Demersal Fish Committee

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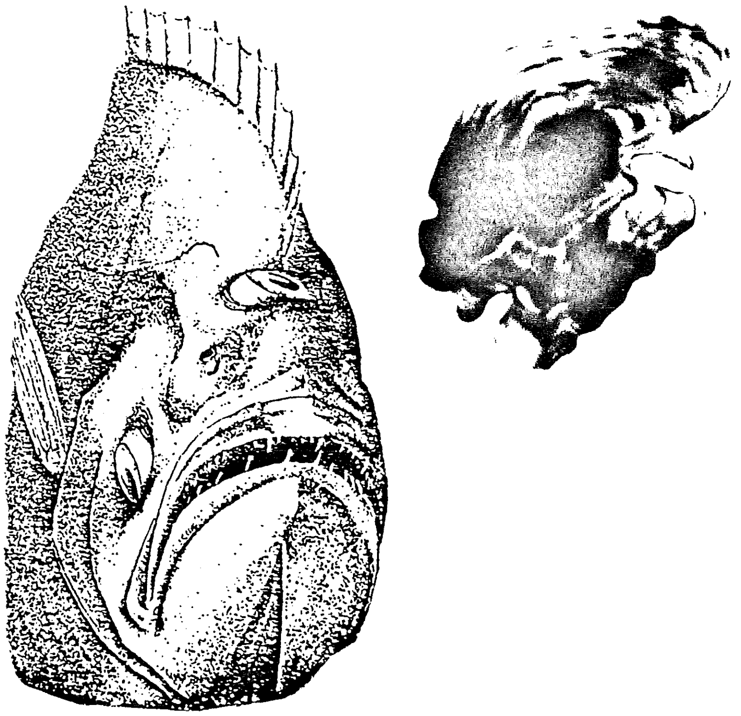
REPORT OF THE
ICES/NAFO WORKSHOP ON GREENLAND HALIBUT AGE DETERMINATION

Reykjavik, Iceland

26 - 29 November 1996



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1.1 Participants

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1.2 Terms of reference

In the 83rd Statutory Meeting of ICES in 1995 it was decided that:

2:37 A Joint ICES/NAFO Workshop on Greenland halibut age reading (Chairmen: K. Nedreaas, Norway, and W.R. Bowering, Canada) will meet in Reykjavik, Iceland from 26-29 November 1996 to:

a) intercalibrate the age reading and age determination methodology of Greenland halibut and describe a protocol for handling Greenland halibut otoliths;

b) evaluate research from comparative age determinations and evaluate results using the methods described by the Working Group on Sampling Strategies for Age and Maturity;

c) establish a protocol for the age determination of otoliths using diagrams and photographs to illustrate age reading criteria;

d) establish a Greenland halibut otolith exchange programme on a regular basis between laboratories involved;

e) in the light of the Workshop results, identify new research and action needed to improve the consistency of age reading.»

1.3 Importance of Age Determination

Most mathematical models used in modern fish stock assessment for the purpose of providing scientific advice to fisheries managers are age based models. Therefore, any errors in age determinations of fish samples introduced to these models will also create errors in the assessment results of the respective fish stocks for which management advice is being developed. The implications can be serious with respect to the fishing industry regarding possible assignment of incorrect catch quotas and other management measures advised from the results of the assessment. In addition, the well being of the fish resources can also be detrimentally affected especially if assigned quotas are inadvertently set too high as a result of these errors.

Besides the importance to fish stock assessment models per se, it must be recognized that the study of biological parameters such as growth rates and maturity rates are very much related to precise knowledge of age structure in order to properly understand the dynamics of commercial fish populations. Results of these studies also play an instrumental role in the formation of appropriate scientific advice used for fisheries management.

1.4 General Biology

1.4.1 Distribution

Greenland halibut *(Reinhardtius hippoglossoides)* are distributed throughout the North Atlantic (Nizovtsev 1970; Sigurdsson 1977, 1980, 1981; Godø and Haug 1987; Bowering and Brodie 1995) in depths up to at least 2200 m (Boje and Hareide 1993; de Cardenas *et al.* 1996) and are known to exhibit extensive migrations (Sigurdsson 1981; Bowering 1984; Godø and Haug 1987). Because the continental slope is rather continuous at such depths from western to eastern Atlantic, Greenland halibut distribution is more or less continuous along the continental slope. Recent mtDNA studies have also concluded that Greenland halibut throughout the entire North Atlantic are genetically homogeneous which is consistent with known depth distribution and migratory patterns. Any variation in phenotypic characteristics within the species is therefore considered to be a result of the environmental influence of the area in which individual fish live (Vis *et al.* 1997). The species comprises a significant commercial groundfish resource in the North Atlantic. In order to regulate fishing, the Greenland halibut population is managed according to six separate management units as follows: 1 - Gulf of St. Lawrence (NAFO Divisions 4RST, 2 - Labrador to Flemish Cap (NAFO Sub-area 2 and Divisions 3KLMNO), 3 - Davis Strait (NAFO Sub-area 0 and Divisions 1B-1F), 4 - Northwest Greenland inshore (NAFO Division 1A), 5 - East Greenland-Iceland-Faroe Islands (ICES Sub-areas V and XIV) and 6 - Northeast Arctic (ICES Regions I and II).

1.4.2 Spawning

In the northwest Atlantic the main spawning area is located in the deep waters (at least 600-1000 m) of Davis Strait (Bowering and Chumakov 1989) although recent investigations have indicated that some spawning occurs all along the continental slope of eastern Canada to as far south as the Flemish Cap (Junquera and Zamarro 1994; Morgan and Bowering 1997). Some localized spawning also takes place in the Gulf of St. Lawrence (Bowering 1982) and possibly in some West Greenland fjords although the extent to which it occurs there is not entirely clear (Riget and Boje 1989). Time of spawning is highly variable and has been observed from December to August (Jensen 1935; Smidt 1969; Junquera and Zamarro 1994; Morgan and Bowering 1997). However, most spawning likely takes place during winter and may not occur on an annual basis for all Greenland halibut that have reached maturity (Fedorov 1971).

In the Iceland area spawning usually occurs in winter northwest Iceland most likely along the continental slope of east Greenland at depths to 1000 m (Sigurdsson 1977). From 0-Group surveys conducted during 1970-79, young of the year Greenland halibut were caught throughout the Irminger Sea from western Iceland to the southern tip of Greenland with the higher catches taken on the east Greenland continental shelf (Sigurdsson 1980). During spring it is reported that most post-spawning fish begin a feeding migration to the north and northeast of Iceland where they encounter a rich food source of shrimp (Nizovtsev 1970). Some fish migrate as far as to the southeast of Iceland. It is further reported that by September the main feeding migration is over and from September to December the return migration to western Iceland takes place for spawning.

According to Godø and Haug (1987) the Greenland halibut in the northeast Atlantic area of the Barents and Norwegian seas spawn mainly during winter along the continental slope from as far south as Traena Bank (66^0 - 67^0 N) northward to 76^0 N off southwestern Spitsbergen. They found that there was a relatively high proportion of small fish north of 76^0 N and this may indicate a nursery area although they also attributed the heterogeneity in size composition in part to a southern migration of larger fish.

1.4.3 Maturity

Proportions of Greenland halibut mature-at-length from the northwest Atlantic are subject to large spatial and temporal variation. Proportions mature-at-age also exhibited inconsistency with the age at 50% maturity ranging from 9.5 to 15.0 years for females and 8.2 to 11.6 years for males (Morgan and Bowering 1997). These authors observed that there were no apparent trends in this variation and considered it to be likely a result of irregularities in the maturation process and spawning of Greenland halibut leading to variability in the distribution of adult fish.

Very little data are readily available on size and age at maturity for the Iceland-East Greenland and northeast Arctic areas. However, data used in the assessment of the Greenland halibut stock in Iceland-East Greenland indicate they reached 50% maturity most often between 9 and 10 years old (sexes combined) since the early 1980's. On the other hand, the estimated age at 50% maturity in 1995 was considerably younger at 7-8 years old (Anon. 1996a). Data from the assessment of the Northeast Arctic Greenland halibut stock (Anon. 1995a) show that males mature at a much younger age than females. Data collected during the 1970's and early 1980's suggest that 50% of males are mature at about 5 years old whereas females reach 50% maturity between 9 and 10 years old. The most recent information from Russian surveys in the Barents Sea (1993-95) show that 50% maturity was reached at about 6 years old for sexes combined.

1.4.4 Age and Growth

Based on age and growth studies of Greenland halibut in the northwest Atlantic as an example, it is believed that they can live to at least 18 years old and are common up to a length of 110 cm (Smidt 1969; Bowering 1978, 1983; Boje and Jørgensen 1991). However, males have a considerably shorter life span than females with very few males encountered beyond age 12 or a length of about 65 cm. These studies also suggest that while there appears to be some divergence of the growth rate between males and females at about the age range of 8-10 years old, it is not significant, likely a result of there being few males available beyond this age. The only comparison in the literature of growth rates of Greenland halibut in the North Atlantic is in Krzykawski (1976). His results show that Greenland halibut have a faster growth rate overall in the Newfoundland area compared to the Barents Sea and those of the Iceland area are the slowest growing of the three areas examined. It must be noted, however, that this study was based on very limited data and a more detailed investigation is warranted before any firm conclusions can be reached.

1.4.5 Mortality

Due to the considerable difference in the age span between males and females it follows that there is likely to be a concomitant difference in natural mortality. Because there is also a depth distribution trend associated with increasing size (see Bowering and Chumakov 1989) the exploitation pattern of commercial fisheries can have a significant effect on a population with respect to differential fishing mortality between the sexes. If fishing effort is mainly directed in deep water, for example, then the catch can often be entirely of large females likely resulting in high fishing mortality that can cause undesirable repercussions for the spawning stock biomass. On the other hand, very low fishing mortality on mature males can result in losses in yield. Trying to reach an appropriate balance between the two presents both a difficult stock assessment problem and serious implications for fisheries management. For a preliminary evaluation of the problem as it exists in the Flemish Cap fishery in the northwest Atlantic see de Cardenas (1996).

2 AGE VALIDATION

The only otolith age validation studies on Greenland halibut that have been published are in Lear and Pitt (1975) for the Canada Newfoundland area and in Smidt (1969) for the West Greenland area. In both instances, the validation work was largely based on evaluating highly distinctive modes in the length frequency distributions (Petersen technique) of young Greenland halibut in conjunction with age distributions determined from otolith interpretations (Figure 2.1). Interpretation of the first year was of paramount importance in order that the subsequent two to three distinctive modes in the length frequency distributions could be determined as age classes. Establishing the first year was greatly enhanced by knowledge of the early life history stages as studied primarily by Jensen (1935). Information from recent pelagic 0-Group surveys in eastern Newfoundland (Figure 2.2) accompanied by length frequencies of Greenland halibut from shrimp surveys conducted mainly during July from 1979-1987 off Labrador (Figure 2.3) confirmed the validation results of earlier studies. In addition, observations on the formation of the growth zones at the otolith edge suggested that very little growth occurs during the months of February and March then increases significantly in spring (Lear and Pitt 1975) (Figure 2.4). Maximum growth occurred during July and August followed by September and October. Growth in November was about the same as in the spring months.

Larval studies by Jensen (1935) and observations from pelagic surveys indicate that Greenland halibut in the western Atlantic spawn mainly in winter to early spring. They have a lengthy pelagic period and in most instances appear to become demersal in late summer to early fall at a length range of 6-8 cm (Figure 2.5). Similar observations were made from 0-Group survey data in both Icelandic (Table 2.1) and Barents Sea waters (Figure 2.6). According to the data in Smidt (1969), 0-Group Greenland halibut first appeared in commercial shrimp trawler catches in September-October at a mode of about 8 cm. By November-December the by-catch of 0-Group Greenland halibut had greatly increased at a size mode of about 9-10 cm (Figure 2.5). It can be inferred from these data that Greenland halibut caught at lengths of 8-10 cm very late in the year are 0-Group and it follows that those of similar size caught early in the year are definitely 1 year olds. Further examination of the length frequency modes also suggest that Greenland halibut can be expected to grow about 6-8 cm per year on average at least for the first 2-4 years for most areas where data were evaluated (Figures 2.3, 2.5 and 2.7). The range of lengths observed for each age class will vary with the length of the spawning season from which a particular year-class is spawned.

It is important to recognize that the validation work is specific for the years and areas in which the respective data were collected. Nevertheless, the above information should serve as general, if not specific, guidelines for interpreting the first 2-4 age groups of Greenland halibut as determined from otoliths.

3 REVIEW OF THE EXCHANGE PROGRAM PRIOR TO THE WORKSHOP

During the North Western Working Group meeting in May 1995, it was recommended that exchange programs of Greenland halibut otoliths should be continued and extended to reveal differences in the age readings prior to a recommended workshop (Anon. 1995b). Altogether four otolith exchanges and respective analyses were conducted in advance of the workshop as follows:

Exchange no.1 (ISBN 87-90024-08-7):
Greenlandic otoliths read by Greenland (TEKCON), Iceland and Norway.

Exchange no.2 (ISBN 87-90024-09-5):
Norwegian otoliths read by Greenland (TEKCON), Iceland and Norway.

Exchange no.3 (ISBN 87-90024-12-5):
Icelandic otoliths read by Canada (St.John's), Canada (Mont Joli), Greenland (TEKCON), Iceland and Norway.

Exchange no.4 (ISBN 87-90024-14-1):
Canadian otoliths (St.John's) read by Canada (St.John's), Canada (Mont Joli), Greenland (Nuuk), Iceland and Norway.

The Greenland Institute of Natural Resources had otoliths for exchanges nos.1-3 read by a private company in Canada (TEKCON Management Ltd.) while a new age reader was being trained at the institute. The exchanges and analyses were conducted under the direction of Gert Bech, Greenland Institute of Natural Resources, P.O. Box 570, 3900 Nuuk, Greenland, and a report from each of the exchanges is available at the above address. For statistical analyses we refer to the individual reports.

Table 3.1 shows the percent agreement. The overall best agreement between the readers was achieved in the last exchange. This is believed to indicate that regular calibrations among readers will increase precision. The rather unusual deviation between the readings by TEKCON and other laboratories during the third exchange was surprising. It may be a result of possible drift in a reader's interpretation of an otolith when collaboration with other readers is not conducted regularly. In three of the exchanges two Norwegian readers participated to show potential inter-reader bias when using exactly the same method. An average of the agreements between the two Norwegian readers was used when comparing with other laboratories. In the last exchange the average agreement between Norway and the other laboratories was 37%, between Iceland and the others 36%, between Greenland and the others 40%, between St.John's and the other 34%, and between Mont Joli and the others 34%.

Pairwise comparisons of the readers from the last two exchanges are shown in Appendix 3.

Some relationships among various pairs of readings show clear examples of bias, either over the entire age range or only for certain parts of the age range. Other relationships are more random and non-systematic. For example, the age-bias plot of the two Canadian readers from Mont Joli and St.John's using the same method indicate that the St.John's reader invariably interpreted more annuli for fish younger than about age 6 while the opposite was observed for fish older than 6 years. A similar type of bias occurs between the Norwegian reader and the St.John's reader (using different methods) in all the exchanges but the deviation in direction of bias takes place at about age 9 as opposed to age 6 above.

Appendix 3 illustrates that readers using the same method can also develop biases similar to those using different methods. This may suggest that methodology used for age-determination by otoliths is not the most important factor for increasing precision among readers. Even two readers from the same laboratory demonstrated bias, although to a small but nevertheless significant extent.

There is considerable subjectivity in determining ages from otoliths, which largely explains why reproduction of the age determinations in multiple readings is such a difficult task both within and between readers. An important consideration in achieving agreement between readers could therefore be developing a clear definition of the first annulus. This does not appear to be so difficult in 1-3 year olds, but may cause a systematic bias when reading otoliths from older fish. However, it is more difficult to establish a convention for interpreting older ages, i.e., to tell annuli from checks. Information about date of capture may, however, minimize the differences in interpretation of the otolith edge.

4 AGE READING COMPARISONS DURING THE WORKSHOP

4.1 Experienced readers comparison

Age readers from the three laboratories most experienced in Greenland halibut otolith age determination (St. John's, Canada; Bergen, Norway and Reykjavik, Iceland) met for the three days prior to the workshop to conduct comparative age reading exercises using their respective methodologies. Analyses of the data were carried out during the workshop. Altogether 50 otoliths from 16-72 cm fish were read by the three readers using three different methods. The otoliths were read untreated in transmitted light (the method most familiar to the Norwegian reader), untreated in reflected light (method most familiar to the Canadian reader) and finally baked using reflected light (method most familiar to the Icelandic reader). Since the main purpose of the exercise was to compare methods, the otoliths were read without information on fish length and only otoliths from fish caught in spring were used.

Percent agreement

Pairwise comparisons of the age readings using the same method were conducted. Pairwise comparisons using the **TLNT-method** (transmitted light, no treatment) indicated percent agreements of 33, 34 and 19% for Norway/Iceland, Norway/Canada and Iceland/Canada, respectively (Table 4.1). The respective percent agreements were 20, 32 and 22% using the **RLNT-method** (reflected light, no treatment), and 36, 33 and 35% for the **RLBA-method** (reflected light, baked otoliths).

Percent agreements +/- 1 year were in the range of 60-83% when using the **TLNT-method,** 56-64% when using the **RLNT-method** and 75-81% when using the **RLBA-method**.

Percent agreements were generally higher for ages below 6 years. For the **TLNT-method** the percent agreement between two readers for ages below 6 years varied from 20-57% and 14-36% for fish of age 6 years and older. Percentage agreement using the **RLNT-method** were in the range of 24-50% and 18-22% and for the **RLBA-method** were in the range of 50-65% and 13-27% agreement for ages less than 6 years and 6 years and older, respectively.

It can be concluded from these results that a certain improvement in precision was achieved when baking the otoliths before reading them in reflected light.

Inter-reader bias tests

Inter-reader bias plots together with Bowker's symmetry test were made according to Anon. 1994. The plots are shown for each pairwise comparison of the three readers for each method in Figures 4.1 - 4.3.

Using the **TLNT-method**, the Bowker's symmetry-test revealed inter-reader bias between Iceland and Canada ($p<0.05$) which also is seen from the plot (Figure 4.1). The slope of the regression line was 0.93, the intercept was significantly different from 0 (H0: intercept=0, $p=0.004$), and 78% of the variation was explained by the regression ($r^2=0.78$).

Comparing Norway and Canada, Bowker's symmetry-test revealed no significant inter-reader bias ($p>0.05$). The slope of the regression line was 1.08 and the intercept was not significantly different from 0 (H0: intercept=0, $p=0.21$). The regression explained 80% of the variation ($r^2=0.80$). Figure 4.1 shows, however, a tendency for the Norwegian reader to read higher ages for fish which Canada aged 5-9 years.

Comparing Norway and Iceland, Bowker's symmetry-test revealed no significant inter-reader bias ($p>0.05$). The slope of the regression line was 1.04, the intercept was not significantly different from 0 ($p=0.54$), and 87% of the variation was explained by the regression ($r^2=0.87$). Figure 4.1 shows, however, that the Icelandic reader read higher ages on the younger fish and lower ages on the older fish compared with the Norwegian reader.

Using the **RLNT-method**, the Bowker's symmetry-test revealed also inter-reader bias between Iceland and Canada ($p<0.05$) which is seen clearly from the plot (Figure 4.2). The slope of the regression line was 1.01, and the intercept was not significantly different from 0 (H0: intercept=0, $p=0.06$). However, only 66% of the variation could be explained by thc regression ($r^2=0.66$).

Comparing Norway and Canada, Bowker's symmetry-test revealed no significant inter-reader bias ($p>0.05$). The slope of the regression line was 0.94, and the intercept was not significantly different from 0 (H0: intercept=0, $p=0.17$). The regression explained 71% of the variation in the data ($r^2=0.71$).

Comparing Norway and Iceland, Bowker's symmetry-test revealed no significant inter-reader bias ($p>0.05$). The slope of the regression line was only 0.71, but the intercept was not significantly different from 0 ($p=0.14$). Only 57% of the variation in the data was explained by the regression ($r^2=0.57$). Figure 4.2 shows especially one striking outlier which was aged 6 and 17 years by Norway and Iceland, respectively.

Using the **RLBA-method**, the Bowker's symmetry-test revealed no inter-reader bias between Iceland and Canada ($p>0.05$) although Iceland in many cases interpreted the otoliths to be much older (Figure 4.3). The slope of the regression line was 0.96 and the intercept was significantly different from 0 (H0: intercept=0, $p=0.03$) although the readers agreed on the interpretation of 1 and 2 year olds. The regression explained 85% of the variation in the data ($r^2=0.85$).

Comparing Norway and Canada, Bowker's symmetry-test revealed no significant inter-reader bias ($p>0.05$). The slope of the regression line was 0.94, and the intercept was not significantly different from 0 (H0: intercept=0, $p=0.17$). The regression explained 85% of the variation in the data ($r^2=0.85$).

Comparing Norway and Iceland, Bowker's symmetry-test revealed no significant inter-reader bias ($p>0.05$). The slope of the regression line was 0.95, and the intercept was not significantly different from 0 ($p=0.92$). The regression explained 87% of the variation in the data ($r^2=0.87$).

The **RLBA-method** was the only one of the three methods investigated where none of the reader comparisons showed any significant deviance from symmetry. The coefficients of determination (r^2) were also generally higher for this method, although the intercept for the regression between the Icelandic and Canadian readers was different from 0.

Residual plots with regression lines

Differences in age readings were plotted against length of the fish (Figure 4.4). However, Figure 4.4 shows variation in the residuals by length. The size of the residuals may differ with regard to the length of the fish and the regression lines also reveal trends in the residuals over the length range.

The transmitted light-no treatment method (**TLNT**) shows higher residuals with increasing length, and the regression lines show a trend in the mean size of the residuals by fish length.

The reflected light-no treatment method (**RLNT**) shows overall higher residuals among readers although the magnitude of the residuals appear to be independent of fish length compared with the **TLNT-method**. Nevertheless, there is a trend in the residuals over the length range of the fish. An outlier of -11 between the Norwegian and the Icelandic reader for a 68 cm fish is not shown in the figure nor in the regression due to the figure scaling.

The reflected light-baked method (**RLBA**) shows overall lower residuals, although there is a slight increase in the residuals with increasing fish length. The regression lines are, however, more flat and close to the zero-line compared to the other two methods.

Comparison of three readers by method

Figure 4.5 shows age-length regressions of the three readers' age interpretations by method. The regression lines among readers are closer to each other for the **RLBA-method**, suggesting a slightly better agreement between the readers. Using the **RLBA-method** there was complete agreement in age interpretation among readers for all fish less than 30 cm.

Comparison of all three methods for each reader

Figure 4.6 illustrates the level of internal consistency for each reader when reading the same otoliths using three different methods. From the regression lines it can be seen, as an example, that Norway would age a 80 cm fish to 13-14 years, Iceland 13-15 years and Canada 11-13 years dependent on method used.

Comparison of the three readers each using their most familiar method

Figure 4.7 compares the age-length regressions for each reader using his or her most familiar method. There is a relatively good agreement for fish less than 30 cm. Canada's readings result in a slightly higher growth rate of Greenland halibut for the samples used compared to Norway and Iceland.

4.2 Other comparisons

In order to facilitate discussion and comparisons among all readers participating at the workshop, several reading exercises were conducted. Due to the time constraints of the workshop and the relatively large number of participants, the sample sizes for comparative readings were necessarily kept small and therefore any statistical comparisons were not considered useful and were not done. The participants' experience in otolith age reading of Greenland halibut ranged from no experience to a maximum of about 6 years.

Exercise 1. Age reading of juvenile (8-23 cm) fish vs. age validation

The results from this exercise are shown in Table 4.2. The main objective was to discuss and then define the first annulus taking into account the sampling date and the growth at the edge of the otolith. The readers used the reading method most familiar to them prior to the workshop. Information on fish length and sampling date were provided to make it possible for the reader to include independent information about growth in the age determination (see Section 2). When all otoliths had been read once, the readers discussed each otolith collectively by viewing it on a video monitor. In many cases readers changed their previous age interpretation as a result of the discussion with others. The readers disagreed in only a few of the otoliths.

Exercise 2. Age reading of juvenile (11-25 cm) fish using baked otoliths

Otoliths from ten juvenile fish were baked in an oven at approximately 190 °C for 2.5 hours to investigate whether this preparation technique increased the precision among the readers. Although the differences were small, no clear improvement could be seen when compared to the exercise conducted above. The results are shown in table 4.3.

Exercise 3. Age reading of adult (45-76 cm) fish using baked otoliths

Otoliths from fifteen adult fish were baked and read knowing the respective fish lengths in advance (Table 4.4). This sample was used for investigating the precision among readers when reading baked otoliths from older fish. It was then used as basis for discussion with respect to the growth at the edge. Differences in age determination between readings of the same fish varied from 0 to 5 years among readers, however, a maximum of +/- 2 years was more the case among the most experienced readers.

Exercise 4. Comparing untreated and baked otoliths from adult (44-74 cm) fish

The purpose of the last exercise was to compare the age readings of the same adult fish before and after baking the otoliths. Only information about sampling date was given in advance. The results which are given in Table 4.5 show that the modes of the two age readings were fairly similar. Although no clear improvement could be seen, the range of ages assigned to each otolith by the readers was reduced after the otoliths had being baked, except for the oldest three fish.

It was concluded by the workshop that different interpretations of the otolith edge may cause systematic bias due to different practices in utilizing information with respect to date of capture.

5 PROTOCOL FOR AGE DETERMINATION OF GREENLAND HALIBUT OTOLITHS

The various techniques used currently by the different laboratories represented at the workshop were reviewed and are summarized for presentation in Tables 5.1-5.3. Examples of Greenland halibut otoliths are shown as illustrations in Figure 5.1.

5.1 Standardized terminology

The workshop agreed that the following terminology be used for consistency among Greenland halibut otolith age readers:

Based on recent international work (Secor *et al.* 1995, Anon. 1996b) that has taken place in order to standardize, as much as possible, the terminology used during otolith interpretation, it is recommended that the following definitions be used when making reference to Greenland halibut otoliths and interpretation of their ages:

- **Accuracy:** The closeness of a measured or computed value (e.g. age) to its true value. Accuracy can be proven or estimated: estimates of accuracy are less valuable, but in some cases only an estimate is possible.

- **Age estimation, age determination:** These terms are preferred when discussing the process of assigning ages to fish. The term aging should not be used as it refers to time-related processes and the alteration of an organism's composition, structure, and function over time.

- **Age-group:** The group of fish that has a given age (e.g., the 5-year-old age-group). The term is not synonymous with year-class.

- **Annulus (pl. annuli):** (Winter zone) A translucent growth zone that forms once a year representing a time of slower growth. For Greenland halibut populations the annulus is generally formed during the fall and winter months.

- **Annual growth zone:** A growth zone that consists of one opaque zone (summer zone) and one annulus (winter zone).

- **Bias:** A lack of precision that is not normally distributed around the mean; it is skewed to one side or the other. For age reading it may apply to one reader's interpretations which are predominantly more or less than those of another for all ages; or it may only apply to a portion of the age range.

- **Birth date:** Based on the internationally accepted standard all Greenland halibut are assumed to have a birth date of January 1.

- **Check:** Translucent zone that forms within the opaque (summer) zone representing a slowing of growth. Such a zone is not usually as prominent as annuli and should not be included in the age estimate.

- **Cohort:** A group of fish that were born during the same year (Jan. 1 - Dec. 31).

- **Edge (marginal) growth:** The amount and type of growth (opaque or translucent) on an otolith`s margin or edge. The amount and type of growth on the edge must be related to the time of year the fish was caught and the internationally accepted and standard January 1st birthday. New opaque growth forming on the margin of the otolith is often referred to as plus growth or incremental growth.

- **Nucleus:** The central area of the otolith formed during the larval stage.

- **Opaque zone:** (Summer zone) A growth zone that restricts the passage of light. In untreated otoliths under transmitted light, the opaque zone appears dark. Under reflected light it appears bright.

- **Precision:** A process that measures the closeness of repeated independent age estimates. Precision relates to reproducibility and is not a measure of accuracy. The degree of agreement among readers is a measure of the precision of the determinations and not the accuracy of the technique.

- **Reflected light:** Light that shines onto the surface of an otolith from above, or from the side if the surface is not shadowed.

- **Sagitta (pl. sagittae):** The largest of three otolith pairs found in Greenland halibut. It is usually compressed laterally and is elliptical in shape. The sagitta is the otolith used most frequently in otolith studies.

- **Summer zone:** Opaque growth that is normally deposited during the spring and summer seasons when fish are growing relatively quickly.

- **Transition zone:** A region of change in an otolith growth pattern between two similar or dissimilar regions. It is recognized as a region of significant change in the form (e.g., width or clarity) of the annual growth zones. A transition zone is often defined as the region of change from juvenile to mature growth. The juvenile annual growth zones are relatively larger than those of later adult zones. For some fishes this transition zone has been validated as coinciding with the onset of first maturity. In some instances otoliths may also show a change in width and clarity of the annual growth zones which may be related to habitat changes (e.g., movement to deeper waters).

- **Translucent zone:** (Hyaline zone, annulus, check) A growth zone that allows a better passage of light. The definition of the term hyaline has often been misunderstood and is not recommended for use. In untreated otoliths under transmitted light, the translucent zone appears bright. Under reflected light it appears dark.

- **Transmitted light:** Light that is passed through the otolith from below (e.g., sections); for broken otoliths is also from the side if the surface is shadowed.

- **Validation:** The process of estimating the accuracy of an age estimation method, etc.

- **Winter zone:** Translucent growth (annulus; not check) that is normally deposited during the fall and winter seasons when fish are growing relatively slowly.

- **Year-class:** The cohort of fish that were born in a given year (Jan. 1 - Dec. 31) (e.g., the 1990 year-class).

- **Zone:** Region of similar structure or optical density (opaque or translucent). Synonymous with ring, band, and mark. The term zone is preferred.

5.2 Sampling and Storing

There were a variety of sampling methods and storing procedures presented to the workshop (see Table 5.1). It was concluded, however, that there did not appear to be any that were considered superior enough to warrant recommending standardization among laboratories recognizing the logistical difficulties that significant changes may pose to some. Nevertheless, it was noted that probability of increased damage may be higher for those stored in paper envelopes and an extra degree of caution should be exercised. There was also some concern that otoliths stored in glycerin solutions may cause long term damage to the clarity of the annuli although this could not be proven conclusively at this time. It was proposed that further investigation in this matter be undertaken.

5.3 Preparation Techniques

A number of techniques used in preparing otoliths for age reading were examined by the workshop and are summarized in Table 5.2. After some debate it was considered that most of the techniques used were largely a matter of personal preference and there were no apparent influences on the precision among readers of the various techniques. Therefore, readers should continue to use the techniques with which they are most comfortable but should experiment with small changes, for example, varying otolith immersion medium among alcohol, immersion oil, glycerin mixtures, etc. Notwithstanding the lack of overall increased precision, many readers did feel that baking the otoliths did increase the resolution between the translucent and opaque zones. It was proposed that this method be the subject of further experimentation.

5.4 Reading Procedure

A summary of current reading practices by the laboratories of the respective participants are presented in Table 5.3.

5.4.1 Reflected versus transmitted light

Most readers used reflected light although some readers used mainly transmitted light. Readers normally using reflected light found it more difficult to become accustomed to transmitted light as they found that transmitted light highlighted the very small check rings more succinctly, making the interpretation of the annuli more difficult. This was even more exaggerated on otoliths that had been baked. On the other hand, the readers normally using transmitted light adjusted to the reflected light method much more easily during the course of the workshop exercises. It was concluded that either method was acceptable if readers felt more comfortable with one more than the other except when reading otoliths that had been baked. It was agreed that reflected light should be used when reading otoliths that had been baked.

5.4.2 Counting axes and magnification

Most readers found the convex side of the left sagital otolith to be more suitable for interpreting the age of Greenland halibut. The reading axis used mostly was somewhere within the widest half of the otolith 's longitudinal axis. While this was the most common approach, all readers when finding difficulty in assigning an age, often used both otoliths in their entirety to assist in interpretation and in some cases used the concave surface to examine the edge. In light of the difficulties encountered in reading Greenland halibut otoliths, the workshop could find no better alternative than this procedure already being used and proposes that it be continued. It was also indicated that all readers each used a fixed magnification between 10-16X. It was agreed that using an individual fixed magnification was appropriate as it maintained a constant perception of where the annuli of particularly the younger years are located. It was also noted that it is acceptable to increase magnification on some large thick otoliths to get some better idea of the zonal formation near the edge, however, magnification should be returned to normal before a final decision on age interpretation is taken.

5.4.3 Determination of the first annulus

The correct interpretation of the first annulus is one of the more critical features of precise aging of Greenland halibut. To assist in this the reader should have otoliths of known age juveniles as determined using the age validation procedures described earlier (see Section 2). Using these otoliths, measurements should be taken with an ocular micrometer to establish the extent of the first year's growth. These measurements should then be used as a general guideline for determination of the first year in other otoliths. When making ocular micrometer measurements it is imperative that they be taken at the usual fixed magnification of the reader and along a constant axis to maintain consistency.

5.4.4 Edge (marginal) growth

Correct interpretation of the extent and type of growth at the otolith edge is necessary in order to assign the appropriate age-class. New (plus) growth at the edge must be related to the time of year the fish was caught and the internationally accepted convention of a standard January 1st birthday . Consequently, it is important to have information available to the reader on the size of fish and time of capture of the samples being aged. In addition, the reader should use the edge growth analysis in Lear and Pitt (1975) as a general guideline regarding the time of year when a particular growth zone is more likely to occur as well as its anticipated size. It is recognized, however, that many exceptions will be encountered especially among different regions where validation data have not been available. Therefore, logic combined with considerable discretion must be exercised. Edge growth may be very difficult to interpret on older otoliths at any time of the year as the growth zones are so small. The reader should try to trace the last annulus seen from the axis of preferred reading, around the edge to establish confidence that the growth zone being traced is in fact an annulus and not a check zone.

6 FUTURE EXCHANGES

In accordance with the terms of reference, it was agreed that an otolith exchange program be continued immediately following the workshop. The Marine Research Institute (MRI) in Iceland was given the responsibility for arranging the first exchange including dispatching Icelandic Greenland halibut otoliths (supplemented with East-Greenland otoliths of juvenile fish if necessary) to Nuuk, Greenland. In addition, the MRI will collect and analyse the data from the various participants and report the results to both ICES and NAFO for scientific review. Responsibility for arranging further exchanges, analyzing the data and reporting the results will alternate among the participating laboratories.

The first exchange should consist of 5 baked otolith samples for each 5 cm length group. The otoliths should be baked following the established Icelandic procedure. The samples should be dispatched in secure, dry condition to Greenland no later than the end of December, 1996 including information on fish length and date of capture. Data on round weight, sex and maturity is also desirable where available. The participating laboratories should not treat the otoliths in any manner that may alter their original condition in order to ensure consistency in the appearance of the samples for all readers.

The otoliths should be dispatched to the countries/laboratories and responsible age readers in the following order:

	Country	**Responsible Reader**
0	Reykjavik, Iceland	Hordur Andresson
1	Nuuk, Greenland	Per Otto Larsen
2	Iqaluit/Winnipeg, Canada	Margaret Keast/John Babaluk
3	Mont Joli, Canada	Bernard Morin
4	St.John's, Canada	Brian Greene
5	Lisbon, Portugal	Lourdes Godinho
6	Vigo, Spain	Susana Junquera
7	Bergen, Norway	Anne Sæverud

Each laboratory should send the results (one set of age readings per laboratory) by postal mail to the responsible laboratory, in this case Iceland, immediately after reading. The otolith sample then should be securely re-packaged and sent to the next laboratory on the list above.

7 RECOMMENDATIONS

The Workshop recommends the following research activities in order to facilitate more precision and ensure accuracy of age interpretations of Greenland halibut otoliths among regions of the North Atlantic:

- Age validation

  In order to assist in the proper assignment of the final age of an otolith, the development of growth increments throughout the year at the edge of the otolith should be described <u>for each fishing area</u> in a fashion similar to that reported in Lear and Pitt (1975).

  Validation of the first 1-3 years of growth should be conducted <u>for each fishing area</u> by analyzing modes in length frequency data (Petersen technique) in conjunction with back-calculation of annual growth increments from the otolith. Following known strong year-classes can be especially helpful in this regard.

  Validation is needed for ages older than approximately 3 years and fish larger than about 30 cm in length. Traditional tagging data that contain otoliths, fish size at tagging and recapture and time in sea between tagging and recapture should be analysed. Although traditional tagging data does not give us an exact age when the fish were first tagged, such analyses can be particularly informative if there is a lengthy period between time of tagging and recapture especially if fish were small when tagged (then Petersen technique may be used to give an approximate age). The Workshop was informed that MRI, Iceland has valuable tagging data that may be useful in this respect and recommends that these data be thoroughly examined as early as possible.

  Oxytetracycline marking in conjunction with regular, traditional tagging programs should be encouraged.

- Radionucleotide dating should be further investigated.

- Investigation into determining an optimal storage medium for Greenland halibut otoliths that could enhance the acuity between annuli without long term detrimental effects to the otolith structure.

- Investigation into determining an optimal temperature and treatment time when baking otoliths for age determination purposes.

- As opportunities arise, any intermediate results from the otolith exchanges should be presented both to ICES and NAFO for review and further recommendations for improvements.

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Table 2.1. Length of 0-Group Greenland halibut off East Greenland during 1970-79 from Icelandic 0-Group surveys.

Year	No. Meas.	Length range (mm)	Average length	Time of survey
1970	9	52-69	60.33	August 1-11
1972	133	40-80	60.91	August 2-25
1973	212	23-72	56.06	August 9-29
1974	14	50-66	57.71	July 27-Aug 8
1976	29	27-72	51.83	August 5-29
1978	94	46-80	63.06	Aug 9-Sept 2
1979	109	41-81	67.60	Aug 20-Sept 10

Table 3.1. Percent agreement in each of four advance exchanges of Greenland halibut otoliths.

Laboratories compared	Exchange no. 1	2	3	4
NOR-ICE	25	29	25	41
NOR-SJ			34	36
NOR-MO			32	32
NOR-GRE				39
NOR-TEK	33	30	9	
ICE-SJ			15	29
ICE-MO			15	36
ICE-GRE				39
ICE-TEK	32	29	29	
SJ-MO			46	28
SJ-GRE				43
SJ-TEK			1	
MO-GRE				39
MO-TEK			4	
NOR1-NOR2	57		69	51

NOR - Norway (average reader 1 and 2)
NOR1, NOR2 - Norway reader 1 and 2, respectively
ICE - Iceland
SJ - Canada, St.John's
MO - Canada, Mont Joli
GRE - Greenland (Nuuk)
TEK - TEKCON (Canadian company reading for Greenland)

Table 4.1. Comparison of age estimates for Greenland halibut from three different otolith methods (all ages).

		Percent agreement		
Norway/Iceland	Age difference (years)	Baked, reflected light	Untreated, reflected light	Untreated, transmitted light
	0	36.2	20.0	33.3
	1	80.9	60.0	83.3
	2	97.9	84.4	97.9
	3	97.9	91.1	100.0
	4	100.0	97.8	
	11		100.0	

		Percent agreement		
Norway/Iceland	Age difference (years)	Baked, reflected light	Untreated, reflected light	Untreated, transmitted light
	0	33.3	32.0	34.0
	1	77.1	64.0	64.0
	2	91.7	86.0	78.0
	3	100.0	92.0	96.0
	4		100.0	98.0
	5			100.0

		Percent agreement		
Norway/Iceland	Age difference (years)	Baked, reflected light	Untreated, reflected light	Untreated, transmitted light
	0	35.4	22.2	18.8
	1	75.0	55.6	60.4
	2	91.7	75.6	89.6
	3	97.9	88.9	95.8
	4	100.0	91.1	100.0
	5		95.6	
	6		97.8	
	7		100.0	

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Table 4.2. Age reading of juvenile fish (8-23 cm) using untreated otoliths and both reflected and transmitted light which varied with readers. Otoliths are from Newfoundland and Norway. Number in brackets is the original reading that was changed after a plenary discussion.

#	Length (cm)	Season	Brian	Anne	Bernard	Ricardo	Per	John	Margaret	Ester	Lourdes	Susana	Hordur
1	14	Fall	1	1	1	1	1	1(2)	1(2)	2	1	1	1(2)
2	15	Fall	1	1	1	1	1	1	1	1	1	1	1
3	16	Fall	1	1	1	1	2	1	1	1	1	1	1
4	18	Fall	1	1	2	1	2	2	1(2)	2	1	1	2
5	19	Fall	2	2	2	2(1)	3	1	2	1	1	2(1)	1
6	9	Spring	1(0)	1(0)	1	1	1	1	1	1	1	1	1
7	8	Fall	0	0	0	0	0	0	0	0	0	0	0
8	8	Fall	0	0	0	0	0	0	0	0	0	0	0
9	18	Spring	2	2	2	2	2	2	2(1)	2	2(1)	2	2
10	20	Spring	2	2	2	2(1)	2	2	2	2	2	2(1)	2
11	22	Spring	2	2	2	2	2	2	2	2	2	2	2
12	23	Fall	2	2	2(3)	2	2(3)	2	2	2	2	2	2
13	8	Fall	0	0	0	0	0	0	0	0	0	0	0
14	8	Fall	0	0	0	0	0	0	0	0	0	0	0
15	8	Fall	0	0	0	0	0	0	0	0	0	0	0
16	21	Spring	2	2	3	2	3	2	2	2	2	2	2

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Table 4.3. Age reading of juvenile fish (11-25 cm) using baked otoliths.

#	Length (cm)	Season	Brian	Anne	Bernard	Richardo	Per	Claus	John	Margaret	Ester	Lourdes	Susana	Hordur
1	13	July	2	1	1	1	?	1	1	1		1		
2	14	July	1	1	1	1	1	1	1	1		1		
3	12	July	1	1	1	1	?	?	1	1		1		
4	11	July	1	1	1	1	1	1	1	1		1		
5	15	Aug.	2	2	2	2	2	2	2	2		2		
6	16	Aug.	2	1	2	2	1	2	2	1		2		
7	18	Aug.	1	1	1	1	1	2	2	1		2		
8	20	Aug.	3	2	3	2	2	2	2	2		2		
9	24	Aug.	2	2	3	2	3	3	1 ?	2		3		
10	25	Aug.	2	3	3	1 or 2	3	3	?	2		3		

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Table 4.4. Age reading of baked otoliths from adult fish (45-76 cm) using both reflected and transmitted light which varied with readers. Otoliths are from Iceland.

#	Length (cm)	Season	Brian	Anne	Bernard	Ricardo	Per	Claus	John	Margaret	Ester	Lourdes	Susana	Hordur
1	52	Summer	7	7	7	6	7	7	6	6	8	7	6	7
2	76	Summer	12	13	11	11	12	11	14	12	15	11	11	16
3	59	Summer	9	10	9	7	7	?	8?	8	9	8	7	9
4	50	Summer	6	7	8	5	6	7	5	6	6	6	5	7
5	51	Summer	7	7	7	7	7	6	7	6?	7	6	6	6
6	47	Summer	7	7	7	6	?	6	6	6	6	5	5	7
7	51	Summer	8	8	8	10	7	8	10	9	7	7	7	7
8	45	Summer	6	6	6	6	6	6?	6	6	6	6	6	6
9	56	Summer	9	9	9	8	8	7	8	6	9	8	8	9
10	49	Summer	7	7	8	6	6	7	7	6	6	7	5	6
11	52	Summer	8	8	8	7	7	7	6	6	8	6	6	8
12	53	Summer	7	7	9	6	7	8	9	6	7	5	5	9
13	49	Summer	7	6	7	6	7	6	7	6	7	7	6	8
14	52	Summer	7	7	8	6	7	5	7	7	7	5	5	7
15	65	Summer	10	9	10	8	10	8	12	8	9	8	8	10

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Table 4.5. Age readings of otoliths from adult fish (44-74 cm), first untreated (A) and then baked (B). Otoliths from Greenland

A) Age reading of untreated otoliths.

#	Length (cm)	Season	Brian	Anne	Bernard	Ricardo	Per	Claus	John	Margaret	Ester	Lourdes	Susana	Hordur	Mode
1	44	Aug.	7	5	8	7	7	8	9	6	9	10	10	7	*7*
2	47	Aug.	6	6	8	9	6	10	7	8	5	7	7	8	*6*
3	53	Aug.	6	6	11	7	8	10	7	6	6	9	6	8	*6*
4	56	Aug.	9	9	12	10	7	8	13	8	7?	10	11	8	*8*
5	59	Aug.	10	9	12	9	8	9	8	9	7	10	10	8	*9*
6	64	March	11	10	10	11	11	9	10	12	7	10	10	10	*10*
7	65	March	10	10	12	9	12	12	10	10	9	8	8	10	*10*
8	69	March	12	10	11	11	9	?	10	11	10?	?	?	12	*11*
9	74	Aug.	10	11	11	9	13	12	9	9	8?	11	12	12	*11*
10	70	Aug.	10	10	10	11	12	10	12	10	?	12	?	11	10

B) Age reading of the otoliths in (A) after baking them.

#	Length	Season	Brian	Anne	Bernard	Ricardo	Per	Claus	John	Margaret	Ester	Lourdes	Susana	Hordur	Mode
1	44	Aug.	5	5	7	7	6	6	6	7		7	8	6	*7*
2	47	Aug.	9	8	10	8	7	7	7	7		10	10	7	*7*
3	53	Aug.	8	6	7	7	7	6	7	6		7	7	7	*7*
4	56	Aug.	8	10	9	9	7	8	6	6		9	9	8	*9*
5	59	Aug.	10	10	11	9	7	8	10	9		10	10	10	*10*
6	64	March	11	9	9	9	8	9	9	8		10	10	10	*9*
7	65	March	9	10	10	11	8	10	10	10		10	12	10	*10*
8	69	March	13	11	11	9	10	?	10	10		11	11	10	*11*
9	74	Aug.	10	12	9	9	9	6	8	10		12	12	10	*10*
10	70	Aug.	10	9	9	10	8	7	9	9		10	10	8	*10*
	Light direction		Refl.	Refl.	Refl.	Refl.	Trans.	Trans.	Refl.	Refl.		Refl.	Refl.	Refl.	

Table 5.1. Various techniques currently used by the different laboratories for sampling and storing Greenland halibut otoliths.

Laboratory	Both otoliths are removed	Scales washed in 1-2% ammonium solution	Stored dry	Stored in 50:50 glycerin:thymol solution
Greenland	X		X	
Iceland	X		X	X
Norway	X		X	
Portugal	X		X	
Russia		X	X	
Spain	X		X	
Canada				
Iqaluit	X		X	
Mont Joli	X		X	
St.John's	X		X	
USA				
Seattle	X			X

Table 5.2. Various preparation techniques currently used by the different laboratories.

Laboratory	Soaked in glycerin: thymol (50:50) for at least 48 hours	Soaked in glycerin: alcohol (25:75) for approx. 12 hours	Baking 190°C, 2-3 hours	280°C, 30 min.	Grinding if necessary	No preparation	Scales placed between two microscope slides
Greenland						X	
Iceland	X		X				
Norway						X	
Portugal				X			
Russia							X
Spain		X					
Canada							
Iqaluit					X		
Mont Joli							
St.John's					X		
USA							
Seattle	X						

Table 5.3 Reading procedures currently used by the different laboratories.

Laboratory	Left/ right otolith	Hyaline vs. opaque zones	Light direction	Reading medium	Magnification	Other
Greenland	Both	Opaque	Transmitted	Water	16x	
Iceland	Left	Hyaline	Reflected	Water	10-16x	
Norway	Both	Opaque	Transmitted	Water	16x	
Portugal	Both	Hyaline	Reflected	Oil	8-10x	
Russia						Microphot projector
Spain	Both	Hyaline	Reflected	Glyc:alcohol	10-16x	
Canada						
Iqaluit	Left	Hyaline	Reflected	Water	10x	
Mont Joli	Left	Hyaline	Reflected	Alcohol	10-16x	
St.John's	Both	Hyaline	Reflected	Alcohol	10x	
USA						
Seattle	Both	Hyaline	Reflected	Water	9x	Image analysis

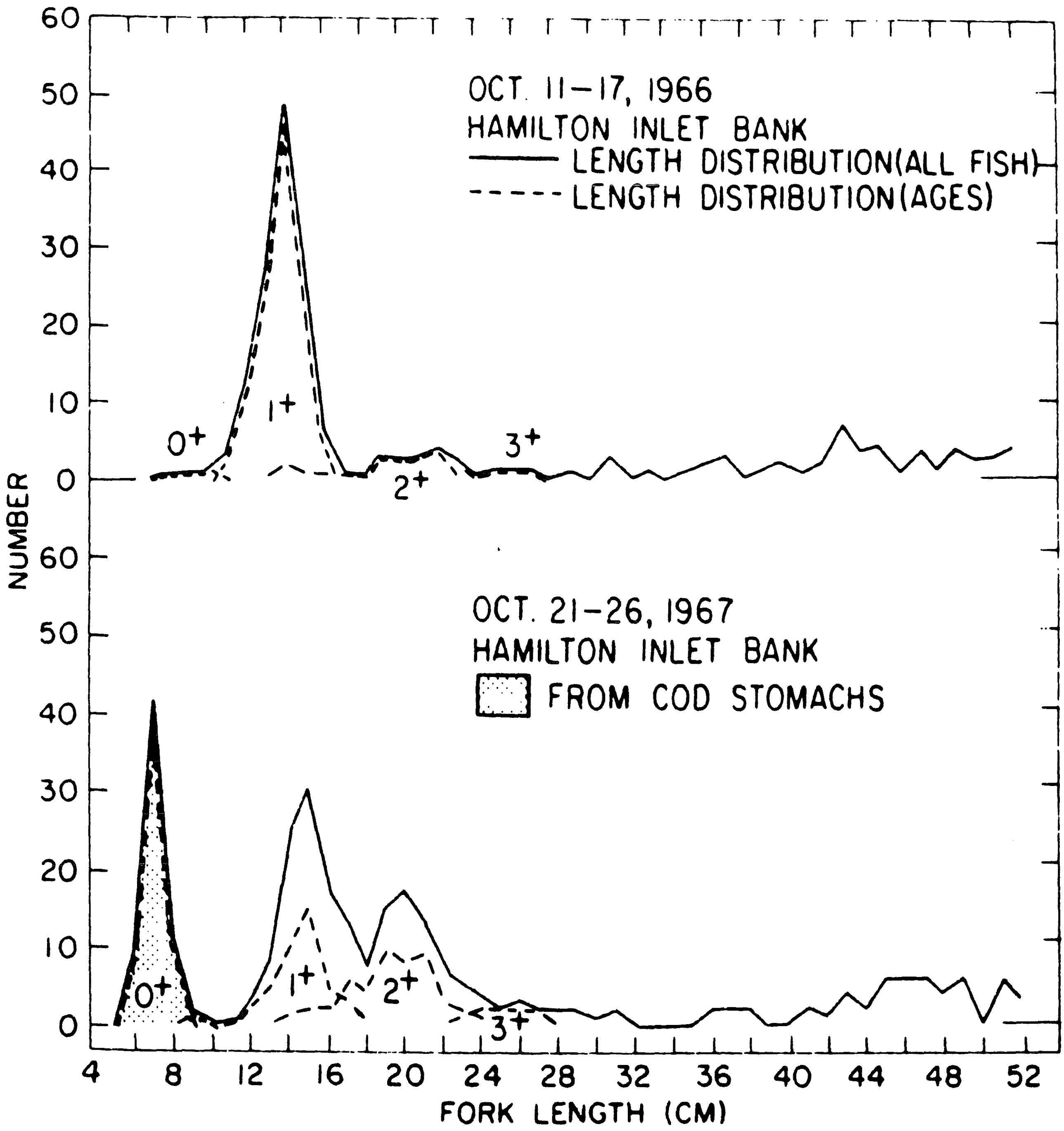


Figure 2.1. Length distributions of otolith age-groups superimposed upon the length distributions of Greenland halibut (*Reinhardtius hippoglossoides*) from Hamilton Inlet Bank during October 11-17, 1966 and October 21-26, 1967. From Lear and Pitt (1975).

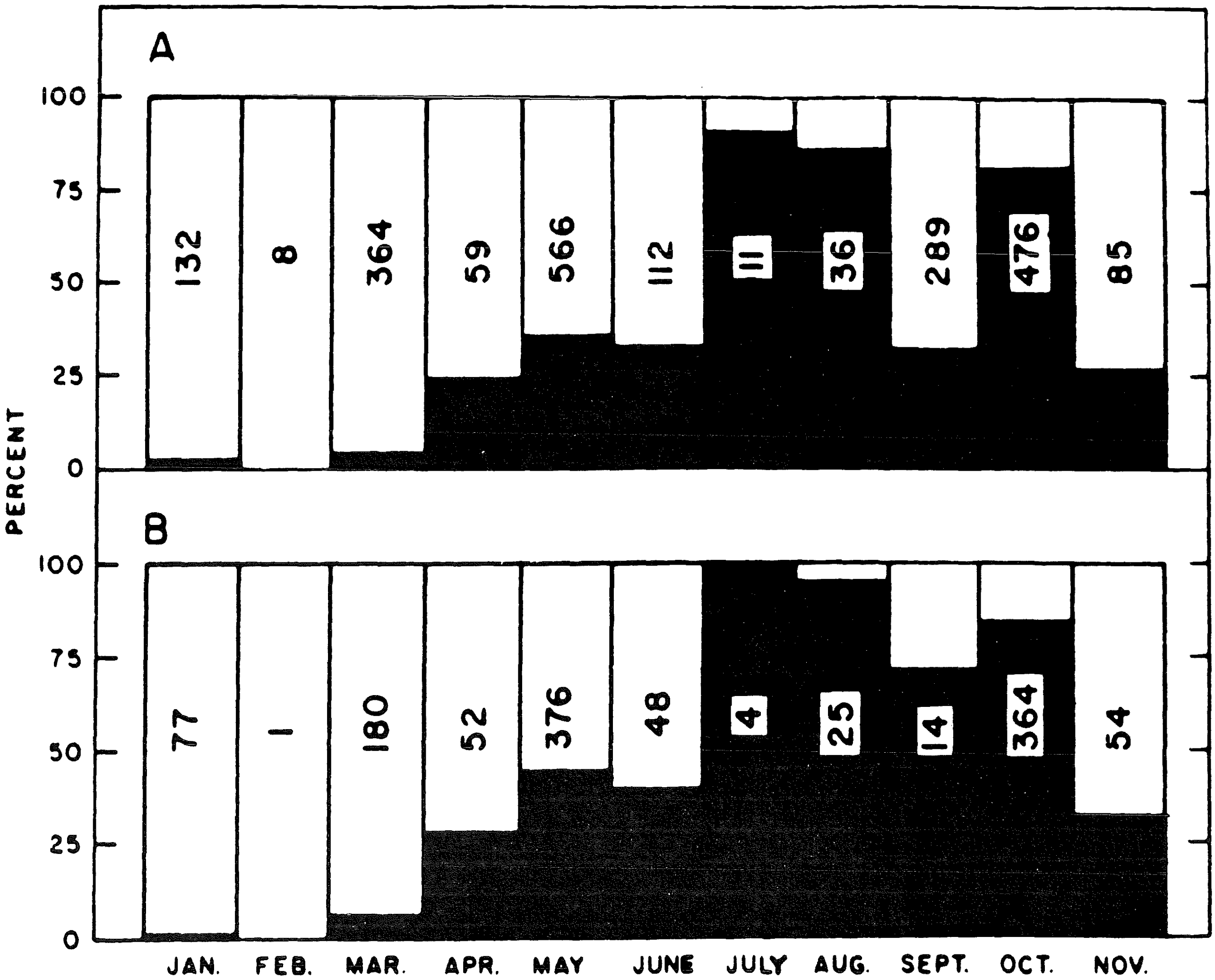


Figure 2.4. Monthly incidence of opaque edge deposits on otoliths from all areas for: A, fish of all ages, and B, fish of age 0+ - 6 years inclusive. Numbers of fish are shown. From Lear and Pitt (1975).

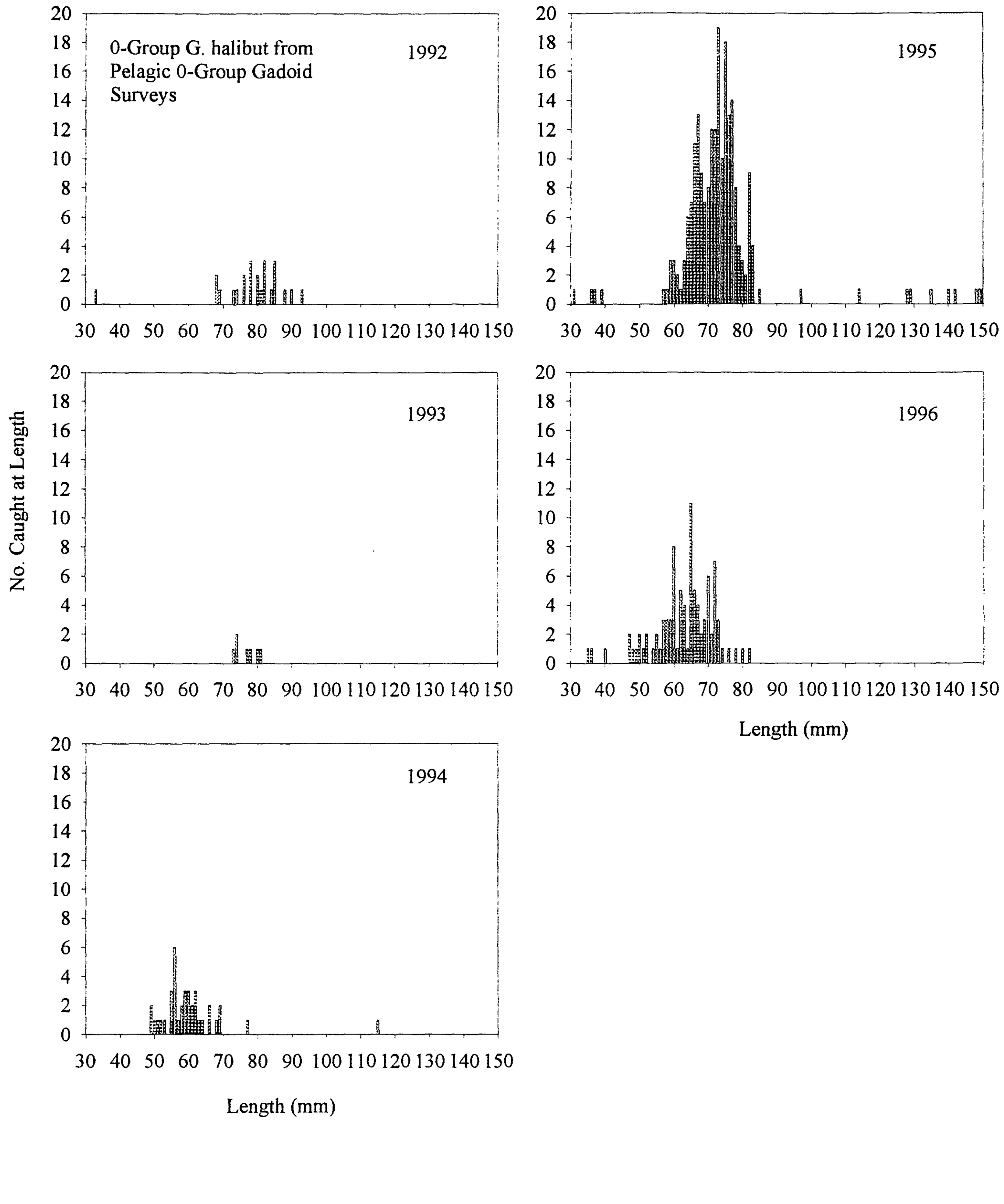


Figure 2.2. Length distributions of 0-group Greenland from Canadian pelagic 0-group gadoid surveys outside eastern Newfoundland in August 1992-1996.

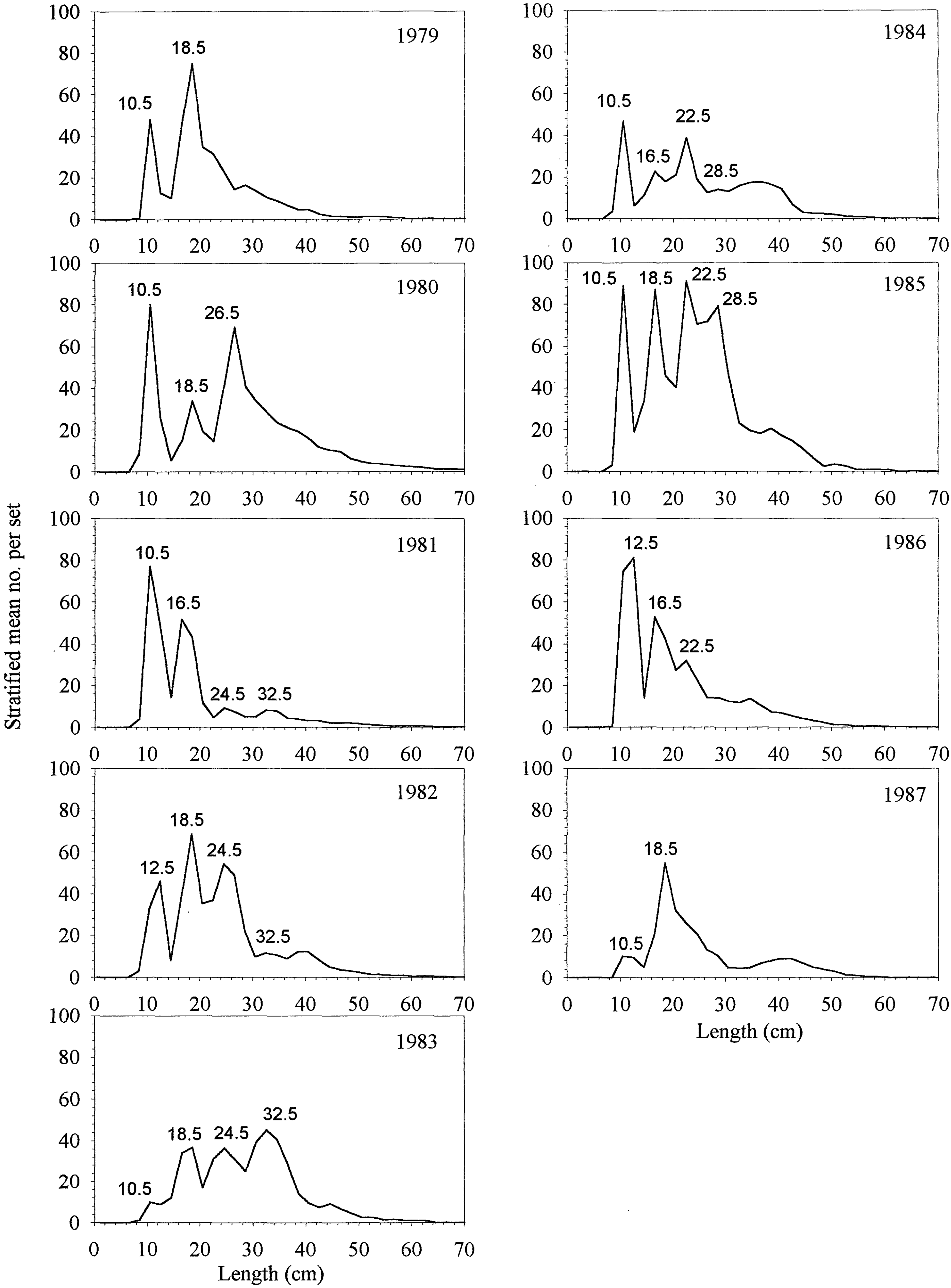


Figure 2.3. Length distributions of Greenland halibut from Canadian shrimp surveys conducted mainly in July off Labrador in 1979-1987.

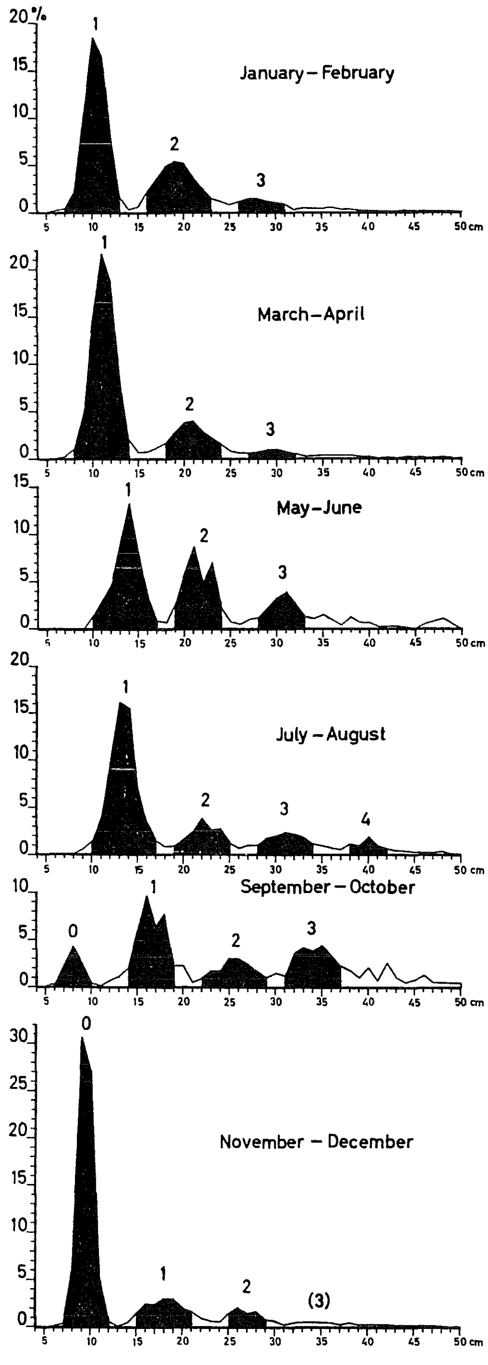


Figure 2.5. Length frequency percentages of fish from shrimp trawl, only fish under 50 cm used. Year-classes indicated by Arabic numerals. Black sections used for calculation of mean lengths of year-classes. Data from nursery ground, coastal area south of Godthåb, (January-February 1954-58, 1960-63; March-April 1954-58, 1960-63; May-June 1956, 1958-61, 1963; July-August 1953-63; September-October 1953, 1955-57, 1960-62; November December 1953-55, 1959-62). From Smidt (1969).

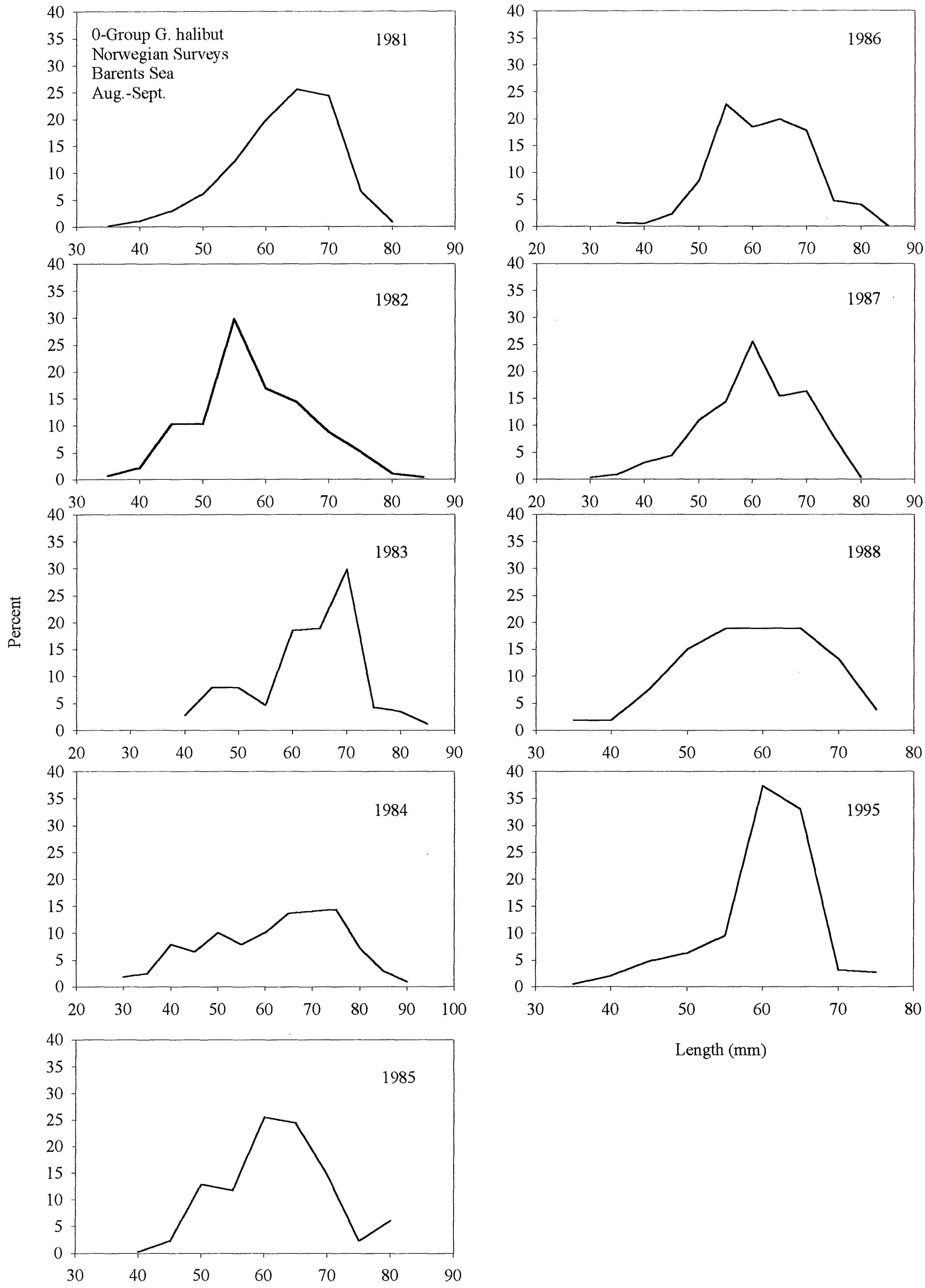
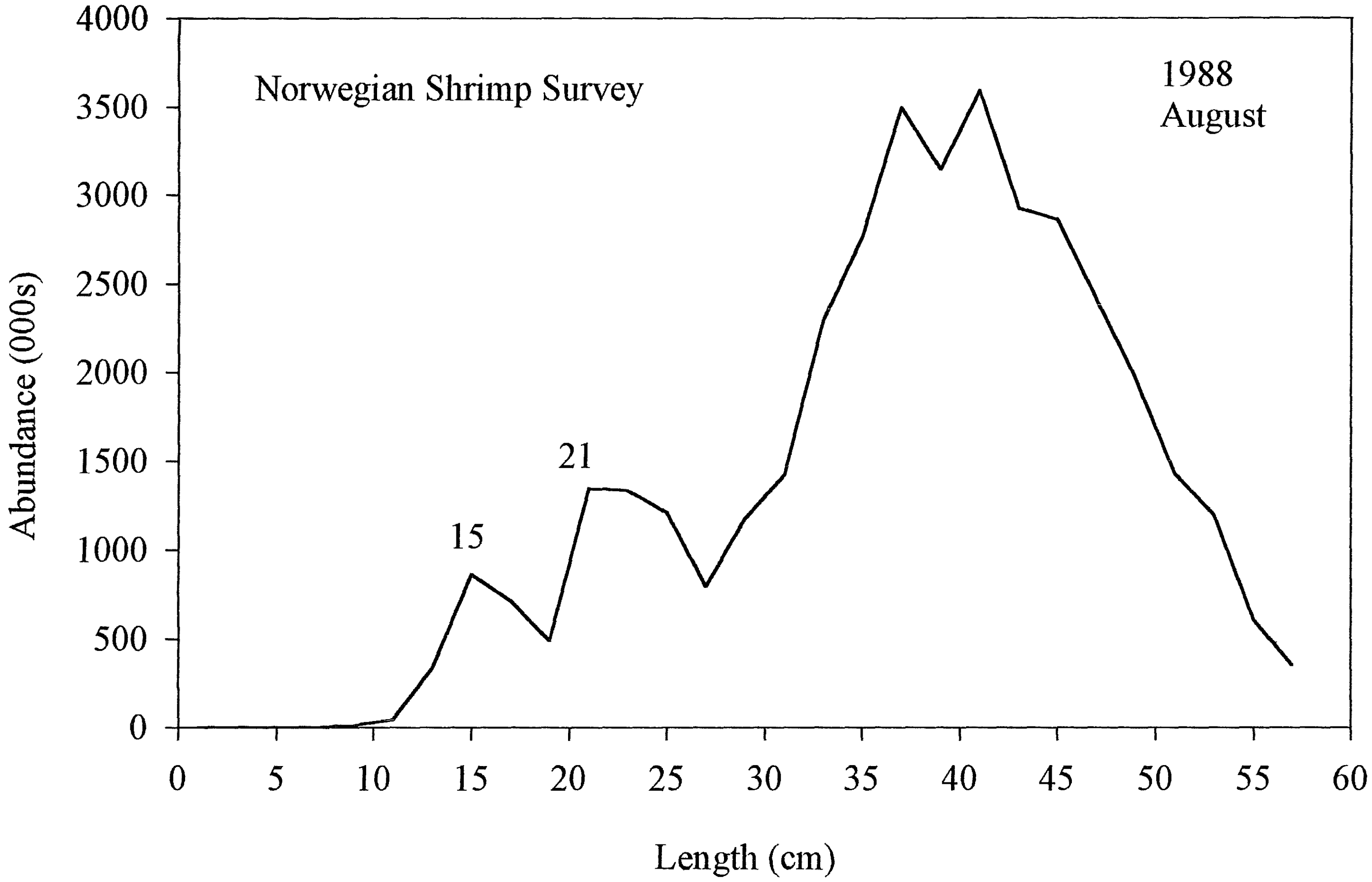


Figure 2.6. Length distributions of 0-group Greenland from joint Norwegian-Russian pelagic 0-group gadoid surveys in the Barents Sea and Svalbard areas in August-September 1981-1988 (i.e., before the recruitment failure) and in 1995 (seem to be a relative good year-class compared to the surrounding ones).



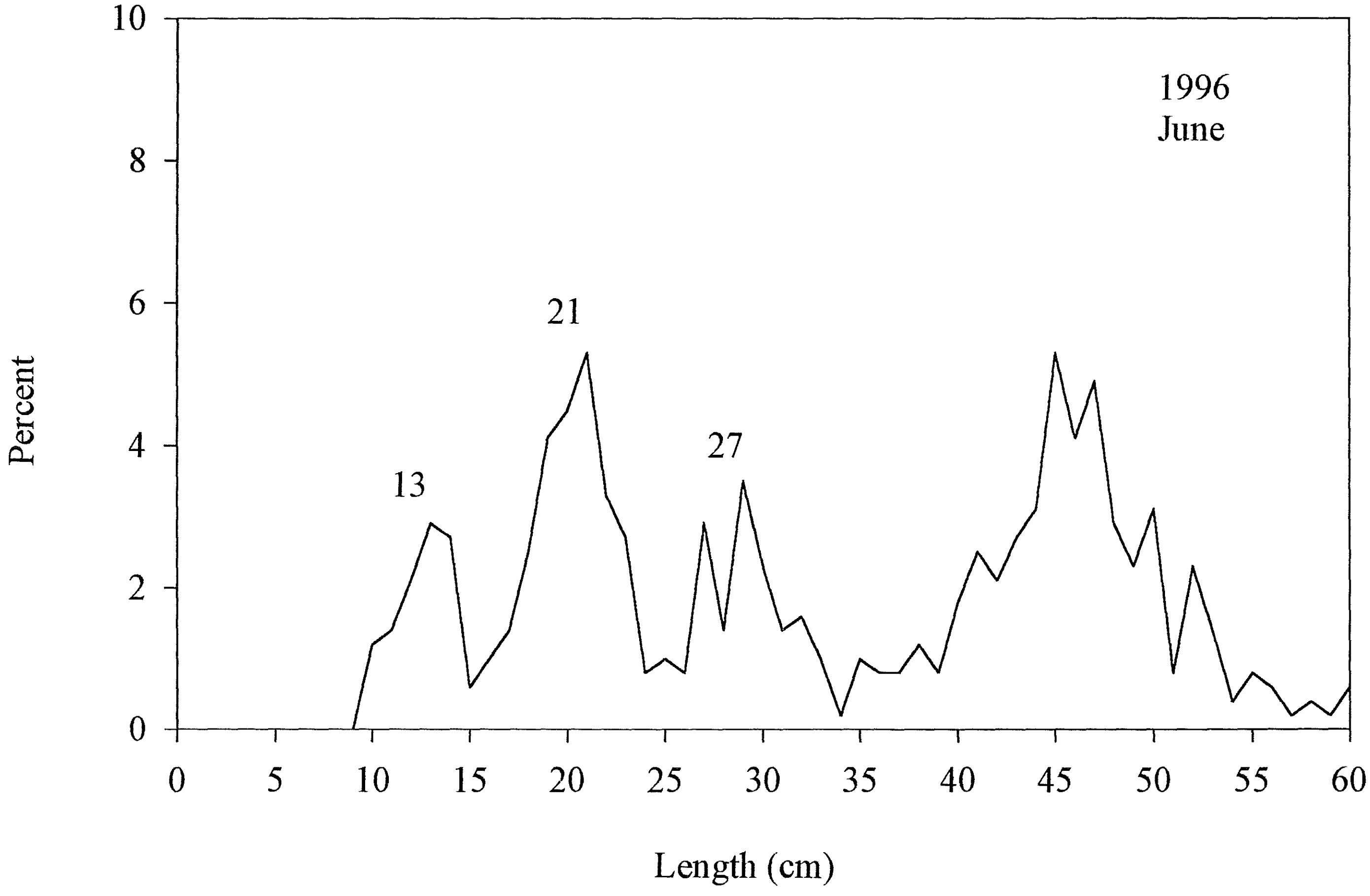


Figure 2.7. Length distributions of Greenland halibut from Norwegian shrimp surveys in the Barents Sea and Svalbard areas in August 1988 (before the recruitment failure) and June 1996 (after a few years with better recruitment). The recruitment in 1989-1993 seem to have been exceptionally poor, and length distributions from this period are therefore not useful for age validation purposes.

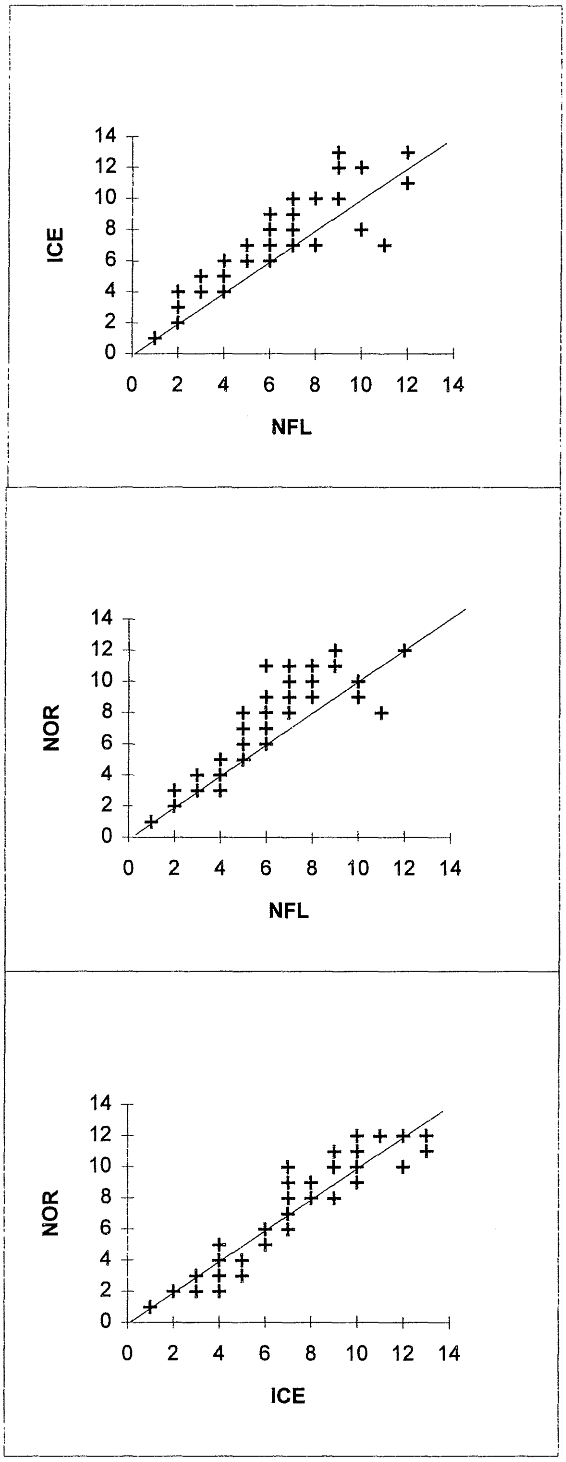


Figure 4.1. Pairwise laboratory comparisons of age readings using untreated otoliths read in transmitted light (TLNT-method). ICE=Iceland, NFL=St.John's and NOR=Norway. Note that some of the crosses may represent more than one fish.

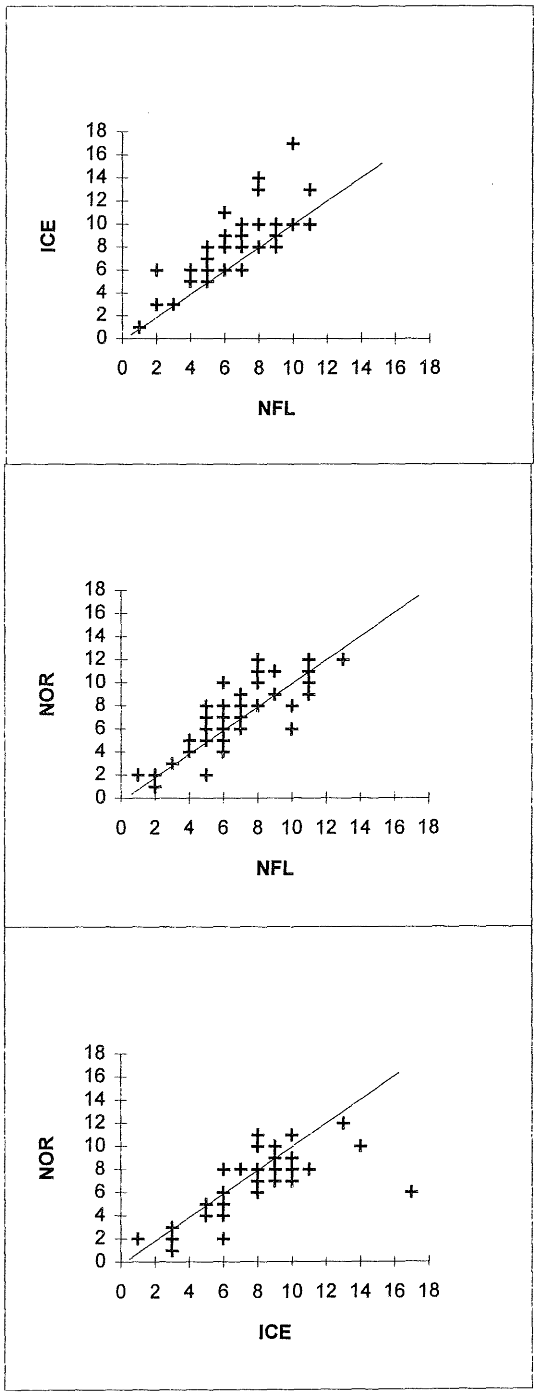


Figure 4.2. Pairwise laboratory comparisons of age readings using untreated otoliths read in reflected light (RLNT-method). ICE=Iceland, NFL=St.John's and NOR=Norway. Note that some of the crosses may represent more than one fish.

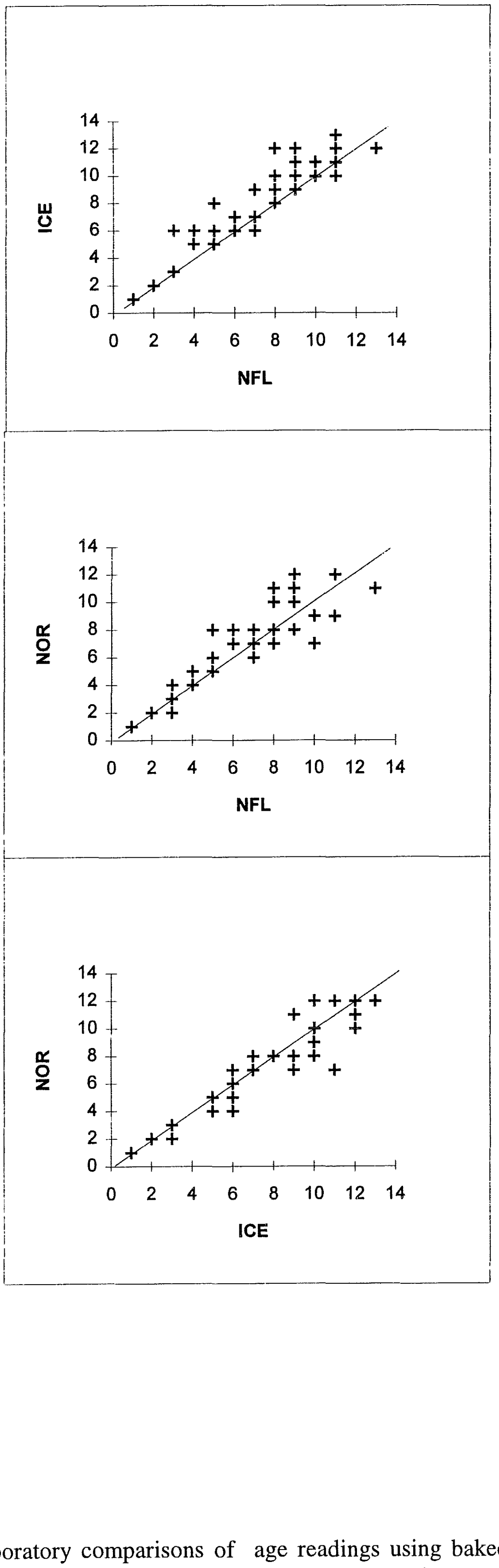


Figure 4.3. Pairwise laboratory comparisons of age readings using baked otoliths read in reflected light (RLBA-method). ICE=Iceland, NFL=St.John's and NOR=Norway. Note that some of the crosses may represent more than one fish.

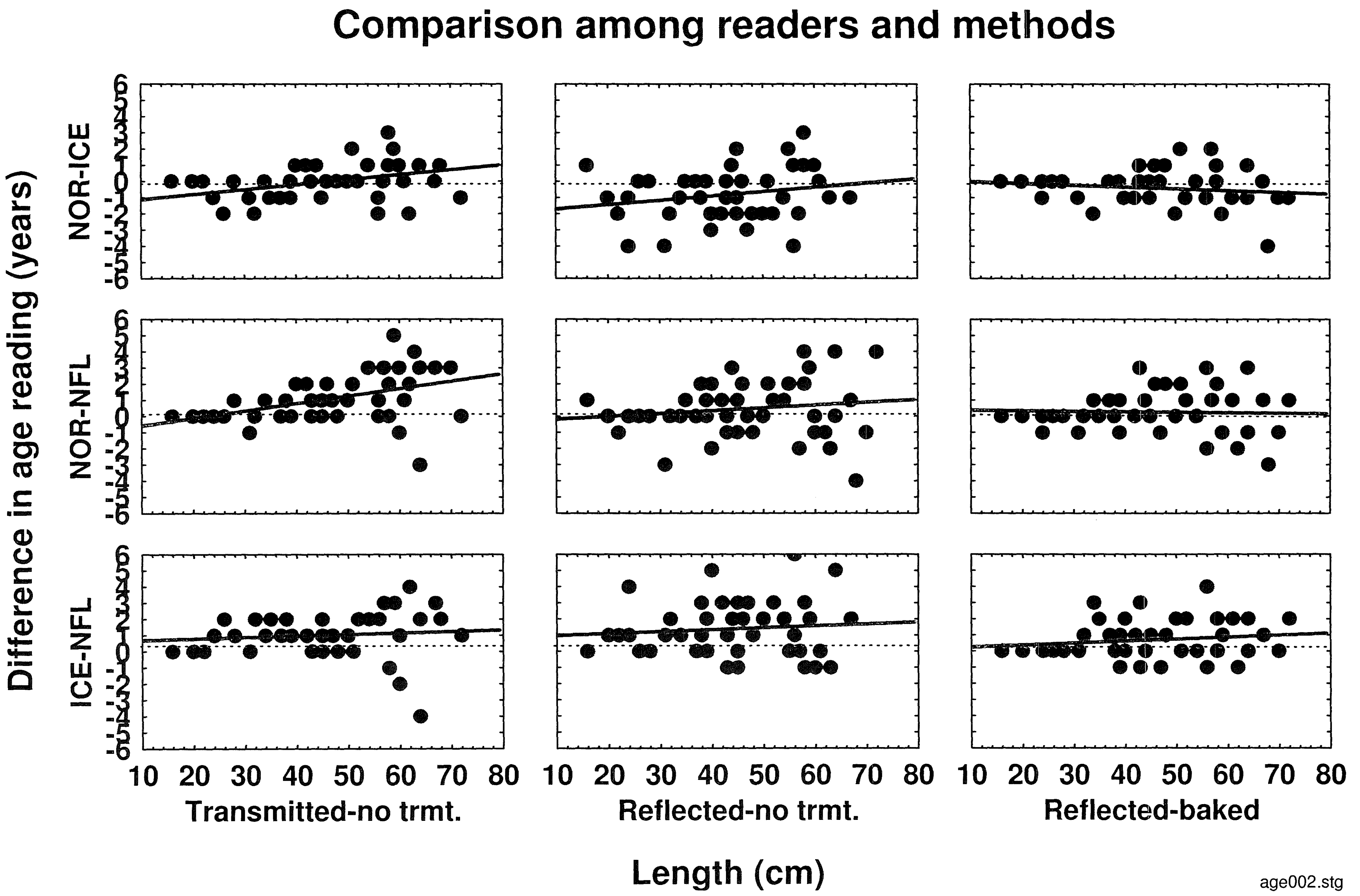


Figure 4.4. Comparison among readers and methods. Residuals are plotted against fish length. Regression lines have been drawn to illustrate any trends in the relations to length. Note that the -11 outlier has been omitted in the plot.

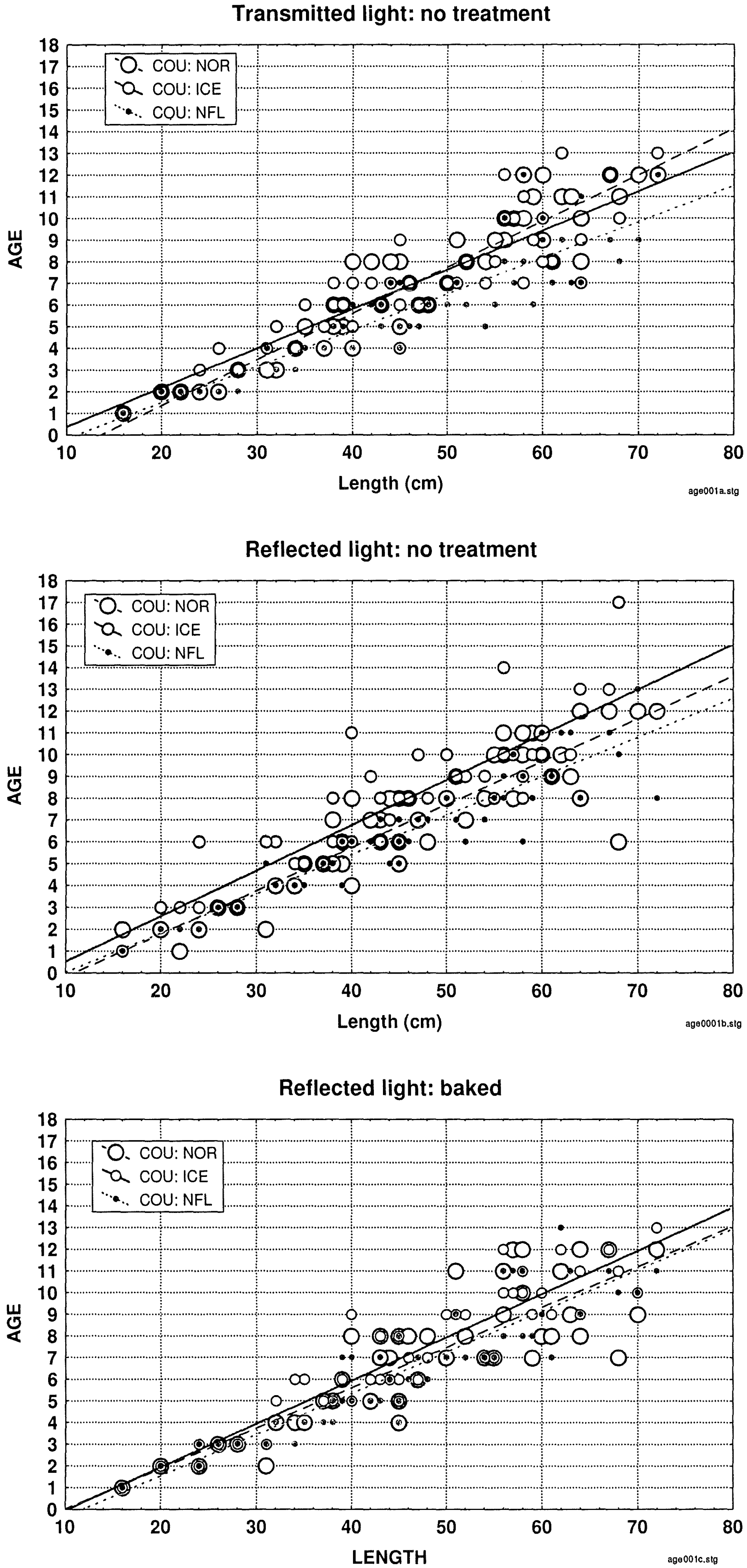
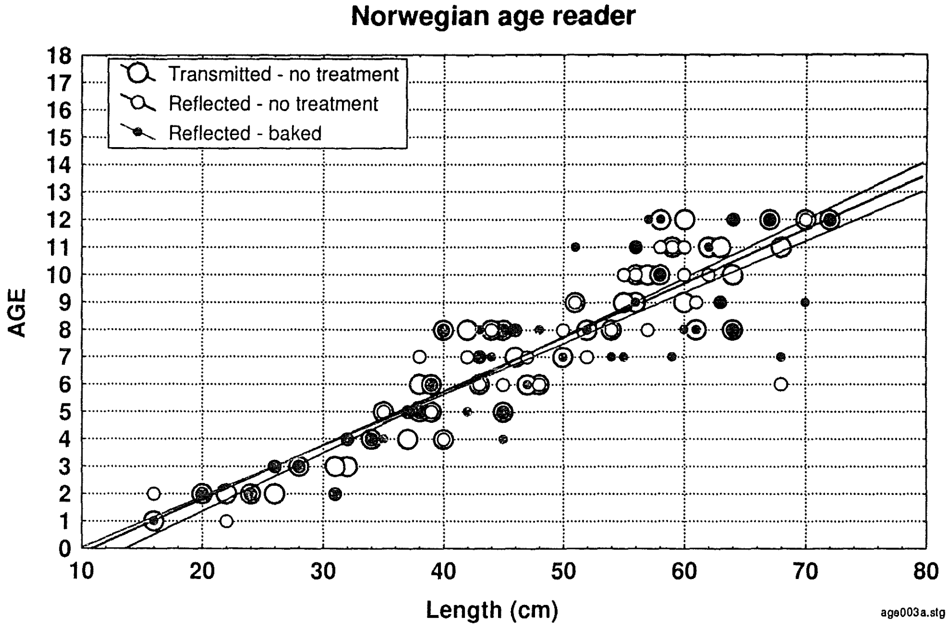
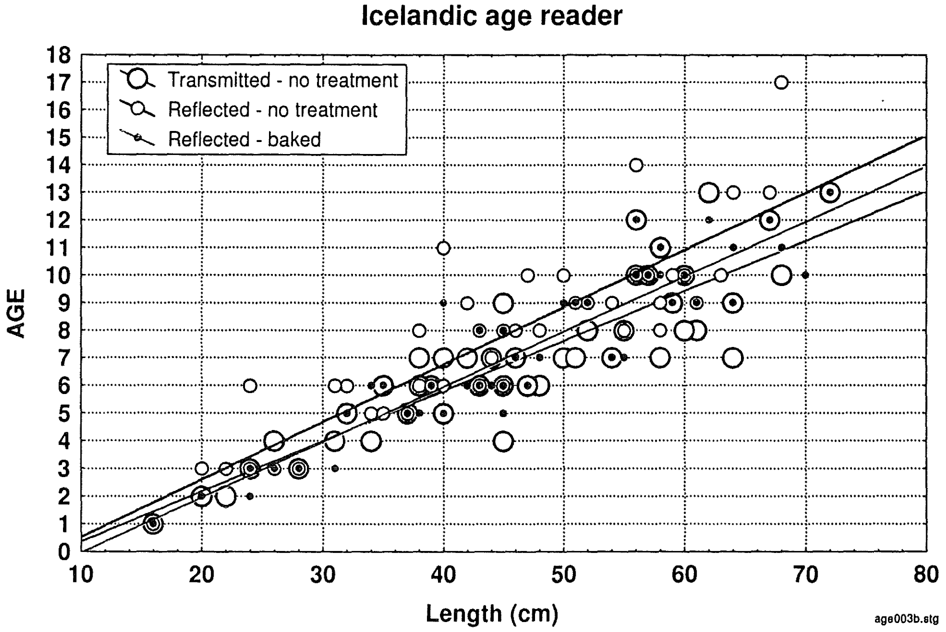


Figure 4.5. Age-length plot of Greenland halibut aged in the experiment. Comparison of three readers by method.





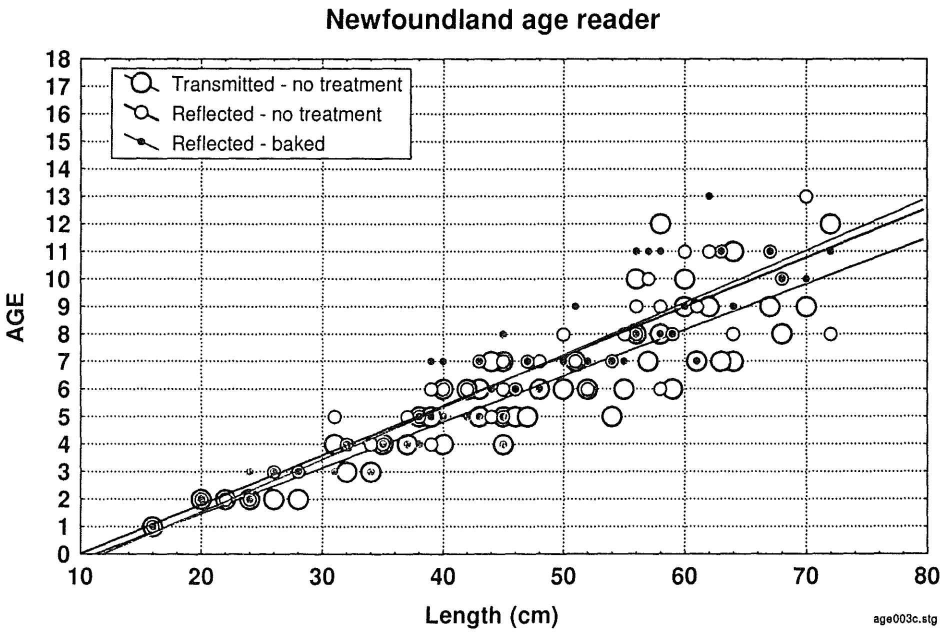


Figure 4.6. Age-length plot of Greenland halibut aged in the experiment. Comparison of all three methods for each reader.

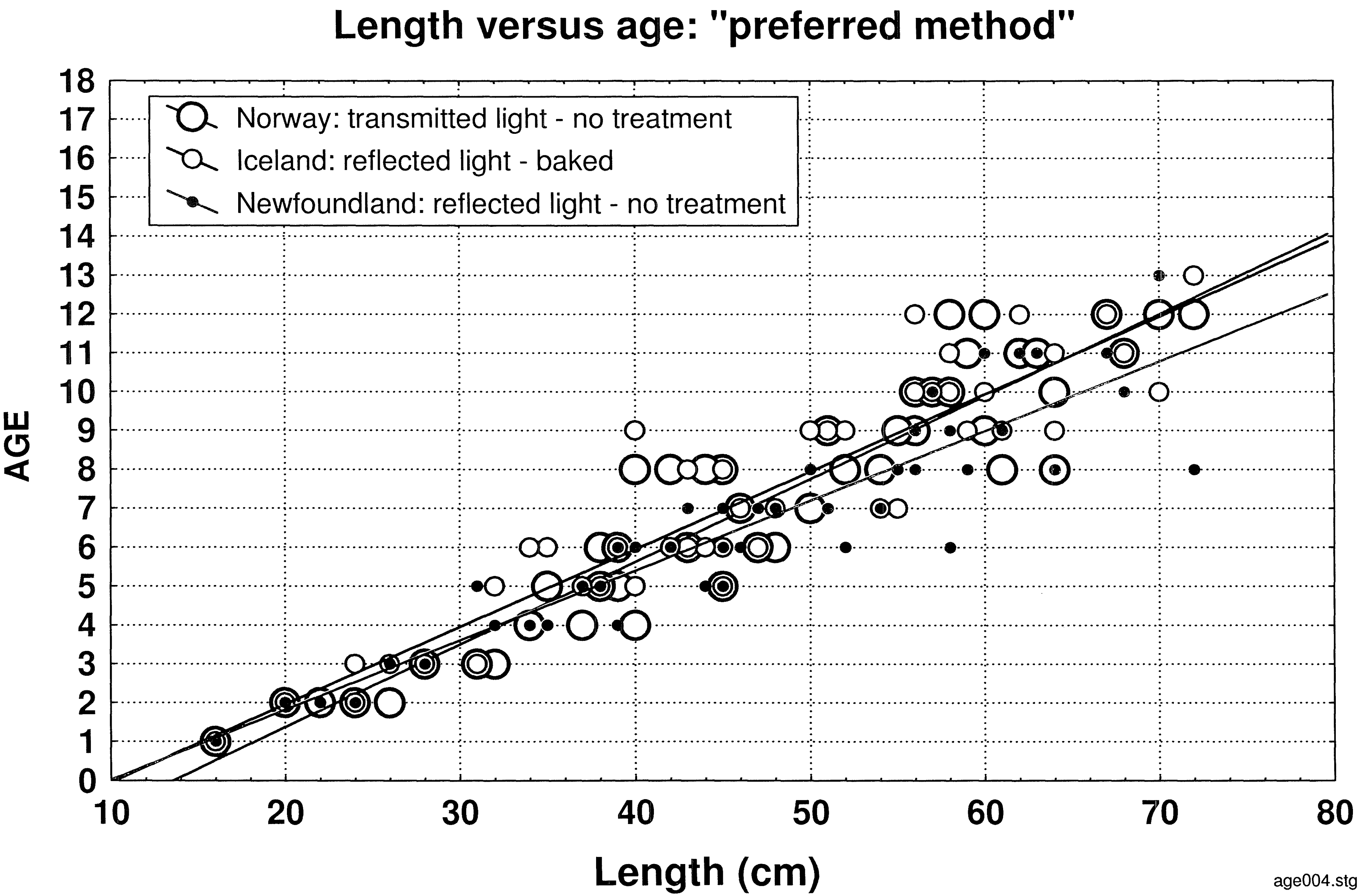


Figure 4.7. Age-length plot of Greenland halibut aged in the experiment. Comparison of the three readers each using their most familiar method.

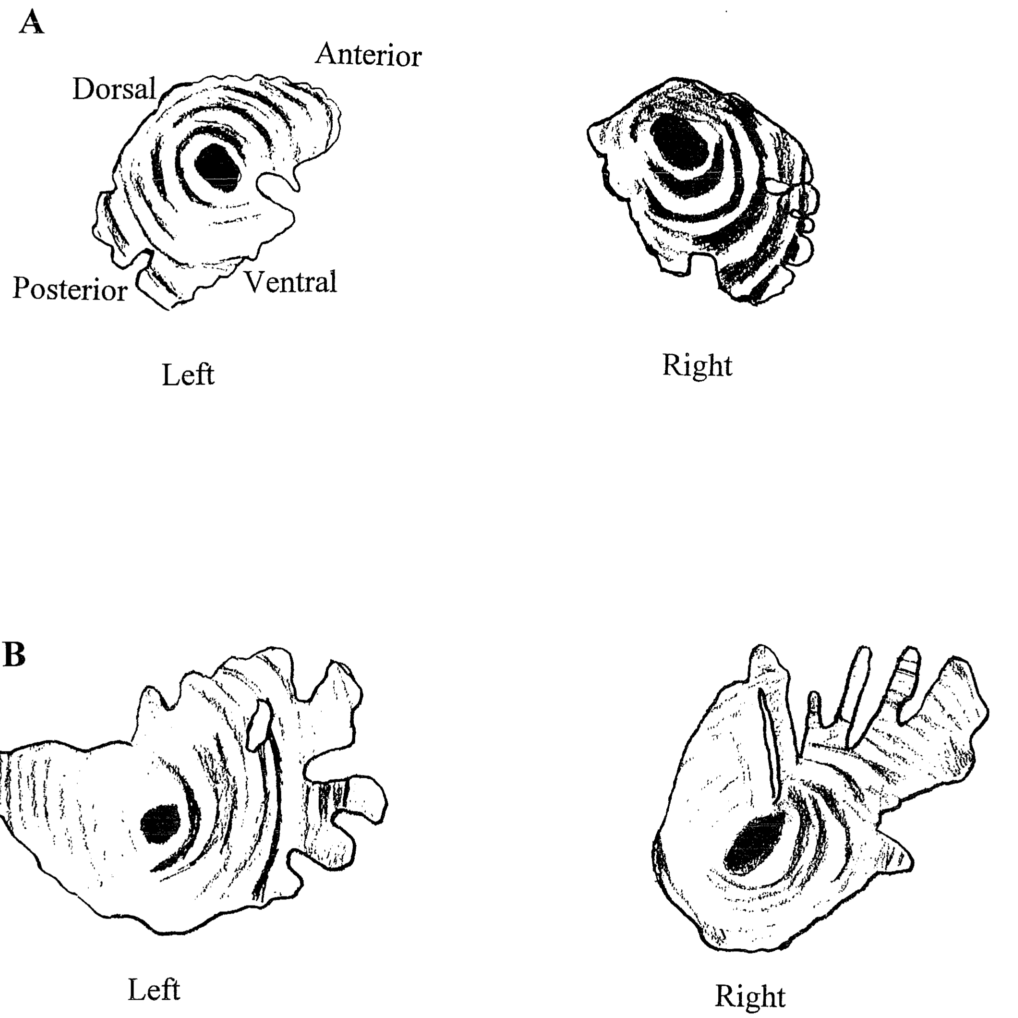


Figure 5.1. Illustration of left and right Greenland halibut otoliths. The left otolith is generally more uniform in shape and has less outstanding «fingers» than the right one, and the nucleus of the left otolith is situated in the center with possible reading axes all around. The right otolith has more outstanding «fingers» when compared with the left otolith from the same specimen, and the nucleus, which may be more oval, is situated more to the posterior part of the otolith making it impossible to read the posterior part of a right otolith. (A) is taken from a 42 cm fish and has been aged to 6 years while (B), which shows that also the left otolith may have «fingers», is from a 69 cm fish which has been aged 11-12 years. The fish were caught in May, and the illustration shows how the otoliths look like in transmitted light (e.g., the opaque zones are dark). The illustrated otoliths were magnified 6.3x.

APPENDIX 1

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APPENDIX 2

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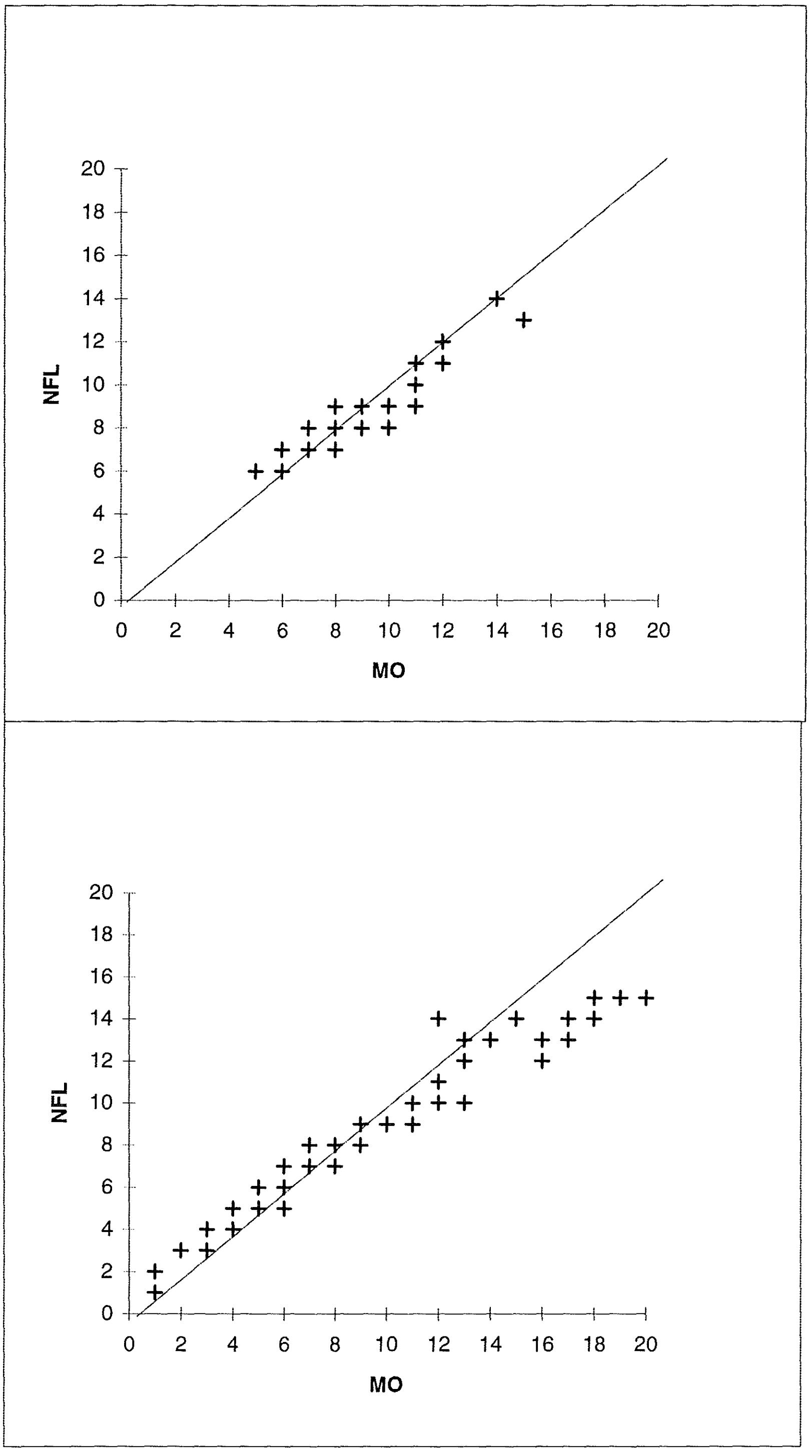
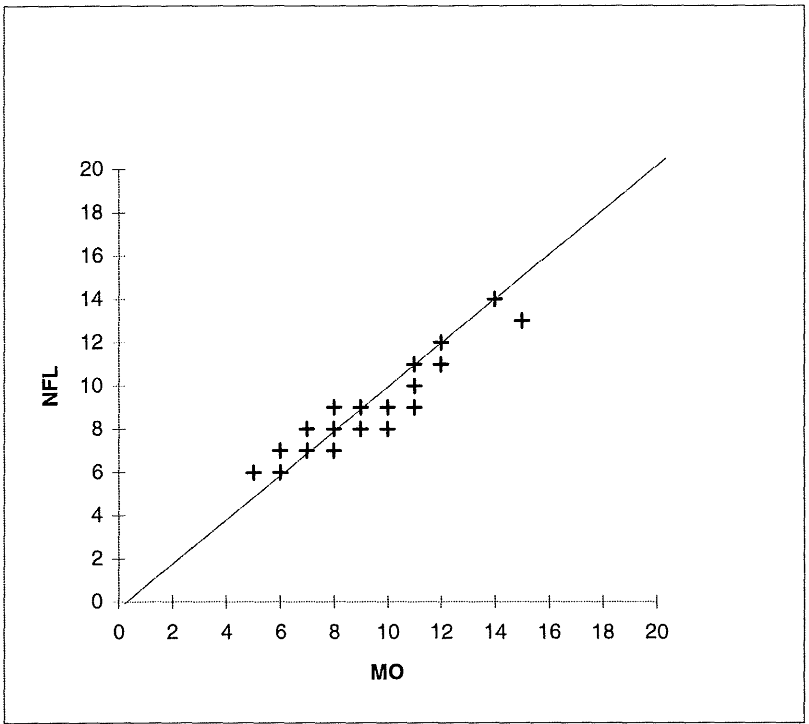
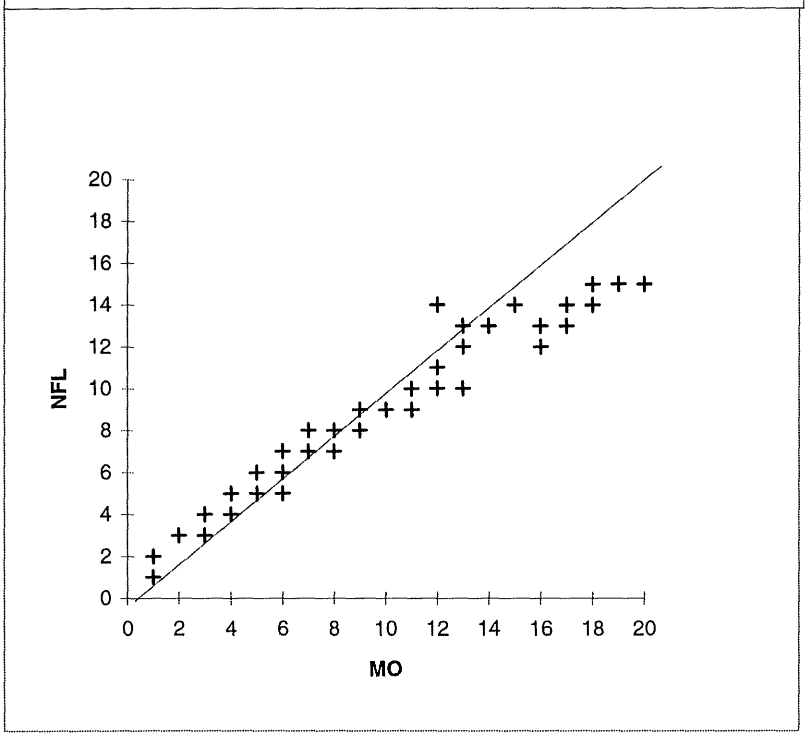
APPENDIX 3

Pairwise comparison plots from the two last otolith exchanges in advance of the workshop.

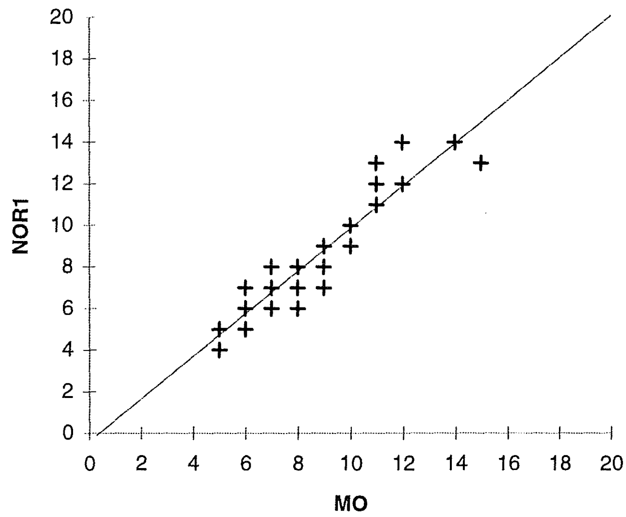


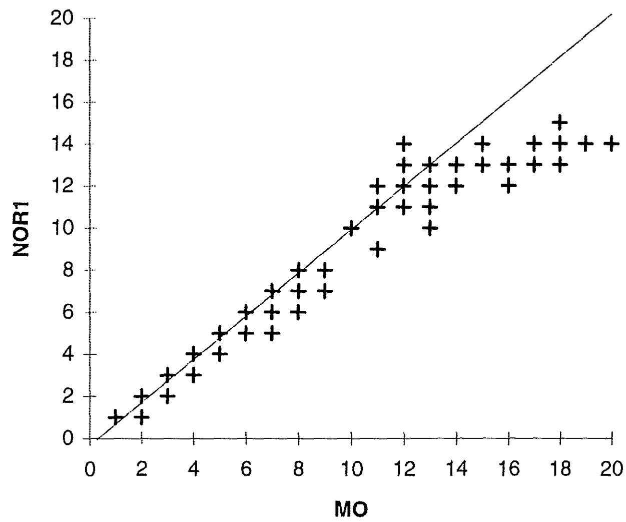
Age-bias plot of St.John's (NFL) and Mont Joli (MO) readings.



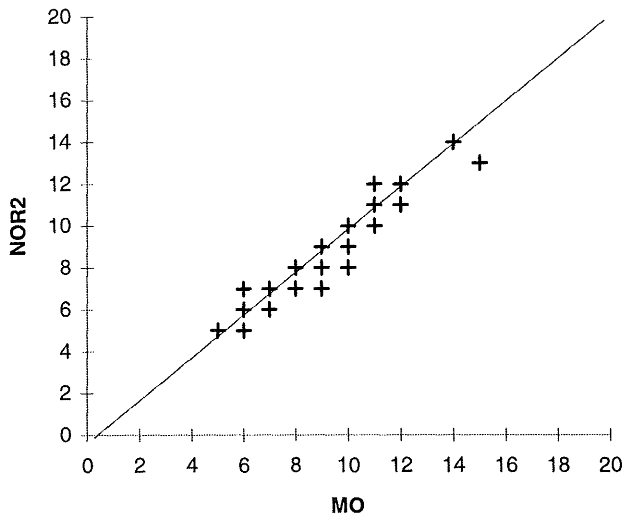


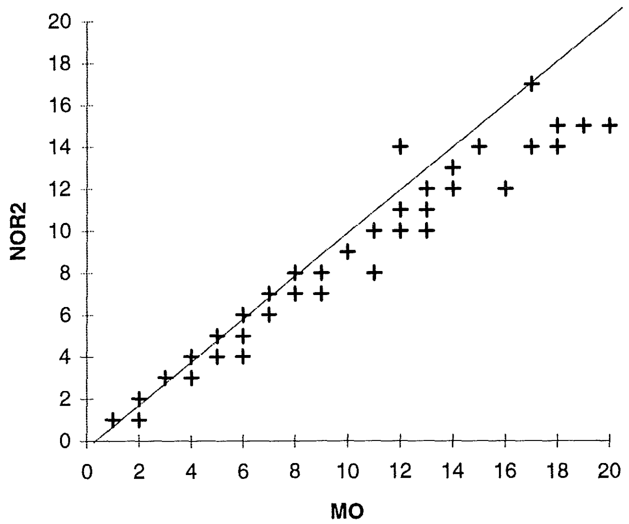
Age-bias plot of St.John's (NFL) and Mont Joli (MO) readings.





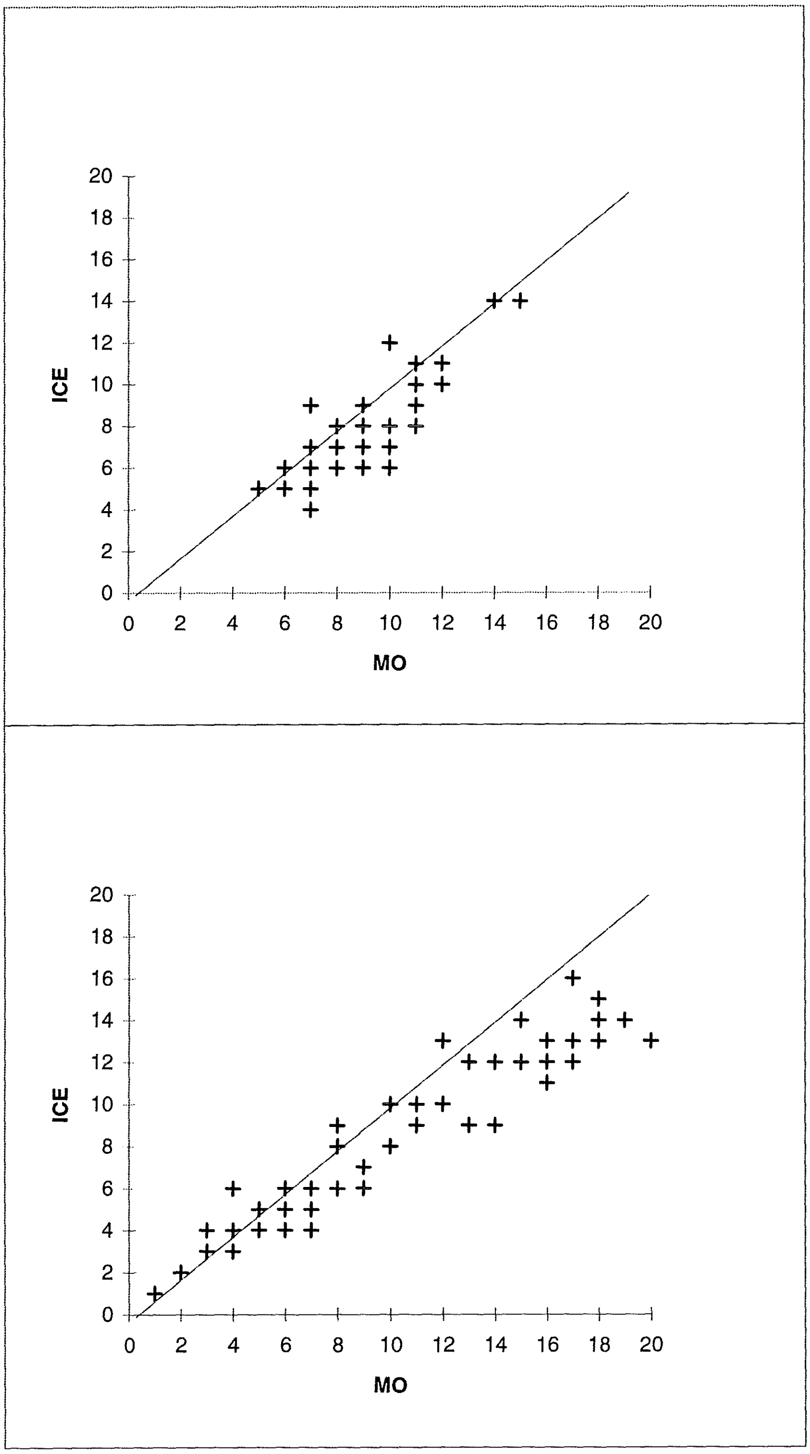
Age-bias plot of Norway, reader 1 (NOR1), and Mont Joli (MO) readings.



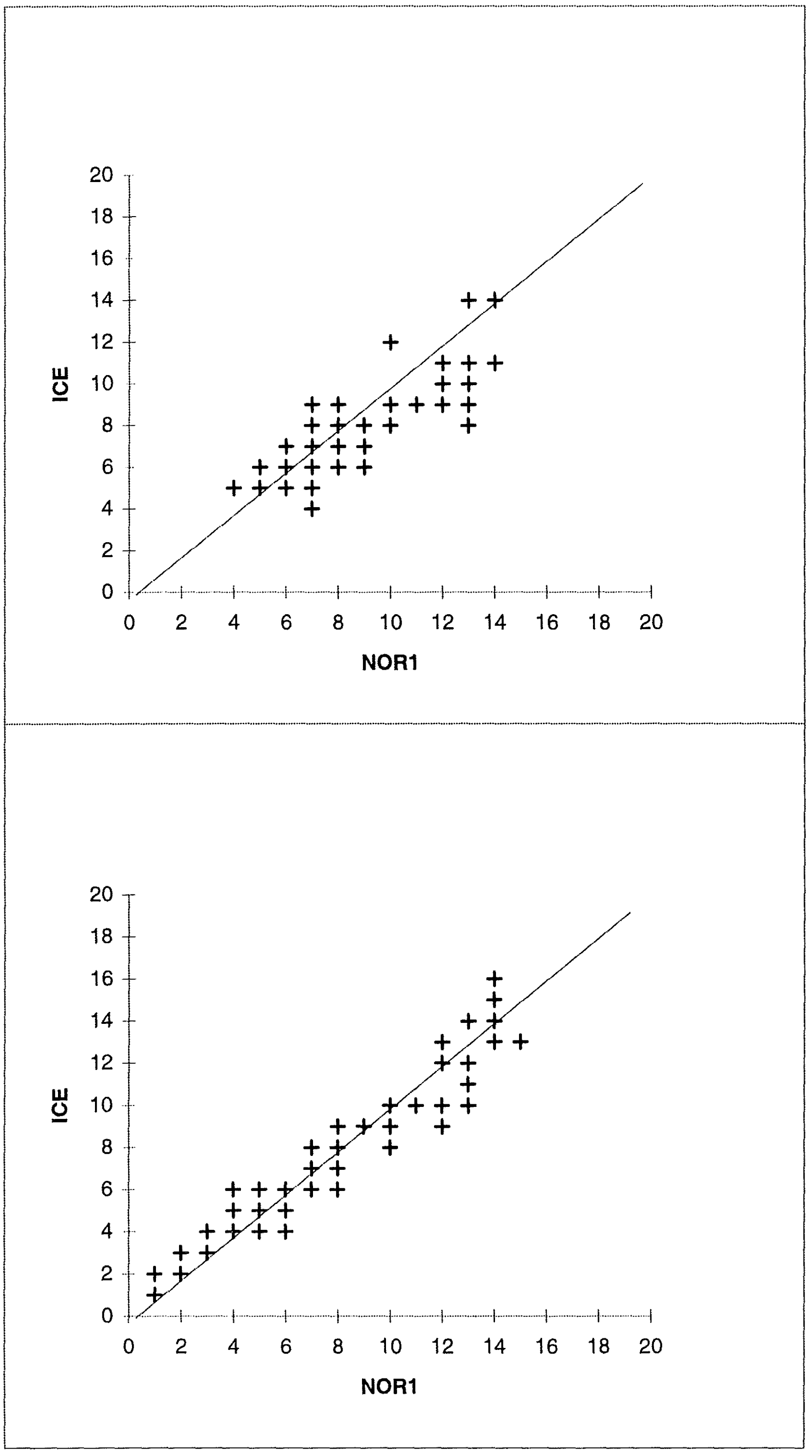


Age-bias plot of Norway, reader 2(NOR2) , and Mont Joli (MO) readings.

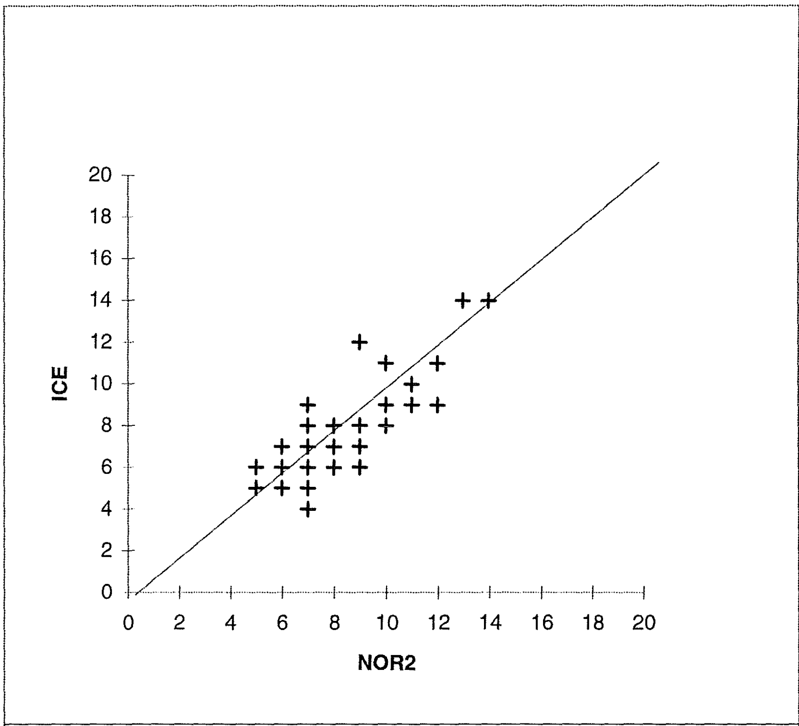
ICE-MO

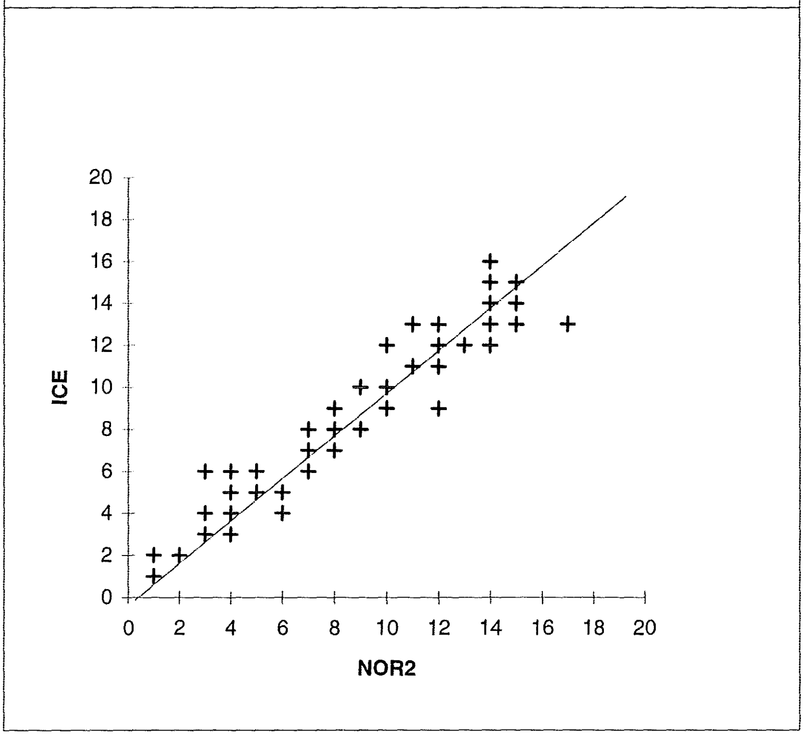


Age-bias plot of Iceland (ICE) and Mont Joli (MO) readings.



Age-bias plot of Iceland (ICE) and Norway, reader 1 (NOR1), readings.





Age-bias plot of Iceland (ICE) and Norway, reader 2 (NOR2), readings.

APPENDIX 4

Raw data from the comparative age reading experiment by the three experienced readers from Iceland, Norway and Canada (St.John's).

TRMT	No.	Length	NOR	ICE	NFL	NOR-ICE	NOR-NFL	ICE-NFL
TLNT	38	16	1	1	1	0	0	0
TLNT	17	20	2	2	2	0	0	0
TLNT	44	22	2	2	2	0	0	0
TLNT	2	24	2	3	2	-1	0	1
TLNT	25	24	2	3	2	-1	0	1
TLNT	5	26	2	4	2	-2	0	2
TLNT	39	28	3	3	2	0	1	1
TLNT	11	31	3	4	4	-1	-1	0
TLNT	32	32	3	5	3	-2	0	2
TLNT	14	34	4	4	3	0	1	1
TLNT	20	35	5	6	4	-1	1	2
TLNT	21	37	4	5	4	-1	0	1
TLNT	4	38	5	6	5	-1	0	1
TLNT	41	38	6	7	5	-1	1	2
TLNT	46	39	5	6	5	-1	0	1
TLNT	47	39	6	6	5	0	1	1
TLNT	7	40	8	7	6	1	2	1
TLNT	26	40	4	5	4	-1	0	1
TLNT	30	42	8	7	6	1	2	1
TLNT	37	43	6	6	5	0	1	1
TLNT	48	43	6	6	6	0	0	0
TLNT	15	44	8	7	7	1	1	0
TLNT	16	45	5	6	5	-1	0	1
TLNT	27	45	5	4	4	1	1	0
TLNT	49	45	8	9	7	-1	1	2
TLNT	29	46	7	7	5	0	2	2
TLNT	28	47	6	6	5	0	1	1
TLNT	34	48	6	6	6	0	0	0
TLNT	36	50	7	7	6	0	1	1
TLNT	31	51	9	7	7	2	2	0
TLNT	12	52	8	8	6	0	2	2
TLNT	18	54	8	7	5	1	3	2
TLNT	40	55	9	8	6	1	3	2
TLNT	6	56	10	12	10	-2	0	2
TLNT	23	56	9	10	8	-1	1	2
TLNT	22	57	10	10	7	0	3	3
TLNT	1	58	10	7	8	3	2	-1
TLNT	50	58	12	11	12	1	0	-1
TLNT	33	59	11	9	6	2	5	3
TLNT	13	60	9	8	10	1	-1	-2
TLNT	35	60	12	10	9	2	3	1
TLNT	45	61	8	8	7	0	1	1
TLNT	24	62	11	13	9	-2	2	4
TLNT	19	63	11	-	7		4	
TLNT	8	64	10	9	7	1	3	2
TLNT	10	64	8	7	11	1	-3	-4
TLNT	43	67	12	12	9	0	3	3
TLNT	9	68	11	10	8	1	3	2
TLNT	42	70	12	-	9		3	
TLNT	3	72	12	13	12	-1	0	1

TRMT	No.	Length	NOR	ICE	NFL	NOR-ICE	NOR-NFL	ICE-NFL
RLNT	1	16	2	1	1	1	1	0
RLNT	2	20	2	3	2	-1	0	1
RLNT	3	22	1	3	2	-2	-1	1
RLNT	4	24	2	3	2	-1	0	1
RLNT	5	24	2	6	2	-4	0	4
RLNT	6	26	3	3	3	0	0	0
RLNT	7	28	3	3	3	0	0	0
RLNT	8	31	2	6	5	-4	-3	1
RLNT	9	32	4	6	4	-2	0	2
RLNT	10	34	4	5	4	-1	0	1
RLNT	11	35	5	5	4	0	1	1
RLNT	12	37	5	5	5	0	0	0
RLNT	13	38	5	6	5	-1	0	1
RLNT	14	38	7	8	5	-1	2	3
RLNT	15	39	5	6	4	-1	1	2
RLNT	16	39	6	6	6	0	0	0
RLNT	17	40	8	11	6	-3	2	5
RLNT	18	40	4	6	6	-2	-2	0
RLNT	19	42	7	9	6	-2	1	3
RLNT	20	43	7	8	7	-1	0	1
RLNT	21	43	6	6	7	0	-1	-1
RLNT	22	44	8	7	5	1	3	2
RLNT	23	45	5	6	6	-1	-1	0
RLNT	24	45	6	8	5	-2	1	3
RLNT	25	45	8	6	7	2	1	-1
RLNT	26	46	8	8	6	0	2	2
RLNT	27	47	7	10	7	-3	0	3
RLNT	28	48	6	8	7	-2	-1	1
RLNT	29	50	8	10	8	-2	0	2
RLNT	30	51	9	9	7	0	2	2
RLNT	31	52	7	9	6	-2	1	3
RLNT	32	54	8	9	7	-1	1	2
RLNT	33	55	10	8	8	2	2	0
RLNT	34	56	10	14	8	-4	2	6
RLNT	35	56	11	10	9	1	2	1
RLNT	36	57	8	10	10	-2	-2	0
RLNT	37	58	10	9	6	1	4	3
RLNT	38	58	11	8	9	3	2	-1
RLNT	39	59	11	10	8	1	3	2
RLNT	40	60	10	-	11		-1	
RLNT	41	60	11	10	11	1	0	-1
RLNT	42	61	9	9	9	0	0	0
RLNT	43	62	10	-	11		-1	
RLNT	44	63	9	10	11	-1	-2	-1
RLNT	45	64	12	13	8	-1	4	5
RLNT	46	64	8	-	8		0	
RLNT	47	67	12	13	11	-1	1	2
RLNT	48	68	6	17	10	-11	-4	7
RLNT	49	70	12	-	13		-1	
RLNT	50	72	12	-	8		4	

TRMT	No.	Length	NOR	ICE	NFL	NOR-ICE	NOR-NFL	ICE-NFL
RLBA	38	16	1	1	1	0	0	0
RLBA	17	20	2	2	2	0	0	0
RLBA	2	24	2	3	3	-1	-1	0
RLBA	25	24	2	2	2	0	0	0
RLBA	5	26	3	3	3	0	0	0
RLBA	39	28	3	3	3	0	0	0
RLBA	11	31	2	3	3	-1	-1	0
RLBA	32	32	4	5	4	-1	0	1
RLBA	14	34	4	6	3	-2	1	3
RLBA	20	35	4	6	4	-2	0	2
RLBA	21	37	5	5	4	0	1	1
RLBA	4	38	5	5	5	0	0	0
RLBA	41	38	5	5	4	0	1	1
RLBA	46	39	6	6	5	0	1	1
RLBA	47	39	6	6	7	0	-1	-1
RLBA	7	40	8	9	7	-1	1	2
RLBA	26	40	-	5	5			0
RLBA	30	42	5	6	5	-1	0	1
RLBA	37	43	8	8	5	0	3	3
RLBA	48	43	7	6	7	1	0	-1
RLBA	15	44	7	6	6	1	1	0
RLBA	16	45	5	6	5	-1	0	1
RLBA	27	45	4	5	4	-1	0	1
RLBA	49	45	8	8	8	0	0	0
RLBA	29	46	8	7	6	1	2	1
RLBA	28	47	6	6	7	0	-1	-1
RLBA	34	48	8	7	6	1	2	1
RLBA	36	50	7	9	7	-2	0	2
RLBA	31	51	11	9	9	2	2	0
RLBA	12	52	8	9	7	-1	1	2
RLBA	18	54	7	7	7	0	0	0
RLBA	40	55	7	7	7	0	0	0
RLBA	6	56	11	12	8	-1	3	4
RLBA	23	56	9	10	11	-1	-2	-1
RLBA	22	57	12	10	11	2	1	-1
RLBA	1	58	10	10	8	0	2	2
RLBA	50	58	12	11	11	1	1	0
RLBA	33	59	7	9	8	-2	-1	1
RLBA	13	60	8	10	9	-2	-1	1
RLBA	35	60	-	-	-			
RLBA	45	61	8	9	7	-1	1	2
RLBA	24	62	11	12	13	-1	-2	-1
RLBA	19	63	9	-	11		-2	
RLBA	8	64	12	11	9	1	3	2
RLBA	10	64	8	9	9	-1	-1	0
RLBA	43	67	12	12	11	0	1	1
RLBA	9	68	7	11	10	-4	-3	1
RLBA	42	70	9	10	10	-1	-1	0
RLBA	3	72	12	13	11	-1	1	2
RLBA	?		10	12	9	-2	1	3

NB!

Demersal Fish Committee

ICES CM1997/G:1
ERRATUM

REPORT OF THE
ICES/NAFO WORKSHOP ON GREENLAND HALIBUT AGE DETERMINATION

Reykjavik, Iceland

26 - 29 November 1996

The attached page should replace Table 4.1 in the report mailed to you on 3 March 1997

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

Table 4.1 Comparison of age estimates for Greenland halibut from three different otolith methods (all ages).

		Percent agreement		
Norway/Iceland	Age difference (years)	Baked, reflected light	Untreated, reflected light	Untreated, transmitted light
	0	36.2	20.0	33.3
	1	80.9	60.0	83.3
	2	97.9	84.4	97.9
	3	97.9	91.1	100.0
	4	100.0	97.8	
	11		100.0	

		Percent agreement		
Norway/Canada	Age difference (years)	Baked, reflected light	Untreated, reflected light	Untreated, transmitted light
	0	33.3	32.0	34.0
	1	77.1	64.0	64.0
	2	91.7	86.0	78.0
	3	100.0	92.0	96.0
	4		100.0	98.0
	5			100.0

		Percent agreement		
Iceland/Canada	Age difference (years)	Baked, reflected light	Untreated, reflected light	Untreated, transmitted light
	0	35.4	22.2	18.8
	1	75.0	55.6	60.4
	2	91.7	75.6	89.6
	3	97.9	88.9	95.8
	4	100.0	91.1	100.0
	5		95.6	
	6		97.8	
	7		100.0	