WORKSHOP ON AGE READING OF NORWEGIAN SPRING-SPAWNING HERRING (*CLUPEA HARENGUS*) (WKARNSSH)

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WORKSHOP ON AGE READING OF NORWEGIAN SPRING-SPAWNING HERRING (*CLUPEA HARENGUS*) (WKARNSSH)

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Contents

i Executive summary

The assessment working group (WGWIDE) for Norwegian spring-spawning (NSS) herring requested an age reading exchange to calibrate age reading. Issues that can bias the age reading were identified in a previous workshop, e.g. different calcified structures are used (otoliths and scales), stock mixing occurs during specific periods and areas, different interpretations of the first winter ring, or different interpretations of the new annual growth occurring in May. Therefore, the aim of this age reading workshop was to address potential age reading issues and thus minimize the bias associated with the age data. Further, this workshop aimed to evaluate if these issues have been resolved following the provided guidelines. Prior to this workshop two exchanges with NSS herring otoliths (SmartDots event 447) and scales (SmartDots event 448) of the same individuals were conducted.

In total, 254 individuals were aged by 9 scale readings (6 advanced, 3 basic) and 18 otolith readings (10 advanced, 8 basic). Modal ages of otoliths and scales were compared directly as well as individual readings combined. The modal age of the independent exchanges resulted in 77.95% percentage agreement (PA) and an average percentage error (APE) of 3.71%. The comparison of all individual readings resulted in a PA of 76% and APE of 6%. The PA of all readers decreased from above 75% to below 50% at age 9 and older, where the otolith age is typically younger than the scale age. An age error matrix is provided that could be used in the stock assessment.

No differences have been observed between samples from varying quarters. Thus, the earlier proposed issue with identifying new growth in May has been resolved. The general understanding of age reading for both structures, otoliths and scales, is consistent among readers. However, other potential issues are highlighted in the report. Disagreement between scales and otoliths occurred especially for older individuals. It needs to be checked if this discrepancy will impact the stock assessment of NSS herring. Furthermore, in terms of age reading, stock mixing seems to be a minor issue and consequently the age reading of stock-mixed samples will have no direct impact on the assessment of NSS herring. However, this needs to be investigated in more detail in the near future.

ii Expert group information

Expert group name	Workshop on age reading of Norwegian spring-spawning herring (*Clupea harengus*) (WKARNSSH)
Expert group cycle	Annual
Year cycle started	2022
Reporting year in cycle	1/1
Chair	Florian Berg, Norway
Meeting venue and dates	17–21 April 2023, Institute of Marine Research, Bergen, Norway (18 participants)

1 Introduction

Workshop on age reading of Norwegian spring-spawning herring (*Clupea harengus*; her.27.1-24a514a)

Ageing of calcified structures in fish, such as otoliths or scales, is the backbone of most stock assessment models. Age-based information is used to infer stock dynamics and status. One of the main objectives for the age reader community is to achieve consistency between age readers estimating the age of a certain species or stock and to minimize the amount of bias in the age data which is used in stock assessment. Such bias can have serious consequences for the scientific advice which is used for the management of fish stocks. Therefore, the aim of this age reading workshop was to address potential age reading issues regarding the Norwegian spring-spawning (NSS) herring stock and thus minimize the bias associated with the age data provided to WGWIDE for the assessment of the stock.

Especially for NSS herring potential issues exist that can bias the age reading, e.g. different calcified structures are used (otoliths and scales), stock mixing occurs during specific periods and areas, different interpretations of the first winter ring, or different interpretations of the new annual growth occurring during the "International ecosystem survey in the Nordic Seas (IESNS)" in May. These issues have been identified in earlier workshops and potential guidelines were provided to improve the age readings (ICES 2016, Godiksen 2017). Particularly, the stock mixing issue and how these data are passed on to the stock coordinators needs to be explored further given the serious implications for the quality of the assessment both in terms of age and stock structure. This workshop aimed to evaluate if these issues have been resolved following the provided guidelines or if they are still existing.

Prior to this workshop two exchanges with NSS herring otoliths (SmartDots event 447[1]) and scales (SmartDots event 448[2]) of the same individuals were conducted simultaneously and their results were compared and discussed at this workshop. Both structures have been collected by several institutions during the IESNS and the "International ecosystem summer survey in the Nordic Seas (IESSNS)" in July. Furthermore, both structures were sampled from Norwegian commercial catches during the first and last quarter of the year. All samples were from 2021. The final reports for each exchange have been published and can be found in Annex 4 and 5 for the otoliths and scales, respectively. This report will only focus on the comparison between the age readings of the two structures as well as highlighting potential issues when using different ageing methods. Age readers have only read the structure they are trained on and familiar with. However, some readers are trained on both, and have therefore read both structures.

[1] https://smartdots.ices.dk/sampleImages/2022/447/SmartDots_Report_Event_447_Otoliths.pdf

[2] https://smartdots.ices.dk/sampleImages/2022/448/SmartDots_Report_Event_448_Scales.pdf

2 Age reading otoliths vs. scales (ToR b and c)

The report for the individual exchanges of otolith and scales can be found in Appendix 4 and 5, respectively. Here, we will only focus on the differences between the two calcified structures. In total, 254 individuals were aged with both structures (Table 2.1) and the modal age of the independent exchanges resulted in 77.95% agreement (PA) and an average percentage error (APE) of 3.71%. This is based on the direct comparison of the modal ages following the guidelines and tools for age reading comparison by Eltink *et al*. (2000). The highest discrepancies occurred for scale ages 10 and older, where the otolith age is typically younger than the scale age (Table 2.2, blue cells). In general, the agreement per scale age was above 75% up to age 9. Agreement for older scale ages drop to <50% (Table 2.3). A similar trend has been observed for the otoliths with higher agreements up to age 8, and a significant drop for age 9 and older (Table 2.3). However, agreement among otoliths was slightly lower compared to the scale agreement.

Table 2.1. Overview of samples used for the age reading workshop where both, otoliths and scales, were available.

Year	Strata	Quarter	Number of samples	Modal age range	Length range
2021	Strata_27.2.a	1	60	3–16	280–375 mm
2021	Strata_27.2.a	2	60	4–10	245–350 mm
2021	Strata_27.5.b	2	27	5–15	285–390 mm
2021	Strata_27.5.a	3	47	5–15	310–390 mm
2021	Strata_27.2.a	4	60	3–8	260–350 mm

Table 2.2. Age matrix for modal age from scales and otoliths. Green cells indicate agreement, blue cells younger age of otolith, orange cells older age of otolith.

Scales	Otoliths																
Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1																	
2																	
3			3														
4				5	1												
5				5	106	2											
6						6	1			1							
7						1	17										
8							6	41	3								
9								1	7	1							
10								1	3	2	2						
11								1	1	3	3	1					
12									2	1	3	4	1				
13											1		3	1	1		
14										1					1		
15							1		1		1	3	2	1	1		
16																	
17																1	

Table 2.3. Number of scales/otoliths per modal age and their percentage agreement (PA) and average percentage error (APE) against the otolith/scale age of the same individual. Here the scale modal age of an individual was directly compared with otolith modal age of the same individual and vice versa.

Scales				Otoliths			
Modal age	Number	PA (%)	APE (%)	Modal age	Number	PA (%)	APE (%)
3	3	100.0	0.0	3	3	100.0	0.0
4	6	83.3	4.2	4	10	50.0	12.5
5	113	93.8	1.2	5	107	99.1	0.2
6	8	75.0	10.4	6	9	66.7	5.6
7	18	94.4	0.8	7	25	68.0	8.6
8	50	82.0	2.2	8	44	93.2	1.7
9	9	77.8	2.5	9	17	41.2	13.1
10	8	25.0	8.8	10	9	22.2	15.6
11	9	33.3	9.1	11	10	30.0	10.0
12	11	36.4	9.1	12	8	50.0	10.4
13	6	50.0	6.4	13	6	50.0	6.4
14	2	0.0	17.9	14	2	0.0	7.1
15	10	10.0	21.3	15	3	33.3	6.7
16	-			16	1	0.0	6.2
17	1	0.0	5.9	17	-		

Besides the comparison of modal ages, all individual readings of the two exchanges were combined. The results were analysed using the "SmartDotsReport_template"[3] through the ICES Transparent Assessment Framework (TAF). For this comparison, 9 scale readings (6 advanced, 3 basic) and 18 otolith readings (10 advanced, 8 basic) were analysed.

The weighted average percentage agreement based on modal ages for all readers is 76%, with the weighted average CV of 10% and APE of 6% (Table 2.4). The PA of all readers decreased from above 75% to below 50% at age 9 and older which is not reflected in the CV which is relatively constant but slightly higher at the weighted mean (Figure 2.1). The same pattern was observed for advanced readers only, but with slightly higher agreements. An age error matrix including only the age readings of advanced readers combined for both scale and otolith ages is provided in Table 2.5.

In general, no differences in terms of PA have been observed between samples from varying quarters. Thus, the earlier proposed issue with identifying new growth in May has been resolved since the last workshop. All readers followed the provided guidelines by WKNSSAGE (ICES, 2015) resulting in overall high agreement. The general understanding of age reading for both

[3] https://github.com/ices-taf/SmartDotsReport_template

structures, otoliths and scales, is consistent among readers. However, the use of both structures by different institutes and different data input (i.e. survey and commercial data) might bias the age estimation used for the assessment of NSS herring. The outcome of this workshop highlights the discrepancies between age reading of the two structures, especially for older ages.

It should be noted that the 2016- and 2013-year classes (i.e. 5- and 8-year-old herring) constituted around 60% of the material. This has probably contributed to the high agreement because they are relatively young and easy to read. This stock structure of one or two dominating year classes might bias some age readers when reading more difficult otoliths or scales. This was however, not observed during this workshop as the dominating year classes are still young.

Table 2.4. Percentage agreement (PA), coefficient of variation (CV), and average percentage error (APE) per modal age for all and advanced (adv) readers for age readings of both otoliths and scales combined.

Modal age	PA (all)	CV (all)	APE (all)	PA (adv)	CV (adv)	APE (adv)
3	85 %	19 %	11 %	88 %	17 %	10 %
4	69 %	12 %	10 %	69 %	11 %	10 %
5	91 %	8 %	3 %	95 %	5 %	1 %
6	82 %	7 %	4 %	85 %	6 %	3 %
7	77 %	16 %	7 %	87 %	15 %	5 %
8	78 %	7 %	4 %	85 %	7 %	3 %
9	55 %	15 %	10 %	68 %	9 %	5 %
10	39 %	16 %	11 %	48 %	15 %	10 %
11	43 %	15 %	9 %	51 %	13 %	8 %
12	38 %	14 %	10 %	51 %	11 %	8 %
13	39 %	14 %	10 %	47 %	12 %	8 %
14	50 %	9 %	6 %	50 %	7 %	5 %
15	38 %	11 %	9 %	43 %	13 %	10 %
16	32 %	21 %	17 %	27 %	17 %	14 %
Weighted Mean	**76 %**	**10 %**	**6 %**	**82 %**	**8 %**	**4 %**

Table 2.5. General age error matrix (AEM). The modal age is in rows and the age classifications by the advanced readers in columns. Only advanced readers are used for calculating the AEM.

Modal age	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
3	0.9	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
4	0.0	0.7	0.3	-	-	-	-	-	-	-	-	-	-	-	-
5	-	0.0	0.9	0.0	0.0	0.0	-	-	-	-	-	-	-	-	-
6	-	-	0.1	0.8	0.1	-	-	-	-	-	-	-	-	-	-
7	-	-	0.0	0.0	0.9	0.1	-	0.0	0.0	-	-	0.0	0.0	-	-
8	-	-	-	0.0	0.1	0.8	0.0	0.0	0.0	0.0	-	-	0.0	-	-
9	-	-	-	-	0.0	0.2	0.7	0.1	0.0	0.0	0.0	-	-	-	-
10	-	-	-	0.0	0.0	0.0	0.1	0.5	0.2	0.0	0.0	0.0	0.0	0.0	-
11	-	-	-	-	0.0	0.0	0.1	0.2	0.5	0.2	0.0	-	0.0	0.0	-
12	-	-	-	-	0.0	0.0	0.0	0.1	0.2	0.5	0.1	0.0	0.0	-	-
13	-	-	-	-	0.0	0.0	-	-	0.1	0.1	0.5	0.1	0.1	0.0	-
14	-	-	-	-	-	-	-	-	-	0.1	0.2	0.5	0.2	0.1	-
15	-	-	-	-	-	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.4	0.0	-
16	-	-	-	-	-	-	0.1	-	0.1	0.1	-	0.1	0.1	0.3	0.3

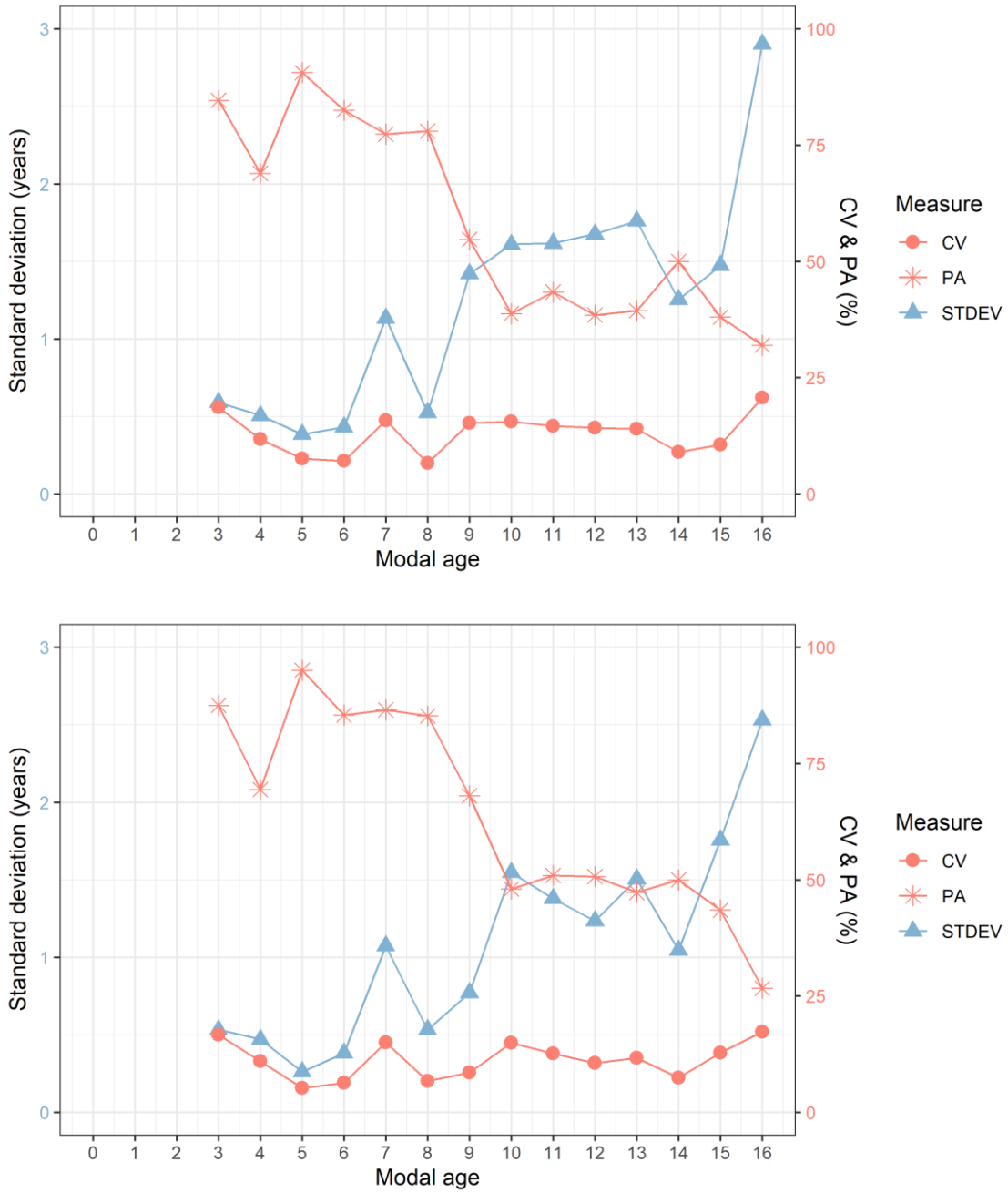

Figure 2.1. Percentage agreement (PA), coefficient of variation (CV), and standard deviation (STDEV) per modal age for all (A) and advanced (B) readers for age readings of both otoliths and scales combined.

3 Update the guidelines, common age reading criteria, and reference collection (ToR d and e)

The overall results of the age reading exchanges for both otoliths and scales were very good and would not introduce any potential bias to the stock assessment. However, this would only be the case when solely one calcified structure would have been used and no stock mixing would occur. During the discussions of the workshop, issues were identified influencing the overall results which were not identifiable based on the statistical analysis presented above. These issues are described in the following.

Issues reading both structures

Within each calcified structure, the agreements were high. Only when comparing the results directly it is apparent that the otolith age is underestimated compared to scale age for ages 8 and above. Unfortunately, this is an issue which cannot be solved easily since it becomes iterative. In general, it is more difficult to age older fish using otoliths than scales. If this was the only concern, reading scales should then be the preferred option. On the other hand, during the IESNS and IESSNS it is very difficult, if not even impossible, to get high quality scales from herring as they are often "washed off" during the trawling process. Consequently, only otoliths are available. Therefore, age readers at the same institutes need to be trained on both structures, which is very time consuming. Reading older otoliths becomes difficult since it is hard to define the edge or even count the narrow rings. This uncertainty could be decreased by reading scales. Therefore, a combination of both structures would be the optimal solution, where both structures are available. However, this will most likely not be feasible in the daily routines of the institutional workloads.

If this discrepancy between otolith and scale age is really an issue for the stock assessment, then this needs to be validated. Ages for most commercial catches are read on scales, where otoliths are mainly used for the index estimation of IESNS and IESSNS; however commercial catches from some areas are only read on otoliths. Typically, internal consistency of cohort strength is tested within each dataset. However, it should be tested if cohort strength can be followed between dataset when different ageing procedures are being applied.

Issues reading scales

In cases when the modal age of the scale and otolith mismatched, it was discussed that sometimes the reason for the discrepancy was the identification of the first winter ring (Annex 6). This issue is most likely linked to stock mixing when suddenly autumn spawners appeared. However, this issue was also apparent within "true" NSS herring. To identify non NSS herring is easier on otoliths than on scales. On scales it is almost impossible to identify different populations or spawning types (e.g. autumn vs. spring).

Issues reading otoliths

In general, age readings of otoliths of age 10 and older have high uncertainty because it is hard to define the edge or even count the rings, which are too narrow. It is also not possible to identify and follow each winter ring around the whole otolith. Therefore, discrepancies between readers might appear when reading direction (e.g. rostrum vs. antirostrum) differs. During this otolith exchange readers were able to choose their preferred direction and the disagreement could not be linked to this issue. The general procedure described by age readers was that although they assigned the age along one preferred direction, they most often followed the winter rings around the otolith when assigning the age.

The otolith exchange included two genetically identified samples (only otoliths available) of mainly identified North Sea autumn-spawning herring. These samples were collected during the IESSNS in July in the management area of NSS herring (north of 62° N). Most readers identified these non NSS herring and overall agreement (76%) was in line with other samples. However, it should be noted that otoliths of autumn-spawning herring are more difficult to read, although agreement was good. It has been discussed that the growth characteristics of NSS herring are much more defined and growth zones clearly separated. Thus, the overlap between opaque and translucent zones is more diffuse in autumn-spawning herring. Since most readers were familiar with reading typically both autumn- and spring-spawning herring this was not an apparent issue this time.

Issue with stock mixing

As mentioned earlier, participating readers were aware of this issue and could identify non NSS herring. It was discussed that this identification is more certain when using otoliths compared to scales. It is questionable if this identification is at all possible when reading scales. This needs to be investigated in future. Genetic stock identification is being implemented more commonly in the daily sampling routines, allowing for future studies. However, it was also demonstrated that not all genetically identified NSS herring had their typical macrostructure characteristics and thus were identified as non NSS herring. Deviations from their typical macrostructure characteristics are apparent. Especially the occurrence of genetically NSS herring growing up along the coast and not following the typical migration route of NSS.

Issues using SmartDots vs. physical material

For both exchanges, otolith and scale, physical materials were shared among participants. However, not all participants had access to the physical material and only read the age directly from images provided via SmartDots. All participants agreed that the quality of image was very high and consequently no differences occurred. In general, to improve the quality of an exchange, high quality images are the backbone of the results. There should be absolutely no issues with image quality, otherwise the result of the exchange will be nearly useless.

For future exchanges, otoliths and scales of the same individual should be used as was done in the current exercise. This needs prior coordination since each institute usually collects only one structure. Also, the quality of the scales and otoliths per se must be high. If an otolith is broken or a scale almost unreadable, high-quality images will not help to achieve good results. It is also recommended to take images of multiple scales from an individual when being compared with otoliths. This will help the age readers better identify the correct age for an individual in case cross-contamination of scales from another fish occurs. This was the case for one individual of the exchange. Both, otolith and scale, resulted in 100% agreement. However, when checking the original scales, the age of all other scales corresponded to the otolith age, expect the photographed one (see Annex 6 for example images).

Reference collection

The material of this workshop is highly recommended for future reference collections. Selection should be based on the agreement with each structure and between the structures. There were quite a lot of individuals achieving 100% agreement for both structures. Here, one important contributing factor may be that ~60 % of the material was assigned to two relatively young year classes (5- and 8-year-olds). This makes the material particularly well suited for discussions regarding e.g. macrostructure of NSS herring, added growth throughout the year and first annual ring comparison between scales and otoliths.

4 Conclusion

Two independent age reading exchanges for otolith and scales off NSS herring, and a subsequent workshop have been conducted successfully. Overall results for both exchanges and the combination were high and at acceptable levels. This time, there were no issues with identifying the new growth during May. In general, no issues directly related to the age reading were identified and therefore, the current guidelines were not updated.

Disagreement between scales and otoliths occurred especially for older individuals (age 8 and above). This is an issue that cannot be resolved by any adjustment of the ageing protocols. It needs to be checked if this discrepancy will impact the stock assessment of NSS herring.

Furthermore, in terms of age reading, stock mixing seems to be a minor issue. Readers achieved high agreement on samples genetically identified as stock-mixed samples. Consequently, the age reading of stock-mixed samples will have no direct impact on the assessment of NSS herring related to the age-based information used. However, this needs to be investigated in more detail in the near future as stock-mixing per se will of course influence the stock assessment. During the workshop potential studies were discussed, e.g. evaluating if autumn-spawning herring have an extra winter ring on the scales compared to otoliths.

5 References

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Annex 1: List of participants

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Annex 2: Resolutions

WKARNSSH – Workshop on age reading of Norwegian spring-spawning herring (*Clupea harengus*)

2022/WK/DSTSG11 **Workshop on age reading of Norwegian spring-spawning herring (*Clupea harengus*[4])** (WKARNSSH), chaired by Florian Berg, Norway, will be established and meet at IMR-Institute of Marine Research, Bergen, Norway, 17–21 April 2023[5] to:

a) Present and analyse issues described by WGWIDE;

b) Analyse the problematic structures (otoliths/scales) from the IESNS-surveys (May-surveys) described by WGWIDE;

c) Clarify the interpretation of annual growth rings using otoliths and scales from the same fish (Science Plan codes: 3.1, 3.2 and 5.2);

d) Improve the protocol of the guideline on age estimation and the applied structure (otolith or scale) (Science Plan codes: 3.1, 3.2 and 5.2);

e) Develop existing reference collections of otoliths/scales and improve the existing database of scales images (Science Plan codes: 3.1, 3.2 and 5.2);

f) Address the generic ToRs adopted for workshops on age calibration (see: WGBIOP 2019 Guidelines for Exchanges And Workshops on Age Reading; Science Plan codes: 3.1, 3.2 and 5.2).

WKARNSSH will report by 1 August 2023 for the attention of WGWIDE, WGIPS, ACOM and DSTSG.

Supporting information

Priority	Age determination is an essential feature in fish stock assessment to estimate the rates of moralities and growth. To arrive at appropriate management advice ageing procedures must be reliable. Otolith/scale processing methods and age reading methods might differ considerably between countries. Therefore, otolith/scale exchanges should be carried out regularly, and if serious problems exist age reading workshops should be organized to solve these problems.
Scientific justification	The mini-workshop aims to review the technical problems regarding the age-reading of Norwegian Spring-spawning herring between Denmark, Norway, Iceland, and the Faroe Islands regarding the extra growth added in May samples. Otoliths and scales from the May–July surveys will be brought to the WK and discussed.
Resource requirements	No specific resource requirements beyond the need for members to prepare for and participate in the meeting.
Participants	Given its relevance to the EU Data Collection Framework (DCF), the workshop is expected to attract interest from ICES Member States.
Secretariat facilities	None.
Financial	Additional funding will be required for facilitating the attendance of the scientists and technicians.

[4] her.27.1-24a514a; Herring (*Clupea harengus*) in subareas 1, 2, 5 and divisions 4.a and 14.a, Norwegian spring-spawning herring (the Northeast Atlantic and Arctic Ocean).

[5] Pre-workshop exchanges are ongoing.

Linkages to advisory and science committees	ACOM.
Linkages to other groups	WGBIOP, WGWIDE, ACOM, RCGs, all WKACs (age calibration workshops).
Linkages to other organizations	There is a direct link with the EU-MAP.

Annex 3: Recommendations[6]

Recipient: WGWIDE/WGIPS

It is recommended to check the age distribution consistency among different surveys and catch data where different calcified structures are used for the age reading. For example, is the age distribution observed during the spawning cruise (purely scales) the same as or the IESNS or IESSNS (mainly otoliths).

[6] Note that the submitted recommendation has not been approved by the ICES Secretariat at the time of publication. This recommendation can be found on the 2023 Recommendations database as issue #103.

Annex 4: Otolith exchange report

SmartDots Report for the 2023 otolith exchange for Norwegian spring-spawning herring stock *her.27.1-24a514a* (event 447)

Coordination and analysis: Florian Berg, Institute for Marine Research, Bergen, Norway, florian.berg@hi.no

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1 Executive summary

The 2023 otolith exchange for the Norwegian spring-spawning herring (*Clupea harengus*) stock *her.27.1-24a514a* took place via the SmartDots platform between August 2022 and March 2023. The exchange was organised following a recommendation from WGWIDE to calibrate age reading especially during May where a potential issue with the interpretation of the new growth zone might exist. 18 readers from eight countries (Denmark, Germany, Faroes Islands, Iceland, Ireland, Norway, Sweden, United Kingdom) took part; ten "advanced" readers (providing age data for the assessment) and eight "basic" readers (do not provide age date for the assessment). For this exchange, most readers had access to the physical material, while readers from Denmark, Germany, and Sweden only had access to the digital images via SmartDots. A total of 329 otoliths, covering commercial samples from 1st and 4th quarter of the year and the two international surveys (IESNS in May and IESSNS in July) providing biomass estimates, were age determined using SmartDots and physical material provided.

The overall agreement (PA) among all readers was 75%, with a weighted average CV of 10% and APE of 5%. The agreement among advanced readers was 81%. Agreement with the modal age was highest from age three to eight years and decreased in older individuals. The results of this exchange demonstrated that there is no issue with new growth occurring in May. All readers interpreted the new growth similarly resulting in high PA among samples from May.

The results if this exchange were presented and discussed at the WKARNSSH (Workshop on age reading of Norwegian spring-spawning herring) in April 2023.

2 Introduction

Ageing of calcified structures in fish, such as otoliths or scales, is the backbone of most stock assessment models. Age-based information are used to infer stock dynamics and status. One of the main objectives for the age reader community is to achieve consistency between age readers estimating the age of a certain species or stock and to minimize the amount of bias in the age data which is used in stock assessment. Such bias can have serious consequences for the scientific advice which is used for the management of fish stocks. The aim of this age reading exchange was to address potential age reading issues apparent with the Norwegian spring-spawning (NSS) herring stock and thus minimize the bias associated with the age data provided to WGWIDE for the assessment of the stock. Especially for NSS herring potential issues exist that can bias the age reading, e.g., different calcified structures are used (otoliths and scales), stock mixing occurs during specific time periods and areas, different interpretations of the first winter ring, are different interpretations of the new annual growth occurring during the international survey IESNS in May. Particularly, the stock mixing issue and how these data are passed on to the stock coordinators needs to be explored further given the serious implications for the quality of the assessment both in terms of age and stock structure. In addition to this otolith exchange, an exchange with NSS herring scales (event 448) was conducted at the same time and their results were compared and discussed at the WKARNSSH (Workshop on age reading of Norwegian spring-spawning herring) in April 2023.

3 Methods

Results presented here are based on output from SmartDots and a standardised r-script. The analysis follows traditional methods where the level of accuracy compared to modal age is indicated by percentage agreement (PA), bias tests and plots, and the level of precision, i.e. the reproducibility of age estimates is indicated by the coefficient of variation (CV). The tables and plots presented are from the Guus Eltink Excel sheet 'Age Reading Comparisons' (Eltink, A.T.G.W. 2000). Additional analyses of age data were included in the form of age error matrices (AEM's).

Percentage Agreement (PA)

The percentage agreement per reader per modal age tells how large is the part of readings that are equal to the modal age. The percentage agreement is estimated by modal age and reader as the proportion (as percentage) of times that the lectures of that reader agreed with the resulting modal age. This percentage is estimated as the number of times that a reader agreed with the modal age divided by the total number of otoliths read by a reader for each modal age.

$$PA = \frac{number\ of\ readings\ that\ agree\ with\ modal\ age}{total\ number\ of\ readings\ by\ modal\ age} \cdot 100\%$$

Coefficient of Variation (CV)

The table presents the Coefficient of Variation (CV) per modal age and reader. The CV's are calculated as the ratio between the standard deviation (σ) and mean value (μ) per reader and modal age:

$$CV = \frac{\sigma}{\mu} \cdot 100\%$$

To the table is also added the CV of all readers combined per modal age and a weighted mean of the CV per reader.

Average Percentage Error (APE)

The Average Percentage Error (APE) was calculated based on the method outlined by Beamish & Fournier (1981). This method is dependent of fish age and thus provides a better estimate of precision than percentage agreement. As the calculations of both CV and APE pose problems if the mean age is close to 0, all observations for which modal age was 0 were omitted from the CV and APE calculations.

The average percentage error is calculated per image as:

$$APE = \frac{100\%}{n} \sum_{i=1}^{n} \left| \frac{a_i - \bar{a}}{\bar{a}} \right|$$

where a_i is the age reading of reader i and $\bar{a}$ is the mean of all readings from 1 to n.

Relative bias

The relative bias is calculated as the difference between the mean and the modal age. This statistic is presented in first place by modal age and reader, but it is also calculated as an average value by modal age for all readers together (or only advanced readers).

Age error matrix (AEM)

Age error matrices (AEM) were produced following procedures outlined by WKSABCAL (2014) where the matrix shows the proportion of each modal age mis-aged as other ages. The sum of each row is 1, which equals 100%. The age data was analysed only including the "advanced" readers. If a reader is "advanced" then they are considered well trained and they provide ages for stock assessment or similar purposes. When the AEM is compiled for assessment purposes it uses only those "advanced" readers who provide age data for the stock assessment for that specific stock.

4 Analysis of age calibration exercise

4.1 Overview of samples and readers

Table 4.1.1: Overview of samples used for the xxx exchange.

Year	ICES area	Strata	Quarter	Number of samples	Modal age range	Length range
2021	27.2.a	27.2.a	1	60	3-16	280-375 mm
2021	27.2.a	27.2.a	2	60	4-10	245-350 mm
2021	27.2.a	27.2.a	3	50	2-14	260-360 mm
2021	27.2.a	27.2.a	4	60	3-8	260-350 mm
2021	27.5.a	27.5.a	3	49	5-15	310-390 mm
2021	27.5.b	27.5.b	2	50	5-13	285-390 mm

Table 4.1.2: Reader overview.

Reader code	Expertise
R02 DK	Advanced
R04 GB	Advanced
R06 NO	Advanced
R08 NO	Advanced
R12 SE	Advanced
R14 IS	Basic
R18 DE	Advanced
R22 NO	Advanced
R28 IE	Basic
R30 IS	Basic
R36 NO	Advanced
R38 FO	Advanced
R40 FO	Advanced
R44 IE	Basic
R48 FO	Basic
R52 GB	Basic
R54 NO	Basic
R58 DE	Basic

4.2 Results

4.2.1 All readers

All samples included

The weighted average percentage agreement based on modal ages for all readers is 75% (Table 4.2.1), with the weighted average CV of 10% (Table 4.2.2) and APE of 5%. The PA decreased from above 70% to below 60% at age 9 and older which is not reflected in the CV which is relative constant but slightly higher at the weighted mean. Figure 4.2.1 shows the age bias plot for all readers and reflects the results in Table 4.2.3. Individual reader bias plots can be found in 6. Annex 1.

Table 4.2.1: Percentage agreement (PA) table represents the PA per modal age and reader, the PA of all readers combined per modal age and a weighted mean of the PA per reader. A rank is also assgned to each reader.

	R02	R04	R06	R08	R12	R14	R18	R22	R28	R30	R36	R38	R40	R44	R48	R52	R54	R58	
Modal age	**DK**	**GB**	**NO**	**NO**	**SE**	**IS**	**DE**	**NO**	**IE**	**IS**	**NO**	**FO**	**FO**	**IE**	**FO**	**GB**	**NO**	**DE**	**all**
2	100 %	50 %	100 %	100 %	100 %	50 %	100 %	0 %	0 %	50 %	0 %	0 %	100 %	0 %	100 %	-	0 %	100 %	**55 %**
3	100 %	100 %	83 %	100 %	83 %	100 %	100 %	83 %	50 %	100 %	80 %	50 %	83 %	100 %	100 %	50 %	67 %	83 %	**84 %**
4	100 %	90 %	100 %	80 %	100 %	80 %	90 %	90 %	60 %	80 %	80 %	70 %	70 %	90 %	100 %	44 %	80 %	80 %	**82 %**
5	82 %	87 %	98 %	98 %	98 %	98 %	98 %	100 %	59 %	94 %	98 %	85 %	97 %	78 %	98 %	72 %	95 %	78 %	**89 %**
6	60 %	80 %	75 %	65 %	85 %	84 %	70 %	79 %	55 %	75 %	68 %	80 %	65 %	55 %	67 %	72 %	58 %	60 %	**70 %**
7	73 %	90 %	81 %	73 %	90 %	81 %	83 %	71 %	67 %	66 %	67 %	83 %	74 %	57 %	80 %	65 %	76 %	63 %	**74 %**
8	74 %	91 %	86 %	86 %	97 %	95 %	86 %	93 %	66 %	88 %	91 %	72 %	88 %	33 %	100 %	56 %	65 %	59 %	**79 %**
9	67 %	67 %	48 %	38 %	90 %	62 %	76 %	68 %	62 %	19 %	65 %	57 %	67 %	26 %	60 %	55 %	50 %	48 %	**57 %**
10	50 %	42 %	33 %	33 %	67 %	42 %	73 %	18 %	42 %	17 %	0 %	67 %	33 %	17 %	50 %	33 %	42 %	25 %	**38 %**
11	50 %	50 %	31 %	43 %	71 %	50 %	77 %	45 %	29 %	29 %	60 %	50 %	23 %	7 %	75 %	33 %	43 %	36 %	**43 %**
12	50 %	80 %	78 %	30 %	50 %	40 %	30 %	44 %	60 %	50 %	56 %	60 %	40 %	10 %	50 %	57 %	11 %	40 %	**46 %**
13	17 %	67 %	50 %	33 %	67 %	50 %	83 %	50 %	33 %	50 %	60 %	33 %	33 %	0 %	0 %	50 %	33 %	17 %	**42 %**
14	25 %	0 %	50 %	25 %	50 %	75 %	75 %	0 %	50 %	25 %	0 %	75 %	75 %	0 %	-	75 %	25 %	0 %	**40 %**
15	50 %	0 %	50 %	50 %	0 %	0 %	50 %	100 %	0 %	100 %	100 %	0 %	100 %	0 %	-	0 %	100 %	0 %	**41 %**
16	0 %	100 %	0 %	100 %	0 %	100 %	100 %	0 %	100 %	100 %	0 %	0 %	0 %	0 %	-	0 %	0 %	0 %	**35 %**
Weighted Mean	**72 %**	**81 %**	**81 %**	**77 %**	**89 %**	**83 %**	**86 %**	**83 %**	**58 %**	**74 %**	**82 %**	**74 %**	**79 %**	**52 %**	**89 %**	**62 %**	**72 %**	**62 %**	**75 %**

Table 4.2.2: Coefficient of Variation (CV) table presents the CV per modal age and reader, the CV of all readers combined per modal age and a weighted mean of the CV per reader. A rank is also assigned to each reader.

	R02	R04	R06	R08	R12	R14	R18	R22	R28	R30	R36	R38	R40	R44	R48	R52	R54	R58	
Modal age	**DK**	**GB**	**NO**	**NO**	**SE**	**IS**	**DE**	**NO**	**IE**	**IS**	**NO**	**FO**	**FO**	**IE**	**FO**	**GB**	**NO**	**DE**	**all**
2	0 %	28 %	-	0 %	0 %	28 %	0 %	0 %	11 %	47 %	20 %	16 %	0 %	-	-	-	0 %	0 %	**45 %**
3	0 %	0 %	14 %	0 %	14 %	0 %	0 %	13 %	32 %	0 %	26 %	22 %	14 %	0 %	0 %	27 %	21 %	14 %	**19 %**
4	0 %	8 %	0 %	10 %	0 %	10 %	8 %	8 %	19 %	16 %	10 %	11 %	14 %	8 %	0 %	12 %	10 %	12 %	**10 %**
5	9 %	8 %	3 %	3 %	3 %	4 %	3 %	0 %	14 %	5 %	3 %	8 %	4 %	11 %	3 %	11 %	7 %	10 %	**8 %**
6	14 %	21 %	8 %	12 %	7 %	6 %	9 %	8 %	15 %	13 %	10 %	7 %	10 %	10 %	11 %	9 %	16 %	13 %	**12 %**
7	9 %	4 %	12 %	9 %	4 %	10 %	7 %	12 %	12 %	15 %	15 %	10 %	15 %	9 %	8 %	19 %	13 %	8 %	**12 %**
8	7 %	4 %	7 %	5 %	2 %	4 %	6 %	6 %	7 %	11 %	7 %	6 %	6 %	9 %	0 %	8 %	7 %	8 %	**7 %**
9	8 %	7 %	8 %	16 %	4 %	10 %	8 %	10 %	7 %	13 %	16 %	9 %	9 %	10 %	8 %	10 %	8 %	8 %	**11 %**
10	9 %	10 %	11 %	10 %	10 %	7 %	5 %	13 %	12 %	13 %	17 %	7 %	15 %	15 %	7 %	14 %	25 %	13 %	**15 %**
11	8 %	8 %	10 %	11 %	8 %	8 %	8 %	7 %	13 %	6 %	14 %	12 %	6 %	15 %	4 %	8 %	16 %	10 %	**12 %**
12	6 %	5 %	6 %	12 %	14 %	9 %	7 %	11 %	7 %	14 %	10 %	7 %	7 %	11 %	6 %	7 %	22 %	8 %	**12 %**
13	24 %	7 %	17 %	8 %	5 %	8 %	6 %	8 %	6 %	6 %	5 %	8 %	6 %	13 %	-	11 %	8 %	9 %	**12 %**
14	10 %	13 %	9 %	3 %	4 %	4 %	4 %	-	13 %	6 %	-	4 %	4 %	11 %	-	4 %	3 %	9 %	**10 %**
15	22 %	18 %	5 %	5 %	11 %	0 %	10 %	0 %	6 %	0 %	0 %	0 %	0 %	0 %	-	0 %	0 %	0 %	**11 %**
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**22 %**
Weighted Mean	**9 %**	**8 %**	**7 %**	**7 %**	**4 %**	**6 %**	**5 %**	**5 %**	**12 %**	**9 %**	**8 %**	**8 %**	**7 %**	**10 %**	**4 %**	**11 %**	**10 %**	**9 %**	**10 %**

Table 4.2.3: Relative bias table represents the relative bias per modal age per reader, the relative bias of all readers combined per modal age and a weighted mean of the relative bias per reader. A rank is also assigned to each reader.

	R02	R04	R06	R08	R12	R14	R18	R22	R28	R30	R36	R38	R40	R44	R48	R52	R54	R58	
Modal age	**DK**	**GB**	**NO**	**NO**	**SE**	**IS**	**DE**	**NO**	**IE**	**IS**	**NO**	**FO**	**FO**	**IE**	**FO**	**GB**	**NO**	**DE**	**all**
2	0.00	0.50	0.00	0.00	0.00	0.50	0.00	1.00	4.50	1.00	1.50	2.50	0.00	1.00	0.00	-	1.00	0.00	-
3	0.00	0.00	-0.17	0.00	-0.17	0.00	0.00	0.17	1.00	0.00	0.40	0.67	-0.17	0.00	0.00	0.00	0.00	-0.17	**0.09**
4	0.00	0.10	0.00	0.20	0.00	0.20	0.10	0.10	0.30	0.30	0.20	0.30	0.10	0.10	0.00	0.56	0.20	0.00	**0.15**
5	-0.11	-0.08	-0.02	0.00	-0.02	0.03	0.01	0.00	0.51	0.06	0.02	0.17	0.00	-0.03	-0.02	0.32	0.02	0.08	**0.05**
6	0.00	-0.05	-0.15	0.10	-0.05	0.16	0.10	0.11	0.20	0.30	0.00	0.20	-0.05	-0.35	0.00	-0.17	0.00	-0.15	**0.01**
7	-0.12	0.10	0.10	0.29	0.10	0.24	0.15	0.37	0.00	0.61	0.43	0.17	0.29	-0.40	0.15	-0.03	0.00	-0.27	**0.12**
8	-0.18	-0.02	-0.07	0.02	0.00	0.03	0.07	0.10	-0.28	0.28	0.14	-0.21	0.02	-0.62	0.00	-0.38	-0.30	-0.36	**-0.10**
9	-0.33	0.05	-0.24	1.00	0.00	0.24	0.38	0.53	-0.10	1.14	0.85	-0.10	0.19	-0.79	0.00	-0.15	-0.10	-0.62	**0.11**
10	-0.70	0.00	-0.17	1.17	-0.17	0.75	0.09	1.45	0.17	1.75	1.67	0.25	0.58	-1.33	0.50	-0.17	0.83	-0.50	**0.34**
11	-0.29	0.36	-0.38	1.14	-0.29	0.14	0.23	0.73	0.07	0.93	1.00	-0.21	0.69	-1.71	0.25	-0.56	0.93	-1.07	**0.11**
12	0.10	0.30	-0.33	0.80	-0.90	0.50	0.60	0.78	-0.30	1.70	0.89	-0.30	0.50	-1.90	0.50	-0.57	0.78	-0.90	**0.12**
13	-2.00	0.17	-1.33	0.50	0.00	0.33	0.33	1.00	-0.83	0.67	0.00	-0.50	1.00	-3.00	1.00	-1.00	0.50	-1.50	**-0.26**
14	-0.50	0.00	-0.25	0.75	-0.50	-0.25	0.25	1.00	-0.50	1.50	1.00	-0.25	0.25	-2.50	-	0.25	0.75	-2.50	-
15	-2.00	1.00	-0.50	0.50	-2.00	-1.00	-1.00	0.00	-2.50	0.00	0.00	-2.00	0.00	-4.00	-	-2.00	0.00	-2.00	-
16	-2.00	0.00	-4.00	0.00	-7.00	0.00	0.00	1.00	0.00	0.00	1.00	-1.00	-5.00	-2.00	-	-7.00	-8.00	-4.00	-
Weighted Mean	**-0.20**	**0.02**	**-0.11**	**0.25**	**-0.09**	**0.13**	**0.10**	**0.24**	**0.16**	**0.44**	**0.25**	**0.05**	**0.12**	**-0.54**	**0.05**	**-0.05**	**0.05**	**-0.29**	**0.05**

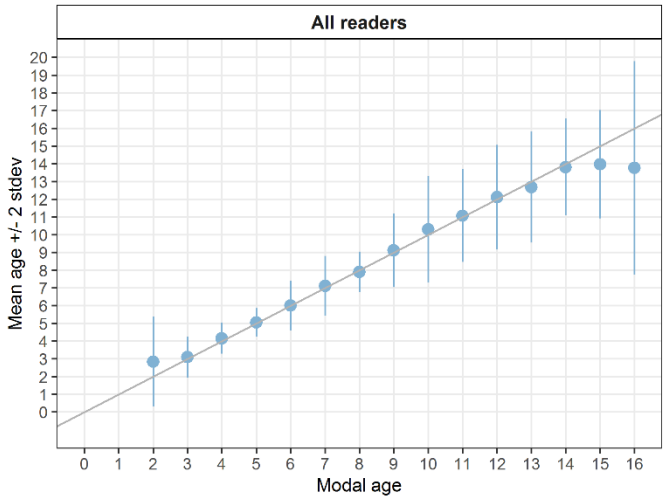


Figure 4.2.1: Age bias plot for all readers. Mean age recorded +/- 2 stdev of each reader and all readers combined are plotted against modal age. The estimated man age corresponds to modal age, if the estimated mean age is on the 1:1 equilibrium line (solid line). Relative bias is the age difference between estimated mean age and modal age.

4.2.2 Advanced readers

All samples included

For advanced readers only, the weighted average percentage agreement based on modal ages is 81% (Table 4.2.4), with the weighted average CV of 8% (Table 4.2.5) and APE of 4%. Again, the PA decreased from above 75% to below 65% at age 9 and older which is not reflected in the CV which is relative constant but slightly higher at the weighted mean. Figure 4.2.2 shows the age bias plot for all readers and reflects the results in Table 4.2.6.

Table 4.2.4: Percentage agreement (PA) table represents the PA per modal age and reader, advanced the PA of all advanced readers combined per modal age and a weighted mean of the PA per reader. A rank is also assgned to each reader.

Modal age	R02 DK	R04 GB	R06 NO	R08 NO	R12 SE	R18 DE	R22 NO	R36 NO	R38 FO	R40 FO	all
2	100 %	50 %	100 %	100 %	100 %	100 %	0 %	0 %	0 %	100 %	**63 %**
3	100 %	100 %	83 %	100 %	83 %	100 %	83 %	80 %	50 %	83 %	**86 %**
4	100 %	91 %	100 %	82 %	100 %	91 %	82 %	73 %	64 %	64 %	**85 %**
5	82 %	87 %	99 %	98 %	98 %	98 %	100 %	98 %	84 %	97 %	**94 %**
6	67 %	78 %	78 %	67 %	83 %	78 %	83 %	76 %	83 %	72 %	**77 %**
7	74 %	92 %	80 %	77 %	95 %	87 %	74 %	72 %	85 %	80 %	**82 %**
8	73 %	92 %	83 %	85 %	98 %	85 %	92 %	92 %	70 %	88 %	**86 %**
9	61 %	65 %	48 %	39 %	96 %	74 %	71 %	70 %	52 %	61 %	**64 %**
10	38 %	50 %	60 %	30 %	90 %	80 %	25 %	0 %	60 %	30 %	**49 %**
11	50 %	50 %	33 %	50 %	92 %	75 %	60 %	50 %	50 %	25 %	**54 %**
12	40 %	80 %	67 %	50 %	50 %	33 %	67 %	71 %	50 %	33 %	**54 %**
13	22 %	56 %	38 %	44 %	56 %	88 %	56 %	57 %	22 %	33 %	**47 %**
14	50 %	0 %	50 %	50 %	50 %	100 %	-	-	100 %	100 %	**62 %**
15	25 %	0 %	50 %	75 %	0 %	50 %	100 %	100 %	0 %	75 %	**45 %**
16	0 %	100 %	0 %	100 %	0 %	100 %	0 %	0 %	0 %	0 %	**30 %**
Weighted Mean	**72 %**	**81 %**	**81 %**	**80 %**	**91 %**	**87 %**	**85 %**	**84 %**	**72 %**	**79 %**	**81 %**

Table 4.2.5: Coefficient of Variation (CV) table presents the CV per modal age and advanced reader, the CV of all advanced readers combined per modal age and a weighted mean of the CV per reader. A rank is also assigned to each reader.

Modal age	R02 DK	R04 GB	R06 NO	R08 NO	R12 SE	R18 DE	R22 NO	R36 NO	R38 FO	R40 FO	all
2	0 %	28 %	-	0 %	0 %	0 %	0 %	20 %	16 %	0 %	**35 %**
3	0 %	0 %	14 %	0 %	14 %	0 %	13 %	26 %	22 %	14 %	**16 %**
4	0 %	7 %	0 %	10 %	0 %	7 %	10 %	11 %	12 %	14 %	**9 %**
5	9 %	8 %	2 %	3 %	3 %	3 %	0 %	3 %	8 %	4 %	**5 %**
6	14 %	23 %	8 %	10 %	7 %	8 %	6 %	8 %	6 %	9 %	**11 %**
7	9 %	4 %	13 %	6 %	3 %	6 %	12 %	13 %	10 %	15 %	**10 %**
8	7 %	4 %	7 %	6 %	2 %	6 %	6 %	8 %	6 %	6 %	**6 %**
9	9 %	11 %	7 %	16 %	2 %	8 %	10 %	15 %	8 %	10 %	**11 %**
10	10 %	7 %	6 %	9 %	3 %	4 %	11 %	17 %	6 %	15 %	**11 %**
11	9 %	8 %	10 %	12 %	3 %	9 %	7 %	13 %	9 %	7 %	**10 %**
12	9 %	5 %	6 %	10 %	15 %	8 %	9 %	9 %	7 %	9 %	**10 %**
13	22 %	13 %	19 %	7 %	17 %	5 %	8 %	7 %	10 %	7 %	**14 %**
14	5 %	16 %	11 %	5 %	5 %	0 %	-	-	0 %	0 %	**6 %**
15	13 %	15 %	4 %	3 %	7 %	7 %	0 %	0 %	4 %	3 %	**9 %**
16	-	-	-	-	-	-	-	-	-	-	**19 %**
Weighted Mean	**9 %**	**8 %**	**6 %**	**6 %**	**4 %**	**5 %**	**5 %**	**8 %**	**8 %**	**8 %**	**8 %**

Table 4.2.6: Relative bias table represents the relative bias per modal age and advanced reader, the relative bias of all advanced readers combined per modal age and a weighted mean of the relative bias per reader. A rank is also assigned to each reader.

Modal age	R02 DK	R04 GB	R06 NO	R08 NO	R12 SE	R18 DE	R22 NO	R36 NO	R38 FO	R40 FO	all
2	0.00	0.50	0.00	0.00	0.00	0.00	1.00	1.50	2.50	0.00	**0.55**
3	0.00	0.00	-0.17	0.00	-0.17	0.00	0.17	0.40	0.67	-0.17	**0.07**
4	0.00	0.09	0.00	0.18	0.00	0.09	0.18	0.27	0.36	0.18	**0.14**
5	-0.10	-0.06	-0.01	0.02	-0.01	0.02	0.00	0.02	0.17	0.00	**0.00**
6	0.00	-0.06	-0.11	0.00	-0.06	0.11	0.17	0.00	0.17	-0.06	**0.02**
7	-0.15	0.03	0.05	0.18	0.00	0.10	0.32	0.30	0.15	0.22	**0.12**
8	-0.22	-0.05	-0.10	0.05	-0.02	0.05	0.08	0.17	-0.23	0.02	**-0.03**
9	-0.22	0.22	-0.35	0.96	-0.04	0.30	0.48	0.70	-0.22	0.22	**0.20**
10	-0.50	0.10	0.20	1.10	0.10	0.20	1.62	1.67	0.20	0.50	**0.52**
11	-0.33	-0.08	-0.33	1.17	0.08	0.25	0.60	1.00	0.00	0.67	**0.30**
12	-0.40	0.30	-0.44	0.40	-1.40	0.33	0.33	0.57	-0.40	0.11	**-0.06**
13	-2.00	-0.44	-1.75	0.56	-0.89	0.25	0.89	0.29	-0.89	0.67	**-0.33**
14	0.50	-0.50	-1.00	0.50	-0.50	0.00	-	-	0.00	0.00	-
15	-2.25	0.25	-0.50	0.25	-1.75	-0.75	0.00	0.00	-1.75	-0.25	**-0.68**
16	-2.00	0.00	-4.00	0.00	-7.00	0.00	1.00	1.00	-1.00	-5.00	**-1.70**
Weighted Mean	**-0.23**	**-0.01**	**-0.14**	**0.22**	**-0.12**	**0.08**	**0.21**	**0.23**	**0.02**	**0.09**	**0.04**

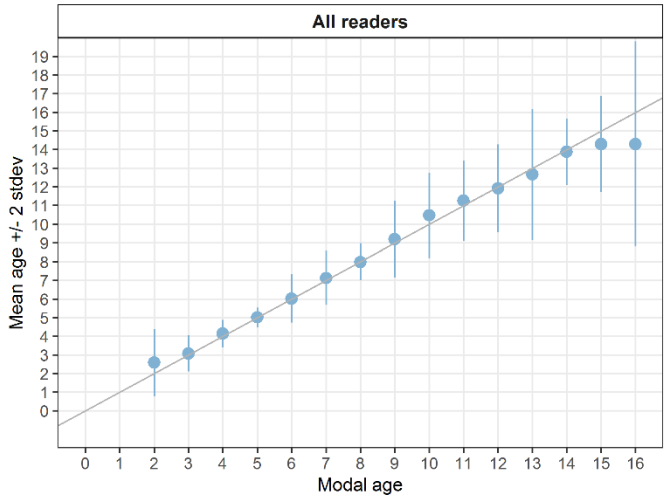


Figure 4.2.2: Age bias plot for advanced readers.

Table 4.2.7: General Age error matrix (AEM). The modal age is in rows and the age classifications by the advanced readers in columns. Only advanced readers are used for calculating the AEM.

Modal age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
2	-	0.63	0.21	0.11	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00
3	-	0.05	0.86	0.05	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	0.99
4	-	-	0.01	0.85	0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	1.01
5	-	-	-	0.03	0.94	0.03	0.00	-	-	-	-	-	-	-	-	-	-	-	1.00
6	0.01	-	-	0.01	0.09	0.77	0.12	0.01	-	-	-	-	-	-	-	-	-	-	1.01
7	-	-	-	-	0.01	0.05	0.82	0.10	0.01	0.01	-	0.01	0.00	-	-	-	-	-	1.01
8	-	-	-	-	-	0.00	0.09	0.86	0.03	0.01	0.01	0.00	-	-	-	-	-	-	1.00
9	-	-	-	-	-	-	0.01	0.14	0.64	0.12	0.04	0.03	0.00	-	0.01	-	-	-	0.99
10	-	-	-	-	-	-	-	0.02	0.16	0.51	0.22	0.07	0.02	-	-	-	-	-	1.00
11	-	-	-	-	-	-	-	-	0.04	0.15	0.53	0.15	0.09	0.03	0.03	-	-	-	1.02
12	-	-	-	-	-	-	-	0.01	0.02	0.08	0.16	0.55	0.14	0.01	0.02	-	-	-	0.99
13	-	-	-	-	-	-	0.02	0.03	0.02	0.01	0.05	0.16	0.47	0.10	0.13	-	-	-	0.99
14	-	-	-	-	-	-	-	-	-	0.04	0.04	0.16	0.12	0.48	0.16	-	-	-	1.00
15	-	-	-	-	-	-	-	-	-	-	0.03	0.05	0.18	0.21	0.45	0.05	-	0.03	1.00
16	-	-	-	-	-	-	-	-	0.10	-	0.10	0.10	-	0.10	0.10	0.30	0.2	-	1.00

5 References

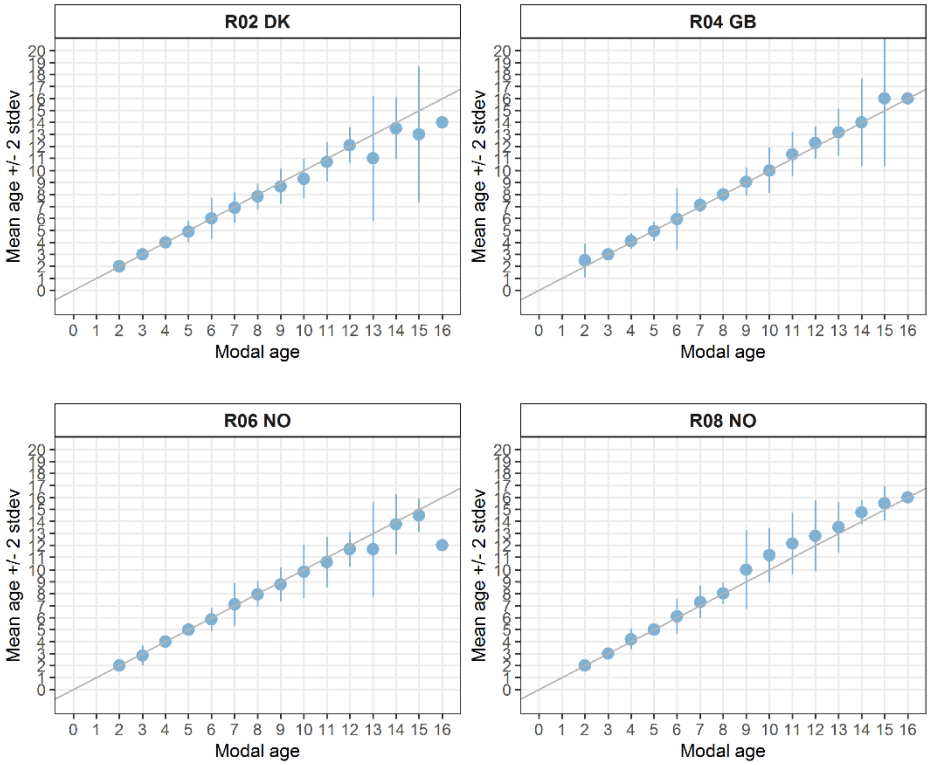
Beamish R. J. and Fournier D. A. (1981) A method for comparing the precision of a set of age determination. Canadian Journal of Fisheries and Aquatic Sciences, 38, 982–983

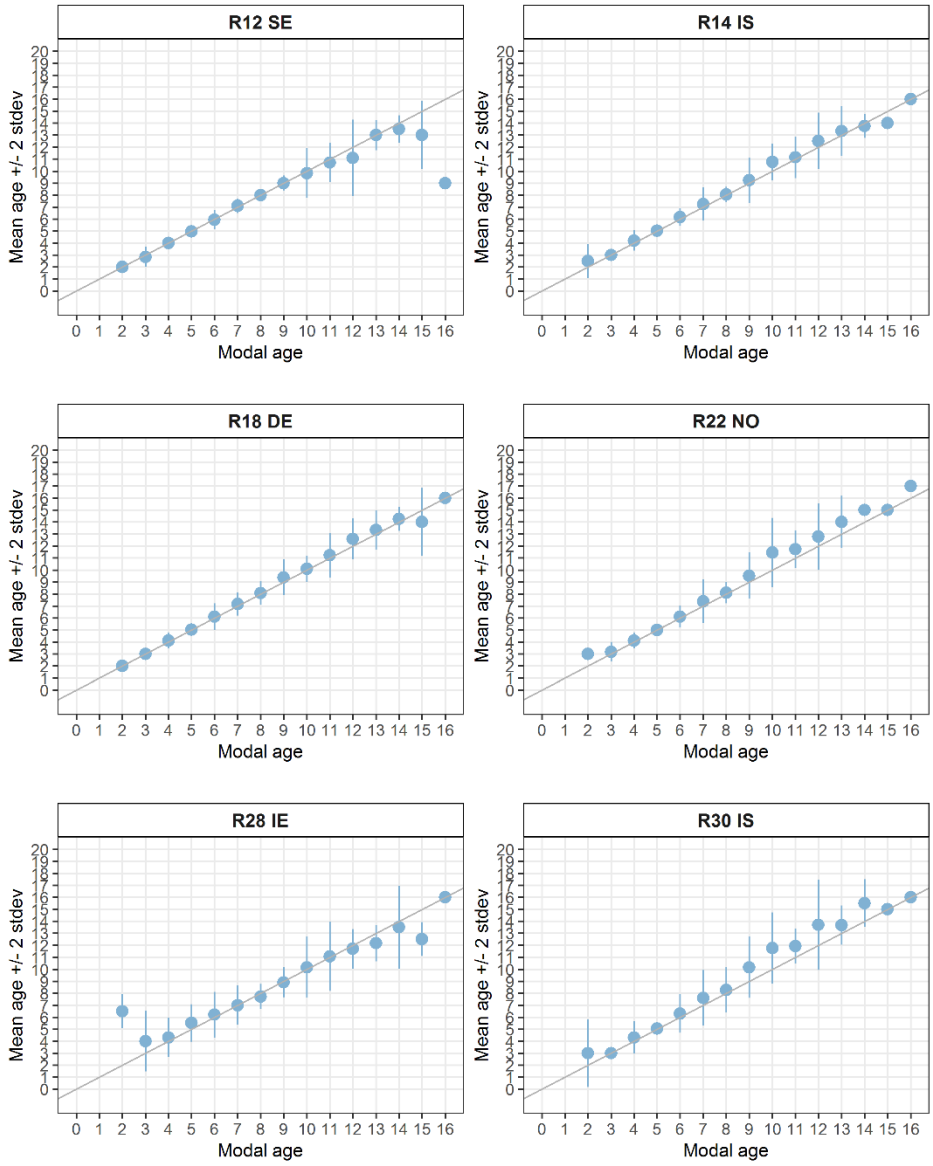
Eltink G. W. (2000) Age reading comparisons. (MS Excel workbook version 1.0 October 2000)

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

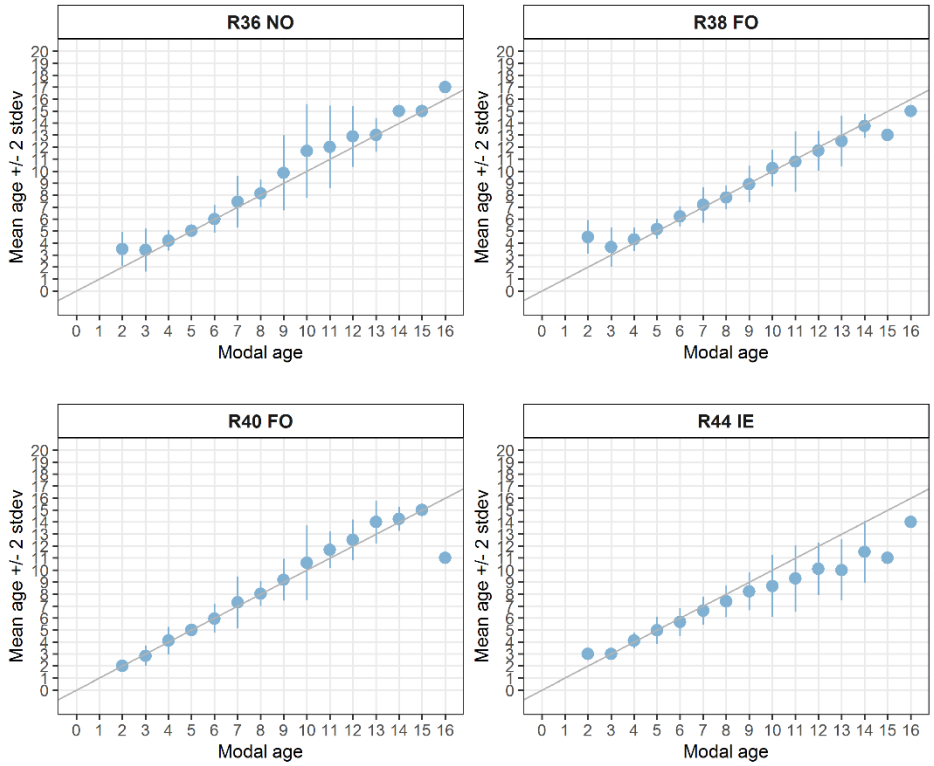
6 Annex 1. Additional results

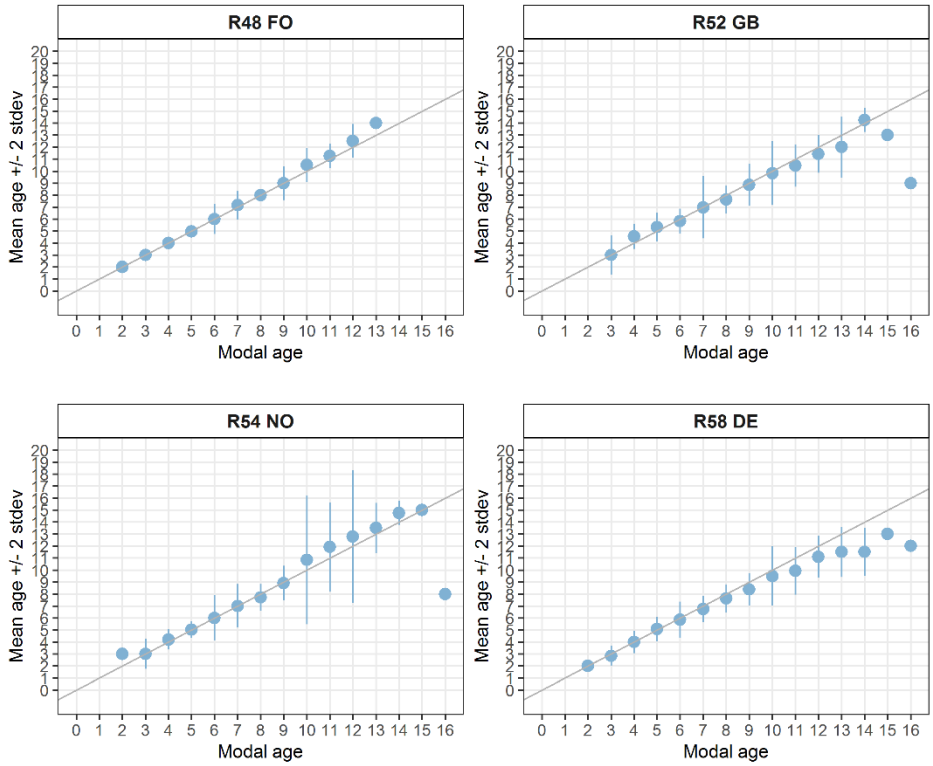
6.1 Results all readers




R12 SE
R14 IS
R18 DE
R22 NO
R28 IE
R30 IS
Mean age +/- 2 stdev
Modal age

18


R36 NO
R38 FO
R40 FO
R44 IE
Mean age +/- 2 stdev
Modal age


R48 FO
R52 GB
R54 NO
R58 DE
Mean age +/- 2 stdev
Modal age

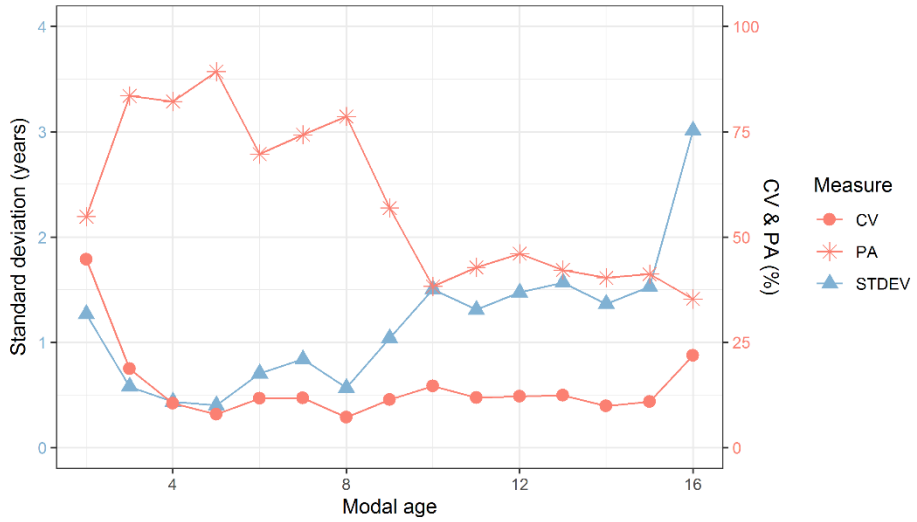


Figure 6.1.1: CV, PA and (STDEV (standard deviation) are plotted against modal age

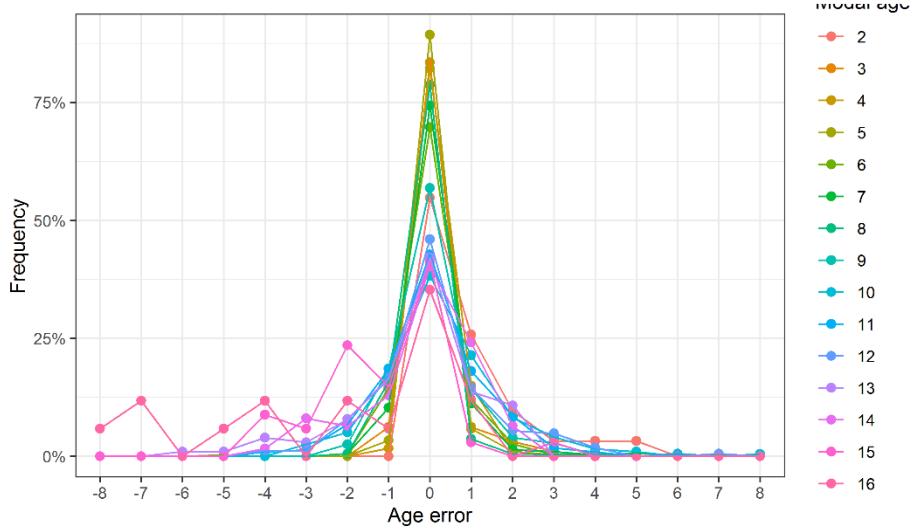


Figure 6.1.2: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age.

6.2 Results Advanced readers

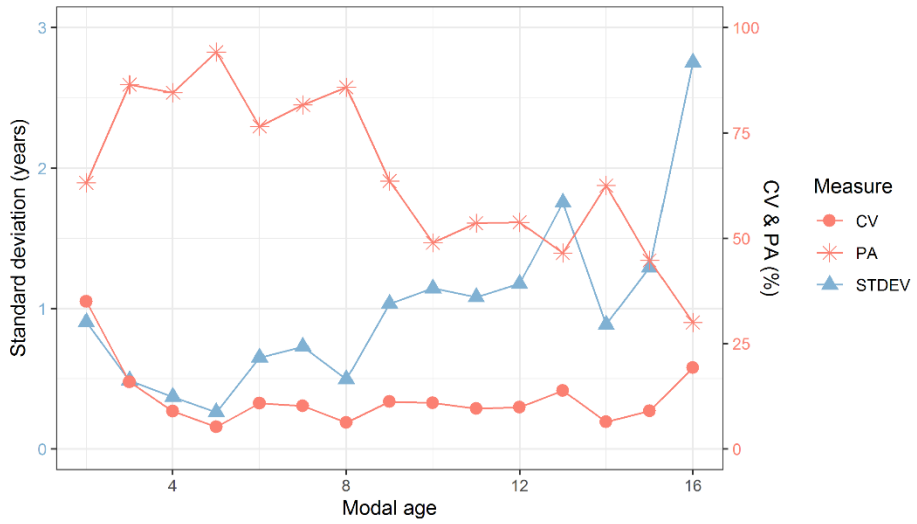


Figure 6.2.1: CV, PA and (STDEV (standard deviation) are plotted against modal age

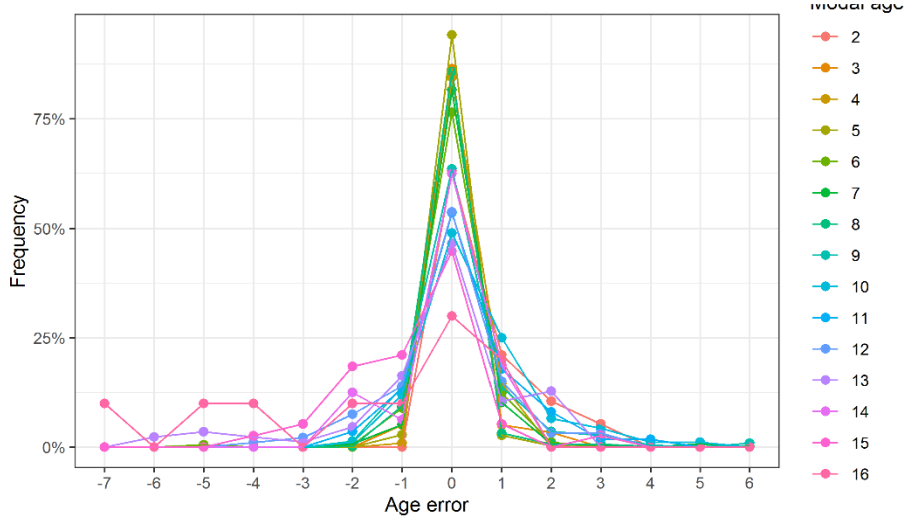


Figure 6.2.2: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age.

Annex 5: Scale exchange report

SmartDots Report for the 2023 scale exchange for Norwegian spring-spawning herring stock *her.27.1-24a514a* (event 448)

Coordination and analysis: Florian Berg, Institute for Marine Research, Bergen, Norway, florian.berg@hi.no

Table of Contents

1 Executive summary

The 2023 scales exchange for the Norwegian spring-spawning herring (*Clupea harengus*) stock *her.27.1-24a514a* took place via the SmartDots platform between August 2022 and March 2023. The exchange was organised following a recommendation from WGWIDE to calibrate age reading especially during May where a potential issue with the interpretation of the new growth zone might exist. Nine readers from three countries (Faroes Islands, Iceland, Norway) took part; six "advanced" readers (providing age data for the assessment) and three "basic" readers (do not provide age date for the assessment). For this exchange, advance readers had access to the physical material, while basic readers only had access to the digital images via SmartDots. A total of 255 scales, covering commercial samples from 1st and 4th quarter of the year and the two international surveys (IESNS in May and IESSNS in July) providing biomass estimates, were age determined using SmartDots and physical material provided. Norway and Iceland are the two institutes who mainly use scales for age estimation.

The overall agreement (PA) among all readers was 80%, with a weighted average CV of 9% and APE of 4%. The agreement among advanced readers was 88%. Agreement with the modal age was highest from age five to seven years and decreased in older individuals. However, high quality scales in several cases of older individuals had a high PA among readers. The results of this exchange demonstrated that there is no issue with new growth occurring in May. All readers interpreted the new growth similarly resulting in high PA among samples from May.

The results if this exchange were presented and discussed at the WKARNSSH (Workshop on age reading of Norwegian spring-spawning herring) in April 2023.

2 Introduction

Ageing of calcified structures in fish, such as otoliths or scales, is the backbone of most stock assessment models. Age-based information are used to infer stock dynamics and status. One of the main objectives for the age reader community is to achieve consistency between age readers estimating the age of a certain species or stock and to minimize the amount of bias in the age data which is used in stock assessment. Such bias can have serious consequences for the scientific advice which is used for the management of fish stocks. The aim of this age reading exchange was to address potential age reading issues apparent with the Norwegian spring-spawning (NSS) herring stock and thus minimize the bias associated with the age data provided to WGWIDE for the assessment of the stock. Especially for NSS herring potential issues exist that can bias the age reading, e.g., different calcified structures are used (otoliths and scales), stock mixing occurs during specific time periods and areas, different interpretations of the first winter ring, are different interpretations of the new annual growth occurring during the international survey IESNS in May. Particularly, the stock mixing issue and how these data are passed on to the stock coordinators needs to be explored further given the serious implications for the quality of the assessment both in terms of age and stock structure. In addition to this scale exchange, an exchange with NSS herring otoliths (event 447) was conducted at the same time and their results were compared and discussed at the WKARNSSH (Workshop on age reading of Norwegian spring-spawning herring) in April 2023.

3 Methods

Results presented here are based on output from SmartDots and a standardised r-script. The analysis follows traditional methods where the level of accuracy compared to modal age is indicated by percentage agreement (PA), bias tests and plots, and the level of precision, i.e. the reproducibility of age estimates is indicated by the coefficient of variation (CV). The tables and plots presented are from the Guus Eltink Excel sheet 'Age Reading Comparisons' (Eltink, A.T.G.W. 2000). Additional analyses of age data were included in the form of age error matrices (AEM's).

Percentage Agreement (PA)

The percentage agreement per reader per modal age tells how large is the part of readings that are equal to the modal age. The percentage agreement is estimated by modal age and reader as the proportion (as percentage) of times that the lectures of that reader agreed with the resulting modal age. This percentage is estimated as the number of times that a reader agreed with the modal age divided by the total number of otoliths read by a reader for each modal age.

$$PA = \frac{number\ of\ readings\ that\ agree\ with\ modal\ age}{total\ number\ of\ readings\ by\ modal\ age} \cdot 100\%$$

Coefficient of Variation (CV)

The table presents the Coefficient of Variation (CV) per modal age and reader. The CV's are calculated as the ratio between the standard deviation (σ) and mean value (μ) per reader and modal age:

$$CV = \frac{\sigma}{\mu} \cdot 100\%$$

To the table is also added the CV of all readers combined per modal age and a weighted mean of the CV per reader.

Average Percentage Error (APE)

The Average Percentage Error (APE) was calculated based on the method outlined by Beamish & Fournier (1981). This method is dependent of fish age and thus provides a better estimate of precision than percentage agreement. As the calculations of both CV and APE pose problems if the mean age is close to 0, all observations for which modal age was 0 were omitted from the CV and APE calculations.

The average percentage error is calculated per image as:

$$APE = \frac{100\%}{n} \sum_{i=1}^{n} \left| \frac{a_i - \bar{a}}{\bar{a}} \right|$$

where a_i is the age reading of reader i and $\bar{a}$ is the mean of all readings from 1 to n.

Relative bias

The relative bias is calculated as the difference between the mean and the modal age. This statistic is presented in first place by modal age and reader, but it is also calculated as an average value by modal age for all readers together (or only advanced readers).

Age error matrix (AEM)

Age error matrices (AEM) were produced following procedures outlined by WKSABCAL (2014) where the matrix shows the proportion of each modal age mis-aged as other ages. The sum of each row is 1, which equals 100%. The age data was analysed only including the "advanced" readers. If a reader is "advanced" then they are considered well trained and they provide ages for stock assessment or similar purposes. When the AEM is compiled for assessment purposes it uses only those "advanced" readers who provide age data for the stock assessment for that specific stock.

4 Analysis of age calibration exercise

4.1 Overview of samples and readers

Table 4.1.1: Overview of samples used for the xxx exchange.

Year	ICES area	Strata	Quarter	Number of samples	Modal age range	Length range
2021	27.2.a	27.2.a	1	60	3-16	280-375 mm
2021	27.2.a	27.2.a	2	60	4-9	245-350 mm
2021	27.2.a	27.2.a	4	60	3-8	260-350 mm
2021	27.5.a	27.5.a	3	48	4-15	310-390 mm
2021	27.5.b	27.5.b	2	27	5-15	285-390 mm

Table 4.1.2: Reader overview.

Reader code	Expertise
R02 NO	Advanced
R04 NO	Advanced
R08 IS	Advanced
R14 NO	Advanced
R16 NO	Basic
R18 IS	Advanced
R24 NO	Advanced
R30 FO	Basic
R32 FO	Basic

4.2 Results

4.2.1 All readers

All samples included

The weighted average percentage agreement based on modal ages for all readers is 80% (Table 4.2.1), with the weighted average CV of 9% (Table 4.2.2) and APE of 4%. The PA decreased from above 70% to below 60% at age 10 and older which is not reflected in the CV which is relative constant but slightly higher at the weighted mean. Figure 4.2.1 shows the age bias plot for all readers and reflects the results in Table 4.2.3. Individual reader bias plots can be found in 6. Annex 1.

Table 4.2.1: Percentage agreement (PA) table represents the PA per modal age and reader, the PA of all readers combined per modal age and a weighted mean of the PA per reader.

Modal age	R02 NO	R04 NO	R08 IS	R14 NO	R16 NO	R18 IS	R24 NO	R30 FO	R32 FO	all
3	67 %	100 %	100 %	67 %	67 %	100 %	33 %	33 %	67 %	**70 %**
4	83 %	100 %	83 %	33 %	100 %	83 %	50 %	80 %	33 %	**72 %**
5	96 %	98 %	98 %	98 %	80 %	96 %	97 %	90 %	88 %	**93 %**
6	100 %	100 %	86 %	100 %	57 %	100 %	86 %	75 %	88 %	**88 %**
7	70 %	95 %	85 %	90 %	70 %	85 %	95 %	80 %	70 %	**82 %**
8	77 %	77 %	92 %	94 %	41 %	93 %	90 %	49 %	51 %	**74 %**
9	86 %	71 %	86 %	100 %	67 %	86 %	86 %	29 %	43 %	**73 %**
10	50 %	50 %	88 %	50 %	57 %	100 %	62 %	38 %	38 %	**58 %**
11	43 %	75 %	89 %	70 %	50 %	50 %	29 %	22 %	40 %	**53 %**
12	67 %	60 %	33 %	50 %	44 %	64 %	71 %	30 %	36 %	**50 %**
13	29 %	75 %	86 %	57 %	14 %	80 %	60 %	29 %	29 %	**48 %**
14	0 %	67 %	67 %	0 %	0 %	0 %	0 %	67 %	67 %	**35 %**
15	50 %	57 %	25 %	100 %	14 %	62 %	100 %	38 %	25 %	**50 %**
16	0 %	0 %	100 %	0 %	100 %	-	0 %	0 %	0 %	**25 %**
Weighted Mean	**80 %**	**87 %**	**89 %**	**88 %**	**63 %**	**89 %**	**87 %**	**68 %**	**67 %**	**80 %**

Table 4.2.2: Coefficient of Variation (CV) table presents the CV per modal age and reader, the CV of all readers combined per modal age and a weighted mean of the CV per reader.

Modal age	R02 NO	R04 NO	R08 IS	R14 NO	R16 NO	R18 IS	R24 NO	R30 FO	R32 FO	all
3	31 %	0 %	0 %	17 %	17 %	0 %	25 %	33 %	43 %	**25 %**
4	10 %	0 %	11 %	11 %	0 %	11 %	12 %	11 %	28 %	**17 %**
5	5 %	3 %	3 %	3 %	10 %	4 %	3 %	6 %	9 %	**6 %**
6	0 %	0 %	6 %	0 %	12 %	0 %	6 %	24 %	31 %	**15 %**
7	10 %	3 %	8 %	5 %	7 %	6 %	3 %	6 %	8 %	**7 %**
8	9 %	8 %	5 %	8 %	12 %	3 %	5 %	13 %	16 %	**10 %**
9	4 %	6 %	4 %	0 %	7 %	4 %	4 %	10 %	12 %	**8 %**
10	18 %	10 %	4 %	9 %	11 %	0 %	9 %	11 %	19 %	**12 %**
11	17 %	8 %	6 %	4 %	15 %	7 %	6 %	12 %	13 %	**11 %**
12	7 %	7 %	6 %	14 %	8 %	10 %	9 %	11 %	17 %	**11 %**
13	18 %	7 %	6 %	10 %	19 %	7 %	8 %	11 %	13 %	**12 %**
14	10 %	4 %	13 %	-	4 %	0 %	0 %	4 %	18 %	**13 %**
15	12 %	8 %	11 %	0 %	23 %	6 %	0 %	18 %	13 %	**13 %**
16	-	-	-	-	-	-	-	-	-	**19 %**
Weighted Mean	**8 %**	**4 %**	**5 %**	**5 %**	**11 %**	**4 %**	**5 %**	**10 %**	**13 %**	**9 %**

Table 4.2.3: Relative bias table represents the relative bias per modal age per reader, the relative bias of all readers combined per modal age and a weighted mean of the relative bias per reader.

Modal age	R02 NO	R04 NO	R08 IS	R14 NO	R16 NO	R18 IS	R24 NO	R30 FO	R32 FO	all
3	0.67	0.00	0.00	0.33	0.33	0.00	1.00	0.00	1.00	**0.37**
4	0.17	0.00	-0.17	0.67	0.00	-0.17	0.50	0.20	1.33	**0.28**
5	0.02	0.00	0.00	0.00	0.10	0.00	0.03	0.01	0.05	**0.02**
6	0.00	0.00	-0.14	0.00	-0.14	0.00	0.14	0.38	0.75	**0.11**
7	-0.15	0.05	0.00	0.00	-0.30	0.05	0.05	-0.10	-0.10	**-0.06**
8	-0.26	-0.06	-0.06	0.14	-0.45	0.02	0.08	-0.30	0.06	**-0.09**
9	-0.14	0.00	-0.14	0.00	0.00	0.14	0.14	-1.00	-1.00	**-0.22**
10	0.50	-0.12	-0.12	0.38	0.43	0.00	0.62	-0.88	-0.50	**0.03**
11	-0.57	-0.12	0.22	0.30	0.00	0.70	0.86	-0.89	-0.40	**0.01**
12	-0.22	-0.10	-0.44	0.50	0.56	0.73	0.57	-0.70	-1.00	**-0.01**
13	-0.57	0.50	-0.29	0.29	-0.29	0.40	0.20	-0.86	-1.14	**-0.20**
14	3.00	-0.33	-1.00	-1.00	2.50	1.00	1.00	-0.33	-1.33	**0.39**
15	-0.12	-0.43	-1.00	0.00	1.00	-0.25	0.00	-1.75	-1.75	**-0.48**
16	-4.00	-2.00	0.00	1.00	0.00	-	1.00	-1.00	-7.00	-
Weighted Mean	**-0.05**	**-0.04**	**-0.09**	**0.10**	**0.00**	**0.08**	**0.15**	**-0.25**	**-0.14**	**-0.02**

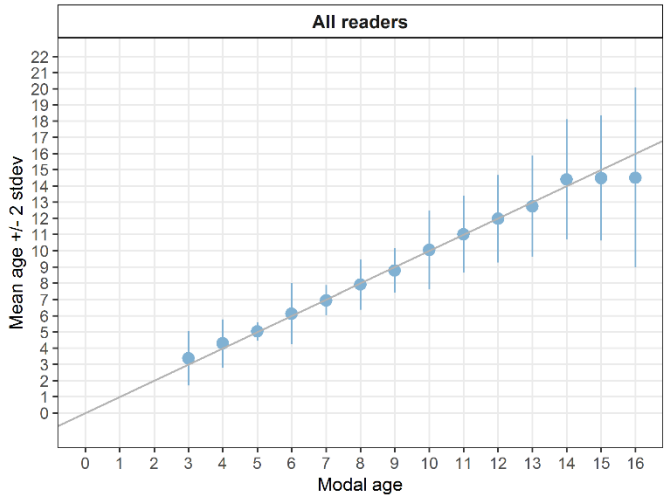


Figure 4.2.1: Age bias plot for all readers. Mean age recorded +/- 2 stdev of each reader and all readers combined are plotted against modal age. The estimated man age corresponds to modal age, if the estimated mean age is on the 1:1 equilibrium line (solid line). Relative bias is the age difference between estimated mean age and modal age.

4.2.2 Advanced readers

All samples included

For advanced readers only, the weighted average percentage agreement based on modal ages is 88% (Table 4.2.4), with the weighted average CV of 6% (Table 4.2.5) and APE of 3%. Again, the PA decreased from above 75% to below 65% at age 10 and older which is not reflected in the CV which is relative constant but slightly higher at the weighted mean. Figure 4.2.2 shows the age bias plot for all readers and reflects the results in Table 4.2.6.

Table 4.2.4: Percentage agreement (PA) table represents the PA per modal age and reader, advanced the PA of all advanced readers combined per modal age and a weighted mean of the PA per reader. A rank is also assgned to each reader.

Modal age	R02 NO	R04 NO	R08 IS	R14 NO	R18 IS	R24 NO	all
3	50 %	75 %	100 %	50 %	100 %	25 %	**67 %**
4	67 %	83 %	100 %	50 %	100 %	50 %	**75 %**
5	95 %	98 %	99 %	99 %	97 %	97 %	**98 %**
6	100 %	100 %	86 %	100 %	100 %	86 %	**95 %**
7	72 %	100 %	94 %	94 %	94 %	100 %	**93 %**
8	73 %	77 %	94 %	94 %	96 %	90 %	**87 %**
9	67 %	56 %	88 %	89 %	78 %	75 %	**75 %**
10	50 %	50 %	88 %	50 %	100 %	62 %	**65 %**
11	43 %	83 %	88 %	78 %	62 %	40 %	**67 %**
12	67 %	70 %	27 %	60 %	82 %	75 %	**63 %**
13	33 %	100 %	67 %	80 %	80 %	60 %	**68 %**
14	0 %	100 %	100 %	0 %	50 %	0 %	**36 %**
15	44 %	50 %	22 %	100 %	70 %	100 %	**62 %**
16	-	-	-	-	-	-	-
17	0 %	0 %	0 %	100 %	-	100 %	**40 %**
Weighted Mean	**78 %**	**86 %**	**89 %**	**90 %**	**93 %**	**88 %**	**88 %**

Table 4.2.5: Coefficient of Variation (CV) table presents the CV per modal age and advanced reader, the CV of all advanced readers combined per modal age and a weighted mean of the CV per reader.

Modal age	R02 NO	R04 NO	R08 IS	R14 NO	R18 IS	R24 NO	all
3	26 %	15 %	0 %	26 %	0 %	23 %	**22 %**
4	12 %	10 %	0 %	12 %	0 %	12 %	**10 %**
5	5 %	3 %	2 %	2 %	3 %	3 %	**3 %**
6	0 %	0 %	6 %	0 %	0 %	6 %	**4 %**
7	8 %	0 %	7 %	3 %	3 %	0 %	**5 %**
8	11 %	7 %	4 %	6 %	3 %	4 %	**6 %**
9	13 %	7 %	4 %	7 %	14 %	5 %	**9 %**
10	18 %	10 %	4 %	9 %	0 %	9 %	**10 %**
11	17 %	8 %	6 %	4 %	8 %	5 %	**9 %**
12	7 %	5 %	7 %	9 %	5 %	4 %	**7 %**
13	21 %	0 %	8 %	7 %	7 %	8 %	**10 %**
14	15 %	-	0 %	10 %	5 %	0 %	**6 %**
15	15 %	7 %	13 %	0 %	5 %	0 %	**10 %**
16	-	-	-	-	-	-	-
17	-	-	-	-	-	-	**14 %**
Weighted Mean	**9 %**	**4 %**	**4 %**	**4 %**	**4 %**	**4 %**	**6 %**

Table 4.2.6: Relative bias table represents the relative bias per modal age and advanced reader, the relative bias of all advanced readers combined per modal age and a weighted mean of the relative bias per reader. A rank is also assigned to each reader.

Modal age	R02 NO	R04 NO	R08 IS	R14 NO	R18 IS	R24 NO	all
3	0.75	0.25	0.00	0.75	0.00	1.25	**0.50**
4	0.33	0.17	0.00	0.50	0.00	0.50	**0.25**
5	0.02	0.00	0.01	0.01	0.01	0.03	**0.01**
6	0.00	0.00	-0.14	0.00	0.00	0.14	**0.00**
7	-0.06	0.00	-0.11	-0.06	-0.06	0.00	**-0.05**
8	-0.33	-0.12	-0.08	0.06	0.00	0.02	**-0.08**
9	0.11	0.22	-0.12	0.22	0.56	0.25	**0.21**
10	0.50	-0.12	-0.12	0.38	0.00	0.62	**0.21**
11	-0.57	-0.33	0.25	0.22	0.62	0.60	**0.13**
12	-0.22	-0.10	-0.36	0.40	0.27	0.25	**0.04**
13	0.17	0.00	-0.17	0.40	0.40	0.20	**0.17**
14	0.50	0.00	0.00	0.00	0.50	1.00	**0.33**
15	0.22	-0.60	-1.44	0.00	0.00	0.00	**-0.30**
16	-	-	-	-	-	-	-
17	-5.00	-3.00	-1.00	0.00	-	0.00	-
Weighted Mean	**-0.05**	**-0.06**	**-0.10**	**0.09**	**0.07**	**0.12**	**0.02**

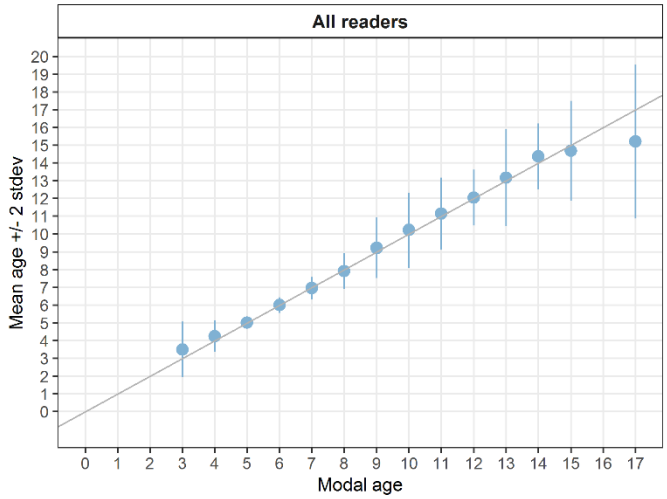


Figure 4.2.2: Age bias plot for advanced readers.

Table 4.2.7: General Age error matrix (AEM). The modal age is in rows and the age classifications by the advanced readers in columns. Only advanced readers are used for calculating the AEM.

Modal age	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
3	0.7	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
4	-	0.8	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
5	-	0.0	1.0	0.0	0.0	-	-	-	-	-	-	-	-	-	-	-	-	1
6	-	-	0.0	0.9	0.0	-	-	-	-	-	-	-	-	-	-	-	-	1
7	-	-	0.0	0.0	0.9	0.0	-	-	-	-	-	-	-	-	-	-	-	1
8	-	-	0.0	0.0	0.1	0.9	0.0	-	0.0	-	-	-	-	-	-	-	-	1
9	-	-	-	-	-	0.1	0.8	0.1	0.0	0.0	0.0	-	-	-	-	-	-	1
10	-	-	-	-	-	0.0	0.1	0.7	0.1	0.1	-	-	0.0	-	-	-	-	1
11	-	-	-	-	0.0	-	0.0	-	0.7	0.2	0.1	-	-	-	-	-	-	1
12	-	-	-	-	-	-	-	0.0	0.2	0.6	0.1	0.0	0.0	-	-	-	-	1
13	-	-	-	-	-	0.0	-	-	0.0	0.0	0.7	0.1	0.1	0.0	-	-	-	1
14	-	-	-	-	-	-	-	-	-	-	0.2	0.4	0.4	0.1	-	-	-	1
15	-	-	-	-	-	-	-	-	0.0	0.0	0.1	0.1	0.6	0.1	-	0	0	1
17	-	-	-	-	-	-	-	-	-	0.2	-	0.2	-	0.2	0.4	-	-	1

5 References

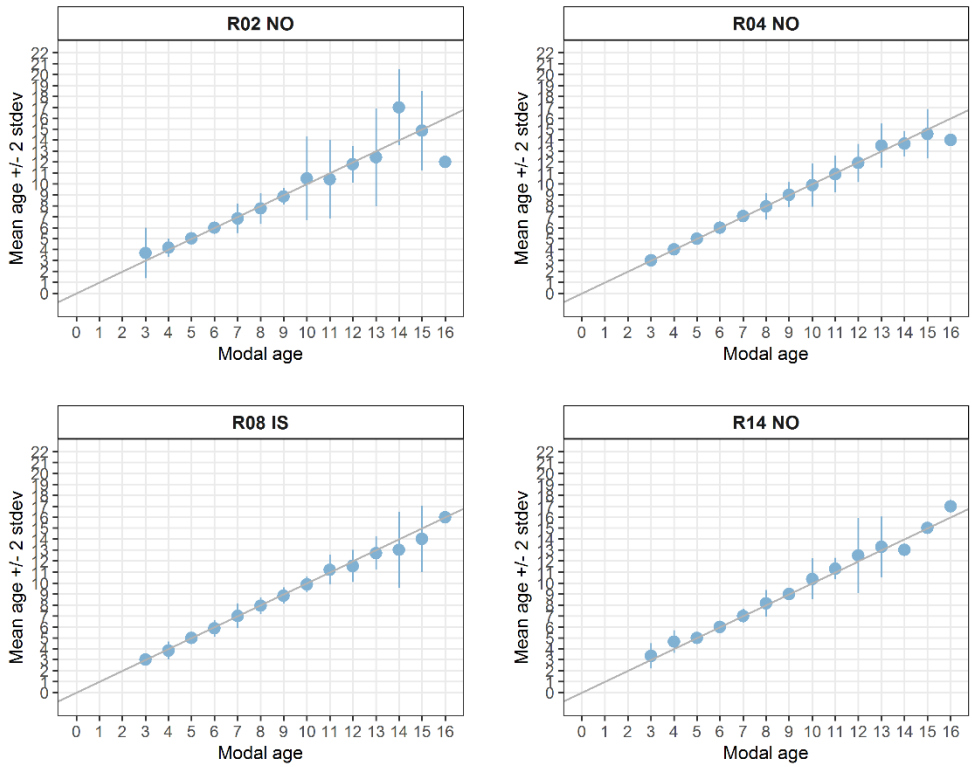
Beamish R. J. and Fournier D. A. (1981) A method for comparing the precision of a set of age determination. Canadian Journal of Fisheries and Aquatic Sciences, 38, 982–983

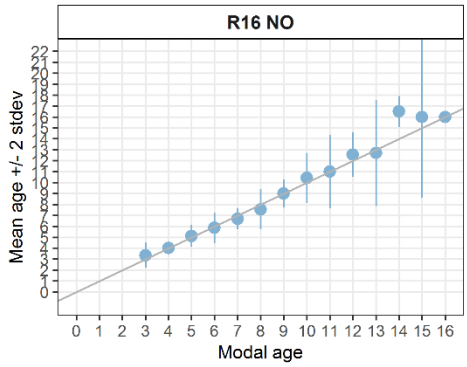
Eltink G. W. (2000) Age reading comparisons. (MS Excel workbook version 1.0 October 2000)

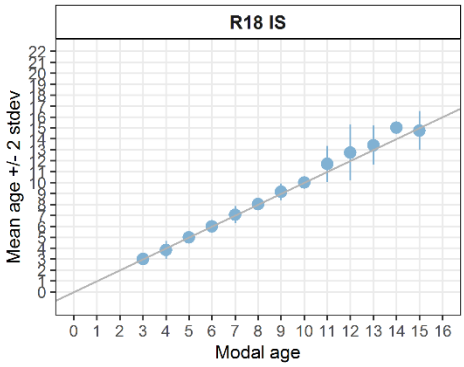
ICES (2014) Report of the Workshop on Statistical Analysis of Biological Calibration Studies (WKSABCAL). ICES CM 2014/ACOM:35

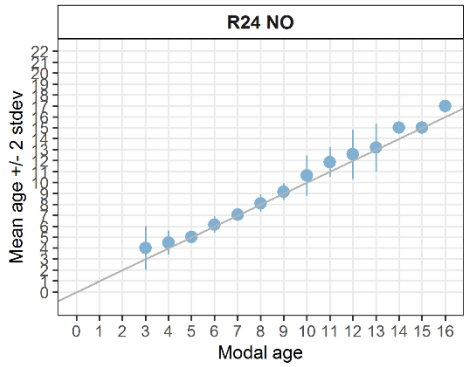
6 Annex 1. Additional results

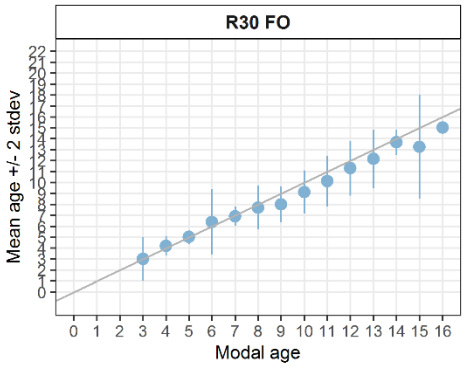
6.1 Results all readers

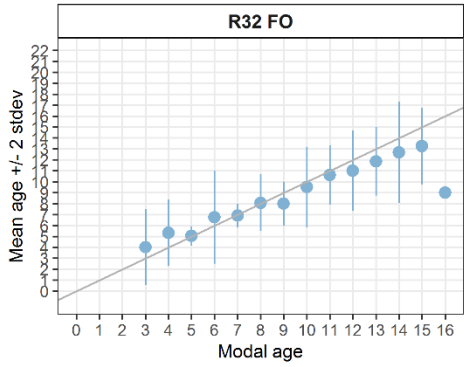



R16 NO
Mean age +/- 2 stdev
Modal age


R18 IS
Mean age +/- 2 stdev
Modal age


R24 NO
Mean age +/- 2 stdev
Modal age


R30 FO
Mean age +/- 2 stdev
Modal age


R32 FO
Mean age +/- 2 stdev
Modal age

17

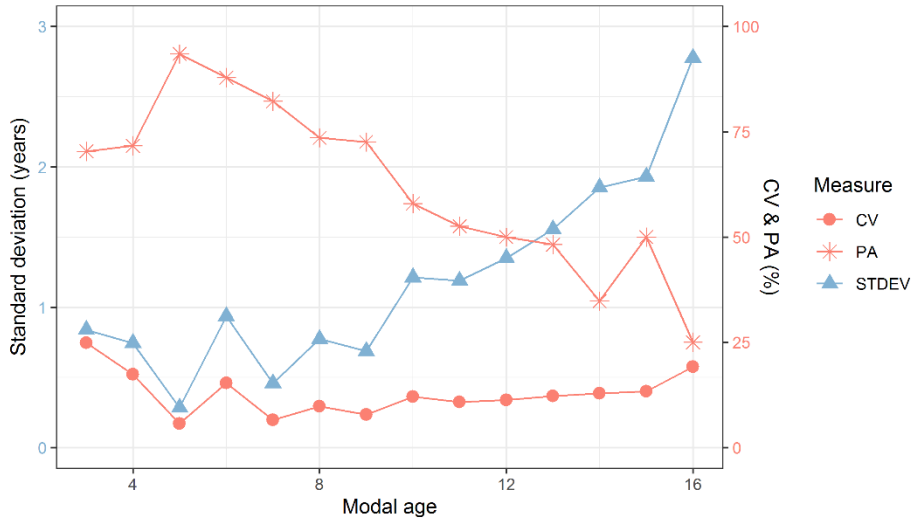


Figure 6.1.1: CV, PA and (STDEV (standard deviation) are plotted against modal age

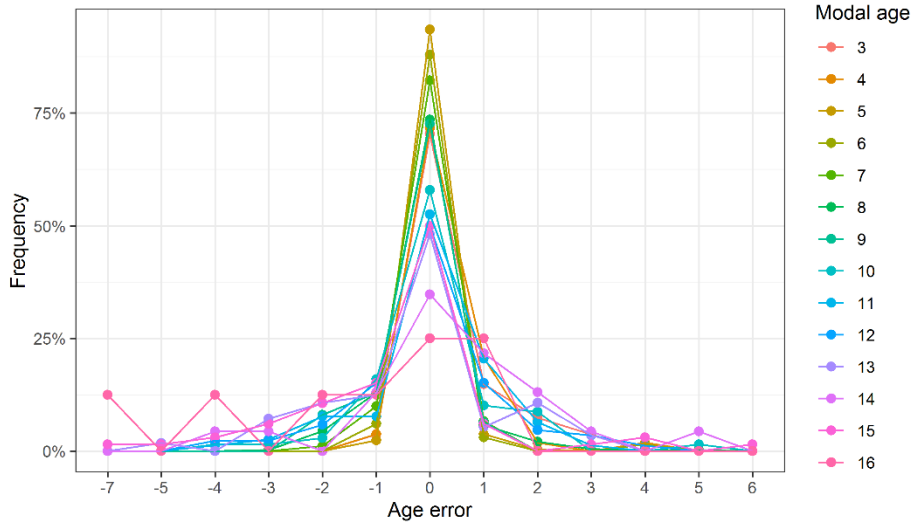


Figure 6.1.2: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age.

6.2 Results Advanced readers

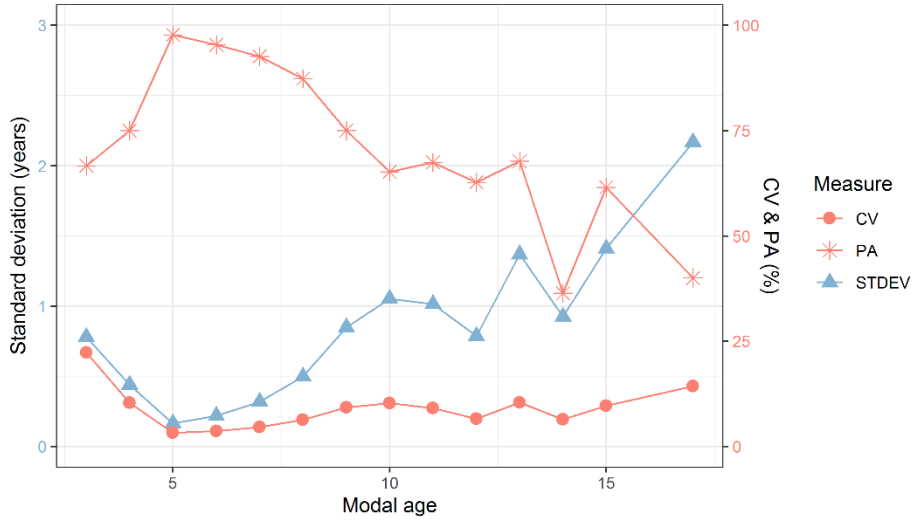


Figure 6.2.1: CV, PA and (STDEV (standard deviation) are plotted against modal age

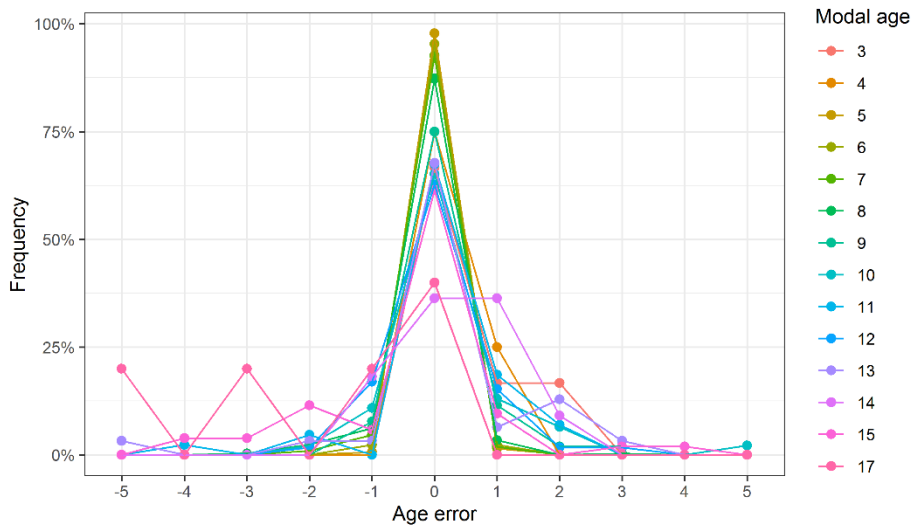


Figure 6.2.2: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age.

Annex 6: Example images

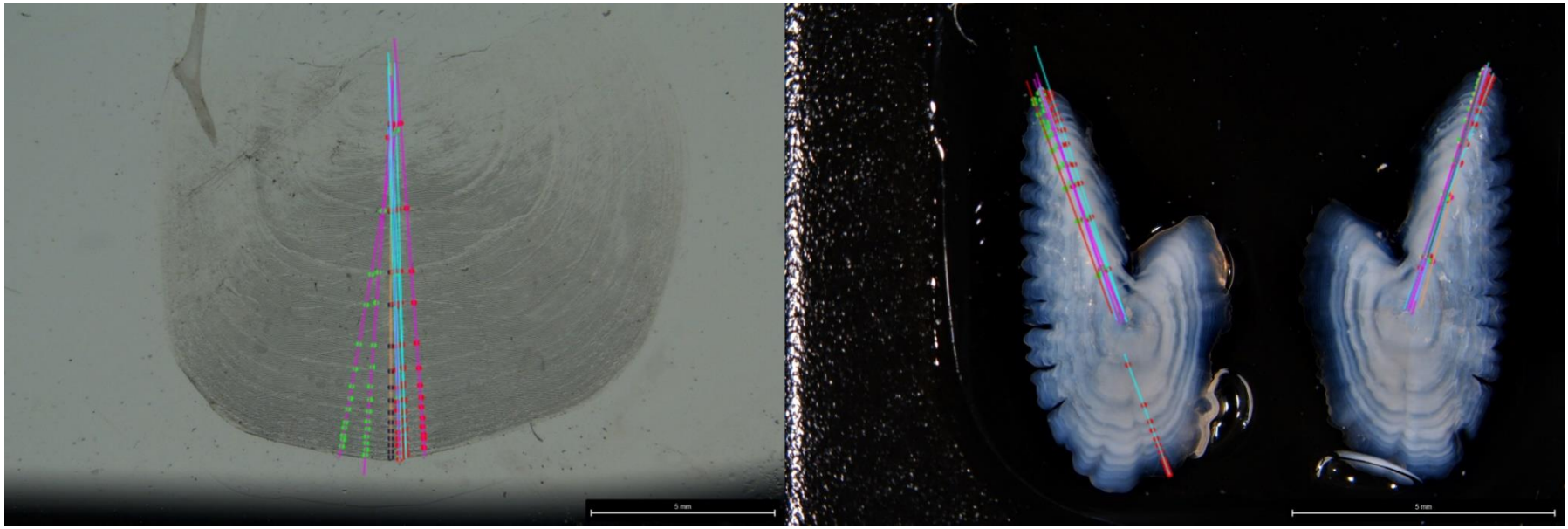


Figure A6.1: Scale (S_21180027_5027 (EventID:448)) of modal age 15 with 100% agreement among experienced readers and otolith (O_21180027_01 (EventID:447)) with model age 13 and only 33% agreement of the same individual. This highlights the discrepancies observed between the two calcified structures for older individuals.

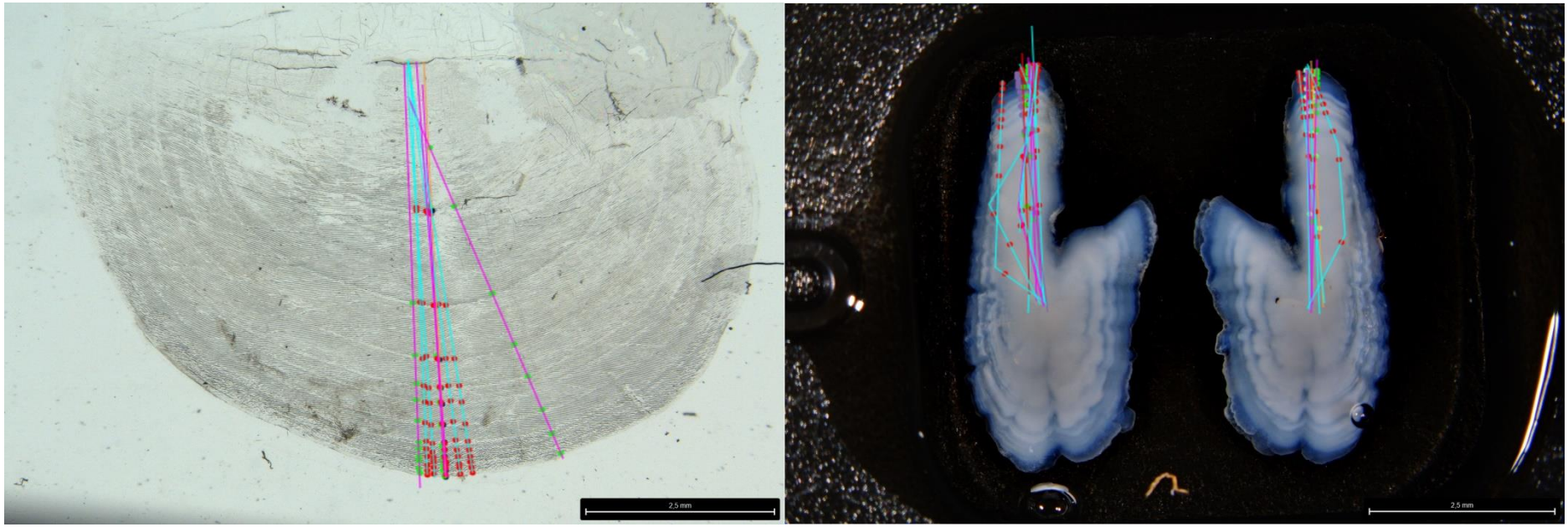


Figure A6.2: Scale (S_39015_09 (EventID:448)) of modal age 12 with 100% agreement among experienced readers and otolith (O_39015_09 (EventID:447)) with model age 12 and only 33% agreement of the same individual. This highlights the discrepancies observed between the two calcified structures for older individuals.

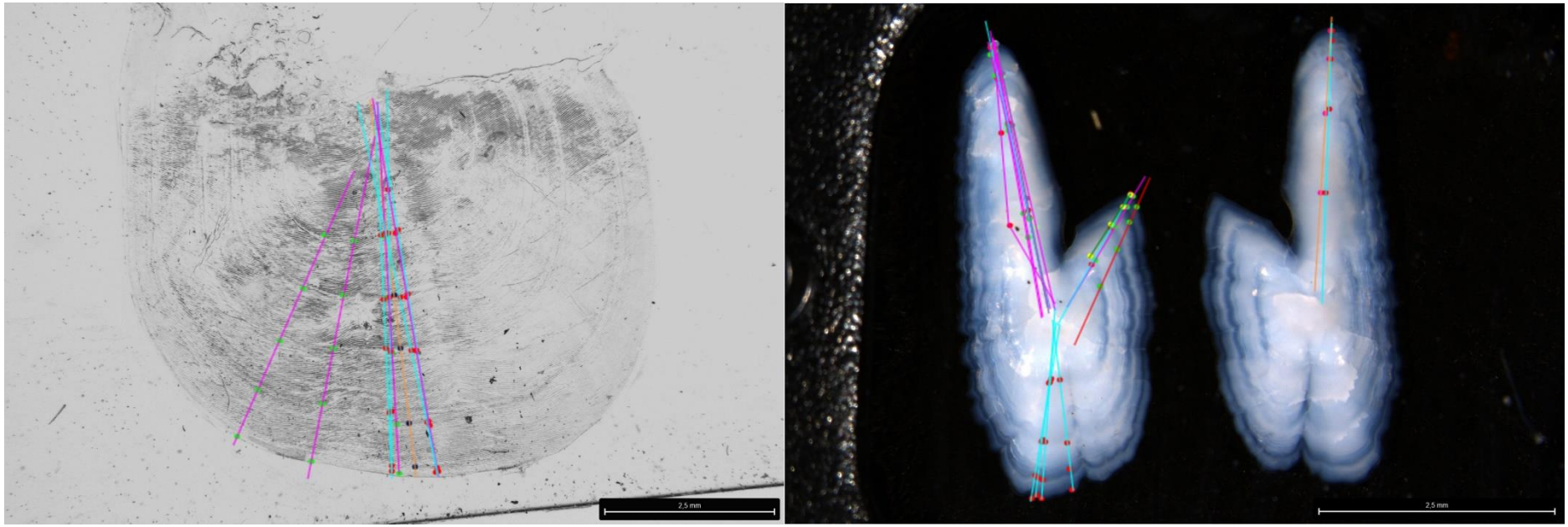


Figure A6.3: Scale (S_22417_06 (EventID:448)) of modal age 5 with 100% agreement among experienced readers and otolith (O_22417_06 (EventID:447)) with model age 4 and 100% agreement of the same individual.

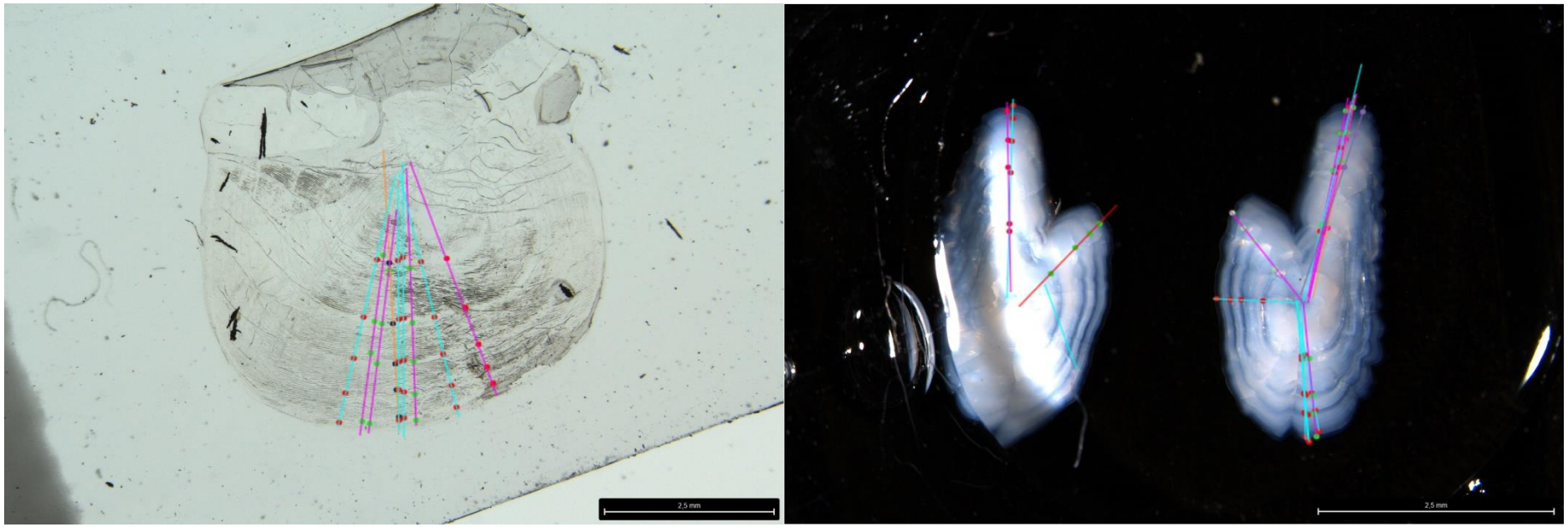


Figure A6.4: Scale (S_22430_20 (EventID:448)) of modal age 5 with 100% agreement among experienced readers and otolith (O_22430_20 (EventID:447)) with model age 4 and 100% agreement of the same individual.

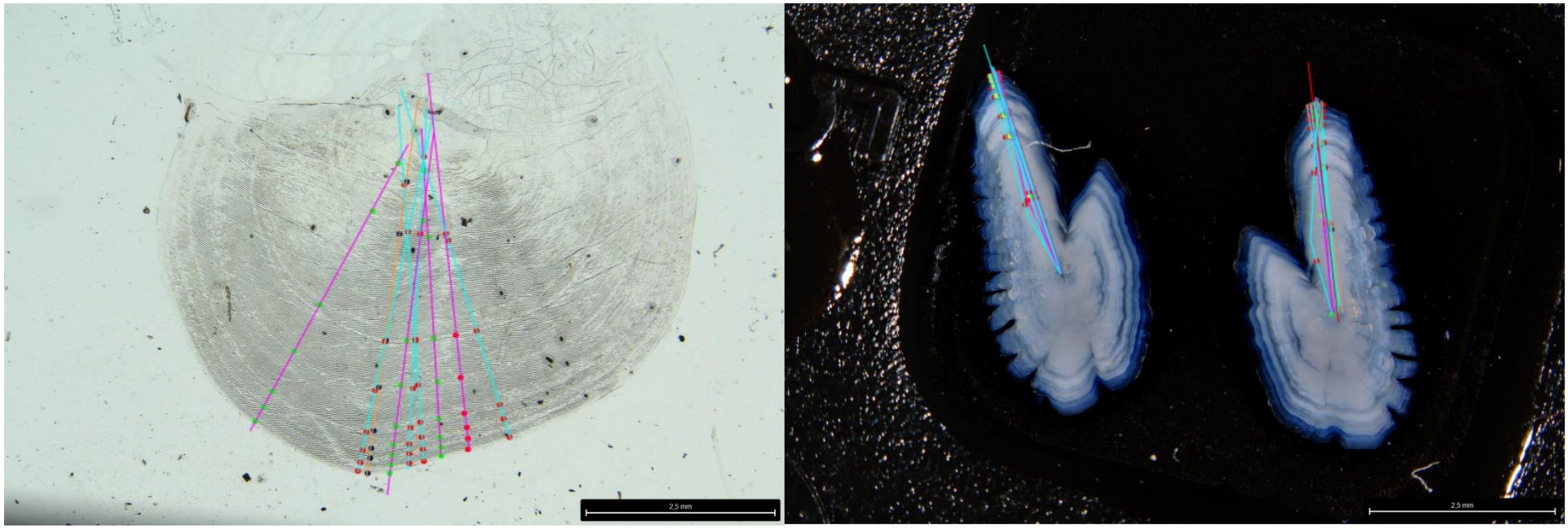


Figure A6.5: Scale (S_39015_05 (EventID:448)) of modal age 8 with 50% agreement among experienced readers and otolith (O_39015_05 (EventID:447)) with model age 7 and 80% agreement of the same individual.

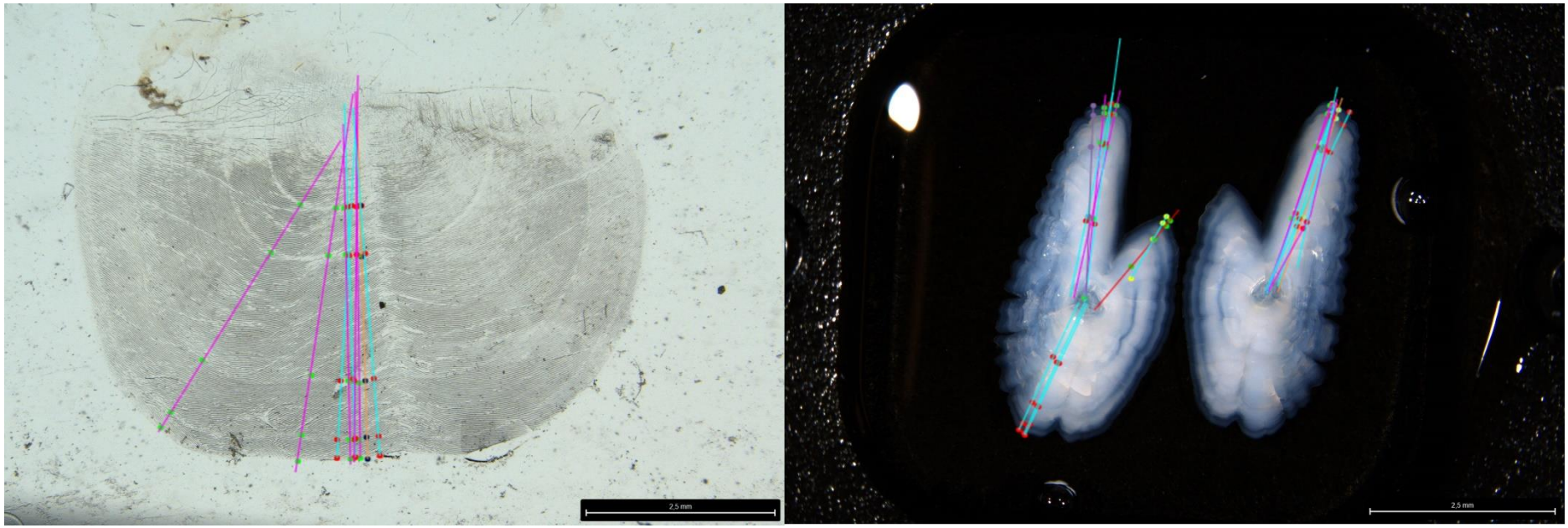


Figure A6.6: Scale (S_39019_02 (EventID:448)) of modal age 5 with 100% agreement among experienced readers and otolith (O_39019_02 (EventID:447)) with model age 4 and 80% agreement of the same individual.

Figure A6.7: Scale (S_22417_01 (EventID:448)) of modal age 4 with 67% agreement among experienced readers and otolith (O_22417_01 (EventID:447)) with model age 5 and 100% agreement of the same individual.

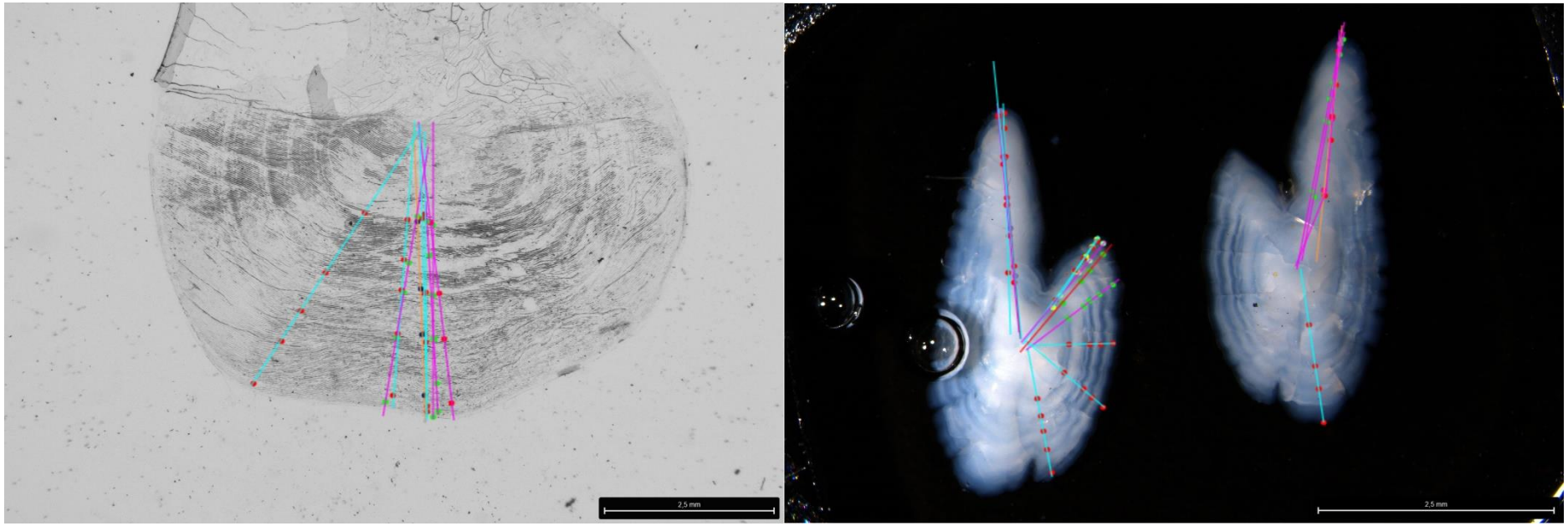


Figure A6.8: Scale (S_22430_21 (EventID:448)) of modal age 4 with 67% agreement among experienced readers and otolith (O_22430_21 (EventID:447)) with model age 5 and 60% agreement of the same individual.

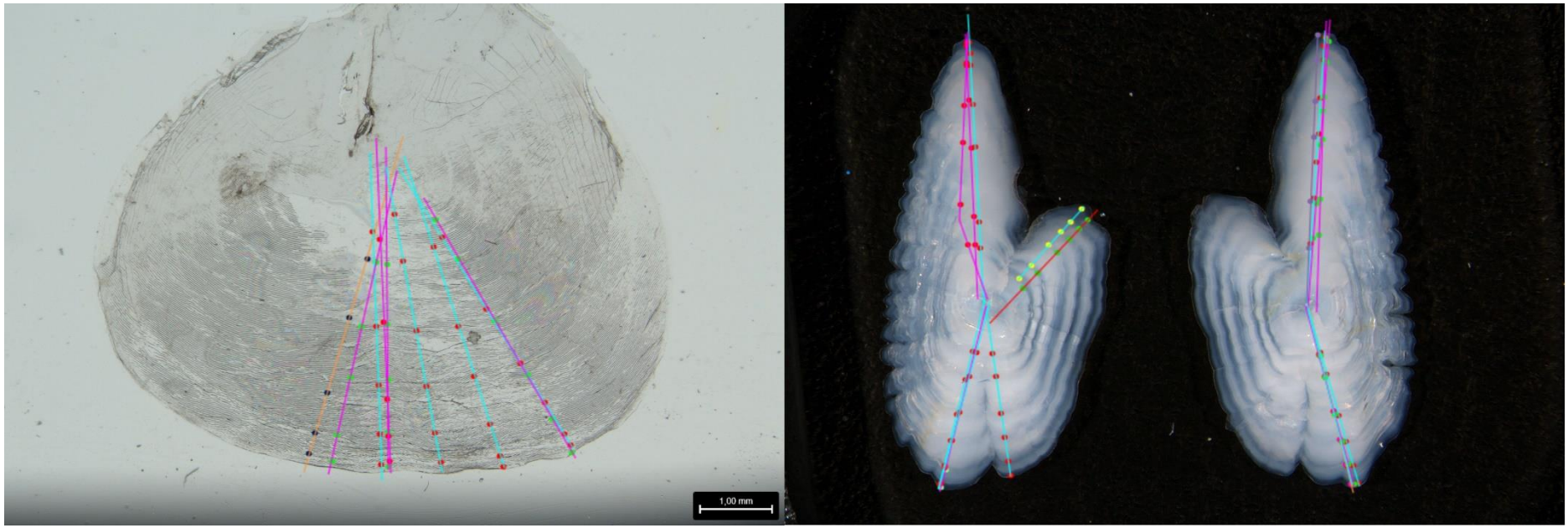


Figure A6.9: Scale (S_311_15 (EventID:448)) of modal age 5 with 50% agreement among experienced readers and otolith (O_311_15 (EventID:447)) with model age 6 and 90% agreement of the same individual