DTU Aqua
National Institute of Aquatic Resources

Report of the 2020 Kattegat cod age reading exercise (SmartDots ID 269 & ID 270)

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1 Executive summary

The 2020 Kattegat cod age reading exercise took place from January to March 2020 on the ICES SmartDots platform. The exercise consists of two events with samples from the same fish, one event with broken otoliths and one event with sectioned otoliths. All samples were collected from ICES subdivision 21 in 2019, from harbour sampling, survey and discard trips by DTU Aqua, National Institute of Aquatic Resources, Denmark. A total of 200 otoliths, stratified primarily by quarter and then age group were included. All sample preparation and digitisation was conducted at the DTU Aqua age reading laboratories prior to uploading to SmartDots. The aim of the exercise was to firstly, identify and resolve any age interpretation issues and secondly, compare the ages estimated from each method.

The last age reading exchange for Kattegat cod took place in 2016 (in preparation for the ICES WKBALT 2017, Benchmark Workshop on Baltic Stocks). Physical samples were exchanged and thus no annotated otolith images available for analysis and comparison of which structures were used to attain the estimated ages back in time. Only the two primary age readers from Denmark and Sweden at that time took part, overall percentage agreement was 95%, with a coefficient of variation of 2.9% and no consistent patterns of bias detectable which would have an effect on the stock assessment of Kattegat cod.

Three age readers from DTU Aqua took part in this exercise. Routine age reading of cod at DTU Aqua is carried out by examination of sagittal otoliths, broken through the nucleus and examined under a stereomicroscope with a reflected light source. In recent years the readers have participated in age reading exercises based on sagittal otoliths which have been sectioned through the nucleus and examined under a stereomicroscope with a transmitted light source. By including otoliths from the same fish in this exercise, with each one of the pair prepared as described (sectioned or broken), a comparison of the ages attained from each method was possible. Based on the results an evaluation of the precision and quality of the age estimations from the two methods was possible.

Overall results show a high level of agreement between readers; for the broken otoliths the overall percentage agreement was 79%, with a coefficient of variation of 28% and an average percentage error of 16%; for the sectioned otoliths the overall percentage agreement was higher at 85%, with a lower coefficient of variation of 23% and a lower average percentage error of 10%. These results indicate that the sectioned method allows for a higher agreement and more precision between readings.

When the readings estimated for each sample were compared, there was agreement reached across methods on 70% of the samples and in the majority of cases where disagreement exists, a higher modal age was reached from the broken method. An examination of the annotated images revealed difficulties in correctly identifying the first winter ring, which can often be confused with the settling ring, mostly in the broken otoliths. Another confounding issue is the apparent change in timing of the translucent zone formation seen in the samples in this exercise. This change has also been observed in young cod from the western Baltic Sea and linked to water temperatures in the juvenile shallow water habitats.

The age estimation process is dependent on knowing the catch date of the sample and the periodicity of the annual deposition of the growth (opaque) and non-growth (translucent) zones. A change in the later requires that readers are made aware of changes in the annual growth pattern and guidelines provided for them on how to interpret these changes when estimating the age of the fish. The results from the exercise identify the need for updated guidelines to be provided for the readers of Kattegat cod otoliths.

2 Introduction

Atlantic Cod (*Gadus morhua*) in the Kattegat are a demersal species distributed across a variety of habitats. As juveniles, they prefer shallower habitats composed of eelgrass beds, boulders and gravel and as adults migrate into deeper, cooler waters. Larger scale migrations occur between spawning, feeding and overwintering areas. It is a commercial species assessed as a single stock (cod.27.21) by the International Council for the Exploration of the Seas (ICES). The Kattegat cod stock assessment has in recent years been challenged due to a large fraction of the population mortality which cannot be explained by either fishing or natural mortality (ICES 2017) but which is likely to be attributable to the migration of cod between the Kattegat and neighbouring areas.

The last age reading exchange for Kattegat cod took place in 2016 (in preparation for the ICES WKBALT 2017, Benchmark Workshop on Baltic Stocks). Based on only the two primary age readers from Denmark and Sweden at the time, the overall percentage agreement was 95%, with a coefficient of variation of 2.9%. Three age readers from Denmark participated in this exchange, (none of which took part in the 2016 exchange) which includes broken and sectioned otoliths from the same fish. The aim of the exercise was to identify any age reading issues and to compare the results achieved from each method, with a view to identifying the most reliable method and improving the overall quality of the age data being utilised in the stock assessment.

The exchange took place via the ICES SmartDots platform. 200 images of broken and sectioned otoliths were uploaded for the readers to annotate and estimate the fish age based on the observed annual growth patterns. Readers were also asked to identify and record the otolith edge type. The analysis follows traditional methods, a standardised report template is produced from an r-script integrated into the SmartDots reporting module. This report is based on that template, text and images have been added to further clarify the results and outline the main age reading issues.

3 Methods

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; average percentage error (APE) and age error matrices (AEM's). Age estimates were made on both broken and sectioned otoliths from the same fish and a comparison of calculated modal age from each method is also included. As SmartDots provides a measure of distance between the annotations made by the readers this data is used as a measure of growth increment width and allows for a comparison of growth curves for each fish and for each reader.

Percentage Agreement

The table presents the percentage agreement (PA) per modal age and reader. The PA's are calculated as the ratio between the total number of age readings in agreement with modal age and the total number of age readings for that sample per reader and modal age:

$$PA = \frac{nmodalage}{ntotal} * 100$$

Added to the table is the PA of all readers combined per modal age and a weighted mean of the PA per reader.

Co-efficient of Variation (CV)

The table presents the 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:

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

Added to the table is the CV of all readers combined per modal age and a weighted mean of the CV per reader.

Average Percentage Error (APE)

APE is 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:

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

where a_i is the age reading of reader i and $\overline{a}$ 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%. In this exchange all readers are “advanced” meaning they provide ages for stock assessment or similar purposes. 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.

Otolith Growth Analysis

SmartDots provides a measure of distance between the annotations made by the readers and thus provides a measure of growth increment width. This data is used to establish growth curves for each fish and for each reader.

4 Results

Overview of samples and readers

Table 1 and Table 2 give an overview of the samples and the readers included in the 2020 Kattegat cod age reading exercise (SmartDots ID 269 and 270).

Table 1: Overview of samples (n=200) used for the 2020 Kattegat cod exercise.

Year	ICES area	Quarter	Number of samples	Modal age range	Length range
2019	27.3.a.21	1	52	1-8	140-1060 mm
2019	27.3.a.21	2	32	1-3	0-330 mm
2019	27.3.a.21	3	29	0-5	110-800 mm
2019	27.3.a.21	4	87	0-4	90-700 mm

Table 2: Reader overview for the 2020 Kattegat cod exercise.

Reader code	Reader initials	Expertise
R01 DK	HR	Advanced
R02 DK	MJ	Advanced
R03 DK	SEL	Advanced

4.1.1 Results of the broken otoliths (ID 269) and the sectioned otoliths (ID 270)

The weighted average percentage agreement (PA) based on modal ages for all readers is 79% for broken otoliths and 85 % for sectioned otoliths (Table 3), meaning the agreement is higher for the sectioned otoliths. The weighted average coefficient of variation (CV) is 28% for broken otoliths and 23 % for sectioned otoliths (Table 4), while the average percentage error (APE) is 16% for broken otoliths and 10 % for sectioned otoliths. The lower CV and APE values for the sectioned otoliths mean that overall, the age readings made on the sectioned otoliths are more precise.

Table 3: 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, per method.

Broken				
Modal age	**R01 DK**	**R02 DK**	**R03 DK**	**all**
0	100 %	92 %	77 %	**90 %**
1	61 %	86 %	100 %	**82 %**
2	95 %	78 %	35 %	**69 %**
3	88 %	56 %	83 %	**76 %**
4	80 %	100 %	30 %	**69 %**
5	100 %	80 %	100 %	**93 %**
6	100 %	100 %	100 %	**100 %**
7				
8				
Weighted Mean	**83 %**	**78 %**	**75 %**	**79 %**

Sectioned				
Modal age	**R01 DK**	**R02 DK**	**R03 DK**	**all**
0	98 %	89 %	81 %	**90 %**
1	78 %	86 %	96 %	**87 %**
2	96 %	61 %	68 %	**75 %**
3	96 %	85 %	87 %	**89 %**
4	88 %	100 %	38 %	**75 %**
5	88 %	38 %	100 %	**75 %**
6	-	-	-	**-**
7	-	-	-	**-**
8	100 %	100 %	100 %	**100 %**
Weighted Mean	**91 %**	**81 %**	**84 %**	**85 %**

Table 4: 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, per method.

Broken				
Modal age	**R01 DK**	**R02 DK**	**R03 DK**	**all**

Sectioned				
Modal age	**R01 DK**	**R02 DK**	**R03 DK**	**all**

0	-	-	-	-
1	64 %	33 %	0 %	**41 %**
2	11 %	28 %	36 %	**32 %**
3	11 %	16 %	13 %	**15 %**
4	16 %	0 %	20 %	**17 %**
5	0 %	9 %	0 %	**5 %**
6	-	-	-	**0 %**
7				
8				
Weighted Mean	**29 %**	**23 %**	**14 %**	**28 %**

0	-	-	-	-
1	47 %	36 %	18 %	**35 %**
2	9 %	31 %	30 %	**27 %**
3	10 %	13 %	12 %	**12 %**
4	9 %	0 %	15 %	**12 %**
5	7 %	17 %	0 %	**10 %**
6	-	-	-	-
7				
8	-	-	-	**0 %**
Weighted Mean	**23 %**	**23 %**	**17 %**	**23 %**

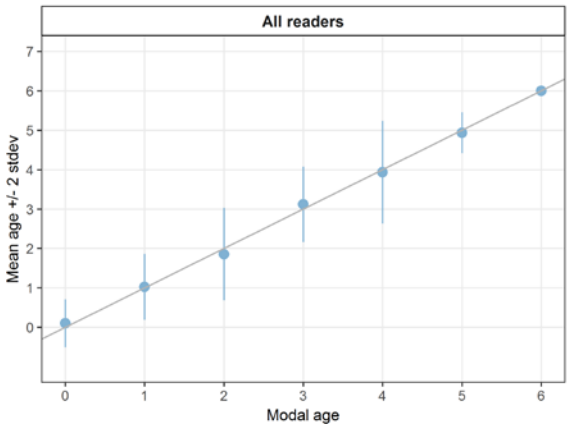
The overall relative bias is 0.02 for both the broken and sectioned otoliths which indicates an overestimation in comparison to modal age (Table 5) but the variation in relative bias at each modal age and for each method needs to be considered. For both the broken and sectioned otoliths the relative bias is positive (indicating overestimation in comparison to modal age) at modal age 0 and 1. For sectioned otoliths there is no bias (based on all readers) at modal ages 2, 3, 5 and 8, with a negative bias at modal age 4. For broken otoliths, the relative bias at modal ages 2, 3, 4 and 5 ranges from -0.14 to 0.12. The relative bias plots for all readers combined (Figure 1) support these results. Individual reader age bias plots can be found in Annex 1.

The results of the inter reader bias tests (Table 6) show that for broken otoliths there is certainty of bias between R02 and R03 with modal age and for sectioned otoliths there is a possibility of bias between R02 and modal age.

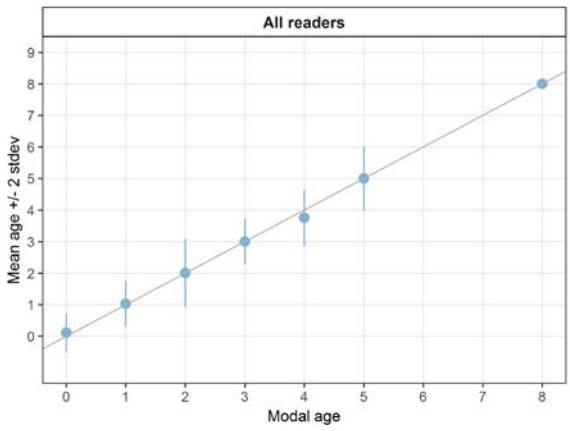
Table 5: Relative bias table represents the relative bias per modal age per reader, the relative bias of all readers combined per modal age and a weighted mean of the relative bias per reader, per method.

Broken				
Modal age	**R01 DK**	**R02 DK**	**R03 DK**	**all**
0	**0.00**	**0.08**	**0.23**	**0.10**
1	-0.02	0.10	0.00	**0.03**
2	0.05	0.16	**-0.65**	**-0.14**
3	0.12	0.40	-0.17	**0.12**
4	0.30	0.00	**-0.50**	**-0.07**
5	0.00	-0.20	0.00	**-0.07**
6	0.00	0.00	0.00	**0.00**
7				
8				
Weighted Mean	**0.05**	**0.18**	**-0.17**	**0.02**

Sectioned				
Modal age	**R01 DK**	**R02 DK**	**R03 DK**	**all**
0	**0.02**	**0.11**	**0.19**	**0.10**
1	0.00	0.06	0.04	**0.03**
2	0.04	0.21	-0.25	**0.00**
3	0.02	0.08	-0.10	**0.00**
4	-0.12	0.00	**-0.62**	**-0.25**
5	0.12	-0.12	0.00	**0.00**
6	-	-	-	-
7	-	-	-	-
8	0.00	0.00	0.00	**0.00**
Weighted Mean	**0.02**	**0.09**	**-0.03**	**0.02**



Broken



Sectioned

Figure 1: Age bias plot for all readers combined for broken and sectioned otoliths. 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).

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)

Broken			
Comparison	**R01 DK**	**R02 DK**	**R03 DK**
R01 DK	-	*	**
R02 DK	*	-	**
R03 DK	**	**	-
Modal age	-	**	**

Sectioned			
Comparison	**R01 DK**	**R02 DK**	**R03 DK**
R01 DK	-	-	-
R02 DK	-	-	*
R03 DK	-	*	-
Modal age	-	*	-

The otolith growth plots (Figure 2) show that for both the broken and the sectioned otoliths there is no overlap between the boxes but there is an overlap between the whiskers and outliers. This indicates that there certainly are otoliths where the readers are not in agreement as to which rings should be counted and that it is not clear to them where the growth structures change from a period of growth to non-growth. The boxes and whiskers are longer for the broken otoliths (even when taking into consideration the difference in the scaling of the y axis), meaning there is more variation in where the readers are identifying the winter rings to be on the broken otoliths.

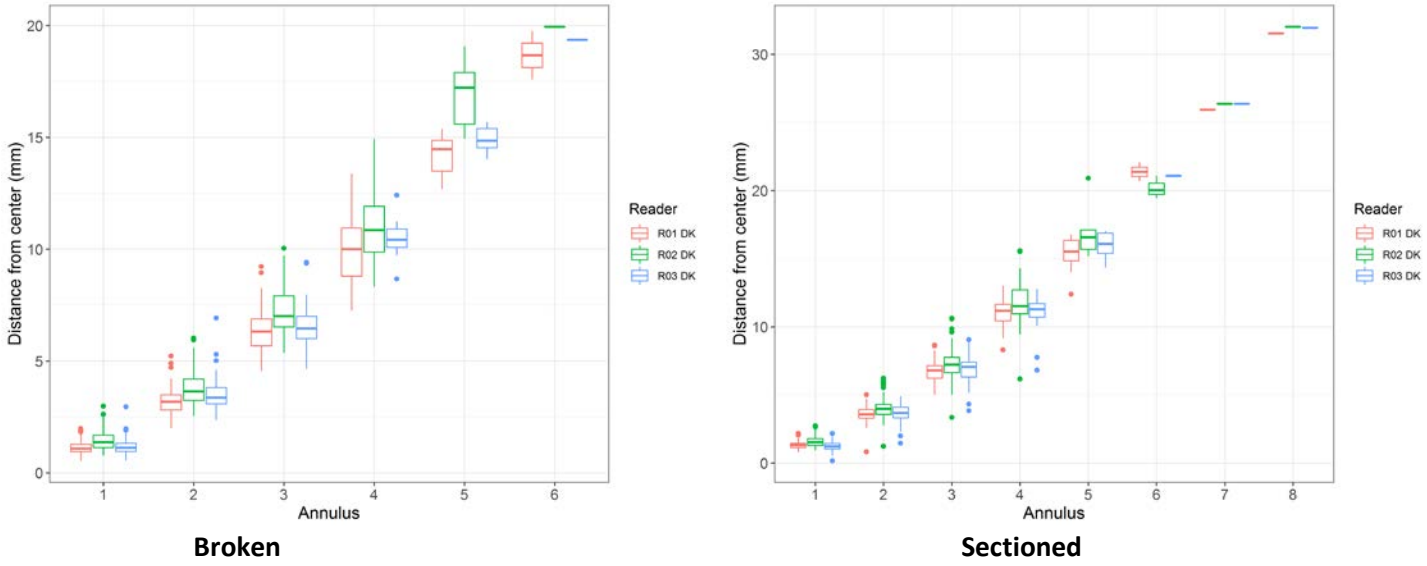


Figure 2: Plot of average distance from the centre to the winter rings for all readers for broken and sectioned otoliths. The boxes represent the median, upper and lower box boundaries of the interquartile range, whiskers represent the minimum and maximum values and the dots represent the outliers.

The age error matrices (AEM's) show the proportions of each modal age mis-aged as other ages and the proportion of samples aged in agreement with modal age (numbers in bold) for each modal age. When comparing the AEM from each method it is clear that there is a larger proportion of mis-aged samples when reading using the broken otoliths (Table 7) compared to the smaller proportions when reading the sectioned otoliths (Table 8). The numbers in bold are higher in Table 8 compared to Table 7 except for modal age 5. The only age where there is no clear difference is at modal age 1

where, for both methods 10% of the samples at modal age 0 are aged to be 1 year old, indicating an overestimation compared to modal age for both methods at modal age 0.

Table 7: Age error matrix (AEM) for broken otoliths. 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. Numbers in bold indicate the proportion of samples aged in agreement with modal age.

Modal age	0	1	2	3	4	5	6
Age 0	**0.90**	0.08	0.01	-	-	-	-
Age 1	0.10	**0.83**	0.22	-	-	-	-
Age 2	-	0.10	**0.69**	0.06	-	-	-
Age 3	-	-	0.07	**0.76**	0.21	-	-
Age 4	-	-	0.01	0.18	**0.69**	0.07	-
Age 5	-	-	-	-	0.07	**0.93**	-
Age 6	-	-	-	-	0.03	-	**1**

Table 8: Age error matrix (AEM) for sectioned otoliths. 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. Numbers in bold indicate the proportion of samples aged in agreement with modal age.

Modal age	0	1	2	3	4	5	6	7	8
Age 0	**0.90**	0.05	-	-	-	-	-	-	-
Age 1	0.10	**0.87**	0.13	-	-	-	-	-	-
Age 2	-	0.08	**0.75**	0.06	-	-	-	-	-
Age 3	-	-	0.11	**0.89**	0.25	-	-	-	-
Age 4	-	-	0.01	0.04	**0.75**	0.13	-	-	-
Age 5	-	-	-	0.01	-	**0.75**	-	-	-
Age 6	-	-	-	-	-	0.13	-		
Age 7	-	-	-	-	-	-	-	-	-
Age 8	-	-	-	-	-	-	-	-	**1**

4.1.2 Modal age comparison of broken (ID 269) and sectioned otoliths (ID 270)

When comparing the modal age of the broken versus the sectioned otoliths the percentage agreement is 70% (Table 9). This means that of the 200 samples included in the exercise there are 140 otoliths where the modal age from the sectioned otoliths is the same as the modal age from the broken otoliths. There are 60 otoliths where the modal ages are not the same. A positive bias of 0.21 indicates overestimation of ages when reading broken otoliths in comparison to reading sectioned otoliths. At modal ages 0 and 1 the percentage agreed is lowest at 56% and 60% respectively, this improves slightly at modal age 2, where it is 75% (Table 10).

Table 9: Results overview of the modal age comparison of broken and sectioned otoliths

No. Aged	200
No. Agreed	140
No. Disagreed	60
Bias	0.21
CV	0.13
% Agreed	70%

Table 10: Modal age comparison results by modal age

Modal Age	No. Broken	No. Sectioned	No. Agreed	% agreed
0	48	27	27	**56%**
1	55	56	33	**60%**
2	28	43	21	**75%**
3	52	56	48	**92%**
4	8	10	5	**63%**
5	8	5	5	**63%**
6	0	1	0	**N/A**
7	0	0	0	**N/A**
8	1	1	1	**100%**

The modal age comparison matrix (Table 11) is based on the 199 samples where a modal age was calculated for each method. The numbers shown are the actual number (not proportions) of otoliths where the modal age calculated was the same for the two methods (green), the modal age calculated based on the broken otoliths was higher compared to the sectioned otoliths (red) and the modal age calculated based on the broken otoliths was lower compared to the sectioned otoliths (blue). The numbers in red total to 51, meaning that of the 60 samples where the modal age is not the same for the two methods there are 51 samples where a higher modal age is reached from the broken method. The main reasons for this are:

1. Readers count an additional translucent zone (TZ) on the broken otolith compared to the sectioned otolith.
2. Readers are uncertain as to the edge type in both methods and when to count a TZ or not
3. Reader specific problems

Table 11: Modal age comparison matrix. Green shaded area is agreement between the two methods, blue represents a lower age from the broken method (underestimation) and red represents a higher age from the broken method (overestimation).

Sectioned modal age	Broken modal age									**Total Broken**
	0	1	2	3	4	5	6	7	8	
0	27	21	0	0	0	0	0	0	0	**48**
1	0	33	21	0	0	0	0	0	0	**54**
2	0	2	21	5	0	0	0	0	0	**28**
3	0	0	1	48	3	0	0	0	0	**52**
4	0	0	0	3	5	0	0	0	0	**8**
5	0	0	0	0	2	5	1	0	0	**8**
6	0	0	0	0	0	0	0	0	0	**0**
7	0	0	0	0	0	0	0	0	0	**0**
8	0	0	0	0	0	0	0	0	1	**1**
Total Sectioned	**27**	**56**	**43**	**56**	**10**	**5**	**1**	**0**	**1**	**199**

1. **Readers count an additional translucent zone (TZ) on the broken otolith compared to the sectioned otolith.**

In Figure 3 all readers agree on age 1 when reading the broken otolith (A), R03 is counting the innermost translucent zone (TZ) and R01 and R02 counting the outermost TZ (marked in red). In Figure 3, the modal age from the sectioned method (B) is age 0, R03 is estimating age 1 and counting innermost TZ (marked in red), R01 and R02 are estimating age 0. R01 is the only reader to estimate the same age from both methods but the innermost ring (diamter =1.32mm measured on the sectioned otolith) is a settling ring and should not be counted. The correct age for this fish is 0.

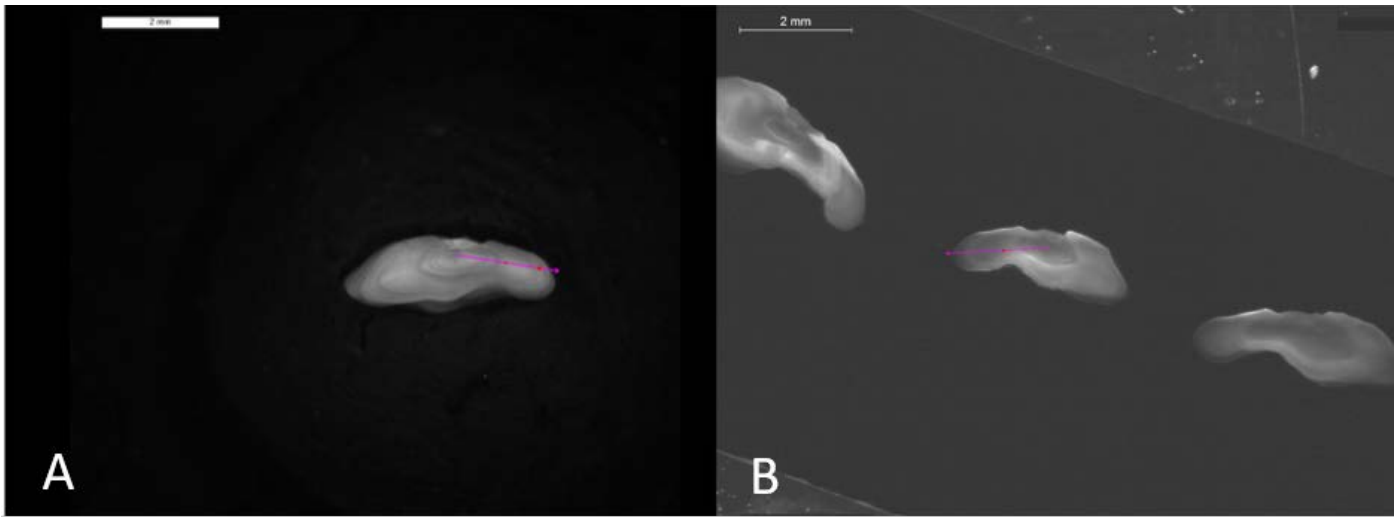


Figure 3. 7994966, capture date 29/08/2019, length 190mm. A. Broken otolith and B. Sectioned otolith

There are numerous examples of the above problem where a higher modal age is estimated from the broken otolith. Other examples of a silimar problem are shown in Figure 4, sample 7995189, where the innermost ring is wider in diameter (1.85mm, measured on the sectioned otolith) and width so is likely to be a real TZ, however because the capture date is August this TZ should not be included in the count of age. On the broken otolith (A) all readers are estimating age 1 from the innermost TZ (marked in red) but on the sectioned otolith (B) only R03 is estimating age 1 and counting innermost TZ (marked in red), R01 and R02 are estimating age 0. The correct age for this fish is 0. The same problem is seen in 7994969 (TL 170mm), 7994970 (TL 160mm), 7995187 (TL 190mm) and 7995188 (TL 180mm) all caught in August.

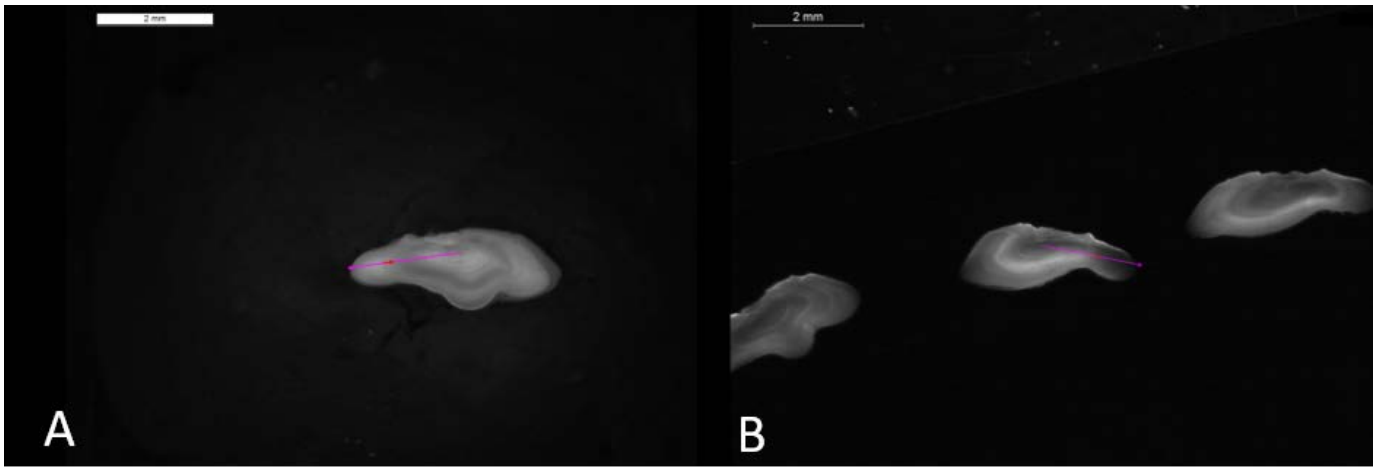


Figure 4 7995189, capture date 26/08/2019, length 170mm. A. Broken otolith and B. Sectioned otolith

The same problem persists when the fish are age 1 and readers will estimate the fish to be 1 year older when reading the broken otolith compared to the sectioned otolith. With sample 7894657 in Figure 5, R01 and R03 estimate age 2 (marked in red) and R02 estimates age 1 (outermost TZ) from the broken otolith (A) but from the sectioned otolith (B) R01 and R02 estimate age 1 (outermost TZ) and R03 estimates age 2 (marked in red). This fish is caught in February 2019 and has a narrow inner TZ, the readers do not agree as to whether the edge is opaque or translucent and different structures are being included in the count of age. In the broken (A) otolith R01 and R02 identify a TZ at the edge and estimate age 2 as a consequence. The correct age for this fish is age 1, it is the innermost TZ which should counted and the edge type is opaque.

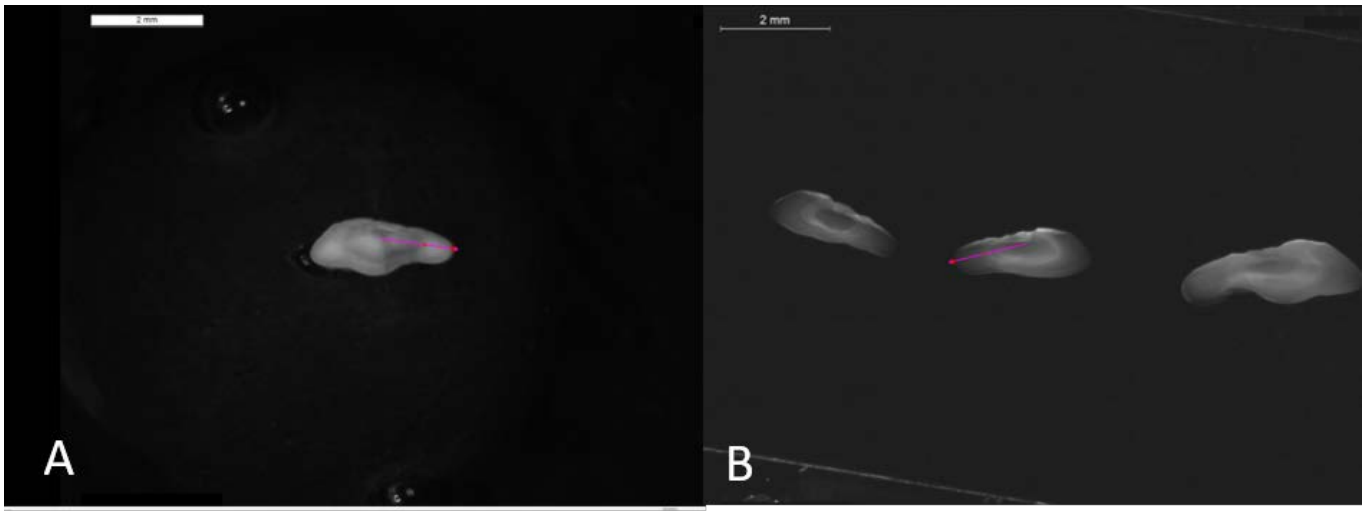


Figure 5 7894657, capture date 27/02/2019, TL 140 mm. A. Broken otolith and B. Sectioned otolith.

Another example of this problem is 7921647 (capture date 30/04/2019, TL 180 mm), R01 and R02 are estimating age 2 on the broken even though they disagree on the edge type whereas R03 only counts the innermost TZ and estimates age 1. On the sectioned otolith, all readers agree on modal age 1 but not by counting the same structures, R02 counts a TZ at the edge and identifies the edge type as translucent whereas it is opaque. The diameter of the innermost TZ, measure on the sectioned otolith is 2.16mm. The correct age for this fish is age 1.

These examples outline the second reason for there being differences in the ages estimated from the two methods, namely the incorrect identification of the edge type. This problem is also attributed to a change in the annual growth pattern observed in the otoliths from this area which is requiring readers to change their perception of how the fish are growing and thus how to assign the correct age to the fish.

2. Readers are uncertain as to the edge type in both methods and when to count a TZ or not

Correct identification of the otolith edge type is needed when estimating the age of a fish. The results of this exchange show that readers are having difficulties with this. Figure 6, sample 8039482 below, caught in November 2018, shows the broken otolith (A) where R02 and R03 identify the edge to be opaque and estimate age 1. R01 estimates age 0 but comments that maybe this is age 1 and identifies the edge to be translucent. In the sectioned

otolith (B) R02 estimates age 1 and identifies the edge to be opaque while R01 and R03 estimate age 0 and a translucent otolith edge. A close examination and brightness adjustment in the image shows the edge type to be opaque even though the TZ is very close to the otolith edge. The correct age for this fish is age 0.

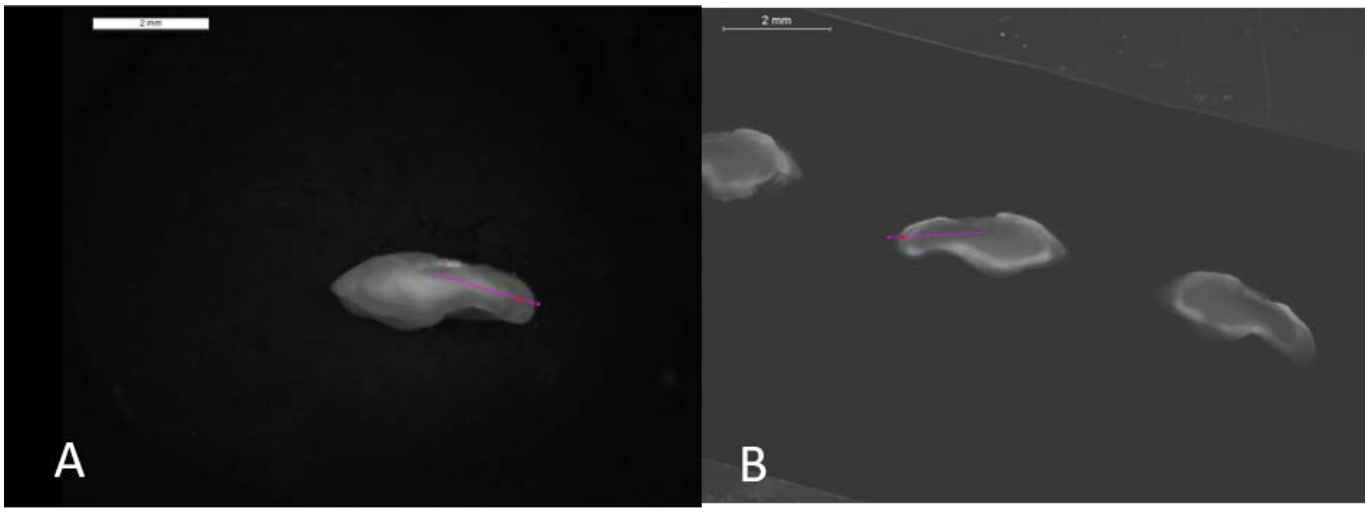


Figure 6 8039482, capture date 12/11/2018, TL 200 mm. A. Broken otolith and B. Sectioned otolith.

Figure 7, sample 8039487 below again shows disagreement between methods but where the TZ's in both images are clearly visible but readers do not agree on the edge type. From the broken otolith (A) R02 and R03 estimate age 1 while R01 estimates age 0. From the sectioned otolith (B) only R02 estimtes age 1 and R01 and R03 estimate age 0. The edge type is clearly opaque, capture date is 12/11/2018 and TL 160 mm. The correct age for this fish is age 0. Other examples include 8039483 (capture date 12/11/2019 TL 190 mm) and 8039484 (capture date 12/11/2019 TL 180 mm).

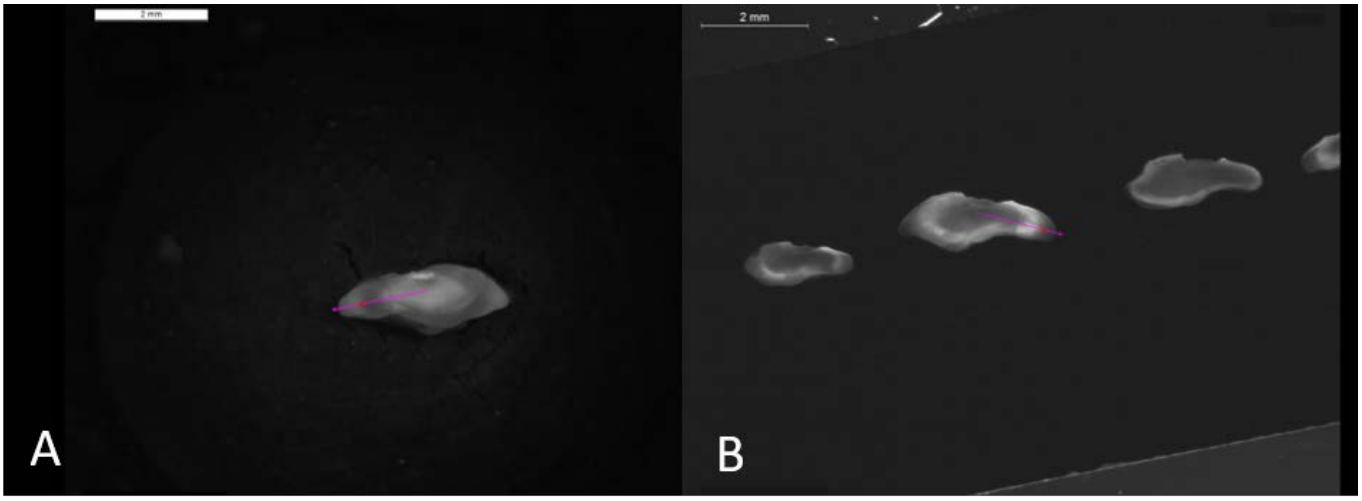


Figure 7 8039487, capture date 12/11/2018, TL 160 mm. A. Broken otolith. B. Sectioned otolith. Both methods showing a clear opaque edge.

In Figure 8, sample 7924580 all readers identify the edge type to be opaque on the sectioned otolith (B) and only R01 identifies it to be translucent on the the broken otolith (A). The problem here is that even though the edge is

identified as opaque on the broken otolith (A) a TZ is counted at the edge and an age of 2 is given. The correct age of this fish is 1. Samples 7949420, 7949421 and 7949422 are good examples of the same problem.

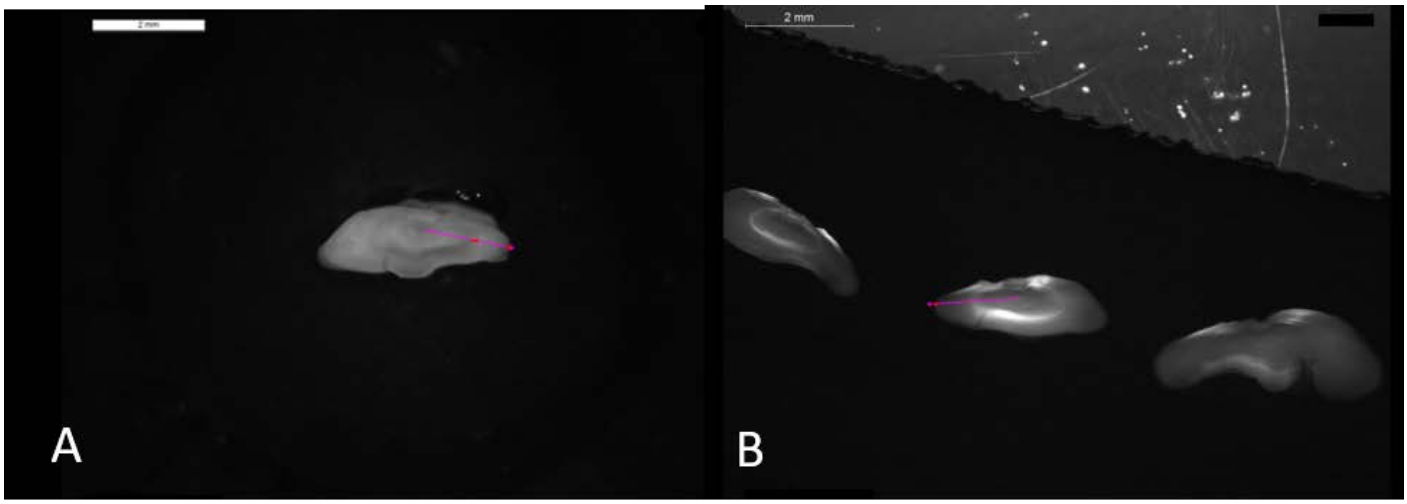


Figure 8 7924580, capture date 07/05/2019, TL 190 mm. A. Broken otolith and B. Sectioned otolith.

3. **Reader specific problems**

In some examples, R02 will count an extra TZ close to the otolith edge, which should not be counted. An example is 8039153 (capture date 13/11/2019, TL 420mm) where the TZ is very close to the edge and an opaque edge is beginning to form on the edge, because of this, age 2 is estimated which is incorrect. The correct age for this fish is age 1. Figure 8 shows a similar problem where a TZ is counted at the edge that is not clearly visible but which readers would expect to see if the traditional growth pattern was being followed. In some examples, R03 will count the settling ring as the first TZ. An example is 7994966 (capture date 29/08/2019, TL 190mm). The settling ring is usually much narrower in diameter and much less defined compared to the first TZ. Both of these issues will lead to an overestimation of age. R01 is not consistent as to where on the TZ the annotation is made, this will not necessarily lead to estimating an incorrect age but makes comparison of readers annotations difficult and leads to variability in the growth plots in Figure 2.

5 Discussion

This exercise includes broken and sectioned otoliths from the same fish in order to clarify the discrepancies between the ages estimated when applying the two different methods. A higher percentage agreement and lower coefficient of variation for the sectioned otoliths indicates this method provides a higher level of age data quality. The analysis of modal age comparison shows that in 51 of 60 samples where there is disagreement between the modal ages, a higher modal age is calculated for the broken method (Bias = 0.21). This is an indication that readings based on the broken method are likely to be overestimated in comparison to the actual age. True validated ages do not exist for any of the samples in this exercise and thus it cannot be concluded which method will provide the true actual age.

The routine method applied at DTU Aqua for cod age reading is the broken method. Readers have varying levels of experience in reading sectioned cod otoliths and only R03 has participated in calibration events on SmartDots using this method. The sectioned method will produce an even cross section of the otolith; this enables correct focussing on the annuli and precision in hitting the otolith nucleus. The broken method will lead to an uneven surface that makes it difficult to focus on the annuli, and the breaking process is unreliable in hitting the otolith nucleus. The other major difference between the two methods is the light source used when viewing the otolith. The sectioned otolith is viewed with transmitted light, leading to white translucent zones and dark opaque zones. The broken otolith is viewed with reflected light, leading to white opaque zones and dark translucent zones. The pattern in growth zones appears reversed when the light source changes from reflected (broken) to transmitted (sectioned) but even when taking this into consideration the results show that readers are able to achieve a higher agreement and level of precision when reading the sectioned otoliths.

In addition to the above, there has been a change over time in the timing of the TZ deposition in the otoliths. Traditionally the TZ's are laid down in the winter months when the fish growth slows down due to lower temperatures and less food, and in the summer months when the water is warmer and food is plentiful the fish are growing and the opaque zones (OZ) are laid down. In Baltic Sea cod a change in the timing of the TZ deposition has occurred, for age 0 and age 1 cod the TZ is completed between September and December (McQueen et al., 2018). This is attributed to peak water temperatures in the shallow water zones being occupied by the fish during these months. Evidence shows that this change in pattern is also occurring in the otoliths of the age 2 and 3 year old fish in the Baltic Sea area (Krumme et al., in press).

Similar studies on Kattegat cod otoliths do not exist but the results from this exercise indicate that a similar change is occurring and the traditional patterns of TZ formation followed by the age readers are no longer reliable. Figure 6 and 7 (both caught in November) clearly show one completed TZ with an opaque zone at the otolith edge, readers do not agree on the edge type or the age because the growth pattern does not match that which they routinely follow when estimating the age of cod from the Kattegat. Sample 8040307, caught in November, is a very good example which underlines the change in timing of the TZ formation problem, both methods show a wide TZ and an opaque edge beginning to form. This is an age 0 fish with a TZ formed between September and November which is not included in the count of age. Only from January in the following year should this TZ be included in the count of age. Samples 8040309 and 8040310 are also good examples of true 0 age fish, as is 8039487 in Figure 7. Sample 7941093, caught in June, is a good example of what an otolith from an age 1 fish looks like with one clear TZ, followed by a wide opaque zone. Sample 7924580 in Figure 8 is another good example of an age 1 fish.

Readers were asked to define the outermost edge type of each otolith as either Opaque (O) or translucent (T) in the SmartDots software. A comparison was made of the reader definitions against the otolith images and this showed that more training is required before reliable data can be obtained from such an exercise. Readers need to be more familiar with both the change in light direction and the change in the timing of TZ deposition.

The measurement tool in the SmartDots software was used in the analysis to measure the diameter of TZ on some of the samples to assess whether or not guidelines could be provided for the readers. On those samples measured the guidelines for Baltic Sea cod (McQueen et al., 2018) held but a more thorough analysis based on a larger number of measurements taken on Kattegat cod otoliths is required before any guidelines can be provided for the readers.

6 Conclusion

The results of this exercise were presented and discussed with the participants and it was agreed that the sectioned method provides a higher quality preparation for age determination and that the results obtained from reading the sectioned otoliths are more reliable than those obtained from the broken method. The ages estimated based on the broken method are higher compared to those estimated on the sectioned method. The guidelines provided for cod in the western Baltic Sea should be followed when ageing cod from the Kattegat (Annex 8.3). For samples caught in Q3 and Q4 the TZ's at the outermost otolith edge should not be counted. The guideline of a mean diameter of the first TZ being 2.0 +/- 0.5 mm can be applied if there is any doubt in regards to the location of the first TZ.

Taking measurements and correct identification of otolith edge type is more reliable on sectioned otoliths and in order to compile data on TZ diameters and otolith edge type for Kattegat cod the sectioned otoliths will be photographed and uploaded to SmartDots for further calibration events. New features of SmartDots enable readers to measure growth zones and record otoliths edge type. A set of reader guidelines will be compiled based on these images.

The classification of otolith edge type has been problematic due to alternating light sources between methods plus this is a new variable which the readers are being asked to provide. More experience in identifying the otolith edge type is required and SmartDots now has a feature which enables the readers to record the edge type for each sample in any event.

Readers emphasised the need for more biological information on area specific spawning times, changes in growth, optimal temperature for growth and reproduction and observed changes in water temperature that are impacting the biological characteristics of this stock. It was discussed that following maturation and first spawning the growth patterns may revert to the traditional pattern and investigation should be carried out on fish age 3 and above and reader guidelines provided.

The events are now open on SmartDots for the readers to compare their readings.

7 References

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8 Annex 1.

8.1 Results from ID 270 – sectioned otoliths

Table 8.1: Summary of statistics

CV	PA	APE
23 %	85 %	10 %

Table 8.2: Data overview for sectioned otoliths including modal age and statistics per sample.

Fish ID	Event ID	length	sex	Catch date	ICES area	R01 DK	R02 DK	R03 DK	Modal age	PA %	CV %	APE %
7864136	270	360	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864142	270	480	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864143	270	450	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864144	270	460	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864146	270	430	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864147	270	420	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864149	270	420	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864151	270	360	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864157	270	380	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864158	270	340	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7892942	270	170	-	25/02/2019 09:19:33	27.3.a.21	1	1	1	1	100	0	0
7892943	270	160	-	25/02/2019 09:19:33	27.3.a.21	1	1	1	1	100	0	0
7894311	270	190	-	26/02/2019 10:43:04	27.3.a.21	2	1	1	1	67	43	33
7894657	270	140	-	27/02/2019 06:02:02	27.3.a.21	1	1	1	1	100	0	0
7894658	270	140	-	27/02/2019 06:02:02	27.3.a.21	1	1	1	1	100	0	0
7895071	270	750	-	27/02/2019 12:22:16	27.3.a.21	5	6	5	5	67	11	8
7895072	270	680	-	27/02/2019 12:22:16	27.3.a.21	3	4	3	3	67	17	13
7895074	270	180	-	27/02/2019 12:22:16	27.3.a.21	2	1	2	2	67	35	27
7895254	270	630	-	27/02/2019 14:48:16	27.3.a.21	4	4	3	4	67	16	12
7895255	270	620	-	27/02/2019 14:48:16	27.3.a.21	3	3	3	3	100	0	0
7895256	270	590	-	27/02/2019 14:48:16	27.3.a.21	4	4	3	4	67	16	12
7895259	270	360	-	27/02/2019 14:48:16	27.3.a.21	3	3	4	3	67	17	13
7895260	270	340	-	27/02/2019 14:48:16	27.3.a.21	3	3	3	3	100	0	0

7895261	270	460	-	27/02/2019 14:48:16	27.3.a.21	3	4	3	3	67	17	13
7895390	270	280	-	28/02/2019 06:22:17	27.3.a.21	3	3	3	3	100	0	0
7895581	270	330	-	28/02/2019 08:52:17	27.3.a.21	3	3	3	3	100	0	0
7895735	270	430	-	28/02/2019 11:33:28	27.3.a.21	4	4	3	4	67	16	12
7895736	270	700	-	28/02/2019 11:33:28	27.3.a.21	5	6	5	5	67	11	8
7895738	270	430	-	28/02/2019 11:33:28	27.3.a.21	3	4	3	3	67	17	13
7895742	270	410	-	28/02/2019 11:33:28	27.3.a.21	4	4	3	4	67	16	12
7895743	270	350	-	28/02/2019 11:33:28	27.3.a.21	3	3	2	3	67	22	17
7895745	270	290	-	28/02/2019 11:33:28	27.3.a.21	3	2	2	2	67	25	19
7897290	270	620	-	02/03/2019 13:34:19	27.3.a.21	5	5	5	5	100	0	0
7897291	270	630	-	02/03/2019 13:34:19	27.3.a.21	4	4	4	4	100	0	0
7897292	270	630	-	02/03/2019 13:34:19	27.3.a.21	5	4	5	5	67	12	10
7897293	270	670	-	02/03/2019 13:34:19	27.3.a.21	6	5	5	5	67	11	8
7897295	270	610	-	02/03/2019 13:34:19	27.3.a.21	5	4	5	5	67	12	10
7900896	270	290	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900897	270	280	-	12/03/2019 06:07:37	27.3.a.21	2	3	2	2	67	25	19
7900898	270	310	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900899	270	350	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900900	270	320	-	12/03/2019 06:07:37	27.3.a.21	2	3	2	2	67	25	19
7900901	270	290	-	12/03/2019 06:07:37	27.3.a.21	3	2	3	3	67	22	17
7900902	270	320	-	12/03/2019 06:07:37	27.3.a.21	3	3	2	3	67	22	17
7900904	270	310	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900905	270	330	-	12/03/2019 06:07:37	27.3.a.21	3	3	2	3	67	22	17
7900909	270	170	-	12/03/2019 06:07:37	27.3.a.21	1	1	1	1	100	0	0
7901553	270	1060	-	13/03/2019 12:28:08	27.3.a.21	8	8	8	8	100	0	0
7910375	270	330	-	27/03/2019 04:20:49	27.3.a.21	3	3	3	3	100	0	0
7910376	270	280	-	27/03/2019 04:20:49	27.3.a.21	2	2	2	2	100	0	0
7910377	270	360	-	27/03/2019 04:20:49	27.3.a.21	3	3	2	3	67	22	17
7910379	270	340	-	27/03/2019 04:20:49	27.3.a.21	3	3	3	3	100	0	0

7921646	270	170	-	30/04/2019 18:40:09	27.3.a.21	1	1	2	1	67	43	33
7921647	270	180	-	30/04/2019 18:40:09	27.3.a.21	1	1	1	1	100	0	0
7921652	270	240	-	30/04/2019 18:40:09	27.3.a.21	2	2	1	2	67	35	27
7921653	270	270	-	30/04/2019 18:40:09	27.3.a.21	2	2	1	2	67	35	27
7923883	270	290	-	30/04/2019 18:45:27	27.3.a.21	2	2	1	2	67	35	27
7923884	270	200	-	30/04/2019 18:45:27	27.3.a.21	2	1	1	1	67	43	33
7923885	270	190	-	30/04/2019 18:45:27	27.3.a.21	2	1	2	2	67	35	27
7924575	270	210	-	07/05/2019 18:45:19	27.3.a.21	2	1	1	1	67	43	33
7924576	270	200	-	07/05/2019 18:45:19	27.3.a.21	2	1	1	1	67	43	33
7924577	270	230	-	07/05/2019 18:45:19	27.3.a.21	1	1	1	1	100	0	0
7924578	270	250	-	07/05/2019 18:45:19	27.3.a.21	1	1	1	1	100	0	0
7924579	270	260	-	07/05/2019 18:45:19	27.3.a.21	2	1	1	1	67	43	33
7924580	270	190	-	07/05/2019 18:45:19	27.3.a.21	1	1	1	1	100	0	0
7940420	270	180	-	20/05/2019 19:15:40	27.3.a.21	1	1	1	1	100	0	0
7940421	270	210	-	20/05/2019 19:15:40	27.3.a.21	1	1	1	1	100	0	0
7940422	270	220	-	20/05/2019 19:15:40	27.3.a.21	1	1	1	1	100	0	0
7941091	270	180	-	14/05/2019 23:15:06	27.3.a.21	1	1	1	1	100	0	0
7941092	270	210	-	14/05/2019 23:15:06	27.3.a.21	1	1	1	1	100	0	0
7941093	270	260	-	14/05/2019 23:15:06	27.3.a.21	1	2	1	1	67	43	33
7941428	270	220	-	20/06/2019 19:40:36	27.3.a.21	1	1	1	1	100	0	0
7941429	270	230	-	20/06/2019 19:40:36	27.3.a.21	0	1	1	1	67	87	67
7941430	270	230	-	20/06/2019 19:40:36	27.3.a.21	1	1	1	1	100	0	0
7941858	270	190	-	15/05/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
7941862	270	0	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7941865	270	0	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7941866	270	0	-	15/05/2019 00:00:00	27.3.a.21	3	3	2	3	67	22	17
7942090	270	170	-	15/05/2019 00:00:00	27.3.a.21	1	1	2	1	67	43	33
7942092	270	180	-	15/05/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
7942096	270	260	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27

7942097	270	270	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7942099	270	310	-	15/05/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
7942100	270	330	-	15/05/2019 00:00:00	27.3.a.21	3	3	2	3	67	22	17
7967582	270	670	-	06/08/2019 00:00:00	27.3.a.21	5	4	5	5	67	12	10
7991244	270	140	-	15/08/2019 18:45:04	27.3.a.21	0	0	0	0	100	-	-
7991246	270	210	-	15/08/2019 18:45:04	27.3.a.21	1	1	1	1	100	0	0
7994962	270	200	-	29/08/2019 18:15:23	27.3.a.21	1	0	1	1	67	87	67
7994963	270	230	-	29/08/2019 18:15:23	27.3.a.21	1	-	1	1	100	0	0
7994964	270	180	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994965	270	280	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994966	270	190	-	29/08/2019 18:15:23	27.3.a.21	0	0	1	0	67	-	-
7994967	270	210	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994969	270	170	-	29/08/2019 18:15:23	27.3.a.21	0	0	1	0	67	-	-
7994970	270	160	-	29/08/2019 18:15:23	27.3.a.21	0	0	1	0	67	-	-
7995182	270	180	-	26/08/2019 19:45:34	27.3.a.21	0	0	1	0	67	-	-
7995183	270	240	-	26/08/2019 19:45:34	27.3.a.21	1	0	1	1	67	87	67
7995184	270	200	-	26/08/2019 19:45:34	27.3.a.21	0	0	1	0	67	-	-
7995185	270	210	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995186	270	200	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995187	270	190	-	26/08/2019 19:45:34	27.3.a.21	0	0	1	0	67	-	-
7995188	270	180	-	26/08/2019 19:45:34	27.3.a.21	0	0	1	0	67	-	-
7995189	270	170	-	26/08/2019 19:45:34	27.3.a.21	0	0	1	0	67	-	-
7995934	270	780	-	03/09/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7995935	270	800	-	03/09/2019 00:00:00	27.3.a.21	4	4	4	4	100	0	0
7995936	270	800	-	03/09/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7999823	270	730	-	04/09/2019 00:00:00	27.3.a.21	5	5	5	5	100	0	0
8004095	270	110	-	26/08/2019 18:40:54	27.3.a.21	0	0	0	0	100	-	-
8004096	270	700	-	26/08/2019 18:40:54	27.3.a.21	3	3	3	3	100	0	0
8008496	270	240	-	19/09/2019 04:30:34	27.3.a.21	0	1	1	1	67	87	67

8008497	270	250	-	19/09/2019 04:30:34	27.3.a.21	1	-	1	1	100	0	0
8008498	270	150	-	19/09/2019 04:30:34	27.3.a.21	0	0	0	0	100	-	-
8008499	270	260	-	19/09/2019 04:30:34	27.3.a.21	1	1	1	1	100	0	0
8039079	270	700	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039081	270	650	-	13/11/2019 00:00:00	27.3.a.21	2	4	3	2	33	33	22
8039082	270	590	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039083	270	620	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039086	270	620	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039087	270	590	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039088	270	610	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039089	270	600	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039090	270	640	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039091	270	670	-	13/11/2019 00:00:00	27.3.a.21	4	4	3	4	67	16	12
8039092	270	550	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039095	270	560	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039098	270	520	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039100	270	550	-	13/11/2019 00:00:00	27.3.a.21	3	4	4	4	67	16	12
8039104	270	480	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039105	270	460	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039107	270	520	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039109	270	540	-	13/11/2019 00:00:00	27.3.a.21	2	3	3	3	67	22	17
8039110	270	480	-	13/11/2019 00:00:00	27.3.a.21	-	2	2	2	100	0	0
8039111	270	510	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039128	270	350	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039129	270	370	-	13/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8039130	270	400	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039132	270	410	-	13/11/2019 00:00:00	27.3.a.21	2	-	1	1	50	47	33
8039134	270	380	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039136	270	450	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19

8039137	270	370	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039139	270	330	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039142	270	490	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039148	270	480	-	13/11/2019 00:00:00	27.3.a.21	3	2	3	3	67	22	17
8039149	270	490	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039151	270	360	-	13/11/2019 00:00:00	27.3.a.21	1	-	1	1	100	0	0
8039153	270	420	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039154	270	420	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039479	270	210	-	12/11/2019 20:41:08	27.3.a.21	0	1	0	0	67	-	-
8039480	270	240	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039482	270	200	-	12/11/2019 20:41:08	27.3.a.21	0	1	0	0	67	-	-
8039483	270	190	-	12/11/2019 20:41:08	27.3.a.21	0	1	0	0	67	-	-
8039484	270	180	-	12/11/2019 20:41:08	27.3.a.21	0	-	0	0	100	-	-
8039485	270	180	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039486	270	120	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039487	270	160	-	12/11/2019 20:41:08	27.3.a.21	0	1	0	0	67	-	-
8039488	270	140	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039489	270	150	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039490	270	130	-	12/11/2019 20:41:08	27.3.a.21	0	0	1	0	67	-	-
8039492	270	100	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039493	270	90	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8040298	270	340	-	14/11/2019 00:58:12	27.3.a.21	1	-	1	1	100	0	0
8040299	270	170	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040300	270	200	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040301	270	190	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040303	270	180	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040304	270	160	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040305	270	140	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040307	270	110	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-

8040308	270	130	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040309	270	100	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040310	270	90	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8041458	270	300	-	15/11/2019 01:07:48	27.3.a.21	2	2	1	2	67	35	27
8041459	270	350	-	15/11/2019 01:07:48	27.3.a.21	1	-	1	1	100	0	0
8041460	270	270	-	15/11/2019 01:07:48	27.3.a.21	0	1	1	1	67	87	67
8041461	270	160	-	15/11/2019 01:07:48	27.3.a.21	0	0	0	0	100	-	-
8041462	270	170	-	15/11/2019 01:07:48	27.3.a.21	0	0	0	0	100	-	-
8041463	270	120	-	15/11/2019 01:07:48	27.3.a.21	0	0	0	0	100	-	-
8041787	270	530	-	15/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8041790	270	160	-	15/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8041791	270	120	-	15/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049082	270	660	-	18/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8049083	270	500	-	18/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8049084	270	90	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049085	270	100	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049086	270	110	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049087	270	120	-	18/11/2019 00:00:00	27.3.a.21	0	1	0	0	67	-	-
8049088	270	130	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049089	270	140	-	18/11/2019 00:00:00	27.3.a.21	1	0	0	0	67	-	-
8049090	270	150	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049366	270	640	-	18/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8049367	270	480	-	18/11/2019 00:00:00	27.3.a.21	2	1	2	2	67	35	27
8049368	270	450	-	18/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8049369	270	360	-	18/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8049370	270	330	-	18/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8049371	270	270	-	18/11/2019 00:00:00	27.3.a.21	0	1	1	1	67	87	67
8049372	270	260	-	18/11/2019 00:00:00	27.3.a.21	0	1	1	1	67	87	67
8049373	270	90	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-

8049374	270	100	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049375	270	110	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-

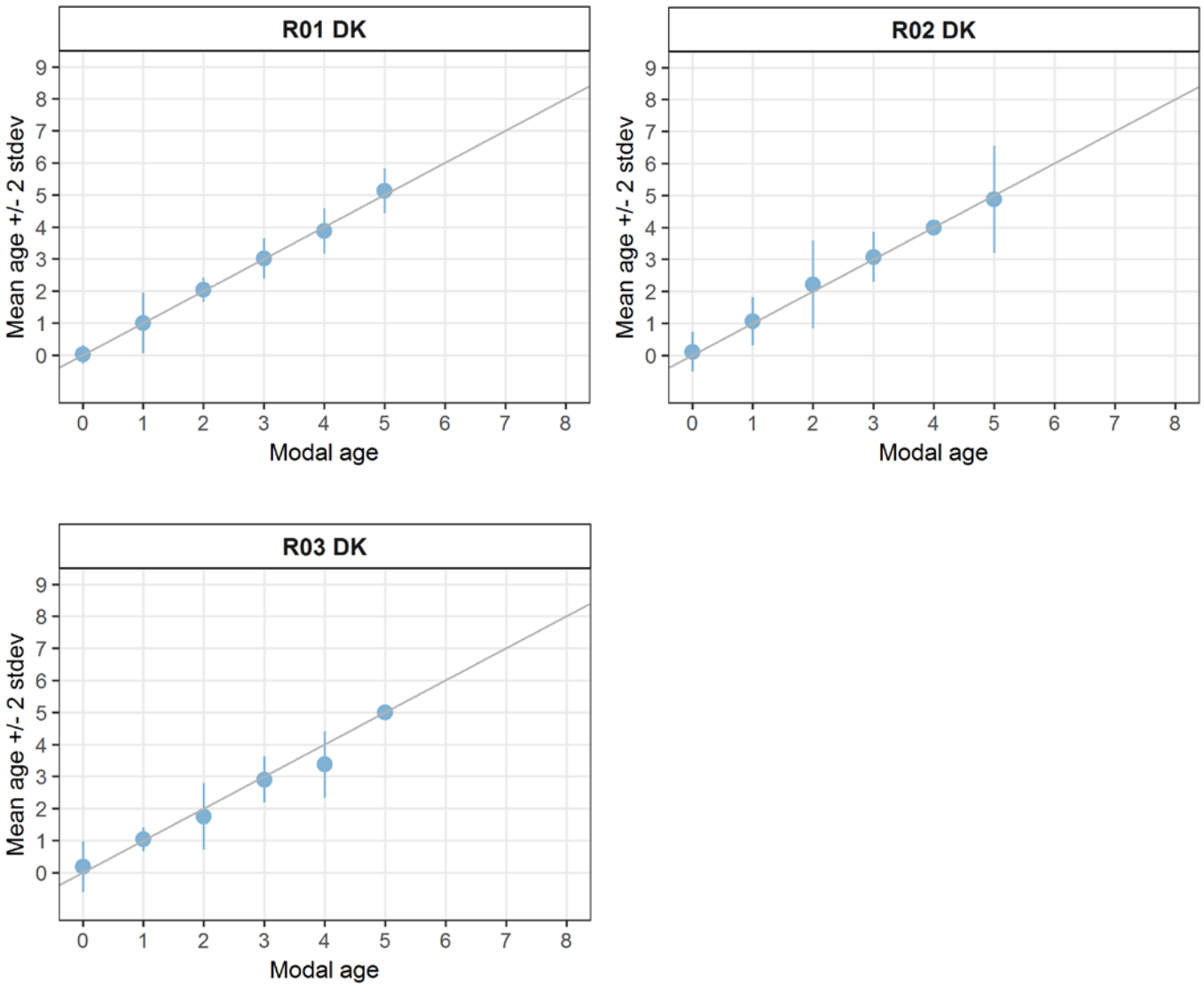


Figure 8.1: Age bias plots for each reader of the sectioned otoliths. Mean age recorded +/- 2 stdev of each reader and all readers combined are plotted against modal age. The estimated mean age corresponds to modal age, if the estimated mean age is on the 1:1 equilibrium line (solid line).

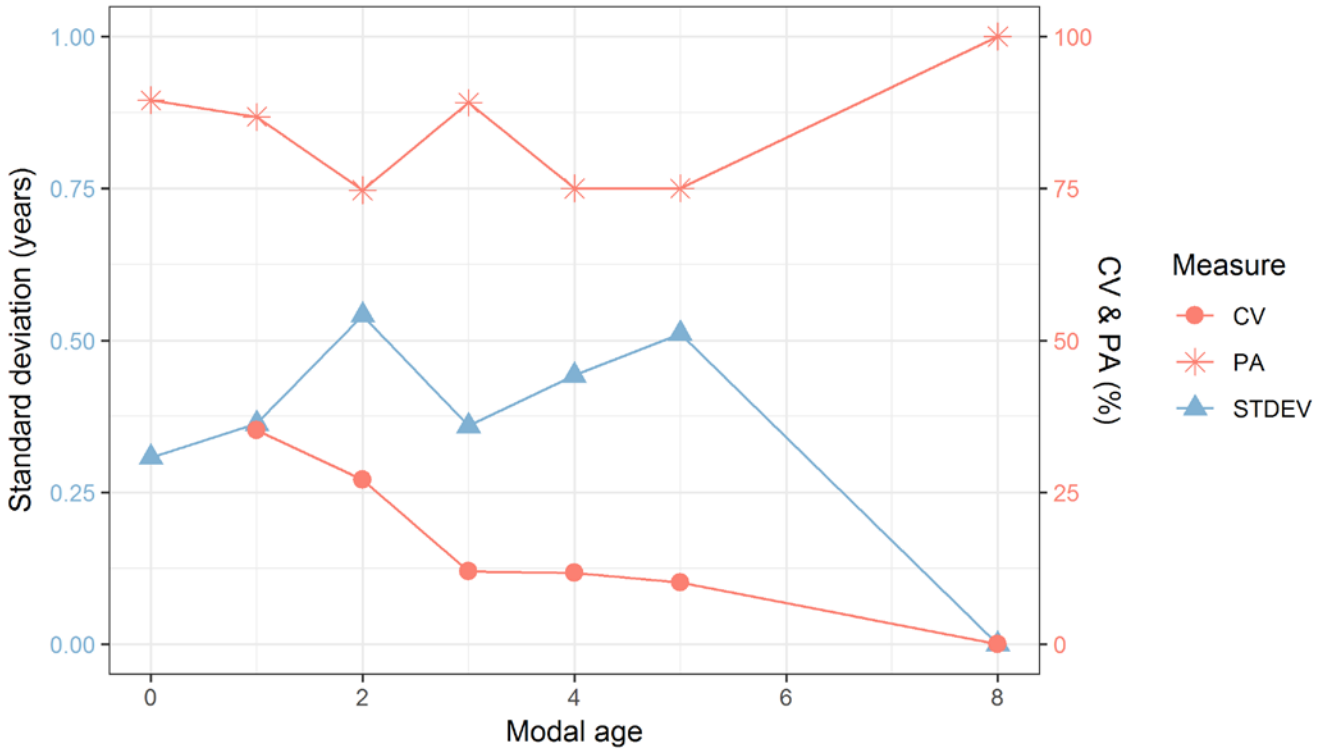


Figure 8.2: CV, PA and (STDEV (standard deviation) are plotted against modal age

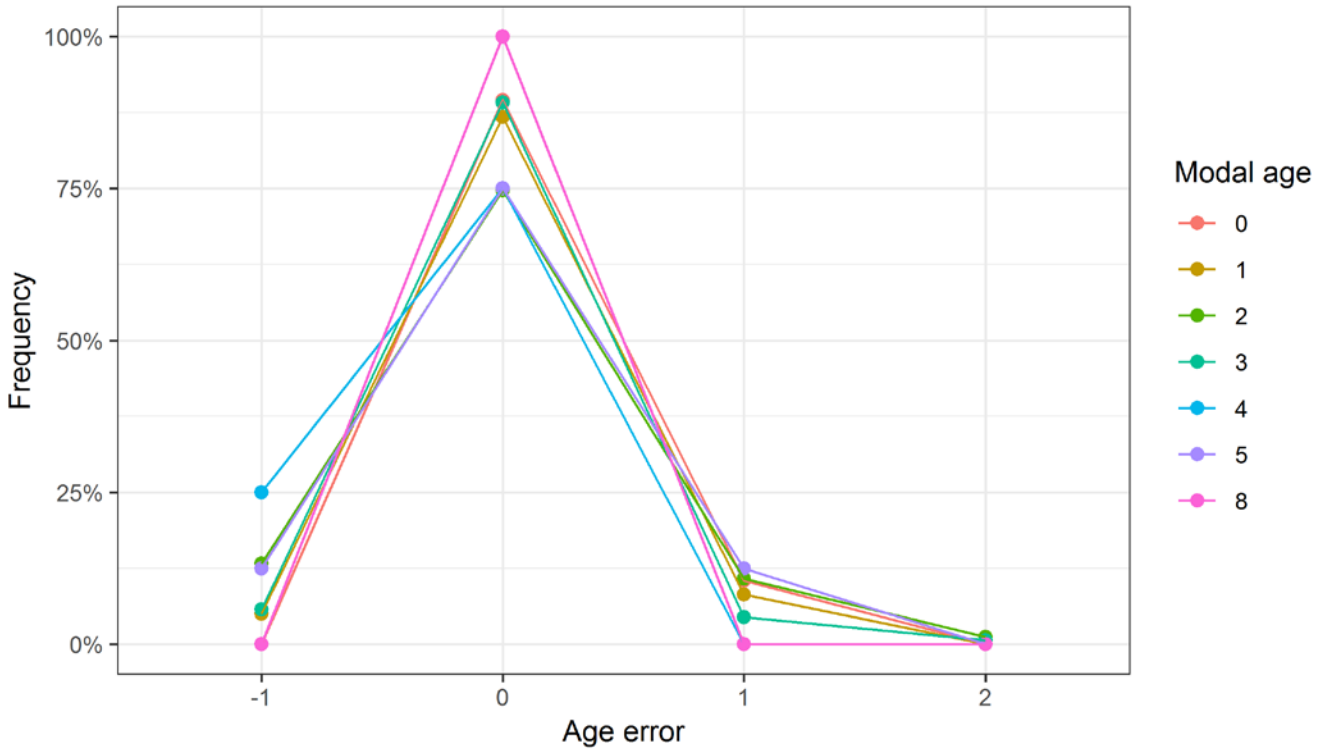


Figure 8.3: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age. The achieved precision in age reading by MODAL age group is

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

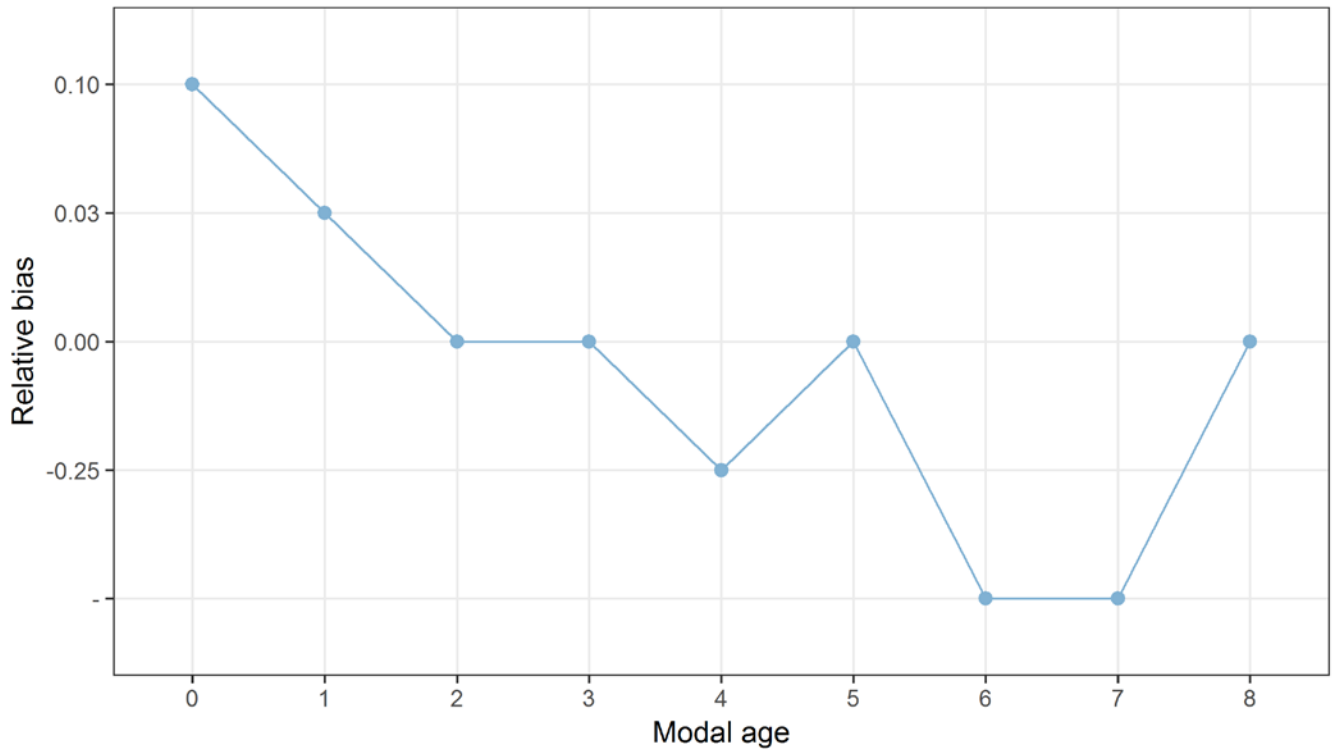


Figure 8.4: The relative bias by modal age as estimated by all age readers combined.

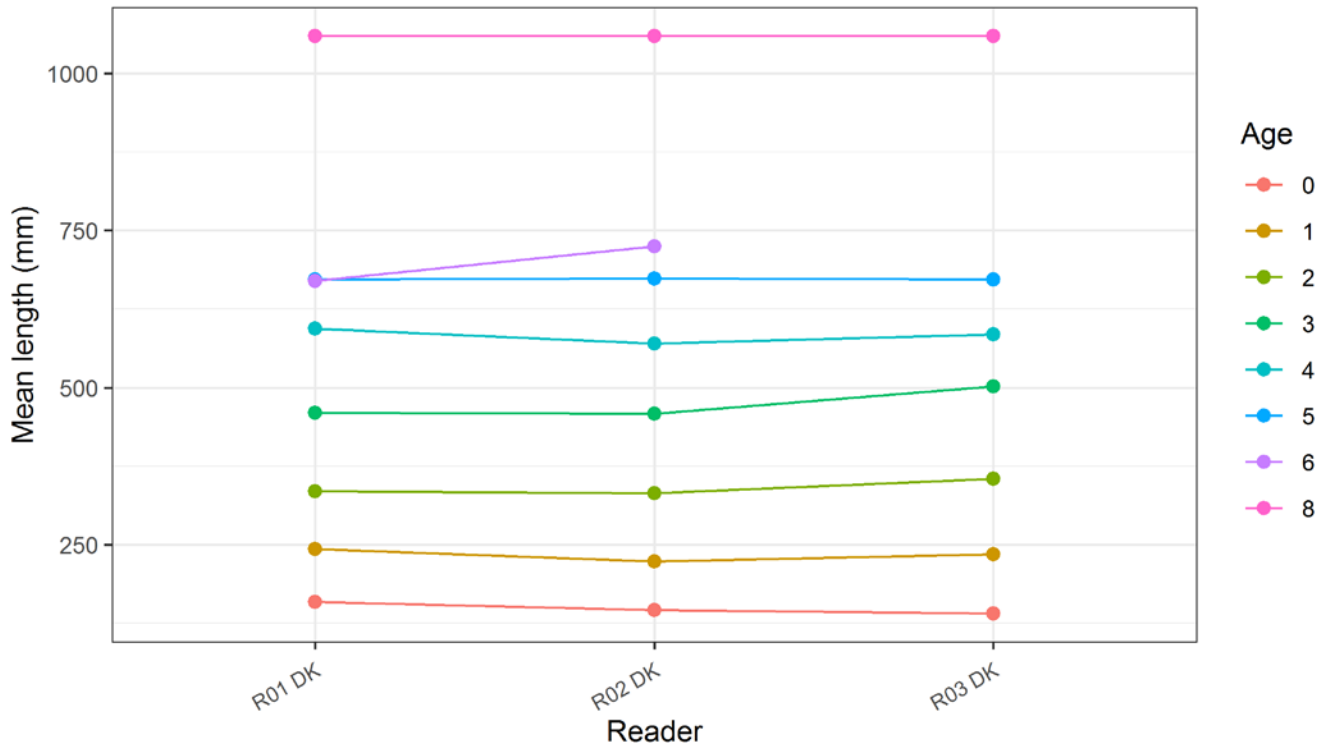


Figure 8.5: The mean length at age as estimated by each age reader.'

8.2 Results from ID 269 – broken otoliths

Table 8.3: Summary of statistics

CV	PA	APE
28 %	79 %	16 %

Table 8.4: Data overview for broken otoliths including modal age and statistics per sample.

Fish ID	Event ID	length	sex	Catch date	ICES area	R01 DK	R02 DK	R03 DK	Modal age	PA %	CV %	APE %
7864136	269	360	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864142	269	480	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864143	269	450	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864144	269	460	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864146	269	430	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864147	269	420	-	08/01/2019 00:00:00	27.3.a.21	3	-	3	3	100	0	0
7864149	269	420	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864151	269	360	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7864157	269	380	-	08/01/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
7864158	269	340	-	08/01/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7892942	269	170	-	25/02/2019 09:19:33	27.3.a.21	2	1	1	1	67	43	33
7892943	269	160	-	25/02/2019 09:19:33	27.3.a.21	2	1	1	1	67	43	33
7894311	269	190	-	26/02/2019 10:43:04	27.3.a.21	2	1	1	1	67	43	33
7894657	269	140	-	27/02/2019 06:02:02	27.3.a.21	2	1	2	2	67	35	27
7894658	269	140	-	27/02/2019 06:02:02	27.3.a.21	2	1	2	2	67	35	27
7895071	269	750	-	27/02/2019 12:22:16	27.3.a.21	6	6	6	6	100	0	0
7895072	269	680	-	27/02/2019 12:22:16	27.3.a.21	3	4	2	2	33	33	22
7895074	269	180	-	27/02/2019 12:22:16	27.3.a.21	2	1	2	2	67	35	27
7895254	269	630	-	27/02/2019 14:48:16	27.3.a.21	4	4	3	4	67	16	12
7895256	269	590	-	27/02/2019 14:48:16	27.3.a.21	3	4	3	3	67	17	13
7895260	269	340	-	27/02/2019 14:48:16	27.3.a.21	3	3	3	3	100	0	0
7895261	269	460	-	27/02/2019 14:48:16	27.3.a.21	4	3	3	3	67	17	13
7895390	269	280	-	28/02/2019 06:22:17	27.3.a.21	3	3	3	3	100	0	0

7895581	269	330	-	28/02/2019 08:52:17	27.3.a.21	4	3	3	3	67	17	13
7895735	269	430	-	28/02/2019 11:33:28	27.3.a.21	4	3	3	3	67	17	13
7895736	269	700	-	28/02/2019 11:33:28	27.3.a.21	5	5	5	5	100	0	0
7895738	269	430	-	28/02/2019 11:33:28	27.3.a.21	3	3	3	3	100	0	0
7895742	269	410	-	28/02/2019 11:33:28	27.3.a.21	4	3	3	3	67	17	13
7895743	269	350	-	28/02/2019 11:33:28	27.3.a.21	3	3	2	3	67	22	17
7895745	269	290	-	28/02/2019 11:33:28	27.3.a.21	3	3	2	3	67	22	17
7897290	269	620	-	02/03/2019 13:34:19	27.3.a.21	5	5	5	5	100	0	0
7897291	269	630	-	02/03/2019 13:34:19	27.3.a.21	4	-	4	4	100	0	0
7897292	269	630	-	02/03/2019 13:34:19	27.3.a.21	5	4	5	5	67	12	10
7897293	269	670	-	02/03/2019 13:34:19	27.3.a.21	5	5	5	5	100	0	0
7897295	269	610	-	02/03/2019 13:34:19	27.3.a.21	5	5	5	5	100	0	0
7900896	269	290	-	12/03/2019 06:07:37	27.3.a.21	3	2	3	3	67	22	17
7900897	269	280	-	12/03/2019 06:07:37	27.3.a.21	3	2	2	2	67	25	19
7900898	269	310	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900899	269	350	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900900	269	320	-	12/03/2019 06:07:37	27.3.a.21	2	2	2	2	100	0	0
7900901	269	290	-	12/03/2019 06:07:37	27.3.a.21	3	3	3	3	100	0	0
7900902	269	320	-	12/03/2019 06:07:37	27.3.a.21	3	3	2	3	67	22	17
7900904	269	310	-	12/03/2019 06:07:37	27.3.a.21	4	4	3	4	67	16	12
7910377	269	360	-	27/03/2019 04:20:49	27.3.a.21	3	3	2	3	67	22	17
7910379	269	340	-	27/03/2019 04:20:49	27.3.a.21	3	4	3	3	67	17	13
7921646	269	170	-	30/04/2019 18:40:09	27.3.a.21	2	0	2	2	67	87	67
7921647	269	180	-	30/04/2019 18:40:09	27.3.a.21	2	2	1	2	67	35	27
7921652	269	240	-	30/04/2019 18:40:09	27.3.a.21	2	2	1	2	67	35	27
7921653	269	270	-	30/04/2019 18:40:09	27.3.a.21	2	2	1	2	67	35	27
7923883	269	290	-	30/04/2019 18:45:27	27.3.a.21	2	2	1	2	67	35	27
7923884	269	200	-	30/04/2019 18:45:27	27.3.a.21	2	2	1	2	67	35	27
7924575	269	210	-	07/05/2019 18:45:19	27.3.a.21	2	2	1	2	67	35	27

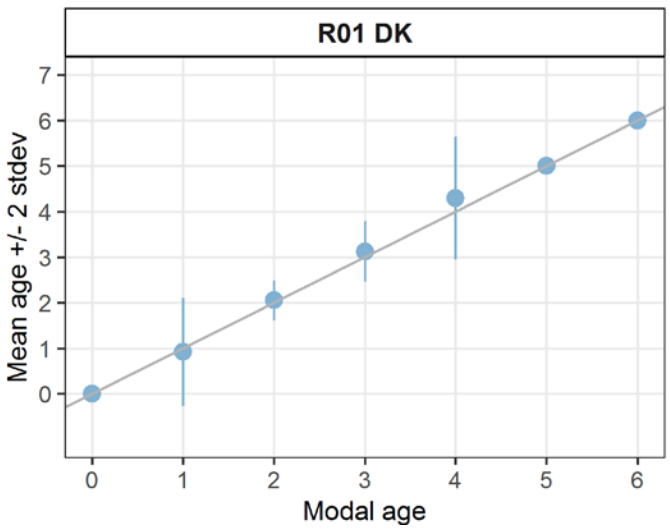
7924576	269	200	-	07/05/2019 18:45:19	27.3.a.21	2	2	1	2	67	35	27
7924577	269	230	-	07/05/2019 18:45:19	27.3.a.21	2	2	1	2	67	35	27
7924578	269	250	-	07/05/2019 18:45:19	27.3.a.21	2	2	1	2	67	35	27
7924579	269	260	-	07/05/2019 18:45:19	27.3.a.21	2	2	1	2	67	35	27
7924580	269	190	-	07/05/2019 18:45:19	27.3.a.21	2	2	1	2	67	35	27
7940420	269	180	-	20/05/2019 19:15:40	27.3.a.21	2	2	1	2	67	35	27
7940421	269	210	-	20/05/2019 19:15:40	27.3.a.21	2	2	1	2	67	35	27
7940422	269	220	-	20/05/2019 19:15:40	27.3.a.21	2	2	1	2	67	35	27
7941091	269	180	-	14/05/2019 23:15:06	27.3.a.21	2	2	1	2	67	35	27
7941092	269	210	-	14/05/2019 23:15:06	27.3.a.21	2	2	1	2	67	35	27
7941093	269	260	-	14/05/2019 23:15:06	27.3.a.21	2	2	1	2	67	35	27
7941428	269	220	-	20/06/2019 19:40:36	27.3.a.21	2	2	1	2	67	35	27
7941429	269	230	-	20/06/2019 19:40:36	27.3.a.21	1	2	1	1	67	43	33
7941430	269	230	-	20/06/2019 19:40:36	27.3.a.21	1	2	1	1	67	43	33
7941858	269	190	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7941862	269	0	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7941865	269	0	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7941866	269	0	-	15/05/2019 00:00:00	27.3.a.21	3	3	2	3	67	22	17
7942090	269	170	-	15/05/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
7942092	269	180	-	15/05/2019 00:00:00	27.3.a.21	2	1	1	1	67	43	33
7942096	269	260	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7942097	269	270	-	15/05/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
7942099	269	310	-	15/05/2019 00:00:00	27.3.a.21	3	3	2	3	67	22	17
7967582	269	670	-	06/08/2019 00:00:00	27.3.a.21	5	4	4	4	67	13	10
7991244	269	140	-	15/08/2019 18:45:04	27.3.a.21	0	0	0	0	100	-	-
7991246	269	210	-	15/08/2019 18:45:04	27.3.a.21	1	-	1	1	100	0	0
7994962	269	200	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994963	269	230	-	29/08/2019 18:15:23	27.3.a.21	2	1	1	1	67	43	33
7994964	269	180	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0

7994965	269	280	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994966	269	190	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994967	269	210	-	29/08/2019 18:15:23	27.3.a.21	1	1	1	1	100	0	0
7994969	269	170	-	29/08/2019 18:15:23	27.3.a.21	-	1	1	1	100	0	0
7994970	269	160	-	29/08/2019 18:15:23	27.3.a.21	1	-	1	1	100	0	0
7995182	269	180	-	26/08/2019 19:45:34	27.3.a.21	1	-	1	1	100	0	0
7995183	269	240	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995184	269	200	-	26/08/2019 19:45:34	27.3.a.21	1	-	1	1	100	0	0
7995185	269	210	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995186	269	200	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995187	269	190	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995188	269	180	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995189	269	170	-	26/08/2019 19:45:34	27.3.a.21	1	1	1	1	100	0	0
7995934	269	780	-	03/09/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7995935	269	800	-	03/09/2019 00:00:00	27.3.a.21	4	4	4	4	100	0	0
7995936	269	800	-	03/09/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
7999823	269	730	-	04/09/2019 00:00:00	27.3.a.21	6	4	5	4	33	20	13
8004095	269	110	-	26/08/2019 18:40:54	27.3.a.21	0	0	0	0	100	-	-
8004096	269	700	-	26/08/2019 18:40:54	27.3.a.21	3	3	3	3	100	0	0
8008496	269	240	-	19/09/2019 04:30:34	27.3.a.21	1	0	1	1	67	87	67
8008497	269	250	-	19/09/2019 04:30:34	27.3.a.21	1	1	1	1	100	0	0
8008498	269	150	-	19/09/2019 04:30:34	27.3.a.21	0	0	1	0	67	-	-
8008499	269	260	-	19/09/2019 04:30:34	27.3.a.21	1	1	1	1	100	0	0
8039079	269	700	-	13/11/2019 00:00:00	27.3.a.21	4	4	3	4	67	16	12
8039081	269	650	-	13/11/2019 00:00:00	27.3.a.21	4	3	3	3	67	17	13
8039082	269	590	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039083	269	620	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039086	269	620	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039087	269	590	-	13/11/2019 00:00:00	27.3.a.21	4	4	3	4	67	16	12

8039088	269	610	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039089	269	600	-	13/11/2019 00:00:00	27.3.a.21	4	3	3	3	67	17	13
8039090	269	640	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039091	269	670	-	13/11/2019 00:00:00	27.3.a.21	4	4	3	4	67	16	12
8039092	269	550	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039095	269	560	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039098	269	520	-	13/11/2019 00:00:00	27.3.a.21	3	3	2	3	67	22	17
8039100	269	550	-	13/11/2019 00:00:00	27.3.a.21	4	4	3	4	67	16	12
8039104	269	480	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039105	269	460	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039107	269	520	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039109	269	540	-	13/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8039110	269	480	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039111	269	510	-	13/11/2019 00:00:00	27.3.a.21	2	3	-	2	50	28	20
8039128	269	350	-	13/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8039129	269	370	-	13/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8039130	269	400	-	13/11/2019 00:00:00	27.3.a.21	3	3	-	3	100	0	0
8039132	269	410	-	13/11/2019 00:00:00	27.3.a.21	2	2	1	2	67	35	27
8039134	269	380	-	13/11/2019 00:00:00	27.3.a.21	2	2	2	2	100	0	0
8039136	269	450	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039137	269	370	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039139	269	330	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039142	269	490	-	13/11/2019 00:00:00	27.3.a.21	2	3	2	2	67	25	19
8039148	269	480	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039149	269	490	-	13/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8039151	269	360	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039153	269	420	-	13/11/2019 00:00:00	27.3.a.21	1	2	1	1	67	43	33
8039479	269	210	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039480	269	240	-	12/11/2019 20:41:08	27.3.a.21	1	1	1	1	100	0	0

8039482	269	200	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039483	269	190	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039484	269	180	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039485	269	180	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039486	269	120	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039487	269	160	-	12/11/2019 20:41:08	27.3.a.21	0	1	1	1	67	87	67
8039488	269	140	-	12/11/2019 20:41:08	27.3.a.21	0	1	0	0	67	-	-
8039489	269	150	-	12/11/2019 20:41:08	27.3.a.21	1	1	1	1	100	0	0
8039490	269	130	-	12/11/2019 20:41:08	27.3.a.21	0	0	1	0	67	-	-
8039492	269	100	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8039493	269	90	-	12/11/2019 20:41:08	27.3.a.21	0	0	0	0	100	-	-
8040298	269	340	-	14/11/2019 00:58:12	27.3.a.21	1	1	1	1	100	0	0
8040299	269	170	-	14/11/2019 00:58:12	27.3.a.21	0	1	1	1	67	87	67
8040300	269	200	-	14/11/2019 00:58:12	27.3.a.21	0	1	-	0	50	-	-
8040301	269	190	-	14/11/2019 00:58:12	27.3.a.21	0	1	1	1	67	87	67
8040303	269	180	-	14/11/2019 00:58:12	27.3.a.21	0	-	1	0	50	-	-
8040304	269	160	-	14/11/2019 00:58:12	27.3.a.21	0	1	1	1	67	87	67
8040305	269	140	-	14/11/2019 00:58:12	27.3.a.21	0	0	1	0	67	-	-
8040307	269	110	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040308	269	130	-	14/11/2019 00:58:12	27.3.a.21	0	0	1	0	67	-	-
8040309	269	100	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8040310	269	90	-	14/11/2019 00:58:12	27.3.a.21	0	0	0	0	100	-	-
8041458	269	300	-	15/11/2019 01:07:48	27.3.a.21	2	1	1	1	67	43	33
8041459	269	350	-	15/11/2019 01:07:48	27.3.a.21	1	1	1	1	100	0	0
8041460	269	270	-	15/11/2019 01:07:48	27.3.a.21	2	1	1	1	67	43	33
8041461	269	160	-	15/11/2019 01:07:48	27.3.a.21	1	1	1	1	100	0	0
8041462	269	170	-	15/11/2019 01:07:48	27.3.a.21	0	1	1	1	67	87	67
8041463	269	120	-	15/11/2019 01:07:48	27.3.a.21	0	0	0	0	100	-	-
8041790	269	160	-	15/11/2019 00:00:00	27.3.a.21	0	1	1	1	67	87	67

8041791	269	120	-	15/11/2019 00:00:00	27.3.a.21	0	0	1	0	67	-	-
8049082	269	660	-	18/11/2019 00:00:00	27.3.a.21	3	4	3	3	67	17	13
8049083	269	500	-	18/11/2019 00:00:00	27.3.a.21	3	3	2	3	67	22	17
8049084	269	90	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049085	269	100	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049086	269	110	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049087	269	120	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049088	269	130	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049089	269	140	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049090	269	150	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049366	269	640	-	18/11/2019 00:00:00	27.3.a.21	3	3	3	3	100	0	0
8049371	269	270	-	18/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8049372	269	260	-	18/11/2019 00:00:00	27.3.a.21	1	1	1	1	100	0	0
8049373	269	90	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049374	269	100	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-
8049375	269	110	-	18/11/2019 00:00:00	27.3.a.21	0	0	0	0	100	-	-



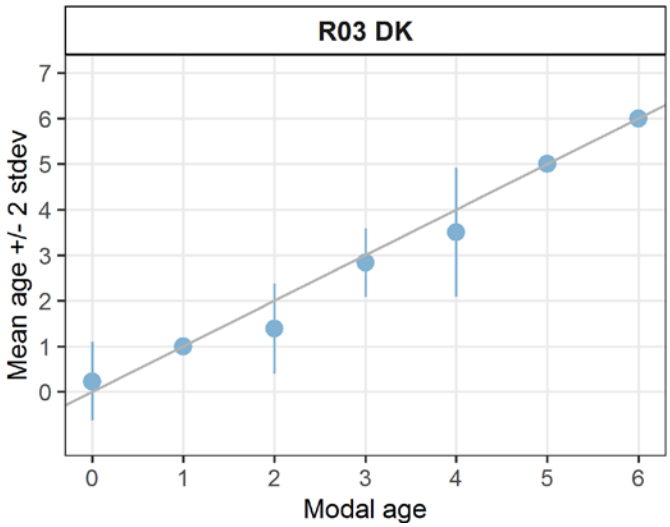


Figure 8.6: Age bias plots for each reader of the broken otoliths. Mean age recorded +/- 2 stdev of each reader and all readers combined are plotted against modal age. The estimated mean age corresponds to modal age, if the estimated mean age is on the 1:1 equilibrium line (solid line).

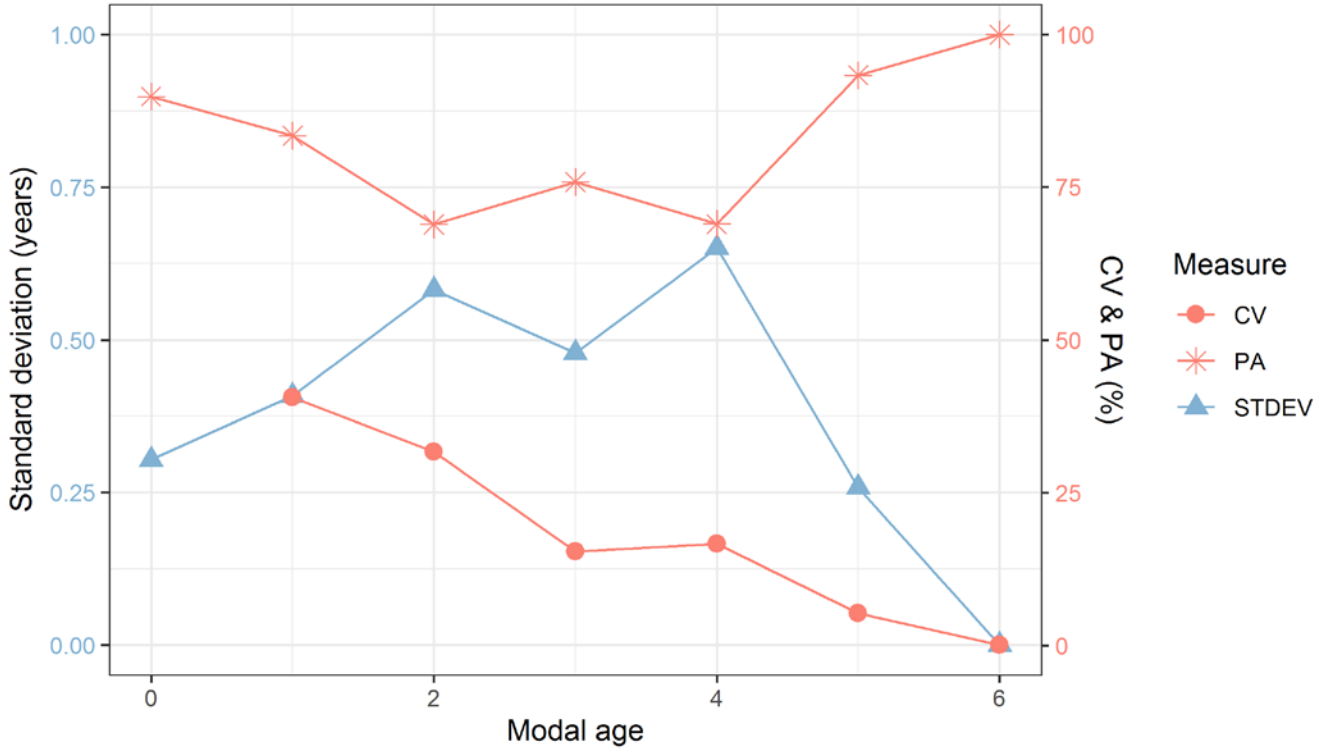


Figure 8.7: CV, PA and (STDEV (standard deviation) are plotted against modal age

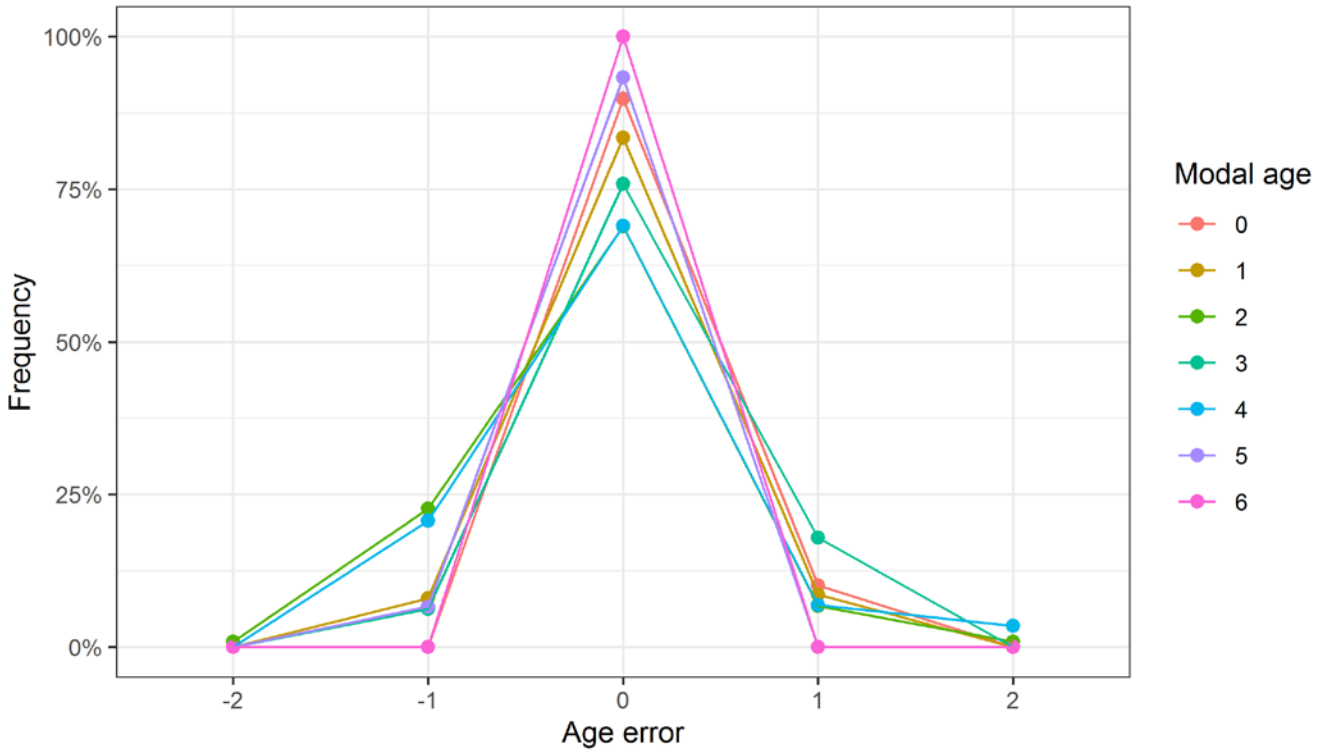


Figure 8.8: The distribution of the age reading errors in percentage by modal age as observed from the whole group of age readers in an age reading comparison to modal age. The achieved precision in age reading by MODAL age group is shown by the spread of the age readings errors. There appears to be no relative bias, if the age reading errors are normally distributed. The distributions are skewed, if relative bias occurs.

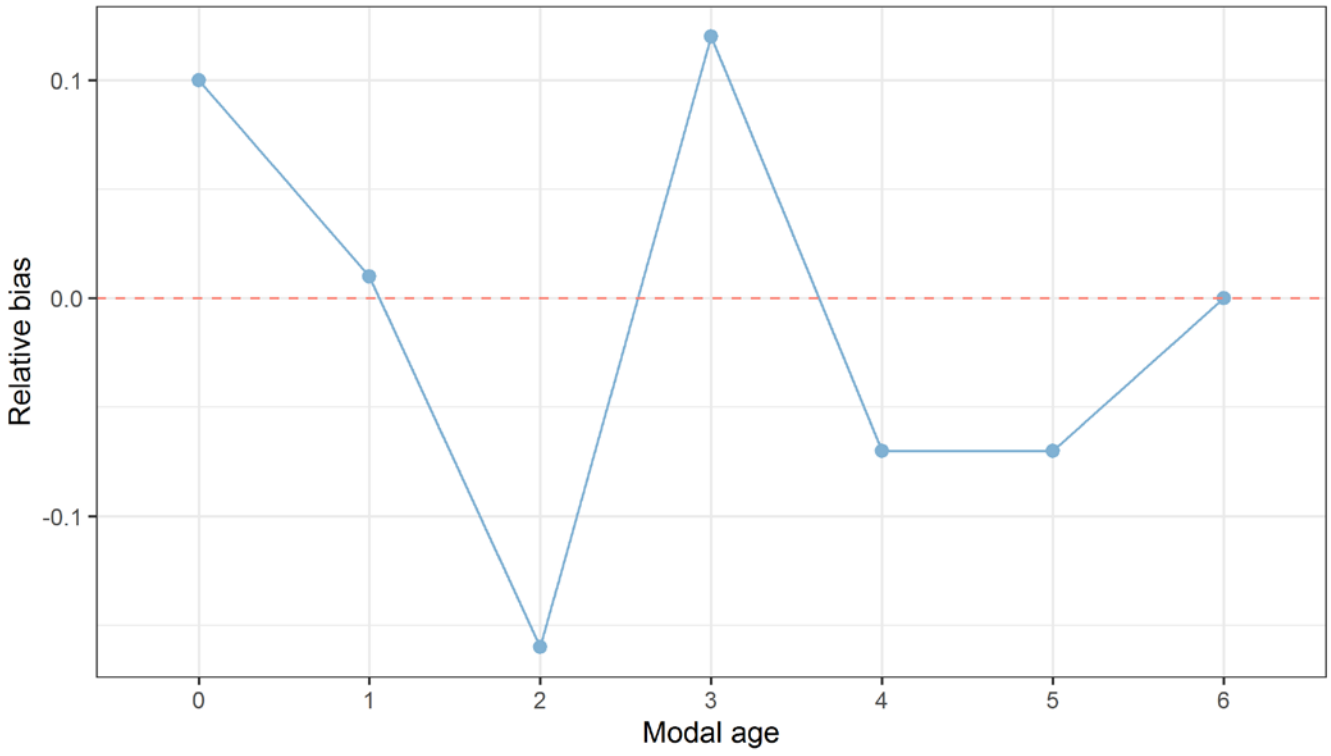
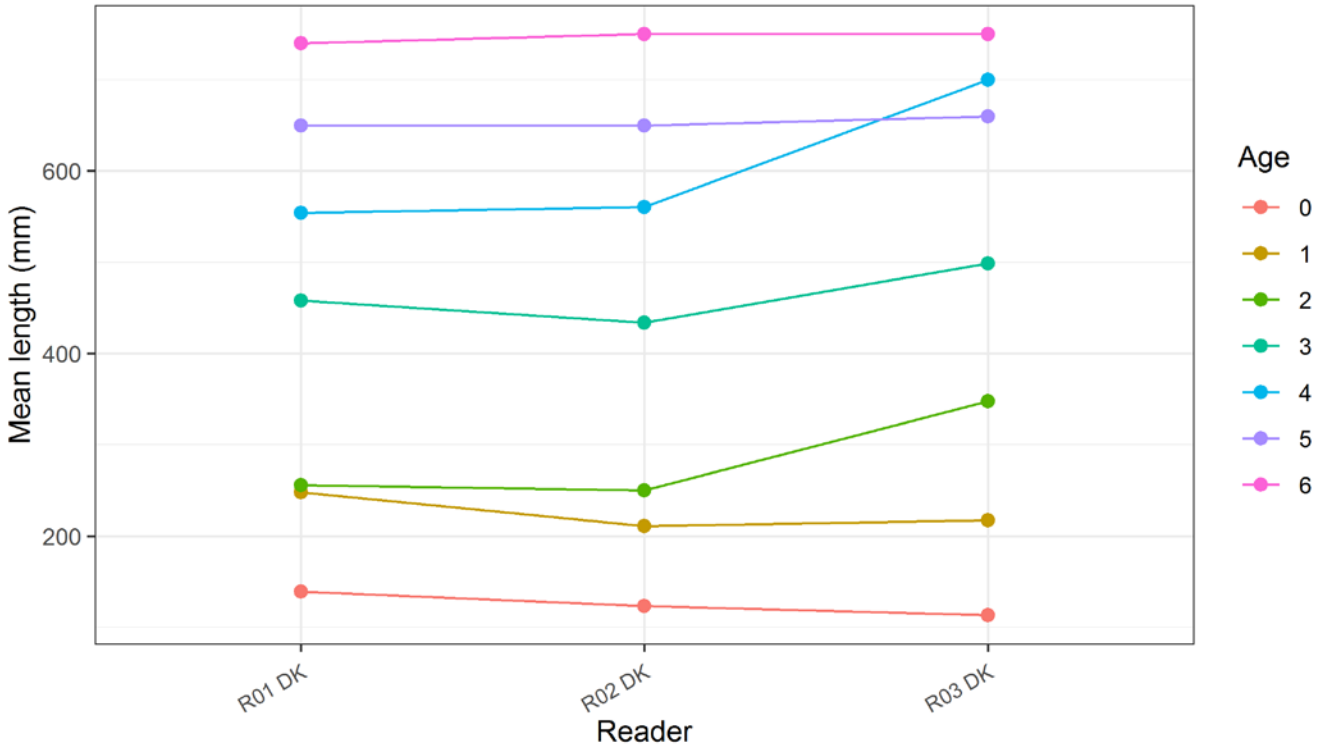


Figure 8.9: The relative bias by modal age as estimated by all age readers combined.



8.3 Baltic cod age reading guidelines

The figure below (McQueen et at., 2018) provides examples of the appearance of the otoliths and how to interpret them in; **0t** = age 0 caught in September with translucent edge, **1o** = age 1 caught in January with opaque edge, **1t** = age 1 caught in October with translucent edge and **2o** = age 2 caught in January with opaque edge.

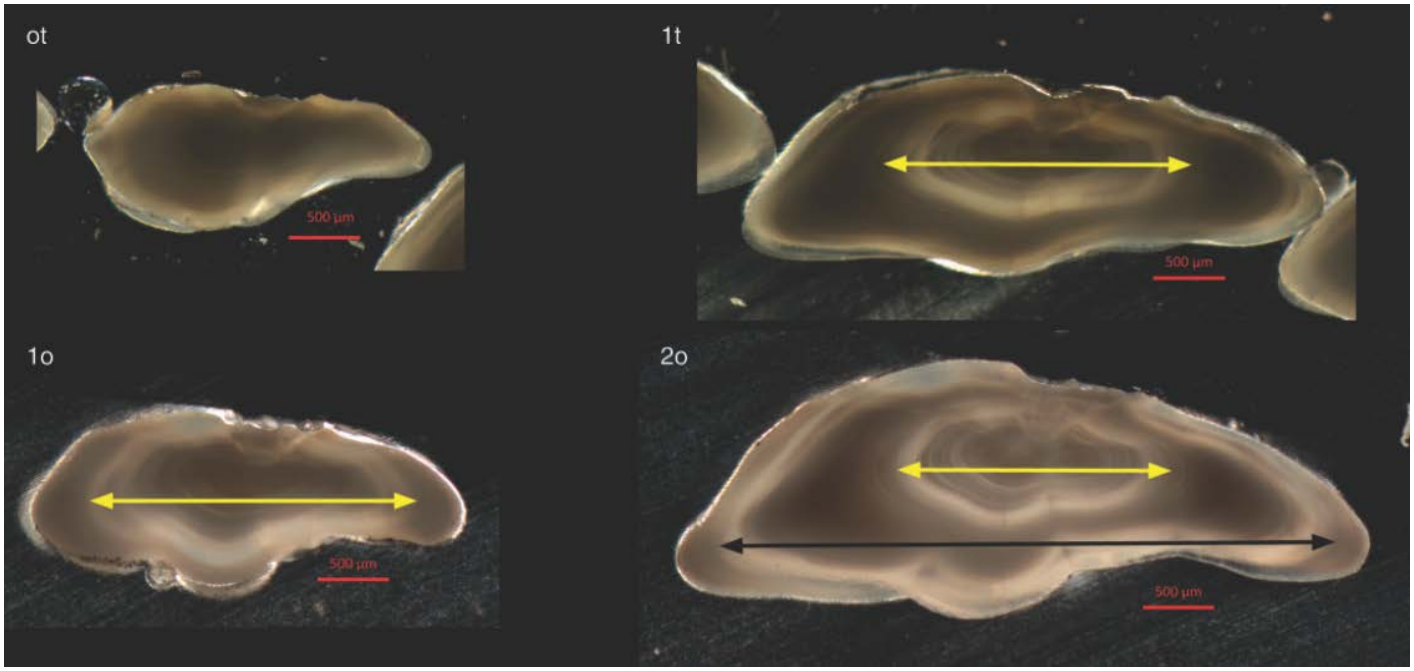


Figure 2. Cross sections of western Baltic cod otoliths. Otolith sections are viewed under transmitted light so TZs appear lighter than the darker opaque zones. Yellow (online version) arrows: diameter of the first TZ; black arrow: diameter of the second TZ. Top row: translucent edge type; bottom row: opaque edge types. Otoliths are from cod captured in pound nets in Fehmarn in 2015 and 2016 [0t: 28.09.2015, total length (TL) 13 cm, age 0; 1o: 12.01.2016, TL 17 cm, age 1; 1t: 14.10.15, TL: 21 cm, age 1; 2o: 12.01.2016, TL 28 cm, age 2]. Scale bar: 500 lm.