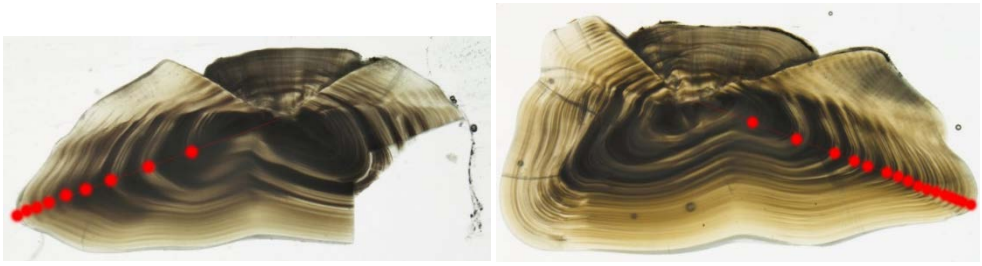
FISH SAMPLE CODE	42_WKARPV_NO	46_WKARPV_NO
LENGTH	850	820
SAMPLING DATE	04.04.2013	04.04.2013
AGE	10	10

FISH SAMPLE CODE	23_WKARPV_NO	49_WKARPV_NO
LENGTH	900	810
SAMPLING DATE	11.10.2014	04.04.2013
AGE	11	11



FISH SAMPLE CODE	13_WKARPV_NO		44_WKARPV_NO
LENGTH	930	890	890
SAMPLING DATE	08.07.2014	04.04.2013	04.04.2013
AGE	12	12	12



FISH SAMPLE CODE	50_WKARPV_NO	42_WKARPV_NO
LENGTH	730	850
SAMPLING DATE	04.04.2013	04.04.2013
AGE	9	10

Annex 5: WKARPV2 terms of reference for the next meeting

The Workshop on Age Reading of Saithe (*Pollachius virens*) 2 (WKARPV2), chaired by Jane Godiksen, Norway and Kélig Mahé, France and will meet in Bergen, Norway, 2022 to:

a) Clarify the interpretation of annual growth rings between otolith section and broken otolith on the same set

b) Clarify the interpretation of annual growth rings between transmitted and reflected light

c) Continue the guidelines and common ageing criteria.

d) Increase existing reference collections of otoliths and improve the existing database of otolith images by adding.

e) Address the generic ToRs adopted for workshops on age calibration (see 'PGCCDBS Guidelines for Workshops on Age Calibration').

Supporting Information

Priority:	Essential. Age determination is an essential feature in fish stock assessment to estimate the rates of mortality and growth. Age data are provided by different countries and are estimated using international ageing criteria. There is necessity to continue to clarify this guideline of age interpretation especially between the preparation methods. Therefore, an appropriate otolith exchange programme will carry out in 2019 for the purpose of inter-calibration between ageing labs. Results of this otolith exchange will discuss during WKARPV2.
Scientific justification:	The aim of the workshop is to identify the current ageing problems between readers and standardize the age reading procedures in order to improve the accuracy and precision in the age reading of this species.
Resource requirements:	No specific resource requirement beyond the need for members to prepare for and participate in the meeting.
Participants:	In view of its relevance to the DCR, and ICES WG, the Workshop try to join international experts on growth, age estimation and scientists involved in assessment in order to progress towards a solution. Participants should announce their intention to participate in the WK no later than two months before the meeting.
Secretariat facilities:	
Financial:	
Linkages to advisory committees:	ACOM, SCICOM
Linkages to other committees or groups:	WGBIOP, WGNSSK, NWWG, AFWG
Linkages to other organizations:	There is a direct link with the EU DCF.

Annex 6: Recommendations

Recommandations	Adressed to
1. WKARPV2 Workshop in 2022	WGBIOP, WGNSSK, NWWG, AFWG, ACOM
2.Otoliths Exchange of P. virens in 2019	WGBIOP, WGNSSK, NWWG, AFWG, ACOM
3. Clarify guideline of ageing criteria	WGBIOP, WGNSSK, NWWG, AFWG, ACOM
4. Develop the WebGR tool	WGBIOP, ACOM