ICES Advisory Committee on Fishery Management
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Report of the
Study Group on Ageing Issues in Baltic Cod

11–14 May 2004
Riga, Latvia

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1 INTRODUCTION

1.1 List of participants

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1.2 Terms of reference according to the 2003 Council Resolution 2ACFM28

A Study Group on Ageing Issues in Baltic Cod [SGABC] (Chair: Johan Modin, Sweden) will be established and will meet in Riga, Latvia, from 11-14 May 2004 to:

a) review the extent of ageing inconsistencies and the impact of these on stock assessments and predictions;

b) revise the age estimation procedures and explore the possibilities to utilize supplementary information for validating estimated age structures. Available methods include:

   I. cod length distribution in surveys and catches

   II. cod otolith size distributions

c) explore the feasibility of using alternative age partitioning for assessments;

d) produce a plan of implementation including time schedule, sub-projects and funding proposals if required.

SGABC will report by 20 May 2004 for the attention of ACFM as well as the Baltic and the Living Resources Committees.

1.3 Suggestions from the WGBFAS

The WGBFAS has commented on the work tasks of the SGABC (ICES 2004: section 1.4.9). In summary, it was stressed that previous comparative age readings have not improved the consistency between readers and therefore such exercises should be kept at a minimum during the meeting. The WGBFAS therefore recommended to investigate methods for the validation of estimated age distributions. Differences in age interpretations could be detected by detailed protocols of otolith structures and by direct observations. It was emphasised that the study group should explore the possibilities to use alternative measures such as fish length and otolith size in order to partition age distributions. The SGABC acknowledge the suggestions from the WGBFAS and have attempted to respond to them.

2 REVIEW OF PREVIOUS MEETINGS ON THE AGE ESTIMATION OF BALTIC COD

The age composition of Baltic cod, as derived from age readings, has been presented at ICES meetings from the late 1940s. By the start of the stock assessments at the start of the 1970s it was found that the assessments were hampered by the lack of proper age composition data.

<u>1972:</u> A working group on Baltic cod met in Gdynia, Poland. At the meeting it was agreed that the disagreements in age determinations could be caused by different interpretation of the central part and the edge of the otoliths. Possible

explanations could be the extended spawning period of the cod and the complicated hydrographical conditions in the Baltic.

1981: A comparative cod age-reading was organised in an exchange program. Each laboratory was asked to sample 50 otoliths. These otoliths were circulated between the readers. (ICES 1985). The analyses showed consistency of the reading between most of the readers but also some cases of a rather large variation within readers.

1994: A work shop on Baltic cod age reading was held in Gdynia, Poland. Cluster analysis of age-length keys suggested that there were two main groups of Baltic cod age readers: one western school with lower and one eastern school with higher estimates of ages (Horbowy 1994). This general pattern reappeared in results from age readings of otolith samples in subsequent years.

1995: A co-ordination meeting of an EU project on improving Baltic cod assessment data was held in Copenhagen, Denmark. The meeting agreed on a sampling strategy and a sampling intensity per country and area. The meeting also agreed on protocols for the preparation of otoliths and the age-reading procedure.

1996: The first meeting of Study Group on Baltic Cod Age Reading (SGBCAR) took place in Rostock, Germany (ICES 1997). Four items were discussed: 1/ primary increment formation in juvenile cod, 2/ daily increments in the otoliths of juvenile and adult cod, 3/ a statistical method to show discrepancies in age reading and 4/ the establishment of a reference collection. Statistical tests of comparative readings suggested again two different "schools" of interpretations of cod ages. The first steps to organise a reference collection were made. Sampling of otoliths from different countries and an exchange between the institutes were organised. The total sample was to become the basic material for the reference collection and consisted about 1 000 pairs of otoliths. The final reference collection consisted of 423 pairs of otoliths. During this meeting there were also a presentation and discussion about the structure of the otoliths and the influence of various environmental conditions on the formation of hyaline zones.

1998: The next meeting of SGBCAR took take place in Charlottenlund, Denmark. (ICES CM 1999/H:4) The Group summarised the results of the otolith exchange program, established a digitised image collection based on the reference collection of otoliths and prepared a first version of a manual for age readers. The Baltic Cod Age Reading Manual was based on the results of the work carried out during all meetings. The manual was presented at the ICES Annual Scientific Meeting in 1999. The image collection consisted of 290 otoliths selected from the reference collection. From these images the group selected 89 images for comments. On the selected images remarks on age, ring formation, and interpretation were inserted. The SGBCAR was of the opinion that the reference collection should provide possibilities for unifying the interpretation of the age-related structures and for training of new age readers. A CD-ROM with digitised images have later been produced by the Danish Institute for Fisheries Research and distributed to the cod age-reading institutes around the Baltic.

2000: The third meeting of SGBCAR was held in Karlskrona, Sweden (ICES 2000). A theoretical evaluation of the effects of different age reading scenarios on assessment was performed. Results indicated large differences in the perception of stock size and exploitation level. The group discussed the possibility to revise assessment data back in time by consistent age-reading procedures. However, the presented analyses indicated a complex pattern of differences between age readers that is likely to remain biased by any application of additive or multiplicative factors to correct numbers at age. Hence, the unsolved problems in age interpretation would hamper any consistent update of historical data. It was pointed out that a prerequisite for any revision or future age estimation activities is the existence of validated methods for assignment of age to representative individuals. The institutes were recommended to continuously update the reference collection with new material. Ongoing research projects indicated that additional parameters such as fish and otolith size might be used as an aid in interpretation. Therefore, the Group suggested to include such data when selecting otoliths for the reference collection. During the meeting a second version of the Manual on Baltic Cod Age Reading was produced. It was pointed out that the manual must be continuously updated and developed.

3 IMPACT OF AGE INCONSISTENCIES

3.1 Impact on stock assessments

Age composition of commercial catches and research surveys is primary inputs to the age structured models (e.g. XSA) that presently are used for stock assessment of Baltic cod.

As noted above several studies show that there are systematic differences in interpretation of otolith structure between age-readers from countries in the Eastern and Western Baltic (informally called the eastern and western school of age-readings) (ICES 1994, ICES 1997, ICES 1999). Besides inconsistencies between national institutes in otolith interpretation there are also inconsistencies within institutes. It can be expected that the derived different age compositions will effect biological data (catch and stock numbers and weights at age, maturity) and therefore tend to produce different estimation of stock size and exploitation pattern from stock assessments. The possible influence of the inconsistencies in age determination on the results of stock assessment of Baltic cod has been investigated in several simulation studies. Brief summaries of three studies are presented here:

Reeves, S.A. 2001. Age-reading problems and the assessment of Eastern Baltic cod. Working document presented to the WGBFAS (ICES 2001).

The aim of this study was to investigate the possible consequences for the assessment of the Eastern Baltic cod stock using datasets corresponding to different schools of age interpretations.

Methods

Three sets of assessment data were constructed:

1. 'EastAll' based on eastern age-readings,

2. 'WestAll' based on western age-readings and

3. 'AsWG' based on the combined data from both age-reading schools, i.e. comparable with the data used by the WGBFAS.

Each dataset comprised catch-at-age constructed for the two age-reading schools by simply excluding data supplied by nations of the other age-reading school and then raised the remaining age compositions to the total catches. Stock weights were set equal to catch weights, which were estimated for each set of assessment data. The proportion of maturity was calculated for each data set by a model that described the relation between catch weights and maturities at age from 1995 to 1999. Natural mortality was set constant across all datasets. Tuning data were not changed since the extent to which the different age-reading schools contribute to the indices is not immediately clear. Catch data disaggregated by country were only available for 1994 and onwards, so for the data for earlier years some approximations was involved (proportional reallocation of catch-at-age data from 1994-1999 to earlier years).

The simulation was restricted to the years from 1981 and onwards due to questionable quality of WG data prior to 1981 (fixed weight-at-age). It was assumed that all vessels used the same gear by area and season and that all nations caught a similar size composition of fish, so the only differences in the catch data were due to differences in age-reading.

Results

Data on catch-at-age (Fig. 3.1.1), weight-at-age and maturity ogives for 1990 from each of the three data sets show that the western school tends to allocate a younger age to a given fish and consequently this school will estimate more fish in the younger ages than the eastern school. The result will also predict a higher weight and maturity at age.

Standard XSA runs showed that there is a marked difference in the exploitation pattern between the 'WestAll' run and the other two data sets. The western age-compositions indicating high fishing mortality at age three, with a peak at age 4, whereas in the other two runs the peak is at age five, with relatively low exploitation of younger fish (Fig. 3.1.2).

The estimated high fishing mortality on the younger ages, together with smaller initial year-classes result in much lower estimates of SSB from the 'WestAll' data compared to the 'EastAll' data, even though these effects are to some extent balanced by increased weights at age and earlier maturation (Fig. 3.1.3). However, around 1992 to 1995 there was a sharp reduction in fishing mortality, which leads to an increase in SSB in all runs. This increase is most marked in the 'WestAll' data, where it results in SSB increasing to around the same size as in the other two runs.

Conclusions

- The different simulation runs of the 'EastAll', 'WestAll' and 'AsWG' assessments show that the assessment results are highly sensitive to the age-reading school.

- The different outcome of the two assessments and the baseline run suggest that the consequences are most pronounced if the Western interpretation is correct.

- While the different runs indicate large differences in the overall level of SSB and the exploitation pattern, the year to year trends are rather similar.

- Ageing errors may cause a substantial reduction in the inter-annual variability in recruitment, since they tend to increase the estimates of abundance of weak year classes and reduce those of strong year classes through mis-classification of fish between year-classes.

- The analyses indicated that the problems with age determination in the Eastern Baltic cod are likely to bias the perception of stock size and exploitation, and as a consequence, the disaggregated age data may not be of a sufficient quality to be used as basis of the assessment and management of the stock.

Horbowy, J. 1997. Comparison of ALKs using Chi-2 test and two-way contingency tables. Working paper presented for the meeting under EU Study Project 94/058, June 1997 (Baltic Cod Stock Assessment: An International Program to Standardise Sampling Protocol, Age Determination and Trawl Surveys).

The aim of this study was to compare the estimated age-length keys of Baltic cod from 1992 and 1993 by estimates of gear, quarter, subdivision and country effects.

Methods

The age-length keys compiled and presented by national institutes were investigated by:

- Cluster analysis

- Plots of mean age at length against length for different age-length keys.

- Statistical tests of frequency distributions ($\chi 2$ test).

Results

Analyses conducted within national data showed a similar pattern:

1. The ALKs from SD 25-28 are not significantly different, when obtained in the same quarter and by the same fishing gear.

2. The ALKs from SD 22 significantly differ from ALKs from SD 24.

3. The ALKs from the 1st and the 2nd quarter are not significantly different, when obtained from the same SD and by the same fishing gear.

4. The ALKs from the 3rd and 4th quarter significantly differ, when obtained from the same SD and by the same fishing gear.

A cluster analysis with data from all countries indicated grouping by national institutes. This effect is likely to be caused by different national practice and procedures for age interpretations.

Radtke, K. 2001. Evaluation of the potential effects of different ageing interpretations of Eastern Baltic cod. Working document presented to WGBFAS (ICES 2001).

The aim of this study was to investigate the impact of different age interpretations on spawning stock biomass (SSB) estimates of Eastern Baltic cod stock using datasets that represent two age-reading schools.

Methods

In order to create datasets resulting from different age interpretations the results of comparative age readings presented in the Report of the Workshop on Baltic Cod Age Reading were used (ICES. 1994).

To illustrate a method for changing the age composition of international catches into age composition corresponding to western school of age interpretations, calculations based on age 1 are presented. For every otolith aged from a 100 otolith sample, a modal age was determined. Within a group of otoliths with the same modal age, the average age for all readers, for Polish readers (eastern school) and for Swedish readers (western school) was calculated (Fig. 3.1.4). The effects on spawning stock biomass (SSB) were calculated and compared to the estimates that was obtained by the WGBFAS 2001.

The average age for otoliths with modal age 1 for all readers equalled 1.226. It was assumed that differences between both schools did not exceed 1 year, which is a certain simplification. In that case, the calculated value 1.226 means that 22.6% were the cods from the age group 2, and 77.4% from age group 1. The average Swedish age for modal age 1 equalled 1.035, which means that 3.5% of cods are from age 2 and 96.5% from age 1. Thus, Swedish readers allocate 19.1% (96.5%-77.4%) more cods to age 1 than all readers. So in order to change the international age composition of catches in a discussed age 1, into a composition corresponding to Swedish age interpretation, 19.1% of individuals from international catches from age 2 were shifted to age 1. Data on catch weight-at-age and stock weight-at-age were left unchanged compared to the WGBFAS input.

Results

The differences between the simulated SSBs and the SSB estimated by the WGBFAS were large (Fig. 3.1.6). The assessment based on the Swedish age composition led to underestimation of SSB as compared to WGBFA estimation, while the assessment based on the Polish age composition led to overestimation.

3.2 Impact on length and age distributions

Some investigations of the BITS database were made in order to understand the nature of age-reading inconsistencies. Although visually it is possible to detect differences in length distribution of cod from BITS surveys, the modal length of the observed peaks in size distribution are, however, very similar (Table 3.2.1 and Figure 3.2.1). Similarities in the length distributions suggest that the age distribution would also be similar. However, this can not be observed from survey age disaggregated indices obtained from database and used tuning of XSA. (ICES 2004: figure 2.4.17). The relationships between age groups in a single year-class are also extremely weak. This can be illustrated by plotting national age length keys from the BITS database for recent years (Figure 3.2.2). It is clear that there are substantial differences in age-determination for fish from the same Sub-division and year. There is variation between nations within year but also between years. The figures suggest that the age-reading inconsistencies are highly complex, and that the classification of age readers into two or three 'schools' of age-reading approaches (e.g. Reeves, 2003) represents a substantial over-simplification of the actual situation.

Similar problems can be seen also from commercial sampling data (Figure 3.2.3). Size distribution in one age group between different countries is significantly different even within one subdivision. These differences were considered to be a result of age reading inconsistencies.

4 INCONSISTENCIES OF AGE DETERMINATIONS

4.1 Estimated from year-class progression

A working document (WD1) by R. Oeberts, Germany, presented estimates of reader differences in age determinations by the use of year-class progression through time. The length distribution of recognisable year-classes within a year was used as an indication of age in that year. The "expected" age within distinct length intervals was compared to the "interpreted" age derived from national age-readers for the same length interval. Data of length distributions was obtained from research surveys (BITS) for Sub-division 24, 25, 26 and 28 from 1993 to 2001. Length distributions of year-classes in 1994 to 1996 and in 2000 to 2003 was compared and assigned to age groups 0 to 3. The data support the hypothesis that the length at age of Baltic cod was similar between years and approximately the same in the studied Baltic Sub-divisions. However, the SGABC members pointed out that further investigation are needed to confirm small differences in the spatial and temporal growth rates of Baltic cod.

Results indicate that age-readers of different national institutes differ in the assignment of ages compared to the length ranges of defined year-classes (eg table 4.1.1). Furthermore, the assigned ages appear to vary between years for some national institutes, i.e. the results indicate a drift in age determination by years. The results were discussed and further studies using year-class progression through time were considered as a productive way to validate age-determinations. . It was also pointed out that more investigations are needed to confirm the hypothesis of similar spatial and temporal growth rates of Baltic cod. It was suggested that the problems of age readings are not the visibility and the determination of the rings, but the interpretation of the rings and the edge of the otolith. This suggestion of differences in ring interpretation is to some extent corroborated by the results of an age-reading exercise (see below).

Generally, it was concluded, that the interpretation of the age composition varies and that standardized procedures to correct historical bias in age determinations should be used with caution due to the high variability in age determinations from year to year. One way to scrutinise the otolith interpretation is the use of other methods such as fish or otolith size distributions for confirmation. It was recommended that such methodology should be further investigated.

4.2 Estimated from age reader comparisons (age reader exercise 1)

Seven age readers from six countries participated in the age reading exercise (Exercise 1). In all 20 otoliths from the Eastern Baltic cod were chosen on an ad hoc basis from the otoliths prepared by the national laboratories. The chosen otoliths were sampled in Sub-divisions 25, 26 and 28 and represented all seasons during 2003 (Table 4.2.1). Before the age reading exercise a protocol for the exercise was agreed. The protocol contained catch date and fish length as supplementary information. The age readers had to determine the age of the cod as well as to record the number of hyaline rings, the zone on the edge of the otolith and to state whether the opaque zone on the edge of the otolith was formed during the previous or current year.

The age reading results are presented in Table 4.2.1. The determined ages were compared with the modal ages. In general, the agreement (ratio of readers that agree with modal age) was low even taking into account the restricted age range (2-4) of the samples. A 100% agreement was achieved for one otolith only. The agreement between separate readers was low, mainly below 60%, and only in one case reached 90% (Table 4.2.2). The level of agreement did not change with the date of the catch (Figure 4.2.1) or with the modal age of the fish (Figure 4.2.2). A somewhat better agreement was achieved for the age determination of the older fishes, which is a reversed result compared to results from age reader exercises on other species. A plausible reason is that age readers often work with older fish, which are sampled from commercial catch samples. Age readers of Baltic cod have less opportunities to age otoliths of younger fish and then only from two seasonal survey samples. The results indicate that training on otoliths from young cod are advisable and that the reference collection should be complemented with samples from young cod.

Table 4.2.3 shows the number of determined hyaline rings by each reader. The agreement (ratio of readers that agree with the mode) is as low as for the age determination. It is also conspicuous that there is a poor relationship between the determined age and the determined number of hyaline rings (Figure 4.2.3). A possible explanation is the difficulty to detect hyaline rings on the edge of the otoliths (Table 4.2.4). Since the hyaline ring is narrower than the opaque ring, it is probably difficult to detect it, unless it appears between two opaque rings. The criteria to identify hyaline edges appear to vary between readers since the results demonstrate large disagreements between readers. In addition, the reader results are not consistent in the classification of the edge zone of the otoliths (Figure 4.2.4). Figure 4.2.4 actually suggest that the readers estimate that two or more hyaline zones are formed within one single year. However, in general the detection of hyaline edge zones should not influence the age determination. Therefore it would not be necessary to spend time and effort on that.

The protocols of all the readers were checked and a number of logical mistakes were found that could influence the correct age assignment. Three readers made no mistakes, one reader had one mistake and three readers had made several mistakes that are shown in the text tables below.

Answer	age	hyaline rings	edge	opaque ring
wrong	2	2	opaque	-
correct	2	2	opaque	+

wrong	age < hyaline rings		
correct	age	=	Hyaline rings
correct	age	>	Hyaline rings

	age	hyaline rings	edge	opaque ring
wrong	5	4	hyaline	
correct	4	4	hyaline	

	age	hyaline rings	edge	opaque ring
wrong	3	1	opaque	-
correct	2	1	opaque	-

	age	hyaline rings	edge	opaque ring
wrong	5	4	opaque	+
correct	5	4	opaque	-

The age readers were asked to answer five questions:

1. How do you determine the belonging of the opaque zone of the edge to a certain year?

2. Do you collect special otolith samples to detect the beginning of opaque zone growth?

3. How often do you collect otolith samples for age determination (monthly or quarterly basis)?

4. Are you able to detect a hyaline ring when it is on the edge?

5. Are the growth conditions of cod different by year resulting in formation of different zones (broad or narrow)? Could they be used as biological markers?

The first two questions dealt with the problem of determining whether the opaque zone on the edge has formed during the current or the previous year. The differences in interpretation could lead to different assigned age. However, it seemed from the answers that the age readers do not pay due attention to the formation of opaque zone on the otoliths. The assignment of the opaque zone to a certain year is mainly performed on the basis of a standard scheme that is permanent for all years. On the other side most of the national laboratories collect otolith samples on monthly basis that could allow detect the beginning of opaque zone formation quite possible (question 3).

All readers considered that it is possible to detect the hyaline zone on the edge (question 4). Most of the readers stated that they do not use biomarkers in age determination (question 5).

The exercise was discussed extensively and it appeared that some readers had misinterpreted some of the tasks. However, the general opinion was that this kind of qualitative assessment could improve the age reading protocol. It was recommended to

- collect more otoliths from young cod in months that are not covered by trawl surveys,
- describe the otolith structure and appearance on a monthly basis in order to detect the formation of opaque and hyaline rings within years.

4.3 Estimated from reader observations (age reader exercise 2)

A second age reading exercise was performed on a Danish set of 50 otoliths collected during the BITS survey in Sub-divisions 25 and 26 during March 2004. The exercise was comprised of two parts: A traditional comparison of ages read from the otoliths under stereo-microscopes and a digital age reading performed on digitised images of the same otoliths. The exercise was more aimed at quantifying the different interpretations of age structures in cod otoliths between age readers than being a classic age reading intercalibration exercise.

Methods

The image analysis system tool used in the exercise makes use of XY-coordinates corresponding to the points, the age reader marks on the digitised image of the otoliths. The two parts of the exercise was performed simultaneously thus the age reader had the otolith exposed under the stereo microscope while pointing at the age structures on the picture using the image analysis system tool and could consult the ‘live’ otolith if the pictures did not show all the desired otolith structures clearly.

Prior to the exercise the readers agreed on one axis, the longest axis, along which all points should be placed. All readings on the digitised images were done by marking the centre of the otolith as the first point and then marking all identified age structures along the agreed axis and ending the reading by marking the edge of the otolith. All points logged on each individual otolith were then transferred into an Excel spreadsheet with the correct ID (otolith number and picture number). The readers were asked to mark the outer edge of each translucent ring identified as an annual structure.

The otolith centre was calculated as the mean X and mean Y for each otolith and each reader. This starting point was then used to compare individual reader interpretations of translucent rings. Distances between the mean centre and each ring was calculated and compared among otoliths and readers. The data coordinates were further subjected to statistical analyses for the variance in different interpretations of the age structures and the span of different positions of the actual structures.

a/ Results using traditional evaluation.

The results from the traditional age calibration exercise underlined the differences in perception of otolith structures between the participating age readers. The overall agreement was no more than 65.2 % with a precision of 18.8% CV. Figure 4.3.1 shows the overall pattern of the readings, showing that the divergences of the interpretations of the otolith structures were not on specific ages, but the disagreement were on all ages. It should be noted that the selected otolith set comprised relatively young individuals, which do not often appear in the majority of samples usually read by the age readers. Table 4.3.1 shows the inter-reader bias and the reader bias with the modal age. Some readers did diverge more from the mode, overestimating the ages compared to the modal age, however the bias patterns observed in the second age reading exercise were not the same as in the first age reading exercise (section 4.2).

The inconsistency of the age determinations by the readers between the two age reading exercises was also demonstrated by some readers that over-estimated the ages of otoliths from subdivision 25 in the first age reading exercise but under-estimating the ages compared to the modal age in the second age reading exercise. The reverse pattern was also observed.

b/ Results by an evaluation of reader marks on otolith images.

The spreadsheet program, which combined image analysis and plots, made it possible to demonstrate where the individual age readers interpret the rings directly on the digitised images of the otoliths. Results suggest that the placement of the first winter ring appeared to be a major source of variation as illustrated by Figure 4.3.2. Some otoliths showed to be very difficult to reach a common interpretation of the age and the points counted as age structures were scattered along the otolith (Figure 4.3.3).

First the quality of the digitised method was examined. Reader interpretations of the X and Y positions of different otolith centres were compared with the median interpretation of X and Y positions of the same otoliths (the X-coordinates are shown in Figure 4.3.4). Then the interpretation of the outer edge was compared in the same way (Figure 4.3.5). There is an obvious higher variation in the position of the centre compared to the edge.

A limit deviation of 30 pixels (equal to 256 μm in the otoliths) was set and all reader-otolith combination exceeding this limit for any of the centre X-Y or edge X-Y positions were excluded from further analyses, these readings amounted to a total of 19.5%.

The variation between otoliths in the median distance to successive rings is shown in figure 4.3.6 as cumulated frequency distributions of the position of each ring. Frequencies may be approximated by normal distributions with similar standard deviation.

As can be seen from figures 4.3.7 and 4.3.8 the interpretation of the edge width and 2nd outmost ring width decreases with otolith total radius as well as with modal age.

The variation in the different age readers' interpretation of the position of each annual growth structures (translucent rings) was investigated by calculating the standard deviation of the distance from the centre to a given structure labelled "point no", with point one being the centre, point two the first annual structure and so on. The standard deviation (STD) of the distance from the centre to the point where the structure was marked was plotted versus the point no for each group of otoliths with modal ages 2, 3, 4, and 5 (figure 4.3.9. a).

The figure 4.3.9.a shows that there was most variation in interpretation of the innermost rings and that the variation declined with ring number; there was also a tendency of increasing variation with increasing interpreted otolith modal age.

From inspection of the position of points on otolith images it was seen that frequently some readers did not mark out rings that other readers interpreted as true annual structures. The effect was investigated by renumbering the distances to the points marked by each reader in each otolith so that they matched the number of the closest median distance. The same standard deviations of distances were plotted versus the adjusted point numbers for each age group of otoliths (figure 4.3.9. b). It appears that this procedure markedly reduced variation in interpretation of rings, and that this variation is most likely due to the readers' decision of accepting or declining a detected structure as being annual.

Difference between reader s having the same modal age

The reduction in variation of the different ring interpretations were then compared by excluding readings not hitting the modal age estimate for a given otolith. The percentage reduction in mean STD of each position (point 2-6 = rings 1-5) within in age groups 2, 3, 4, and 5 is shown in Table 4.3.2.

Table 4.3.2

point	modal age 2	modal age 3	modal age 4	modal age 5
2	1% (n=7)	19% (n=9)	-25% (n=22)	-19% (n=5)
3	18% (n=7)	8% (n=9)	-24% (n=22)	0% (n=5)
4	-36% (n=5)	-18% (n=9)	-34% (n=22)	-3% (n=5)
5		-37% (n=9)	-45% (n=22)	5% (n=5)
6			-57% (n=22)	37% (n=5)

Comparing readers with the same age interpretation there is a tendency of reduced variation in interpretation of ring position, thus all rings of modal age 4 show reduced mean STD of position, there are however exceptions.

However, the general level of the STD does not reduce to the level of the adjusted point number (compare figure 4.3.9.a and 4.3.9.b) indicating that there remains an among reader variation in ring positioning even when the overall age interpretation is the same.

Edge identification

The variation in edge interpretation was studied using standard deviation (STD) of the distance from second last point (final translucent ring) to the last point (the otolith section outline), among readers for each otolith. First variation of all readers were compared using the mean STD per age group, and then for each otolith the STD was calculated only for readers having the modal age interpretation (Table 4.3.3). It appears from the table that no reduction in variation occurred when only analysing modal age readings, indicating that edge interpretation is not a major source of disagreement in total age estimation.

Table 4.3.3				
modal age	2	3	4	5
mean STD of all readers	16.4	20.4	12.8	10.0
n	*7*	*9*	*23*	*5*
mean STD of readers=modal age	19.2	21.2	10.5	8.2
n	*4*	*8*	*18*	*3*

Conclusions

The overall result of the age readings is that there is a general low agreement between readers, with a variable precision of individual readers.

The earlier impression of different Eastern and Western schools of interpretation is however not supported by the present comparison exercise.

The lack of precision may be grouped into two major categories:

1) Reasonably common interpretation of individual rings where some readers choose to leave out specific rings identified by other readers as true annual rings.

2) Large apparently random variation in location of identified rings leading to different total number of rings

There are some apparent correlations in the material. Differences in interpretation are largest for the innermost rings, and the older ages are more difficult than the younger ages.

Readings, which estimate age equal to the modal age, do not all have the same interpretation of ring position.

5 ALTERNATE METHODS FOR AGE PARTITIONING

5.1 Otolith morphometrics and fish size

A working document (WD2) by R. Oeberst, Germany, was presented and discussed. The aim of the study was to relate fish size (length, weight) to otolith morphometrics such as otolith weight, area, length and width. The hypothesis is that otolith parameters are correlated to fish size. Verified correlations imply that otolith parameters can be used to supplement or even replace the current age estimation procedure of counting otolith annual rings. The study is a step to evaluate whether otolith parameters are suitable for correcting and updating historical age distributions.

Data on fish and otolith parameters were compiled from samples that were obtained during the BITS surveys in Sub-division 22 and 24 during autumn 2003. These data were complemented with data of young cod that were sampled in the same areas during the autumns 1993 to 1996. Otoliths were weighed and otholith area, length and width were measured by image analysis.

Results indicate that the relation between fish and otolith parameters are highly correlated ($r>0.9$ for most models). The best correlations were obtained with curvilinear models. The quotient between weight of the otolith and the body weight could be separated in three phases: 1/ In pelagic juvenile cod the weight of the otolith increases faster than body weight, 2/ in benthic juvenile cod the body weight increases faster in relation to the weight of otolith, and the residual variability of the relations between the different parameters is very small, 3/ in all cod the residual variability increases with increasing otolith size. However, residual analysis suggests that the relations between fish and otolith parameters do not differ significantly between areas or years (although only small cod were analysed for earlier years). This result suggest that a possible update of historical data will not require extensive sampling since otolith weights can in general be related to the already measured length distributions.

It was concluded that:

- the otolith and fish parameters are highly correlated.
- the development of the otolith can be described in relation to fish length and weight.
- the strong correlations between the otolith and fish parameters show that the use of frequency distributions of otolith parameter and total length have equal rights
- the use of total length or weight of otoliths have advantages and disadvantages

The SGABC participants agreed that this method could be supplement to the current age determination procedure and therefore also be a tool for the calibration of age reading. It was noticed that special software and hardware (image analysis system) are required in order to obtain measurements of otolith area, length and width.

5.2 Otolith validation by weight distributions

Data on otolith weights from the known age Faeroe cod were presented (FABOSA 2002). Otoliths taken from the same cohort at the same time of the year in successive years gave samples of otoliths with increasing weight as a result of age and growth. Results from the FAbOSA project indicate that more than 80% of the variation in cod age may be explained by using a combination of otolith size (weight) and shape characters, when known age material is at hand.

A method to split the overall weight distribution of samples with unknown ages into age classes was presented. The method had a high success rate although individual fish were not assigned a specific age (figure 5.2.1).

Comparing age composition by the methods of weight splitting and traditional reading showed a much higher agreement with true age distribution in the weight based method, with a success rate of 98% (weight based) and 60-95% (traditional reading depending on individual reader experience).

In a working document by Stuart Reeves, Denmark (WD3), the combination of otolith weight and cod length for splitting age groups was investigated by a modelling approach. Under different scenarios of variation in fish and otolith growth as well coupling – uncoupling of the two processes it was demonstrated that additional power of the analysis would be obtained by the combination of otolith and fish size, especially when the two processes were coupled.

A study was presented on the time expenditure for the total process of otolith weighing and punching of individual data linking otolith weight to fish ID. The frequency distribution of time spent is shown in figure 5.2.2. It appears that it typically requires about 20 sec per otolith when the scale is connected to a computer via an interface, the right hand tail of the distribution is probably influenced by additional data entry or examination of broken otoliths to ensure that all pieces are put on the scale.

Conclusions

Validation methods should be developed that link otolith weight distributions to age distributions. These may be based on multi-annual samples of otolith weight distributions and be tested by known age material which could be produced by mark/recapture programmes in the Baltic.

Statistical method should be developed to make robust interpretations of age distributions from combined measures of otolith and fish parameters.

Age readers of earlier material should be involved in the revision process and specific interpretations registered for the benefit of correcting old age distributions.

6 QUALITY ASSURANCE FOR BALTIC COD AGE READING

The main principal goal is improving the basis for assessment and the development of methods applicable to the range and scope of the fish age determination activities. Laboratories involved in development and continued success of ageing programs suggest a Quality Assurance procedure including developing an ageing method, age validation, preparing a reference collection and quality control monitoring (Campana, 2001)

6.1 Development of a method for age determination

It is shown by age-reading exercises during this and other meetings that there is a need for standardisation of otolith interpretation. To realize standardisation the need to document the process is necessary. The main source for a successful standardisation of Baltic Cod age reading would presently be a manual containing a very detailed method description of age determination including various elements of the process.

The manual should be under constant development, as input from research, discussions with National laboratories and inter-calibrations between readers should contribute new knowledge to the field. A revision of the existing manual should be considered to be developed to contain a detailed method description of age determination including various elements of the process. The outline of this type of manual is well described in the EFAN report (Mc Curdy et. al. 2000).

6.2 Age validation

Validation as a term is used in two ways; either proving that the age determination is accurate (direct validation) or to determine the meaning of the growth increment used in ageing (indirect validation) (Morales-Nin 2000). Indirect validation is also in some literature referred to as corroboration i.e. a method to support and is correlated to the method of ageing without being directly linked to it.

It would be desirable to actually be able to use a direct validation for Baltic Cod. The Danish Fisheries Research Institute has ongoing research with chemically marked wild fish in a tagging and release project which might become useful for validation purposes.

It is also feasible to start with projects aiming for indirect validation to corroborate the age determined by the traditional ageing procedure.

Age reading is presently a subjective process and often readers are left to deal with the quality issue on their own. Quality of the age readings is secured by the long individual experience of age-readers. This is a system, which is highly vulnerable and jeopardizes reproducibility. A well implemented age reading program should encourage the development of the age readers' skills but also be defined by another, independent, method than the one used in the original analysis.

The objective is therefore to involve the Baltic Cod age readers in the process of including data in the age reading process that possibly could corroborate the age determined. The first step towards this is including weight of the otolith in the protocol for age reading. An investigation performed with simulated data indicated that weight of otolith combined with length of fish could be linked to the age of the fish (WD3).

6.3 Preparing a reference collection

Reference collections are an important element of quality control of age reading. Today the reference collection of Baltic Cod is scarcely used and the material needs to be updated on a regular basis to fulfil its purposes. A continuous exchange program in line with that of the Baltic Herring Age Reading Group is desirable. The recently started Baltic Regional Planning Group may be a possible forum to develop an independent schedule for Baltic Cod Age Reading meetings. The Quality control monitoring process include inter institute contacts via regular meetings and access to a common website.

6.4 Quality control monitoring

Once the age reading procedure is planned and standardised a quality control program should be implemented. This should ensure the ageing consistency over time and measure accuracy and precision of the process.

The acceptable threshold of quality should be discussed and established in the planning of the program and in the quality control statistical models should quantify the deviation from the agreed level. After this a method of correcting should be used in accordance with the results from the validations. Quality control monitoring is a cyclic procedure continuously updated by the group involved in age reading. Actions should not only be implemented and followed by all involved in ageing of cod from the Baltic, but also revised frequently in the group, so the methods and results of ageing is kept in line with state of the art. The objective is that the best practise available is the standard age reading procedure. It is well understood that this kind of work takes a lot of time and therefore may be costly but in the long run Quality Assurance is as a process that in most cases have proven to be cost efficient.

7 INTERSESSIONAL WORK

The SGABC members are aware of the present problems to conduct reliable stock assessments of Baltic cod. There are several indications that part of the problem depends on inconsistencies in the age determination. A prime objective of the SGABC is therefore to implement a consistent age determination protocol and to outline methods to revise historical age distributions.

It was agreed that a new age determination protocol must include supplementary information such as fish or otolith size besides the traditional age estimation. Fish length and weight are already sampled for stock assessment purposes.

Several studies (see above) suggest that otolith weight is a parameter that can be used to predict age distributions with acceptable statistical properties. Otolith weight is also easy to include in the present sampling scheme of landings, discards and surveys, compared to more elaborate measures such as otolith area, length and width (which require equipment for image analysis).

The inclusion of otolith weight as a supplement or replacement for traditional age estimation methods will be achieved in two steps: 1/ validation of otolith weight distributions as a method for age (yearclass) estimation and 2/correction and update of historical data of age distributions.

7.1 Validation of otolith weight for age estimation

It was agreed that national data on otolith weight from research surveys should be obtained from the years 2001-2003 in Sub-divisions 25, 26 and 28. All weights should be measured with a resolution of 1 mg. The data will be used for a statistical evaluation of otolith weight distributions as a measure of age distributions within years. Data collection and compilation will be supervised by a coordinator, Yvonne Walther, Sweden. The deadline for submission of otolith data to the coordinator is 31 October 2004. The statistical analysis and evaluation will be organised by Henrik Mosegaard, Denmark and results will be reported to the European Fisheries and Aquaculture Organisation (EFARO) in December 2004 and to the next SGABC in January 2005. The time schedule and extent of data collection was agreed by the study group members from Denmark, Germany, Latvia, Lithuania, Poland and Sweden. However, the SGABC recommends that all national institutes that have collected otoliths from Sub-divisions 25, 26 and 28 during 2001 to 2003 should provide data to the coordinator.

In summary:

Collection of individual otolith weights for validation purposes				
Area	Time	Origin	Amount	Institutes*
Baltic Sub-divisions 25, 26, 28	By month (or if not available: quarters) in 2001, 2002, 2003	Research surveys or if not available: from market or discard sampling.	No less than 400 otolith weights by sampling area and time (month or quarter)	Denmark Germany Latvia Lithuania Poland Sweden

*national institutes from other nations are recommended to submit otolith weight data as specified.

Task	Organiser	Deadlines
Coordination and data compilation	Yvonne Walther, Sweden	31 October 2004
Statistical analysis and evaluation	Henrik Mosegaard, Denmark	31 December 2004

7.2 Investigations in reader inconsistencies by a qualitative exchange program

Results from the comparative exercise on reader observations on otoliths (section 4.3) suggest that the method can be used to disentangle and explain reader inconsistencies both between and within readers. It was agreed that this exercise was valuable and should be continued in an intersessional exchange program. Around 50 representative otoliths will be selected and photographed. Both otoliths and their respective images will be circulated between cod age readers of the national institutes around the Baltic. The program will be initiated during the 2nd half of 2004. The task was assigned to Lotte Worsøe Clausen, Denmark, who will report preliminary results at the next SGABC meeting.

7.3 Initiation of routine sampling and historical update of otolith weight data

It was agreed that validation must be a prerequisite to a routine sampling of otolith weights. However, the present problems in stock assessment of Baltic cod, do warrant a swift upstart of routine sampling or at least a testing period of sampling, which can be used to evaluate full-scale sampling procedures. The SGAC therefore recommends that all national laboratories should start to sample otolith weights together with traditional length frequencies and age determinations from the 3rd quarter 2004. The recommendation covers all age-determined cod from market, discard and survey samples. The collected length, age and otolith weight data should be sent to the assigned coordinator Yvonne Walther, who will compile the data and report to the next SGABC and WGBFAS in 2005.

Methods to update historical age distributions need to be developed. One possibility is to relate otolith weight to fish length and thereby use the observed length distributions for an update. A more direct method is to update the calculated age distributions from an historical update on otolith weight distributions. The SGABC recommends that relevant statistical methods shall be evaluated and reported to the next SGABC meeting. The recommendation implies that an historical update of age distributions will not be available to the WGBFAS in the 2005 meeting.

The extra measurements on otolith weight will require extra resources for the national institutes. Measurements at the Danish Institute for Fisheries Research suggest an average extra time of 20 seconds per weighted otolith. The number of aged cod of the eastern stock in market and survey samples was 18979 during 2002 (ICES 2003). This implies an extra workload of 18979 x 20 seconds = 105 hours work around the clock. In practice this work may be estimated on average to more than one week extra labour per national institute and year. The inclusion of discard sampling will further increase the expected workload. In addition weight balances (1 mg resolution) of approximately 1000 EURO must be obtained. It was also recognised that intersessional work in 2004 to sample otolith data for the validation and routine sampling during 2004 will impose a small but yet significant extra workload in 2004. However, representatives of the national institutes that took part in the SGABC meeting indicated that this extra workload during 2004 could be handled within normal budgets.

Further work on the historical update and routine sampling will therefore require extra funding. The SGABC agreed that the possibilities for external funding should be investigated. Extra funding may be obtained for old EU member states within the national programmes for Data Collection (EU Council Regulation1543/2000). Other possible funding may be provided by the Baltic Sea Regional Project, which is intended to support scientific investments the in Baltic states, Poland and Russia. Investigations on the possibility for external funding were assigned to Yvonne Walther, Sweden, Peter Ernst, Germany and Maris Plikshs, Latvia in cooperation. They shall report to the next SGABC meeting.

7.4 Agreement on a common protocol for individual fish measurements

The age readers went through the currently applied methods in the respective institutes to assess which methods that were the same between the institutes. These were summed up in a schematic protocol suggestion as shown in table 7.4.1. Only Denmark and Latvia have weighed otoliths on a routine basis so far, but all participating institutes decided to include weighing otoliths as a part of the routine procedure in the laboratory from the second part of the year 2004 and onwards.

It was discussed whether to include information on the level of experience of the individual readers in the protocol (e.g. the numbers of otoliths read – 10.000 or 25.000), but the conclusion was that such a classification would not be useful for scientific purposes. Further, a suggestion was put forward to include information of the reading frequency of the individual reader, e.g. whether the age reading is performed on a weekly or monthly basis, but it was decided not to include this information in the common protocol.

Notation of the character of the edge of the otolith has been suggested to be included in the protocol. However, the first age reading exercise clearly showed a large variation in the perception of this feature and thus it was decided not to include this in the suggested common protocol.

Through the discussion it was discovered that the maturity scales used by the different institutes were not the same, however a key to converge these scales does exist in the Manual for sampling of the Baltic Sea Commercial Fisheries (Guidebook for observers and fishery biologists International Baltic Sea Sampling Programme EU 98/024.) and the appendix II of the Manual for the Baltic International Trawl Surveys (ICES 2002).

Table 7.4.1 includes the agreed data that will be submitted for the validation of otoliths collected by research vessels in 2001-2993.

8 RECOMMENDATIONS

The SGABC recommends:

8.1 General recommendations

- To encourage age reading exercises or exchange programs that reveals qualitative differences between age readers in the age interpretation of Baltic cod otoliths.
- To make efforts to compile and present known-age material (from taggings or indirect methods) that can be used for age validation.
- To investigate and document changes in otolith structures by monthly samples.
- To collect otoliths from young cod, which are not collected in the period between routine research surveys (e.g. from non routine scientific surveys or discard sampling), in order to better understand otolith growth of young cod.
- To investigate individual drift in the interpretation of otolith age and possible methods to correct for observed drift.
- To evaluate historical age distributions by the engagement of age readers that have experience from age reading of Baltic cod otoliths from the 1970s and the 1980s.
- To encourage participation of statisticians and assessment experts in the SGABC work.

8.2 Specific recommendations to fishery institutes engaged in studies of Baltic cod.

- To weigh aged otoliths from research surveys that has been conducted in Sub-division 25, 26 and 28 during 2001 to 2003 and to report the otolith weight data to the coordinator Yvonne Walther no later than 31 October 2004. (Since no systematic difference between left and right sagitta exists the second preferably unbroken otolith should be used).
- To develop statistical approaches to estimating age distributions from otolith biometrics. This task will be organised by Stuart Reeves, Denmark.
- To participate in the evaluation on the validity of using otolith weight data to estimate age distributions. The organisation of this evaluation will be coordinated by Henrik Mosegaard, Denmark.
- To initiate national programmes for a routine sampling of otolith weights in addition to aged otoliths from market, discard and survey samples of Baltic cod and to report these data to the WGBFAS meeting in 2005. Preliminary reports are expected by 31 December 2004.
- To participate in an exchange program of otoliths and accompanied images that will be used for further examination of age inconsistencies and possibly age validation. The program will be initiated and coordinated by Lotte Worsøe Clausen, Denmark, in the 2nd half of 2004. Preliminary results will be reported at the next SGABC meeting.
- To prepare for the inclusion of otolith weight in national databases and to report on such achievements to the SGABC.

8.3 Recommendation on the next SGABC meeting

The next meeting of the SGABC (Chair: Johan Modin, Sweden) will take place in January, 2005 in Riga, Latvia, with the following terms of references:

- To review intersessional work and suggest further studies based on the intersessional results,
- To review progress in developing approaches to estimating age distributions from otolith biometrics,
- To develop a robust statistical method to correct historical age distributions by nation, year, season and area,

- To plan and organise an update of historical data of age and otolith weight data for at least the past 10 years,
- To review progress of the exchange validation program and investigate its usefulness for an update of historical data,
- To report to the WGBFAS, ACFM and other relevant bodies.

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9.1 Cited literature

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Morales-Nin, B. 2000. Guidelines for validation studies. Report of the European Fish Ageing Network (EFAN) 4/2000.

Reeves, S.A. 2003. A simulation study of the implications of age-reading errors for stock assessment and management advice. ICES Journal of Marine Science 60:314-328.

9.2 Working documents

WD1: Oeberst, R. 2004. What does the year-classes 1995 and 2001 of Baltic cod tell us? Working Document to the ICES Study Group on Ageing Issues in Baltic Cod, Riga, May 2004.

WD2: Oeberst, R. 2004. Use of otolith parameters and total length for supporting the ageing process of Baltic cod. Working Document to the ICES Study Group on Ageing Issues in Baltic Cod, Riga, May 2004.

WD3: Reeves, S. 2004. Simulation studies to investigate the possible use of otolith weight in the age-determination of Baltic cod. Working Document to the ICES Study Group on Ageing Issues in Baltic Cod, Riga, May 2004.

Table 3.2.1 Modal length (cm) of observed peaks in length distributions of cod from BITS in 2001-2003

Year	Vessel	QTR	1st peak	2nd peak	3rd peak
2001	Argos, Sweden	1	11	26	
	Atlantida, Russia	1	12	33	42
	Baltica, Poland	1	10	27	
	Dana, Denmark	1	12	26	
2002	Argos, Sweden	1	10	22	
	Baltica, Poland	1	10	22	
	Dana, Denmark	1	8	26	
2002	Argos, Sweden	4	7	24	33
	Dana, Denmark	4	7	21	35
2003	Argos, Sweden	1	12.5	27	33
	Atlantida, Russia	1	8	28	39
	Baltica, Poland	1	10	26	38
	Dana, Denmark	1	12	27	37

Table 4.2.1 Age estimates by age reader 1-7 in the age reader exercise 1. Agreement is the ratio of age readers that agree with the modal age.

	Sub-division	Length (cm)	Catch month	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Modal age	Agreement (%)
1	26	19	2	1	2	2	2	2	2	1	2	71.4
2	26	35	2	3	3	4	4	3	4	2	3	42.9
3	26	34	2	2	3	3	3	3	3	3	3	85.7
4	26	35	2	2	4	3	3	3	4	3	3	57.1
5	26	34	2	2	3	3	3	2	3	3	3	71.4
6	26	44	2	4	4	4	4	4	4	4	4	100.0
7	25	47	9	4	4	5	5	4	5	5	5	57.1
8	25	46	9	4	4	4	3	4	6	4	4	71.4
9	25	44	9	3	4	3	3	4	4	5	3	42.9
10	25	39	9	3	3	4	3	3	3	4	3	71.4
11	25	40	9	3	3	4	3	3	4	4	3	57.1
12	26	38	6	4	4	5	3	4	3	4	4	57.1
13	26	51	6	4	5	5	5	5	5	5	5	85.7
14	28	43	10	4	4	4	2	4	4	4	4	85.7
15	26	41.5	11	3	4	3	2	4	4	4	4	57.1
16	26	44	8	4	4	4	3	4	5	5	4	57.1
17	26	26	11	1	2	2	1	2	1	3	1	42.9
18	28	48	10	4	4	4	3	4	5	5	4	57.1
19	28	35	10	3	3	3	2	3	3	4	3	71.4
20	26	46	2	4	5	5	5	5	4	5	5	71.4
		Average age		3.1	3.6	3.7	3.1	3.5	3.8	3.85	Average	65.7

Table 4.2.2 Agreement (%) between readers of the age reader exercise 1 (D-disagreement, A-agreement according to Wilcoxon test).

Reader	1	2	3	4	5	6	7
1		55	40	25	60	30	25
2	D		60	40	90	55	45
3	D	A		50	60	50	55
4	A	D	D		40	50	35
5	D	A	A	A		45	45
6	D	A	A	D	A		50
7	D	A	A	D	D	A	

Table 4.2.3 The determined number of hyaline rings of the age reader exercise 1.

No.	Sub-division	Length (cm)	Date (month)	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Mode	Agreement hyaline (%)	Agreement age (%)
1	26	19	2	1	1	1	1	2	1	1	1	85.7	71.4
2	26	35	2	3	2	4	4	2	3	2	2	42.9	42.9
3	26	34	2	2	2	3	2	1	3	3	2	42.9	85.7
4	26	35	2	2	3	3	3	2	3	3	3	71.4	57.1
5	26	34	2	2	2	2	2	1	3	3	2	57.1	71.4
6	26	44	2	4	3	4	4	4	4	4	4	85.7	100.0
7	25	47	9	4	4	5	5	3	5	4	4	42.9	57.1
8	25	46	9	4	4	4	3	3	6	4	4	57.1	71.4
9	25	44	9	3	4	3	3	3	4	5	3	57.1	42.9
10	25	39	9	3	3	4	3	3	4	4	3	57.1	71.4
11	25	40	9	3	3	4	3	3	4	4	3	57.1	57.1
12	26	38	6	4	4	5	3	4	3	4	4	57.1	57.1
13	26	51	6	4	5	5	5	4	5	4	5	57.1	85.7
14	28	43	10	4	4	4	3	4	4	5	4	71.4	85.7
15	26	41.5	11	3	4	3	3	3	4	4	3	57.1	57.1
16	26	44	8	4	4	4	4	3	5	5	4	57.1	57.1
17	26	26	11	1	2	2	2	2	1	3	2	57.1	42.9
18	28	48	10	4	4	4	4	3	5	5	4	57.1	57.1
19	28	35	10	3	3	3	3	3	3	4	3	85.7	71.4
20	26	46	2	4	4	5	5	5	4	5	5	57.1	71.4

Table 4.2.4 Determination of the zone on the edge of the otolith (O-opaque, H-hyaline). The otoliths (Nr) is sorted according to the date of the catch.

No.	Sub-division	Length (cm)	Date (month)	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Dominant edge type
1	26	19	2	O	O	O	O	O	O	H	O
2	26	35	2	H	O	H	H	O	O	O	O
3	26	34	2	O	O	H	O	O	H	O	O
4	26	35	2	H	O	H	H	O	O	O	O
5	26	34	2	O	O	O	O	O	H	O	O
6	26	44	2	O	O	H	H	O	H	O	O
20	26	46	2	O	O	H	H	O	H	H	H
12	26	38	6	O	H	H	H	O	O	O	O
13	26	51	6	O	H	H	H	O	H	H	H
16	26	44	8	H	O	H	H	O	H	O	H
7	25	47	9	H	O	O	H	H	O	H	H
8	25	46	9	O	O	O	O	H	H	H	O
9	25	44	9	O	O	O	O	O	O	O	O
10	25	39	9	O	O	O	O	O	H	O	O
11	25	40	9	O	O	O	O	O	O	H	O
14	28	43	10	O	O	H	H	O	H	O	O
18	28	48	10	O	O	H	H	O	H	H	H
19	28	35	10	H	O	H	H	H	O	O	H
15	26	41.5	11	H	H	H	H	O	H	H	H
17	26	26	11	O	H	H	H	O	O	O	O

Table 4.3.1 Wilcoxon's test for bias between age readers and reader against modal age. Reader 8 and 5 clearly show bias compared to the modal age and most of the other readers.

	Inter-reader bias test and reader against MODAL age bias test							
	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8
Reader 1		-	-	-	**	-	**	**
Reader 2	-		-	-	**	-	**	*
Reader 3	-	-		-	**	*	**	*
Reader 4	-	-	-		**	-	**	*
Reader 5	**	**	**	**		**	**	-
Reader 6	-	-	*	-	**		-	**
Reader 7	**	**	**	**	**	-		**
Reader 8	**	*	*	*	-	**	**	
MODAL age	-	-	-	-	**	-	**	*

- = no sign of bias (p>0.05)
* = possibility of bias (0.01<p<0.05)
* * = certainty of bias (p<0.01)

Table 7.4.1 Data that are collected of individual cod by national institutes (x = yes, - = no, x = specific standard). The headline "Required" indicate the agreed data that will be collected for the validation of otoliths collected by research vessels in 2001-2993.

	DK	SWE	POL	LAT	GER	LIT	RUS	REQUIRED
No.	x	x	x	x	x	x	?	x
Date	x	x	x	x	x	x	?	x
Subdivision	x	x	x	x	x	x	?	x
							?	
Length	x	x	x	x	x	x	?	x
Weight	x	x	x	x	x	x	?	x
Sex	survey only	survey only	x	x	x	x	?	-
Maturity stage	survey only scale 1-10	survey only scale 1-5	x scale 1-8	x scale 1-6/1-5	x scale 1-5	x scale 1-6	?	-
Otolith weight	x	Starting	Starting	x	Starting	-	?	x
Otolith length	-	-	-	x	-	x	?	-
Edge	-	-	-	x	x	-	?	-
Nucleus	-	-	-	x	-	-	?	-
Zones	-	-	-	-	-	-	?	-
Reader ID								x

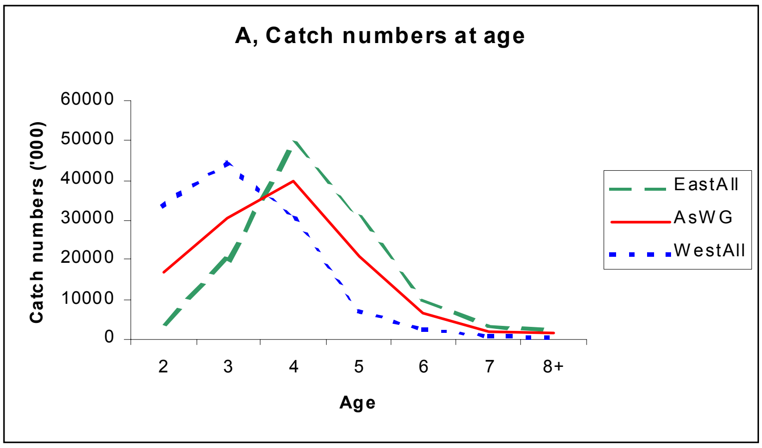


Figure 3.1.1 Assessment input data for 1990 for the three datasets on different age compositions.

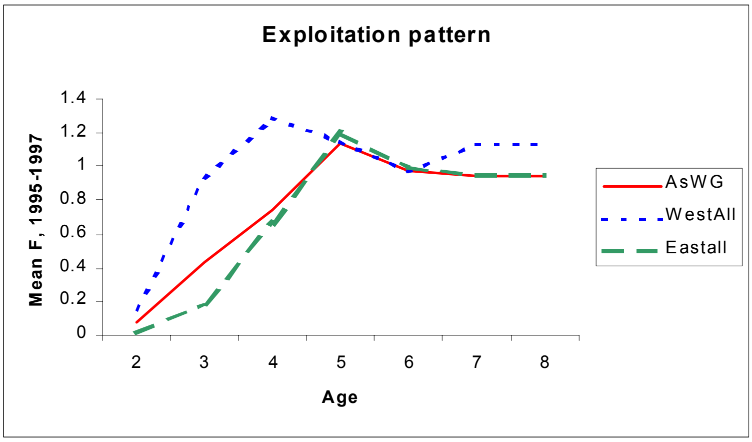


Figure 3.1.2 Mean exploitation pattern from XSA runs (mean F at age from 1995 to 1997) using the three different datasets as inputs.

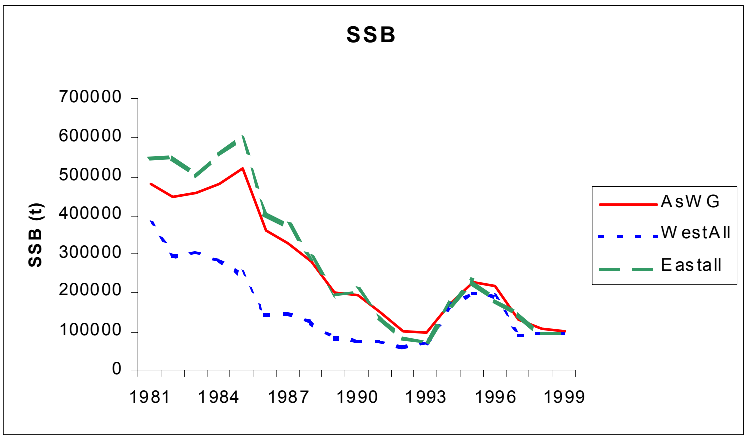


Figure 3.1.3 Trends in spawning stock biomass from three XSA runs based on the three different datasets.

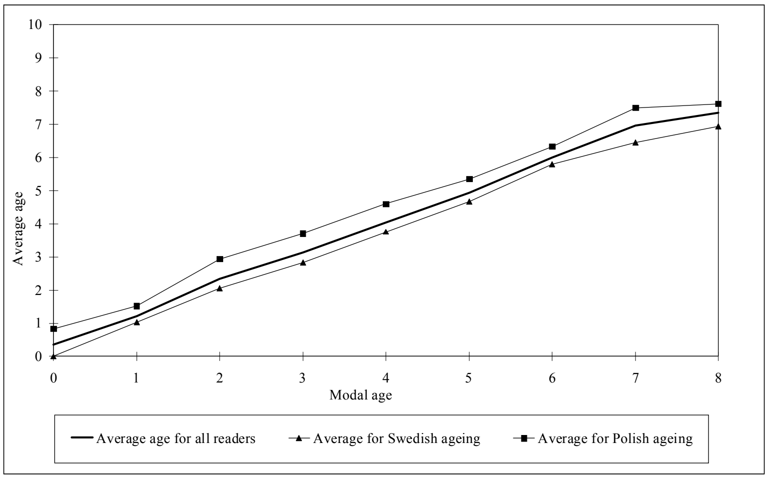


Figure 3.1.4 Average estimated age by all readers and by Swedish and Polish age readers against modal age.

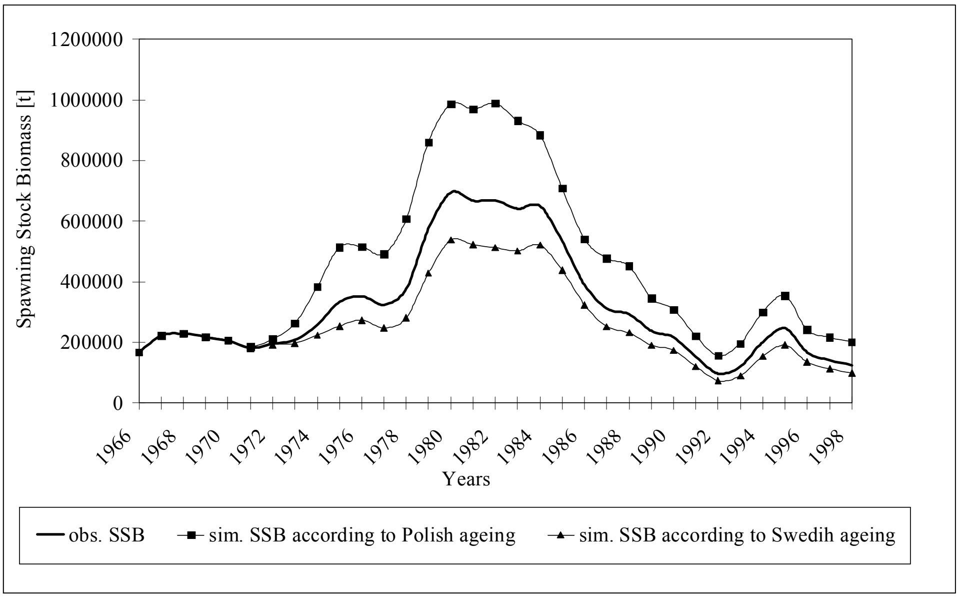


Figure 3.1.6 Simulated spawning stock biomasses (sim. SSB) of cod in the Eastern Baltic compared with estimates of biomasses (obs. SSB) from the WGBFAS (2000).

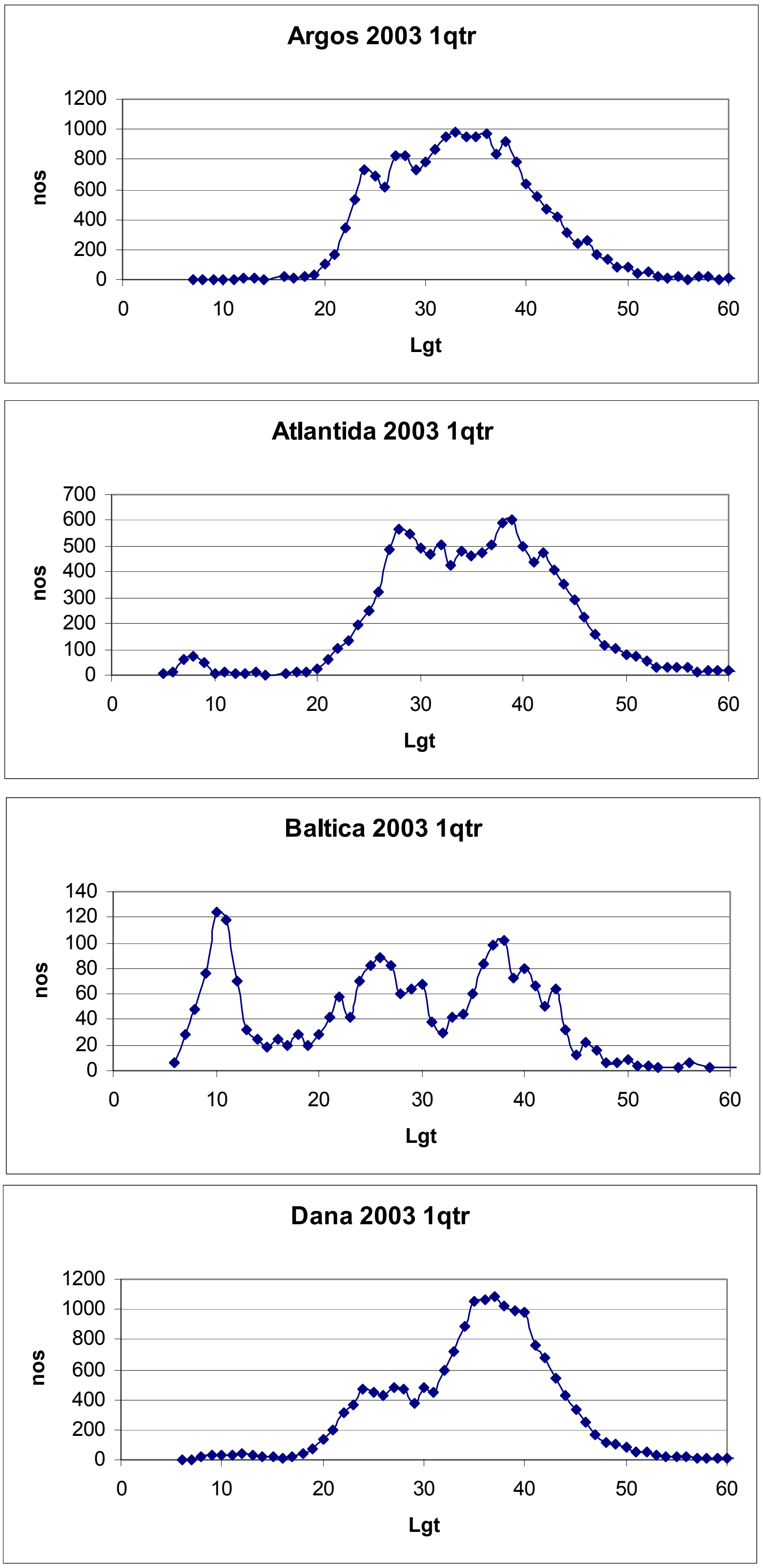
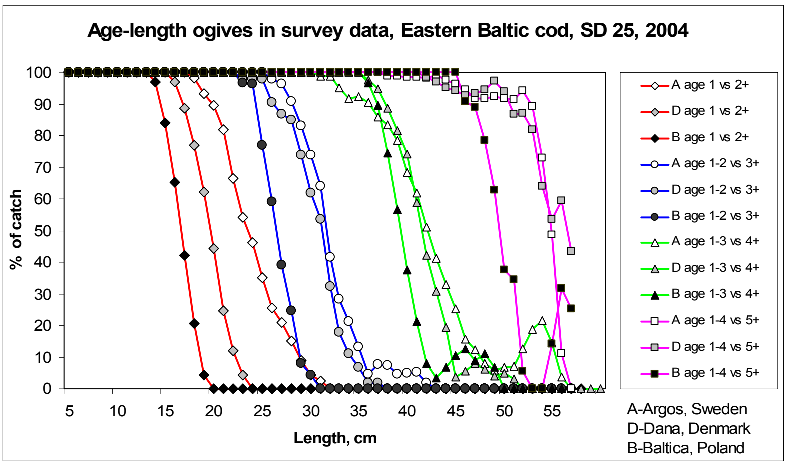
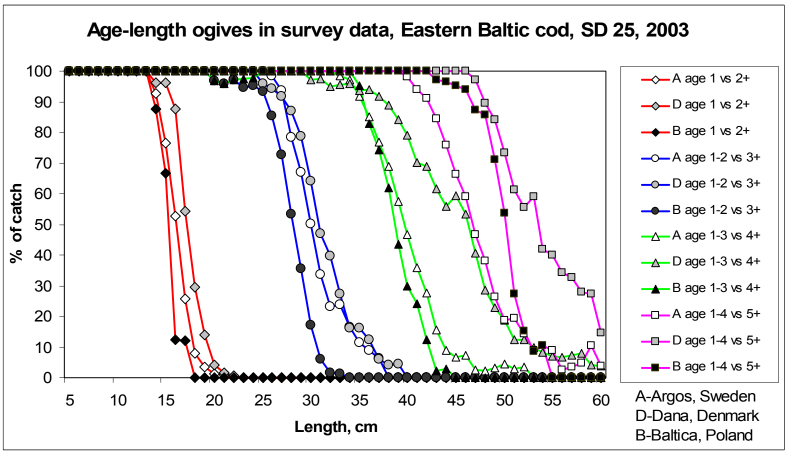


Figure 3.2.1 Cumulative length distributions from the BITS survey in 1st quarter from Swedish (R/V Argos), Russian (R/V Atlantica), Polish (R/V Baltica) and Danish (R/V Dana) vessels.





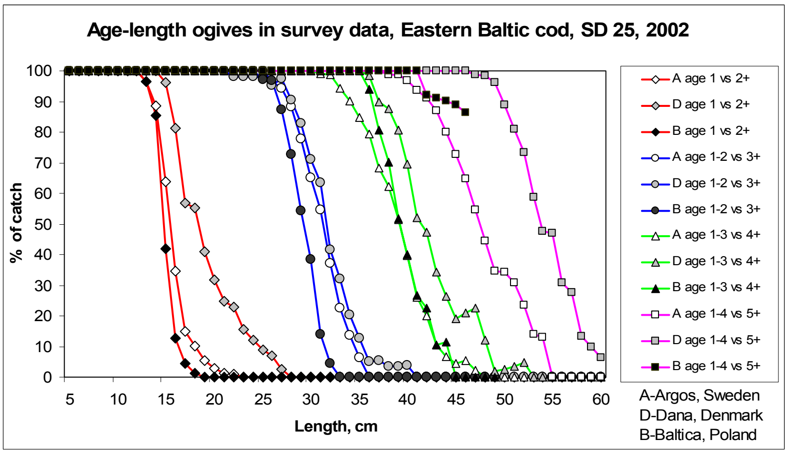
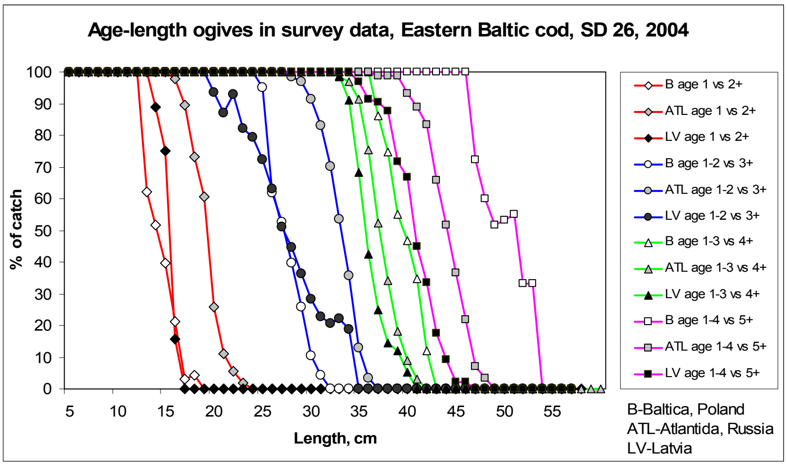
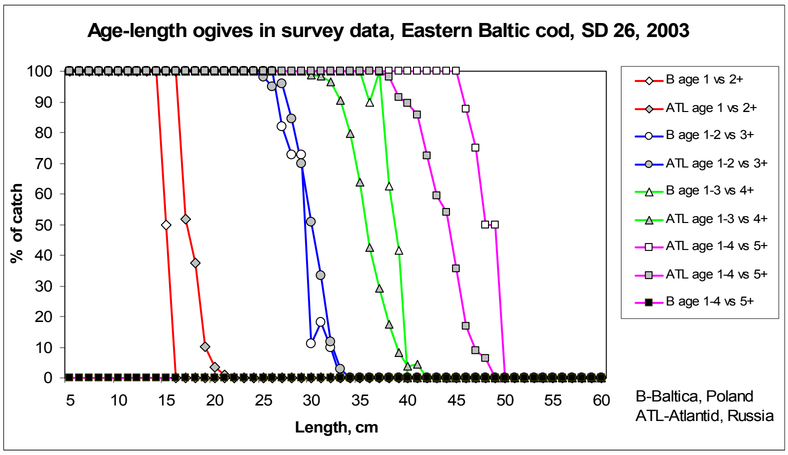


Figure 3.2.2 Age-length ogives in BITS data. Note that the length distribution by age can be similar between some countries in one year but differ between countries in the next year.





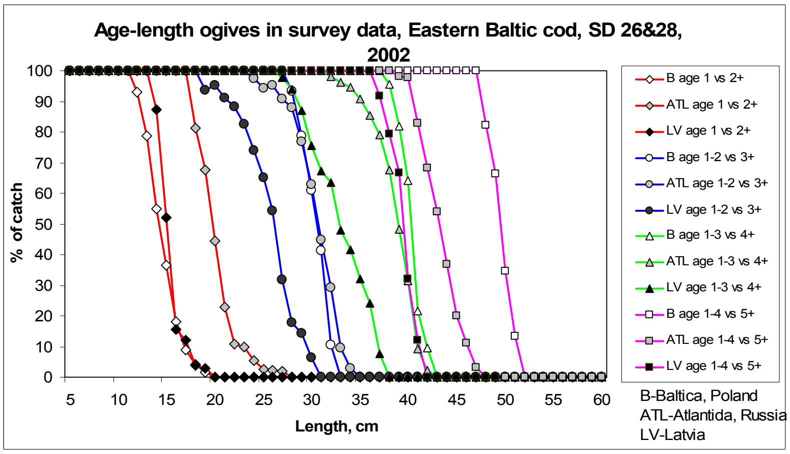
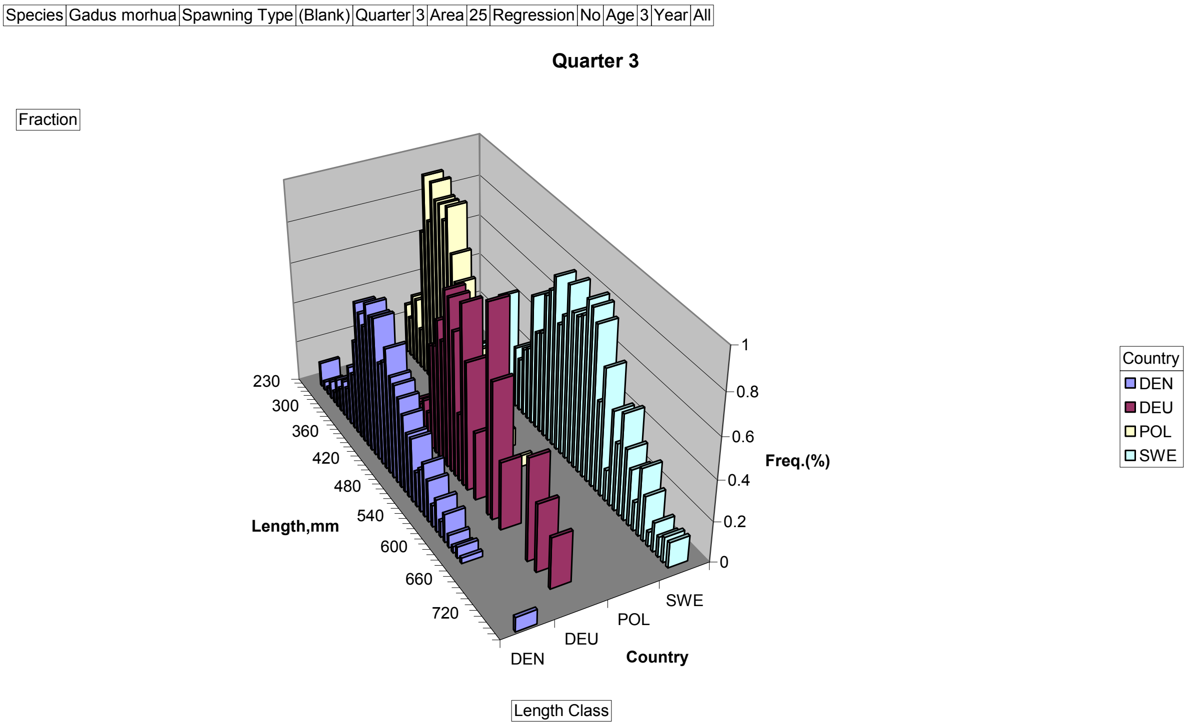


Figure 3.2.2 Cont.: Age-length ogives in BITS data



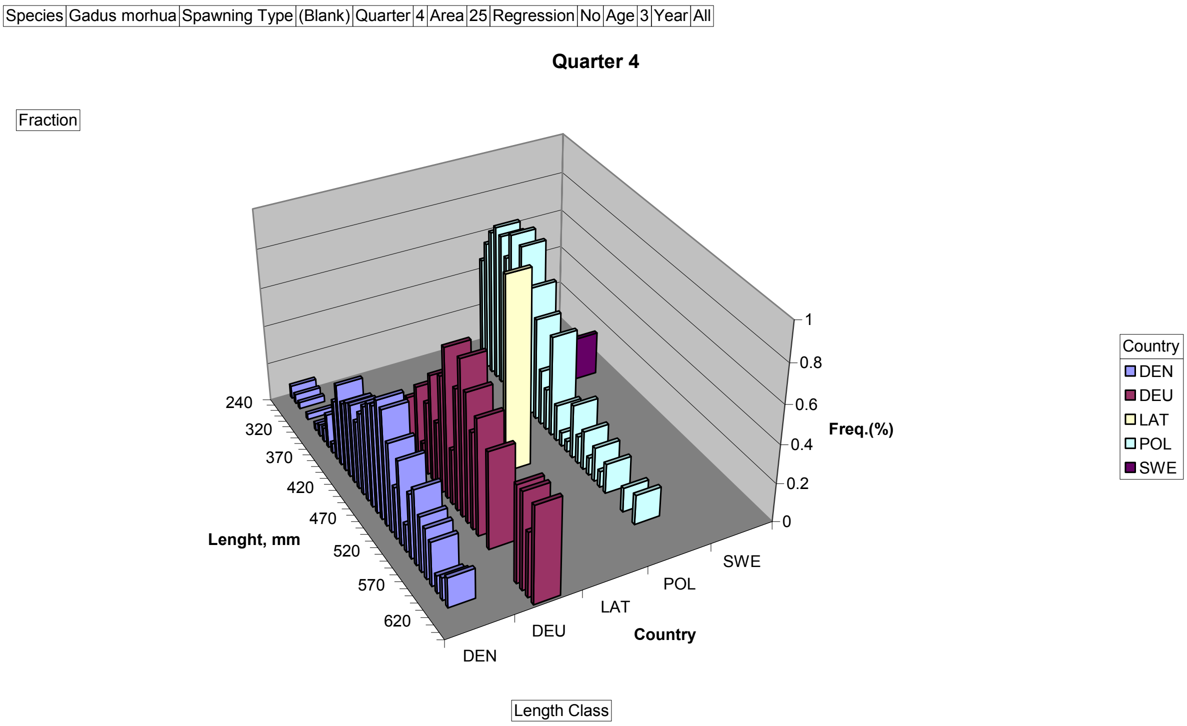


Figure 3.2.3 Length distribution of age group 3 cod from commercial sampling by country in Sub-division 25 (data extracted from the FishFrame database: www.fishframe.org)

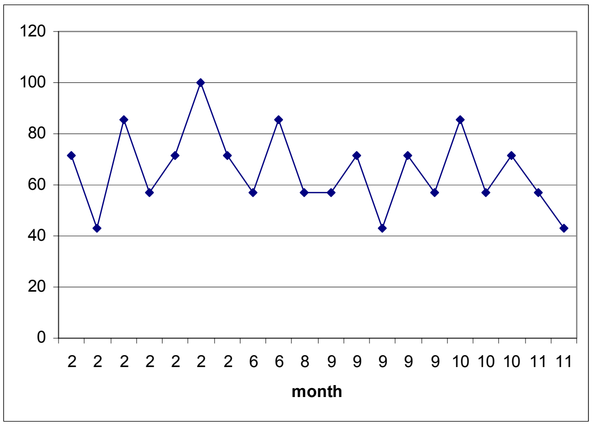


Figure 4.2.1 Agreement (Y-axis in %) of age determination in relation to the date of catch.

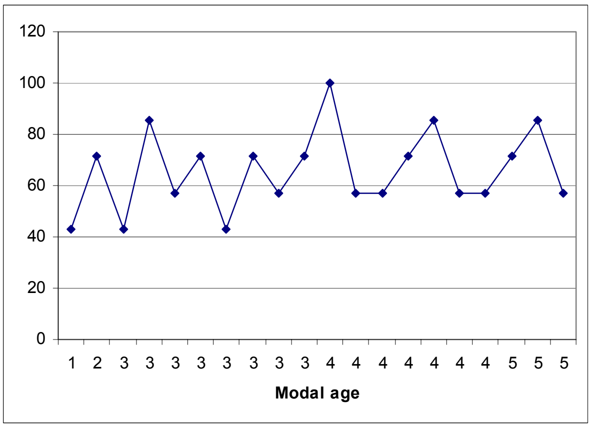


Figure 4.2.2 Agreement (%) of age determination in relation to the modal age.

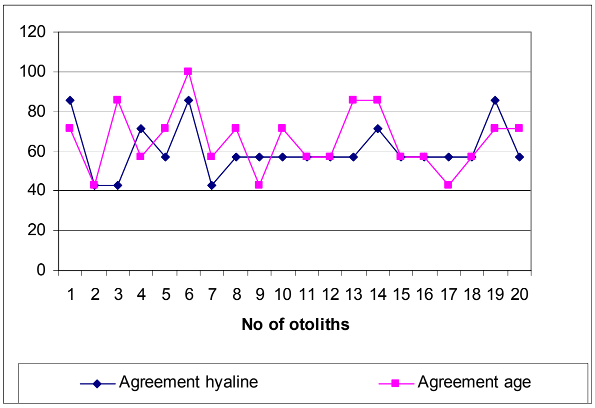


Figure 4.2.3 Agreement (%) in the determination of age and hyaline rings.

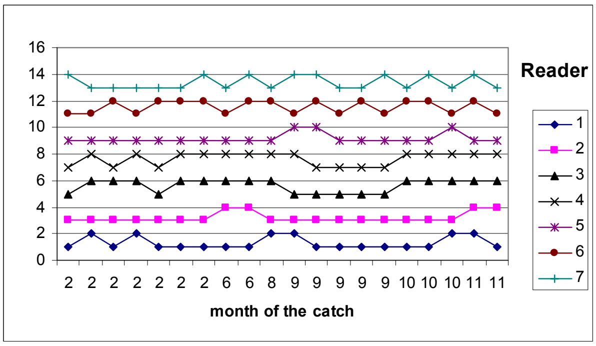


Figure 4.2.4 Assignment of opaque (odd numbers) or hyaline (even numbers) zones to the edge of the otolith. From theory there should only be one hyaline and one opaque zone per year.

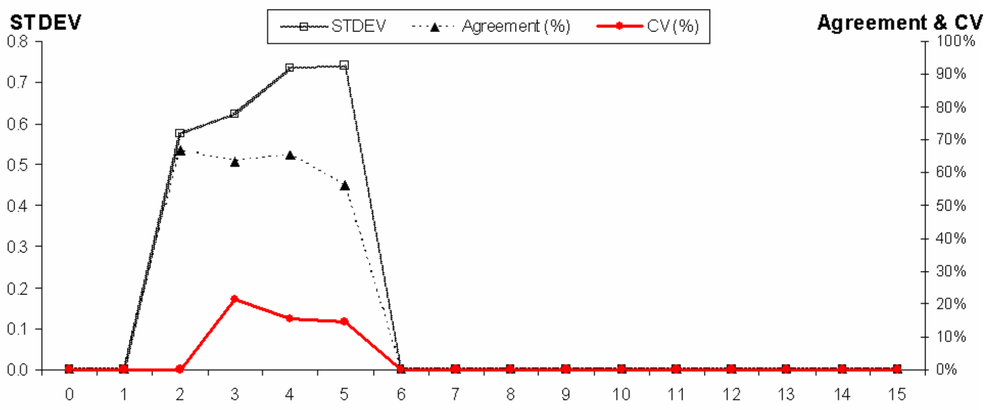


Figure 4.3.1 The coefficient of variation (CV%), percent agreement and the standard deviation (STDEV) are plotted against MODAL age. CV is much less age dependent than the standard deviation (STDEV) and the percent agreement and is therefore a better index for the precision in age reading. The more or less constant CV indicates that all ages seem to be difficult to be agreed upon between the readers.

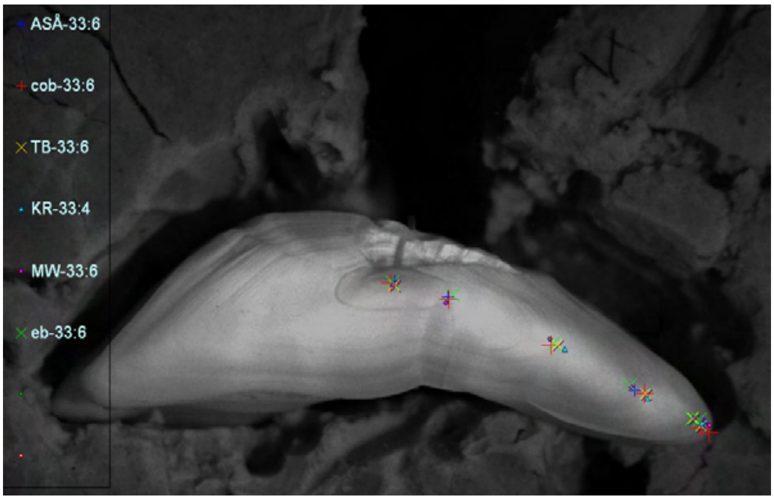


Figure 4.3.2 Example of the variability in determining the first age structure. Two out of six readers did not include the first translucent structure as an age structure.

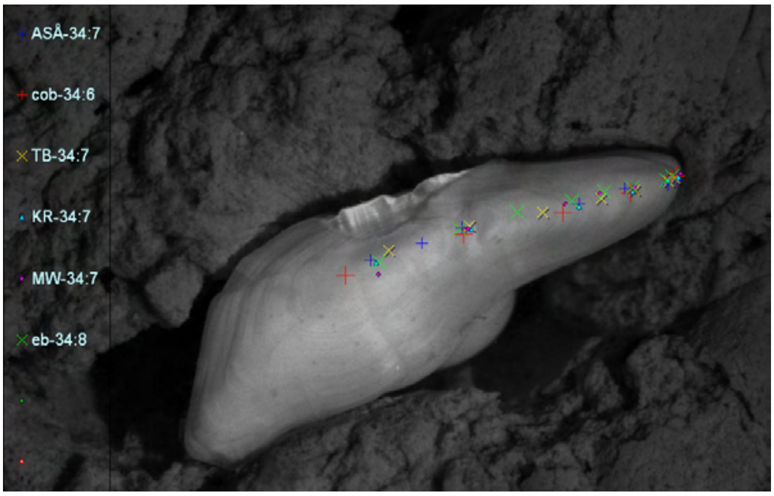


Figure 4.3.3. Example of the variability in determining age structures in a cod otolith. One half of the readers interpreted this cod to be 6 years old where the other half interpreted it to be 7 years old and, apparently, no readers agreed upon where to point to the age structures in the otolith.

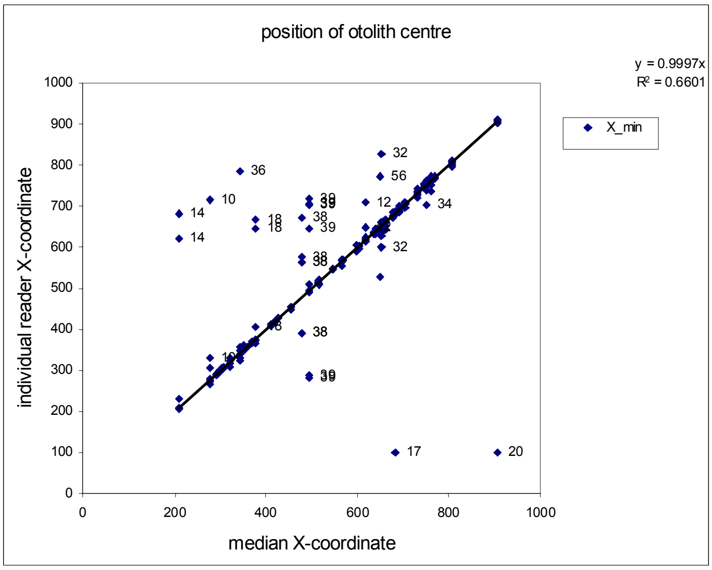


Figure 4.3.4 Quality checking by comparing reader positioning of X-coordinate of otolith center with median position for each otolith. Excluded reader-otolith combinations are labeled with the otolith number.

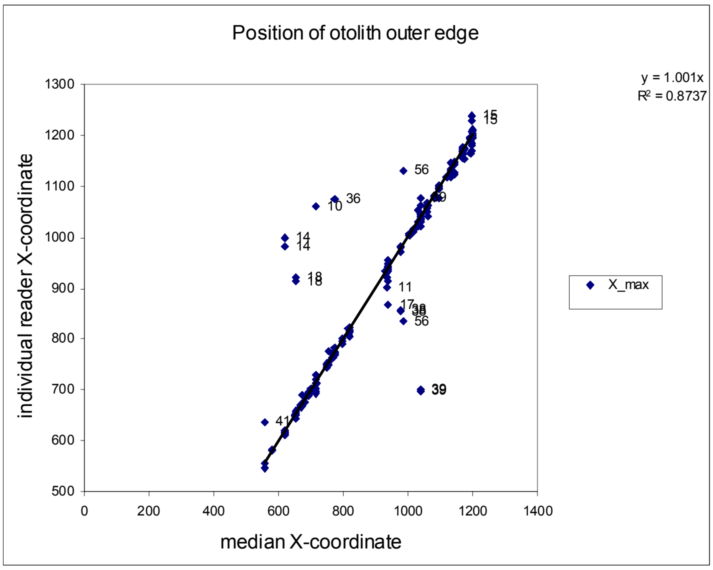
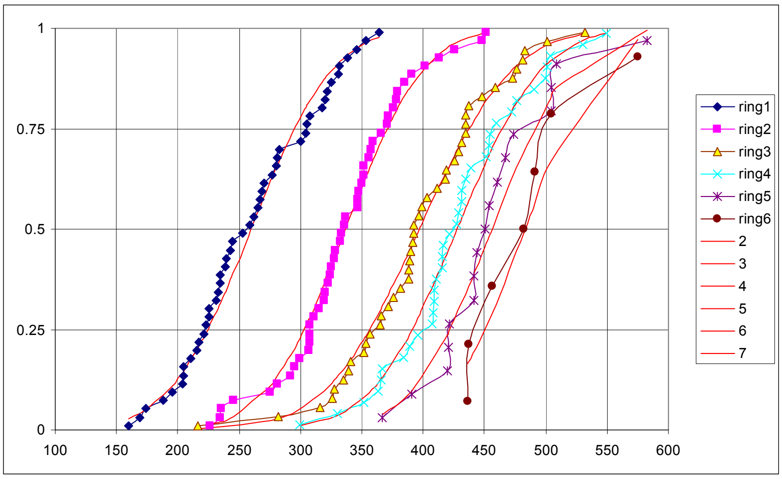


Figure 4.3.5 Quality checking by comparing reader positioning of X-coordinate of otolith outer edge with median position of edge for each otolith.



Annuli	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6
Mean	259.7	336.8	396.9	427.5	456.0	483.3
St. dev.	52.3	50.2	59.8	54.2	50.4	48.4

Figure 4.3.6 Variation in the median distance to rings (annuli) from the standardised centre of the otolith. The variation isdepicted as a cumulative distribution (symbols). Fitted normal distributions (lines) are inserted for comparision. The text table indicates the corresponding means and standard deviations.

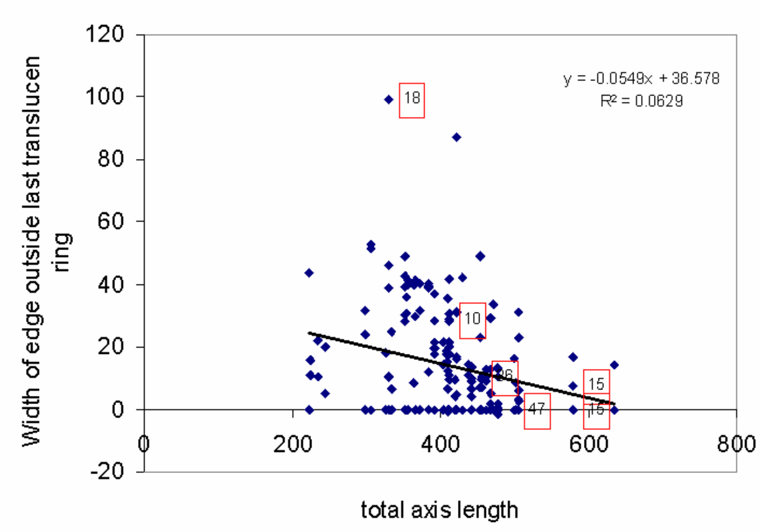


Figure 4.3.8 Negative relationship between edge width and median total length of the otolith axis. Scatter plot leaving out outliers in form of center and edge XY coordinates of individual reader's interpretations.

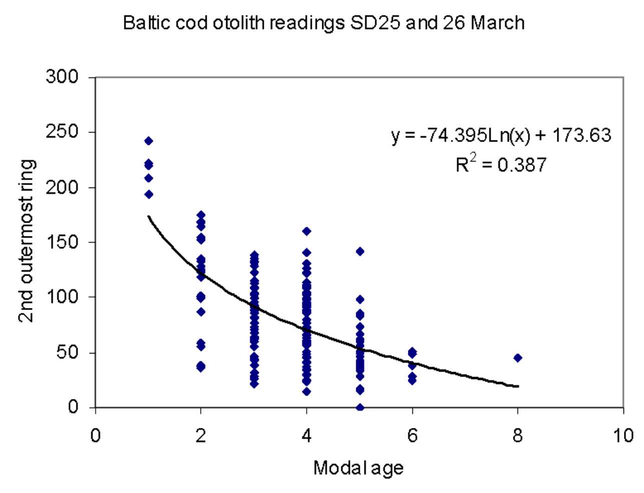


Figure 4.3.8 Negative relationship between width of 2nd to outermost growth structure and the modal age interpretation. Scatter plot leaving out outliers in form of center and edge XY coordinates of individual reader's interpretations.

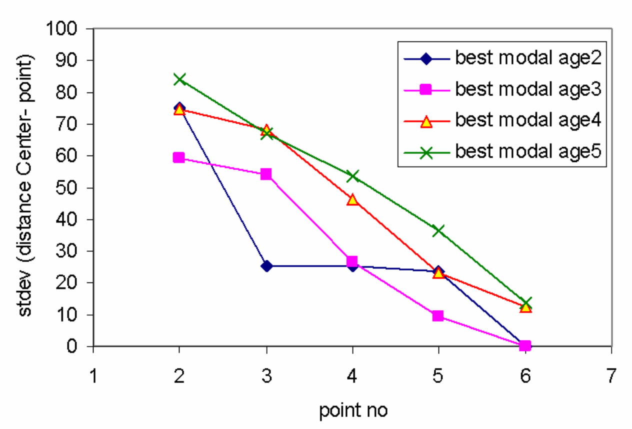


Figure 4.3.9.a) Variation in interpretation of position of specific age structures (age ring = point no. minus one).

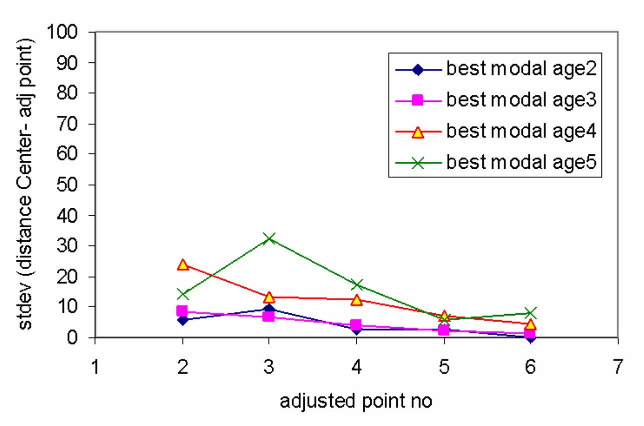


Figure 4.3.9. b) Variation in position of specific age structures adjusted to the point no. of the nearest median position.

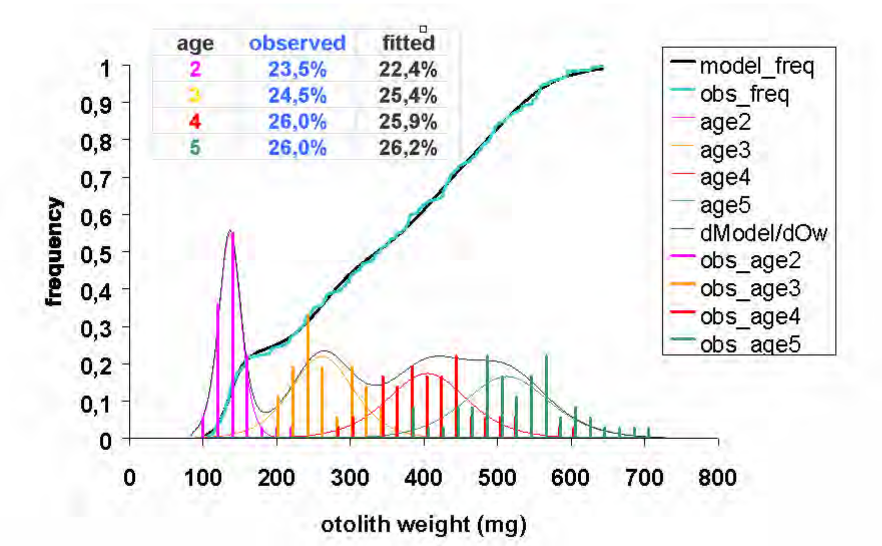


Figure 5.2.1 Age proportions from otolith weight distribution in known age Faeroe cod.

Figure 5.2.2 Frequency distribution of time expenditure (in sec) for otolith weighing and registration in a computer interfaced process.