

# Report of the spring 2019 Western Baltic cod (*Gadus morhua*) age reading exchange – SD 22

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SmartDots event ID: 201

## Introduction

In spring 2019 the first SmartDots age reading comparison for Western Baltic cod (cod2224) was conducted after the last age reading comparison that had taken place in 2014/15 (ICES,2014; ICES,2015).

This spring 2019 otolith exchange included a relatively small number of images of sliced otoliths (n=49) covering quarter 3 and 4 of recent years and the age range from 0 to 10 years. The otoliths originated from SD 22. A total of three age readers from three countries participated. It should be noted that images of sliced cod otoliths are only used in Germany. Denmark and Sweden still use broken cod otoliths for ageing.

After the analysis of the exchange, an online meeting was conducted on 20.02.2019 to discuss the results with all age readers. Frequent errors and uncertainties in the age readings were highlighted to support the learning process. The exchange was carried out using SmartDots.

The objectives of the present exchange were:

- Evaluate the accuracy and precision in age reading of sliced Western Baltic cod otoliths (SD22)
- Identify common error sources in age reading
- Discuss and agree on next steps in an online workshop

## Methods

### Overview of samples and readers

Three age readers from three countries participated in the Western Baltic cod otolith exchange in spring 2019 (Table 1). All participants were advanced readers who are considered as well trained and provide age readings for the stock assessment (Germany: age reader is responsible for both survey and commercial samples; Denmark: only the age reader responsible for the commercial samples participated; Sweden: age reader is

responsible for both survey and commercial samples). All images were from sectioned otoliths; however, the age readers from Denmark and Sweden only read broken cod otoliths in their routine work.

**Table 1:** Reader overview.

Country	Reader code	Expertise	Standard method
Denmark	R02 DK	Advanced	Broken
Germany	R04 DE	Advanced	Sliced
Sweden	R06 SE	Advanced	Broken

In total, 49 otoliths covering fish total lengths between 12 and 100 cm were included in this exchange. Samples covered quarter 3 and 4 and represented samples from the Baltic International Trawl Survey (BITS) and commercial fisheries (samples in quarter 3) from the years 2017 and 2018. All otoliths were provided by Germany and covered ICES SD22.

**Table 2:** Overview of samples used for the Overview of samples used for the Western Baltic cod spring 2019 exchange.

Year	ICES area	Quarter	Number of samples	Modal age range	Length range
2017	SD 22	4	5	1	150-360 mm
2018	SD 22	3	27	3-10	650-1000 mm
2018	SD 22	4	17	0-5	120-720 mm

## Statistical analysis

In the first part of analysis the tables and plots from the Guus Eltink Excel sheet ‘Age Reading Comparisons’ (Eltink, A.T.G.W. 2000) are presented. The order and numbering of tables and plots are the same as in the excel sheet. Tables 6.1 - 6.4 from the ‘Age Reading Comparisons’ sheet are not output since these are merely used to do calculations for the other tables.

When this exchange was carried out, first results of McQueen et al. (2019) had been circulated among the participants of this exchange. The first results of Krumme et al. (2020) had been presented to the ICES assessment working group in April 2016 during WGBFAS (ICES 2016) and to the age reading coordinators of Denmark and Sweden in October 2016 (WGBIOP 2016).

The following metrics were determined:

### Percentage Agreement

The percentage agreement (PA) is calculated as the ratio between the number of age readings in agreement with the modal age and the total number of age readings for that sample per reader and modal age. The weighted mean is calculated based on the number of age readings.

$$PA = \frac{n_{modalage}}{n_{total}} * 100$$

### Co-efficient of Variation (CV)

The CV's are calculated as the ratio between the standard deviation ( $\sigma$ ) and mean value ( $\mu$ ) per reader and modal age:

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

### Average Percentage Error (APE)

APE was calculated based on the method outlined by Beamish & Fournier (1981). This method is not independent of fish age and thus provides a better estimate of precision. As the calculations of both CV and APE 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  $n$ .

### 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 twice, the first time all readers were included and the second time only the "advanced" readers were included. When the AEM is compiled for assessment purposes, it uses only those readers who provide age data for the stock assessment in that specific area.

# Results

## All readers

### All samples included

The weighted average percentage agreement based on modal ages for all readers was 85 %, with the weighted average CV of 15 % and APE of 9 %.

**Table 3:** 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 DK	R04 DE	R06 SE	all
0	-	-	-	-
1	37 %	64 %	28 %	45 %
2	0 %	0 %	21 %	19 %
3	0 %	0 %	0 %	0 %
4	0 %	0 %	12 %	9 %
5	0 %	8 %	0 %	5 %
6	0 %	0 %	0 %	0 %
7	0 %	0 %	6 %	6 %
8	7 %	0 %	0 %	5 %
9	-	-	-	-
10	0 %	7 %	0 %	4 %
<b>Weighted Mean</b>	<b>9 %</b>	<b>16 %</b>	<b>11 %</b>	<b>15 %</b>

The percentage agreement per reader per modal age gives the percentage of readings which are equal to the modal age. The weighted mean included at the bottom of the table, is weighted according to number of age readings. At modal age 0, the PA calculated across all readers was only 67 %, with one reader having 0 % agreement. The PA of modal ages 0, 1 and 7 was below 80 %.

**Table 4:** 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.

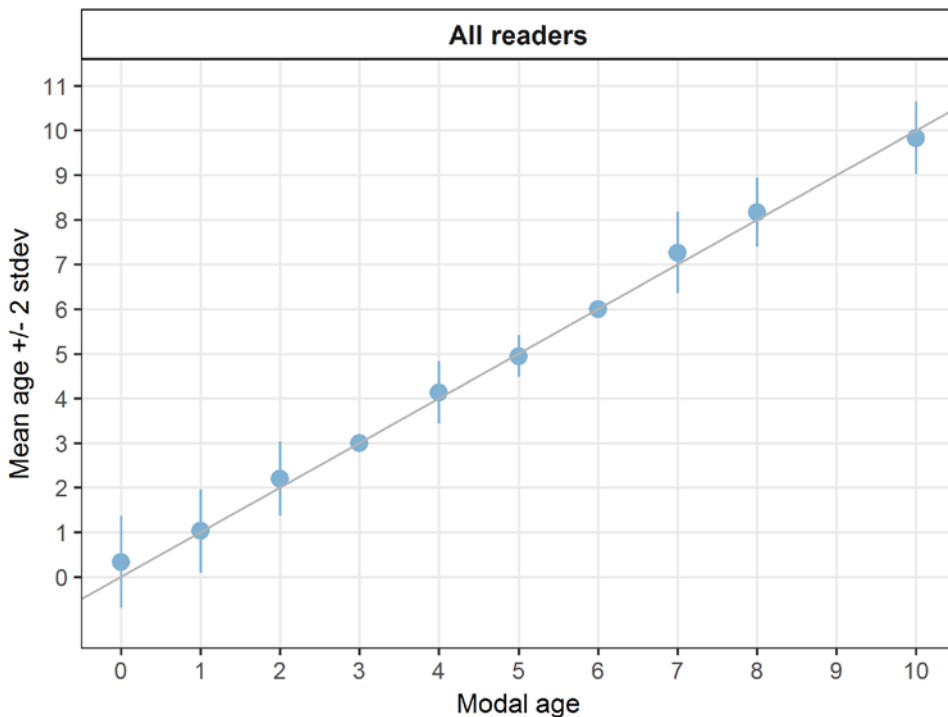
Modal age	R02 DK	R04 DE	R06 SE	all
0	0 %	100 %	100 %	67 %
1	73 %	73 %	91 %	79 %
2	100 %	100 %	40 %	80 %
3	100 %	100 %	100 %	100 %
4	100 %	100 %	60 %	87 %
5	100 %	83 %	100 %	94 %
6	100 %	100 %	100 %	100 %
7	100 %	100 %	20 %	73 %
8	50 %	100 %	100 %	83 %
9	-	-	-	-
10	100 %	50 %	100 %	83 %
<b>Weighted Mean</b>	<b>85 %</b>	<b>90 %</b>	<b>80 %</b>	<b>85 %</b>

The relative bias is the difference between the mean age (per modal age per reader) and the modal age. A positive bias indicates an overestimation of age compared to the modal age. As for Table 5, a combined bias for all readers and weighted means were calculated. While modal ages 0-3, 4, 7 and 8 showed an overestimation of age compared to the modal age, modal age 5 and 10 showed an underestimation of age compared to the modal age. Generally, R02 DK and R06 SE overestimated the age compared to the modal age and R04 DE underestimated the age compared to

modal age resulting in a slightly positive weighted mean which indicates an overestimation of age compared to the modal age.

**Table 5:** 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. Red and blue values indicate positive and negative bias, respectively.

Modal age	R02 DK	R04 DE	R06 SE	all
0	1.00	0.00	0.00	0.33
1	0.27	-0.27	0.09	0.03
2	0.00	0.00	0.60	0.20
3	0.00	0.00	0.00	0.00
4	0.00	0.00	0.40	0.13
5	0.00	-0.17	0.00	-0.06
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.80	0.27
8	0.50	0.00	0.00	0.17
9	-	-	-	-
10	0.00	-0.50	0.00	-0.17
<b>Weighted Mean</b>	<b>0.15</b>	<b>-0.10</b>	<b>0.20</b>	<b>0.08</b>



**Figure 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 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. Individual reader age biases can be found in the annex (Fig. 5).

**Table 6:** Inter reader bias test. The Inter-reader bias test gives probability of bias between readers and with modal age. - = no sign of bias ( $p > 0.05$ ), \* = possibility of bias ( $0.01 < p < 0.05$ ), \* \* = certainty of bias ( $p < 0.01$ )

Comparison	R02 DK	R04 DE	R06 SE
R02 DK	-	**	-
R04 DE	**	.	**
R06 SE	-	**	-

Modal age - . -

**Table 7:** Age error matrix (AEM) for cod2224 resulting from the present exchange. The AEM shows the proportional distribution of age readings for each modal age. Age column should sum to one but due to rounding there might be small deviations in some cases.

Modal age	0	1	2	3	4	5	6	7	8	10
Age 0	0.5	-	-	-	-	-	-	-	-	-
Age 1	0.5	0.82	-	-	-	-	-	-	-	-
Age 2	-	0.18	0.7	-	-	-	-	-	-	-
Age 3	-	-	0.3	1	-	-	-	-	-	-
Age 4	-	-	-	-	0.8	-	-	-	-	-
Age 5	-	-	-	-	0.2	1	-	-	-	-
Age 6	-	-	-	-	-	-	1	-	-	-
Age 7	-	-	-	-	-	-	-	0.6	-	-
Age 8	-	-	-	-	-	-	-	0.4	0.75	-
Age 9	-	-	-	-	-	-	-	-	0.25	-
Age 10	-	-	-	-	-	-	-	-	-	1

## Discussion

This is the first SmartDots age reading comparison for Western Baltic cod. Since the last age reading comparison in 2015 organized by Karin Hüsey and Uwe Krumme, surprisingly the uncertainties and national differences in age interpretation of Western Baltic cod in SD 22 had increased, despite progress in age validation. Especially ages 0-2 and 7-10 showed particularly low PAs. An average PA of 85 % and a CV of 15 % for advanced readers is not satisfactory for a stock for which otolith age reading is validated and considered relatively clear and easy.

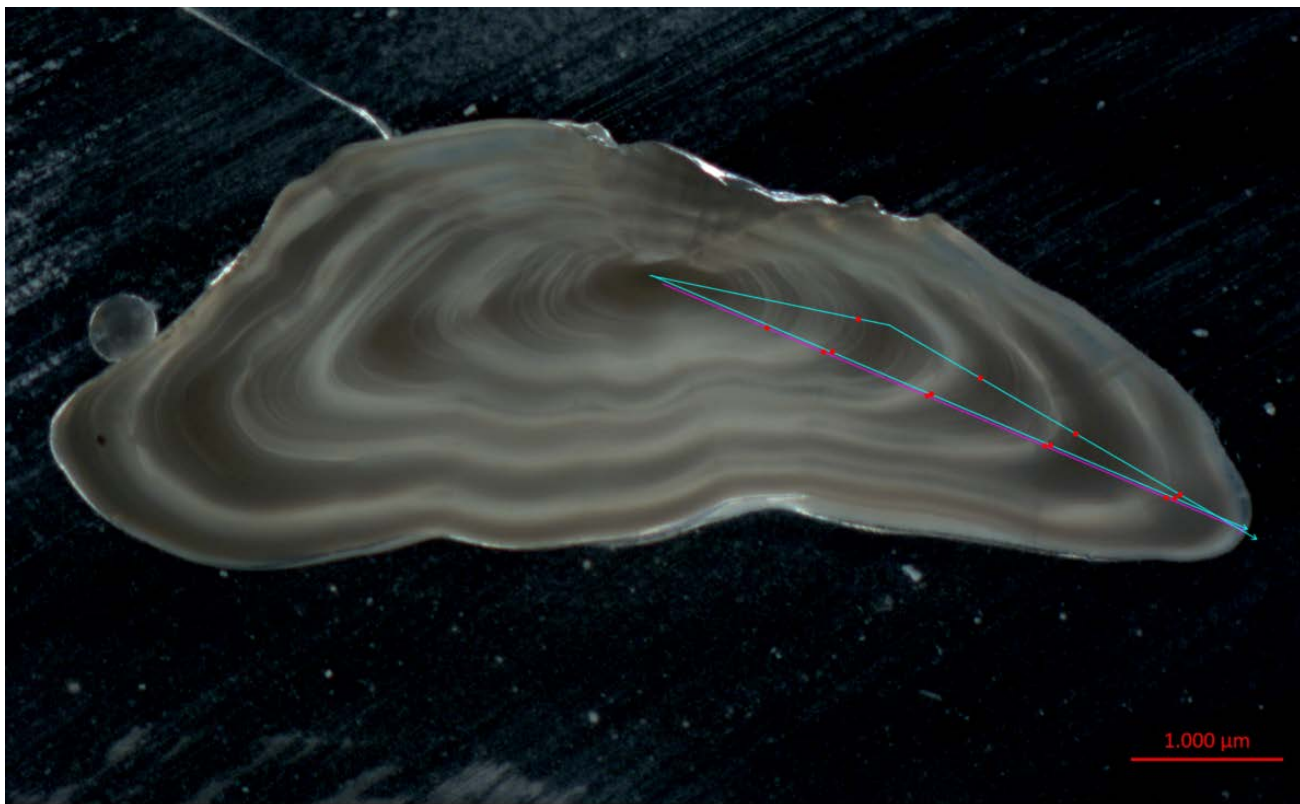
However, it has to be kept in mind that Sweden and Denmark do not read sliced otoliths on a routine basis, which were used for this and the previous exchange and readers might therefore have been less trained in reading sliced otoliths. Moreover, Swedish age readers usually do not read cod otoliths from SD22 because Sweden is not fishing in SD22 and also is not involved in surveys in SD22.

This exchange is now closed in SmartDots and can be used for further training purposes because all readers' annotations are now visible for comparisons. Table 8 gives an overview about the individual readers' ages, PA, CV and APE per sample ID.

### Examples of main discrepancies in age interpretation

Discrepancies in age determination can be categorized into three error sources:

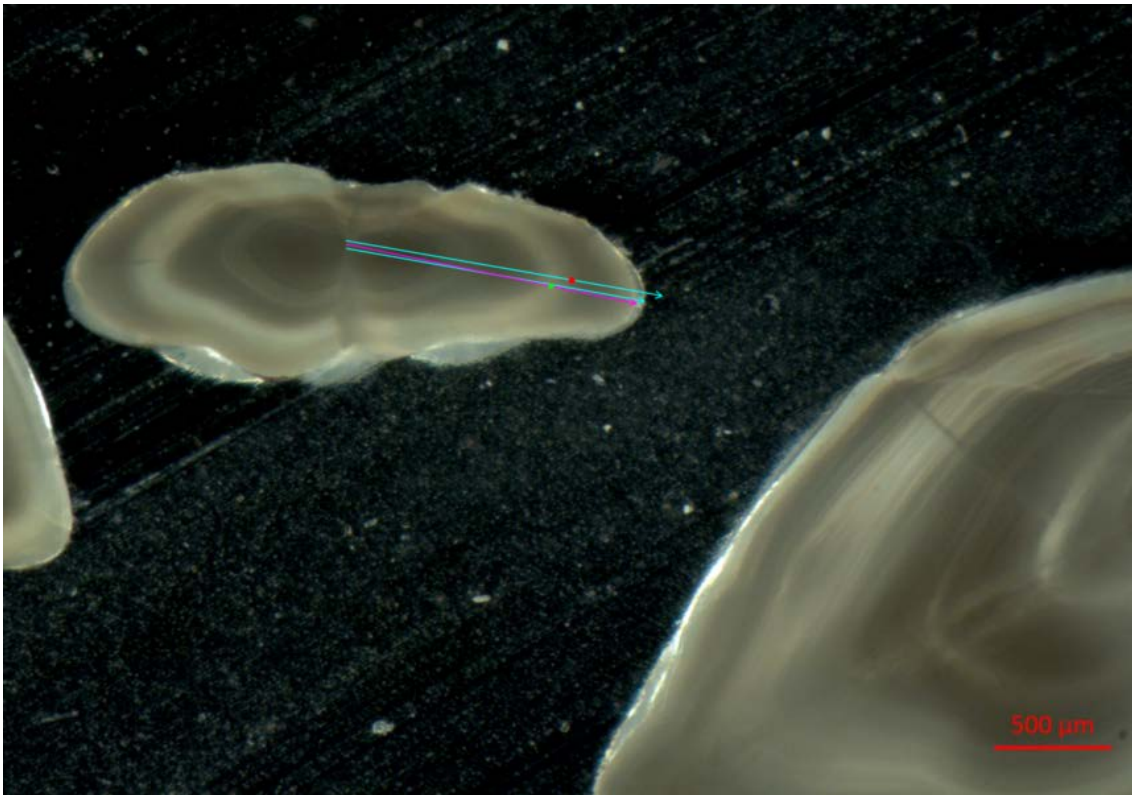
1. Misinterpretation of the first translucent summer ring:



**Figure 2:** Sliced otolith of a 78 cm cod caught on 11.09.2018 (FishID: 9, age: 4). Image taken using transmitted light. Dots and lines indicate individual markers from three age readers.

The first translucent ring which is marked by one age reader is not distinct enough and too close to the next one to be counted separately. The diameter of the first translucent ring is slightly larger than 2 mm. One age reader double-counted the first ring. This 78 cm cod was recaptured in September, has experienced 5 summers (indicated by five translucent zones – see the assignment of the green age reader) and is hence 4 years old.

2. Misinterpretation of the edge zone/ not accounting for recapture month

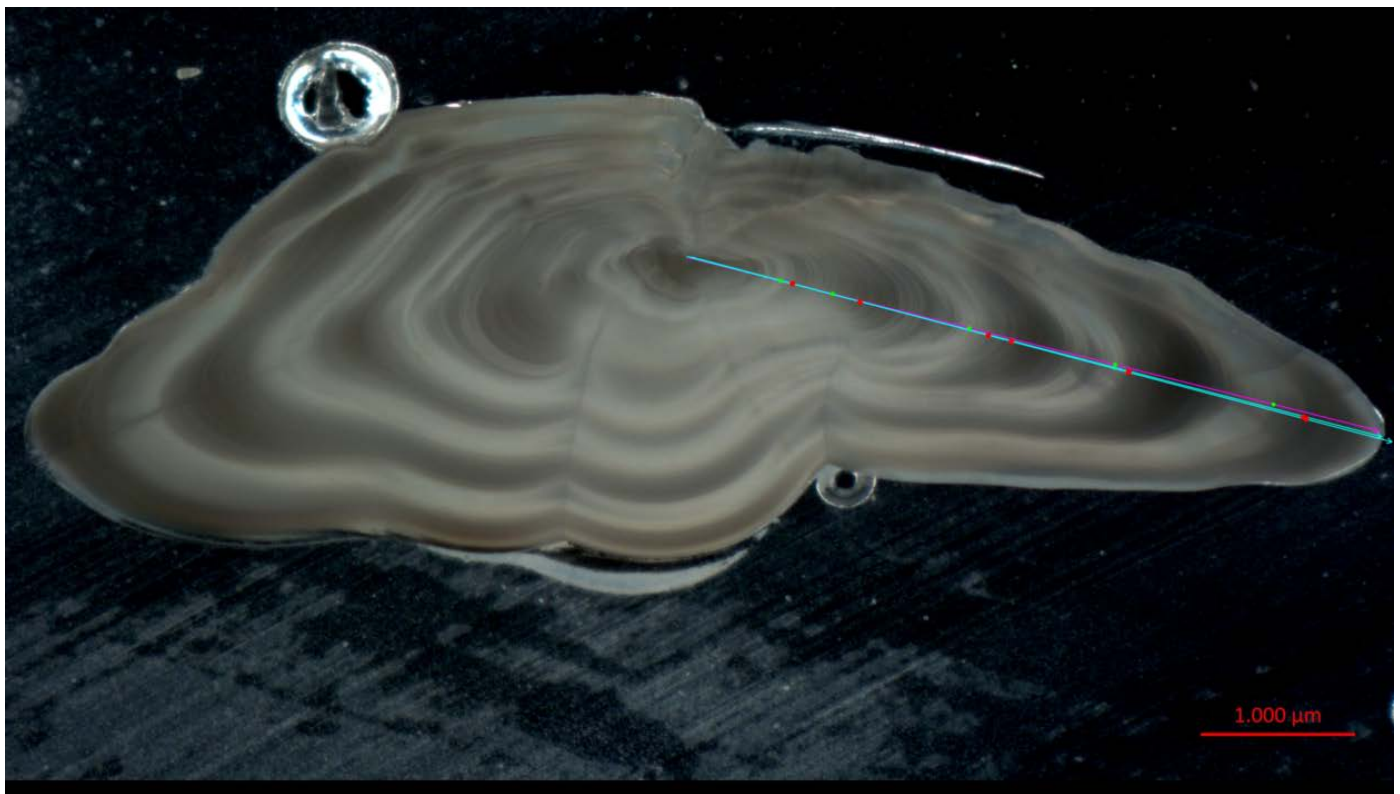


**Figure 3:** Sliced otolith of a 13 cm cod caught on 10.11.2018 (FishID: 48, age: 0). Image taken using transmitted light. Dots and lines indicate individual markers from three age readers.

The first translucent ring of the otolith in Figure 3 is formed during summer, i.e. it is a summer ring. This 13 cm fish was recaptured in November; hence it was age 0. If the translucent ring had been considered a winter ring, this otolith would have been mis-classified as an age-1 cod.

### 3. Counting of double rings





**Figure 4:** Image of the sliced otolith of a 78 cm cod caught on 11.09.2018 (FishID: 26, age: 4). Image taken using transmitted light. Dots and lines indicate individual markers from three age readers.

Juvenile cod grow relatively fast and with increasing length, growth decreases. In Figure 4 it is unrealistic that a second ring is formed so close to the first ring, especially given the distance to the translucent ring of the second summer. Since it was recaptured in September, this 78 cm cod was age 4.

## Outlook

After the otolith exchange the results were discussed by national age reading coordinators and age readers. The group concluded on the following:

- Regular otolith exchanges of sliced otoliths of Western Baltic cod will be continued because the quality of the age reading has to be and can be improved; the next exchange will take place in autumn 2019 and will include a larger sample size and quarter 1 otoliths. To prepare for this second exchange, another age reading online workshop between Germany, Denmark and Sweden will be organized. Germany will manage the next exchange in autumn 2019.
- Results of this and the next age reading comparison will be presented at WKBALTCOD 2019 and WGBFAS 2019.
- The routine use of different age reading methods (sectioned vs broken otoliths) in a relatively small stock with a limited number of age-read otoliths each year makes the comparison of the age readings quite

difficult. In fact, one may question whether or not a comparison of 3 age readers where 2 are used to broken otoliths and 1 is used to sliced otoliths, is useful at all because the significance of an exchange on the routine age-reading of broken otoliths is unclear. There are several quality issues that clearly are in favour of the sliced method (e.g. documentation of the ageing because sliced otoliths are photographed, correction of errors, quality of the age reading because the diameter of the first ring can be measured on images (McQueen et al. 2019) but not in broken otoliths, use of images of sliced otoliths in SmartDots) but it is considered more laborious.

- Germany will send around small reports on the results of the Q1 and Q4 BITS age readings in SD22 involving images of sliced, representative otoliths, so that the age readers from Denmark and Sweden can become more and more used to age-read sliced otoliths, which will be used in the next SmartDots comparisons.
- In case it is considered helpful, the Thünen Institute offered to assist other labs by slicing up to 1000 Western Baltic cod otoliths per year.

## 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
- ICES, 2014. Report of the Workshop on Scoping for Integrated Baltic Cod Assessment (WKSIBCA), 1–3 October 2014, Gdynia, Poland. ICES CM 2014/ACOM:62. 51 pp.
- ICES, 2015. Report of the Benchmark Workshop on Baltic Cod Stocks (WKBALTCOD), 2–6 March 2015, Rostock, Germany. ICES CM 2015/ACOM:35. 172 pp.
- Krumme U, Stötera S, McQueen K, Pahlke E (2020) Age validation of age 0-3 wild cod *Gadus morhua* in the western Baltic Sea through mark-recapture and tetracycline marking of otoliths. *Mar Ecol Progr Ser* 645:141-158, DOI:10.3354/meps13380
- McQueen K, Hrabowski J, Krumme U (2019) Age validation of juvenile cod in the western Baltic Sea. *ICES J Mar Sci* 76(2):430–441, DOI:10.1093/icesjms/fsy175

# Results all readers

## Data Overview

**Table 8:** Summary of statistics; PA (%), CV (%) and APE (%).

CV	PA	APE
15 %	85 %	9 %

**Table 9:** Data overview including modal age and statistics per sample.

Fish ID	Event ID	Image ID	length	sex	Catch date	ICES area	R02 DK	R04 DE	R06 SE	Modal age	PA %	CV %	APE %
2	201	15021	980	-	22/08/2018 00:00:00	27.3.d	10	10	10	10	100	0	0
3	201	15022	990	-	22/08/2018 00:00:00	27.3.d	9	8	8	8	67	7	5
4	201	15023	1000	-	22/08/2018 00:00:00	27.3.d	10	9	10	10	67	6	5
6	201	15025	910	-	22/08/2018 00:00:00	27.3.d	8	8	8	8	100	0	0
7	201	15026	830	-	11/09/2018 00:00:00	27.3.d	6	6	6	6	100	0	0
8	201	15027	880	-	11/09/2018 00:00:00	27.3.d	6	6	6	6	100	0	0
9	201	14977	780	-	11/09/2018 00:00:00	27.3.d	4	4	5	4	67	13	10
10	201	14978	720	-	11/09/2018 00:00:00	27.3.d	4	4	4	4	100	0	0
11	201	14979	850	-	11/09/2018 00:00:00	27.3.d	5	5	5	5	100	0	0
12	201	14980	720	-	11/09/2018 00:00:00	27.3.d	5	5	5	5	100	0	0
13	201	14981	840	-	11/09/2018 00:00:00	27.3.d	6	6	6	6	100	0	0
14	201	14982	830	-	11/09/2018 00:00:00	27.3.d	6	6	6	6	100	0	0
15	201	14983	980	-	11/09/2018 00:00:00	27.3.d	8	8	8	8	100	0	0
16	201	14984	860	-	11/09/2018 00:00:00	27.3.d	5	5	5	5	100	0	0
17	201	14985	760	-	11/09/2018 00:00:00	27.3.d	4	4	4	4	100	0	0
18	201	14986	950	-	11/09/2018 00:00:00	27.3.d	7	7	8	7	67	8	6
19	201	14987	830	-	11/09/2018 00:00:00	27.3.d	7	7	8	7	67	8	6
20	201	14988	910	-	11/09/2018 00:00:00	27.3.d	9	8	8	8	67	7	5
21	201	14989	930	-	11/09/2018 00:00:00	27.3.d	7	7	7	7	100	0	0
22	201	14990	990	-	11/09/2018 00:00:00	27.3.d	7	7	8	7	67	8	6
23	201	14991	650	-	11/09/2018 00:00:00	27.3.d	3	3	3	3	100	0	0
25	201	14993	820	-	11/09/2018 00:00:00	27.3.d	5	5	5	5	100	0	0
26	201	14994	780	-	11/09/2018 00:00:00	27.3.d	4	4	5	4	67	13	10
27	201	14995	830	-	11/09/2018 00:00:00	27.3.d	4	4	4	4	100	0	0
28	201	14996	750	-	11/09/2018 00:00:00	27.3.d	3	3	3	3	100	0	0
29	201	14997	900	-	11/09/2018 00:00:00	27.3.d	-	6	6	6	100	0	0
30	201	14998	870	-	11/09/2018 00:00:00	27.3.d	7	7	8	7	67	8	6
31	201	14999	150	-	11/11/2017 00:00:00	27.3.d	1	1	1	1	100	0	0
32	201	15000	160	-	11/11/2017 00:00:00	27.3.d	1	1	1	1	100	0	0
33	201	15001	360	-	12/11/2017 00:00:00	27.3.d	1	1	2	1	67	43	33
34	201	15002	240	-	12/11/2017 00:00:00	27.3.d	2	1	1	1	67	43	33
35	201	15003	280	-	13/11/2017 00:00:00	27.3.d	1	1	1	1	100	0	0
36	201	15004	580	-	08/11/2018 00:00:00	27.3.d	3	3	3	3	100	0	0
37	201	15005	120	-	08/11/2018 00:00:00	27.3.d	1	0	0	0	67	-	-
38	201	15006	180	-	08/11/2018 00:00:00	27.3.d	1	0	1	1	67	87	67
39	201	15007	130	-	08/11/2018 00:00:00	27.3.d	1	0	0	0	67	-	-
40	201	15008	530	-	09/11/2018 00:00:00	27.3.d	3	3	3	3	100	0	0
41	201	15009	420	-	09/11/2018 00:00:00	27.3.d	2	2	3	2	67	25	19
42	201	15010	420	-	09/11/2018 00:00:00	27.3.d	2	2	3	2	67	25	19
43	201	15011	200	-	09/11/2018 00:00:00	27.3.d	2	1	1	1	67	43	33
44	201	15012	260	-	09/11/2018 00:00:00	27.3.d	1	1	1	1	100	0	0
45	201	15013	150	-	09/11/2018 00:00:00	27.3.d	1	0	1	1	67	87	67
46	201	15014	270	-	10/11/2018 00:00:00	27.3.d	2	2	2	2	100	0	0
47	201	15015	220	-	10/11/2018 00:00:00	27.3.d	2	1	1	1	67	43	33
48	201	15016	130	-	10/11/2018 00:00:00	27.3.d	1	0	1	1	67	87	67
49	201	15017	620	-	10/11/2018 00:00:00	27.3.d	2	2	3	2	67	25	19

50	201	15018	430	-	11/11/2018 00:00:00	27.3.d	2	2	2	2	100	0	0
51	201	15019	670	-	11/11/2018 00:00:00	27.3.d	5	5	5	5	100	0	0
52	201	15020	720	-	11/11/2018 00:00:00	27.3.d	5	4	5	5	67	12	10

**Table 10:** Number of age readings table gives an overview of number of readings per reader and modal age. The total numbers of readings per reader and per modal age are summarized at the end of the table.

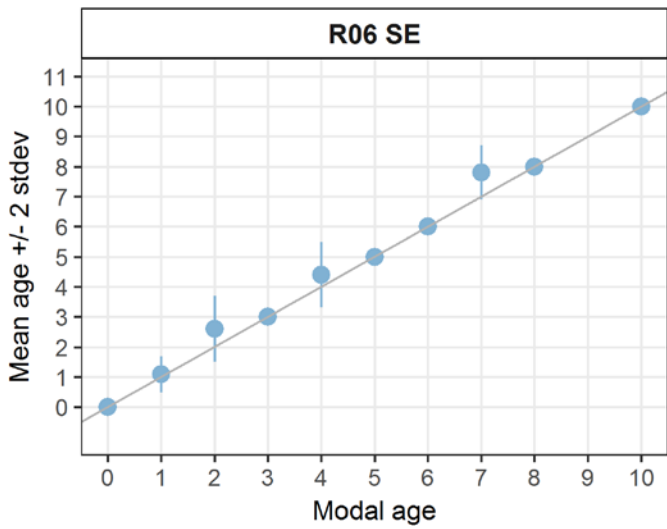
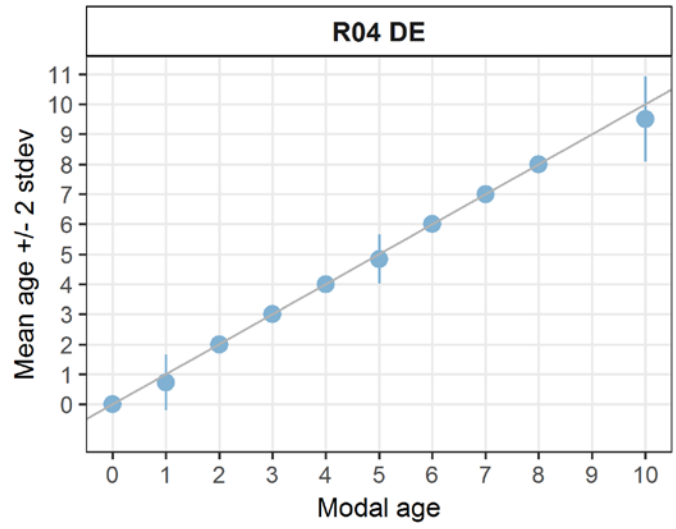
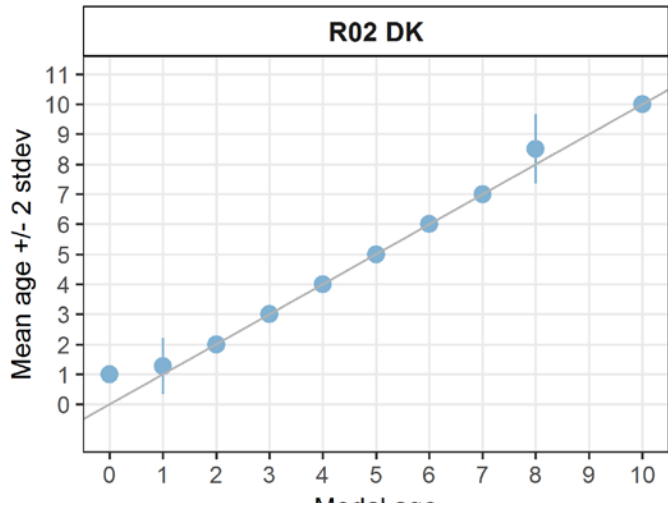
Modal age	R02 DK	R04 DE	R06 SE	total
0	2	2	2	6
1	11	11	11	33
2	5	5	5	15
3	4	4	4	12
4	5	5	5	15
5	6	6	6	18
6	4	5	5	14
7	5	5	5	15
8	4	4	4	12
9	0	0	0	0
10	2	2	2	6
<b>Total</b>	<b>48</b>	<b>49</b>	<b>49</b>	<b>146</b>

**Table 11:** Age composition by reader gives a summary of number of readings per reader.

Modal age	R02 DK	R04 DE	R06 SE
0	0	5	2
1	10	8	10
2	8	5	3
3	4	4	7
4	5	6	3
5	6	5	8
6	4	5	5
7	5	5	1
8	2	4	8
9	2	1	0
10	2	1	2
<b>Total</b>	<b>48</b>	<b>49</b>	<b>49</b>

**Table 12:** Mean length at age per reader is calculated per reader and age (not modal age) and for all readers combined per age. A weighted mean is also given.

Age	R02 DK	R04 DE	R06 SE
0	-	142 mm	125 mm
1	192 mm	234 mm	197 mm
2	352 mm	432 mm	353 mm
3	628 mm	628 mm	567 mm
4	774 mm	765 mm	770 mm
5	773 mm	784 mm	775 mm
6	845 mm	856 mm	856 mm
7	914 mm	914 mm	930 mm
8	945 mm	948 mm	929 mm
9	950 mm	1000 mm	-
10	990 mm	980 mm	990 mm
<b>Weighted Mean</b>	<b>614 mm</b>	<b>620 mm</b>	<b>620 mm</b>



**Figure 5:** Individual age reading bias plots by age reader.

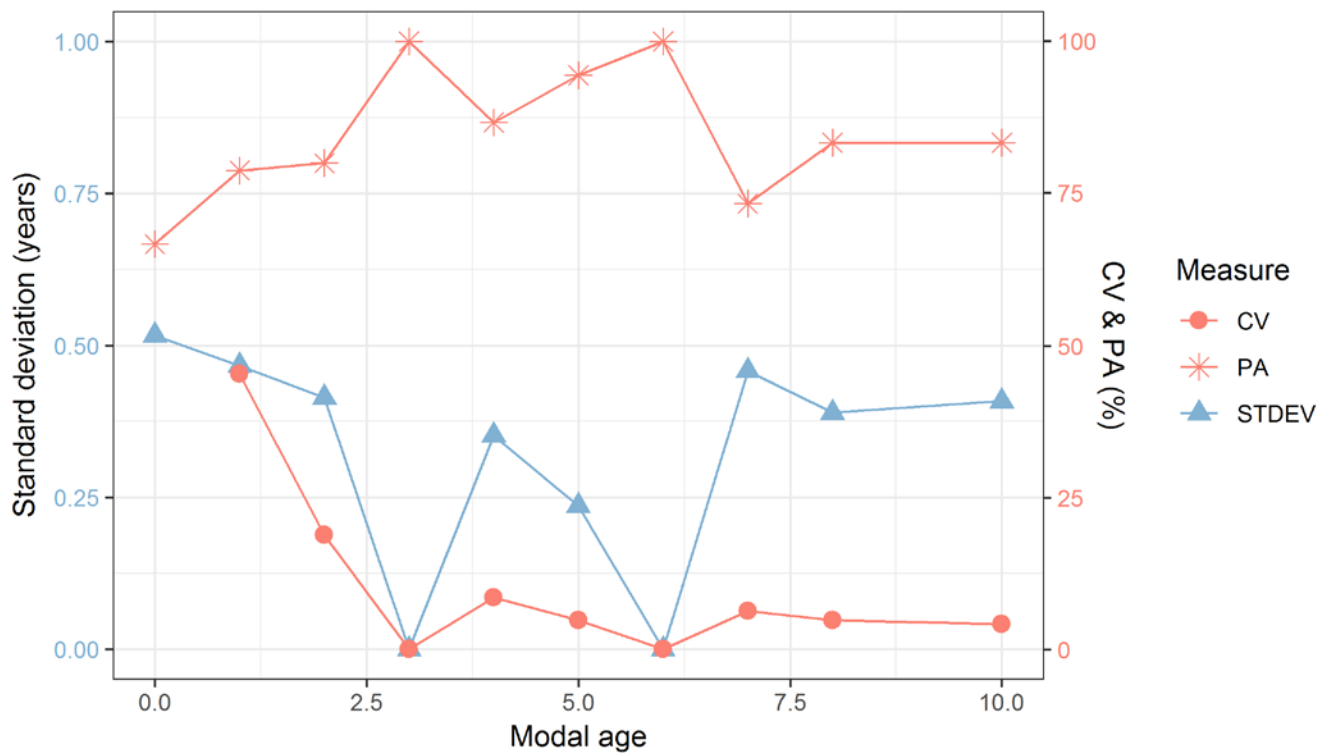


Figure 6: CV, PA and (STDEV (standard deviation) are plotted against modal age

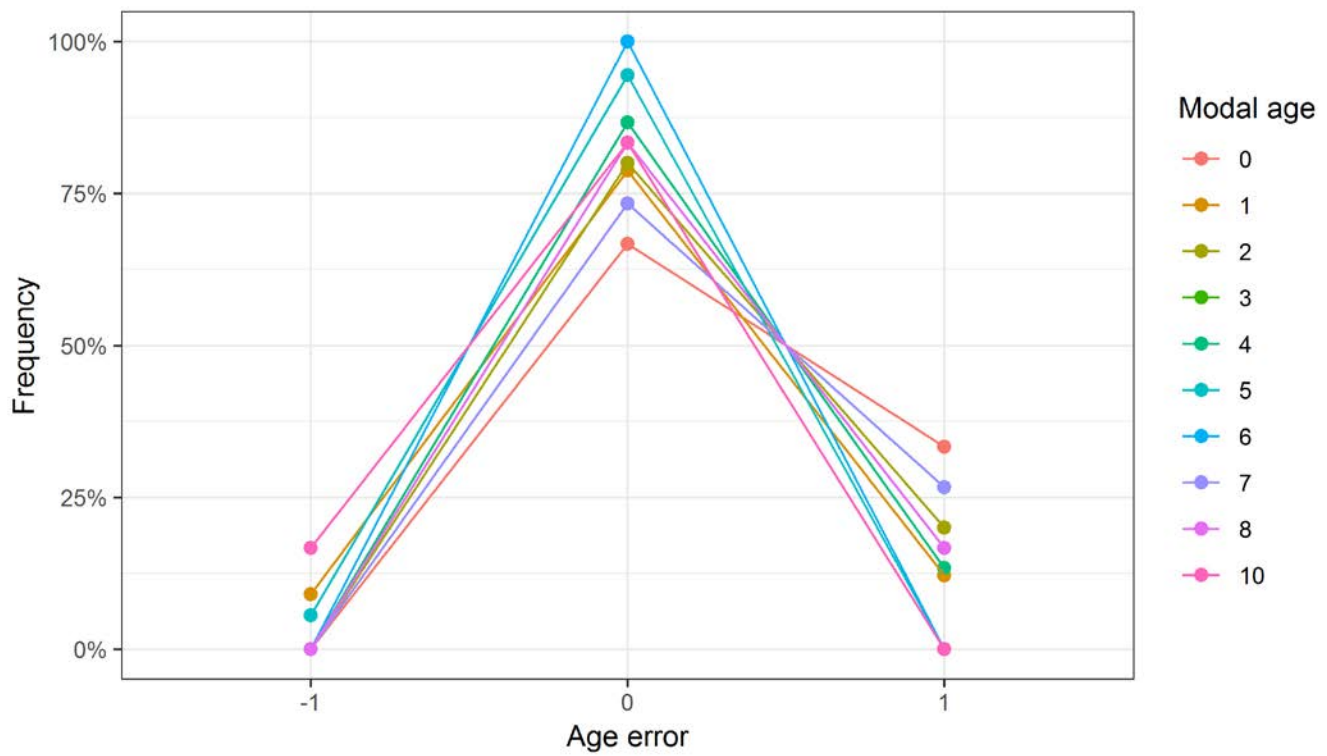
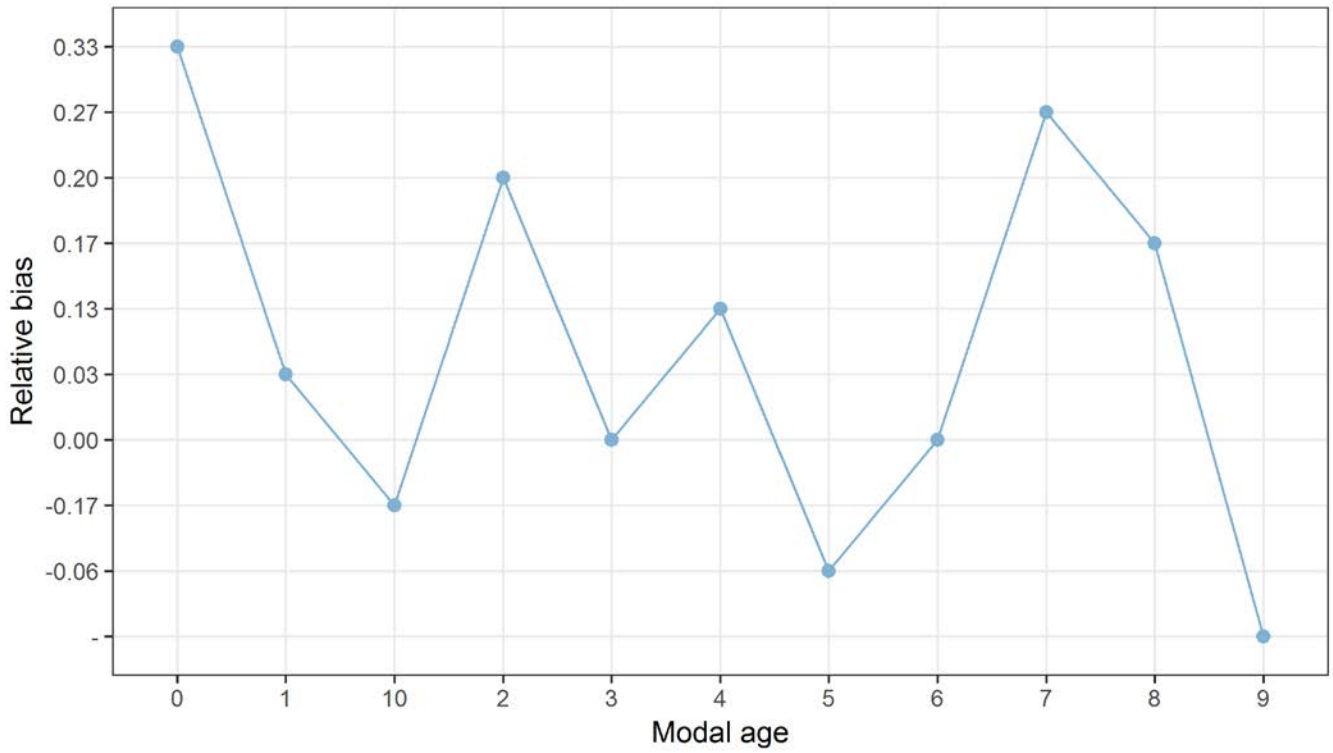
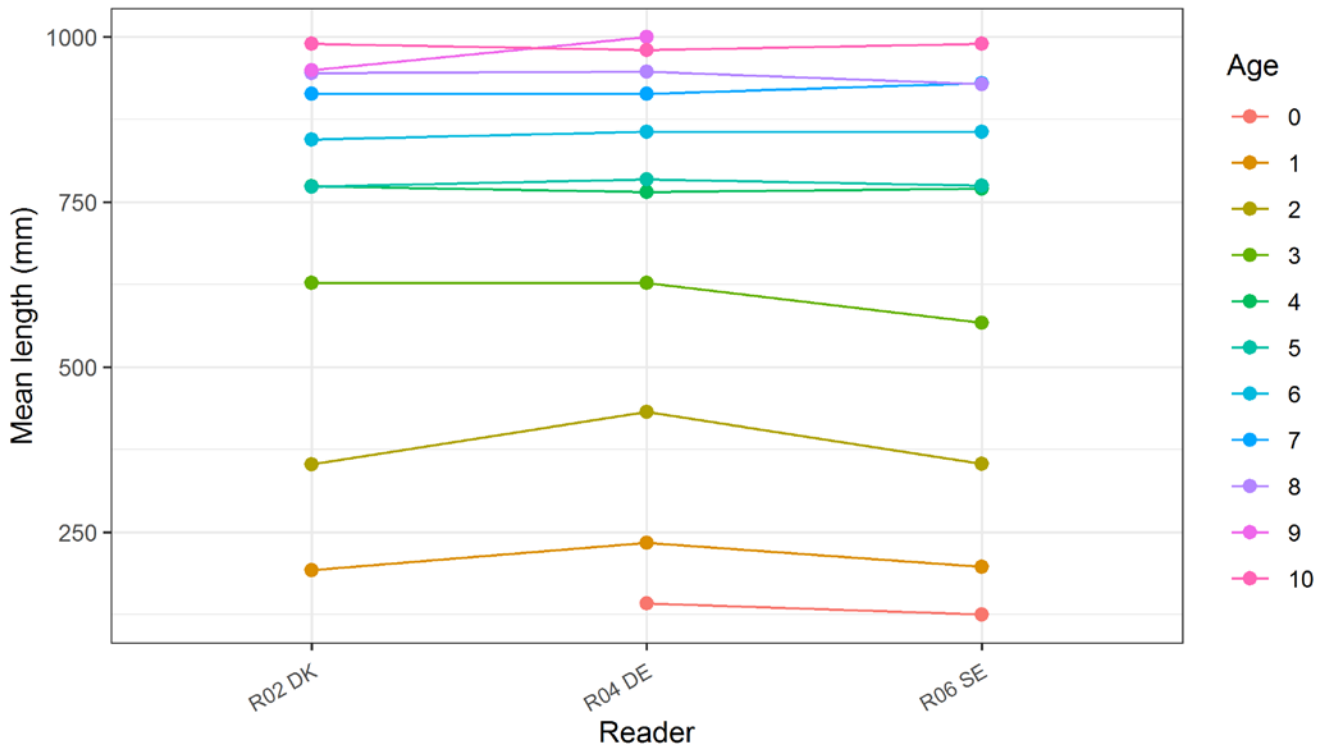


Figure 7: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age. The achieved precision in age reading by MODAL age group is shown

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



**Figure 8:** The relative bias by modal age as estimated by all age readers combined.



**Figure 9:** The mean length at age as estimated by each age reader.